
Diane Dolores Kent

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An Optimization of
a Coal Supply Network

By Mine Production Levels and
Coal Distribution Flows

by

Diane Dolores Kent

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(date)

Professor in Charge

Chairman of Department
The author would like to acknowledge Christopher Mack for his programming expertise, Lucy Minaya for her typing patience and the Fuel Development staff of the Pennsylvania Power and Light Company for their encouragement in the completion of this manuscript.
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Abstract

The optimization of an electric utility's fuel supply system is of paramount concern in this era of increasing energy costs and uncertain fuel supplies. A method for determining total system costs for a generalized fuel network was proposed in this document. Included were revenue requirements calculations for mine production costs and several different contract formulation calculations. A general form of the optimization subroutine was presented then applied to a specific bituminous coal supply network developed for central and eastern Pennsylvania.

The author concluded that given a specific supply network, it is possible to decrease total system costs by redistributing coal flows over the existing transportation structure. Optimal levels for mine output and supply contracts can also be determined.

This model was developed to optimize an existing coal supply strategy. It can be employed as a short-term, mid-term or long-term planning tool with its capability to optimize over a period as short as 1 year or as long as 35 years. In addition, it can be used in the development of alternate fuel supply strategies.
CHAPTER 1

INTRODUCTION

1. BACKGROUND

The economic incentive for optimizing an electric utility's fuel supply plans is obvious in this era of increasing and uncertain fuel prices. Over the past 15 years, the cost of fuel has risen from 15% of a utility's operating revenues to almost 50%. Increasing oil prices and an uncertain future for nuclear fuel generation both contribute to the desirability of bituminous coal fired steam electric plants. Intermittent strikes by the UMW union bestow a measure of uncertainty to the bituminous coal supply. Contingency plans for fuel interruptions should be in-place and continually updated to reflect changing market perceptions. Despite the potential problems associated with bituminous coal availability (i.e., strikes and insufficient supplies), it is fundamental to the efficient operation of generating facilities to optimally schedule those fuel supplies at hand.

There are several regulatory and operating constraints which prevent utilities from operating at a true optimum. All electric generating stations are subject to the Clean Air Act Amendments of 1970 and 1977. National ambient air quality standards limit the amount of
pollutants and particulates released into the atmosphere. Furthermore, individual states are permitted to establish more stringent standards. Power plants or industrial boilers built after September 1978 are subject to more rigid regulations than those constructed before that time.

Restrictions at the supply location may be regulatory or physical. Dust control and surface reclamation efforts are monitored by the Office of Surface Mining (OSM). Shaft supports and ventilation passages in underground mines are controlled by the Mining Safety and Health Administration (MSHA). The speed at which coal can be mined and loaded for transport is limited by the type of mining equipment used and size of the loading facility. All of these items compel the utility to operate at a most-favorable level which may not be an economic optimum.

2. HISTORICAL REFERENCE

The topic of an optimal fuel supply strategy has received considerable attention in the past decade. G.E. Seymore [4] presented a paper at a SIAM conference in 1980 discussing overall fuel scheduling problems. He has pointed out two major areas of concern:
1. Fossil Fuel Management

2. Unit Commitment and Economic Dispatch

When referencing the fuel planning issue, which is an application of the economic theory of the optimal allocation of a scarce resource, Seymore concludes,

"General purpose linear programming codes,..., do offer more modeling flexibility than network codes. For example, utilities wishing to carefully model and constrain the sulfur content of coal or oil inventories may find that explicit codes are required,..."

In a more comprehensive report managed by C. J. Frank and investigated by Seymore (1), specific algorithms were identified for short-term, mid-term and long-term fuel scheduling. I have added an additional category of nodes to those developed by Seymore:

CATEGORIES OF NODES

- Source nodes, at which flows originate
- Transshipment nodes, at which flow is neither created nor destroyed
- Sink nodes, at which flows terminate

---

1 G. E. Seymore, Long-term, Mid-term and Short-term Fuel Scheduling, (EPRI EL-1319, Research project 1048-6, January 1980), p. 5-3.
I broke the "source nodes" into two levels. The first level defines where flows originate. The second level may or may not alter the composition of the flow as the coal is processed through a cleaning and/or loading facility:

Revised Categories of Nodes
- Resource nodes
- Cleaning or Loading nodes
- Transshipment nodes
- Sink nodes

Ravindran and Hanline (3) presented the possibility of establishing centralized blending plants that "could take coals of varying sulfur content and produce a product that would meet" utility operating standards. The authors clearly present their model for selecting plant sites in a given region. Unfortunately, the specific utility in the case study (Chapter 4) did not have the flexibility to add a blending plant in their supply region. However, the authors' constraint definitions were of a form useful when developing the general constraints for this study (Chapter 3).

3. PROBLEM DEFINITION

The specific area to be addressed is that of minimizing total bituminous fuel costs for a specific utility. The fuel supply is defined by three types of resource processes:
1. utility owned mines
2. coal supply contracts
3. open market purchases

The fuel demand will be defined by annual megawatt requirements. The system will determine an optimal supply/demand balance. A network approach was used in defining the overall supply system (see Chapter 2).

The critical issues to be discussed are (1) What is the optimal mine production level for each captive operation? and (2) What is the optimal flow of coal from source to sink? A specific case will be cited in its relation to these two questions. And finally, the relevance of several input parameters will be analyzed as to their importance in making planning decisions.

4. PROGRAMMING REQUIREMENTS

The equations for the coal cost calculation routine were developed by the author (Appendix I). The optimization routine was designed and coded similarly to interface with the cost calculation program and a general purpose mathematical programming code. The cost calculation subroutine is over 18,000 lines of code and requires less one second to compute all supply costs. The optimization
routine is nearly 3,000 lines of code and requires less than .5 seconds to find an optimal solution (if one exists).
CHAPTER 2

COAL SUPPLY CALCULATOR

1. INTRODUCTION

All of the cost calculations input to the optimization routine are performed in a front-end subroutine called the Coal Supply Calculator (CSC). The Coal Supply Calculator was developed to consistently calculate supply costs from various resource types. The CSC is a deterministic model, i.e., there are no decision variables. The user directs the flow of coal through the supply network. These user-directed coal flows are ignored by the optimization routine (to be discussed in Chapter 3).

As a deterministic model, the analyst has the ability to exactly represent the current operating environment. In conjunction with operational specialists, the analyst develops and enters the initial input parameters. A reasonable level of detail for all of the subcomponents of the total cost of fuel has been identified. Each individual cost parameter can be bounded by an upper and lower limit. If the CSC is run for an expected, upper and lower value for

---

1 Operational specialists include Fuel Procurement Agents, Transportation Engineers and Mining Engineers.
each input parameter (holding all other variables constant), it is possible to identify those parameters that have the greatest impact on the total cost of fuel. This type analysis gives the user a quantitative basis to recommend areas for cost reduction efforts. In addition, the operational specialists may be more receptive to those recommendations since they were involved in the data development.

The Coal Supply Calculator also provides a convenient source of documentation for operating plans. Not only is the CSC a consistent accounting tool, it records perceptions of future plans at specific points in time. This documentation is very important when evaluating past decisions with the benefit of hindsight. Should a particular decision go awry, it is possible to prove that it was the best alternative given the operating environment at the time the decision was made.
2. NETWORK FORMULATION

The simulator calculates the total cost of fuel by evaluating coal supplies and demands over time. Exhibit 2-A displays the physical flow of coal costs through the network. The analyst enters input data at the resource level (the boxes on the left). The system then computes a per ton cost of coal which is stored on each output link. If the user has determined that the coal must be cleaned prior to shipment to the power plants, the CSC calculates the additional cleaning costs. Loading and transportation charges are added to the resource price to determine a delivered price of coal. Since the CSC is user driven, each power plant knows where to draw its supply of coal. Finally the total cost of fuel is calculated for each power plant. The network calculation sequence was computerized to eliminate manual errors and increase turn around time.

The user defines the supply/demand relationships using a "flag table" (Exhibit 2-B). The flag table is a matrix of zeroes and ones indicating which paths are valid from each supply node to each power plant node (lines 1 and 2). The CSC has the ability to store up to 12 supply regions and up to 8 power plants (Note: Only plants 1-4 and supply region 1-8 are turned on.) Exhibit 2-C is a general representation of such a supply network at a macro level. The lines connecting the supply regions with the power plants are called
links. There is the possibility of $12 \times 8$ or 96 links connecting supply and demand. It is quite likely that all 96 links would not be necessary to define the actual operating environment. For example, new electric generating stations are designed for a specific type of coal from one or more mine locations. Therefore, this new plant may require as few as 1 input link from a supply region or up to the maximum of 12 potential supply links. Any combination of supply links may be indicated and varied over the operating life of the power plant.

The model begins the cost calculations by first reading the flag table to determine which power plants and supply regions are turned on and should be calculated. After computing the cost and quantity of coal from each supply region, the system reads the transportation matrix, which is a subset of the flag table, in order to determine the quantity of coal shipped from each supply region to each power plant. Excess shipments are sold back to the general market and insufficient shipments are fulfilled by the general market allocation (Section 7).

3. DEMAND DEFINITION

The CSC is a demand driven model. In particular, a minimum amount of fuel must be received by each power plant to meet its annual load
requirement. Power plant demand requirements are specified by millions of BTUs per year. Millions of BTUs per year are defined by the nameplate rating (KWH), heat rate (BTU/KW) and capacity factor of each power plant. From each supply region the user has defined the amount of coal shipped to the power plants. The system converts tons of coal shipped from each region to millions of BTUs required by the plants. If committed sources, such as mine supplies or contracts, do not satisfy the annual operating requirements of a particular plant, the balance of its BTU requirements are supplied by a general spot market allocation. The general spot market allocation resource acts like an infinite supply of coal to meet power plant demands. This system simplification accurately reflects standard operating procedures for supplying coal to power plants.

4. SUPPLY STRUCTURE: GENERAL

As indicated on Exhibits 2-B and 2-C, there are twelve supply regions. The flag table (line 2) indicates whether or not a specific region is valid and should be calculated. In order to remain consistent for each supply region definition, one general supply network was designed (Exhibit 2-D).

The supply region calculation sequence is sub-divided into three parts:
1. Resource Costs
2. Cleaning and Loading Costs
3. Transportation Costs

At each supply location, the user can identify up to 30 unique resource inputs. The flag table indicates which of these 30 processes are valid (lines 3-14). The 30 processes break down into 10 resource types each with 3 time-dependent cases. This large number of potential resources is necessary to reflect different mining operations and various types of coal supply contracts available at each supply location. The user can also reflect the different cost calculations associated with the production or purchase of raw or clean coal. Raw coal is coal that must be processed through a cleaning plant to meet operating specifications before being shipped to a power plant. Clean coal can be shipped directly from the loading facility to the power plant. Five resource types may be defined as raw coal (R1-R5) and five as clean coal (R6-R10) processes (see Exhibit 2-D).

The individual resource calculations are differentiated by:

1. Mine Production
2. Contract Arrangements
a. Cost Plus,
b. Base Price Plus Escalator,
c. Market Indicator Adjustment

3. Local Spot Market

At each supply region, any combination of the aforementioned resource processes maybe used to identify the particular operating structure in question.

5. SUPPLY STRUCTURE: MINE COSTS

Mine production costs are calculated using a standard revenue requirements approach. This is the accepted method of costing mining operations in the utility industry. The revenue requirements methodology assumes a given production plan over the life of the mine. From this plan, the system calculates the per unit labor, administrative, mine supply and maintenance costs. Capital accounts are differentiated by the economic life of the equipment. Book and tax depreciation calculations are separated in order to capture the tax advantages of purchasing new equipment rather than leasing it. If the depreciable equipment life expires before the mine plan, the system automatically purchases an identical piece of equipment at the appropriate time and cost. Fixed costs such as royalty or lease
payments, depletion and amortization accounts are also identified and written off on a per ton basis over the life of mine. The financial calculation subroutine enables the user to reflect different financial structures from 100% debt financing to 100% equity financing.

Other than different capital structures associated with underground or surface mining operations, the user also has the ability to model new mine development or existing mine purchases. In the instance of new mine development, the necessary accounting tools for preproduction costs and less than full production mining have been incorporated into the code. All preproduction expenses are accumulated over the developmental period and written off on a per ton basis over the life of the mine after full production has begun. Any coal mined during the preproduction period is sold at a market price and the revenues are used to reduce total costs in that time period. If a utility purchases an existing mining operation, there are separate cost calculations associated with the purchase of existing capital equipment versus new capital acquisitions. All existing equipment must be reappraised and depreciated over its remaining economic life. Once existing capital is depreciated, the system does not purchase another identical piece of equipment as it does under the new capital account calculations.
The output from the revenue requirements subroutine is a required per unit price over time necessary to recover full costs. The CSC also carries the annual production level, average BTU value and percent sulfur of the coal mined on the link out of each resource node.

6. SUPPLY STRUCTURE: CONTRACTS

There are three types of contractual arrangement models in the CSC. Operationally, all contracts are written for a required tonnage, minimum BTU per pound level and sulfur limit over a specified period of time. The length of the contract can be a minimum of one year up to a maximum of 35 years. The first contract type reflects a cost plus arrangement. The cost paid for the coal includes all of the producers costs plus a reasonable rate of return on his investment. You will note that cost-plus calculations parallel the revenue requirements calculations previously discussed. Cost-plus contracts require very close supervision by the utility so that unwarranted cost overruns are not automatically rolled into the price of the coal.

The second type of contract has historically been the most common. The price of coal is based on a dollar/ton value plus annual real increases above or below the national inflation rate. If the real
costs of coal are projected to increased faster than the inflation rate then the real increase rates are positive. Otherwise the rates are negative reflecting a depressed market situation. This type contract is by far the easiest to calculate yet requires a very clear crystal ball to capture all future market fluctuations.

The third and final contract type reflected in this system is a contract price based on an assessment of an average market price. The "market" is defined to be a representative set of competitor utilities. Since all utility purchases must be reported to the Federal Energy Regulatory Commission (F.E.R.C.), an average market price for all of the utilities identified can be calculated from a monthly F.E.R.C. report. It is this average market price calculation that is used as a basis for the price of coal in contract negotiations. Each individual vendor is paid for his coal based on a percent of the average market price assessment.

7. SUPPLY STRUCTURE: SPOT MARKETS

The last resource type is a representation of local spot markets. In this case, the "market" is defined to be the local mining operations which compete with one another in a particular geographic location. Depending on the annual mine production or contractual commitments, purchases from the local spot market will vary for each
supply region. This is the only resource with variable quantity values on the output links. All others, mine production and contracts, are defined for a given level of output over time. The price of coal at the local spot market level is based on a general spot market forecast. For example, one or another region may be a low cost production area but contain less than desirable coal. This nuance is readily captured in the CSC.

