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An Evaluation of the Coal and Electric Utilities Model Documentation

by

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At an early stage in this project we participated in the Workshop on Documentation Guidelines and Standards (April 1979) organized by the National Bureau of Standards and sponsored by the Office of Analysis Oversight and Access. The ideas presented in Section 2.3 of this report were first presented and discussed in the Workshop. In particular we acknowledge the contributions of Saul Gass, Richard Jackson, Lambert Joel, Karla Hoffman and Patsy Saunders (NBS); Fred Murphy and Phyllis Gilmore (DOE); John Dearien (EG&G Idaho); Mary Barcella and Michael Shaw (LMI); John Maybee (Los Alamos); and Marianne Legan (NESC, Argonne).

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1. INTRODUCTION AND SUMMARY

Introduction

The Energy Information Administration's Office of Analysis Oversight and Access (OAQA)* is sponsoring the M.I.T. Energy Model Analysis Program (EMAP) in a study of methods and procedures for the effective internal management and control of information model development, evaluation, and application. This project is part of a larger OAQA program to improve the quality and credibility of energy information developed and published by the EIA. Central to EIA's concern in developing good management practices is a recognition that documentation of information models and applications is the key to effective communication of results credible to EIA's clients. Accordingly, this first report of the EMAP project is concerned with the development of procedures for planning and implementing effective documentation.

EIA's interest in the development of good model documentation practice is an outgrowth of many pressures and needs.** As a result of its enabling legislation, EIA is responsible for carrying out a program of energy data/information collection, evaluation, analysis and dissemination [44]. The Office of Applied Analysis, in particular, is involved in producing energy analysis reports and forecasts and in developing, evaluating and maintaining the tools by which such analysis

*Within the Applied Analysis Division at the Energy Information Administration (EIA).

**Predecessors to the Energy Information Administration (EIA) include the Federal Energy Administration, the Federal Energy Office, and the Office of Energy Data and Analysis of the Department of Interior. In this report we will refer to "EIA," instead of "EIA and predecessor agencies," unless the context requires more careful identification.
is performed. Energy information models have played an ever-increasing role in this work. However, to realize all the potential contributions of such models, the modeling process must be understandable and credible to all concerned. An essential ingredient of credibility is the potential for outside review of the models utilized. The model's documentation is, of course, the key to this review.

This critical need for model documentation was recognized by many groups after the production of the Project Independence Report (PIR) [27]. Although the system of models underlying that report was described in some detail in a series of appendices to the PIR, and in twenty separate technical reports, some of several volumes, the materials were not perceived as being complete, and comprehensible enough for effective digestion by administration and congressional policy makers. In addition, concerns were widespread that the models were somehow being tampered with by those interested in promoting either industry goals or Executive Office policies. These pressures, described in more detail elsewhere ([42] and [43]) were factors leading to the legislative mandate in the Energy Conservation and Production Act of 1976 requiring the "complete structural, parametric and operational" documentation of the PIES model [45]. In addition, the same law established an interagency oversight committee, called the Professional Audit Review Team (PART) to "review and evaluate EIA's work and to determine whether data collection and analysis activities are being performed in an objective and professional manner consistent with the intent of the Congress [47, p.3]." PART annually produces a report to Congress on its findings. In its first such report, dated December 5, 1977 [27] PART made the following comments on the state of model documentation within EIA.
"Computer models can be useful tools, providing valuable assistance to energy policymakers. However, certain procedures and practices should be followed to insure that such models make credible predictions. These include ... procedures to document, verify, validate, and test the model. OEIA fell short [in its first 10 months of operation] in meeting these goals, and as a result, the credibility of its models has not been established."

In response to such mandates, the EIA launched a program for evaluating model documentation, for producing documentation of models already used at EIA, and for producing guidelines for the production of future model documentation.

This report, one of several sponsored by OAOA, presents the results of an M.I.T. analysis of policy model documentation and EIA's approach to it. As a means both of facilitating our analysis and of illustrating its application in documentation evaluation, a case study was undertaken of a particular energy model, the ICF Coal and Electric Utilities Model (CEUM). The third annual report of the PART staff to Congress stated that the first priority of EIA's documentation program is to "document all models used for the development of forecasts and analyses published in the Annual Report to Congress" [47]. The version of the CEUM maintained at the DOE's computer facility, known as the National Coal Model (NCM) is used to support the Annual Report to Congress. Therefore, the choice of the CEUM as a case study model met EIA's goals; in addition the M.I.T. group was concurrently conducting an in-depth assessment of the CEUM with the sponsorship of the Electric Power Research Institute (EPRI).

Approach

The case study approach has been useful in forming our ideas about preparing and evaluating documentation and has produced a great deal of information about the CEUM. Our approach involved the following steps.
We first obtained the EIA Draft Documentation Guidelines prepared by the OAOA. These guidelines are in a sense a synthesis of many sets of documentation standards, and of discussions held amongst modelers and model analysts. These guidelines call for five types of documents including Model Summaries, Description of Methodology, Model Description, Guide to Model Applications, and User's Guide. Together, the documents require a comprehensive description of a model, and they provided a starting point against which we could measure the case study documentation. In discussions with the modelers, however, it became evident that the documentation objectives represented by the guidelines did not conform to the objectives of the model developers (and presumably their sponsors), and that many of the documents suggested in the guidelines did not exist for that model. While we did not always agree with their objectives, the perspective provided by the modelers, in conjunction with our own analysis, led us to conclude that fixed documentation standards applicable to any policy model might not be the best approach to the production of cost-effective, complete, and satisfactory model documentation. Accordingly, in this report, we present the results of the use of the EIA interim documentation guidelines as criteria for evaluating the CEUM documentation, but also develop and apply an alternative recommendation for the planning and production of policy model documentation. This alternative approach is summarized in the next section.

Another important part of our approach to the case study model documentation evaluation was to conduct a verification of the documentation and its consistency with the computer code. Model verification of documentation and code includes the following
activities: (1) examining the internal consistency of the documentation and its consistency with the coded version of the model, thereby uncovering errors or omissions in the documentation, (2) carefully inspecting the model's code for accuracy and internal consistency, thereby uncovering coding errors, and (3) describing potentially misleading aspects of the model of which the user should be aware.

The first step in the CEUM verification process was to certify that the version of this model transferred by ICF to the EIA computer center was in fact the version that DOE had agreed was to be evaluated. This was accomplished by having ICF independently replicate the Base Case using the transferred model.

The actual CEUM verification consisted of documentation/code comparisons and analysis of the computer code, plus the additional activity of independent reprogramming of a key portion of the code. The reprogramming focused upon the production costing portion of the coal supply submodel. The original purpose of this activity was to develop a means of obtaining analytical expressions for elasticities relating average production costs to geologic characteristics of coal deposition. However, it soon became clear that this reprogramming, using a different logical sequence, was also an extremely effective method of code verification since several errors in the original code were discovered in this way. The correspondence of the two codes was assured by parallel runs that matched coal supply prices to five decimal places, both with and without the errors.

Finally, as a result of the analytic work performed both under this contract and for a concurrent contract with the Electric Power Research Institute, additional documentation for the CEUM model was produced by
the M.I.T. group. This documentation is presented in this report in a series of appendixes.

Guidelines for Planning and Preparing Model Documentation: Policy model documentation must be sufficient to satisfy the requirements of several different model clients including peer modelers, model users and operators, analysts using model-based results, decision makers, and constituencies potentially affected by model-influenced policies. Types of documentation to satisfy the various needs of these groups include technical description and development of scientific results employed in the model; technical documentation of the manner in which policy concepts and instruments are integrated with scientific results; documentation of model implementation and operator instructions; and documentation of model applications including input data and interpretation of results.

The extent of documentation requirements will depend upon two major factors: (1) the model development environment, and (2) the model use environment. For example, policy models developed to study highly conflicted issues and requiring new scientific research will require more extensive and formal documentation than models involving accepted scientific results and/or less conflicted policy issues. Similarly, the use environment dictates much of the extent and formality of documentation. For example, models to be operated only by the originators will require minimal documentation of operating procedures (sufficient to demonstrate good practice), whereas models intended for use by many users at sites of their choosing will require considerable formalism in operations instructions. Regardless of the planned environment, however, documentation must be sufficient to support independent replication of model structure, associated data, and applications by peer modelers and scientists.
The documentation appropriate for any particular model thus depends upon many factors. Our analysis has led us to conclude that an effective procedure for considering these factors and developing a documentation plan would be the joint preparation of a documentation requirements analysis by the modeler and sponsor, at the initiation of model development activities. The objectives of the documentation requirements analysis would be:

- To provide an analysis of the expected policy model development and use environments to determine the document types, style, content, and format necessary to meet the needs of all model clients;

- To enable modelers, model sponsors, and other model clients to develop shared expectations about the documentation types, style, content, and format of documentation;

- To estimate resources (both financial and skills) required to support the modeler and documentation support groups in preparing satisfactory documentation.

The result of the analysis would be a documentation plan. The documentation categories included in the EIA interim documentation standards provide a good resource for the model sponsor and modeler in their consideration of documentation needs. If the modeler and model sponsor together formulate the plan for the production and distribution of documentation, misunderstandings or misplaced expectations should be avoided. The result should produce more meaningful and effective documentation, increasing the potential for model use and credibility.

While documentation requirements analysis may produce different documentation plans for each model, depending upon the development and use environments, the minimum acceptable level of documentation must be sufficient to permit in-depth scientific and peer review and evaluation of the model, including formulation and structure, associated data, and computer code. Such documentation represents the fundamental statement of the model.
Case Study Evaluation of CEUM Documentation: As noted, the preliminary evaluation of the CEUM documentation identified some differences between the EIA interim guidelines and the ICF documentation objectives. The results of the evaluation of the CEUM documentation against those guidelines are presented in Table 1. However, the model documentation was also evaluated in the context of the two factors described above, that is, the model development environment and the model use environment. Examining the documentation from these two perspectives, we concluded that the approach to model documentation adopted by ICF and its sponsors was most nearly consistent with (1) a development environment in which a well-known approach was being adopted, and (2) a use environment in which the modeler was to be the primary user and operator. Accordingly, our evaluation focused upon

- effectiveness in satisfying requirements for the perceived development and use environments;
- effectiveness of technical documentation of concepts and data employed in implementing the model; and
- correspondence between technical documentation and computer implementation.

In our view the CEUM documentation is most consistent with an environment in which the modeler/analyst works closely with an analyst/client to develop and interpret the application scenario. Thus the documentation of CEUM model-based studies is quite good when viewed from the perspective of the client's ability to understand how his scenario was combined with the model data to produce certain results. The documentation is also effective (with some exceptions) in communicating to the analyst/client the sources and characteristics of the model data base. The CEUM documentation is less successful in
<table>
<thead>
<tr>
<th>Document Type and Description *</th>
<th>CEUM Materials</th>
<th>Primary Audience</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Summary: nontechnical descriptions of the model and model applications</td>
<td>Ref. 5, Section I; Various Sections of Ref. 7,8,9,15</td>
<td>Nontechnical</td>
<td>Uniformly excellent discussions of study objectives and results; good descriptions of scenario data and methods of data development; good summary descriptions of model structure; poor or non-existent discussion of rationale and alternatives for key model concepts, a level of resolution required for intended applications.</td>
</tr>
<tr>
<td>Model Methodology: technical description of rationale, precedents, and comparative evaluations with alternative approaches</td>
<td>Ref. 5, Section II and Appendix D</td>
<td>Modelers, Peers, Model users, other Analysts</td>
<td>Good descriptions of modeling approach, but not usually in the &quot;natural language&quot; for peers/other modelers. Very little technical discussion justifying model concepts, approach; almost no comparative discussion of alternative approaches.</td>
</tr>
<tr>
<td>Model Description: presentation of the model sufficient to describe its structure, associated data, and conditions for understanding and interpreting results</td>
<td>Ref. 5, Section III and Appendix E; Ref. 7, Appendix; Ref. 8, Appendix; Ref. 9, Appendix</td>
<td>Analysts performing policy research</td>
<td>Consistently good description of associated data and results; relatively poor documentation of actual model implementation; almost no discussion of results in terms of limitations and approximations used in developing data at resolution required by the model. No adequate complete and detailed technical description of the model is provided. For additions to the technical documentation see Appendices B,C,D,E, and F of this report.</td>
</tr>
<tr>
<td>Guide to Model Applications: nontechnical description of model, and model applications to support interpretation and use of model-based analyses</td>
<td>Ref. 5, Appendix A</td>
<td>Nontechical groups, analysts interpreting policy research</td>
<td>A guide to applications is provided for the NCM. However, this is not complete and has not been updated for the CEUM.</td>
</tr>
</tbody>
</table>

*Based on EIA Interim Documentation Guidelines [24].
satisfying the needs of peer modelers in understanding the scientific basis of the concepts embodied in the model structure and of the procedures used in developing model data. Finally, a number of inconsistencies between the model documentation and computer code have been identified and several logical errors and questionable assumptions have been noted.

Summary results of the verification work performed on the CEUM documentation and computer code are listed below. The substantive errors found in the verification analysis include:

- incorrectly modeling the deep-cleaning of all metallurgical coals, resulting in the double counting of deep-cleaning costs for certain coal types, and other related problems,
- incorrectly escalating base-year (1975) price data for existing mines,
- skipping one year of cost escalation between the base year and the case year (1985) in the calculation of real annuity coal prices,
- inappropriate method for approximating treatment of initial capital cost expenditures,
- incorrectly escalating the property taxes and insurance component of coal mine operating costs,
- incorrectly calculating base-year Union Welfare Costs for coal mines,
- changing the smallest seam thickness input value in the midst of cost calculations for deep mines, and
- improperly allocating more than 100 percent of deferred capital over the lifetime of a mine when the lifetime is not perfectly divisible by four.

Other problems identified include:

- In parts, the CEUM Supply Code relates to old code used for the PIES Coal Supply Analysis. Such code can only lead to confusion and should be deleted;
- Because of an undocumented "patch" that exogenously overrides the coal supply curve output for Utah bituminous low-sulfur
coal, this particular supply curve should be considered invalid for CEUM sensitivity runs involving regeneration of supply curves;

- Real escalation of cost factors is not appropriately accounted for in 1990 and 1995 case-year model runs;

- The implementation of a change in the general rate of inflation is not at all straightforward and requires changes in both supply and non-supply oriented components of the CEUM;

- The real rail-rate escalation factor for transportation costs is not implemented as documented;

- All hydroelectric costs except for pumped storage O&M are excluded from the objective function of the linear program (and also from the imputed cost of electricity); and

- Electricity distribution costs are ignored in the LP but are added exogenously at the report-writing stage. This procedure is not documented.

Our effort in verifying implementation of the CEUM was intensive, both because this aspect of model evaluation is important, and because the CEUM technical documentation was not sufficient to permit our continuing on to further in-depth validation efforts. The errors and the proposed corrections were reviewed with DOE and the ICF modelers.

Conclusions

The documentation guidelines presently used by EIA are just that -- guidelines. Applying these guidelines in evaluating the CEUM documentation has demonstrated that the actual scope and extent of successful documentation requires more active analysis and planning. Documentation requirements analysis should be an integral part of the model development planning process reflecting the interests and expectations of the modeler, model sponsor, client and/or users, and must be separately budgeted for both financial and skill requirements. We recommend that EIA consider implementing such a procedure for all new modeling projects.
In the process of conducting this case study a number of errors and problems with the current documentation and implementation of the CEUM were identified. As noted, these have been discussed in detail with representatives from the EIA Office of Coal and Electric Utilities and with ICF. Since, with only one exception, all our points have been accepted, they should be incorporated into all current versions of the model. We include as Appendix H listings of the corrected versions of the relevant code.
2. EVALUATION OF THE ICF COAL AND ELECTRIC UTILITIES MODEL DOCUMENTATION

In this chapter we provide an evaluation of the technical documentation and computer implementation of the CEUM. In the next section, we provide an overview description of the model. In Section 2.2 we summarize the model development, evaluation and application history, and describe the materials available for evaluation. In Section 2.3 we discuss guidelines for documentation evaluation. In Section 2.4.1 we describe and evaluate the ICF approach to documentation. In Section 2.4.2 we evaluate the computer implementation of the CEUM and in Section 2.4.3 we note several points concerning differences between technical documentation and the computer implementation.

2.1 Overview Description of the ICF Coal and Electric Utilities Model

We begin with a general description of the CEUM.* The CEUM is a model of U.S. coal supply, transportation, and use structured as a static linear program. The model consists of three major components including a coal supply component providing coal via a transportation network to satisfy at minimum cost utility coal demands as well as all other coal demands. The coal supply submodel is based upon the distribution of coal resources by geologic characteristics, on mining costs for coal types by geologic characteristic, and on behavioral assumptions concerning producer decisions to open new mines. The output of the coal supply submodel analysis are step functions relating coal supply and the producers' minimum acceptable, or reservation, price. These step functions, the transportation network connecting coal supply regions with

*The primary source for information on CEUM structure is [5, Sections I and II].
utility demand regions, and a model of utility capacity expansion and generation comprise the linear program. The objective function is to minimize the total cost of electricity delivered by utilities and the costs of coal consumed by the non-utility sectors. A distinguishing characteristic of the model is that utility capacity expansion decisions explicitly include consideration of scrubber technologies so that the model evaluates the trade-off between capacity type, control technology, and the type and quality of fuel input.

Table 2 summarizes the major components of the CEUM. Although the model formulation is static, in application intertemporal linkages are proxied by setting lower bounds on coal flows to insure that contracts undertaken in earlier years would continue in force, and setting lower bounds on utility capacity additions equal to those in prior years, Table 3 summarizes the key endogenous and exogenous variables in the CEUM. The model is essentially static in formulation, projecting changes in activities between a base year and a case year. The model workings may be characterized as follows.

1. Coal supply schedules are generated consistent with information on coal resources distributed by geologic characteristics and by cost of mining.

2. Coal mining activities transfer coal from available coal reserves to coal "stocks" in supply regions. Coal stocks may be deep cleaned to adjust coal quality, allowing for cleaning losses.

3. Transportation activities move coal from supply region coal stocks to utility region fuel piles, consistent with characteristics of the transportation network.
TABLE 2. Coal and Electric Utilities Model -- Major Components
(From CEUM documentation, page II-2)

<table>
<thead>
<tr>
<th>SUPPLY</th>
<th>UTILITY DEMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Regions</td>
<td>35 Regions</td>
</tr>
<tr>
<td>40 Coal types</td>
<td>19 Coal piles</td>
</tr>
<tr>
<td>5 Btu categories</td>
<td>3 Ranks of coal</td>
</tr>
<tr>
<td>8 sulfur levels</td>
<td>6 Sulfur categories</td>
</tr>
<tr>
<td>Existing capacity</td>
<td>Metallurgical pile includes only the highest grades of coal</td>
</tr>
<tr>
<td>Contract (large mines)</td>
<td>Utility Sector</td>
</tr>
<tr>
<td>Spot (small mines)</td>
<td>Point estimates for KWH sales by region</td>
</tr>
<tr>
<td>Surge (up to 25 million tons)</td>
<td>KWH sales allocated to four load categories (base, intermediate, seasonal peak, and daily peak)</td>
</tr>
<tr>
<td>New Capacity</td>
<td>Existing generating capacity utilized by model on basis of variable cost</td>
</tr>
<tr>
<td>Based upon BOM demonstrated reserve base</td>
<td>New generating capacity utilized by model on basis of full costs (including capital costs)</td>
</tr>
<tr>
<td>Reserves allocated to model mine types</td>
<td>Air pollution standards addressed explicitly</td>
</tr>
<tr>
<td>Minimum acceptable selling prices estimated for each model mine type</td>
<td>Transmission links between regions</td>
</tr>
<tr>
<td>Upper bounds of new mine capacity for each region based upon planned mine openings</td>
<td>Oil and gas prices fixed</td>
</tr>
<tr>
<td>Coal washing</td>
<td>Coal prices determined from supply sector through transportation network</td>
</tr>
<tr>
<td>Basic washing assumed for all bituminous coals</td>
<td></td>
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<tr>
<td>Deep cleaning option available to lower sulfur content to meet New Source Performance Standard or a one percent sulfur emission limitation for existing sources</td>
<td></td>
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<table>
<thead>
<tr>
<th>NON-UTILITY DEMAND</th>
<th>TRANSPORTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Five non-utility sectors (metallurgical, export, industrial, residential/commercial, synthetics)</td>
<td>Direct links</td>
</tr>
<tr>
<td>Point estimates of Btu's demanded</td>
<td>Cost based upon unit train or barge shipment rates</td>
</tr>
<tr>
<td>Allowable coals specified in terms of btu and sulfur content</td>
<td>Lower bounds used to represent long-term contract commitments</td>
</tr>
<tr>
<td>No price sensitivity</td>
<td>Upper bounds could be used to represent transportation bottlenecks or limited capacity</td>
</tr>
</tbody>
</table>
Table 3. CEUM Variables

<table>
<thead>
<tr>
<th>Endogenous Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Supply/Production</td>
</tr>
<tr>
<td>Coal Cleaning and Mixing</td>
</tr>
<tr>
<td>Coal Transport Patterns</td>
</tr>
<tr>
<td>Oil/Gas Procurement by Utilities</td>
</tr>
<tr>
<td>Coal Procurement by Non-Utilities</td>
</tr>
<tr>
<td>Electricity Generation from Coal</td>
</tr>
<tr>
<td>Electricity Generation from Non-Coal Sources</td>
</tr>
<tr>
<td>Electricity Transmission</td>
</tr>
<tr>
<td>Building Electrical Generating Capacity</td>
</tr>
<tr>
<td>Building Scrubber Capacity</td>
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<table>
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<tr>
<th>Exogenous Variables</th>
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<tbody>
<tr>
<td>Electricity Demand</td>
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<tr>
<td>Non-Utility Coal Demand</td>
</tr>
<tr>
<td>Bounds on New Coal-Fired Capacity</td>
</tr>
<tr>
<td>Fixed Nuclear and Hydro Capacity Additions</td>
</tr>
<tr>
<td>Bounds on Scrubber Capacity</td>
</tr>
<tr>
<td>Oil/Gas Prices</td>
</tr>
<tr>
<td>Capital Costs, O&amp;M Costs, Transportation Costs, Etc.</td>
</tr>
<tr>
<td>Cost Adjustment Factors Used in Production Costing</td>
</tr>
<tr>
<td>Available Coal Reserves and Resources by Region by</td>
</tr>
<tr>
<td>Characteristic</td>
</tr>
</tbody>
</table>
4. Oil/gas procurement activities locate these fuels in utility region fuel piles at a price, but with no explicit production/transportation representation.

5. Coal procurement activities for non-utility use remove coal from fuel piles to satisfy exogenous non-utility demands, consistent with restrictions on coal quality.

6. Coal-fired electricity generation activities remove coal from utility region fuel piles, and employ generating capacity and possibly scrubber capacity, to produce electricity. In parallel, non-coal-fired electricity generation activities remove non-coal fuels from fuel piles and use generating capacity to produce electricity.

7. Electricity transmission activities connect utility regions. In any region the sum of electricity generation minus exports plus imports satisfies exogenous electricity consumption requirements, allowing for both transmission and distribution losses.

8. In the process of satisfying exogenous electricity demand, new electrical generating and scrubbing capacity may be created, subject to expansion limits.

It is useful to place the CEUM in the context of a more general model of energy markets. In Figure 1 we characterize a more general energy market model, which includes the CEUM model, to illustrate both the coverage and the key linkage assumptions of the CEUM. Our energy market model includes the obvious end-use, conversion, and fuel production sectors and highlights the interaction of fuel production, demand, and the determination of equilibrium prices and quantities. In Figure 1, the overlay of the CEUM on the energy market model is designated by the heavy lines.
Figure 1. Market Equilibrium Analysis of Energy Production

Prices

\[ C = \text{coal} \quad E = \text{electricity} \]

\[ D = \text{demand} \quad \text{FD} = \text{final demand} \]

\[ \text{DD} = \text{derived demand} \quad G = \text{industrial goods} \]

Supply & Demand Functions

\[ P = \text{price} \quad \text{FD} = \text{final demand} \]

Quantities

\[ O = \text{oil/gas} \quad \text{NI} = \text{national income} \]

\[ \text{general model} \quad \text{CEUM} \]
The CEUM contains only two sectors of the energy market model, electricity production and coal production. Final demand, industrial production, and oil and gas production are omitted. Note that there are six sets of linking variables between the CEUM and the complementary parts of the energy market model, including the prices of electricity, oil and coal, the total demand for electricity, the derived demand for coal and industrial production, and the derived demand for oil and electricity generation. Three of these variables—the demand for electricity, the industrial derived demand for coal, and the price of oil—are exogenously specified in CEUM. The other three variables—the price of electricity, the price of coal, and the derived demand for oil for electricity generation—are endogenous variables in CEUM. For the exogenous linking variables to be constant the CEUM must assume that (i) the supply functions for oil and gas are perfectly elastic, and (ii) that the demand for electricity and the industrial derived demand for coal are perfectly inelastic.

A distinctive feature of the CEUM is the effort to provide detail on coal production regions, quality, relation between geologic disposition, and mining costs. The coal supply submodel develops price-sensitive, multi-step coal supply curves for each coal type by coal supply region. The step function measures potential production levels at various prices. Each step of the function represents a different type of mine, with the length of the step indicating the potential production level for that mine type, and the step height measuring the minimum acceptable selling, or reservation, price. The reservation price is based upon average variable cost for mines currently in operation, and on average total cost for new mines.
The method for developing the coal supply functions is based upon analyses of data on the available coal resources classified by various coal quality and geologic factors, and a method of estimating mining costs sensitive to the geologic factors characterizing coal deposition. The key steps are the distribution of coal resources to the various geologic categories when no independent data are available, and the method by which the economic costs of mining resources with particular geologic characteristics are specified.