The general spot market prices reflect an official coal forecast. In the current depressed market, there is sufficient excess capacity for the general spot market allocation to act like an infinite supply of coal.

8. LOADING OR CLEANING FACILITIES

As was previously mentioned, the CSC was designed to give the user the ability to model raw coal or clean coal production and purchases. Each of the five resource types discussed can be defined for raw or clean coal; hence, allowing the user 10 different resource types (5 raw and 5 clean) per supply region. Coal that is mined clean or purchased clean only incurs an additional handling cost at the loading facility level. This is simply a fixed per unit charge to load the coal onto the rail cars or trucks.
Raw coal, coal that does not meet utility specifications, must be processed before it is loaded and shipped to the power plants.

"Cleaning costs" are a combination of fixed and variable costs. The total fixed costs are incurred regardless of the level of throughput of the cleaning facility; therefore, the higher the throughput, the lower the per unit fixed costs. Variable costs, such as; labor, supplies and handling, are dependent upon the amount of coal processed and the capacity of the cleaning plant. For example, the third shift will have lower per unit labor costs since this shift is normally used for maintenance and requires fewer employees. Similar to the revenue requirements approach, the cleaning plant calculations were written to incorporate standard book depreciation on plant equipment and interest expenses on invested capital.

Once the clean coal is loaded and the raw coal is cleaned and loaded, it is treated as one "type" of coal. The sulfur and BTU per pound values of all the resource coals in each supply region are blended together and the result is an average coal type from that region.

9. TRANSPORTATION

The final additional cost at each supply region is that of transporting the coal from the loading facility to the power plant.
The per unit transportation costs are dependent on the geographic location of the supply region in relation to each power plant. For each of the 96 possible links from supply to demand, there is a uniquely identified transportation cost. Depending on the proximity of each loading facility and the existing rail and truck routes, it is possible that many unit transportation costs will be the same value. It is as critical to know those costs that are the same as it is to know those costs that are different. Historically, one supply region may be feeding one power plant even though an alternate coal type might satisfy the power plants requirements. Would it be cheaper to reroute the coal? The optimization routine (to be discussed) will solve this distribution question.

Having gone through the resource cost calculations, the loading or cleaning calculations and the per unit transportation calculations, the total cost of fuel to each power plant is defined as the product of the delivered price of coal and the quantity of coal delivered in that year. If the system is defined such that a particular power plant receives more coal than it requires on an annual basis, the excess coal is sold back to the general market at the average market price for that year. In actuality if we have over-committed supplies of coal to each power plant, we would adjust the transportation network and ship the committed coal to an other-than-normal demand location.
10. SUMMARY

The coal supply cost calculator develops the delivered price of coal starting at the resource level, mine production or purchases, continues through the cleaning or loading facility and finally incurs transportation costs as the coal is shipped to each power plant. On each link in the system, the per unit price, quantity, BTU per pound and sulfur value of the coal represented is retained. The system calculates the total annual cost of fuel to each power plant then sums across all power plants to determine a total cost of fuel for the utility. The present value of this final stream of numbers is calculated and it is that number that is used as a basis for comparison for different supply plans.

Appendix I contains all of the equations discussed in this section. Following the appendix is a glossary of the mnemonics used in the equations.
Base Case
Data Inputs
Cleaning and Loading Processes
Transportation Links
Demand Outputs

MINE COSTS
- Capital
- Operating
- Productivity

CONTRACTS
- Quantity
- Length

SPOT MARKET

Cleaning Plant

Loading Facility

Reject

Rail or Truck

POWER PLANT

General Coal Flows
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Flag Table 2-B
Exhibit 2-D
General Network Description
-25-
CHAPTER 3

OPTIMIZATION FORMULATION

1. INTRODUCTION

The process of supplying fuel to meet generating station requirements is usually the result of a series of short-term decisions. The decision of opening a new mine, purchasing an operating mine, signing new short or long-term contracts or increasing spot market purchases is only evaluated as it affects the present coal supply mix. Also, the decision is rarely considered as to how it will affect the total system operations. The Coal Supply Calculator (discussed in Chapter 2) enables the user to evaluate all supply decisions on a consistent, system-wide basis. The optimization routine will aid in determining the flow of coal from the various constrained and unconstrained sources to the demand locations.

2. PROBLEM IDENTIFICATION

It is essential to the efficient operation of a utility for there to exist a coal supply strategy. This strategy should set guidelines for the most desirable coal supply mix between committed and noncommitted sources. The fuel management department has the
responsibility of meeting the strategy guidelines at the minimum total cost. It is exactly this question of minimizing total system cost that the optimization routine addresses. Given a base case set of plans, what is the least cost way of satisfying system operating requirements?

As the network was defined in the previous section (see Exhibits 2-B and 2-C), there are potentially 360 unique resources (12 supply regions x 10 resource processes x 3 cases) capable of being committed to a maximum of 8 power plants. In addition, there is a slack variable associated with each power plant which acts like an infinite supply of coal. This is a classic example of the Transportation Problem: minimize the cost of transporting a commodity from m sources to n destinations forcing an equilibrium solution.

A question may arise regarding this system's applicability to the Transshipment Problem; which states, a commodity may pass through other sources and destinations before eventually reaching its ultimate destination. There are several factors which exclude this particular example from a transshipment problem formulation. Physical constraints limit mining coal at one location and shipping the coal from point A to point B then on to its ultimate destination. Once coal is loaded onto the rail cars, specific
unloading facilities are required to either rotate the car 180° or allow the coal to drop out of the bottom of the car. These facilities simply do not exist at any supply locations. The converse of this constraint is true for all power plant locations. The facilities to unload the coal by either method exist; however, once unloaded it is pushed around by bulldozers. Tipples required to load the cars do not exist at any power plants.

3. GLOSSARY

The following is a list of definitions for the mnemonics used in this and subsequent chapters.

1. CC(j,m) = cleaning cost for supply region j in year m.

2. CBTURF(j) = BTU recovery factor for supply region j.

3. CSULRF(j) = sulfur recovery factor for supply region j.

4. CTONRF(j) = tonnage recovery factor for supply region j.

5. LC(j, m) = loading cost for supply region j in year m.

6. LCAP(j) = loading facility capacity for supply region j.
7. \( \text{LTONS}(k) = \) lower limit for tonnage output from resource \( k \).

8. \( \text{MMBTUR}(i,m) = \) millions of BTUs required by power plant \( i \) in year \( m \).

9. \( \text{PSULF}(i) = \) lbs/\( \text{SO}_2 \) limit at power plant \( i \).

10. \( \text{RLBTULB}(k,m) = \) BTU/lb for resource \( k \) in year \( m \).

11. \( \text{RLPPT}(k,m) = \) resource \( k \) price per ton in year \( m \).

12. \( \text{RLPPT}(i,m) = \) general spot market price at power plant \( i \) in year \( m \).

13. \( \text{RLSULF}(k,m) = \) pounds of sulfur dioxide for resource \( k \) in year \( m \).

14. \( \text{STRANS}(i,j,m) = \) per unit transportation charge from supply region \( j \) to power plant \( i \) in year \( m \).

15. \( \text{SULF}(i,m) = \) pounds of sulfur dioxide emitted by power plant \( i \) in year \( m \).

16. \( \text{UTONS}(k) = \) upper limit for tonnage output from resource \( k \).
17. \( X(k,i) \) = tons of coal from resource process \( k \) to power plant \( i \).

4. PROBLEM OBJECTIVE

The system objective is to minimize the total cost of fuel such that 
BTU and sulfur requirements are met at the power plants and capacity 
constraints are not violated at the supply regions. The total cost 
is a function of three costing parameters:

1. \( \text{RLPPT}(k,m) \) or \( \text{RLPPT}(i,m) \)

2. \( \text{CC}(j) \) or \( \text{LC}(j) \)

3. \( \text{STRANS}(i,j,m) \)

The resource costs are calculated as per mine production, contract 
specification or spot market calculations. If the resource costs 
are on a raw ton basis, the cleaning costs must be computed external 
to the resource calculations. Cleaning and transportation costs are 
stated on a clean ton basis; therefore, to accurately represent 
these additional costs, the raw ton parameters must be multiplied by 
a tonnage recovery factor, \( \text{CTONRF}(j) \). This parameter reflects the 
inverse by the tonnage reject rate for each cleaning facility in 
that supply region. Those resources that are calculated as clean
coal supplies only incur the additional costs of loading and transportation. The general spot market coal (RLPPT(i,m) i = 1,8), which acts like an infinite supply for power plant, is stated on an FOB basis. FOB, free-on-board, includes all resource costs less transportation.

5. DECISION VARIABLES

The decision variables are identified by resource type in each supply region and by ultimate destination. There are at most 368 unique coal links from source to sink. Eight links are uniquely associated with each power plant. The other 360 links represent a resource process in each supply region. Each resource must be uniquely identified by the computer code, so that all costs get transferred properly. Given the supply region number, resource number, and case number, a simple formula calculates the resource identifier. The general form is:

\[ l = (j - 1) \times 30 + (k - 1) \times 3 + c. \]

- \( j \) = Supply region 1 through 12
- \( k \) = Resource process 1 through 10
- \( R_1 \) (R6) = raw (clean) coal production
- \( R_2 \) (R7) = raw (clean) cost plus contract
R3 (R8) = raw (clean) base price plus escalator contract
R4 (R9) = raw (clean) FERC indicator contract
R5 (R10) = raw (clean) local spot market

c = Case number 1 through 3.

For example, if we wish to identify the second clean FERC indicator contract in supply region 3, the calculations are as follows:

(5.2) \[ 1 = (3 - 1) \times 30 + (9 - 1) \times 3 + 2 \]
\[ 1 = 60 + 24 + 2 \]
\[ 1 = 86. \]

The second identifier for the decision variable is its ultimate destination, i.e., power plant \( i \), \( i = 1, \ldots, 8 \). Hence, the decision variable takes on the general form \( X(l, i) \).

6. OBJECTIVE FUNCTION

The objective function is a total cost equation for the entire supply network. Mathematically, the total cost equation is:

(6.1) \[
\sum_{i=1}^{8} \sum_{j=1}^{12} \sum_{k=1}^{5} (RLPPT(k) + (CC(j) + STRANS(i,j)) \times \]
---

-32-
\[ \text{CTONRF}(j) \cdot X(l,i) + \sum_{k=6}^{\infty} (\text{RLPPT}(k) + \text{LC}(j) + \text{STRANS}(i,j)) \cdot X(l,l) + (\text{RI.PPT}(l) + \text{STRANS}(i,j) \cdot X(l,i). \]

Since the system is minimized on an annual basis, the year identifier "m" is not included in the objective function.

7. CONSTRAINT: BTU REQUIREMENTS

The first set of constraints which are identified are the BTU requirements at each power plant. The right-hand-side of the constraint is calculated by the CSC. To reiterate, the BTU requirements are expressed in millions of BTUs (MMBTU). A power plant's annual operating requirement is determined by the following equation:

\[ (7.1) \quad \text{MMBTUR}(i,m) = \text{nameplate rating of power plant } i \text{ (KWH)} \times \text{heat rate of power plant } i \text{ (BTU/KW)} \times \text{annual capacity factor in year } m \times 8760 \text{ hours.} \]
The BTU value of coal at each resource process is expressed in BTU/lb. It is necessary to convert this input value to one that is consistent with right-hand-side value. Since there are 2000 lbs. per ton of coal, the coefficient becomes:

\[(7.2)\quad RL\text{BTU}(k,m) = 2000 \text{ lbs/ton} \times RL\text{BTULB}(k,m).\]

In the case of raw coal resource processes, the BTU value is altered by the cleaning process. Therefore, those coefficients associated with raw coal production or purchases must be multiplied by a BTU recovery factor (\(\text{CBTURF}(j)\)). There must be exactly one BTU requirement constraint for each power plant defined by the flag table. The general form of the equation is:

\[12\quad 5\]

\[(7.3)\quad \sum_{j=1}^{12} \sum_{k=1}^{5} RL\text{BTU}(k) \times CBTURF(j) \times X(1,i) = \]

\[10\]

\[\sum_{k=6}^{10} RL\text{BTULB}(k) \times X(1,i) + RL\text{BTULB}(i) \times X(1,i) \geq \text{MMBTUR}(i).\]
8. CONSTRAINT: SULFUR LIMITS

The next set of constraints limit the quality of coal burned at each power plant. All electric generating stations are governed by state and federal regulations which limit the amount of particulates and pollutants that may be emitted into the atmosphere. The restrictions are written in the form of pounds of sulfur dioxide per millions of BTUs (lbs $SO_2/\text{MMBTU}$). Since the CSC calculates the MMBTU requirement for each plant, it is necessary to multiply the $SO_2$ limit by this factor to determine the maximum pounds of sulfur dioxide that can be produced by each power plant. The right-hand-side of the equation is:

\[(8.1) \quad \text{SULF}(i,m) = \text{PSULF}(i)/\text{MMBTUR}(i,m).\]

The sulfur value of coal at the resource level is expressed in percent of sulfur of that coal. The $\%S$ value must be converted to pounds of sulfur dioxide per ton of coal for each resource process in the following manner:

\[(8.2) \quad \text{RLSULF}(k,m) = \% \text{Sulfur} \times 2 \times 2000 \text{ lbs/ton}.\]

Since the sulfur content of coal is one of the main reasons coal is cleaned, there is a sulfur recovery factor ($\text{CSULRF}(j)$) which must be
applied to the raw coal sulfur values. As was the case with the BTU requirement constraints, there must be one sulfur constraint for each power plant. The general form of the equation is:

\[
\sum_{k=1}^{12} \sum_{i=1}^{5} RLSULF(k) \cdot CSULRF(j) \cdot X(1,i) + \\
\sum_{k=6}^{10} RLSULF(k) \cdot X(1,i) + RLSULF(i) \cdot X(1,i) \leq SULF(i). 
\]

The factor of 2 is necessary in this equation due to the atomic weight of \(SO_2\) for a given amount of sulfur.
There are two physical limitations at each supply region. Coal cleaning plants are designed for a specified throughput. Depending upon whether the plant operates with one or two shifts, the amount of clean coal output can be more than doubled from the minimum operating level. If a third shift is scheduled, it is a maintenance shift. However, the capacity of a cleaning plant is never the limiting factor for the amount of coal shipped from a supply region. The supply region capacity constraint is based on the amount of coal the tipple can load (LCAP(j)). The capacity of the tipple must always exceed the cleaning plant. If the opposite were true, coal from the cleaning plant would get backed up at the loading facility which is economically inefficient. Secondly, purchased coal, either contract or spot, could not be loaded at the supply region. The tonnage recovery rate applied to the cost coefficients in the objective function must also be applied to the raw ton production and purchases to accurately reflect the tons lost during the cleaning process. The general form of the equation is:

\[
8 \sum_{i=1}^{5} \sum_{k=1}^{10} \text{CTONRF}(j) \cdot X(1,i) + \sum_{k=6}^{9} X(1,i) \leq \text{LCAP}(j).
\]
10. CONSTRAINT: BOUNDED VARIABLES

The final set of constraints set up the bounds for the decision variables. Since the network is a single direction matrix (see Exhibit 2-C), all coal flows must take on a value greater than or equal to zero. Those resource processes associated with mine production or contracts must be bound on the lower and upper end. Since mine production costs are piece-wise linear (see Chapter 4, Section 5 for a specific example), bounds are placed around the input production level:

for \( k = 1 \) or 5;

\[
\begin{align*}
(10.1) \quad & UTONS(k) = (1 + a\%) \times \text{production tons}, \\
(10.2) \quad & LTONS(k) = (1 - b\%) \times \text{production tons}.
\end{align*}
\]

If the upper limit bounds the decision variable infeasible, then we have an economically desirable mine and should attempt to purchase similar reserves or expand the existing mine production. If the decision variable is bound by the lower production limit, the next increment of per unit costs must be input. The original lower limit becomes the new upper limit at the new unit cost and a new lower limit must be established. The economic shut-down point must be
identified and if the optimization crosses this point, the mine must be terminated.

All contracts are negotiated for a predetermined quantity of coal at specific sulfur and BTU/lb levels. There is a provision in contracts for either the vendor or receiver to vary the tonnage deliveries within a designated range. This range is calculated similar to the calculation for mine production levels:

for \( k = 2, 3, 4, 7, 8, 9; \)

\[
\text{UTONS}(k) = (1 + a\%) \times \text{contract tons,}
\]

\[
\text{LTONS}(k) = (1 - b\%) \times \text{contract tons.}
\]

If either bound serves as a limiting factor in the optimal solution, then there is cause to renegotiate the contracts by the vendor or receiver depending on which bound is constraining.

The local spot market resources \((k = 5, 10)\) do not require upper bounds since the loading facility capacity factor will constrain the supply. Their lower bound is obviously zero.
11. SOFTWARE

Except for coefficient conversion equations, all of the cost calculations are performed by the Coal Supply Calculator. The optimization subroutine reads the output from the CSC, performs the conversions calculations and formats the data in a manner compatible with the linear programming software. The linear programming software, that the optimization subroutine calls, employs the revised simplex solution method. The software is from IBM entitled Mathematical Programming System Extended/370.
CASE STUDY

1. INTRODUCTION

The general form of the optimization network was developed in Chapters 2 and 3. This Chapter will provide the specific example for the network in Exhibit 4-A. All of the data was collected for an eastern Pennsylvania electric utility. The company owns and operates four bituminous coal steam electric plants, five cleaning plants and five mining operations (4 underground and 1 surface). Over one half of the annual coal requirements are supplied by the affiliated mine operations or by contract. The balance of the operating requirements are met by local and general spot market purchases.

2. THE PROBLEM

The problem facing the utility is to minimize the direct cost of power charged to its customers. Two main components in the direct cost of power are total fuel costs and power plant availability and performance. Utilities nationwide have developed cooperatives to sell electricity to their customers at the lowest cost. These cooperatives or grid systems also increase the total system
reliability by allowing member utilities to service customers out of their normal service area. The utility in question is a member of the Pennsylvania-New Jersey-Maryland (PJM) Interconnection. The four bituminous units in question are among the most efficient units in this interconnection. Power plant availability is crucial due to the fact that if one of these plants is out of service, the utility must purchase more expensive electricity on the interconnection to fulfill its base load requirements.

The question of power plant performance has been addressed by Dussinger and Kroboth [2]. The authors concluded that variances in coal characteristics do change the total energy output from a given power plant. Using the model they developed, Dussinger and Kroboth were able to assign dollar per ton premiums and penalties to different coals depending on its characteristics. An area for future enhancement of the Coal Supply Calculator is to incorporate a power plant performance subroutine into the demand calculations.¹

¹This concept was not identified in the original problem; hence, its incorporation is deferred to a later date.
It would be necessary to add the additional coal characteristics of ash, moisture, grind and fusion temperature to the existing sulphur and heating value data to have a complete picture of the coal being burned. The problems of power plant availability and performance are beyond the scope of this paper but are mentioned to alert the readers to the many facets of electricity generations.

3. THE NETWORK

The total cost of fuel includes the resource price and the transportation charges. All of these costs have been developed for the supply network in Exhibit 4-A. The four bituminous coal units are defined by Pl-4. There were 8 supply regions isolated. They are identified by Al-8. Each supply region ends with an allocation process (A) which distributes the coal from that region to any of the four power plants. There are only 16 out of a possible 32 links displayed on this network. Physical or a contractual arrangements limit the transportation of coal from a particular supply region to a particular power plant. For example, coal from regions 1, 4 or 6 would never be sent to power plant 4 because P4 does not have the train unloading facilities to accept coal from any of those three regions. Coal from regions 2 and 3 is contractually committed to power plant 2; hence, no links are shown from supply regions 2 or 3 to any of the other three power plants.
4. POWER PLANT CHARACTERISTICS

To determine the annual BTU requirements, each power plant requires three input parameters. The following table summarizes this data. Please note that the capacity factors vary over time; only two forecast years have been included.

<table>
<thead>
<tr>
<th>TABLE I</th>
</tr>
</thead>
<tbody>
<tr>
<td>POWER PLANT DATA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating</td>
<td>300</td>
<td>1515</td>
<td>1464</td>
</tr>
<tr>
<td>Heat Rate</td>
<td>11803</td>
<td>9342</td>
<td>9793</td>
</tr>
<tr>
<td>Capacity Factor:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>60</td>
<td>78</td>
<td>75</td>
</tr>
<tr>
<td>1985</td>
<td>62</td>
<td>77</td>
<td>78</td>
</tr>
<tr>
<td>1990</td>
<td>57</td>
<td>77</td>
<td>76</td>
</tr>
</tbody>
</table>

The sulphur limit, as determined by State and Federal Regulations, is the same for all four power plants. Even though these plants are located at four very different geographic locations in Pennsylvania, they all lie within similar air basins and must abide by the same
air quality regulations. The systems sulphur limit is 3.7 pounds of sulphur per million BTU.

5. MINE DEFINITION

The mine production calculations require the most input data values (see Chapter 2). Each of the four underground mines has a cleaning plant associated with its mine production calculations. The cleaning process not only reduces the sulphur content of the coal but also eliminates excess rock and dirt mined with the coal in an underground operation. Since the miners are able to be more selective at a surface operation, there is no cleaning facility associated with the one surface coal operation (S4). The coal from this region is mined and loaded directly on to the cars without any preparation. Table II displays a summary of the clean coal cost values for the five mines.
TABLE II

MINE PRODUCTION COSTS

($) per Clean Ton

<table>
<thead>
<tr>
<th>Supply Region</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>45.00</td>
<td>36.96</td>
<td>32.40</td>
<td>46.09</td>
<td>41.42</td>
</tr>
<tr>
<td>1985</td>
<td>58.88</td>
<td>50.79</td>
<td>42.20</td>
<td>59.07</td>
<td>NA</td>
</tr>
<tr>
<td>1990</td>
<td>88.40</td>
<td>58.36</td>
<td>63.45</td>
<td>89.14</td>
<td>NA</td>
</tr>
</tbody>
</table>

The per unit clean costs for supply regions 3 and 6 are very similar even though they are very different mining operations. Region 3 is a very large capital intensive underground mine, whereas region 6 is a much smaller labor intensive underground operation. Supply region 5 is very similar in construction to region 6 but the coal from region 5 need not be processed to the extent that region 6 coal must be to meet power plant specification. The fourth underground mine region 7 expires in the year 1984. The one surface operation, region 4, exhibits the lowest cost structure over time.

As was previously mentioned, mine production costs are piece-wise linear. Within a relatively narrow output range, per unit marginal
costs do not vary with marginal production. Beyond the limits of the range, i.e., the breakpoints, the marginal costs are greater than the marginal production levels warranted. Breakeven analysis must be based on a constant selling price which is a valid constraint given the transfer pricing mechanism between the utility and its affiliated mines.

The specific breakpoints for the captive underground mines investigated indicate more flexibility at the lower end of the design output. Any of the in-place capital equipment is operated near its maximum capacity. The breakeven points for resources 5, 9, 11 and 14 are +7.5% and -10.5% of the mine design output. Chart 1 graphically represents this data.
Since this utility owns a large number of operating mines, there is little need to assure a coal supply with contractual arrangements; however, it is reasonable to diversify one's sources. There are four contract processes defined by this network. In this system, the contracts were all written for the delivery of clean coal (even though it is possible to write contracts for raw coal). Also, each contract has been designated for a particular power plant. Power plant 1, one of the smaller units, does not have any contracts specifically designated for itself. The following table summarizes all of the contracts by supply region.

<table>
<thead>
<tr>
<th>Supply Region</th>
<th>1982</th>
<th>1985</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>34.99</td>
<td>49.51</td>
<td>95.88</td>
</tr>
<tr>
<td>8</td>
<td>34.27</td>
<td>49.51</td>
<td>95.88</td>
</tr>
</tbody>
</table>
Beyond 1985, there are no contracts presently in existence. In order to retain consistency within the network, the same contract cost forecast was employed for both regions.

7. OTHER COAL SUPPLIES

Neither contracts nor mines are part of the calculations in supply region 1. It is the only region totally defined by local spot market purchases. At location S1, there is a cleaning plant which handles raw and clean coal purchases. Not having an operating mine directly associated with this plant allows the utility to enjoy extra measure of diversification. Table IV displays the average supply region costs. Each value represents an aggregate calculation of mine costs, contract costs, and spot market purchases.
8. TRANSPORTATION

Once all of the cost calculations have been successfully completed by the Coal Supply Calculator, the data is retrieved and formatted according to conventions required by the MPSX Software package. Appendix II displays the computer code which performs this transformation. The coding was done using PL/1 (Programming Language/1). The reader will note a close similarity between PL/1
and Fortran and Basic. The matrix displayed in Exhibit 4-B corresponds to the network description (Exhibit 4-A) of the current operating environment. This matrix was generated by the MPSX Program from the input data file.

9. 1982 CONVERGENCE

The optimization routine confirms that this utility is operating in an efficient manner. After 35 iterations, a feasible solution was located and after 50 iterations the system converged on an optimal solution. Even though the in place plans for 1982 have provided an optimal solution, guidance can be deemed from investigating which bounds are limiting and determining if any action can be taken to extend those limiting valves.

The optimal solution for 1982 schedules each power plant to purchase the minimum amount of BTUs required to meet annual operating levels. It is operationally desirable to maintain minimum stock pile levels at the power plants and it would be difficult to persuade operators that it is cost effective to purchase more coal than is required at a particular point in time.

Three of the four power plants are well within the sulphur regulations for central and eastern Pennsylvania. The one exception...
is power plant 1 which is scheduled to emit the maximum allowable amount of sulphur dioxide into the environment. An obvious area for future investigation is Federal and State relaxation of the emission standards for Pl. None of the loading facility's capacity factors serve as a limiting factor for coal distribution in 1982.

10. 1982 RESOURCE PRODUCTION

The most interesting information is derived from the optimal operating levels for each of the individual resource of processes. Table V summarizes the findings for 1982.
## TABLE V

**Resource Process Output Levels**

(1982 - K Tons)

<table>
<thead>
<tr>
<th>Process Number</th>
<th>Planned Output</th>
<th>Optimal Output</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>860</td>
<td>946</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>305</td>
<td>335.5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>432</td>
<td>388.8</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1200</td>
<td>1320.</td>
<td>lower limit</td>
</tr>
<tr>
<td>5</td>
<td>2000</td>
<td>2024</td>
<td>upper limit</td>
</tr>
<tr>
<td>6</td>
<td>.1</td>
<td>.1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>360</td>
<td>396</td>
<td>upper limit</td>
</tr>
<tr>
<td>8</td>
<td>250</td>
<td>275</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>500</td>
<td>733.3</td>
<td>upper limit</td>
</tr>
<tr>
<td>10</td>
<td>220</td>
<td>242</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>581</td>
<td>639</td>
<td>upper limit</td>
</tr>
<tr>
<td>12</td>
<td>200</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>2</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>250</td>
<td>270.8</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>66</td>
<td>59.4</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>160.</td>
<td>176.</td>
<td>upper limit</td>
</tr>
<tr>
<td>17</td>
<td>68</td>
<td>68.6</td>
<td></td>
</tr>
</tbody>
</table>
Three out of five operating mines are constrained by their maximum design output. It may be beneficial to investigate expanding these three mines. If the economics remain the same, the utility will be better off. Mine processes 5 and 14 are unconstrained at their optimal operating levels. Mine production costs are in direct competition with local and general spot market purchases. If the price of spot market coal prices jump beyond all expectations, the utility will appear to have made a very wise decision in developing captive mine operations. The converse is also true; if the bottom drops out of the spot market, then those captive mining operations will be priced much higher than market. (Total fuel cost sensitivity to spot market prices will be further investigated in Chapter 5).