The dimensions of the ICF coal supply submodel are as follows. Thirty coal supply regions are distinguished producing coal with eight ranges of sulfur content, and five ranges of heat content. Two general types of mines are distinguished—surface and deep. For surface mines there are six possible mine sizes and seven possible overburden ratios (cubic yards of overburden per ton of coal in ground). For deep mines there are five mine sizes, five seam thickness categories and four seam depth categories.

The basic data used in allocating resources by production regions were the Bureau of Mines Reserve Base of U.S. Coal by Sulfur Content 1. The Eastern States (IC8680) and The Reserve Base of U.S. Coal by Sulfur Content 2. The Western States (IC8693). These data were updated to account for production and mine closings through 1975. The model makes use of the uniform distribution to allocate resources by geologic characteristics when no direct measurements are available. For example, the model uses this distribution to allocate resources to the seven categories of overburden ratio. The ICF argument is that when no real information is available to inform this distribution process, then the simplest distribution should be used, namely the uniform distribution.
A second significant aspect of the CEUM Coal Supply Submodel is the method used in evaluating mining costs for coal deposited by geologic characteristics (seam thickness, depth, etc.). The fixed and variable cost associated with a "model" mine were developed based on studies by the Bureau of Mines and TRW. The approach was to perform mining engineering analyses based on knowledge of existing technology and productivity. A deep mine characterized as producing one million tons annual output with mine characteristics of seventy-two inch seam thickness and seven hundred feet seam depth, and a one million ton per year surface mine with overburden ratio 10:1 (ten to one) were specified. Mining costs for mines associated with coal deposited by other geologic characteristics were developed by use of cost adjustment factors based on changes in mine size and geologic characteristics.

2.2 History of CEUM Development, Description of Materials Available for Evaluation, and Approach to Evaluation

The history of the ICF CEUM is complex, involving both sponsored model development for FEA, and subsequent unsponsored research by ICF to extend the model for application in support of studies sponsored by various government agencies including EPA, the Department of Interior, and the Office of Policy Analysis of the DOE. These policy studies each involved further extensions and refinements to the model, including the addition of new activities and then updating and improving the data base.

The earliest phase of model development begins with the contributions of ICF consultants in the preparation of the Project Independence Report [27] in 1974. In particular, Mr. Hoff Stauffer of ICF was a key consultant in transforming data and information provided by the Project Independence Coal Task Force into a form usable in the Project
Independence Evaluation System (PIES), and in interpreting PIES scenario results. Subsequently, a more formal effort to develop a coal supply model based upon the efforts of the Task Force and its contractors (primarily TRW) was initiated by ICF with FEA sponsorship. The product of this effort, the PIES Coal Supply Analysis, is documented in [1]. Subsequently an effort was undertaken to extend the PIES/CSA to include a utility coal demand submodel, a transportation network, and to close the extended system by specifying non-utility coal demands exogenously, thus providing a complete U.S. coal supply and demand model. This model was identified as the National Coal Model (NCM) and is documented in [4].

Upon completion of the NCM for FEA, ICF undertook an unsponsored research effort to extend the model still further to support policy studies relating to development of the domestic coal industry. Perhaps the most convenient way to summarize the relation between NCM and CEUM is to quote directly from the ICF report [5]:

"Although the ICF model is based upon the National Coal Model (NCM) that ICF developed for the Federal Energy Administration, the ICF Coal and Electric Utilities Model is substantially different from the FEA's NCM. For example, the ICF model identifies the marginal deep mine by depth, size, and seam thickness instead of by only seam thickness, handles partial scrubbing and has a different procedure for estimating electrical transmission costs and losses. [5, Preface]

The description of the changes between the NCM and the first version of CEUM are described in Appendix E of [5], the remainder of which is the documentation of the NCM. Appendix E of [5] includes some 25 memoranda analyzing issues and data considered for revisions in the NCM-to-CEUM transition.

"These memoranda recommend various changes to the data inputs and model structure. Essentially, all the data inputs have already been developed and are contained herein. Similarly, most if not all the changes to model structure (which are neither numerous nor major) have been thought through." [5, Appendix E, p. 8]
"Some of our recommendations are to do nothing, because our in-depth analysis indicated the current data inputs are okay or because we have not yet been able to resolve the issue. Other of our recommendations concern changes that are refinements which will make the model more credible but will not necessarily impact the forecasts substantially. However, other of our recommendations concern changes that are much more than refinements; they are corrections of major mistakes." [5, Appendix E, p. 8]

Thus the revisions to NCM were primarily improvements to the associated data, not structural improvements. That these revisions were expected to produce significant changes in model results is indicated in Table 4 extracted from [5, Appendix E].*

The next phase of the CEUM development effort has involved the application of the CEUM in support of a series of policy studies focused on analysis of alternative new source performance standards (ANSPS)—changes in sulfur oxide emission standards—and on western coal development. The first major study is presented in a report prepared for EPA, reviewing the current new source performance standard (NSPS) following the 1977 amendments to the Clean Air Acts [7]. These amendments mandate the use, in new large fossil-fuel burning installations, of the best available technologies for pollution control.

A second study using CEUM was sponsored by the Departments of Interior and Energy, and deals with the demand for western coal and demand sensitivity to selected uncertainties, and considers the question of the need for additional leasing of Federal lands in the west [8]. The principal difference between this and the earlier study was development of a new, and significantly different, set of exogenous end-use electricity and non-utility coal demands.

*We are unaware of any subsequent analysis to evaluate the actual effects of the revisions.
<table>
<thead>
<tr>
<th>Model or Data Revision</th>
<th>Expected Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Marginal deep mines</td>
<td>10 to 20 percent increase from original NCM data base values</td>
</tr>
<tr>
<td>- Productivity, wage rates, UMW Welfare and black lung</td>
<td>-10 to +20 percent change in mine-mouth prices</td>
</tr>
<tr>
<td>- Income taxes</td>
<td>8 percent decline in mine-mouth price</td>
</tr>
<tr>
<td>- Severance taxes and royalties</td>
<td>12 percent increase in mine-mouth price on Federal lands</td>
</tr>
<tr>
<td>- Coal preparation costs</td>
<td>25 percent increase in coal mine-mouth prices</td>
</tr>
<tr>
<td>- Western coal in eastern boilers</td>
<td>major changes in regional production levels</td>
</tr>
<tr>
<td>- Variation in scrubber costs</td>
<td>10 percent or less decrease in kwh cost from coal-fired plant with scrubber plus major impact on scrubber builds</td>
</tr>
<tr>
<td>- Utility capital and O&amp;M costs</td>
<td>30 percent increase in kwh costs</td>
</tr>
<tr>
<td>- Transmission costs</td>
<td>300 percent increase in new long distance transmission costs per kwh</td>
</tr>
<tr>
<td>- Transportation costs</td>
<td>40 percent increase in transportation costs in the East</td>
</tr>
</tbody>
</table>

Source: [5, Appendix E, p. 8]
A third study, sponsored jointly by EPA and DOE focuses again on the impacts of ANSPS [9]. The primary differences between this and the earlier study include significant modifications in the end-use demand assumptions, much closer to the DOI/DOE assumptions, and new scenario specifications on the meaning and costs of ANSPS.

Each of the three studies has involved extensions and updates to the model, and in each case the revisions are documented in appendices to the report in a style and format similar to that described above. Most of the revisions are to data, not model structure. Thus the basic CEUM documentation consists of:

- Coal and Electric Utilities Model Documentation, July 1977 [5].
- Appendix B of Effects of Alternative New Source Performance Standards for Coal-Fired Electric Utility Boilers on the Coal Markets and on Utility Capacity Expansion Plans, Draft, September 1978 [7]. (Also see Scenario Specifications in Section II of [7].)
- Appendix C of The Demand for Western Coal and its Sensitivity to Key Uncertainties, Draft, June 1978 [8].

In September 1978, ICF transferred the CEUM and associated data base extant at that time to the Energy Information Administration. It is the documentation and computer code associated with this version of the model which is considered in this report. The reader should note that ICF has continued its government sponsored studies with the model, and has recently published Still Further Analyses of Alternative New Source Performance Standards for New Coal-Fired Powerplants, a preliminary draft report to EPA [15]. This report includes some further model extensions, most importantly new data on scrubber costs. However, the style and general content of the new report is entirely consistent with the earlier
work, and so will not affect our evaluation of the documentation.

Finally, the reader should note that various evaluations of the CEUM and its ancestors have been conducted, or are in progress. The original coal supply analysis in the Project Independence Report was reviewed by MIT [16] and by Battelle Memorial Institute [17]. The PIES Coal Supply Analysis effort [1] was reviewed by Resources for the Future in [2], and by Gordon in [3]. The NCM [4] was also reviewed by Gordon in [3]. The CEUM study reports [7, 8, 9, 15] have been extensively reviewed by the sponsoring agencies and their scientific consultants although, to our knowledge, none of this peer review has been, or will be, published. Finally, an in-depth evaluation of the CEUM is now being conducted by the MIT Energy Model Analysis Program. A summary of all this history is presented in Table 5.
<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 1976 - May 1976</td>
<td>PIES Coal Supply Analysis</td>
</tr>
<tr>
<td>August 1976</td>
<td>RFF Evaluation of PIES Coal Supply Methodology</td>
</tr>
<tr>
<td>October 1976</td>
<td>National Coal Model (NCM) Documentation</td>
</tr>
<tr>
<td>July 1977</td>
<td>Gordon's Critique of NCM</td>
</tr>
<tr>
<td>July 1977</td>
<td>CEUM Documentation (NCM Documentation plus extensions in Appendix E)</td>
</tr>
<tr>
<td>September 1977 - April 1978</td>
<td>CEUM EPA Study</td>
</tr>
<tr>
<td>April 1978 - June 1978</td>
<td>CEUM DOI/DOE Study</td>
</tr>
<tr>
<td>April 1978 - September 1978</td>
<td>CEUM EPA/DOE Study</td>
</tr>
<tr>
<td>September 1978</td>
<td>Transfer of CEUM and associated database to EIA</td>
</tr>
<tr>
<td>September 1979</td>
<td>MIT Evaluation of CEUM Documentation</td>
</tr>
<tr>
<td>December 1979</td>
<td>MIT Independent Evaluation of CEUM</td>
</tr>
</tbody>
</table>
2.3 Guidelines for Documentation Evaluation*

2.3.1 Background

When policy modelers and model users meet it is a certainty that the topic of model documentation, or lack thereof, will be discussed, usually with considerable emotion. The gist of such discussions seems to center on differing perceptions by modelers and user/analysts as to what constitutes appropriate documentation. As one example: In 1976 at the EPRI-sponsored Workshop for Considering a Forum for the Analysis of Energy Options, the importance of appropriate documentation in establishing credibility of energy system models and model-based studies, although not on the Workshop agenda, was discussed with increasingly sharply worded exchanges between modelers and user/analysts. The Workshop report summarized the issues raised in the discussion as follows:

The call for better documentation was repeated by nearly every speaker. The existence, timeliness, completeness, readability, dissemination, and purposes of most documentation were challenged or criticized by the workshop participants. The importance of a comprehensible documentation was emphasized to the degree of producing a proposal that the function of the Forum is to read and translate detailed model documentations. However, the sanctity of belief in good documentation was challenged by counter charges that current documentation is not read. There is no financial support for documentation preparation because, despite the rhetoric, users are not interested in having or reading documentation. When combined with the problems of disseminating proprietary information or defining good documentation, there is evidence of a major issue which deserves further discussion in the profession [8, p. III-5].

The need for "further discussions" was emphasized further by the unprecedented congressional attention to the documentation of the FEA Project Independence Evaluation System (PIES) expressed in Section 113 of the Energy Conservation and Production Act of 1976 in which "full and complete" structural, parametric and operating documentation was required to be produced for the model. Further the Congress created the

*This material draws heavily on [43].
Professional Audit Review Team (PART) for the purpose of auditing EIA (and predecessor agency) activities [2]. The first PART report was most critical in comments relating to documentation of EIA models. Thus,

...the credibility of OEIA's [now Energy Information Administration] models has not been established because documentation, verification, and validation have been neglected. Furthermore, publications describing the current models are scarce, and procedures for public access to them are almost nonexistent. As a result, it is practically impossible for interested parties outside FEA [now part of the Department of Energy] to know whether OEIA's current models have been constructed properly and used correctly and thus whether OEIA's analytical products and forecasts can be used with confidence [26]

The EIA has responded to the concerns of the Congress and the PART in a variety of ways. For example, an Office of Analysis Oversight and Access (OAOA) has been organized to develop, implement and monitor operational procedures for internal management and control of model development, documentation, and application. Among its activities, OAOA has formulated and implemented a set of "Interim Model Documentation Standards" [24] to be applied to all new EIA-sponsored modeling efforts. The EIA standards include five types of documents as follows:

1. **Model Summary**: A short, one to two page, nontechnical description of the model. These summaries describe the model's role and usefulness in DOE analyses, its general structure including inputs needed and answers produced, its relationship to other models, and finally the status of any ongoing enhancements or model development. These summaries would be used to provide general information about the modeling activities of EIA.

2. **Methodology Description**: This constitutes a detailed description of a model's rationale, precedent for the model in the literature, and comparison to other similar models or approaches. This level of documentation details the capabilities of the model as well as its assumptions and limitations. The basic purpose of this documentation is to explain why the model structure chosen was selected and to communicate how the model compares to, and was chosen over, alternatives.
3. Model Description: A statement of the equations and other procedures which constitute the formal model structure, a description of the data and other information utilized in developing the model structure, statistical characteristics of estimated portions of the model and any other information necessary to an understanding of what the model is and how results derived from the model are obtained.

4. Guide to Model Applications: A nontechnical description of how to use a model for analysis or forecasting, how to specify alternative input assumptions and data, and how to interpret model output. The purpose of this documentation category is to communicate the range of issues the model is designed to address and the limitations of the model. The intended audience are those who would use model results.

5. User's Guide: This constitutes a detailed description of a model's operating procedures including names and locations of input files and computer programs, naming conventions, and required job control statements. These documents are intended for the use of EIA staff who actually operate the model on the computer and should enable an informed staff member to make model runs and label his input files and output files, so that subsequent users will be able to properly identify the files. An annotated listing of the computer program should be an appendix to the operating documentation. This documentation category will require frequent revision to be kept current.

The current interim standards are under review and evaluation by OAOA. In April, 1979 a workshop of EIA contractors working in the area of model assessment was held to discuss the effective standards for policy model documentation.* As a result a revised and much more detailed set of documentation standards, based largely on the proposals of Gass [18], is being considered by OAOA [23]. Thus, the description of the model development process and the generic document types necessary to record that process provide the framework for developing and implementing a documentation plan for a specific model, a plan which reflects

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*Organizations participating in the workshop included Argonne National Laboratory Energy Software Center, Idaho National Energy Laboratory, Logistics Management Institute, Los Alamos National Laboratory, MIT Energy Laboratory, and National Bureau of Standards.
the interests and legitimate needs, and expectations and perceptions of modelers, the model sponsor(s), and other model clients. We believe the generic framework provided by Gass should be employed by EIA in the analysis of model documentation requirements. In the remainder of this section we consider the obstructions to developing and implementing a documentation plan, and the factors to be considered in the planning process.

2.3.2 Guidelines for Planning Policy Model Documentation

The document types and general contents included in the EIA interim standards and the more detailed classification by Gass [18] provide a framework and checklist for documentation planning. The details of a plan for any particular policy model will depend upon a variety of factors dictating the particular document types required, their extent, format, and style, and their costs (both financial and skills), consistent with the legitimate needs of the model clients. The objective of the documentation planning process is to ensure the systematic evaluation of these factors, and to effectively communicate the results so that model clients (including the modeler and model sponsor) share common expectations about the outcome, and so that sufficient resources are devoted to satisfying documentation needs.

Table 6 summarizes the factors to be considered in the documentation planning process. We distinguish the model development from its application environment. Analysis of the model development environment will be most influential in determining the extent of technical documentation required. A policy model based upon new scientific results, concepts, or methods, will require more comprehensive
TABLE 6. Factors for Consideration in the Preparation of a Documentation Needs Analysis

**Environment for Model Development**
- Importance and scope of policy issues to be modeled.
- Diversity of potentially affected policy constituencies
- Potential contribution to state of the art.
- Role of model sponsor in the policy process.

**Environment for Model Use**
- Kinds of potential users and their needs
  - Scientific peers, other policy modelers
  - Policy analysts/users
  - Operators
  - Other groups concerned about the policy issue(s) under analysis
  - Sponsoring agency
    - model development sponsor
    - application client
  - Decision makers
- Potential Logistics of Model Use
  - Hardware and software requirements
  - Proprietary software or data considerations
  - Need for portability: potential users
    - modeler only
    - single nonmodeler user at one site
    - many nonmodeler users at many sites
- Probable end uses of model
  - Specific to one application; specific problem-solving
  - Foundation for broad policy decisions
  - Forecasting many interrelated results
documentation than a model based upon well-established scientific results. Likewise the more important and conflicted the policy issues under consideration, the greater the need for extensive technical documentation which motivates and describes the modeling approach, the scientific results employed, and the associated data used to implement the model. While the fundamental criterion for technical documentation is to ensure the understanding of peers, and possible replication of model implementation and model-based results, importance of issues and/or novelty of scientific basis may dictate efforts beyond this minimum level in order to establish model credibility.

The application environment for a policy model also influences the documentation plan. Important factors to consider include the needs of the different model clients, the potential uses of the model, and the logistics of model use. Distinguishing the legitimate documentation requirements of the different clients for a policy model and for model-based analysis is perhaps the single most important factor in the documentation planning process. Clearly a nontechnically oriented decision maker will have a different set of needs than a policy analyst, a computer operator, or a scientific peer from the modeling community.

Potential model clients often overlooked in discussions of model documentation requirements are groups who have a vested interest in the policy issue under analysis. Technical documentation, users' guides, and well-documented studies will partially satisfy the needs of such groups depending upon their analytic abilities. Planning for public access to the model may also help in meeting their concerns; the EIA project to transfer important models to the Argonne Software Center is a good example. But many groups will not have the analytical ability and/or
resources to take advantage of such documentation or public access. When the importance of the users and the role of the model sponsor warrant it, more must be done to satisfy such groups that the models and model-based analyses are not "black boxes of predetermined results." Model sponsor support of peer review and evaluation of policy models and model-based studies with presentation aimed at both technical and nontechnical audiences is one way to deal with the legitimate concerns of this group.

A second major set of model characteristics affecting the need for documentation is that of the logistical requirements of the model design plan for use. As Table 6 indicates, such factors include data, hardware and software requirements, as well as consideration of the need for transferring the model. A model which was intended to be run by the developer at only one site might need different forms of documentation than one which was intended to be generally portable to a variety of sites.

Finally, consideration must be given in documentation planning to the kind of model results which will be produced. Has the model been designed to problem-solve in only one application with relatively simple and straightforward results, or will it produce a highly complex set of results that are interrelated in nature, complicated to analyze and apply, and perhaps controversial in terms of policy implications? Clearly, the document types, and their style, format, and content will differ between these two extreme applications.

The systematic planning for documentation requirements will go far to redress the problems of documentation discussed earlier. The minimum acceptable level of documentation, that which will permit full analytical review of the model, will fulfill the most basic needs to justify
scientific acceptability. Further documentation, as determined through the analysis, will fulfill the needs of analyst/users, operators and other model clients. Advance planning will contribute to understanding and common expectations among modelers, model sponsors, and other model clients. In short, a documentation planning process will lead to a more orderly, thorough and competent production of model documentation, and should significantly increase credibility and usability of the model.
2.4 Evaluation of the ICF Documentation of the Coal and Electric Utilities Model (CEUM)

We now turn to an evaluation of the CEUM documentation. Our approach to evaluation is as follows: We first adopted the EIA interim documentation standards as a framework for documentation evaluation. In parallel we obtained from ICF the relevant model documentation, including technical documents, policy study applications, and the computer code. These materials were described in Section 2.2. The computer code represents the version of the model and associated data base as of September 1, 1978, as transferred to EIA by ICF. An important aspect of our effort was to certify that the transfer was complete and correct. This was accomplished by having ICF replicate a base case run using the transferred model, in order to satisfy themselves that the model was properly transferred (see Appendix A).

The next stage was to analyze the model documentation materials and to evaluate them in terms of the EIA categories and our own documentation needs analysis. The outcome of this effort was mixed, since ICF's documentation objectives differed significantly from the EIA categories. In Section 2.4.1 we provide an analysis of the factors which contribute to the ICF approach, and a summary evaluation.

The third stage involved the comparative evaluation of documentation and actual implementation. This analysis is presented in two parts: an analysis of the correspondence between the documentation and the computer implementation for the non-coal supply components of the model (Section 2.4.3); and a more detailed analysis and verification of the computer implementation of the coal supply component of the CEUM (Section 2.4.2). In the process of
this effort we have both augmented existing and developed new technical
documentation (see Appendixes B, C, D, E, and F).

2.4.1 Summary Evaluation and Comparative Documentation Requirements
Analysis for CEUM

A summary evaluation of the ICF CEUM documentation organized by EIA
documentation categories is presented in Table 7. The single most
striking feature of the evaluation is its binary character. When the ICF
objectives correspond to an EIA category, the result is always excellent;
but in several instances, ICF objectives do not include EIA categories,
and so no documentation is available. In the remainder of this section we
consider retrospectively how ICF arrived at its particular view of
documentation requirements.

Recall from Section 2.3.2 the factors important in developing
documentation requirements. They included:

Model Use Environment
- applications, their importance and "conflictedness,"
- model clients,
- logistics of use.

Model Development Environment
- maturity of scientific results being integrated into the model,
  and relation to state of the art,
- role of modeler/model sponsor in the policy process,
- complexity of policy issues.

Through review of the documentation and discussion with ICF
representatives, the ICF perspective on these factors would seem to be as
follows.
<table>
<thead>
<tr>
<th>Document Type and Description *</th>
<th>CEUM Materials</th>
<th>Primary Audience</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Summary: nontechnical descriptions of the model and model applications</td>
<td>Ref. 5, Section I; Various Sections of Ref. 7,8,9,15</td>
<td>Nontechnical</td>
<td>Uniformly excellent discussions of study objectives and results; good descriptions of scenario data and methods of data development; good summary descriptions of model structure; poor or non-existent discussion of rationale and alternatives for key model concepts, and level of resolution required for intended applications.</td>
</tr>
<tr>
<td>Model Methodology: technical description of rationale, precedents, and comparative evaluations with alternative approaches</td>
<td>Ref. 5, Section II and Appendix D</td>
<td>Modelers, Peers, Model users, other Analysts</td>
<td>Good descriptions of modeling approach, but not usually in the &quot;natural language&quot; for peers/other modelers. Very little technical discussion justifying model concepts, approach; almost no comparative discussion of alternative approaches.</td>
</tr>
<tr>
<td>Model Description: presentation of the model sufficient to describe its structure, associated data, and conditions for understanding and interpreting results</td>
<td>Ref. 5, Section III and Appendix E; Ref. 7, Appendix; Ref. 8, Appendix; Ref. 9, Appendix</td>
<td>Analysts performing policy research</td>
<td>Consistently good description of associated data and results; relatively poor documentation of actual model implementation; almost no discussion of results in terms of limitations and approximations used in developing data at resolution required by the model. No adequate complete and detailed technical description of the model is provided. For additions to the technical documentation see Appendixes B,C,D,E, and F of this report.</td>
</tr>
<tr>
<td>Guide to Model Applications: nontechnical description of model, and model applications to support interpretation and use of model-based analyses</td>
<td>Ref. 5, Appendix A</td>
<td>Nontechnical groups, analysts interpreting policy research</td>
<td>A guide to applications is provided for the NCM. However, this is not complete and has not been updated for the CEUM.</td>
</tr>
</tbody>
</table>

*Based on EIA Interim Documentation Guidelines [24].
Intended Applications: The CEUM is intended as an energy policy model for analysis of issues relating to U.S. coal production, conversion, and use. Reference [5, pp. I-1,2] includes the following application areas for the model.

- western coal development,
- Clean Air Act Amendments,
- strip mine reclamation requirements

- Energy Supply and Environmental Conversion Act conversion orders,
- effect of taxes on industry (depletion, investment tax credit),
- effect of changing factor and competing fuel prices,
- effect of changing equipment constraints, both in coal industry and in coal-using industry (e.g., utilities),
- impact of new technologies which use or compete with coal (e.g., synthetic fuels).

Thus the CEUM is intended for use in a wide variety of applications involving the most difficult and conflicted issues regarding the future production and use of coal resources in the U.S.

Model Clients: In understanding ICF's view on this element and its relation to documentation requirements, it is important to distinguish the sponsored model development by FEA from ICF's subsequent company-sponsored efforts. While the FEA-sponsored effort to develop the NCM was intended to be internalized and applied within the FEA policy analysis group, the extension of the NCM into the CEUM was an ICF-sponsored activity intended to provide an analytical capability to support ICF consultants in coal-related policy studies primarily for government clients. The style of the subsequent policy studies confirms this view. Typically, ICF consultants work with a client in structuring
the issue to be analyzed and in developing data and information relevant to that issue. A part of this activity focuses upon structuring scenarios which may be analyzed via application of the model. Specific studies may identify a need to extend the model and/or its associated data base. The end result is an analysis report targeted to the issue of interest to the client using the model, as appropriate, to analyze specific scenarios.

The type and extent of documentation for technical extensions to the model are the result of client perceptions as to what is required to interpret model-based results, as well as what is required to establish the credibility of these results for others considering the study results in a larger policy context. The importance of the CEUM in policy research related to Alternative New Source Performance Standards, as well as in studies of the development of the U.S. coal industry, suggests that the technical documentation is judged acceptable by the clients of these studies.

Logistics of Use: Since the principal clients are interested in model-based results, the model is intended for use only by ICF analysts. Thus, preparation of user and operator guides, beyond that necessary for ICF personnel, is unnecessary.

Maturity of Scientific Basis: Recall from Section 2.2 the evolution of the CEUM. In the first stages ICF consultants were involved in interpreting and transforming data and information from the PIR Coal Task Force into a form usable by PIES. The results were not a formal model so much as a structuring of the data for assimilation in the PIES LP framework. The next phase involved formalization of the data structures into a model for FEA. The working relation between ICF and FEA was very
close, and FEA's intent was primarily to incorporate the results as a PIES submodel. The important concepts such as the model mine concept, were considered mature at least by the ICF/FEA community. The subsequent extension to include the utility submodel and to close the model with respect to non-utility coal demands also employed a well-accepted approach, that being the PIES methodology. The effort to extend the NCM into CEUM involved primarily data revisions and extensions, not structural changes [5, Appendix C, p. 8]. Since the methodology (LP) was straightforward, and the model concepts mature, the need for detailed technical documentation was not thought to have significant value. Thus, in the basic report only 19 pages [5, Section II] are devoted to technical documentation, and all of this is descriptive of the model or of its potential applications. Almost none of the material may be interpreted as presenting scientific evidence which justifies and/or supports the choice of the LP formulation or the particular concepts and methods employed in the model.

Role of Modeler/Model Sponsor in Policy Process: The CEUM is clearly intended by ICF for use in support of their contract policy research for both government and private clients. ICF's self image is as a consultant to the community of those concerned with a particular issue, not as the agent for one or another of the various constituencies of that community. The relevant professional standards are to determine if the concerns of the potential client can be served by the consultant and, if so, to provide as complete and objective an analysis as possible consistent with the client's requirements and the consultant's perceptions as to what is necessary to understand and interpret his/her analysis. Given the maturity and relatively simplicity of the model
methodology and concepts, ICF has interpreted good professional practice to mean careful attention to model data, and especially to the data associated with the client-oriented scenarios.

This analysis of key factors influencing the ICF perspective suggests that ICF's documentation objectives were as follows.

- The most important documentation objective is to describe the model and associated data in a format designed to facilitate general understanding by study clients, as well as interpretation of specific studies and applications.

- Technical documentation of the scientific basis for the model, as contrasted with model description, is relatively unimportant since
  -- the methodology and basic concepts are relatively simple and widely understood,
  -- study clients do not need or require such documentation.

- The model is intended for use by ICF analysts and operators, not for transfer to other groups. Hence operator and user guides need only satisfy the requirements of good internal management and practice.

With this understanding of the ICF documentation objectives, the reader should now be able to interpret the evaluation of CEUM documentation presented in Table 7. In general we find the documentation to be excellent in terms of describing the model and model studies. There is little effort to justify the scientific basis for the model. Thus,

"Even though the structural approach taken in the NCM is conceptually simple and straightforward, the NCM may appear complex. The model's apparent complexity is a result of the large number of options and fine level of resolution built into the model's design...

"...the NCM design is based upon a series of engineering cost relationships and production functions. This attribute allows the components of the model to be easily understood, easily checked, and easily revised." [5, p. II-18]

"The basic NCM structure is conceptually straightforward in that a supply component via a transportation network provides coal to satisfy the demand from both utility and non-utility consumers at least cost." [5, p. II-1]
As noted above we feel such scientific documentation is essential for any policy model, and so disagree with ICF's excluding it. The argument that clients do not require, or value, such documentation clearly is relevant—especially for a commercial model developer—but good professional and scientific practice should dictate the preparation of such documentation independent of the model application environment.
2.4.2 Verification of the CEUM Supply Code*

A discussion of errors, proposed corrections, programming improvements, questionable assumptions, and aspects for user awareness in the CEUM Supply Code (consisting of the SUPIN and RAMC files) is given below. The points discussed can roughly be broken down into the following categories:

A. Errors: Points 1, 5, 6a, 7, 8, 10, 14, 18, 19, 20, 21, 22.

B. Aspects of the code of which the user should be aware:
   Points 3, 4, 6b, 11, 15, 16, 17, 25, 26, 27.

C. Questionable Assumptions: Points 2, 9, 12, 13.


The most substantive errors are those discussed in points 5, 6a, 7, 8, 10, 14, 18, and 20. The reader should note that the order in which points are presented has significance only in that the material is contextually related. For the aid of the reader, points relating to errors are denoted by an asterisk. Also, the referenced line numbers, from our versions of SUPIN and RAMC, are based on the consecutive numbering of all lines (including comment lines) by tens. These line numbers may not match precisely with the line numbers appearing in other versions of the code.

*This material also appears in [50].
1.* On the first page of SUPIN, lines 15-16, global values of 0.1 are given to the parameters ISR (Illegal Surface Reserve Fraction) and IDR (Inaccessible Deep Reserve Fraction). In the RAMC code the values of ISR and IDR in SUPIN are assigned to B(21) and B(1) respectively (see RAMC, line 219). For regional use, the values of vector B are assigned to vector C (RAMC, line 352). Then, whenever there is a regional override for values of ISR and/or IDR, the new values are placed in C(1) and C(21), respectively (RAMC, lines 500-509 and 37-40). -- Note the curious interchange. -- Furthermore, the Equivalence statement on line 54 of RAMC verifies not only that the regional values of ISR and IDR (ISRR and IDRR) are in C(1) and C(2), respectively, but that the global values, ISRG, and IDRG, are in B(1) and B(21), respectively. This is in direct opposition to the manner in which the parameters are first read into RAMC, as mentioned above. Note that there are no resulting errors only because the initial global values of ISR and IDR in SUPIN are equal. The simplest correction would be to interchange lines 15 and 16 of SUPIN.

2. The user should note that the total base-year values of deferred capital (not present-valued) for surface and deep mines, given on line 14 of SUPIN, are for a mine lifetime of 20 years. These values are extrapolated for shorter or longer mine lifetimes in the Mine Costing Subroutine of RAMC, lines 1574-1580. No rationale is given for the manner in which the extrapolations are made. Of particular interest is why deferred capital is assumed to be zero for mine lifetimes of 10 years or less. Also, the non-operational comment on line 1577 which assumes a maximum lifetime of 30 years, should be deleted.
3. The user should be aware that the Annuity Price Factor, APFAC, exogenously specified as 16.748 in SUPIN, line 28, is both a function of mine lifetime and the real utility discount rate.

Recall that:

\[ APFAC = \sum_{i=1}^{N} \frac{1}{(1+k_u)^i} = k_u^{-1} \left[ 1 - (1+k_u)^{-N} \right] \]  

(1)

where: 
\[ 1 + k_u = \frac{(1+k_u)}{(1+g)} \]
\[ g = \text{inflation rate} = .055 \]
\[ k_u = \text{utility's after-tax nominal cost of capital} \]
\[ \text{(defined as RUT in RAMC)} = .10 \]
\[ K_u = \text{utility's after-tax real cost of capital} = .04265 \]
\[ N = \text{mine lifetime} \]

For \( N = 30 \), \( APFAC = 16.748 \).
For \( N = 20 \), \( APFAC = 13.276 \).
For \( N = 40 \), \( APFAC = 19.305 \). Etc.

After we discussed this point with Phil Childress of DOE, he internalized the calculation of APFAC in the DOE version of the CEUM. The version of the code that Michael Wagner of ICF certified for M.I.T. does not have APFAC internalized.

4. In general, the user should be aware that almost all of the global parameter values given at the beginning of the SUPIN file (see lines 15-26 and 29-32) can be overridden in regional data (e.g., see lines 48-49). It appears that the utility discount rate, RUT, and the annuity price factor, APFAC, cannot be overridden regionally because of their effect on the fixed charge rate used by utilities.
5.* In Memo 0, Appendix E of the CEUM Documentation [5], cleaning costs for bituminous coals, in dollars per clean ton, are defined as follows:

<table>
<thead>
<tr>
<th></th>
<th>Fixed Cost</th>
<th>Variable Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Cleaning</td>
<td>1.14</td>
<td>0.56</td>
</tr>
<tr>
<td>Deep Cleaning</td>
<td>2.03</td>
<td>1.67</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3.17</strong></td>
<td><strong>2.23</strong></td>
</tr>
</tbody>
</table>

The cleaning costs given in SUPIN and employed in RAMC should relate only to the basic cleaning of bituminous coals. Deep cleaning costs occur in the LP (only for C and E sulfur level coals) as the objective function coefficients for the deep-cleaning variables. The cleaning costs specified in SUPIN for ZA, ZB, ZC, ZD, and ZE coals are total costs including deep-cleaning and should not include the deep cleaning component.

We have learned that ICF believes that all metallurgical coals should be deep-cleaned and this was their reason for adding deep-cleaning charges in SUPIN, as described above. In addition to the fact that there has been no documentation of this change, it appears that there have been errors made in implementing it. On page III-108 of the CEUM Documentation [5] it is stated that 70% of metallurgical coal is drawn from the ZA, ZB, ZC, or ZD coal types while the remaining 30% is drawn from a blend of ZF, HF, and MF coal types. By simply adding deep-cleaning charges in SUPIN for the ZA, ZB, ZC, ZD, and ZE coal types (and thereby claiming that all metallurgical is now deep-cleaned) several problems result:

- double counting of deep-cleaning costs occurs whenever a ZC or ZE coal type is deep-cleaned in the LP,
- deep-cleaning is not charged for the required percentage of ZF
coal (it is charged only for those ZE coals not deep-cleaned in the LP), and

- there is no allowance for deep-cleaning the percentage of HF and MF coals used to meet metallurgical coal demand.

It is also curious that in addition to increasing the cleaning costs for ZA through ZE coals in SUPIN, ICF has lowered the YIELD factors (both surface and deep) for ZA through ZD coals but not for ZE coals.

In our corrected version of the CEUM, we have decided to omit all exogenously imposed deep-cleaning charges for ZA through ZE coals in SUPIN, thereby allowing deep-cleaning to occur only via the LP, as was originally intended. While it may well be true that without ICF's adjustment not enough deep-cleaning of metallurgical coals occurs in the CEUM, the method that ICF chose to remedy the situation is inconsistent and incorrect, and at best represents only a crude approximate approach to modeling the deep cleaning of all metallurgical coals.

6.(a)* The factor used to escalate the average 1975 base-year price data for existing mines to the case year, 1985, is incorrect. The calculation is made on lines 360-367 of RAMC. A derivation of the correct escalator follows.

Let:

\[
P_{1975} = \text{given average 1975 price for an existing mine (includes a capital component)}
\]

\[
f_L = \text{fraction of } P_{1975} \text{ relating to labor costs} = .32
\]

\[
f_S = \text{fraction of } P_{1975} \text{ relating to supplies} = .53
\]

\[
f_C = \text{fraction of } P_{1975} \text{ relating to capital} = .15
\]

\[
g_L = \text{total nominal escalation rate for labor costs} = .065
\]

\[
g = \text{general inflation rate} = \text{total nominal escalation rate for supplies} = .055
\]
\[ P^*_{1975} = \text{variable cost component of } P_{1975} \]
\[ = (1-f_C) P_{1975} = (f_L + f_S) P_{1975} \]

\[ P^*_{1985} = 1985 \text{ price for an existing mine due to variable costs only} \]

\[ E = \text{escalator of interest} = \frac{P^*_{1985}}{P_{1975}} \]

Note that only variable costs for existing mines are subject to inflation.

It can easily be shown that:

\[ P^*_{1985} = \frac{f_L}{f_L + f_S} P^*_{1975} (1+g_L)^{10} + \frac{f_S}{f_L + f_S} P^*_{1975} (1+g)^{10} \]

\[ = \frac{P^*_{1975}}{f_L + f_S} \left[ f_L(1+g_L)^{10} + f_S(1+g)^{10} \right]. \quad (2) \]

We then have:

\[ \frac{P^*_{1985}}{P_{1975}} = E = f_L (1 + g_L)^{10} + f_S (1 + g)^{10} \quad (3) \]

With the values given above, \( E = 1.506 \). In RAMC the escalator is called ESCAL1 and is given by (see RAMC, lines 364-365):

\[ \text{ESCAL1} = [1 + (f_L g_L + f_S g)]^{10} = 1.628 \quad (4) \]

ESCAL1 is incorrect and gives a value that is too high by 8.1%.

(b) A further correction of the escalator \( E \) may be necessary. As discussed below (Point 7), it appears that base year costs for new mines are in 'end of 1975 dollars', and the real annuity coal prices in RAMC output are in 'end of 1984 dollars'. If the \( P_{1975} \) prices for existing mines are also in 'end of 1975 dollars' then the exponent used in the above calculation of \( E \) should be 9 instead of 10. If the \( P_{1975} \) prices are in 'end of 1974 dollars' or in 'beginning of 1975 dollars', then the exponent of 10 used in calculating \( E \) is correct. We believe that the latter statement is true, so the exponent used in Equation (3) is correct.
7.* Recall the following facts from the CEUM Documentation [5]:

(a) Initial capital is inflated at the nominal capital escalation rate from the base year, 1975, to eight months before the case year, 1985.

(b) Deferred capital, labor, and power and supplies are each escalated, using the appropriate rate, to the end of the year in which the money is considered spent (i.e., all cash expenses occur at the end of the year).

It can be verified from the Mine Costing Subroutine of RAMC (lines 1635 to 1719) that if real annuity coal prices (RACP) are calculated in 'end of 1984 dollars' then base-year mine costs must be in 'end of 1975 dollars'. If the RACPs for the 1985 case-year projection are considered to be in 'early 1985 dollars' (i.e., as of 1/1/85), then the base-year mine costs must be in 'early 1976 dollars' (not in 1975 dollars). If the base-year mine costs are truly meant to be given in 'end of 1974 dollars' or in 'early 1975 dollars' then the following corrections must be made in the Mine Costing Subroutine in order to calculate the RACPs in 'end of 1984 dollars' or in 'early 1985 dollars', respectively:

(a) In lines 1641 and 1664, LL = JJ + NYR instead of LL = JJ + NYR - 1.

(b) The exponent in line 1649 should be (NYR - 2./3.) instead of (NYR - 5./3.).

(c) The exponent in line 1689 should be (NYR + 1) instead of NYR.

Note that this point is currently under active consideration by DOE personnel.

Even if we assume that base-year mine costs are indeed given in 'end of 1975 dollars', there are other errors and questionable assumptions related to the calculation of real annuity coal prices in the Mine Costing Subroutine (lines 1635-1719 of RAMC). -- See Points 8 through 21.
8.* By assuming that all initial capital is sunk (spent) at the end of April 1984, ICF is crudely approximating a stream of initial capital expenditures over time, together with the explicit use of 'interest during construction' at the nominal cost of capital for coal producers, as a means of summing these fractional expenditures. While ICF's approximation clearly simplifies the accounting of initial capital, the approximation is poor and its derivation is not documented. We believe that it is necessary to further escalate the sunk value of initial capital by eight months to the end of 1984 before it can appropriately be added to the present value of deferred capital as of 12/31/84 (for the purpose of calculating cash flow), i.e., initial capital and the present value of deferred capital must be in equivalent dollars before they can be added. For simplicity we implemented the required additional escalation using the general rate of inflation although, as seen from our formal discussion of how initial capital costs should have been treated in the CEUM (given below), the appropriate rate is the nominal cost of capital for coal producers. (Although we resolved this issue too late for the most appropriate correction to be implemented in our corrected version of the CEUM code, our approximation is more accurate than ICF's, as seen below.) Note that while both ICF and DOE personnel disagree with the need for any correction, there is no documentation or other evidence available to support the validity of their argument. A description of our implementation of the correction is as follows:

(a) After initial capital is escalated at the nominal escalation rate for capital, ECAP, to the end of April 1984 (eight months prior to the case year, 1985) and before the result is added to the present value
of deferred capital as of the end of 1984 (i.e., 12/31/84), it must be escalated eight months at a rate we chose to be the general inflation rate. (Note that the appropriate rate is ROR, the nominal cost of capital for coal producers--see the formal treatment of initial capital costs given below.) A general GNP deflator is not defined in RAMC, but the cost of power and supplies escalates at the general inflation rate and its escalator, EPAS, can be used as a proxy for this rate. The correction for the escalation of initial capital can thereby be made as follows in line 1649 of RAMC:

\[ Y(1,1) = IC\times((1 + ECAP)^{NYR - 5./3.})\times((1 + EPAS)^{2./3.}) \]  

(5)

The effect is a 3.6% increase in \( Y(1,1) \). Note that \( Y(1,JJ) \) has been set equal to \( Y(1,1) \), and with \( NYR = 10 \) the total number of years of escalation is 9, i.e., from the end of 1975 to the end of 1984. It can also be shown, from lines 1650-1654, that deferred capital in base year dollars is first escalated 9 years to the end of 1984 and then the spending of deferred capital over the mine lifetime (starting at the end of 1985) is present-valued to the end of 1984, i.e., 12/31/84.

(b) Because of our change in the calculation of escalated initial capital (Equation (5) above), an adjustment is required in the calculation of the annual depreciation charge (total nominal capital costs divided by the mine lifetime). Line 1680 of RAMC should now read:

\[ Y(21,JJ) = (Y(6,MYR) + (Y(1,1)/((1+EPAS)^{2./3.}))))/MYR \]  

(5a)

rather than

\[ Y(21,JJ) = (Y(6,MYR) + Y(1,1))/MYR \]
Formal Treatment of Initial Capital Costs

Let:

$g = \text{general rate of inflation} = 0.055$

$g_c = \text{nominal escalation rate in coal mine capital costs (} g_c \text{ is denoted by ECAP in the CEUM)} = 0.060$

$k_p = \text{nominal after-tax cost of capital for coal producers (} k_p \text{ is denoted by ROR in the CEUM)} = 0.150$

$IC_{75} = \text{initial capital cost in base year (beginning-1975) dollars}$

$IC_t = \text{initial capital spent at end of year } t, \text{ in current year dollars}$

$f_t = \text{fraction of initial capital spent at end of year } t$

$PV_{IC} = \text{present value of initial capital costs in case year dollars (as of the end of 1984)}$

Following the convention that all expenditures occur at the end of the year, it can easily be shown that:

$IC_t = IC_{75} (1 + g_c)^t f_t$, and

$PV_{IC} = \sum_{t=1}^{10} IC_t (1 + k_p)^{10-t} = IC_{75} \sum_{t=1}^{10} (1 + g_c)^t (1 + k_p)^{10-t} f_t . \tag{5b}$

We now illustrate calculations of $PV_{IC}$ in terms of $IC_{75}$, using three different assumptions for the fractions $f_t$, and the parameter values of $g_c$, $k_p$, and $g$ given above. The third case represents the assumption made by ICF.

(a) Assume equal initial capital expenditures in each year, i.e.,

$f_t = 0.10 \text{ for } t = 1, \ldots, 10.$ Using Equation (5b) we have:

$PV_{IC} = IC_{75} (2.656)$.

(b) Assume all initial capital is spent at the end of 1984, i.e., $f_t = 0$ for $t = 1, \ldots, 9$ and $f_t = 1$ for $t = 10$. This case results in the lowest possible value of $PV_{IC}$, and using Equation (5b) we have:
(c) Assume all initial capital is spent at the end of April 1984. This case represents the assumption made by ICF. Note that there is no documentation available to support the intent or validity of this assumption. Using the logic of Equation (5b) we have:

\[ PV_{IC} = IC_{75} (1 + g_c)^{9+1/3} (1 + k_p)^{2/3} = IC_{75} (1.8908) . \]

The expression used by ICF is a poor approximation given by:

\[ PV_{IC} = IC_{75} (1 + g_c)^{9+1/3} = IC_{75} (1.7226) . \]

The correction implemented by M.I.T. is given by:

\[ PV_{IC} = IC_{75} (1 + g_c)^{9+1/3} (1 + g)^{2/3} = IC_{75} (1.7852) . \]

While our multiplier understates the true value by 5.6%. ICF's multiplier understates it by 8.9%. To implement the appropriate multiplier in the CEUM code, EPAS should be replaced by ROR in Equations (5) and (5a) given above.

Finally, it should be noted that the overall effect on CEUM output of the correction discussed in this point is small.

9. There is a question concerning the way in which two factors entering into the calculation of operating costs in the base year are escalated over time. The two factors are Royalty fees and Licensing fees, each specified on a dollar-per-clean-ton basis. They are both escalated over the mine lifetime using the nominal escalation rate for capital, ECAP (see lines 1672-1673). Why are these factors not simply escalated at the general inflation rate (using EPAS as a proxy)? While the intent could well have been to have these factors escalate somewhat faster than inflation (i.e., at a rate equal to ECAP), no justification is given.
It should be noted that a Licensing fee of $.10 per clean ton is charged in all regions and that all Royalty fees in the data base have been set to zero. Federal Royalties, applying to coal mined on Federal Lands, have now been included and are treated, like regional Severance Tax Rates, as a percentage charge on sales. The Royalty charge is 12.5% for surface coal and 8% for deep coal; it occurs only in the following regions: North Dakota, Eastern and Western Montana, Wyoming, Colorado South, Colorado North, and New Mexico.

The full Federal Royalty is applied to all coal from these regions even though, as stated in Memo N, Appendix E of the CEUM Documentation [5], less than 100% of the coal-bearing land is Federally owned. ICF's argument is that Federal reserves are such a large percentage of the total that they will set the price. This may be true for all the relevant regions except North Dakota, where only 25% of the reserves are Federally owned. In the other regions more than 50% of the coal lands are Federal.

10.* Property Taxes and Insurance, another factor entering into the calculation of operating costs, has been escalated incorrectly over the mine lifetime. Assuming that this factor, calculated as a percentage of initial capital costs, escalates with the nominal capital escalation rate, line 1676 of RAMC should read:

\[ Y(20, JJ) = .02*(Y(1,1)/((1+EPAS)**(2./3.))*(1+ECAP)**(JJ+2./3.) \] (6)

rather than

\[ Y(20, JJ) = .02*Y(1,JJ)*(1+ECAP)**LL \] (7)

Note that the correction for \( Y(1,JJ) \) should be made as noted in Equation (5) (see Point 8) and that \( JJ = 1,2,\ldots,MYR \) and \( LL = JJ+9 \), where
MYR = Mine Lifetime. The effect of the correction is a 38.5% decrease in the taxes and insurance charge for each year of the mine lifetime. Note that if Equation (7) is incorrectly used, there effectively will be a double counting of the number of years between the base year and the case year. (Referring to the discussion at the end of Point 8: we have become convinced that the most appropriate correction to Equation (7), which we ultimately formulated too late to be implemented in our corrected version of the CEUM code, is given by Equation (6) with EPAS replaced by ROR; however, the expression used in Equation (6) above gives results much closer to the appropriate values of Y(20,JJ) than does Equation (7) used by ICF.)

There is also a question concerning the rationale for using the capital escalation rate for property taxes and insurance. One argument, at least concerning insurance, is that the expenses incurred over the mine lifetime should cover the mine's replacement value.

11. The fixed (capital) components of both Reclamation and Cleaning Costs, escalated from the base year to the end of 1985, are added (in addition to the variable components) to operating costs in every year of a mine's lifetime (see lines 1689-1690 of RAMC). Apparently, this implies that the fixed charges must have been pre-annualized over mine lifetime and have been calculated, or are assumed, to be constant in nominal terms (constant in current dollars per clean ton per year) starting at the end of 1985. Such a procedure used to arrive at these data inputs has not been documented.
12. For each region in which Severance Taxes are non-zero, either a Severance Tax Rate (SEVTR) as a percentage of sales or a Severance Tax in base-year dollars per clean ton (SEVT$) is charged. The user should be aware that the RAMC code does not allow for the escalation of SEVT$ in the calculation of sales for each year of a mine's lifetime. It thereby assumes that SEVT$ is constant in nominal terms. If we were to assume that SEVT$ escalates at the general inflation rate (i.e., SEVT$ constant in real terms), then we would again use EPAS as a proxy for this rate, and replace SEVT$ by SEVT$(1+EPAS)**LL in lines 1696, 1698, 1701, and 1702. Note that if SEVTR is used, the tax escalates with sales over time. Clearly, the allowance for a severance tax charge remaining constant in nominal terms could well have been intentional.

13. It should be noted that insurance charges for Black Lung Disease in base-year dollars per clean ton are assumed constant in nominal terms (i.e., are not escalated over time). See line 1691 of RAMC. It appears that Federal law does not provide for escalation of these charges.

There is also another add-on charge, AMR, given in base-year dollars per clean ton and assumed constant in nominal terms (see line 1691). This charge, defined in the CEUM case study application [8], is an abandoned mine reclamation tax mandated by Federal law.

14.* For both deep mines and surface mines, there is a question concerning the units of the input measure of tons per man-day (TPMD). Are they given in raw tons or in clean tons? If, as we strongly suspect, they are meant to be given in raw tons per man-day, then the calculation of base-year Union Welfare Costs has incorrectly used the YIELD factor. Line 1592 of RAMC should read:
\[ B(16, KK) = 1000 \times SZ \times (WEL \times YIELD + \frac{WPD}{TPMD}) \quad (8) \]

rather than
\[ B(16, KK) = 1000 \times SZ \times (WEL + \frac{WPD}{TPMD}) \times YIELD \quad (9) \]

If the data inputs for TPMD are given in clean tons per man-day, then:

(a) in the equations for the associated cost adjustment factors (lines 1561 and 1796, for surface and deep mines, respectively) mine size, SZ, must be multiplied by the YIELD factor; and

(b) in the equations calculating base-year labor costs (lines 1562 and 1799, for surface and deep mines, respectively) SZ must be multiplied by the YIELD factor.