11. 1982 DISTRIBUTION PLAN

Even though all of the resource process output levels are optimized within the current operating environment, the distribution of coal over the existing transportation network shows some enlightening facts. The optimization routine has determined that in most cases it is cheaper to transport coal from one supply region to only one power plant rather than split the output as is currently done. In this manner, a total of six transportation links could be deleted from the network in Exhibit 4-A. These links are:
From the data summarized on Table VI, two processes deserve special attention. The in-place operating plans specify over 50% of the coal from S1 should be transported to P1. The optimization routine has determined that all of the coal from supply region 1 should be transported to power plant 3. The "lost" coal from power plant 1 is supplied from supply region 6. Since most of the coal from supply region 6 is currently scheduled to go to power plant 3, these two modifications compliment one another. The transportation links already exist from S1 to P3 and from S6 to P1; therefore, the utility should investigate the feasibility of changing the usage of these links to coincide with the optimization routines output. Most of the other links that are zeroed out by the optimization routine are minimumly traversed. This slight redistribution of coal flows for 1982 can be expected to reduce the total cost of fuel by almost $11,000,000. This represents a 3% reduction from the budgeted $425,000,000.
<table>
<thead>
<tr>
<th>Source - Destination</th>
<th>Planned</th>
<th>Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 - P1(P3)</td>
<td>464(396)</td>
<td>0(946)</td>
</tr>
<tr>
<td>R2 - P1(P3)</td>
<td>165(140)</td>
<td>0(335.5)</td>
</tr>
<tr>
<td>R3 - P2</td>
<td>432</td>
<td>388.8</td>
</tr>
<tr>
<td>R4 - P2</td>
<td>1200</td>
<td>1320.</td>
</tr>
<tr>
<td>R5 - P2</td>
<td>2000</td>
<td>2024.</td>
</tr>
<tr>
<td>R6 - P2</td>
<td>.1</td>
<td>.1</td>
</tr>
<tr>
<td>R7 - P1(P2)(P3)</td>
<td>14(61)(284)</td>
<td>7.2(0)(388.8)</td>
</tr>
<tr>
<td>R8 - P1(P2)(P3)</td>
<td>10(43)(198)</td>
<td>0(0)(275)</td>
</tr>
<tr>
<td>R9 - P3(P4)</td>
<td>660(7)</td>
<td>733.3(0)</td>
</tr>
<tr>
<td>R10 - P3(P4)</td>
<td>218(2)</td>
<td>242(0)</td>
</tr>
<tr>
<td>R11 - P1(P2)(P3)</td>
<td>35(12)(535)</td>
<td>454.3(0)(184.8)</td>
</tr>
<tr>
<td>R12 - P1(P2)(P3)</td>
<td>12(4)(184)</td>
<td>220(0)(0)</td>
</tr>
<tr>
<td>R13 - P1(P2)(P3)</td>
<td>.1(.04)(1.8)</td>
<td>0(0)(2.2)</td>
</tr>
<tr>
<td>R14 - P3(P4)</td>
<td>15(235)</td>
<td>0(270.8)</td>
</tr>
<tr>
<td>R15 - P3(P4)</td>
<td>4(62)</td>
<td>0(59.4)</td>
</tr>
<tr>
<td>R16 - P3(P4)</td>
<td>147(13)</td>
<td>176.(0)</td>
</tr>
<tr>
<td>R17 - P3(P4)</td>
<td>63(5)</td>
<td>68.6(0)</td>
</tr>
</tbody>
</table>
12. LONG-RUN OPTIMIZATION

The analyst must be forewarned against offering a short-run optimum policy at the expense of an overall long-term strategy. The Coal Supply Calculator has the capacity to calculate prices for a 35 year time horizon and the optimization routine can interface with any valid year of data. Mine production costs and long-term contract costs can be accurately forecast for ten to fifteen years. However, the general rate of inflation and spot market prices are somewhat hazy beyond twelve to eighteen months.

In some respects, the long-term is much easier to forecast. It is merely the average of short-term disequilibrium points (Chapter II). The challenge in the short-time is to identify the turning points, i.e., the troughs and valleys.

[Chart II]

[Graph showing short-term and long-term price movements over time]
12. LONG-RUN OPTIMIZATION

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Chart II

![Chart II Diagram](image-url)
CORRECTION

The preceding document has been re-photographed to assure legibility and its image appears immediately hereafter.
12. LONG-RUN OPTIMIZATION

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In some respects, the long-term is much easier to forecast. It is merely the average of short-term disequilibrium points (Chapter II). The challenge in the short-time is to identify the turning points, i.e., the troughs and valleys.
The general rate of inflation, implicit in the spot coal price forecast, is 9% through 1990. At the present time, the spot coal producers in central Pennsylvania are operating below their marginal rate of return of their investment. Many operators have been going out of business; a few are hanging on. As demand becomes constrained and oil conversion units (primarily from New England) are completed, real price increases of coal can be expected to be higher than the general rate of inflation (see Chapter 5, Section 2). The expected market price track input with the base case data is:
TABLE VII
EXPECTED SPOT MARKET PRICES
($/Ton FOB)

1982  34.60
1983  39.30
1984  44.60
1985  50.70
1986  57.10
1987  64.60
1988  74.30
1989  85.30
1990  98.20

13. LONG-RUN MINE PLANS

The critical question facing a utility with captive operations is; given the forecasts displayed in TABLES I - IV and VII, what is an optimal mine production policy? In all cases from 1982 through 1990, the captive mine production levels are optimized within their original design structure. Since three of the five mines are scheduled for maximum production in 1982, there is a temptation to expand the mining complex beyond its current limits. At resource 9, this may be a reasonable course of action since it continues to
produce at its maximum level through 1990. However, resources 7 and 11, which produce at maximum levels in 1982, decline in output requirements during the middle years then increase production back to maximum levels starting in 1987. Mine process 14 expires in 1984. The following table summarizes the mine process output for selected years.

### TABLE VIII

**OPTIMAL RESOURCE PROCESS OUTPUT**

(K-Tons)

<table>
<thead>
<tr>
<th></th>
<th>1982</th>
<th>1985</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>R5</td>
<td>2024</td>
<td>1790</td>
<td>2150</td>
</tr>
<tr>
<td>R7</td>
<td>396</td>
<td>324</td>
<td>396</td>
</tr>
<tr>
<td>R9</td>
<td>733.3</td>
<td>733.3</td>
<td>733.3</td>
</tr>
<tr>
<td>R11</td>
<td>639</td>
<td>574.6</td>
<td>639</td>
</tr>
<tr>
<td>R14</td>
<td>i/o</td>
<td>expires</td>
<td></td>
</tr>
</tbody>
</table>

In a volatile market, such as the central Pennsylvania coal fields, it is unwise to make any dramatic changes without considering future implications. The results displayed in Table VIII only clearly support the expansion of mine process 9 before 1985.
The second consideration the utility must face is the potential for a changing distribution network over time. With a few minor exceptions, the optimal transportation matrix remains constant over the next eight years. The expiration of mine process 14 in 1984 and a major contract in 1983 (process R4) trigger the redistribution of coal over the existing transportation network. Due to the size of the expired contract, plant 2 is forced to acquire coal from five new resources beginning in 1984. Supply regions 4 and 6 (which contain resource processes 7 & 8 and 11, 12 & 13, respectively) replace the R4-P2 link. Please note from Table VI that R7 and R8 were eliminated from the 1982 supply base for plant 2. A ripple effect is subsequently felt by power plants 3 and 4. Prior to 1984, the five aforementioned resource processes supplied a major portion of the coal to P3. Resources 14 and 15 are rescheduled to fill this void. And finally resources 16 and 17, originally satisfying P4's requirements, are redirected to plant 4.

The system effect of the expiration of mine process 14 is not nearly as dramatic as the previous discussion. The magnitude of the coal "lost" from R14 versus R4 is nearly five times smaller. The contracts from supply region 8 (R16 and R17) are pushed to their maximum level in 1985 and remain there through 1990. In total, the
optimal link data from Table VI updated to 1990 on Table IX shows very little variance over time.
<table>
<thead>
<tr>
<th>Source-Destination</th>
<th>Planned</th>
<th>Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 - P1(P3)</td>
<td>464(396)</td>
<td>0(774)</td>
</tr>
<tr>
<td>R2 - P1(P3)</td>
<td>165(140)</td>
<td>0(274.5)</td>
</tr>
<tr>
<td>R3 - P2</td>
<td>700</td>
<td>630</td>
</tr>
<tr>
<td>R4 - P2</td>
<td>expired</td>
<td></td>
</tr>
<tr>
<td>R5 - P2</td>
<td>2000</td>
<td>2193</td>
</tr>
<tr>
<td>R6 - P2</td>
<td>.1</td>
<td>.1</td>
</tr>
<tr>
<td>R7 - P1(P2)(P3)</td>
<td>14(61)(284)</td>
<td>30(0)(365.6)</td>
</tr>
<tr>
<td>R8 - P1(P2)(P3)</td>
<td>10(43)(198)</td>
<td>0(50)(225)</td>
</tr>
<tr>
<td>R9 - P3(P4)</td>
<td>660(7)</td>
<td>733.3(0)</td>
</tr>
<tr>
<td>R10 - P3(P4)</td>
<td>218(2)</td>
<td>198(0)</td>
</tr>
<tr>
<td>R11 - P1(P2)(P3)</td>
<td>35(12)(535)</td>
<td>473.1(121.5)(44.4)</td>
</tr>
<tr>
<td>R12 - P1(P2)(P3)</td>
<td>12(4)(184)</td>
<td>180(0)(0)</td>
</tr>
<tr>
<td>R13 - P1(P2)(P3)</td>
<td>.1(.04)(1.8)</td>
<td>0(1.8)(0)</td>
</tr>
<tr>
<td>R14 - P3(P4)</td>
<td>expired</td>
<td></td>
</tr>
<tr>
<td>R15 - P3(P4)</td>
<td>expired</td>
<td></td>
</tr>
<tr>
<td>R16 - P3(P4)</td>
<td>1000(220)</td>
<td>1048.5(49.5)</td>
</tr>
<tr>
<td>R17 - P3(P4)</td>
<td>18(282)</td>
<td>0(270)</td>
</tr>
</tbody>
</table>
15. SUMMARY

The bottom value measure for the optimization routine is the present value of the total cost of fuel over a specified time horizon. Given the operating and market assumptions discussed in the previous sections, the utility could expect to save $79,000,000 from 1982 through 1990 by adjusting the mine output levels and coal distribution plan to those proposed in Sections 13 and 14. Table X summarizes the actual budgeted total cost of fuel and the optimized values for the same years.
TABLE X

TOTAL COST OF FUEL

($M)

<table>
<thead>
<tr>
<th>Year</th>
<th>Budget</th>
<th>Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>425</td>
<td>414</td>
</tr>
<tr>
<td>1983</td>
<td>475</td>
<td>463</td>
</tr>
<tr>
<td>1984</td>
<td>531</td>
<td>517</td>
</tr>
<tr>
<td>1985</td>
<td>592</td>
<td>583</td>
</tr>
<tr>
<td>1986</td>
<td>651</td>
<td>641</td>
</tr>
<tr>
<td>1987</td>
<td>704</td>
<td>696</td>
</tr>
<tr>
<td>1988</td>
<td>788</td>
<td>781</td>
</tr>
<tr>
<td>1989</td>
<td>887</td>
<td>882</td>
</tr>
<tr>
<td>1990</td>
<td>995</td>
<td>992</td>
</tr>
</tbody>
</table>

The present value of column 1 (Budget) is $3707M and of column 2 (Optimal) is $3649M. Given a 12% discount rate, the total savings $58,000,000 in today's dollars. A 12% discount rate was chosen to reflect the weighted cost of money to a utility.

Chart 3 is a graphical representation of the data displayed in Table X. This utility has forecast that they will be operating very near
optimal by the end of the time period studied. This is a reasonable result since any company will project an ever improving operating environment. However, it would not be surprising to see a wider spread between budget and optimal data values when this system is run in the year 1990. Any unforeseen perturbation of the norm may cause the budget line to jump in either direction hence negating the current "optimal" solution.
BUDGET VS. OPTIMAL TOTAL COSTS
NOMINAL DOLLARS

Chart 3

Millions of Dollars

Years

Budget
Optimal
Key: M=Mine, S=Spot Coal, C=Contract, CL=Cleaning Plant and P=Power Plant
Exhibit 4-B
Matrix
-69-
It is critical in any analysis to always be cognizant of the input assumptions. If the base case set of assumptions seem reasonable to all individuals involved in setting up the data, then the results should reflect the group's best guess. Should the perception of any of the basic parameters change, it is necessary to reevaluate the initial conclusions.

The basic mining data assumptions are not subject to fluctuate widely and have a minimal effect on the total cost of fuel. The implicit inflation factors are dependent upon factors beyond the control of any isolated company and will effect all costs across the system. A change in the inflation assumption will change the bottom line values but the relative position of all alternatives will remain the same.

2. MARKET PRICE FORECASTS

The most critical element over which the utility maintains some degree of control is the market price track. The expected market
price track (see Chapter 4 - Table VII) is based on the assumption that central Pennsylvania coal producers will return to full cost production by 1987. It is possible that this may occur earlier or later. Since it is difficult to predict the timing of this occurrence, it is prudent to run a sensitivity on different market price tracks. Table I identifies the range of values to be investigated.

### TABLE I

**MARKET PRICE TRACKS**

($/Ton)

<table>
<thead>
<tr>
<th></th>
<th>Pessimistic</th>
<th>Expected</th>
<th>Optimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>34.60</td>
<td>34.60</td>
<td>34.60</td>
</tr>
<tr>
<td>1983</td>
<td>38.60</td>
<td>39.30</td>
<td>40.40</td>
</tr>
<tr>
<td>1984</td>
<td>43.00</td>
<td>44.60</td>
<td>46.90</td>
</tr>
<tr>
<td>1985</td>
<td>47.90</td>
<td>50.70</td>
<td>54.30</td>
</tr>
<tr>
<td>1986</td>
<td>53.30</td>
<td>57.10</td>
<td>65.10</td>
</tr>
<tr>
<td>1987</td>
<td>59.30</td>
<td>64.60</td>
<td>77.50</td>
</tr>
<tr>
<td>1988</td>
<td>66.00</td>
<td>74.30</td>
<td>91.50</td>
</tr>
<tr>
<td>1989</td>
<td>73.30</td>
<td>85.30</td>
<td>107.40</td>
</tr>
<tr>
<td>1990</td>
<td>81.50</td>
<td>98.20</td>
<td>125.40</td>
</tr>
</tbody>
</table>
The pessimistic price track assumes a continued depressed market through 1990. The optimistic values assume market recovery by 1985.

In the long-term, the lower band implies a 7% decrease in total costs in 1990; whereas, the upper band results in a 10% increase in total costs in the same year. A 17% range is certainly within engineering tolerance for 1990 values.

3. MINE OUTPUT LEVELS

Since the pessimistic forecast delays the return of procedure's full cost pricing, it is not surprising to learn that the optimum mine production levels are lower than the expected case values. Given the sunk costs in each mine, the utility would choose to operate their mines at a very low level and increase their spot market purchases. By the end of the study time horizon the mines are scheduled to return to near their expected case production levels.

The optimistic price track, which forecasts a rapidly increasing price track, yields the opposite results. The affiliated mines are scheduled to produce at their maximum design capacity for most of the next 9 years. Given a minimum of a 2 year lead time to marginally increase production and the additional capital costs involved in such a venture, the utility will want to be assured that
the market has turned around. Therefore, it would be at least 4 years into an optimistic market environment before the utility could adequately increase their captive operations output. In this analysis, that time perspective would place any future benefits at the end of and beyond the research period.

Table II summarizes the optimal mine production levels for the pessimistic and optimistic market price tracks. The base case values were presented in Chapter 4.
### Table II

**Optimal Mine Production**

(K Tons)

<table>
<thead>
<tr>
<th>Resource</th>
<th>1985</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lo/hi</td>
<td>lo/hi</td>
</tr>
</tbody>
</table>

| R5       | 1800/1800 | 1800/2200 |
| R7       | 324/390   | 396/396   |
| R9       | 733/733   | 733/733   |
| R11      | 523/639   | 586/639   |
| R14      | expired   |          |

### 4. DISTRIBUTION MATRIX

As would be expected, the overall coal distribution flows are not affected by the different market price tracks. All of the modifications suggested in Chapter 4 are still valid. The quantity of coal from the mine processes is less than the base case for the pessimistic forecast and vice versa for the optimistic forecast;
however, this is due to mine output levels and not the cost levels which fluctuate with inflation.

5. NEW MINE DEVELOPMENT

The question of new mine development is not applicable to this case study. Regardless of which price forecast the market follows, there is no indication to even consider a new operation prior to 1985. Since an underground mine requires a minimum of 8 years to fully develop, the mine development process would have to begin in 1983 to be in service by 1990. Over the next few years careful attention must be given to the bituminous coal spot market in order to begin mine development early enough to capture all of the benefits of a captive operation.

Surface coal has been all but unavailable for acquisition by this utility.
In addition to the contra-indications with regard to spot market prices for opening a new mine, there are two other items to consider. The utility in question is in the process of constructing a nuclear facility. It is expected to be in-service third quarter 1983. Coal units have historically been dispatched as base load generation units. Nuclear units having a lower marginal cost will replace the coal units as base load generation. This will not initially reduce the coal requirements due to the fact that there are many oil units with very high marginal costs in this utilities generating environment which must be mothballed before any coal units. All of the coal mines in this study can be expected to produce through their design life well before coal steam electric plants are replaced by nuclear facilities.

Secondly, eastern Pennsylvania contains a large quantity of untapped anthracite reserves. It seems probable that the next coal steam electric plant built in this area will be fueled by anthracite coal. In addition, since there is more than an adequate reserve margin for electricity with the nuclear coming on-line in the near future, any new generating facility construction would start beyond 1990.
5. SUMMARY

I have presented data and information which has allowed me to conclude that this utility can save a reasonable amount of money by initiating a few minor changes. The dollar value is great but the percent of total cost has confirmed that knowledgeable individuals are able to operate effectively and efficiently without the aid of a sophisticated tool. However, it is beneficial to have such quantitative support (as was presented in Chapters 3 and 4) in order to confirm your position with upper management. Also by having all of the operating data on-line in computer storage, it is relatively easy to respond to any upper management interrogatives in a timely fashion.

Finally, I have only considered the bituminous coal portion of the total cost of fuel. To truly minimize the total cost of all fuels, the concept of interfuel competition must be incorporated into the model.
BIBLIOGRAPHY

1. Frank, C. J. (Project Manager) and Seymore, G. E. (Principal Investigator), Long-Term, Mid-Term and Short-Term Fuel Scheduling, EPRI Research Project 1048-6, (Washington, January 1980)


APPENDIX I

COAL SUPPLY COST CALCULATIONS,
OPTIMIZATION SET-UP EQUATIONS
and
GLOSSARY

I. SUPPLY STRUCTURE

A. General

1. \( PPTGM(m) = \text{MKT}(m) \times (1 + \text{INF}(m))^{m-1} \)

B. Mine Production

1. General

   a. \( nn = PYR - BYR + m - 1 \)
   
   b. \( fp = FPYR - PYR + 1 \)
   
   c. \( if = FPYR - PYR + MLIFE \)

2. Operating

   a. \( \text{BLAB} = \text{NUM} \times \text{WAGE} \times \text{HRS} \times (1 + \text{SUPP}) \times (1 + \text{LBEN}) \)
   
   b. \( \text{LAB}(m) = \text{BLAB} \times (1 + \text{resc})^{nn-1} \)
   
   c. \( \text{ADMIN}(m) = \text{BLAB} \times \text{MGT} \times (1 + \text{MBEN}) \times (1 + \text{resc})^{nn-1} \)
   
   \hspace{1cm} + \text{OHD} \times (1 + \text{resc})^{nn-1} \)

   d. \( \text{SUP}(m) = \text{USUP} \times (1 + \text{resc})^{nn-1} \)

   e. \( \text{TRK}(m) = \text{TRA} \times \text{MILE} \times (1 + \text{resc})^{nn-1} \)

   f. \( \text{CLC}(m) = \text{FRCL} \times \text{UCLC} \times (1 + \text{resc})^{nn-1} \)

   g. \( \text{CTONS}(m) = \text{FRCL} \times \text{REC} \times \text{TONS}(m) \)

   h. \( \text{LLC}(m) = (1 - \text{FRCL}) \times \text{ULLC} \times (1 + \text{resc})^{nn-1} \)

   i. \( \text{ROY}(m) = \text{UROY} \times (1 + \text{resc})^{nn-1} \)

   j. \( \text{MAINT}(m) = \sum_{s=1}^{\infty} \text{CAP}(s,m) \times (1 + \text{resc})^{nn-1} \)
k. \( \text{TOP}(m) = \text{LAB}(m) + \text{ADMIN}(m) + \text{MAINT}(m) + (\text{SUP}(m) + \text{TRK}(m) + \text{CLC}(m) + \text{LLC}(m) + \text{ROY}(m)) \times \text{TONS}(m) \)

3. Fixed

a. \( \text{BDEP}(m) = \sum_{s=1}^{\infty} \frac{\text{CAP}(s,m)}{s} \)

b. \( \text{BVAL}(m) = \sum_{s=1}^{\infty} \text{CAP}(s,m) - \sum_{m=m-1}^{\infty} \text{BDEP}(m) \)

c. \( \text{TDEP}(m) = 2 \times (\sum_{s=1}^{\infty} \text{CAP}(s,m) - \sum_{m=m-1}^{\infty} \text{TDEP}(m)) / s \)

d. \( \text{PPE}(m) = \text{PP} - (\sum_{m=nn}^{m=fp-1} \text{ETONS}(m) \times \text{MKT}(m)) \)

e. \( \text{ECAP} = \sum_{m=nn}^{m=fp-1} \text{CAP}(s,m) + \text{PPE} \)

f. \( \text{YY}(m) = \text{RPP} \times (1 + \text{RCR})^{nn-1} + \sum_{s=1}^{\infty} \frac{\text{CAP}(s,m)}{s} \)

\( \text{IDC}(m) = (\sum_{m=nn}^{m=fp} (\text{YY}(m-1) + \text{IDC}(m-1))) + \text{YY}(m)/2) \times \text{DRAT} \)

g. \( \text{ITC}(m) = \sum_{s=1}^{\infty} \text{CAP}(s,m) \times \text{ITCR} \)

h. \( \text{ZZ} = \sum_{m=nn}^{m=fp} \frac{\text{TONS}(m)}{\sum_{m=fp}^{m=fp} \text{TONS}(m)} \)

i. \( \text{DDEP} = \sum_{m=nn}^{m=fp} \text{BDEP}(m) \times \text{ZZ} \)

j. \( \text{DEPL} = \frac{\text{RPP}}{\sum_{m=fp}^{m=fp} \text{TONS}(m)} \)
k. \( \text{CAPA} = \text{ECAP} \times ZZ \)

\[ m = fp-1 \]

l. \( I \text{DCA} = \sum_{m=nn}^{m=fp-l} \text{IDC}(m) \times ZZ \)

m. \( I \text{TCA} = \sum_{m=nn}^{m=fp-l} \text{ITC}(m) \times ZZ \)

n. \( \text{TAMORT} = \text{RPP} + \text{ECAP} + \sum_{m=nn}^{m=fp-l} \text{IDC} \)

o. \( \text{AMORT}(n) = \text{DEPL} + \text{CAPA} + \text{IDCA} \)

p. \( \text{ACCT}(m) = \text{TAMORT} - \sum_{n=1}^{n=m-1} \text{AMORT}(n) \)

q. \( \text{TOTBV}(m) = \text{ACCT}(m) + \text{BVAL}(m) \)

4. Financial

a. \( \text{IE}(m) = \text{TOTBV}(m) \times \text{DBT} \times \text{DRAT} \)

b. \( \text{ROE}(m) = \text{TOTBV}(m) \times (1 - \text{DBT}) \times \text{ERAT} \)

c. \( \text{TAX}(m) = (\text{BLTX} + \text{FED}) \times \text{CTONS}(m) \)

d. \( \text{IT}(m) = (\text{ITR} / (1 - \text{ITR})) \times (\text{ROE}(m) + \text{BDEP}(m) - \text{TDEP}(m) - \text{ITCA}(m) - \text{DDEP}(m)) \)

5. Revenue Required

a. \( \text{MRR}(m) = \text{TOP}(m) + \text{BDEP}(m) + \text{DEPL} + \text{CAPA} + \text{IDCA} + \text{IE}(m) + \text{ROE}(m) + \text{TAX}(m) + \text{IT}(m) \)

b. \( \text{RLP}(k,m) = \text{MRR}(m) / \text{TONS}(m) ; k=1 \)

\( \text{RLP}(k,m) = \text{MRR}(m) / \text{TONS}(m) ; k=6 \)
B. Contracts

1. Cost-plus
   a. same calculations as mine production
      \[
      (1.) \ RLP(k,m) = \frac{MRR(m)}{TONS(m)} ; k=2,7
      \]

2. Base Price plus Escalator
   a. \[ RLP(k,m) = BPR(k) \times (1 + besc)^{m-1} \times (1 + resc)^{m-1} ; k=3,8 \]

3. Market Indicator
   a. \[ RLP(k,m) = MADJ(k) \times DMKT(m) ; k=4,9 \]

C. Spot Market

1. \[ RLP(k,m) = MADJ(k) \times PPTGM(m) ; k=5,10 \]

II. OPTIMIZATION SET-UP

A. Loading costs
   \[ k=10 \]
   1. \[ RLPPT(k,m) = \sum_{k=6}^{9} RLP(k,m) \times ULC(j) \times (1 + resc)^{m-1} \]
   b. Cleaning costs
      1. \[ ODEP(n) = \frac{PLV}{LFE} \]
      \[ n=m-1 \]
      2. \[ OBV(m) = PLV - \sum_{n=1}^{m-1} ODEP(n) \]
      3. \[ OINT(m) = OBV(m) \times RIR \]
      4. \[ OFOC(m) = FC \times (1 + resc)^{m-1} \]
      \[ n=3 \]
      5. \[ OVOC(m) = \sum_{n=1}^{m-1} (UCL(n) \times CCAP(n)) \times (1 + resc)^{m-1} \]
6. \[ CC(j,m) = \frac{(ODEP(m) + OINT(m) + OFOC(m) + OVOC(m))}{\sum_{k=1}^{5} X(k,j,i,m) * CTONRF(j)} \]

7. \[ RLPPT(k,m) = RLP(k,m) + CC(j,m) \]

III. DEMAND DEFINITION

A. \[ MMBTU(i,m) = CF(i,m) * HTRT(i) * NRAT(i) * 8760 \]

\[ \sum_{j=1}^{12} \]

B. \[ BTUGM(i,m) = MMBTU(i,m) - \sum_{j=1}^{12} X(k,j,i,m) * BTU(k,j,m) \]

C. \[ XGM(i,m) = BTUGM(i,m) / MMBTU(i,m) \]

IV. TOTAL COST

\[ \sum_{j=1}^{12} \sum_{k=1}^{10} \]

A. \[ TC(i,m) = \sum_{j=1}^{12} \sum_{k=1}^{10} (RLPPT(j,k,m) + STRANS(i,j,m)) \]

\[ \sum_{i=1}^{8} \]

B. \[ TOTCOST(m) = \sum_{i=1}^{8} TC(i,m) \]

\[ \sum_{i=1}^{8} \]

C. \[ PVTOT = \sum_{i=1}^{8} TOTCOST(m) / (1 + RDIS)^{m-1} * (1 + INF(m))^{m-1} \]
V. GLOSSARY

A. General

1. \( \text{resc} \) = unique real escalation factor for each equation

2. \( i \) = power plant identifier

3. \( j \) = supply region identifier

4. \( k \) = resource process identifier

5. \( m \) = year

B. MNEUMONICS

1. \( \text{ACCT}(m) \) = remaining amortization account in year \( m \)

2. \( \text{ADMIN}(m) \) = annual administrative costs

3. \( \text{AMORT}(n) \) = annual amortization charges

4. \( \text{BDEP}(m) \) = straight-line book depreciation in year \( m \)

5. \( \text{besc} \) = real escalation rate

6. \( \text{BLAB} \) = base labor rate

7. \( \text{BLTX} \) = Black Lung Tax

8. \( \text{BPR}(k) \) = base contract price for resource \( k \)

9. \( \text{BTU}(k,j,m) \) = BTU/lb value for resource \( k \)
10. BTUGM(i,m) = total BTUs required for the general market allocation.