Furthermore, although never stated in the code, the data inputs for reclamation costs, cleaning costs, royalty fees, licensing fees, and the union welfare costs per ton, must all be given in base-year dollars per clean ton according to their use in the Mine Costing Subroutine.

15. A Dimension statement in the Mine Costing Subroutine (line 1419 of RAMC) assumes a maximum mine lifetime of 30 years by dimensioning \( Y(23, 30) \) and \( DCFRAC(30) \). The \( Y \) matrix contains cost factors for each year of a mine's lifetime and \( DCFRAC \) is a vector defining fractions of deferred capital to be spent over the lifetime of each mine. Clearly, if mine lifetimes greater than 30 years are to be considered, the Dimension statement must be changed.
16. A confusing aspect of the Mine Costing Subroutine is that in parts it relates to the code used for the old PIES Coal Supply Analysis, with calculations of minimum acceptable selling prices (MASP) for only the first year of mines. Although never stated, it should be made clear that these prices (case-year MASP in base-year dollars, not annuitized over mine lifetime--see line 1629 of RAMC) are calculated under the assumptions of no inflation and no real escalation, and thereby the code must incorrectly assume that the coal producer's discount rate, ROR, is given in real terms. An example of this confusion is the use of the present value factor PVFAC (calculated in Subroutine PRVAL for use in Subroutine MC) for the present-valuing of deferred capital. The calculation of PVFAC ignores inflation, real capital escalation, and uses the nominal discount rate, ROR. Clearly, in an older version of the code, ROR was real and calculations were in constant dollars with no real escalation.

Now, to be fair, PVFAC and the MASP are never used in the calculation of the real annuity coal prices (RACP) for each mine type. However, their unexplained presence in the code is misleading and can only lead to confusion. Such code should be omitted.

17. There are still other portions of the RAMC code (not only in the Mine Costing Subroutine) that appear to relate either to old PIES calculations or to early versions of the supply component of the CEUM. A prime example is the calculation and use of two factors, COEF1 and COEF2. These factors are calculated early in the main program of RAMC as follows:
COEF1 = (1+ECAP)**(10./2.), and  
(10)  
COEF2 = (10./40.)*(1+ECAP)**(10./4.)  
(11)

COEF1 and COEF2 next appear at the end of the Mine Costing Subroutine after the calculations of the real annuity coal prices (RACP). They are suddenly used, in the creation of output, as escalators for the base-year values of initial and deferred capital divided by the annual output for each mine type (see RAMC, lines 1870 and 1893). The resulting values of SCAP and DCAP, for surface-mine and deep-mine types, respectively, appear in the RAMC output under column CAPL.

The first escalator, COEF1, appears to relate to an old definition of the point at which initial capital is assumed sunk (an updated definition is now used in the calculation of the RACP--see Point 8 above). There is no reasonable explanation of the second escalator.

At any rate, the output appearing under the column CAPL has an unclear meaning, is misleading, has no direct relationship to the production and price (RACP) output, and should be deleted.

18.* At the beginning of the calculations of real annuity coal prices for deep mines, the smallest seam thickness measure is suddenly changed from 28 to 24 inches (see line 1771 of RAMC). Recalling that coal reserves are allocated to seam thickness categories beginning at 28 inches, there can be no justification for this change. Interestingly, the RAMC output continues to display 28 instead of 24 inches as the smallest seam thickness measure used in pricing coal from deep mines (see line 1782 of RAMC). This is misleading. The simplest resolution of this problem is to delete line 1771 of RAMC.
19.* An error has been made in the Mine Costing Subroutine of RAMC by not declaring the variable LAB (1975 labor cost in thousands of dollars per year) as REAL. The default declaration on variable names beginning with I, J, K, L, M, or N is INTEGER. Thus, the fractional component of the labor cost for each mine is inadvertently dropped.

20.* In Subroutine PRVAL of RAMC, the fractions of deferred capital to be spent over a mine's lifetime are calculated and stored in vector DCFRAC. This vector is an important factor in the calculation of Cash Flow and Depreciation within the Mine Costing Subroutine. If careful attention is given to the allocation scheme used to create DCFRAC in Subroutine PRVAL, it can be shown that due to truncations with integer variables when the mine lifetime, MYR, is not perfectly divisible by four, more than 100% of deferred capital is allocated over the life of the mine. (The error is largest when MYR divided by four has a remainder of three, e.g., when MYR = 35.) An amended version of the allocation scheme that remedies this situation is as follows:

After line 1957 of RAMC, in Subroutine PRVAL, insert:

```plaintext
IF ( (MYR-(M75+M99)) .NE. 2) GO TO 120
M50 = M50+1
M75 = M75+1
GO TO 130
120 IF ( (MYR-(M75+M99)) .NE. 3) GO TO 130
M25 = M25+1
M75 = M75+1
M99 = M99+1
130 CONTINUE
```
21.* In Memo I, Appendix E of the July 1977 CEUM Documentation [5], the calculation of two separate UMW Welfare Costs, one in 1975 dollars per clean ton and the other in 1975 dollars per man-day, for both surface and deep mines, is discussed. The Welfare Cost in dollars per man-day is determined to be $1.37 per hour or $10.96 per man-day. This data input, for both surface and deep mines, is correctly displayed on line 25 of SUPIN. Unfortunately, the main program of RAMC reads in values of $10.90 per man-day for this Welfare Cost (for both surface and deep mines) because of an error in the associated FORMAT statement, number 8010, on line 1013 of RAMC. A FORMAT of F4.2 is used instead of F5.2. Line 1013 of RAMC should read:

\[
\text{T30,F4.2,2(,/T23,F5.2,T50,F5.2),/T15,F4.2,/,T27,F6.3,}
\]

rather than

\[
\text{T30,F4.2,2(,/T23,F4.2,T50,F4.2),/T15,F4.2,/,T27,F6.3,}
\]

We note that the Welfare cost in dollars per man-day, denoted as WPD in the Mine Costing Subroutine, enters into the calculation of each mine's Operating Cost via lines 1592 and 1671 of RAMC.

It should also be noted that other variables, such as Mine Lifetime, Base Year, and Case Year, are displayed as floating point variables in SUPIN but are read into RAMC as integers. This would only result in errors if fractional values of these variables were specified in SUPIN.

22.* The variable reclamation cost, in base-year dollars per clean ton, for an overburden ratio of 15 in region OK (Oklahoma), is given on line 1308 of SUPIN as 0.30. This value is lower than the values 0.42 and 0.46 given for overburden ratios of 5 and 10, respectively. Since in every other supply region both fixed and variable reclamation costs
increase with overburden ratio, this entry is suspicious and could well have been meant to be 0.50, given the value of 0.52 for an overburden ratio of 20 that follows it.

23. The value of YTD (deep-coal yield in clean tons per raw ton) for ZD coal in region OK (Oklahoma) should most likely be 0.60 instead of 0.70, as given in line 1356 of SUPIN. In every other supply region the value of YTD for ZD coal is given as 0.60. This possible data error has no effect since there are no deep ZD reserves in region OK.

24. There is a minor error in initializing the regional overburden ratio distribution vector on line 337 of RAMC. The Do Loop on I should be from 1 to 7 instead of 1 to 4. This error is innocuous.

25. The user should note that the RAMC code on lines 355-359, creating a distribution over deep-mine size given seam thickness and seam depth, is completely overridden by the code on lines 456-469.

26. Since the counter IK must equal 4 at line 947 of RAMC (see lines 750-752), lines 947-963 of the code can be omitted.

27. The user should be aware that the RAMC supply curve output for coal type UTHB (Utah Bituminous Low Sulfur Coal) is exogenously overridden in the GAMMA REVISE file of the CEUM computer code. The override exogenously resets the production level (supply curve step width) of each new mine type (defined by a particular combination of physical variables) on the UTHB supply curve at twice the value computed
by RAMC. Note that the override refers only to the number of the supply curve step and not to the particular mine type associated with the step. The undocumented reason for this 'patch' seems to be that the LP is infeasible without it.

An important consequence is that whenever a sensitivity analysis run of the CEUM is attempted that requires changes in the Supply Code and therefore, regeneration of all supply curves, the full-model (as opposed to RAMC) supply curve output for UTHB coal will most likely be incorrect and should be ignored. The only situation in which no error occurs—an example is our Corrected Base Case (CBC) model run—would be one in which the number, order, and production levels of the UTHB mine types recomputed by RAMC remain identical to those computed by RAMC in the Base Case or Corrected Base Case. This is unlikely.

Three possible error-producing situations regarding UTHB coal can arise when full-model sensitivity runs involving changes in the Supply Code are attempted.

(a) The number of supply steps generated by RAMC for UTHB coal in the sensitivity run remains the same as in the Base Case (or CBC). If this occurs but the mine-type order and the associated production levels change, then the 'patch' will reset production levels at values equal to twice the Base Case (or CBC) production levels but not equal to twice the new values.

(b) The number of supply steps generated by RAMC for UTHB coal in the sensitivity run is fewer than in the Base Case (or CBC). If this occurs, the model will not run because the 'patch' will try to reset production levels of supply steps that do not exist. Once the relevant supply steps are deleted from the 'patch', the model will run but the
basic problem referred to in (a) remains.

(c) The number of supply steps generated by RAMC for UTHB coal in the sensitivity run is greater than in the Base Case (or CBC). If this occurs, the 'patch' will not reset the production levels of the additional mine types generated in the sensitivity run, and as described in (a) it will also incorrectly reset those production levels in the Base Case (or CBC) that have now changed.

In summary, the UTHB supply curve should be considered invalid for CEUM sensitivity runs involving regeneration of supply curves via changes in the Supply Code.
2.4.3 Verification of Non-Supply Components of the CEUM

The following presents a list of undocumented aspects of non-supply oriented components of the CEUM of which the user should be aware and documented aspects of these parts of the model that have either not been implemented or have been implemented incorrectly by ICF.* The reader should note that the order in which points are presented has no particular significance.

1. We have learned, via communications with ICF personnel, that a most important but undocumented aspect of the CEUM is that real escalation of cost factors is not appropriately accounted for (with one exception) in the 1990 and 1995 case year model runs. The real annuity coal prices calculated in RAMC in 1985 dollars for 1985 case year model runs (see Section 2.4.2 and Appendix E), and later deflated to 1978 dollars for use in the LP, are used without change in the 1990 and 1995 case year model runs. This means that the coal-type supply curves generated in RAMC for 1985 model runs are not regenerated for 1990 and 1995 model runs. The only adjustments relate to depletion of resources for existing (as of 1975) mines. It should be noted that in the calculation of the RACPs for 1985 model runs, real escalation in capital and labor costs is employed over the life of mines beginning in 1985. For the 1990 and 1995 case year model runs, 5 years and 10 years of real escalation are omitted, respectively, prior to mine openings. Therefore, the 1990 and 1995 model runs use cost estimates appropriate only for mines opening in 1985.

*Note that points 1 and 2 in this section concern the entire CEUM and not just the non-supply oriented components of the model.
On the utility side, utility capital costs escalate in real terms only until 1985 (see Point 3 below). The one exception referred to above concerns real rail-rate escalation. A real escalation factor is employed over the entire model horizon but not as a constant percentage per year independent of the case year and not in a manner implied in the documentation (see Point 4 below).

2. In Memo J, Appendix E of the July 1977 CEUM Documentation [5] it is implied that in future applications the model will use a general inflation rate of 6%/yr, replacing the original rate of 5.5%/yr. Upon examination of the CEUM computer code it can be shown that this change has never been implemented and for all applications to date the CEUM has continued to use 5.5%/yr as the general rate of inflation.

3. On page 51 of ICF's first case study for EPA using the CEUM [7], it is stated that utility capital costs escalate at 7.5%/yr through 1985 and at 6.0%/yr thereafter. This statement is not entirely correct. In the CEUM case study applications [7], [8], [9], and [15], utility capital costs escalate at 7.5%/yr until 1985 and at the general rate of inflation, 5.5%/yr thereafter.

4. The version of the CEUM existing as of September 1, 1978 and as applied in ICF's third case study, prepared for EPA and DOE [9], claims to incorporate a real rail-rate escalation factor of 1%/yr over each year of the 1975-95 time horizon of the model. If implemented correctly, transportation costs, after being inflated appropriately from 1975 to 1978 dollars, would be multiplied by: 
Upon examination of the CEUM computer code it can be shown that what the model actually does is apply a transportation multiplier (TCMLT) of $(1.01)^{20} = 1.22019$ for all case year model runs. The implicit effect of such an implementation is that real rail rates escalate at approximately 2%/yr from 1975-85 for a 1985 model run, 1.34%/yr from 1975-90 for a 1990 model run, and 1%/yr from 1975-95 for a 1995 model run.

5. (a) All costs appearing in the LP objective function are in 1978 dollars. In particular, the objective function coefficients of the build activity variables are case year annualized utility capital costs in 1978 dollars per KW-year (or $10^6$/GW-yr), taking into account real capital escalation. The CEUM calculates these costs by first converting exogenously specified 1975 (base year) utility capital costs in 1975 dollars to case year costs in 1978 dollars, as follows:

Let:

Case Year = 1985

$\text{CAP}_{78\$}(85) = 1985 \text{ utility capital cost in 1978 dollars per KW}$

$\text{CAP}_{75\$}(75) = 1975 \text{ utility capital cost in 1975 dollars per KW}$

(exogenously specified)

$g_{uc} = \text{total (nominal) capital escalation rate for utilities}$

(including inflation)

$g = \text{general rate of inflation.}$

We then have:

$$\text{CAP}_{78\$}(85) = \frac{(1 + g_{uc})^{10}}{(1 + g)^7} \text{CAP}_{75\$}(75)$$
Note that both the 1990 and 1995 case year utility capital costs in 1978 dollars per KW are also given by \( \text{CAP}_{78s}(85) \) since utility capital costs escalate at the general rate of inflation after 1985 (see Point 3 above).

The case year costs in 1978 dollars are annualized by multiplying by a real fixed charge rate (FCR). The model uses a real FCR of 10%, except in Eastern and Western Tennessee where a value of 5% is used.

Applying the CEUM values of \( g_{uc} = .075 \) and \( g = .055 \), the annualized utility capital costs are given by:

\[
\text{CAP}_{78s}(85) = (1.4168)(\text{FCR}) \text{CAP}_{75s}(75)
\]

\[
= (0.14168)\text{CAP}_{75s}(75), \text{ outside Tennessee}
\]

\[
= (0.07084)\text{CAP}_{75s}(75), \text{ in Tennessee}.
\]

(b) It has been learned via personal communications with ICF personnel that before plant capital costs are annualized there is a $50/KW add-on charge for hooking up the new plant to the existing local utility grid, i.e., for intermediate or intraregional transmission. Long-distance capital charges for new interregional transmission lines are treated separately.

6. The user should be aware that nuclear plant capacities are exogenously set, by utility region, in both 1985 and 1990. In 1995 the exogenous specification is derived differently. A national nuclear capacity is exogenously set and regional capacities are determined by multiplying each 1990 regional capacity by the ratio of the national 1995 capacity to the national 1990 capacity (the latter value being the sum of the 1990 regional capacities).
One of ICF's apparent reasons for fixing, rather than upper bounding, nuclear capacity is that nuclear plants have lower unit costs than coal plants in almost all utility regions. If nuclear capacity were treated as upper bounded rather than fixed, then examples of extreme "knife-edge" optimization could result if the unit costs of nuclear plants were increased. Other reasons for fixing nuclear capacity include very long construction lead times and political considerations.

7. All hydroelectric costs, both capital and O&M, are excluded in the CEUM except for new pumped storage O&M. The associated activity variables for building hydroelectric plants and operating existing hydroelectric plants thereby have zero cost. It has been learned via personal communications that ICF's justification for excluding these hydroelectric costs is that the costs are relatively small (they would just appear as add-on costs in the objective function) and that all the available capacity will be locked into the model solution. However, upon examination of the model output it can be observed that new hydroelectric capacity is upper bounded, not fixed as with nuclear, and that several utility regions have unused free hydroelectric capacity. Furthermore, in the Montana utility region, new oil/gas turbine capacity is built at a non-zero cost to meet daily peaking demands while free hydroelectric capacity is unused. This is quite strange. Either the LP has not reached a true optimal solution as is claimed or there are undocumented constraints that prevent utilization of Montana's hydroelectric capacity.
8. Distribution costs for the electricity distribution activity variables by utility region are also ignored by the CEUM. The apparent undocumented justification for this omission is that demands for electricity are fixed and distribution costs would be just an add-on to the objective function. Strangely, distribution costs suddenly appear in the CEUM's model output (Table 4 of the CEUM's Small Report)* with no explanation of how they are calculated. We have learned via personal communications with ICF personnel that an add-on distribution charge of $500/KW is used and annualized appropriately by region. From our examination of many model runs, it can be observed that nationally these distribution costs can be between 10 and 15% of total annual utility costs and can vary as much as 30% between runs. Thus it appears that such costs should be included in the objective function coefficients of the electricity distribution activity variables of the LP, rather than being added in an exogenous ex-post fashion at the report-writing stage.

9. The CEUM can set exogenous building limits on coal plant capacity by utility region individually for new NSPS bituminous, subbituminous, and lignite plants and for new ANSPS bituminous, subbituminous, and lignite plants. These build limits are treated as upper bound constraints on the associated build activity variables in the LP. At the same time there can be joint upper bound constraints on total (bituminous + subbituminous + lignite) new NSPS and total new ANSPS coal plant capacity by utility region. It should be noted that the joint upper bounds are not always consistent with the sum of the individual limits (when they all exist) on bituminous, subbituminous, and lignite plant capacity. For regions in

---

*References to CEUM Large and Small reports cite categories of computer output generated by running the model.
which all individual coal plant type build limits are set (for either NSPS or ANSPS plants), there are instances in which the associated joint upper bound is greater than the sum of the individual bounds. This causes no problems so long as it is understood that the sum of the individual limits is the binding constraint. Unfortunately, in Table 8 of the CEUM's Large Report, the total new coal build limits displayed, for the cases of interest, are the sums of the NSPS and the ANSPS joint upper bounds rather than the sums of the individual limits. This can be quite misleading in that the table will show extra unused capacity that could never exist under the given constraints. Furthermore, the user should be aware that in Table 8 of the CEUM's Large Report for case years 1990 and 1995 the build limits displayed are those for case year 1985 and have not been updated appropriately. This is the reason for the frequent appearance of negative unused capacity figures in this table for 1990 and 1995 model runs.

10. Recall from Point 5 that the case year utility capital costs (in base year dollars) take account of the full modeling period's real capital escalation above and beyond inflation. These case year costs are used for making all the base year to case year build decisions. This has the effect of strongly exaggerating impacts of the real escalation rate. A more appropriate approach might be to simulate an averaged effect of accumulated escalation over the modeling period, which could be approximated by reducing by about one-half the real escalation rate imposed.
11. We have learned via communications with ICF personnel that whenever the appropriate partial scrubbing fraction (percentage of the flue-gas scrubbed) is greater than 0.8 but less than 1.0, the model fully scrubs rather than partially scrubs the associated coal. The apparent undocumented justification for this procedure is that the magnitude of the cost savings associated with partially scrubbing such coals is small. ICF has no calculations available to support this claim. For a full discussion of this point see Appendix F.
REFERENCES


AN EVALUATION OF THE COAL AND ELECTRIC UTILITIES MODEL DOCUMENTATION

by

M.I.T. Energy Model Analysis Program
APPENDIXES

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APPENDIX A - LETTER ON CERTIFICATION OF MODEL TRANSFER
Dr. David Wood  
M.I.T. Energy Laboratories  
Massachusetts Institute of Technology  
Cambridge, Massachusetts 02139

Dear Dave:

We believe that the base case equivalence run has been satisfactorily completed. There are three separate model versions relevant to the discussion:

Version A: Used to generate the September EPA case labelled "RF5x";

Version B: Our own copy of the version that we thought had been transmitted to Phil Childress;

Version C: Transmitted from Phil Childress to ICF.

The only difference between Version A and Version B is in the supply curves. We have demonstrated this by solving Version B with the "A" supply curves substituted. The "B" supply curves correct errors in the "A" curves, with the overall effect of increasing coal minimum acceptable supply prices by about 5%. The "A" curves can no longer be generated.

Version C differs from Version B in four known substantive respects:

a. The 1985 revise in "C" does not contain the "BNDMAX" adjustment.

b. The Arizona ANSPS standard in "C" is .8 rather than .5.

c. The 1985 revise in "C" does not eliminate H coal for ANSPS plants.

d. The supply curves in "C" contain a seven percent payroll cost premium for surface coal in Western Montana.
The differences a), b), and c) are due to minor errors or scenario mis-specification in Version "C". Difference d) indicates that "C" supply curves post-date the "B" curves.

We have run a case using "C" with differences a)-c) corrected and with the "B" supply curves substituted. This differs from the all "B" version by less than one part in 70000 in objective function value (for reasons which we have not been able to determine). We propose that the modified "C" version with the "B" supply curve substitution be used in analysis. We have made a few non-substantive changes in operating procedures in the version.

Sincerely,

Michael H. Wagner

Michael H. Wagner

MW/adh

cc: Hoff Stauffer
APPENDIX B AN ILLUSTRATIVE LINEAR PROGRAMMING MATRIX*

The general structure of the ICF Coal and Electric Utilities Model (CEUM) consists of a supply component that provides coal, via a transportation network, to satisfy, at minimum cost, demands from both utility and non-utility users. The CEUM generates an equilibrium solution through a conceptually straightforward linear programming formulation that balances supply and demand requirements for each coal type for each region. The objective function of the linear program minimizes, over all regions, the total costs of electricity delivered by utilities and the costs of coal consumed by the non-utility sectors. The output of the model includes projections of coal production, consumption, and price by region, by consuming sector, and by coal type for the target year under consideration. The impacts of air pollution standards on electricity generation from coal are also considered explicitly.

Figure 1 outlines the basic elements of each of the four major components of the CEUM:

1. Coal Supply
2. Utility Demand
3. Non-Utility Demand
4. Transportation

This appendix focuses on the linear programming formulation and structure of the CEUM. By the use of an illustrative linear programming matrix it will be shown, in general terms, how the CEUM's four major components interrelate. This matrix is loosely based on an incomplete and unexplained sample matrix that appears in Appendix A of the CEUM Documentation [5]. Considerable reconstruction and interpretation were necessary.

*This material also appears in [51].
<table>
<thead>
<tr>
<th>SUPPLY</th>
<th>UTILITY DEMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 30 Regions</td>
<td>- 39 Regions</td>
</tr>
<tr>
<td>- 40 Coal types possible</td>
<td>- 19 Coal piles</td>
</tr>
<tr>
<td>- 5 Btu categories</td>
<td>- 19 Coal piles</td>
</tr>
<tr>
<td>- 8 sulfur levels</td>
<td>- 3 Ranks of coal</td>
</tr>
<tr>
<td>- Existing capacity</td>
<td>- 6 Sulfur categories</td>
</tr>
<tr>
<td>- Contract (large mines)</td>
<td>- Metallurgical pile includes only the highest grades of coal</td>
</tr>
<tr>
<td>- Spot Surge</td>
<td>- Utility Sector</td>
</tr>
<tr>
<td>No longer included in model</td>
<td>- Point estimates for KWH sales by region</td>
</tr>
<tr>
<td>- New Capacity</td>
<td>- KWH sales allocated to four load categories (base, intermediate, seasonal peak, and daily peak)</td>
</tr>
<tr>
<td>- Based upon BOM demonstrated reserve base</td>
<td>- Existing generating capacity utilized by model on basis of variable cost</td>
</tr>
<tr>
<td>- Reserves allocated to model mine types</td>
<td>- New generating capacity utilized by model on basis of full costs (including capital costs)</td>
</tr>
<tr>
<td>- Minimum acceptable selling prices estimated for each model mine type</td>
<td>- Air pollution standards addressed explicitly</td>
</tr>
<tr>
<td>- Upper bounds of new mine capacity for each region based upon planned mine openings</td>
<td>- Transmission links between regions</td>
</tr>
<tr>
<td>- Coal washing</td>
<td>- Oil and gas prices fixed</td>
</tr>
<tr>
<td>- Basic washing assumed for all bituminous coals</td>
<td>- Coal prices determined from supply sector through transportation network</td>
</tr>
<tr>
<td>- Deep-cleaning option available to lower sulfur content to meet New Source Performance Standard or a one-percent sulfur emission limitation for existing sources</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NON-UTILITY DEMAND</th>
<th>TRANSPORTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Five non-utility sectors (metallurgical, export, industrial, residential/commercial, synthetics)</td>
<td>- Direct links</td>
</tr>
<tr>
<td>- Point estimates of Btu's demanded</td>
<td>- Cost based upon unit train or barge shipment rates</td>
</tr>
<tr>
<td>- Allowable coals specified in terms of Btu and sulfur content</td>
<td>- Lower bounds used to represent long-term contract commitments</td>
</tr>
<tr>
<td>- No price sensitivity</td>
<td>- Upper bounds could be used to represent transportation bottlenecks or limited capacity</td>
</tr>
</tbody>
</table>

Figure 1. Coal and Electric Utilities Model--Major Components (From CEUM Documentation [5], page II-2)
The linear programming (LP) matrix (Figure 2) presented on pages B-7 through B-11 illustrates the basic structure and the naming conventions used in the ICF Coal and Electric Utilities Model (CEUM) for one supply region, Virginia (VA), and one demand region, Western Pennsylvania (WP).