11. BVAL(m) = total book value in year m

12. BYR = base year in which all of the cost are set

13. CAP(s,m) = capital account in year m with equipment of life s

14. CAPA = capital equipment amortization account

15. CC(j,m) = total cleaning costs at supply region j in year m

16. CCAP(n) = cleaning facility capacity for shift n

17. CF(i) = annual capacity factor for power plant i

18. CLC(m) = mine supply cleaning costs in year m

19. CTONS(m) = equivalent clean ton production

20. DBT = percent financing by debt issues

21. DDEP = deferred depreciation account

22. DEPL = resource depletion account

23. DMKT(m) = demand market indicator cost in year m

24. DRAT = annual debt financing rate

25. ECAP = total capitalized expenses

26. ERAT = annual equity financing rate
27. ETONS(m) = tons produced prior to full production

28. FED = Federal Reclamation Tax rate

29. FPYR = full production year

30. FRCL = percent of mined coal cleaned

31. HRS = total mine work hours in any year

32. HTRT(i) = heat rate for power plant i

33. IDC(m) = interest during construction in year m

34. IDCA = interest during construction amortization account

35. IE(m) = total interest expense in years after full production

36. INF(m) = annual inflation rate

37. IT(m) = income tax in year m

38. ITC(m) = investment tax credits in year m

39. ITCA = investment tax credit amortization account

40. ITCR = investment tax credit rate

41. ITR = income tax rate
42. LAB(m) = total labor related costs in year m
43. LBEN = percent labor benefits
44. LFE = remaining life a cleaning facility
45. LLC(m) = total loading costs at mine location
46. MADJ(k) = percent of general market costs at supply region k
47. MAINT(m) = equipment maintenance costs in year m
48. MBEN = percent management benefits
49. MGT = percent management above base labor costs
50. MILE = total trucking distance
51. MKT(m) = general market price track in real dollars
52. MLIFE = original mine design life
53. MMBTU(i,m) = total BTU requirements at power plant i in year m
54. MRR(m) = minimum revenues required
55. NRAT(i) = nameplate rating for power plant i
56. NUM = total number of wage rate employees
57. \( OBV(m) \) = cleaning plant book value in year \( m \)

58. \( ODEP(n) \) = straightlined depreciation for cleaning plant

59. \( OFOC(m) \) = cleaning plant fixed costs in year \( m \)

60. \( OHD \) = per unit overhead charges

61. \( OINT(m) \) = cleaning plant interest expenses in year \( m \)

62. \( OVOC(m) \) = cleaning plant variable cost in year \( m \)

63. \( PLV \) = original cleaning plant book value

64. \( PP \) = total preproduction expenses

65. \( PPE(m) \) = preproduction amortization account

66. \( PPTGM(m) \) = general market price track in nominal dollars

67. \( PYR \) = mine purchase year

68. \( PVTOT \) = present value of total system costs

69. \( RCR \) = reserve carrying rate

70. \( RDIS \) = real discount rate

71. \( REC \) = tonnage recovery rate

72. \( RIR \) = real interest rate
73. \( RLP(k,m) \) = preliminary costs from resource \( k \)

74. \( RLPPT(k,m) \) = total FOB costs from resource \( k \)

75. \( ROE(m) \) = return on equity in year \( m \)

76. \( ROY(m) \) = annual royalty payments

77. \( RPP \) = reserve purchase price in base year dollars

78. \( STRANS(i,j,m) \) = unit transportation charge from supply region \( j \) to power plant \( i \) in year \( m \)

79. \( SUP(m) \) = annual mine supply costs

80. \( SUPP \) = percent union supervision

81. \( TAMORT \) = total amortization account

82. \( TAX(m) \) = total taxes in year \( m \)

83. \( TC(i,m) \) = total costs at power plant \( i \) in year \( m \)

84. \( TDEP(m) \) = double declining balance tax depreciation

85. \( TONS(m) \) = total tons out of the mine in year \( m \)

86. \( TOP(m) \) = total operating costs

87. \( TOTBV(m) \) = total book value at the mine

88. \( TOTCOST(m) \) = total system costs in year \( m \)
89. TRK(m) = annual trucking expenses

90. TRA = per ton-mile trucking rate

91. UCL(n) = per unit cleaning cost for shift n

92. UCLC = base unit cleaning rate

93. ULC(j) = per unit loading cost

94. ULLC = base unit loading rate

95. UROY = base royalty payment rate

96. USUP = base mine supply costs

97. WAGE = mining union wage rate

98. X(k,j,i,m) = quantity of coal from resource k, supply region j to power plant i

99. XGM(i,m) = quantity of coal supplied to power plant i from the general market

100. YY(m) = base for interest expense calculations

101. ZZ = ratio for amortization account write-off
* PROCESS; /* BDUMP */
BDUMP: PROC(OPTIONS,#OPTIONS); /*** 04/06/82 17:00 D.KENT ***/

/************ DUMP DATA TO MPSX PROGRAM ***********/

%INCLUDE(P0ENN30);
%INCLUDE(P0ENN32);
%INCLUDE(P0ENN34);
%INCLUDE(P0ENN31);

DCL A(0:58,39) FLOAT DEC(6),
    CC(7,35) FLOAT DEC(6),
    LC(8,35) FLOAT DEC(6),
    AH FLOAT DEC(6) INIT(100.0),
    AK FLOAT DEC(6) INIT(1000.0),
    AM FLOAT DEC(6) INIT(1000000.0),
    (I,J,K,L,M,N) FIXED BIN(15),
    (ID,IR) FIXED BIN(15),
    URLT0NS(21,35) FLOAT DEC(6),
    LRLT0NS(21,35) FLOAT DEC(6),
    BTUR(8) FLOAT DEC(6),
    SULF(8) FLOAT DEC(6),
    LCAP(8) FLOAT DEC(6),
    DE0NN31 FILE OUTPUT;

/******* WORK VARIABLES *******/

DCL DTRESA(12,8,50) FLOAT DEC(6) STATIC EXTERNAL,
    DLFESA(12,50) FLOAT DEC(6) STATIC EXTERNAL,
    DTCCA(12,35) FLOAT DEC(6) STATIC EXTERNAL,
    DCQITOTA(12,35) FLOAT DEC(6) STATIC EXTERNAL,
    INYR FIXED BIN(15),
    OPTIONS(9) CHAR(10) CONN,
    #OPTIONS FIXED BIN(15),
    ERROR FIXED BIN(15),
    RDATA(10) FLOAT DEC(6),
    ITEM(10) CHAR(10),
    UCONV EXTERNAL ENTRY,
    SYSPRINT FILE PRINT,
    NUM FIXED BIN (15);
DCL P(60) FIXED BIN(15) INIT(13,28,62,55,61,88,106,118,121,148,161,163,178,181,193,232,238);

IF #OPTIONS = 1 THEN
DO;
   PUT FILE(SYSPRINT) EDIT('** INVALID OPTIONS **')(SKIP,A);
   RETURN;
END;

NUM-1; ERROR = 0;
ITEM(1) = OPTIONS(1);
CALL UCONV(ITEM,NUM;RDATA,ERROR);
IF ERROR=0 THEN
   DO;
      PUT FILE(SYSPRINT) EDIT('CONVERSION ERROR ON OPTIONS(1)')
         (SKIP,A);
      RETURN;
   END;
END;

INYR=RDATA(1);
IF INYR < BSTARTYR | INYR > BSTOPYR THEN
   DO;
      PUT FILE(SYSPRINT) EDIT('INYEAR = ',INYR,' IS NOT VALID')
         (SKIP,A,F(4,0),A);
      RETURN;
   END;

M=INYR - BSTARTYR + 1;
N= 79 + M;

PUT FILE(SYSPRINT)
EDIT('M = ',M,' INYR = ',INYR)(SKIP,A,F(4,0),A,F(4,0));

/******** INITIALIZE FOR PROPOSED CONTRACTS ******/
IF M > 3 THEN
DO;
P(3) = 53;
P(16) = 233;
END;
ELSE
   DO;
P(3) = 52;
P(16) = 232;
END;
**CALCULATE PER UNIT CLEANING COST**

CC(*,*) = 0.0;
IF M > 5 THEN
DO;
IF DCQTOTA(1,M) > 1.0 THEN CC(1,M) = DTCCA(1,M)/DCQTOTA(1,M);
ELSE PUT FILE(SYSPRINT) EDIT
(' DCQ < 1.0 FOR 1,M = ',M,DCQTOTA(1,M)) (SKIP,A,F(4,0),X(2),
F(15,2));
IF DCQTOTA(3,M) > 1.0 THEN CC(3,M) = DTCCA(3,M)/DCQTOTA(3,M);
ELSE PUT FILE(SYSPRINT) EDIT
(' DCQ < 1.0 FOR 3,M = ',M,DCQTOTA(3,M)) (SKIP,A,F(4,0),X(2),
F(15,2));
IF DCQTOTA(5,M) > 1.0 THEN CC(5,M) = DTCCA(5,M)/DCQTOTA(5,M);
ELSE PUT FILE(SYSPRINT) EDIT
(' DCQ < 1.0 FOR 5,M = ',M,DCQTOTA(5,M)) (SKIP,A,F(4,0),X(2),
F(15,2));
IF DCQTOTA(7,M) > 1.0 THEN CC(7,M) = DTCCA(7,M)/DCQTOTA(7,M);
ELSE PUT FILE(SYSPRINT) EDIT
(' DCQ < 1.0 FOR 7,M = ',M,DCQTOTA(7,M)) (SKIP,A,F(4,0),X(2),
F(15,2));
END;
ELSE
DO;
IF DCQTOTA(1,M) > 1.0 THEN CC(1,M) = DTCCA(1,M)/DCQTOTA(1,M);
ELSE PUT FILE(SYSPRINT) EDIT
(' DCQ < 1.0 FOR 1,M = ',M,DCQTOTA(1,M)) (SKIP,A,F(4,0),X(2),
F(15,2));
IF DCQTOTA(3,M) > 1.0 THEN CC(3,M) = DTCCA(3,M)/DCQTOTA(3,M);
ELSE PUT FILE(SYSPRINT) EDIT
(' DCQ < 1.0 FOR 3,M = ',M,DCQTOTA(3,M)) (SKIP,A,F(4,0),X(2),
F(15,2));
IF DCQTOTA(5,M) > 1.0 THEN CC(5,M) = DTCCA(5,M)/DCQTOTA(5,M);
ELSE PUT FILE(SYSPRINT) EDIT
(' DCQ < 1.0 FOR 5,M = ',M,DCQTOTA(5,M)) (SKIP,A,F(4,0),X(2),
F(15,2));
IF DCQTOTA(7,M) > 1.0 THEN CC(7,M) = DTCCA(7,M)/DCQTOTA(7,M);
ELSE PUT FILE(SYSPRINT) EDIT
(' DCQ < 1.0 FOR 7,M = ',M,DCQTOTA(7,M)) (SKIP,A,F(4,0),X(2),
F(15,2));
END;
/*calculate per unit loading cost*/
LC(*,*)=0.0;
DO J - 1 TO 8;
   LC(J,M)=LLDCST(J)*DLFESA(J,M);
END;

/*calculate bounds for resource links*/
DO J - 1 TO 17;
   URLTONS(J,M) = 1.1 * RLTOTONS(P(J),M)/AK;
   LRLTONS(J,M) = .9 * RLTOTONS(P(J),M)/AK;
END;
DO J - 18 TO 21;
   L = L + 1;
   URLTONS(J,M) = 1.1 * PTNSG(L,M)/AK;
   LRLTONS(J,M) = .9 * PTNSG(L,M)/AK;
END;

/*calculate BTU and sulfur constraint values*/
DO J - 1 TO 4;
   BTUR(J) = (PBTUR(J,M)/AM);
   SULF(J) = PSULF(J)*BTUR(J);
END;

/*calculate loading region capacity*/
DO J - 1 TO 8;
   LCAP(J) = LCAPF(J)/AK;
END;

/*calculate coefficients for objective function*/
A(0,1)=RLPPT(13,M)*(CC(1,M)+STRANS(1,1)*DTRESA(1,1,M)) *CTONRF(1);
A(0,2)=RLPPT(28,M)+LC(1,M)+STRANS(1,1)*DTRESA(1,1,M);
A(0,3)=RLPPT(106,M)+LC(4,M)+STRANS(4,1)*DTRESA(4,1,M);
A(0,4)=RLPPT(118,M)+LC(4,M)+STRANS(4,1)*DTRESA(4,1,M);
A(0,5)=RLPPT(151,M)+(CC(6,M)+STRANS(6,1)*DTRESA(6,1,M)) *CTONRF(6);
A(0, 6) = RLPPT(163, M) + CC(6, M) + TRANS(6, 1) * DTRESA(6, 1, M) * CTONRF(6)
A(0, 7) = RLPPT(178, M) + LC(6, M) + TRANS(6, 1) * DTRESA(6, 1, M)
A(0, 8) = RLPPT(P(3), M) + LC(2, M) + TRANS(2, 2) * DTRESA(2, 2, M)
A(0, 9) = RLPPT(55, M) + LC(2, M) + TRANS(2, 2) * DTRESA(2, 2, M)
A(0, 10) = RLPPT(G1, M) + CC(3, M) + TRANS(3, 2) * DTRESA(3, 2, M) * CTONRF(3)
A(0, 11) = RLPPT(88, M) + LC(3, M) + TRANS(3, 2) * DTRESA(3, 2, M)
A(0, 12) = RLPPT(106, M) + LC(4, M) + TRANS(4, 2) * DTRESA(4, 2, M)
A(0, 13) = RLPPT(118, M) + LC(4, M) + TRANS(4, 2) * DTRESA(4, 2, M)
A(0, 14) = RLPPT(151, M) + CC(6, M) + TRANS(6, 2) * DTRESA(6, 2, M) * CTONRF(6)
A(0, 15) = RLPPT(163, M) + CC(6, M) + TRANS(6, 2) * DTRESA(6, 2, M) * CTONRF(6)
A(0, 16) = RLPPT(178, M) + LC(6, M) + TRANS(6, 2) * DTRESA(6, 2, M)
A(0, 17) = RLPPT(13, M) + CC(1, M) + TRANS(1, 3) * DTRESA(1, 3, M) * CTONRF(1)
A(0, 18) = RLPPT(28, M) + LC(1, M) + TRANS(1, 3) * DTRESA(1, 3, M)
A(0, 19) = RLPPT(106, M) + LC(4, M) + TRANS(4, 3) * DTRESA(4, 3, M)
A(0, 20) = RLPPT(118, M) + LC(4, M) + TRANS(4, 3) * DTRESA(4, 3, M)
A(0, 21) = RLPPT(121, M) + CC(5, M) + TRANS(5, 3) * DTRESA(5, 3, M) * CTONRF(5)
A(0, 22) = RLPPT(148, M) + LC(5, M) + TRANS(5, 3) * DTRESA(5, 3, M)
A(0, 23) = RLPPT(151, M) + CC(6, M) + TRANS(6, 3) * DTRESA(6, 3, M) * CTONRF(6)
A(0, 24) = RLPPT(163, M) + CC(6, M) + TRANS(6, 3) * DTRESA(6, 3, M) * CTONRF(6)
A(0, 25) = RLPPT(178, M) + LC(6, M) + TRANS(6, 3) * DTRESA(6, 3, M)
A(0, 26) = RLPPT(181, M) + CC(7, M) + TRANS(7, 3) * DTRESA(7, 3, M) * CTONRF(7)
A(0, 27) = RLPPT(193, M) + CC(7, M) + TRANS(7, 3) * DTRESA(7, 3, M) * CTONRF(7)
A(0, 28) = RLPPT(P(16), M) + LC(8, M) + TRANS(8, 3) * DTRESA(8, 3, M)
A(0, 29) = RLPPT(238, M) + LC(8, M) + TRANS(8, 3) * DTRESA(8, 3, M)
A(0, 30) = RLPPT(121, M) + CC(5, M) + TRANS(5, 4) * DTRESA(5, 4, M) * CTONRF(5)
A(0, 31) = RLPPT(148, M) + LC(6, M) + TRANS(5, 4) * DTRESA(5, 4, M)
A(0, 32) = RLPPT(181, M) + CC(7, M) + TRANS(7, 4) * DTRESA(7, 4, M) * CTONRF(7)
A(0, 33) = RLPPT(193, M) + CC(7, M) + TRANS(7, 4) * DTRESA(7, 4, M) * CTONRF(7)
-95-
\begin{verbatim}
A(0,34) - RLPPT(P,16,M) * LC(8,M) * STRANS(8,4) * DTRESA(8,4,M);
A(0,35) - RLPPT(238,M) * LC(8,M) * STRANS(8,4) * DTRESA(8,4,M);
A(0,36) - BPRICEA(M) * PTRNSG(1,M);
A(0,37) - BPRICEA(M) * PTRNSG(2,M);
A(0,38) - BPRICEA(M) * PTRNSG(3,M);
A(0,39) - BPRICEA(M) * PTRNSG(4,M);