Each column in the LP matrix represents either a physical or a notional economic activity. Positive entries in a column represent an input into the associated activity; negative entries represent an output of the activity. The last entry in each column represents the annualized cost of operating each activity at unit level and forms the coefficient of that activity in the objective function. The numerical values appearing in the LP matrix, while representative, are used only for illustrative purposes.

Nine major types of activities appear in the illustrative LP matrix. These are:

- coal mining
- coal cleaning
- coal transportation
- oil/gas procurement
- coal procurement by non-utilities
- electricity generation from coal
- electricity generation from non-coal sources
- electricity transmission, delivery, and load management
- building electrical generating and scrubber capacity.

Each row of the LP matrix, except for the last, represents a constraint associated with a physical stock (coal, heat energy, electricity, etc.) or, in some cases, with a consumption requirement. Physical stocks may be of fixed size, exogenously specified, or of variable size, created by activities within the model. Constraints
associated with stocks of variable size are called material balances; they force quantities created within the model to equal or exceed quantities used.

Seven major constraint categories appear in the illustrative LP matrix. These are:

1. available coal reserves by mine type at supply regions
2. coal stocks by coal type at supply regions (material balances)
3. fuel "piles" at demand regions (material balances)
4. non-utility energy requirements at demand regions
5. electricity constraints, including electricity consumption requirements, and electricity supplies (material balances), at demand regions
6. electrical generating and scrubber capacity constraints, including fixed generating capacity constraints for existing plants, material balances for capacities not yet built (new plants), and material balances for scrubber capacity on both existing and new plants
7. new capacity building limitations for generating electricity

The following conventions have been adopted with respect to constraint rows in the LP matrix:

1. constraints imposed by exogenous size limitations of existing stocks are specified with positive entries on the right-hand sides of the associated rows
2. material balance constraints are specified with zero entries on the right-hand sides of the associated rows
3. constraints imposed by exogenous consumption requirements are specified with negative entries on the right-hand sides of the associated rows
4. negative entries in a constraint row indicate additions to a stock; positive entries indicate subtractions or use

The last row of the LP matrix designates the objective function. Its entries are the costs (1985 annuitized costs in 1978 dollars) of
operating the associated activities at unit level. While the
interpretation of most of these entries is straightforward, we note that
the objective function coefficients for the electricity generation
activities represent annualized O&M costs for all plants (existing and
new) except for nuclear capacity which is modeled with its annualized
fuel costs as part of its O&M expenses. The objective function
coefficients for all building activities represent annualized capital
costs, where a real annual fixed charge rate of 10% is used.

Each activity operates on stocks designated in one or more
constraint categories. For example, consider Activity 1, SVAC1ZB. This
is a coal mining activity in supply region VA, extracting coal type ZB
from mine type C1ZB. There is a +1 entry in Row 1, associated with ZB
coal reserves in mine type C1ZB in region VA, because these reserves are
an input into the mining activity. There is a -1 entry in Row 7, the ZB
coil type material balance row in region VA, because this material
balance stock at supply region VA receives the output of the mining
activity. The objective function entry for Activity 1 appears in Row
34. This quantity, 20.80, represents the cost (minimum acceptable real
annuity price), in millions of dollars, of extracting 106 tons of ZB
coil from mine type C1ZB in supply region VA.

In general, the various activities in the LP matrix have the
following effects:

0 Coal mining activities transfer coal from available coal
reserves to coal stocks at supply regions.

0 Coal cleaning activities transfer coal from a stock of one coal
type to a stock of another coal type (always of lower sulfur
level), allowing for cleaning losses. (There are also
non-cleaning activities that transfer to a higher sulfur level
coals that could be but are not deep-cleaned.)
Coal transportation activities transfer coal from coal stocks at supply regions to fuel piles at demand regions.

Oil/gas procurement activities place oil and gas in fuel piles at demand regions.

Coal procurement activities by non-utilities remove coal from fuel piles in order to satisfy exogenous non-utility energy demands.

Activities for electricity generation from coal remove coal from fuel piles, use electrical generating capacity and possibly scrubber capacity, and create electricity supplies.

Activities for electricity generation from non-coal sources remove non-coal fuels from fuel piles, use electrical generating capacity, and create electricity supplies.

Electricity transmission activities reduce electricity supplies in one region and increase them in another region, allowing for transmission losses. Electricity delivery activities reduce electricity supplies in order to satisfy exogenous electricity consumption requirements, allowing for distribution losses.

Activities for building electrical generating or scrubbing capacity create new capacities. Exogenously specified limits may be imposed.

The unit of measurement is given for each activity variable and constraint in the illustrative LP matrix. For purposes of simplicity the time dimension has been omitted. All activity variables and constraints should be considered to be on a per-year basis except for those measured in capacity units of gigawatts (GW).
Figure 2. Illustrative LP Matrix for the ICF Coal and Electric Utilities Model

<table>
<thead>
<tr>
<th></th>
<th>Coal Mining (10^6 Tons)</th>
<th>Coal Cleaning (10^6 Tons)</th>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
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<tr>
<td>2</td>
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Figure 2. (continued)

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<tr>
<th>Coal Transport (10^6 Tons)</th>
<th>Oil/Gas (Quads)</th>
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Figure 2. (continued)

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<th>Electricity Generation Non-Coal (10^9 KWH)</th>
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*Note: The table continues with additional data not visible in the image.*
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## CONSTRAINT IDENTIFICATION

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<td>Total Cost (10^6$)</td>
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*Upper bound constraint on activity variable.*
This appendix details the naming conventions used in the column (activity variable) and row (constraint) structure of the CEUM LP matrix. A complete description of this type is not presented in the CEUM Documentation [5]. The LP matrix contains approximately 14,000 activity variables and 2000 constraints. In addition, there are on the order of 1000 nonbinding (free) rows used either to collect information or to force activity in the 1990 or later case years. The reader should note that definitions of supply regions, utility demand regions, and all BTU content levels and sulfur content levels can be found in the tables at the end of this appendix.

A. COLUMNS - Activity Variables

Coal Mining (10^6 Tons/year)

S(CR)(IT)(CT)

-coal supply columns, where

(CR) = coal region

(IT) = cost-of-extraction level

(CT) = coal type

(IT)(CT) = mine type

e.g., SVACLZB -- note that C1 refers to the first existing mine of coal type ZB; N1 would refer to the first new ZB mine; etc.

*This material also appears in [5].
Coal Cleaning ($10^6$ Tons/year)

\text{C(CR)(CT_1)(CT_2)}

-convert coal type $CT_1$ to $CT_2$, where the coal types that can be "deep cleaned" have sulfur levels C & E; the coal is either cleaned up to sulfur levels B & D, respectively, or not cleaned, in which case it is included in sulfur levels D & F, respectively.

\text{e.g. CVAHCHB}

Coal Transportation ($10^6$ Tons/year)

\text{T(CR)(UR)(CT)}

-transport coal type CT (in $10^6$ tons/year) from coal region CR to demand region UR; in the demand region, each "coal pile" is in units of Quads ($10^{15}$ BTUs), and BTU levels Z, M, and H are combined into B (bituminous).

\text{e.g. TVAWPZB}

\text{T(CR)(UR)(C(S))}

-transport coal type C(S) into the metallurgical (coking coal) pile, MT, where C = BTU level Z, and S = sulfur levels A, B, or D.

\text{e.g. TVAWPCB}
Procurement of Other Fuels (Quads/year)

TPI(UR)OG
- provide old gas to demand region (UR)

TPI(UR)PG
- provide oil/gas to demand region (UR)

E.g. TPIWPPG

Note that in the model's more recent versions the energy form OG is no longer used; OG is replaced by DG and refers to distillate oil or gas for turbines, while PG refers to residual oil or gas for steam plants.

Coal Procurement by Non-Utilities (Quads/year)

D(UR)(OD)(UE)
- activity to satisfy non-utility demand of type (OD) using energy form (UE) in region (UR), where:

(OD) = MT (metallurgical coal)

= RC (residential/commercial)

= IN (industrial)

= EX (export)

= SY (synthetic fuel)
and:

\[(UE) = MT \text{ (metallurgical coal from MT pile)} \]
\[= BA, BB, BD, BF, BG, BH, \]
\[SA, SB, SD, SF, SG, SH, \}
\[LA, LB, LD, LF, LG, LH \}
\[= OG \text{ (old gas)} \]
\[= PG \text{ (oil/gas)} \]
\[= HG \text{ (hydro or geothermal)} \]
\[= NU \text{ (nuclear)} \]

- e.g. DWPINBB
- D(UR)(OD)(BL)
- activity to satisfy non-utility coal demand of type (OD)
- using coal blend (BL) = 01, 02, ..... in region (UR).
- e.g. DWPMT01

Electricity Generation from Coal (109 KWH/year)

0(UR)(P)(UE)(L)
- operate in demand region (UR), coal plant type (P) using
- energy form (UE) in load mode (L), where:

\[(P) = O \text{ (old existing)} \]
\[= E, F, G \text{ (existing w/o scrubber, subject to}
- sulfur standards 1, 2, 3, respectively)} \]
\[= S \text{ (existing w/existing scrubber)} \]
\[= P, Q, R \text{ (existing w/o scrubber, build scrubber,}
- subject to sulfur standards 1, 2, 3, respectively)} \]
\[= N \text{ (new w/o scrubber, New Source Performance}
- Standard -- NSPS)} \]
= M (new w/scrubber, NSPS)
= B (new w/scrubber, Alternative New Source Performance Standards -- ANSPS)
= 0 (new MHD)
= 1 (new combined cycle) \{ Not used in the model' recent versions. \)
= 2 (new coal gas turbine)
= 5, 6, 7 (existing with new conversion facility, subject to sulfur standards 1, 2, 3, respectively)
etc.

and:

(L) = B (base)
= I (intermediate)
= P (seasonal peak)
= Z (daily peak)

e.g. OWPOBBI

O(UR)(P)(BL)(L)
-operate in demand region (UR), coal plant type (P) using coal blend (BL) in load mode (L), where (BL) = 01, 02, 03, ....etc.; note that these activities are unnecessary if coal mixing activities are employed (see page C-9).

e.g. OWPNO1B

Electricity Generation: Non-Coal (10^9 KWH/year)

O(UR)(P)(UE)(L)
-operate in demand region (UR), non-coal plant type (P) using energy form (UE) = OG, PG, HG, or NU, in load mode, (L), where:

(P) = J (old gas steam)
= K (existing oil/gas steam)
= L (new oil/gas steam)
= T (existing oil/gas turbine)
= U (new oil/gas turbine)
= H (existing hydro)
= I (new hydro)
= Y (existing nuclear)
= Z (new nuclear)

etc.

e.g. OWPKPGI

**Electricity Transmission** (10^9 KWH/year)

**T**\((\text{UR}_1)(\text{UR}_2)\text{EX}\)

- transmit baseload electricity from region (\(\text{UR}_1\)) to region (\(\text{UR}_2\)) using existing transmission links.

e.g. TWPNUEX

**T**\((\text{UR}_1)(\text{UR}_2)\text{NW}\)

- transmit baseload electricity from region (\(\text{UR}_1\)) to region (\(\text{UR}_2\)) using new transmission links.

e.g. TWPCONW

**Electricity Delivery to Consumers - Demand** (10^9 KWH/year)

**D**\((\text{UR})\text{ELXX}\)

- activity to satisfy total electricity requirement by consumers (total sales) in demand region (\(\text{UR}\)); note that electricity generation will be greater than sales due to line losses.

e.g. DWPELXX
Electricity Load Management (10^9 KWH/year)

C(UR)ELEL

-activity that combines electricity from different load modes into a "total electricity pile" in demand region (UR).

e.g. CWPELEL

Building Electrical Generating Capacity (GW)

B(UR)(PT)(ID)

-build, in demand region (UR), new electrical generating capacity for power plants of type (PT) with identifier (ID), where:

(PT) = CL (coal, NSPS; on line by end of 1982)
    = C9 (coal, ANSPS; on line after 1982)
    = HG (hydro or geothermal)
    = NU (nuclear)
    = PT (oil/gas turbine)
    = PS (oil/gas steam)
    = NT (new technology)
    = CV (conversion facility)
    etc.

and:

(ID) = 06 (new bituminous coal plant, NSPS)
    = 07 (new sub-bituminous coal plant, NSPS)
    = 08 (new lignite coal plant, NSPS)
    = 14 (new hydro plant)
= 16 (new nuclear plant)
= 18 (new oil/gas turbine plant)
= 21 (new oil/gas steam plant)
= 22 (new bituminous coal plant, ANSPS)
= 23 (new sub-bituminous coal plant, ANSPS)
= 24 (new lignite coal plant, ANSPS)
= 25, 26, 27 (new conversion facilities on existing coal plants, subject to sulfur standards 1, 2, 3, respectively)
= 28 (new MHD plant)
= 29 (new combined cycle plant)
= 30 (new coal gas turbine plant)

etc.

e.g. BWPCLOG

**Building Scrubber Capacity (GW)**

B(UR)(ST)XX

-build, in demand region (UR), new scrubber capacity,

where:

(ST) = S1 (existing plants)

= S2 (new plants, NSPS)

= S3 (new plants, ANSPS, sulfur level ≤ A)

= S4 (new plants, ANSPS, sulfur level = A)

e.g. BWPS1XX
Coal Mixing (Quads/year)

MX(UR)(CT₁)(CT₂)(CT₃)

-activity in demand region UR that mixes fractions of two coal types (coal pile fuels), CT₁ and CT₂, each with the same BTU level but different sulfur levels, to yield a unit of a third coal type, CT₃, with the same BTU level and a sulfur level in between those of CT₁ and CT₂.

e.g. MXWPBADB -- mixes coal types BA and BD to produce coal type BB.

Note that this type of activity is not represented in the illustrative LP matrix. If it is employed, there is no longer a need for operate activities using coal blends.

B. ROWS - Constraints

Constraints that represent simple bounds (upper, lower, or fixed) on activity variables are not named below. Nonbinding (free, accounting) rows are also not named below nor do they appear in the illustrative LP matrix of Appendix B. A descriptive list of the important constraint-types follows.

LC(CR)(CT) e.g. LCVAZB

-coal stocks (material balances) at supply region (CR) by coal type (CT); one row for each coal type in each supply region; 10⁶ Tons/year.

LU(UR)(UE) e.g. LUWPMT

-fuel piles (material balances) of energy form (UE) at demand region (UR); both for utility and non-utility fuels; Quads/year.
EU(UR)(OD)   e.g. EUWPMT
-exogenous non-utility energy requirements (demands) of
type (OD) in demand region (UR); Quads/year.

EU(UR)XX    e.g. EUWPXX
-exogenous total electricity consumption requirement
(demand) in demand region (UR); 10^9 KWH/year.

LU(UR)EL    e.g. LUWPEL
-total electricity supplies (material balance) in demand
region (UR); 10^9 KWH/year.

LU(UR)(L)   e.g. LUWPEB
-electricity supplies (material balances) by load category
(L) in demand region (UR), where (L) = B, I, P, or Z;
10^9 KWH/year.

LU(UR)(ID)  e.g. LUWPO1
-electrical generating capacity for plants identified by
(ID) in demand region (UR), where (ID) = 01, 02, 03, ...;
includes fixed generating capacity constraints for
existing plants and material balances for new plant
capacity; GW.

For new plants an ID listing is given on pages C-7
and C-8
For existing plants:
C-11

(ID) = 01 (old existing coal plants)
   = 02, 03, 04 (existing coal plants
   subject to sulfur standards 1, 2, 3,
   respectively)
   = 05 (existing coal plant w/existing
   scrubber)
   = 09 (existing baseload hydro plant)
   = 10 (existing intermediate load hydro
   plant)
   = 11 (existing daily peaking hydro plant)
   = 15 (existing nuclear plant)
   = 17 (existing oil/gas turbine plant)
   = 19 (existing old gas steam plant)
   = 20 (existing oil/gas steam plant)
   etc.

LU(UR)(ST) e.g. LUWPS1
- material balances for new scrubber capacity for existing
  plants (ST) = S1, or for new plants (ST) = S2, S3, S4, in
  demand region (UR); GW.

LU(UR)CL e.g. LUWPCL
- constraint row for total new coal plant capacity under
  NSPS, in demand region (UR); GW.
LU(UR)C9  
- constraint row for total new coal plant capacity under ANSPS, in demand region (UR); GW.

GA(CR)(UR)  
- constraint row to force an aggregate or joint lower bound on coal transported between supply region (CR) and demand region (UR); note that this row-type does not appear in the illustrative LP matrix of Appendix B; \(10^6\) Tons/year.

GU(UR)S2  
- constraint row to lower bound S2 scrubber capacity in demand region (UR); note that this row-type does not appear in the illustrative LP matrix of Appendix B; GW.

G(UR)(P)RET  
- constraint row to lower bound retrofit scrubber capacity in demand region (UR) for coal plant types P, Q, and R; note that this row-type does not appear in the illustrative LP matrix of Appendix B; GW.

NUSCST  
- objective function row; minimization of total cost in millions of dollars per year.
### BTU CONTENT CATEGORIES AND CODES

<table>
<thead>
<tr>
<th>Millions of BTU's per Ton</th>
<th>Code</th>
<th>Approximate Rank of Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;26</td>
<td>Z</td>
<td>bituminous</td>
</tr>
<tr>
<td>23-25.99</td>
<td>H</td>
<td>bituminous</td>
</tr>
<tr>
<td>20-22.99</td>
<td>M</td>
<td>bituminous</td>
</tr>
<tr>
<td>15-19.99</td>
<td>S</td>
<td>sub-bituminous</td>
</tr>
<tr>
<td>&lt;15</td>
<td>L</td>
<td>lignite</td>
</tr>
</tbody>
</table>

**Source:** Coal and Electric Utilities Model Documentation, [5], p. III-5.

### SULFUR LEVEL CATEGORIES AND CODES

<table>
<thead>
<tr>
<th>Pounds Sulfur per Million BTU's</th>
<th>Code</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00-0.40</td>
<td>A</td>
<td>can be blended with higher sulfur coals to meet Federal new source performance standard</td>
</tr>
<tr>
<td>0.41-0.60</td>
<td>B</td>
<td>meets Federal new source performance standard</td>
</tr>
<tr>
<td>0.61-0.63</td>
<td>C</td>
<td>can be deep cleaned to meet new source performance standard (five percent decline in sulfur content)</td>
</tr>
<tr>
<td>0.64-0.83</td>
<td>D</td>
<td>roughly one percent sulfur (.01 x 2,000 pounds per ton = 24 mmbtu/per ton = .833 pounds/mmbtu)</td>
</tr>
<tr>
<td>0.84-0.92</td>
<td>E</td>
<td>can be deep cleaned to meet one percent SIP standard (10 percent decline in sulfur content)</td>
</tr>
<tr>
<td>0.93-1.67</td>
<td>F</td>
<td>roughly two percent sulfur</td>
</tr>
<tr>
<td>1.68-2.50</td>
<td>G</td>
<td>roughly three percent sulfur</td>
</tr>
<tr>
<td>&gt;2.50</td>
<td>H</td>
<td>greater than three percent sulfur</td>
</tr>
</tbody>
</table>

**Source:** Coal and Electric Utilities Model Documentation, [5], p. III-5.
<table>
<thead>
<tr>
<th>PIES Region</th>
<th>CEUM Region</th>
<th>BOM Districts</th>
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</thead>
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<tr>
<td>Northern Appalachia</td>
<td>Pennsylvania (PA)</td>
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<td>Ohio (OH)</td>
<td>4</td>
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<tr>
<td></td>
<td>Maryland (MD)</td>
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<td></td>
<td>West Virginia, north (NV)(^1)</td>
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<td>Central Appalachia</td>
<td>West Virginia, south (SV)</td>
<td>7, 8</td>
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<tr>
<td></td>
<td>Virginia (VA)</td>
<td>7, 8</td>
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<tr>
<td></td>
<td>Kentucky, east (EK)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Tennessee (TN)</td>
<td>8, 13</td>
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<tr>
<td>Southern Appalachia</td>
<td>Alabama (AL)</td>
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<tr>
<td>Midwest</td>
<td>Illinois (IL)</td>
<td>10</td>
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<tr>
<td></td>
<td>Indiana (IN)</td>
<td>11</td>
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<tr>
<td></td>
<td>Kentucky, west (WK)</td>
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<tr>
<td>Central West</td>
<td>Iowa (IA)</td>
<td>12</td>
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<td></td>
<td>Missouri (MO)</td>
<td>15</td>
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<tr>
<td></td>
<td>Kansas (KN)</td>
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<td></td>
<td>Arkansas (AR)</td>
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<td>Oklahoma (OK)</td>
<td>14, 15</td>
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<td>Gulf</td>
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<td>Eastern Northern</td>
<td>North Dakota (ND)</td>
<td>21</td>
</tr>
<tr>
<td>Great Plains</td>
<td>South Dakota (SD)</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Montana, east (EM)(^2)</td>
<td>22</td>
</tr>
<tr>
<td>Western Northern</td>
<td>Montana, west (WM)</td>
<td>22</td>
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<tr>
<td>Great Plains</td>
<td>Wyoming (WY)</td>
<td>19</td>
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<td></td>
<td>Colorado, north (CN)</td>
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<tr>
<td>Rockies</td>
<td>Colorado, south (CS)</td>
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<td></td>
<td>Utah (UT)</td>
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<tr>
<td>Southwest</td>
<td>Arizona (AZ)</td>
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<tr>
<td></td>
<td>New Mexico (NM)</td>
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<td>Washington (WA)</td>
<td>23</td>
</tr>
<tr>
<td>Alaska</td>
<td>Alaska (AK)</td>
<td>23</td>
</tr>
</tbody>
</table>

\(^1\) Includes all of Nicholas County.

\(^2\) Includes the following counties: Carter, Daniels, Fallon, Mc Cone, Prairie, Richland, Roosevelt, Sheridan, Valley, and Widaux.

Source: Coal and Electric Utilities Documentation, [5], p. III-3.
### REGIONAL DEFINITIONS FOR CEUM DEMAND REGIONS

<table>
<thead>
<tr>
<th>Census Region</th>
<th>CEUM Region</th>
<th>State</th>
<th>Counties</th>
</tr>
</thead>
<tbody>
<tr>
<td>New England</td>
<td>MV</td>
<td>Maine</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vermont</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New Hampshire</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>Massachusetts</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Connecticut</td>
<td>All</td>
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<td></td>
<td></td>
<td>Rhode Island</td>
<td>All</td>
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<tr>
<td>Middle Atlantic</td>
<td>NU</td>
<td>New York, upstate</td>
<td>All counties not in New York, downstate</td>
</tr>
<tr>
<td></td>
<td>PJ</td>
<td>New York, downstate</td>
<td>Suffolk, Orange, Putnam, Bronx, Rockland, Richmond, Nassau, Westchester, New York, Queens, Kings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New Jersey</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>WP</td>
<td>Pennsylvania, west</td>
<td>All counties not in Pennsylvania, east</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>VM</td>
<td>Virginia</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maryland</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Delaware</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td></td>
<td>District of Columbia</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>WV</td>
<td>West Virginia</td>
<td>All</td>
</tr>
<tr>
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<td>CA</td>
<td>North Carolina</td>
<td>All</td>
</tr>
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<td>South Carolina</td>
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<td></td>
<td>GF</td>
<td>Georgia</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Florida, north</td>
<td>All counties not in Florida, south</td>
</tr>
<tr>
<td></td>
<td>SF</td>
<td>Florida, south</td>
<td>Nassau, Duval, Baker, Union, Bradford, Clay, St. Johns, Putnam, Flagler, Volusia, Indian River, Okeechobee, Martin, St. Lucie, Manatee, Sarasota, DeSota, Charlotte, Glades, Palm Beach, Lee, Hendry, Collier, Broward, Monroe, Dade</td>
</tr>
<tr>
<td>East North Central</td>
<td>ON</td>
<td>Ohio, north</td>
<td>Lucas, Ottawa, sandusky, Erie, Lorain, Cuyahoga, Lake, Ashtabula</td>
</tr>
</tbody>
</table>
### REGIONAL DEFINITIONS FOR CEUM DEMAND REGIONS

<table>
<thead>
<tr>
<th>Census Region</th>
<th>CEUM Region</th>
<th>State</th>
<th>Counties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OM</td>
<td>Ohio, central</td>
<td>All counties not in Ohio, north or Ohio, south</td>
</tr>
<tr>
<td></td>
<td>OS</td>
<td>Ohio, south</td>
<td>Hamilton, Clermont, Brown, Highland, Adams, Pike, Scioto, Lawrence, Gallia, Jackson, Meigs, Athens, Washington, Morgan, Noble, Noble, Monroe, Belmont, Harrison, Jefferson, Columbiana</td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>Michigan</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>IL</td>
<td>Illinois</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>IN</td>
<td>Indiana</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>WI</td>
<td>Wisconsin</td>
<td>All</td>
</tr>
<tr>
<td>East South Central</td>
<td>EK</td>
<td>Kentucky, east</td>
<td>Mason, Lewis, Fleming, Bath, Montgomery, Menifee, Clark, Powell, Madison, Estill, Jackson, Rockcastle, Pulaski, Laurel, Clinton, Wayne, McCrery, Greenup, Rowan, Carter, Boyd, Elliott, Lawrence, Morgan, Johnson, Martin, Wolfe, Magoffin, Floyd, Pike, Lee, Breathitt, Knott, Owslay, Perry, Letcher, Clay, Leslie, Knox, Bell, Harlan, Whitley</td>
</tr>
<tr>
<td></td>
<td>WK</td>
<td>Kentucky, west</td>
<td>All counties not in Kentucky, east</td>
</tr>
<tr>
<td></td>
<td>ET</td>
<td>Tennessee, east</td>
<td>Pickett, Fentress, Scott Morgan, Cumberland, Bledsoe, Sequatchie, Marion, Hamilton, Rhea, Meigs, Roan, Campbell, Claiborne, Union, Anderson, Knox Loudon, Blount McMinn, Monroe, Bradley, Polk, Hancock, Hawkins, Grainger, Hamblen, Jefferson, Sevier, Cocke, Greene, Sullivan, Washington, Unicoi, Carter, Johnbson</td>
</tr>
<tr>
<td></td>
<td>WT</td>
<td>Tennessee, west</td>
<td>All counties not in Tennessee, east</td>
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<td></td>
<td>AM</td>
<td>Alabama</td>
<td>All</td>
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<tr>
<td></td>
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<td>Mississippi</td>
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<tr>
<td>West North Central</td>
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<td>IA</td>
<td>Iowa</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>MO</td>
<td>Missouri</td>
<td>All</td>
</tr>
<tr>
<td>West South Central</td>
<td>AO</td>
<td>Arkansas</td>
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<tr>
<td></td>
<td></td>
<td>Oklahoma</td>
<td>All</td>
</tr>
</tbody>
</table>
## REGIONAL DEFINITIONS FOR CEUM DEMAND REGIONS

<table>
<thead>
<tr>
<th>Census Region</th>
<th>CEUM Region</th>
<th>State</th>
<th>Counties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountain</td>
<td>TX</td>
<td>Texas</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>MW</td>
<td>Montana</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wyoming</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idaho</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>Colorado</td>
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<td>UN</td>
<td>Utah</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>AN</td>
<td>Nevada</td>
<td>All</td>
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<td></td>
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<td>Arizona</td>
<td>All</td>
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<td></td>
<td></td>
<td>New Mexico</td>
<td>All</td>
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<tr>
<td>Pacific</td>
<td>WO</td>
<td>Washington</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oregon</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>CN</td>
<td>California, north</td>
<td>All counties not in California, south San Diego, Imperial, Orange, Santa Barbara, Ventura, Los Angeles, San Bernardino, Kern, Inyo, Mono</td>
</tr>
<tr>
<td></td>
<td>CS</td>
<td>California, south</td>
<td>All</td>
</tr>
</tbody>
</table>

Source: Coal and Electric Utilities Documentation, [5], pp. III-57 to III-59.
APPENDIX D - DETAILED MATHEMATICAL FORMULATION OF THE CEUM*

In this section a detailed mathematical formulation of the basic set of equations employed in the ICF Coal and Electric Utilities Model is presented. An explicit formulation of this type is not presented in the CEUM documentation. This formulation does not necessarily adhere to the CEUM naming conventions documented in Appendix C.

A. Definition of Subscript Categories

Note that an underscore on a subscript implies that a particular value of the subscript category is being used.

- **CR** = coal supply region.
- **IT** = cost-of-extraction level associated with step-heights on the appropriate coal supply curve.
- **HL** = BTU content level, in supply regions; the levels are Z, H, M, S, L; (see Appendix C, page C-13).
- **SL** = sulfur content level; the levels are A, B, C, D, E, F, G, H, with levels C and E omitted in demand regions; (see Appendix C, page C-13).
- **UR** = utility demand region.
- **UE** = utility fuel type; a listing of fuel types is given in Appendix C on page C-4. (Note that the coal fuel types in each demand region are identified by rank and sulfur level. The ranks are B, S, and L, corresponding to bituminous, sub-bituminous, and lignite, respectively, where B coal comes from the three highest BTU categories, Z, H, and M, in the supply regions.)
- **OD** = non-utility demand type; a listing of demand types is given in Appendix C on page C-3.

*This material also appears in [51].
BLM = coal blend type for metallurgical demand; e.g. BLM = 11, 12, ....

BLE = coal blend type for export demand; e.g. BLE = 10, 13, ....

P = plant type for electricity generation activities; a listing of both existing, P_e, and new plant types, P_n, is given in Appendix C on pages C-4, C-5, and C-6.

L = load mode; a listing of load modes is given in Appendix C on page C-5.

ID = plant type identifier; a listing is given in Appendix C on pages C-7, and C-8 for new plant type identifiers, ID_n, and on page C-11 for existing plant type identifiers, ID_e.

PT = plant type for build activities; a listing is given in Appendix C on page C-7.

B. Definition of Parameters

\[ \xi_C = \text{fractional coal loss in deep cleaning.} \]

\[ \xi_D(UR) = \text{fractional electricity distribution loss in delivery to consumers in demand region UR, measured in terms of the additional fraction of pre-delivered electricity required to produce a unit of delivered electricity.} \]

\[ \xi_{TE}(UR_i, UR_j), \xi_{TH}(UR_i, UR_j) = \text{fractional electricity transmission losses over existing and new lines, respectively, from source region UR}_i \text{ to sink region UR}_j. \]
\( l_{PS} \) = fractional electricity loss in the pumped storage process, measured in terms of the additional fraction of baseload electricity required to produce a unit of daily peaking electricity from pumped storage.

\( h_{c(CR,HL)} \) = heat content of coal of BTU level HL, in Quads/10^6 Tons, in supply region CR.

\( h_{r(UR,P,L)} \) = heat rate in Quads/10^9 KWH, in demand region UR, for plant type P, operating in load mode L.

\( f_{UE(BLM)} \) = fraction of fuel type UE in metallurgical blend type BLM.

\( f_{UE(BLE)} \) = fraction of fuel type UE in export blend type BLE.

\( f_L(UR) \) = fraction, in load mode L, of total electricity supplies in demand region UR.

\( f_{SC(P,SL,L)} \) = partial scrubbing fraction; the fraction of a plant type's exhaust required to be scrubbed, associated with a scrubber on plant type P, operating in load mode L, using coal of sulfur level SL.

\( CF(UR,L) \) = capacity factor (in decimal form) for plants operating in load mode L, in demand region UR.
C. Definition of Activity Variables

Coal Mining--Supply ($10^6$ Tons/year):

Coal Cleaning ($10^6$ Tons/year):

Coal Transportation ($10^6$ Tons/year):

Oil/Gas Procurement (Quads/year):

Non-Utility Coal Procurement (Quads/year):

Electricity Generation ($10^9$ KWH/year):

Electricity Transmission ($10^9$ KWH/year)

Existing Lines:

New Lines:

Electricity Delivery--Distribution to Users ($10^9$ KWH/year):

Electricity Load Management ($10^9$ KWH/year):

Building Electrical Generating Capacity (GW):

Building Scrubber Capacity (GW):
D. Constraint Equations

1. Available Coal Reserves (10^6 Tons/year)

\[ S_{CR,IT,HL,SL} \leq S_{CR,IT,HL,SL}^* \]  (1)

where \( S_{CR,IT,HL,SL}^* \) represents exogenous supply limitations on coal types, by mine type in each supply region.

2. Coal Stocks by Coal Type at Supply Regions--Material Balances (10^6 Tons/year)

(a) For HL ≠ Z and SL = A, or for any HL with SL = G or H:

\[- \sum_{IT} S_{CR,IT,HL,SL} + \sum_{UR} T_{CR,UR,HL,SL} \leq 0 \]  (2)

(b) For HL ≠ Z and SL = B:

\[- \sum_{IT} S_{CR,IT,HL,B} - (1 - \varepsilon) C_{CR,HL,C,B} + \sum_{UR} T_{CR,UR,HL,B} \leq 0 \]  (3)

(c) For any HL and SL = C:

\[- \sum_{IT} S_{CR,IT,HL,C} + C_{CR,HL,C,B} + C_{CR,HL,C,D} \leq 0 \]  (4)

(d) For HL ≠ Z and SL = D:

\[- \sum_{IT} S_{CR,IT,HL,D} - C_{CR,HL,C,D} - (1 - \varepsilon) C_{CR,HL,E,D} + \sum_{UR} T_{CR,UR,HL,D} \leq 0 \]  (5)
(e) For any HL and SL = F:
\[- \sum_{IT} S_{CR,IT,HL,F} + C_{CR,HL,F,E} + C_{CR,HL,F,D} + C_{CR,HL,F,E,F} \leq 0 \]  
(6)

(f) For any HL and SL = F:
\[- \sum_{IT} S_{CR,IT,HL,F} - C_{CR,HL,F,E} + \sum_{UR} T_{CR,UR,HL,F} \leq 0 \]  
(7)

(g) For HL = Z and SL = A, B, or D, in Equations (2), (3), and (5), respectively: replace \( T_{CR,UR,Z,SL} \) by \( T_{CR,UR,C,SL} + T_{CR,UR,Z,SL} \).

(A definition of activity \( T_{CR,UR,C,SL} \) is given in Appendix C on page C-2).

3. Fuel Piles at Demand Regions--Material Balances (Quads/year)

For simplicity we ignore coal blending for industrial coal demand, and electricity generation activities that use coal blends. Coal mixing activities are also excluded.

(a) For UE = BA, BB, BD, BF, BG, BH and HL = Z, H, M:
\[- \sum_{CR} \sum_{HL=Z,H,M} hc(CR,HL) T_{CR,UR,HL,SL} + \sum_{BLM} f_{UE}(BLM) D_{UR,MT,BLM} \\
+ \sum_{BLE} f_{UE}(BLE) D_{UR,EX,BLE} + \sum_{OD,MT,EX} D_{UR,OD,UE} \\
+ \sum_{P} \sum_{L} hr(UR,P,L) O_{UR,P,UE,L} \leq 0 \]  
(8)

(b) For UE = SA, SB, SD, SF, SG, SH, LA, LB, LD, LF, LG, LH:
\[- \sum_{CR} hc(CR,HL) T_{CR,UR,HL,SL} + \sum_{OD,MT,EX} D_{UR,OD,UE} \\
+ \sum_{P} \sum_{L} hr(UR,P,L) O_{UR,P,UE,L} \leq 0 \]  
(9)
(c) For \( \text{UE} = \text{MT}, \text{HL} = \text{Z}, \) and \( \text{SL} = \text{A, B, or D}: \)

\[
- \sum_{\text{CR}} \text{hc}(\text{CR}, \text{Z}) T_{\text{CR}, \text{UR}, \text{C}, \text{SL}} + \sum_{\text{BLM}} f_{\text{MT}}(\text{BLM}) D_{\text{UR}, \text{MT}, \text{BLM}} + \sum_{\text{BLE}} f_{\text{MT}}(\text{BLE}) D_{\text{UR}, \text{EX}, \text{BLE}} \leq 0 \tag{10}
\]

(d) For \( \text{UE} = \text{OG, PG}: \)

\[
-\text{TP}_{\text{UR, UE}} + \sum_{\text{P}} \sum_{\text{L}} \text{hr}(\text{UR, P, L}) O_{\text{UR, P, UE, L}} \leq 0 \tag{11}
\]

4. **Lower Bounds on Transportation Activities** (if required)

\( (10^6 \text{ Tons/year}) \)

\[
T_{\text{CR, UR, HL, SL}} \geq T^*_{\text{CR, UR, HL, SL}} \tag{12}
\]

where \( T^*_{\text{CR, UR, HL, SL}} \) represents exogenous lower bounds on transport between regions CR and UR.

5. **Upper Bounds on Old Gas Procurement** (Quads/year)

\[
\text{TP}_{\text{UR, OG}} \leq \text{TOPG}^*_\text{UR} \tag{13}
\]

where \( \text{TOPG}^*_\text{UR} \) represents exogenous upper bounds on procurement of old gas in demand regions UR.

6. **Non-Utility Energy Requirements at Demand Regions** (Quads/year)

(a) For \( \text{OD} \neq \text{MT} \) or \( \text{EX}: \)

\[
- \sum_{\text{UE}} D_{\text{UR, OD, UE}} = -D^*_{\text{UR, OD}} \tag{14}
\]

where \( D^*_{\text{UR, OD}} \) represents exogenous consumption requirements of demand type OD in demand regions UR.
(b) For OD = MT:

\[- \sum_{BLM} D_{UR, MT, BLM} = - DMT_{UR} \]  \hspace{1cm} (15)

where DMT_{UR} represents exogenous metallurgical coal demand in regions UR.

(c) For OD = EX:

\[- \sum_{BLE} D_{UR, EX, BLE} = - DEX_{UR} \]  \hspace{1cm} (16)

where DEX_{UR} represents exogenous export coal demand in regions UR.

7. Electricity Consumption Requirements \((10^9 \text{ KWH/year})\)

\[-DEL_{UR} = - DEL^*_{UR} \]  \hspace{1cm} (17)

where DEL^*_{UR} represents exogenous electricity consumption requirements in demand regions UR.

8. Total Electricity Supplies--Material Balances \((10^9 \text{ KWH/year})\)

\[ \sum_{UR_j} \left( TRE_{UR_i, UR_j} + TRN_{UR_i, UR_j} \right) + \left( 1 + \xi_D(UR_i) \right) DEL_{UR_i} - CEL_{UR_i} \leq 0 \]  \hspace{1cm} (18)

where UR_i represents source regions and UR_j represents sink regions.

9. Electricity Supplies by Load Category--Material Balances
\((10^9 \text{ KWH/year})\)

(a) For L = B:

\[- \sum_{P} \sum_{UE} O_{UR_j, P, UE, B} + \left( 1 + \xi_{PS} \right) \sum_{P=H, I} O_{UR_j, P, HG, Z} \]

\[+ f_B(UR_j) CEL_{UR_j} - \sum_{UR_i} \left[ \left( 1 - \xi_{TE}(UR_i, UR_j) \right) TRE_{UR_i, UR_j} \right] \]

\[+ \left( 1 - \xi_{TN}(UR_i, UR_j) \right) TRN_{UR_i, UR_j} \] \leq 0  \hspace{1cm} (19)
(b) For $L \neq B$:

$$- \sum_p \sum_{U} O_{UR,P,UE,L} + f_{L}(UR) \cdot C_{E L,UR} \leq 0$$

(20)

10. Electrical Generating Capacity for Existing Plants (GW)

Let:

- $P_e$ = existing plant types,
- $I_{De}$ = plant type identifiers for existing plant types.

Recall from the lists given in Appendix C that:

- $P_e = (0, E, F, G, S, P, Q, R, H, Y, T, J, K)$, and
- $I_{De} = (01, 02, 03, 04, 05, 02, 03, 04, (09, 10, 11), 15, 17, 19, 20)$.

Note that there are three identifiers, one for each of load modes $L = B, I$ and $Z$, associated with existing plant type $H$.

(a) For $P_e = O, S, Y, I, J, K$:

$$\sum_{UE} \sum_{L} \left[ (8.76) \cdot CF(UR, L) \right]^{-1} O_{UR,P_e,UE,L} \leq EGW^*_UR,I_{De}$$

(21)

where $EGW^*_UR,I_{De}$ represents exogenous electrical generating capacity limits on existing plant types identified by $I_{De}$ in demand regions $UR$.

(b) For $P_e = E$ and $P$:

$$\sum_{P_e = E,P} \sum_{UE} \sum_{L} \left[ (8.76) \cdot CF(UR, L) \right]^{-1} O_{UR,P_e,UE,L} + B_{P,UR,CV,25} \leq EGW^*_UR,02$$

(22)
(c) For $P_e = F$ and $Q$:

$$
\sum_{P_e = F, Q} \sum_{UE} \sum_{L} \left[ (8.76) \, CF(UR, L) \right]^{-1} O_{UR, P_e, UE, L}
$$

$$
+ BP_{UR, CV, 26} \leq EGW_{UR, 03} \quad (23)
$$

(d) For $P_e = G$ and $R$:

$$
\sum_{P_e = G, R} \sum_{UE} \sum_{L} \left[ (8.76) \, CF(UR, L) \right]^{-1} O_{UR, P_e, UE, L}
$$

$$
+ BP_{UR, CV, 27} \leq EGW^*_{UR, 04} \quad (24)
$$

(e) For $P_e = H$ and $L = B, I, Z$:

$$
\left[ (8.76) \, CF(UR, L) \right]^{-1} O_{UR, H, HG, L} \leq EGW^*_{UR, ID_e} \quad (25)
$$

11. Electrical Generating Capacity for New Plants--Material Balances (GW)

Let:

$$
P_n = \text{new plant types, and}
$$
$$
ID_n = \text{plant type identifiers for new plant types.}
$$

Recall from the lists given in Appendix C that:

$$
P_n = (N, M, 8, 9, 1, 2, 5, 6, 7, I, Z, U, L)
$$

$$
ID_n = ((06, 07, 08), (06, 07, 08), (22, 23, 24), 28, 29, 30, 25, 26, 27, 14, 16, 18, 21), \text{ and}
$$

$$
PT = (CL, CL, C9, NT, NT, NT, CV, CV, CV, HG, NU, PT, PS).
$$

Note that there are three identifiers, one for each coal rank, associated with new plant types $P_n = N, M$ and $B$. 

(a) For $P_n \neq N, M, \text{ or } 8$:

$$\sum_{\text{UE}} \sum_{L} \left[ (8.76) \ CF(UR,L) \right]^{-1} O_{UR,P_n,UE,L} - B_{UR,PT,ID} \leq 0 \quad (26)$$

(b) For $P_n = N$ and $M$ and $\text{UE} = \text{BA, BB, BD, BF, BG, BH}$:

$$\sum_{P_n=N,M} \sum_{\text{UE}} \sum_{L} \left[ (8.76) \ CF(UR,L) \right]^{-1} O_{UR,P_n,UE,L} - B_{UR,CL,06} \leq 0 \quad (27)$$

(c) For $P_n = N$ and $M$ and $\text{UE} = \text{SA, SB, SD, SF, SG, SH}$ use Equation (27) with $B_{UR,CL,06}$ replaced by $B_{UR,CL,07}$.

(d) For $P_n = N$ and $M$ and $\text{UE} = \text{LA, LB, LD, LF, LG, LH}$ use Equation (27) with $B_{UR,CL,06}$ replaced by $B_{UR,CL,08}$.

(e) For $P_n = 8$ and $\text{UE} = \text{BA, BB, BD, BF, BG, BH}$:

$$\sum_{\text{UE}} \sum_{L} \left[ (8.76) \ CF(UR,L) \right]^{-1} O_{UR,8,UE,L} - B_{UR,C9,22} \leq 0 \quad (28)$$

(f) For $P_n = 8$ and $\text{UE} = \text{SA, SB, SD, SF, SG, SH}$ use Equation (28) with $B_{UR,C9,22}$ replaced by $B_{UR,C9,23}$.

(g) For $P_n = 8$ and $\text{UE} = \text{LA, LB, LD, LF, LG, LH}$ use Equation (28) with $B_{UR,C9,22}$ replaced by $B_{UR,C9,24}$.

12. Scrubber Capacity on Existing Coal Plants--Material Balances (GW)

$$\sum_{P_e=P,Q,R} \sum_{\text{UE}} \sum_{L} f_{SC}(P_e,SL,L) \left[ (8.76) \ CF(UR,L) \right]^{-1} O_{UR,P_e,UE,L} - B_{S1,UR} \leq 0 \quad (29)$$
13. **Scrubber Capacity on New Coal Plants--Material Balances (GW)**

(a) NSPS (New Source Performance Standard) Coal Plants, \( P_n = M \):

\[
\sum_{UE} \sum_{L} f_{SC}(M, SL, L) \left[ (8.76) \ CF(UR, L) \right]^{-1} \quad O_{UR, M, UE, L} - BS_{2UR} \leq 0 \quad (30)
\]

(b) ANSPS (Alternative NSPS) Coal Plants, \( P_n = 8, \ SL \neq A \):

\[
\sum_{UE} \sum_{L} f_{SC}(8, SL, L) \left[ (8.76) \ CF(UR, L) \right]^{-1} \quad O_{UR, 8, UE, L} - BS_{3UR} \leq 0 \quad (31)
\]

(c) ANSPS Coal Plants, \( P_n = 8, \ SL = A \):

\[
\sum_{UE=BA, SA, LA} \sum_{L} f_{SC}(8, A, L) \left[ (8.76) \ CF(UR, L) \right]^{-1} \quad O_{UR, 8, UE, L}
- BS_{4UR} \leq 0 \quad (32)
\]

14. **New Capacity Building Limits (GW)**

(a) NSPS Coal Plants, \( PT = CL \):

\[
\sum_{ID_n=06, 07, 08} B_{UR, CL, ID_n} \leq BCL^*_{UR} \quad (33)
\]

where \( BCL^*_{UR} \) represents exogenous new capacity limits on NSPS coal plants in demand regions \( UR \).

(b) ANSPS Coal Plants, \( PT = C9 \):

\[
\sum_{ID_n=22, 23, 24} B_{UR, C9, ID_n} \leq BC9^*_{UR} \quad (34)
\]

where \( BC9^*_{UR} \) represents exogenous new capacity limits on ANSPS coal plants in demand regions \( UR \).
(c) Nuclear Plants, \( PT = NU, \ ID_n = 16 \):

\[
BP_{UR,NU,16} = BNU_{UR}^*
\]

(35)

where \( BNU_{UR}^* \) represents exogenously specified fixed nuclear capacity in demand regions \( UR \).

(d) Hydro Plants, \( PT = HG, \ ID_n = 14 \):

\[
BP_{UR,HG,14} = BHG_{UR}^*
\]

(36)

where \( BHG_{UR}^* \) represents exogenously specified fixed hydro capacity in demand regions \( UR \).

(e) Oil/Gas Steam Plants, \( PT = PS, \ ID_n = 21 \):

\[
BP_{UR,PS,21} = 0.0
\]

(37)

(f) There are no capacity building limits for:

- Oil/Gas Turbine Plants: \( PT = PT, \ ID_n = 18 \),
- New Technology Plants: \( PT = NT, \ ID_n = 28, 29, 30 \),
- Conversion Facilities: \( PT = CV, \ ID_n = 25, 26, 27 \).

15. **Lower Bounds on Scrubber Capacity for NSPS Coal Plants (GW)**

\[
\sum_{UE} \sum_{L} \left[(8.76) \ CF(UR,L)\right]^{-1} O_{UR,M,UE,L} \geq BS2_{UR}^*
\]

(38)

where \( BS2_{UR}^* \) represents exogenous lower bounds on scrubber capacity for NSPS coal plants in demand regions \( UR \).
E. **Objective Function** ($10^6$ $$/ \text{year})$$

Minimize \[
\sum_{CR} \sum_{IT} \sum_{HL} \sum_{SL} \text{RACP}(CR, IT, HL, SL) \cdot S_{CR, IT, HL, SL}
\]

\[+ \text{DCC} \sum_{CR} \sum_{HL} \left( C_{CR, HL, C, B} + C_{CR, HL, E, D} \right)
\]

\[+ \sum_{CR} \sum_{UR} \sum_{UE=0G, PG} \text{FC}(UR, UE) \cdot TP_{UR, UE}
\]

\[+ \sum_{UR} \sum_{P} \sum_{UE} \sum_{L} \text{OMC}(P, UE, L) \cdot O_{UR, P, UE, L}
\]

\[+ \sum_{UR_i} \sum_{UR_j} \text{TRC}(UR_i, UR_j) \cdot TRN_{UR_i, UR_j}
\]

\[+ \sum_{UR} \text{DC}(UR) \cdot DEL_{UR}
\]

\[+ \sum_{UR} \sum_{PT} \sum_{ID_n} \text{ACP}(UR, PT, ID_n) \cdot BP_{UR, PT, ID_n}
\]

\[+ \sum_{UR} \left\{ \text{ACS}_1(UR) \cdot BS_{1UR} + \text{ACS}_2(UR) \cdot BS_{2UR} + \text{ACS}_3(UR) \cdot BS_{3UR}
\]

\[+ \text{ACS}_4(UR) \cdot BS_{4UR} \right\}
\]

(39)

where:

- **RACP** = real annuity coal price (see Appendix E), $$/ \text{Ton}
- **DCC** = deep cleaning cost, $$/ \text{Ton}
- **TC** = transportation cost, $$/ \text{Ton}
FC = non-coal fuel cost, $10^6$/Quad
OMC = O&M cost (includes fuel cost for nuclear plants), mills/KWH
TRC = transmission cost for new lines, mills/KWH
DC = electricity delivery cost, mills/KWH
ACP = annualized capital cost for new power plants, $/KW-yr
ACS1 = annualized capital cost for scrubber-type S1, $/KW-yr
ACS2 = annualized capital cost for scrubber-type S2, $/KW-yr
ACS3 = annualized capital cost for scrubber-type S3, $/KW-yr
ACS4 = annualized capital cost for scrubber-type S4, $/KW-yr.
F. Additional Details

There are a few additional minor factors that would complicate the preceding mathematical formulation without substantially adding to a further understanding of the model. For those interested in such additional precise details see Appendix F of this report and several descriptive memoranda appearing in Appendix E of [5]. These details, not explicitly accounted for in the preceding mathematical formulation, concern the following:

1. (a) Heat rate penalties and capacity factor penalties due to full or partial scrubbing.
   (b) Capital cost and O&M cost savings due to partial rather than full scrubbing.
   (c) The fact that the partial scrubbing fraction is a function of the relevant environmental standard and the scrubber efficiency, in addition to the sulfur level of the coal being scrubbed.
2. Coal blending for industrial coal demand and coal mixing activities.
3. Joint (aggregate) lower bounds on total coal transported from supply to demand regions, where required.
4. (a) Both upper and lower bounds on electricity transmission via existing lines between demand regions, where required.
   (b) Lower bounds on electricity transmission via new lines between demand regions, where required.
5. Some changes in the CEUM's more recent versions pointed out in parts of Appendix C, such as the use of DG in place of OG, the omission of new technologies, etc.
APPENDIX E  THE CONCEPT OF MINIMUM ACCEPTABLE REAL ANNUITY COAL PRICES--
A FORMULATION*

The ultimate objective of the coal supply component of the ICF Coal and Electric Utilities Model is to produce supply schedules for coal as viewed by purchasers. Supply schedules reflecting the producer's point of view are derived, and these schedules are then adjusted to reflect the purchaser's point of view. A central concept of this procedure is the notion of minimum acceptable real annuity coal prices. The CEUM Documentation [5] does not adequately describe this concept; our own construction of it is included below.