/***** CALCULATE COEFFICIENTS FOR MIN BTU CONSTRAINT ******/

A(1,1) - 2 * RLBTULB(13) * CBTURF(1);
A(1,2) - 2 * RLBTULB(28);
A(1,3) - 2 * RLBTULB(106);
A(1,4) - 2 * RLBTULB(118);
A(1,5) - 2 * RLBTULB(151) * CBTURF(6);
A(1,6) - 2 * RLBTULB(163) * CBTURF(6);
A(1,7) - 2 * RLBTULB(178);
A(1,8) - 2 * RLBTULB(P,3);
A(1,9) - 2 * RLBTULB(65);
A(1,10) - 2 * RLBTULB(61) * CBTURF(3);
A(1,11) - 2 * RLBTULB(88);
A(1,12) - 2 * RLBTULB(106);
A(1,13) - 2 * RLBTULB(118);
A(1,14) - 2 * RLBTULB(151) * CBTURF(6);
A(1,15) - 2 * RLBTULB(163) * CBTURF(6);
A(1,16) - 2 * RLBTULB(178);
A(1,17) - 2 * RLBTULB(13) * CBTURF(1);
A(1,18) - 2 * RLBTULB(28);
A(1,19) - 2 * RLBTULB(106);
A(1,20) - 2 * RLBTULB(118);
A(1,21) - 2 * RLBTULB(121) * CBTURF(5);
A(1,22) - 2 * RLBTULB(148);
A(1,23) - 2 * RLBTULB(151) * CBTURF(6);
A(1,24) - 2 * RLBTULB(163) * CBTURF(6);
A(1,25) - 2 * RLBTULB(178);
A(1,26) - 2 * RLBTULB(181) * CBTURF(7);
A(1,27) - 2 * RLBTULB(193) * CBTURF(7);
A(1,28) - 2 * RLBTULB(P,16);
A(1,29) - 2 * RLBTULB(238);
A(1,30) - 2 * RLBTULB(121) * CBTURF(5);

A(2,1) - 2 * RLBTULB(13) * CBTURF(1);
A(2,2) - 2 * RLBTULB(28);
A(2,3) - 2 * RLBTULB(106);
A(2,4) - 2 * RLBTULB(118);
A(2,5) - 2 * RLBTULB(151) * CBTURF(6);
A(2,6) - 2 * RLBTULB(163) * CBTURF(6);
A(2,7) - 2 * RLBTULB(178);
A(2,8) - 2 * RLBTULB(P,3);
A(2,9) - 2 * RLBTULB(65);
A(2,10) - 2 * RLBTULB(61) * CBTURF(3);
A(2,11) - 2 * RLBTULB(88);
A(2,12) - 2 * RLBTULB(106);
A(2,13) - 2 * RLBTULB(118);
A(2,14) - 2 * RLBTULB(151) * CBTURF(6);
A(2,15) - 2 * RLBTULB(163) * CBTURF(6);
A(2,16) - 2 * RLBTULB(178);
A(2,17) - 2 * RLBTULB(13) * CBTURF(1);
A(2,18) - 2 * RLBTULB(28);
A(2,19) - 2 * RLBTULB(106);
A(2,20) - 2 * RLBTULB(118);
A(2,21) - 2 * RLBTULB(121) * CBTURF(5);
A(2,22) - 2 * RLBTULB(148);
A(2,23) - 2 * RLBTULB(151) * CBTURF(6);
A(2,24) - 2 * RLBTULB(163) * CBTURF(6);
A(2,25) - 2 * RLBTULB(178);
A(2,26) - 2 * RLBTULB(181) * CBTURF(7);
A(2,27) - 2 * RLBTULB(193) * CBTURF(7);
A(2,28) - 2 * RLBTULB(P,16);
A(2,29) - 2 * RLBTULB(238);
A(2,30) - 2 * RLBTULB(121) * CBTURF(5);

A(3,1) - 2 * RLBTULB(13) * CBTURF(1);
A(3,2) - 2 * RLBTULB(28);
A(3,3) - 2 * RLBTULB(106);
A(3,4) - 2 * RLBTULB(118);
A(3,5) - 2 * RLBTULB(121) * CBTURF(5);
A(3,6) - 2 * RLBTULB(148);
A(3,7) - 2 * RLBTULB(151) * CBTURF(6);
A(3,8) - 2 * RLBTULB(163) * CBTURF(6);
A(3,9) - 2 * RLBTULB(178);
A(3,10) - 2 * RLBTULB(181) * CBTURF(7);
A(3,11) - 2 * RLBTULB(193) * CBTURF(7);
A(3,12) - 2 * RLBTULB(P,16);
A(3,13) - 2 * RLBTULB(238);
A(3,14) - 2 * RLBTULB(121) * CBTURF(5);

A(4,1) - 2 * RLBTULB(13) * CBTURF(1);
A(4,2) - 2 * RLBTULB(28);
A(4,3) - 2 * RLBTULB(106);
A(4,4) - 2 * RLBTULB(118);
A(4,5) - 2 * RLBTULB(121) * CBTURF(5);
A(4,6) - 2 * RLBTULB(148);
A(4,7) - 2 * RLBTULB(151) * CBTURF(6);
A(4,8) - 2 * RLBTULB(163) * CBTURF(6);
A(4,9) - 2 * RLBTULB(178);
A(4,10) - 2 * RLBTULB(181) * CBTURF(7);
A(4,11) - 2 * RLBTULB(193) * CBTURF(7);
A(4,12) - 2 * RLBTULB(P,16);
A(4,13) - 2 * RLBTULB(238);
A(4,14) - 2 * RLBTULB(121) * CBTURF(5);
\end{verbatim}
A(4, 31) - 2*RLBTULB(148);
A(4, 32) - 2*RLBTULB(181)*CBTURF(7);
A(4, 33) - 2*RLBTULB(193)*CBTURF(7);
A(4, 34) - 2*RLBTULB(P(16));
A(4, 35) - 2*RLBTULB(238);
A(1, 36) - 2*BBLTULB;
A(2, 37) - 2*BBLTULB;
A(3, 38) - 2*BBLTULB;
A(4, 39) - 2*BBLTULB;

/****** CALCULATE COEFFICIENTS FOR SULFUR LIMIT ******/

A(5, 1) - 4*AM*RLSULF(13);
A(5, 2) - 4*AM*RLSULF(28);
A(5, 3) - 4*AM*RLSULF(106);
A(5, 4) - 4*AM*RLSULF(118);
A(5, 5) - 4*AM*RLSULF(161)*CSULRF(6);
A(5, 6) - 4*AM*RLSULF(163)*CSULRF(6);
A(5, 7) - 4*AM*RLSULF(178);
A(5, 8) - 4*AM*RLSULF(P(3));
A(5, 9) - 4*AM*RLSULF(55);
A(6, 10) - 4*AM*RLSULF(61)*CSULRF(3);
A(6, 11) - 4*AM*RLSULF(88);
A(6, 12) - 4*AM*RLSULF(106);
A(6, 13) - 4*AM*RLSULF(118);
A(6, 14) - 4*AM*RLSULF(151)*CSULRF(6);
A(6, 15) - 4*AM*RLSULF(163)*CSULRF(6);
A(6, 16) - 4*AM*RLSULF(178);
A(7, 17) - 4*AM*RLSULF(13)*CSULRF(1);
A(7, 18) - 4*AM*RLSULF(28);
A(7, 19) - 4*AM*RLSULF(106);
A(7, 20) - 4*AM*RLSULF(118);
A(7, 21) - 4*AM*RLSULF(121)*CSULRF(5);
A(7, 22) - 4*AM*RLSULF(148);
A(7, 23) - 4*AM*RLSULF(161)*CSULRF(6);
A(7, 24) - 4*AM*RLSULF(163)*CSULRF(6);
A(7, 25) - 4*AM*RLSULF(178);
A(7, 26) - 4*AM*RLSULF(181)*CSULRF(7);
A(7, 27) - 4*AM*RLSULF(193)*CSULRF(7);
A(7, 28) - 4*AM*RLSULF(P(16));
\begin{verbatim}
A(7,29) = 4*AM*RLSULF(238);
A(8,30) = 4*AM*RLSULF(121)*CSULRF(6);
A(8,31) = 4*AM*RLSULF(148);
A(8,32) = 4*AM*RLSULF(181)*CSULRF(7);
A(8,33) = 4*AM*RLSULF(193)*CSULRF(7);
A(8,34) = 4*AM*RLSULF(P(16));
A(8,35) = 4*AM*RLSULF(238);
A(6,36) = 4*AM*BSULF;
A(6,37) = 4*AM*BSULF;
A(7,38) = 4*AM*BSULF;
A(8,39) = 4*AM*BSULF;

/******* CALCULATE COEFFICIENTS FOR SUP REGION CAP *******/

A(9,1) = CTONRF(1);
A(9,2) = 1;
A(12,3) = 1;
A(12,4) = 1;
A(14,5) = CTONRF(6);
A(14,6) = CTONRF(6);
A(14,7) = 1;
A(10,8) = 1;
A(10,9) = 1;
A(11,10) = CTONRF(3);
A(11,11) = 1;
A(12,12) = 1;
A(12,13) = 1;
A(14,14) = CTONRF(6);
A(14,15) = CTONRF(6);
A(14,16) = 1;
A(9,17) = CTONRF(1);
A(9,18) = 1;
A(12,19) = 1;
A(12,20) = 1;
A(13,21) = CTONRF(5);
A(13,22) = 1;
A(14,23) = CTONRF(6);
A(14,24) = CTONRF(6);
A(14,25) = 1;
A(15,26) = CTONRF(7);
\end{verbatim}
A(15,27)=CTONRF(7);
A(16,28)=1;
A(16,29)=1;
A(13,30)=CTONRF(5);
A(13,31)=1;
A(15,32)=CTONRF(7);
A(16,33)=CTONRF(7);
A(16,34)=1;
A(16,35)=1;