ICF's objectives in employing the minimum acceptable real annuity coal pricing concept were twofold. First, the coal prices ought to reflect the stream of required prices for the entire life of the mine, and second, the prices must be internally consistent with other inflating price series such as oil/gas prices, coal transportation costs, and electric utility O&M costs. The objectives were achieved by the use of real annuity prices that implicitly inflate at the general rate of inflation, thereby remaining constant in real terms. All other inflating series employed in the CEUM are expressed in similar terms.

In this appendix the coal pricing logic employed in the CEUM and in its more recent versions is explained in a step-by-step manner starting with the calculation of the coal producer's minimum acceptable selling price. The

*This material also appears in [49].
analysis employs two relevant Verification Corrections (Points 7 and 8) from Section 2.4.2.

1. For each model mine type in each supply region the present value of capital investment (as of the case year, 1985) is calculated using a given initial capital cost and a given distribution of deferred capital costs over the mine lifetime.*

The present value of the total capital investment of coal producers, $PV_{CAP}$ (in case year dollars, as of the beginning of the case year, 1985) is given by:

$$PV_{CAP} = PV_{IC} + PV_{DC}$$

$$PV_{IC} = IC_{75}(1 + g_c)^{10-2/3}(1 + k_p)^{2/3}$$

$$PV_{DC} = DC_{75}(1 + g_c)^{10} \sum_{i=1}^{N} DCF_i \frac{(1 + g_c)^{i}}{(1 + k_p)^{i}}$$  \hspace{1cm} (1)

where:

$PV_{IC}$ = present value of initial capital cost, in case year dollars, as of beginning of case year (1985)

$PV_{DC}$ = present value of deferred capital cost, in case year dollars, as of beginning of case year (1985)

$IC_{75}$ = initial capital cost in base year, beginning-1975, dollars

$DC_{75}$ = deferred capital cost in base year, beginning-1975, dollars

*Note that the table of costs for the base case model mines given on page III-51 of the CEUM Documentation uses ICF's PIES costing (constant dollars for cash flow) rather than the CEUM methodology (current dollars, constant in nominal terms). The table also implies a real discount rate of 8% for coal producers. This is inconsistent with the statement on page III-55 of the documentation that a nominal rate of 15% is used together with a 5% capital inflation rate. In more recent versions of the model, a 6% capital escalation rate is used, including approximately (1/2)% real escalation.
\[ DCF_i \] = fraction of deferred capital spent at end of year \( i \)

\[ kp \] = coal producer's nominal discount rate (after-tax nominal cost of capital)

\[ g_c \] = total capital escalation rate (including general inflation and real escalation)

\[ g \] = general rate of inflation

\[ N \] = mine lifetime in years

Note that initial capital is inflated at the nominal escalation rate from the base year to eight months before the case year. Deferred capital is escalated to the end of the year in which the money is considered spent.

Let: \( K_p \) = coal producer's real discount rate (after-tax real cost of capital)

Recalling that \( 1 + K_p = \frac{1+k}{1+g} \), we point out that

\[
PV_{CAP} = PV_{IC} + DC_{75} (1 + g_c) 10 \sum_{i=1}^{N} \frac{DCF_i}{(1 + K_p)^{i}}
\]  

Equation (2) only holds if \( g = g_c \).

Using the distribution for deferred capital costs given on page III-49 of the CEUM Documentation [5], we have for \( N = 20 \):

\[
DCF_i = \begin{cases} 
0.01 & , \ i = 1-5 \\
0.09 & , \ i = 6-15 \\
0.0125 & , \ i = 16-19 
\end{cases}
\]

Except for mine lifetime, the following parameters values represent recent figures used by ICF to calculate \( PV_{CAP} \). Although ICF is currently using a mine lifetime of 30 years, we use a value of 20 years in Equations (3) and (4) since for this lifetime, the distribution used by ICF for deferred capital costs is documented.

\[
k_p = 0.15 \quad , \quad g_c = 0.06 \quad , \quad g = 0.055
\]
1 + K_p = 1.15/1.055 \Rightarrow K_p = 0.09

Utilizing Equations (1) and (3), we now have:

\[
PV_{\text{CAP}} = PV_{\text{IC}} + DC_75(1 + g_c)^{10} \left[ 0.01 \sum_{i=1}^{5} \left( \frac{1.06}{1.15} \right)^i + 0.09 \sum_{i=6}^{15} \left( \frac{1.06}{1.15} \right)^i + 0.0125 \sum_{i=16}^{19} \left( \frac{1.06}{1.15} \right)^i \right].
\] (4)

2. A minimum acceptable or required annual cash flow (equivalent to annualized capital cost) in nominal terms, CF, can be calculated by annualizing PV_{\text{CAP}} using the coal producer's nominal discount rate, k_p, and the mine lifetime, N. This cash flow is constant in nominal terms (i.e., constant in current year dollars). It is given by:

\[
CF = \frac{PV_{\text{CAP}}}{\sum_{i=1}^{N} \frac{1}{(1+k_p)^i}} = PV_{\text{CAP}} \cdot CRF_{k_p, N}
\] (5)

where:

\[
CRF_{k_p, N} = \text{capital recovery factor} = k_p \left[ 1 - (1+k_p)^{-N} \right]^{-1}. \quad \text{(based on nominal discount rate)}
\]

A minimum acceptable annual cash flow with the same present value but constant in real terms is obtained simply by substituting K_p for k_p in Equation 4.
Note that for ICF's PIES analysis, a cash flow constant in real terms was used. Such a cash flow is implicit in the costing table on page III-51 of the CEUM Documentation [5]. Also, the PIES analysis assumes no real escalation and employs constant base year dollars.

3. Utilizing given total operating costs for the base year, depreciation, and the above calculated minimum acceptable annual cash flow, total required revenues (referred to as sales by ICF) for the case year can be estimated from the appropriate equation on page III-50 of the CEUM Documentation [5]. (Since ICF assumes that the depletion allowance equals 10 percent of required revenues up to 50 percent of gross profit, there are two possible required-revenue equations. Both are derived in the addendum to this appendix. Adjustments to these equations, including severance tax rates as a percentage of sales, severance tax charges in dollars per ton, and Federal royalties, are not included.)

The coal producer's minimum acceptable selling price, MASP, for the case year is determined by dividing required revenue by the annual output of the mine. Note that the case year MASP in case year dollars, calculated in the CEUM via a required cash flow in nominal terms, is higher than the MASP would be for the same model mine type in ICF's PIES analysis, which uses a cash flow in real terms and works in constant base year dollars.

4. Starting from the MASP in the case year, 1985, a minimum acceptable coal price series in nominal terms is generated over the assumed 20-year mine lifetime as follows: The minimum acceptable cash flow or annualized capital cost is constant in nominal terms over the mine
lifetime. Variable costs are escalated from year to year over the life of the mine using a 6.5% rate for labor costs, including approximately 1% real escalation, and the 5.5% general inflation rate for the cost of power and supplies and for other operating expenses. Required revenues are recalculated (as described in step 3 above) for each year, creating a stream of minimum acceptable prices in nominal terms (i.e., in current year dollars). By construction, via this required price stream, the coal company will recover all of its costs and earn the required return on its investment.

5. The coal producer's minimum acceptable coal price series in nominal terms, calculated in the previous step, is present-valued or discounted to the case year using the after-tax nominal cost of capital to electric utilities, \( k_u \). The utility industry's discount rate is used at this stage because the utilities decide which stream of prices is preferable (i.e., which mines are opened) and make the trade-off decisions between various fuels and between capital-intensive and high-variable cost plants. Currently, ICF is using a 10% after-tax nominal cost of capital to utilities. The present-value (as of the case year) of the coal price series, \( PV_{ps} \), is calculated as follows (note that the values \( p_i \) are neither constant in real terms nor in nominal terms):

\[
P_{ps} = \sum_{i=1}^{N} \frac{p_i}{(1+k_u)^i} = \sum_{i=1}^{20} \frac{p_i}{(1.10)^i}
\] (6)
where:

\[ p_i = \text{coal producer's minimum acceptable coal price in ith year in nominal terms (for model mine type and supply region under consideration)}. \]

6. Finally, a minimum acceptable "real annuity coal price," RACP, is calculated from \( PV_{ps} \) using \( k_u \) and the general inflation rate, \( g \). This calculation implicitly defines an after-tax real cost of capital to electric utilities, \( K_u \).

\[
RACP = \frac{PV_{ps}}{\sum_{i=1}^{N} \left( \frac{1 + g}{1 + k_u} \right)^i} = \frac{PV_{ps}}{\sum_{i=1}^{N} \frac{1}{(1 + K_u)^i}} \tag{7}
\]

where:

\[ APFAC = \text{annuity price factor, and} \]

\[ 1 + K_u = 1.10/1.055 \Rightarrow K_u \approx .0427. \]

The real annuity coal price is a case year value in case year dollars that inflates at the general rate of inflation (i.e., RACP is constant in real terms). Note that while the methodology described above is projecting coal prices \( p_i \) in actual nominal terms, it is only the present value of the coal price series that is important. The associated real annuity, given by Equation (7), has the same present value to the utility as does the nominal price series.

Other prices in the CEUM are all assumed to inflate at the general rate of inflation (i.e., to remain constant in constant case year
dollars). Therefore, the 1985 price for, say, oil/gas is both its actual price in 1985 and the value of the real annuity for oil/gas stated in 1985 dollars. So the real annuity coal price has the advantage of being consistent with other data inputs, such as oil prices. Its other advantage is that it makes the CEUM's static linear programming framework possible.

It is the minimum acceptable real annuity coal price (deflated to 1978 dollars), for each model mine type in each supply region, that appears in the linear programming matrix as the cost coefficients of the coal mining activity variables in the objective function (see Appendix B).
Addendum: Derivation of Required-Revenue (Sales) Equations
(For further discussion see page III-50 of the CEUM Documentation [5].)

Case 1: Depletion = 0.50 * Gross Profit (GP) (1)

By definition:
Annual Cash Flow (CF) = Net Profit (NP) + Depreciation (DEP) + Depletion. (2)

Assuming a 50% Federal income tax rate,
NP = 0.50 (GP - Depletion) (3)

Substituting Equation (1) into Equation (3) yields:
NP = 0.50 (GP - 0.50 GP) = 0.25 GP (4)

Substituting Equations (1) and (4) into Equation (2) we have:
GP = 4 (CF-DEP)/3. (5)

By definition:
GP = Required Revenue - Operating Costs (OC) (6)

From Equations (5) and (6) we have:
\[
\text{Required Revenue} = \text{OC} + \frac{4}{3} (\text{CF-DEP}) .
\] (7)

Case 2: Depletion = 0.10 * Required Revenue (8)

From Equations (3) and (8):
NP = 0.50 (GP - 0.10 Required Revenue) (9)

Substituting Equations (6), (8), and (9) into Equation (2) yields:
CF - DEP = (0.55) Required Revenue - (0.50)OC (10)

Rearranging Equation (10) we have:
\[
\text{Required Revenue} = \frac{(0.50)OC + CF - DEP}{0.55} .
\] (11)
This appendix presents a detailed analytical description of the use of partial scrubbing in the CEUM. An explicit presentation of this material does not appear in the CEUM Documentation [5] nor in the applications reports [7], [3], [9], and [15].

Several alternative new source performance standards (ANSPS) are analyzed by ICF in [9]. Each ANSPS is defined by a floor and a ceiling on $SO_2$ emissions. For any ANSPS coal plant, scrubbers are mandatory and 85% sulfur removal (on a daily average basis) down to the specified floor is required. Note that utilities are not required to reduce emissions below the floor, thus allowing for partial scrubbing (i.e., floors are emissions limitations that can be met in place of a percentage removal requirement). The ceiling is an emission limitation that cannot be exceeded on a daily average basis unless there are exemptions allowed that permit it to be exceeded three days per month. In "without exemptions" cases the scrubber efficiency is assumed to be 75%. Under the current new source performance standard (NSPS), scrubbers are not mandatory and a maximum emission level of 1.2 lbs. $SO_2/10^6$ Btu is required. If scrubbers are employed with an NSPS coal plant, a 90% efficiency on an annual average basis is employed.

A. Definition of Terms

Let: $S =$ average sulfur content in a specified coal type; note that 1 lbs. $5/10^6$ Btu = $(1/2)$ lbs. $SO_2/10^6$ Btu.

$C =$ ceiling or cap on $SO_2$ emissions in lbs. $SO_2/10^6$ Btu.

$F =$ floor on $SO_2$ emissions in lbs. $SO_2/10^6$ Btu.

*This material also appears in [51].
E = scrubber efficiency (percentage sulfur removal) on a daily average basis = .85 (with exemptions), .75 (without exemptions).

$E_A$ = scrubber efficiency (percentage sulfur removal) on an annual average basis = .90.

$R_A$ = annual $SO_2$ emissions rate in lbs. $SO_2/10^6$ Btu.

$X$ = percentage of flue-gas scrubbed (partial scrubbing fraction).

$RSD = \text{relative standard deviation above the long-run mean sulfur content of a specified coal; this daily average variability factor accounts for differences in peak sulfur content on a daily basis versus an annual average; 3 RSD's are assumed in the "without exemptions" ANSPS scenarios and 2 RSD's are assumed in the "with exemptions" scenarios; RSD = 0.15.}$

B. Definitions of Sulfur Levels in Utility Demand Regions

<table>
<thead>
<tr>
<th>Level</th>
<th>Range</th>
<th>Assumed Average Sulfur Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(lbs. S/10^6 Btu)</td>
<td>(lbs. S/10^6 Btu)</td>
</tr>
<tr>
<td>Low</td>
<td>A 0.00-0.40</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>B 0.41-0.60</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>D 0.61-0.83</td>
<td>0.83 (approximately 1% S)</td>
</tr>
<tr>
<td>Medium</td>
<td>F 0.84-1.67</td>
<td>1.67 (approximately 2% S)</td>
</tr>
<tr>
<td></td>
<td>G 1.68-2.50</td>
<td>2.50 (approximately 3% S)</td>
</tr>
<tr>
<td>High</td>
<td>H greater than 2.50</td>
<td>3.33</td>
</tr>
</tbody>
</table>
C. Alternative New Source Performance Standards (ANSPS)

Each of the ANSPS listed below is analyzed in [9] and is denoted by:
ceiling/floor, exemption status. The ceilings and floors are given in
lbs. SO\textsubscript{2}/10\textsuperscript{6} Btu.

1.2 (current NSPS)
1.2/.2, with exemptions; 1.2/.2, without exemptions;
1.2/.5, with exemptions; 1.2/.5, without exemptions;
1.2/.67, with exemptions;
1.2/.80, with exemptions

D. Determination of Maximum Allowable Sulfur Contents under Alternative Standards

Let: \( S_{\text{max}} \) = maximum allowable sulfur content, given an emissions
ceiling and an enforcement standard.

1. Annual Average Enforcement--NSPS:
\[
2S(1 - E_A) = C
\]

\[ \Rightarrow S_{\text{max}} = \frac{1.2}{2(1 - .90)} = 6.0 \] (1)

2. Daily Average Enforcement--ANSPS:
\[
2S(1 - E)(1 + n \times \text{RSD}) = C, \ n = 2, \ \text{with exemptions}
\]
\[
\text{without exemptions:} \quad S_{\text{max}} = \frac{1.2}{2(1 - .85)(1.3)} = 3.08 \] (2)
\[
\text{without exemptions:} \quad S_{\text{max}} = \frac{1.2}{2(1 - .75)(1.45)} = 1.66 \] (3)

3. Coal Types Disallowed:

From Equations (1), (2), and (3) and the definition of sulfur levels
in Section B, we have:

ANSPS cases with exemptions: H
ANSPS cases without exemptions: G, H
NSPS: none
E. Calculation of Partial Scrubbing Fractions

1. Annual Average Enforcement--NSPS:

\[ F = 2S(1 - E_A)X + 2S(1 - X) \]  

\[ \Rightarrow X = \frac{(1 - F/2S)/E_A}{1 - E_A} \]  

Recall that for NSPS: \( F = C = 1.2 \) and \( E_A = .90 \).

2. Daily Average Enforcement--ANSPS:

Note here that partial scrubbing fractions are calculated by ICF using the 'with exemptions' parameters.

\[ F = 2S(1 + 3\cdot RSD)(1 - E)X + 2S(1 + 3\cdot RSD)(1 - X) \]  

\[ \Rightarrow X = \frac{1 - F/[2S(1 + 3\cdot RSD)]}{E} = 1 - F/(2.9)S^{.85} \]  

F. Calculation of Annual Emissions Rate for ANSPS Standards

\[ R_A = 2S(1 - E_A)X + 2S(1 - X) \]  

where \( E_A = .90 \) and \( X \) is determined from Equation (7).

G. Determination of Coals That Must Be Fully Scrubbed and Coals That Can Be Partially Scrubbed Under Alternative Standards

Let: \( S_{\min} \) = minimum sulfur level that requires full scrubbing, i.e., \( X = 1 \).

1. Annual Average Enforcement--NSPS:

From Equation (4) we have:

\[ F = 2S_{\min}(1 - E_A) \]  

\[ \Rightarrow S_{\min} = \frac{F}{2(1 - E_A)} = \frac{1.2}{2(.1)} = 6.0 \]  

The following table displays the scrubbing status of coals for different floors with annual average enforcement. Equation (9) and the definition of sulfur levels in Section B are used.
From Equation (6) we have:

\[ F = 2S_{\text{min}}(1 + 3 \times \text{RSD})(1 - E) \]

\[ \Rightarrow S_{\text{min}} = \frac{F}{2(1.45)(.15)} = .435 \]  \hspace{1cm} (10)

The following table displays the scrubbing status of coals for each ANSPS scenario under daily average enforcement. The definition of sulfur levels in Section B, the results of Section D, and Equation (10) are used. Note that we have added an ANSPS that duplicates the NSPS but under daily average enforcement (E = .85) and with exemptions.
It is important to point out the manner in which ICF has chosen to implement the information contained in the preceding table. We have learned via communications with ICF personnel that whenever the partial scrubbing fraction is greater than 0.8 but less than 1.0, the model fully scrubs (i.e., sets $X = 1$) rather than partially scrubs the associated coal.* The apparent undocumented justification for this procedure is that the magnitude of the cost savings associated with partially scrubbing coals when $0.8 < X < 1$ is small. ICF has no calculations available to support this claim.

*The effected coals (those fully scrubbed instead of partially scrubbed) in the case of daily average enforcement are: with a .2 floor, A coals; with a .5 floor, B and D coals; with a .67 floor, D coals; with a .80 floor, F coals; and with a 1.2 floor, F and G coals. The effected coals in the case of annual average enforcement are: with a .2 floor, B and C coals; with a .5 floor, F coals; with a .67 floor, F and G coals; with a .80 floor, F, G, and H coals; with a 1.2 floor (NSPS), G and H coals.
1. Introduction: Model Structure and Operation

The Coal and Electric Utilities Model (CEUM), developed by ICF, Inc., was maintained on the DOE Energy Information Administration's IBM 370 facility at OSI in Rockville, Maryland. While the general design and key characteristics of the CEUM have been discussed elsewhere in this report (see Section 2.1 and Appendix B), here we consider the operating characteristics and ease of use of the model. It is important to note that no user or operator guide was provided with the model. While the EIA has prepared a draft User's Manual for their version of the model that was of some interest to us, our ability to run the CEUM is largely based upon a study of the computer code and extensive consultation with the modelers. In particular, Dr. Michael Wagner of ICF was extremely helpful in our learning process.

The CEUM is a large-scale, linear programming (LP) model with a highly resolved data base, and it has been designed to be run for three case years: 1985, 1990, and 1995. For each year, a large LP matrix is generated, consisting of approximately 2,000 constraints and 14,000 variables. The matrix is first generated for 1985, and is subsequently updated through a revision operation for the other two case years. In order to complete its operations, the CEUM relies upon a fairly complex file structure. System files are used to generate data files, a composite data tape (GAMOUTC), a matrix file, revise files, and various output files. Major aspects of this file structure are illustrated in Figure 1. Here we provide a summary discussion of each of the major

*This material also appears in [52].
Figure 1. Flow Diagram Indicating the Basic File Structure of the CEUM (Not a Comprehensive Listing of All Files)
steps, together with an indication of the estimated CPU time required for execution of those steps. It should be noted that elapse time for accomplishing each of these steps is a function of the condition of the machine. It might also be noted that in our experience these jobs were run at low priority, and were subject to being lost when the system crashed.

The first major step involves creation of the basic input data files, and the execution of the coal supply module.* The basic data files contain input data for the coal supply model, the utility model, and data characterizing the transportation system. The output of this processing is a single file (GAMOUTC) structured for input to the LP matrix. The time required to process all input data and execute the coal supply model varies depending upon the number of updates, etc. On average the required time is 5 to 6 CPU minutes.

Given the basic input data, the next major phase of the system is to generate the constraint matrix and to solve the LP for the first case year (1985). The matrix generation program, written in GAMMA, takes the variables and puts them in a format usable by the LP algorithm. The LP is then solved, using a software package called MPSIII. The output of this activity consists of files produced for use by the report generators. The estimated CPU time to complete this phase of operations

---

*The coal supply data are treated somewhat differently from the other basic data inputs. Coal supply data are entered via a file entitled SUPIN, and are then run through a FORTRAN program called RAMC. RAMC produces supply curves for coal types in step form. Each step represents a different type of mine with the height of the step representing the cost of production, and the width representing the maximum level of operation for that mine type. In short, RAMC supplies the upper limits to the coal production activities in the model.
is 25-30 minutes. It is, however, possible to enter and make a run of the CEUM from an advanced basis. When only minor updates are made to the constraint matrix and the advanced basis from which the solution begins is very close to the new solution, the estimated solution and output report times are somewhat shorter in duration.

Finally, the report writers convert the LP solution into output format. Approximately 15 CPU minutes are required to generate the reports containing model output for the 1985 case year.

Solutions for the case years subsequent to 1985 require some modification of the constraint matrix and solution. Approximately 10 to 15 minutes of CPU time usually are required. However, generation of the output reports for subsequent case years requires the same amount of time as for 1985, approximately 15 CPU minutes.

As noted above, the elapse time for accomplishing these tasks will vary significantly depending upon the status of the equipment.

2. Evaluation of Operating Characteristics

In general, the characteristics of a model that are of importance to the operator are as follows:

1) Ease of updating data,
2) Flexibility through input and parameter changes only,
3) Extensibility of model structure,
4) Efficiency of operation,
5) Interpretability of model output,
6) Clarity of model format, and
7) Transferability--accessibility of documentation, training required, ease of use by persons other than the modeler.
We have considered the CEUM in the context of each of these characteristics, and a summary of each point is presented below.

2.1 Ease of Updating Data

M.I.T. operators found that updating model data is not as easily accomplished and straightforward a process as one might suppose. As illustrated in Figure 1 and discussed above, the CEUM computational structure is complex, involving many input, intermediate, and output files. Attached to this appendix is a listing and brief description of the files associated with the model. In order to update data, the user enters the GAMMA-coded data files and appropriately inserts the new information. However, these new data are not always carried automatically through the necessary series of intermediate steps. It is up to the operators to remember which files the new data may explicitly and implicitly affect, and to change those as well. In short, the many interdependencies among various levels of the structure cause data updating to be a highly operator-dependent operation.

2.2 Flexibility Through Input and Parameter Changes

The above comments on data changes are also applicable to input and parameter changes. The CEUM is not set up to easily accommodate changes to parameters. Again, operator knowledge is required to ensure that correct changes are made in all the necessary places. At this time, given the existing documentation, only the model developer or experienced assessors of this model have a chance of being fully cognizant of all the places in the code where such changes may be necessary.
2.3 Extensibility of Structure

Issues concerning the structure of the CEUM are discussed in detail in Appendix B. In brief, the model is structured as a complex set of preliminary programs that feed information into a straightforward linear programming framework that has a very high level of disaggregation. The modelers' emphasis on detail necessitated a simple model design, which resulted in both structural advantages and disadvantages.

From an operational point of view, the LP structure is simple to understand and execute. In general, revised data or new activities can be added to the model without significant difficulty, providing that the operator understands the matrix generation language and is aware of all places where changes must be made. Some structural changes are, however, not that easy to make. For example, one of the proposed audit runs involved substantial regional aggregation of the model. This run was not completed due to the complexity of implementing the change. In such cases, changes or extensions of the structure would be quite complicated, and would require extensive reprogramming.