/******* INITIALIZE MATRIX FOR X *******/

A(17, 1)=1;
A(18, 2)=1;
A(23, 3)=1;
A(24, 4)=1;
A(27, 5)=1;
A(28, 6)=1;
A(29, 7)=1;
A(19, 8)=1;
A(20, 9)=1;
A(21,10)=1;
A(22,11)=1;
A(23,12)=1;
A(24,13)=1;
A(27,14)=1;
A(28,15)=1;
A(29,16)=1;
A(17,17)=1;
A(18,18)=1;
A(23,19)=1;
A(24,20)=1;
A(25,21)=1;
A(26,22)=1;
A(27,23)=1;
A(28,24)=1;
A(29,25)=1;
A(30,26)=1;
A(31,27)=1;
A(32,28)=1;
A(33,29)-1;  
A(28,30)-1;  
A(26,31)-1;  
A(30,32)-1;  
A(31,33)-1;  
A(32,34)-1;  
A(33,35)-1;  
A(34,36)-1;  
A(35,37)-1;  
A(36,38)-1;  
A(37,39)-1;  
A(38,1)-1;  
A(39,2)-1;  
A(44,3)-1;  
A(46,4)-1;  
A(45,5)-1;  
A(47,6)-1;  
A(49,6)-1;  
A(50,7)-1;  
A(40,8)-1;  
A(41,9)-1;  
A(42,10)-1;  
A(43,11)-1;  
A(44,12)-1;  
A(45,13)-1;  
A(48,14)-1;  
A(49,15)-1;  
A(50,16)-1;  
A(38,17)-1;  
A(39,18)-1;  
A(44,19)-1;  
A(45,20)-1;  
A(46,21)-1;  
A(47,22)-1;  
A(48,23)-1;  
A(49,24)-1;  
A(50,25)-1;  
A(51,26)-1;  
A(52,27)-1;  
A(53,28)-1;
```
\text{BEGIN MPSX FORMATTING */***/}

\text{PUT FILE(DEON31) EDIT('NAME', 'MIN', N)(SKIP, A, COL(15), A, F(4,0));}
\text{PUT FILE(DEON31) EDIT('ROWS')(SKIP, A);}
\text{PUT FILE(DEON31) EDIT('N', 'TOTCOST')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('G', 'BTUR(1)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('G', 'BTUR(2)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('G', 'BTUR(3)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('G', 'BTUR(4)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'SULF(1)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'SULF(2)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'SULF(3)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'SULF(4)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'CAP(1)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'CAP(2)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'CAP(3)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'CAP(4)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'CAP(5)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'CAP(6)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'CAP(7)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'CAP(8)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'MAX(1)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'MAX(2)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'MAX(3)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'MAX(4)')(SKIP, COL(2), A, COL(5), A);} 
\text{PUT FILE(DEON31) EDIT('L', 'MAX(5)')(SKIP, COL(2), A, COL(5), A);} 
```
PUT FILE(DEO.N31) EDIT('L', 'MAX(G)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(7)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(8)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(9)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(10)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(11)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(12)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(13)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(14)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(15)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(16)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(17)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(18)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(19)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(20)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('L', 'MAX(21)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(1)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(2)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(3)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(4)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(5)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(6)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(7)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(8)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(9)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(10)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(11)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(12)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(13)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(14)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(15)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(16)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(17)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(18)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(19)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(20)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('G', 'MIN(21)')(SKIP, COL(2), A, COL(5), A);
PUT FILE(DEO.N31) EDIT('COLUMNS')(SKIP, A);
PUT FILE(DEONN31) EDIT (''X1',''TOTCOST',A(0,1)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X1',''BTUR(1)',A(1,1)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X1',''SULF(1)',A(5,1)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X1',''CAP(1)',A(9,1)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X1',''MAX(1)',A(17,1)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X1',''MIN(1)',A(38,1)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X2',''TOTCOST',A(0,2)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X2',''BTUR(1)',A(1,2)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X2',''SULF(1)',A(5,2)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X2',''CAP(1)',A(9,2)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X2',''MAX(2)',A(18,2)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X2',''MIN(2)',A(39,2)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X3',''TOTCOST',A(0,3)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT (''X3',''BTUR(1)',A(1,3)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT
('X3', 'SULF(1)', A(5, 3))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X3', 'CAP(4)', A(12, 3))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X3', 'MAX(7)', A(23, 3))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X3', 'MIN(7)', A(44, 3))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X4', 'TOTCOST', A(0, 4))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X4', 'BTUR(1)', A(1, 4))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X4', 'SULF(1)', A(5, 4))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X4', 'CAP(4)', A(12, 4))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X4', 'MAX(8)', A(24, 4))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X4', 'MIN(8)', A(45, 4))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X5', 'TOTCOST', A(0, 5))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X5', 'BTUR(1)', A(1, 5))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X5', 'SULF(1)', A(5, 5))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X6', 'CAP(6)', A(14, 5))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X6', 'MAX(11)', A(27, 6))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X6', 'MIN(11)', A(48, 5))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X6', 'TOTCOST', A(0, 6))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X6', 'BTUR(1)', A(1, 6))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X6', 'SULF(1)', A(6, 6))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X7', 'CAP(G)', A(14, 7))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X7', 'MAX(12)', A(28, 6))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X7', 'MIN(12)', A(49, 6))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X7', 'TOTCOST', A(0, 7))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X7', 'BTUR(1)', A(1, 7))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X7', 'SULF(1)', A(6, 7))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X7', 'CAP(G)', A(14, 7))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X7', 'MAX(13'), A(29, 7)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X7', 'MIN(13'), A(50, 7)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X8', 'TOTCOST', A(0, 8)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X8', 'BTUR(2)', A(2, 8)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X8', 'SULF(2)', A(6, 8)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X9', 'CAP(2)', A(10, 9)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X9', 'MAX(4)', A(20, 9)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X9', 'MIN(4)', A(41, 9)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X10', 'TOTCOST', A(0, 10)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X10', 'BTUR(2)', A(2, 10)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X10', 'SULF(2)', A(6, 10)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X10', 'CAP(3)', A(11, 10)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X10', 'MAX(D)', A(21, 10)) (SKIP, COL(5), A, COL(10), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X10', 'MIN(5)', A(42, 10)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X11', 'TOTCOST', A(0, 11)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X11', 'BTUR(2)', A(2, 11)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X11', 'SULF(2)', A(6, 11)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X11', 'CAP(3)', A(11, 11)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X11', 'MAX(6)', A(22, 11)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X11', 'MIN(6)', A(43, 11)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X12', 'TOTCOST', A(0, 12)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X12', 'BTUR(2)', A(2, 12)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X12', 'SULF(2)', A(6, 12)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X12', 'CAP(4)', A(12, 12)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X12', 'MAX(7)', A(23, 12)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X12', 'MIN(7)', A(44, 12)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X13', 'TOTCOST', A(0, 13)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X13', 'BTUR(2)', A(2, 13)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X13', 'SULF(2)', A(6, 13)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X13', 'CAP(4)', A(12, 13)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X13', 'MAX(8)', A(24, 13)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X13', 'MIN(8)', A(45, 13)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X14', 'TOTCOST', A(0, 14)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X14', 'BTUR(2)', A(2, 14)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X14', 'SULF(2)', A(6, 14)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X14', 'CAP(6)', A(14, 14))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X14', 'MAX(11)', A(27, 14))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X14', 'MIN(11)', A(48, 14))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X15', 'TOTCOST', A(0, 15))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X15', 'BTUR(2)', A(2, 15))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X15', 'CAP(6)', A(14, 15))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X15', 'MAX(12)', A(28, 15))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X15', 'MIN(12)', A(49, 15))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X16', 'TOTCOST', A(0, 16))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X16', 'BTUR(2)', A(2, 16))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X16', 'SULF(2)', A(6, 16))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X16', 'CAP(6)', A(14, 16))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X16', 'MAX(13)', A(29, 16))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X16', 'MIN(13)', A(50, 16))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X17', 'TOTCOST', A(0, 17))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X17', 'BTUR(3)', A(3, 17))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X17', 'SULF(3)', A(7, 17))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X17', 'CAP(1)', A(9, 17))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X17', 'MAX(1)', A(17, 17))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X17', 'MIN(1)', A(38, 17))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X18', 'TOTCOST', A(0, 18))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X18', 'BTUR(3)', A(3, 18))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X18', 'SULF(3)', A(7, 18))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X18', 'CAP(1)', A(9, 18))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DEONN31) EDIT
  ('X18', 'MAX(2)', A(18, 18))(SKIP, COL(5), A, COL(15), A, COL(25),
                         F(12, 2));
PUT FILE(DE0NN31) EDIT
('X18', 'MIN(2)', A(39, 18))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X19', 'TOTCOST', A(0, 19))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X19', 'BTUR(3)', A(3, 19))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X19', 'SULF(3)', A(7, 19))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X19', 'CAP(4)', A(12, 19))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X20', 'TOTCOST', A(0, 20))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X20', 'BTUR(3)', A(3, 20))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X20', 'SULF(3)', A(7, 20))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X20', 'CAP(4)', A(12, 20))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X20', 'MAX(8)', A(24, 20))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X20', 'MIN(8)', A(45, 20))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X21', 'TOTCOST', A(0, 21))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X21', 'BTUR(3)', A(3, 21)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X21', 'SULF(3)', A(7, 21)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X21', 'CAP(5)', A(13, 21)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X21', 'MAX(9)', A(25, 21)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X21', 'MIN(9)', A(46, 21)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X22', 'TOTCOST', A(0, 22)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X22', 'BTUR(3)', A(3, 22)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X22', 'SULF(3)', A(7, 22)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X22', 'CAP(5)', A(13, 22)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X22', 'MAX(10)', A(26, 22)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X22', 'MIN(10)', A(47, 22)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X23', 'TOTCOST', A(0, 23)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X23', 'BTUR(3)', A(3, 23)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('X23', 'SULF(3)', A(7, 23)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X23', 'CAP(6)', A(14, 23)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X23', 'MAX(11)', A(27, 23)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X23', 'MIN(11)', A(48, 23)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X24', 'TOTCOST', A(0, 24)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X24', 'BTUR(3)', A(3, 24)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X24', 'SULF(3)', A(7, 24)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X24', 'CAP(6)', A(14, 24)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X24', 'MAX(12)', A(28, 24)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X24', 'MIN(12)', A(49, 24)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X25', 'TOTCOST', A(0, 25)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X25', 'BTUR(3)', A(3, 25)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DE0NN31) EDIT
('X25', 'SULF(3)', A(7, 25)) (SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE (DEONN31) EDIT
('X25', 'CAP(6)', A(14, 25))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X25', 'MAX(13)', A(29, 25))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X25', 'MIN(13)', A(50, 25))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X26', 'TOTCOST', A(0, 26))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X26', 'BTUR(3)', A(3, 26))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X26', 'SULF(3)', A(7, 26))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X26', 'CAP(7)', A(16, 26))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X26', 'MAX(14)', A(30, 26))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X26', 'MIN(14)', A(51, 26))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X27', 'TOTCOST', A(0, 27))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X27', 'BTUR(3)', A(3, 27))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X27', 'SULF(3)', A(7, 27))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE (DEONN31) EDIT
('X27', 'CAP(7)', A(16, 27))(SKIP, COL(5), A, COL(15), A, COL(25),
   F(12, 2));
PUT FILE(DEVN31) EDIT
('X27', 'MAX(15)', A(31, 27))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X27', 'MIN(15)', A(52, 27))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X28', 'TOTCOST', A(0, 28))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X28', 'BTUR(3)', A(3, 28))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X28', 'SULF(3)', A(7, 28))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X28', 'CAP(8)', A(16, 28))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X29', 'MAX(16)', A(33, 29))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X29', 'MIN(16)', A(53, 29))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X29', 'TOTCOST', A(0, 29))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X29', 'BTUR(3)', A(3, 29))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X29', 'SULF(3)', A(7, 29))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X29', 'CAP(8)', A(16, 29))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X29', 'MAX(17)', A(33, 29))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));

PUT FILE(DEVN31) EDIT
('X29', 'MIN(17)', A(54, 29))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X30', 'TOTCOST', A(0, 30) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X30', 'BTUR(4)', A(4, 30) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X30', 'SULF(4)', A(8, 30) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X30', 'CAP(5)', A(13, 30) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X30', 'MAX(9)', A(25, 30) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X30', 'MIN(9)', A(46, 30) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X31', 'TOTCOST', A(0, 31) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X31', 'BTUR(4)', A(4, 31) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X31', 'SULF(4)', A(8, 31) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X31', 'CAP(5)', A(13, 31) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X31', 'MAX(10)', A(26, 31) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X31', 'MIN(10)', A(47, 31) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
( '"X32', 'TOTCOST', A(0, 32) ) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
  ('X32', 'BTUR(4)', A(4,32))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X32', 'SULF(4)', A(8,32))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X32', 'CAP(7)', A(16,32))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X32', 'MAX(14)', A(30,32))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X32', 'MIN(14)', A(51,32))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X32', 'TOTCOST', A(0,33))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X32', 'BTUR(4)', A(4,33))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X32', 'SULF(4)', A(8,33))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X32', 'CAP(7)', A(16,33))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X32', 'MAX(15)', A(31,33))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X32', 'MIN(15)', A(52,33))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X34', 'TOTCOST', A(0,34))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
  ('X34', 'BTUR(4)', A(4,34))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DE0NN31) EDIT
('X34','SULF(4)',A(8,34))(SKIP,COL(5),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X34','CAP(8)',A(16,34))(SKIP,COL(5),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X34','MAX(16)',A(32,34))(SKIP,COL(5),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X34','MIN(16)',A(53,34))(SKIP,COL(5),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X35','TOTC0ST',A(0,35))(SKIP,COL(5),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X35','BTUR(4)',A(4,35))(SKIP,COL(5),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X35','SULF(4)',A(8,35))(SKIP,COL(5),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X35','CAP(8)',A(16,35))(SKIP,COL(5),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X35','MAX(17)',A(33,35))(SKIP,COL(5),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X35','MIN(17)',A(54,35))(SKIP,COL(5),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X36','TOTC0ST',A(0,36))(SKIP,COL(6),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X36','BTUR(1)',A(1,36))(SKIP,COL(6),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X36','SULF(1)',A(5,36))(SKIP,COL(6),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DE0NN31) EDIT
('X36','MAX(18)',A(34,36))(SKIP,COL(5),A,COL(15),A,COL(25),
F(12,2));
PUT FILE(DEONN31) EDIT
('X36', 'MIN(18)', A(55, 36))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X37', 'TOTCOST', A(0, 37))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X37', 'BTUR(2)', A(2, 37))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X37', 'SULF(2)', A(6, 37))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X37', 'MAX(19)', A(36, 37))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X37', 'MIN(19)', A(56, 37))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X38', 'TOTCOST', A(0, 38))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X38', 'BTUR(3)', A(3, 38))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X38', 'SULF(3)', A(7, 38))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X38', 'MAX(20)', A(36, 38))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X38', 'MIN(20)', A(57, 38))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X39', 'TOTCOST', A(0, 39))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X39', 'BTUR(4)', A(4, 39))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEONN31) EDIT
('X39', 'SULF(4)', A(37, 39)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('X39', 'MAX(21)', A(37, 39)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('X39', 'MIN(21)', A(58, 39)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT ('RHS') (SKIP, A);
PUT FILE(DEONN31) EDIT
('R', 'BTUR(1)', BTUR(1)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'BTUR(2)', BTUR(2)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'BTUR(3)', BTUR(3)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'SULF(1)', SULF(1)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'SULF(2)', SULF(2)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'SULF(3)', SULF(3)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'SULF(4)', SULF(4)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'CAP(1)', LCAP(1)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'CAP(2)', LCAP(2)) (SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'CAP(3)', LCAP(3))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'CAP(4)', LCAP(4))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'CAP(5)', LCAP(5))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'CAP(6)', LCAP(6))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'CAP(7)', LCAP(7))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'CAP(8)', LCAP(8))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'MAX(1)', URLT0NS(1,M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'MAX(2)', URLT0NS(2,M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'MAX(3)', URLT0NS(3,M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'MAX(4)', URLT0NS(4,M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'MAX(5)', URLT0NS(5,M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'MAX(6)', URLT0NS(6,M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));

PUT FILE(DEONN31) EDIT
('R', 'MAX(7)', URLT0NS(7,M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12,2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(8)', URLTONS(8, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(9)', URLTONS(9, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(10)', URLTONS(10, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(11)', URLTONS(11, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(12)', URLTONS(12, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(13)', URLTONS(13, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(14)', URLTONS(14, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(15)', URLTONS(15, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(16)', URLTONS(16, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(17)', URLTONS(17, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(18)', URLTONS(18, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(19)', URLTONS(19, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(20)', URLTONS(20, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DEONN31) EDIT
('R', 'MAX(21)', URLTONS(21, M))(SKIP, COL(5), A, COL(15), A, COL(25),
F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(1)', LRLTONS(1, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(2)', LRLTONS(2, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(3)', LRLTONS(3, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(4)', LRLTONS(4, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(5)', LRLTONS(5, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(6)', LRLTONS(6, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(7)', LRLTONS(7, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(8)', LRLTONS(8, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(9)', LRLTONS(9, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(10)', LRLTONS(10, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(11)', LRLTONS(11, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(12)', LRLTONS(12, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DE0NN31) EDIT
('R', 'MIN(13)', LRLTONS(13, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEFONN31) EDIT
  ('R', 'MIN(14)', LRLTONS(14, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEFONN31) EDIT
  ('R', 'MIN(15)', LRLTONS(15, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEFONN31) EDIT
  ('R', 'MIN(16)', LRLTONS(16, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEFONN31) EDIT
  ('R', 'MIN(17)', LRLTONS(17, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEFONN31) EDIT
  ('R', 'MIN(18)', LRLTONS(18, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEFONN31) EDIT
  ('R', 'MIN(19)', LRLTONS(19, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEFONN31) EDIT
  ('R', 'MIN(20)', LRLTONS(20, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEFONN31) EDIT
  ('R', 'MIN(21)', LRLTONS(21, M))(SKIP, COL(5), A, COL(15), A, COL(25), F(12, 2));
PUT FILE(DEFONN31) EDIT('ENDATA')(SKIP, A);
END BDLMP;
Vita

Diane Dolores Kent

Born: April 30, 1957
Philadelphia, Pennsylvania

Parents: Mrs. Lorraine D. Braunlich
Dr. Richard B. Kent

Education: Smith College
Northampton, Massachusetts
A.B. in Mathematics (1979)

Lehigh University
Bethehem, Pennsylvania
Candidate for M.S. in Industrial Engineering (1982)

Professional Affiliations: International Association of Energy Economists
Philadelphia, Pennsylvania

Society of Women Engineers
Allentown, Pennsylvania

Experience: Pennsylvania Power and Light Company
Analyst - Fossil Fuels Department
June, 1979 to Present