2.4 Efficiency of Model Operation

The version of the CEUM evaluated by M.I.T. is somewhat inefficient in terms of operating time. As discussed above, several model operations, particularly the solve and report-generation steps, are quite time-consuming in CPU minutes. Table 1 below indicates the approximate amount of time required to execute a specific model run entitled EDMD for 1985 and 1990 (1995 run times would be similar if not identical to 1990 run times).
TABLE 1
Time Required to Run EDMD 1985 and 1990

<table>
<thead>
<tr>
<th>Step</th>
<th>Approximate CPU Minutes Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creation of GAMOUTC</td>
<td>3.5</td>
</tr>
<tr>
<td>Generation of 1985 Matrix</td>
<td>2.3</td>
</tr>
<tr>
<td>Completion of LP Solution for 1985</td>
<td>10.9</td>
</tr>
<tr>
<td>Generation of Report-Writing Files</td>
<td>15.8</td>
</tr>
<tr>
<td>Creation of Reports</td>
<td>9.8</td>
</tr>
<tr>
<td>Revise, Set-up, and Solve for 1990</td>
<td>15.1</td>
</tr>
<tr>
<td>Creation of Reports for 1990</td>
<td>9.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>66.4</td>
</tr>
</tbody>
</table>

While these numbers are approximate due to the large number of steps of extremely short duration, the large amount of time required by certain processes is evident.

It should be observed that there is a trade-off between model extensibility and computational efficiency. In the present system, some model extensibility is preserved at the expense of using a generalized matrix generator program. The computational costs of this interpretive language are substantial, and could be reduced by programming the model in a compiler language such as FORTRAN. The disadvantage of such reprogramming would be that extensions to the model would be more costly to implement.

EPRI is currently supporting ICF in developing a FORTRAN version of the CEUM system. Concurrent with this effort, ICF has been analyzing
various decompositions of the model to obtain improvements in computational efficiency. It is our understanding that such improvements could dramatically decrease the amount of CPU execution time required for model runs.

2.5 Interpretability of Output

The output from model runs is presented in four formats: (1) a "small" report, (2) a "large" report, (3) an LP solution report, and (4) a "slim file" which reproduces selected results. In general, the tables are well organized, and finding specific model outputs is not a difficult task. Operationally speaking, interpreting output is a straightforward process. However, as discussed in the documentation evaluation (Section 2.4), interpreting the meaning of results and comprehending their implications are very difficult with the CEUM, due to gaps in the descriptions of assumptions, methodology, and mathematical structure. In addition, several hundred pages of output per run are expensive to print and unwieldy to use and store.

2.6 Clarity of Model Format

As discussed above, the CEUM has proven to be somewhat difficult to comprehend from an analytical viewpoint, due to the obscure nature of some of its scientific and methodological bases. However, from an operational viewpoint, the structural relationships, although very cumbersome, are straightforward and provide no difficulty for the competent operator willing to make a substantial time commitment. The aspect of awkwardness is contributed to by the model's size, and the corresponding complexity of its file structure.
2.7 Transferability

Our evaluating team concluded that effective transfer of control of the CEUM is for all practical purposes impossible without significant input from the model developer. (As mentioned earlier, our own grasp of the model was made possible by the cooperation we received from ICF.) Given modeler assistance, it is not extraordinarily difficult to gain enough control over the model to perform straightforward sensitivity analysis. However, personal assistance is essential; the extant documentation and user's materials are not, by themselves, sufficient to enable operation. This fact, coupled with the complexity of the file structures, makes transfer of the CEUM an expensive process. Moreover, since the model has not been transferred from one type of machine environment to another, but has always been run on one specific configuration of IBM equipment, we are unable to comment on further procedures that such a transfer might require.

In order to be able to work with the CEUM, the operator must have, at a minimum, a working knowledge of the following systems:

- FORTRAN
- GAMMA (the matrix- and report-generating system)
- MPSIII (a proprietary software package developed by Ketron; used to solve the linear program)
- SUPERWYLBUR (an editing system necessary for operation at OSI)
- IBM 370 JCL

These language and system requirements present something of an operating problem, since GAMMA and SUPERWYLBUR are not widely known, and MPSIII is proprietary. Any learning time associated with the software must be added to the start-up time.
In addition, as discussed above, the documentation is not presented in a sufficiently complete fashion to permit more than a basic marginal control over the model. If important or complex structural changes were desired, much more personal training of the operator by the modeler would be required.

The evaluation of these seven categories has led us to conclude that, while the model structure is straightforward, several problems exist with model operation, including difficulties in transferability, file complexity, and computation times. Attached below is a listing of the files associated with the CEUM.

2.8 Basic File Structure of the CEUM

'FGAM' is the generic name of the data base from which the run is to be made.

'FRUN' is the generic name of the output files corresponding to various "rim" changes on a given data base.

(These "rim" changes are implemented via the REVISE files.)

'YYYY' represents the system files required by the model (additional sets such as 'XXXX' and 'ZZZZ' may be utilized to make additional parallel runs).

'FGAM' Files

FGAM.GAMOUTC - Data Base  
FGAM.MATRIX - Matrix  
FGAM.THINDIR } Directory and report-writer-files to publish SLIM and 
FGAM.THINRWF } SMALL reports  
FGAM.GAMDIR } Report-writer files to publish  
FGAM.GAMRWF } LARGE reports
'FRUN' Files

FRUN85/90/95.LPSOLN - Contains solution to LP in MPSIII format
FRUN85/90/95.SMALL - SMALL output report
FRUN85/90/95.LARGE - LARGE (detailed) output report

System files ('XXXX'/ 'YYYY'/ 'ZZZZ')

XXXX.SLIM85
XXXX.SLIM90 Files used to pass information from 1985 to 1990 run and from 1990 to 1995 run
XXXX.SLIM95
XXXX.REV90 Revise files for 1990 and 1995
XXXX.REV95

XXXX.PROBFILE

XXXX.PROB90 Probfiles required by MPSIII to solve LP;
Special characteristic: //SPACE = (TRK, (80),, CONTIG)
XXXX.PROB95

XXXX.BASIS85
XXXX.BASIS90 Basis files for LP
XXXX.BASIS95

Input Data Files ('GD' Files)

GDS Coal Supply Files
GDSX

GDU
GDUO Utility Sector Files
GDU1
GDU2
GDT - Transportation File
GDPART - Partial Scrubbing File
GDH - Historical Data File
GDL - Library File
GDC - Case File - Global Parameters

Revise Files

DATA.REV85 - 1985 revise deck created by GAMMA.REV85

GAMMA.REVISE - Revise program for the 1990 and 1995 case years; generates revise decks in YYYY.REV90 and YYYY.REV95

GAMMA Programs

GMG - Matrix generator program
THIN
THINNER - Programs to create SLIM and SMALL, respectively
GRW - Program to create LARGE report

GAMMA.REVISE - See above
GAMMA.REV85 - Program that generates DATA.REV85

JCL Files

GRACE85 - Contains the entire JCL to prepare data, to generate the LP matrix, to revise, convert, and solve the LP, and to extract and publish the SLIM, SMALL, and LARGE reports for 1985.

GRACE90 - Contains JCL to revise the LP matrix for the 1990 case year, to solve the LP, and to extract and publish the SLIM, SMALL, and LARGE reports for 1990

GRACE95 - Same as GRACE90 but for the 1995 case year

RAMCJCL - Contains the JCL to create GDS using the input file SUPIN; GDS is the file containing the coal supply curves
GRACE.REV - Contains the JCL to create DATA.REV85 from the GAMMA program GAMMA.REV85

Miscellaneous Files for Special Purposes

ALLOC - Creates space for a file whose name is used in place of "FILE"

CRPROBS - Creates space for Probfiles (special characteristics)

PRINTREP - Program to print output reports on line printer

UNCAT - Program to uncatalog a file

RESTORE - Program to restore a file that has been retired

WHIZ85 - Program used to solve the LP if, due to some problem in the system, the LP solution fails before an optimal solution is found
APPENDIX H

LISTING OF THE CEUM SUPPLY CODE AS CORRECTED BY EMAP
(CONSISTING OF THE SUPIN AND RAMC FILES)

Note: The corrections to the CEUM Base Case that were implemented to produce this "corrected" supply code relate to the verification errors detailed in Points 1, 5, 6a, 7, 8, 10, 14, 15, 18, 19, 20, 21, 22, 23 and 24 of Chapter 2.4.2.
GLOBAL PARAMETERS

CASE=1985 BASE CASE 8/11

SEAM THICKNESS VS MINE SIZE (PERCENT DISTRIBUTION) - DEEP MINE

<table>
<thead>
<tr>
<th>Size (Immt)</th>
<th>0.1</th>
<th>0.5</th>
<th>1.0</th>
<th>2.0</th>
<th>3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>54-45</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>45-65</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>36-40</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>29-36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

RECOVERY FACTOR: SURF=0.8 DEEP=0.6

MINE LIFE IN YEARS=SURF (1. MMT=20., SURF =>1. MMT=20.

CONTRACT LIFE YEARS=20

ICAP SURF= 17730. ICAP DEEP= 29300. DCAP SURF= 3200. DCAP DEEP= 11700.


$SV=$EV TAX $/CLEAN TON=00.00 $SV=$EV TAX RATE=0.00

$SD=$PMD SURF=78.04 $DD=$PMD DEEP=69.24

PSS=F&S SURF=1226. PDS=P&S DEEP=2835.

SWL=WELF FUND/TN SURF=72. DWL=WELF FUND/TN DEEP=0.72

CUT=COAP. TAX=0.50

RUT=UTILITY DISCOUNT RATE=0.100

APR=ANNUITY PRICE FACTOR=13.276

INS=EXPOSURE INSURANCE $/$100 PAYROLL COST SURF=00.00

IND=EXPOSURE INSURANCE $/$100 PAYROLL COST DEEP=00.00

TS=CLEAN TON YIELD, FRACTION OF RAW TONS SURF=0.85

TDD=CLEAN TON YIELD, FRACTION OF RAW TONS DEEP=0.80

MINE SIZE MM/TONS=4.0, 3.0, 2.0, 1.0, 0.5, 0.1

ENDPAR

ENDTABLE
FILE: ML20C  SUPIN A  CONVERSATIONAL MONITOR SYSTEM

JSN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.  SUP01110
CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)=00.56  SUP01120
DMR=DEMONSTRATED RESERVE DEPTH=  86. DEPTH=  17. SURF=  8.  SUP01130
CMR=COMMITTED RESERVE DEEP=002.15 SURF=005.36  SUP01140
TEXT  PROD PRCE SURF  SUP01150
CIHD CTR.01 .276 14.90 0.77  SUP01160
ENDCOAL  SUP01170
COAL TYPE HE $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.  SUP01180
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.  SUP01200
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.  SUP01210
CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)=00.56  SUP01220
DMR=DEMONSTRATED RESERVE DEPTH=  66. DEPTH=  30. SURF=  18.  SUP01230
ENDCOAL  SUP01240
COAL TYPE HF $ COAL
PRT=1  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.  SUP01250
KSW=1  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.  SUP01270
ISN=1  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.  SUP01280
CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)=00.56  SUP01290
DMR=DEMONSTRATED RESERVE DEPTH=  830. DEPTH=  3868. SURF=  218.  SUP01300
CMR=COMMITTED RESERVE DEEP=109.61 SURF=144.30  SUP01310
TEXT  PROD PRCE SURF  SUP01320
CIHF CTR.01 8.994 14.90 0.64  SUP01330
ENDCOAL  SUP01340
COAL TYPE HG $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.  SUP01350
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.  SUP01370
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.  SUP01380
CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)=00.56  SUP01390
DMR=DEMONSTRATED RESERVE DEPTH=  1258. DEPTH=  1578. SURF=  235.  SUP01400
CMR=COMMITTED RESERVE DEEP=439.57 SURF=160.45  SUP01410
TEXT  PROD PRCE SURF  SUP01420
CIHG CTR.01 19.49 14.90 0.33  SUP01430
ENDCOAL  SUP01440
COAL TYPE HH $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.  SUP01450
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.  SUP01470
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.  SUP01480
CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)=00.56  SUP01490
DMR=DEMONSTRATED RESERVE DEPTH=  84. DEPTH=  34. SURF=  0.  SUP01500
CMR=COMMITTED RESERVE DEEP=084.16 SURF=000.30  SUP01510
TEXT  PROD PRCE SURF  SUP01520
CIHH CTR.01 1.965 14.90 0.00  SUP01530
ENDCOAL  SUP01540
ENDREGION******* PA $ PENNSYLVANIA
TABLE OH $ OHIO  SUP01550
RCL=RECLAMATION COST  SUP01560
          1.59  2.63  3.49  SUP01570
          4.47  5.29  6.24  SUP01580
          9.10
          1.31  2.06  2.37  SUP01590
          3.38  3.97  4.65  SUP01600
          6.71
GBR=OVERBURDEN RATIO DISTR 0 MIN=17. MAX=46.  SUP01610
TSM=SEAM THICKNESS DISTR 0 MIN=28. MAX=60.  SUP01620
MDM 0 0 3 3 2 0 1 3 3 2 0 2 4 3 2 0 5 4 3 2  SUP01630
CONVERSATIONAL MONITOR SYSTEM

FILE: ML20C  SUPIN  A

DSM=SEAM DEPTH DISTR DR=00.0  D04=30.0  D07=35.0  D10=35.0
MSS=SURFACE MINE SIZE DISTR  SIX=33.4  33.3  33.3  00.0  00.0  00.0

OVR $SV=.04  TSD=41.4  TDD=18.2  INS=18.

OVR ISR=.21  IND=34.

ENDTABLE

COAL TYPE ZG $ COAL

PRT=0  THIS IS PRINT.W.IF=1,PRINT PRODUCTION AND CUM PROD.

KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.

ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)=00.56

DMR=DEMONSTRATED RESERVE DEEPTHN= 476.  DEEPTHK= 645.  SURF= 4.

CMR=COMMITTED RESERVE DEEP=003.27  SURF=000.53

TEXT PROD PRCE SURF

C1ZG  CTR.01  .109  13.04  0.17

ENDCOAL

COAL TYPE HF $ COAL

PRT=0  THIS IS PRINT.W.IF=1,PRINT PRODUCTION AND CUM PROD.

KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.

ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)=00.56

DMR=DEMONSTRATED RESERVE DEEPTHN= 3139.  DEEPTHK= 5619.  SURF= 2002.

CMR=COMMITTED RESERVE DEEP=000.00  SURF=024.94

TEXT PROD PRCE SURF

C1HG  CTR.01  .891  11.45  1.00

ENDCOAL

COAL TYPE HG $ COAL

PRT=0  THIS IS PRINT.W.IF=1,PRINT PRODUCTION AND CUM PROD.

KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.

ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)=00.56

DMR=DEMONSTRATED RESERVE DEEPTHN= 641.  DEEPTHK= 1536.  SURF= 362.

CMR=COMMITTED RESERVE DEEP= 0.59  SURF= 0.00

TEXT PROD PRCE SURF

C1HG  CTR.01  .891  11.45  1.00

ENDCOAL

COAL TYPE MF $ COAL

PRT=0  THIS IS PRINT.W.IF=1,PRINT PRODUCTION AND CUM PROD.

KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.

ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)=00.56

DMR=DEMONSTRATED RESERVE DEEPTHN= 154.  DEEPTHK= 13.  SURF= 32.

CMR=COMMITTED RESERVE DEEP=000.00  SURF=003.66

TEXT PROD PRCE SURF

C1MF  CTR.01  .130  11.17  1.00

ENDCOAL

COAL TYPE MG $ COAL

PRT=0  THIS IS PRINT.W.IF=1,PRINT PRODUCTION AND CUM PROD.

KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.

ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)=00.56

DMR=DEMONSTRATED RESERVE DEEPTHN= 154.  DEEPTHK= 13.  SURF= 32.

CMR=COMMITTED RESERVE DEEP=000.00  SURF=003.66

TEXT PROD PRCE SURF

C1MF  CTR.01  .130  11.17  1.00

ENDCOAL
### Table MD $ MARYLAND

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<thead>
<tr>
<th>Clean Cost</th>
<th>Surf</th>
<th>Text</th>
<th>Prod Price Surf</th>
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### Table OH $ OHIO

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### Table MD $ MARYLAND

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### Table OH $ OHIO

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**COAL TYPE MH $ COAL**

**COAL TYPE ZD $ COAL**

**COAL TYPE ZF $ COAL**

**COAL TYPE ZG $ COAL**
**CONVERSATIONAL MONITOR SYSTEM**

**DMR=DEMONSTRATED RESERVE DEPTHN= 50. DEEPHTH= 10. SURF= 19.**

**ENDCOAL**

**COAL TYPE HD $ COAL**

**PRT=0** THIS IS PNRCTR.IF=1,PRINT PRODUCTION AND CUM PROD.

**KSW=0** THIS IS KSW.IF=1,PRINT BALANCE SHEETS.

**ISN=0** THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

Cleansing Cost $/TON (FIXED) = 1.14 (VARIABLE) = 0.56

**DMR=DEMONSTRATED RESERVE DEPTHTH= 0. DEEPHTH= 0. SURF= 14.**

**CMR=COMMITTED RESERVE DEEP=044.22 SURF=007.98**

**TEXT**

**PROD PRC SURF**

**C1HD CTR.01 .292 11.10 1.00**

**ENDCOAL**

**ENDREGION*********** MD $ MARYLAND**

**TABLE NV $ W.VIRGINIA,NORTH**

**RCL=RECLAMATION COST**

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**OVR=OVERBURDEN RATIO DISTR 0 MIN=17. MAX=46.**

**TSM=SEAM THICKNESS DISTR 0 MIN=28. MAX=60.**

**MCM 0 2 3 2 0 2 3 2 0 2 3 2 0 2 4 3 2**

**DSM=SEAM DEPTH DISTR DR=05.0 D04=25.0 D07=35.0 D10=35.0**

**MSS=SURFACE MINE SIZE DISTR SIX=33.4 33.3 33.3 00.0 00.0 00.0**

**OVR SVT=.0385 TSD=.41.4 TDD=18.2**

**INS=6. OVR IND=.13. ISR=.25**

**ENDTABLE**

**ENDCOAL**

**COAL TYPE ZA $ COAL**

**PRT=0** THIS IS PNRCTR.IF=1,PRINT PRODUCTION AND CUM PROD.

**KSW=0** THIS IS KSW.IF=1,PRINT BALANCE SHEETS.

**ISN=0** THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

Cleansing Cost $/TON (FIXED) = 1.14 (VARIABLE) = 0.56

**DMR=DEMONSTRATED RESERVE DEPTHTH= 69. DEEPHTH= 51. SURF= 26.**

**CMR=COMMITTED RESERVE DEEP=041.92 SURF=002.75**

**OVR YTS=.70 YTD=.60**

**TEXT**

**PROD PRC SURF**

**C1ZA CTR.01 1.241 16.66 0.08**

**ENDCOAL**

**COAL TYPE ZB $ COAL**

**PRT=0** THIS IS PNRCTR.IF=1,PRINT PRODUCTION AND CUM PROD.

**KSW=0** THIS IS KSW.IF=1,PRINT BALANCE SHEETS.

**ISN=0** THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

Cleansing Cost $/TON (FIXED) = 1.14 (VARIABLE) = 0.56

**DMR=DEMONSTRATED RESERVE DEPTHTH= 690. DEEPHTH= 833. SURF= 229.**
<table>
<thead>
<tr>
<th>Coal Type</th>
<th>Production and Cum Prod.</th>
<th>Coal</th>
<th>Cleanin Cost ($/Ton)</th>
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<tbody>
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</table>
FILE: ML20C CONVERSATIONAL MONITOR SYSTEM

PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KS=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=Demonstrated Reserve DEPTHN= 13. DEPTHK= 57. SURF= 9.
CMR=Commited Reserve DEEP=017.39 SURF=002.56

TEXT

PROD PRICE SURF
C1HF CTR.01 .563 13.64 0.16
ENDCOAL

COAL TYPE HE $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KS=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=Demonstrated Reserve DEPTHN= 81. DEPTHK= 542. SURF= 32.
CMR=Commited Reserve DEEP=008.20 SURF=022.12

TEXT

PROD PRICE SURF
C1HF CTR.01 .931 13.64 0.82
ENDCOAL

COAL TYPE HG $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KS=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=Demonstrated Reserve DEPTHN= 199. DEPTHK= 1238. SURF= 99.
CMR=Commited Reserve DEEP=006.20 SURF=022.12

TEXT

PROD PRICE SURF
C1HF CTR.01 12.12 13.64 0.08
ENDCOAL

ENDREGION********** NV $ W.VIRGINIA,NORTH

TABLE SV $ W.VIRGINIA,SOUTH

RCL=RECLAMATION COST

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OBR=OVERBURDEN RATIO DISTR 0 MIN=12. MAX=46.
TSM=SEAM THICKNESS DISTR  0 MIN=28. MAX=54.
MCD= 1 1 2 2 2 2 2 2 3 3 3 3 3 3 2 4 4 3 2
DSM=SEAM DEPTH DISTR DR=05.0 DO4=25.0 D07=35.0 D010=35.0
MSS=Surface Mine Size DISTR SX=33.4 33.3 33.3 00.0 00.0 00.0
OVR SVT=.0385 TSD=32.4 TDD=17.3 INS=6.

ENDTABLE

COAL TYPE ZA $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KS=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.

SUP03860 SUP03870 SUP03880 SUP03890
SUP03900 SUP03910 SUP03920 SUP03930
SUP03940 SUP03950 SUP03960 SUP03970
SUP03980 SUP03990 SUP04000 SUP04010
SUP04020 SUP04030 SUP04040 SUP04050
SUP04060 SUP04070 SUP04080 SUP04090
SUP04100 SUP04110 SUP04120 SUP04130
SUP04140 SUP04150 SUP04160 SUP04170
SUP04180 SUP04190 SUP04200 SUP04210
SUP04220 SUP04230 SUP04240 SUP04250
SUP04260 SUP04270 SUP04280 SUP04290
SUP04300 SUP04310 SUP04320 SUP04330
SUP04340 SUP04350 SUP04360 SUP04370
SUP04380 SUP04390 SUP04400
| ISN=0  | THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE. | SUP04410 |
| CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56 | SUP04420 |
| DMR=DEMONSTRATED RESERVE DEPTHN= 109. DEEPHK= 19. SURF= 24. | SUP04430 |
| CMR=COMMITTED RESERVE DEEP=448.25 SURF=001.99 | SUP04440 |
| OVR YTS=.70 YTD=.60 | SUP04450 |
| TEXT PROD PRCE SURF | SUP04460 |
| C1ZA CTR.01 12.71 23.67 0.01 | SUP04470 |
| ENDCOAL | SUP04480 |
| COAL TYPE ZB $ COAL | SUP04490 |
| PRT=1 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD. | SUP04500 |
| KSW=1 THIS IS KSW.IF=1, PRINT BALANCE SHEETS. | SUP04510 |
| ISN=1 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE. | SUP04520 |
| CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56 | SUP04530 |
| DMR=DEMONSTRATED RESERVE DEPTHN= 2689. DEEPHK= 3935. SURF= 1867. | SUP04540 |
| CMR=COMMITTED RESERVE DEEP=078.15 SURF=152.35 | SUP04550 |
| OVR YTS=.70 YTD=.60 | SUP04560 |
| TEXT PROD PRCE SURF | SUP04570 |
| C1ZB CTR.01 8.038 23.67 0.73 | SUP04580 |
| ENDCOAL | SUP04590 |
| COAL TYPE ZD $ COAL | SUP04600 |
| PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD. | SUP04610 |
| KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS. | SUP04620 |
| ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE. | SUP04630 |
| CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56 | SUP04640 |
| DMR=DEMONSTRATED RESERVE DEPTHN= 963. DEEPHK= 1534. SURF= 323. | SUP04650 |
| CMR=COMMITTED RESERVE DEEP=137.02 SURF=026.18 | SUP04660 |
| OVR YTS=.70 YTD=.60 | SUP04670 |
| TEXT PROD PRCE SURF | SUP04680 |
| C1ZD CTR.01 4.866 23.67 0.21 | SUP04690 |
| ENDCOAL | SUP04700 |
| COAL TYPE ZE $ COAL | SUP04710 |
| PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD. | SUP04720 |
| KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS. | SUP04730 |
| ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE. | SUP04740 |
| CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56 | SUP04750 |
| DMR=DEMONSTRATED RESERVE DEPTHN= 172. DEEPHK= 161. SURF= 32. | SUP04760 |
| ENDCOAL | SUP04770 |
| COAL TYPE ZF $ COAL | SUP04780 |
| PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD. | SUP04790 |
| KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS. | SUP04800 |
| ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE. | SUP04810 |
| CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.00.56 | SUP04820 |
| DMR=DEMONSTRATED RESERVE DEPTHN= 574. DEEPHK= 674. SURF= 19. | SUP04830 |
| CMR=COMMITTED RESERVE DEEP=152.26 SURF=009.03 | SUP04840 |
| TEXT PROD PRCE SURF | SUP04850 |
| C1ZF CTR.01 4.637 20.71 0.08 | SUP04860 |
| ENDCOAL | SUP04870 |
| COAL TYPE HB $ COAL | SUP04880 |
| PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD. | SUP04890 |
| KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS. | SUP04900 |
| ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE. | SUP04910 |
| CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.00.56 | SUP04920 |
| DMR=DEMONSTRATED RESERVE DEPTHN= 145. DEEPHK= 457. SURF= 312. | SUP04930 |
| CMR=COMMITTED RESERVE DEEP=000.00 SURF=024.42 | SUP04940 |
| TEXT PROD PRCE SURF | SUP04950 |
FILE: ML20C  SUPIN  A  CONVERSATIONAL MONITOR SYSTEM  PAGE 010

C1HB CTR.01  .935 18.81 1.00
ENDCOAL

COAL TYPE HE $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=DEMONSTRATED RESERVE DEEPHN= 134. DEEPTHK= 54. SURF= 0.
CMR=COMMITTED RESERVE  DEEP=166.92  SURF=000.00

TEXT  PROD PRCE SURF
C1HB CTR.01 4.705 18.81 0.00

ENDCOAL

COAL TYPE HG $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=DEMONSTRATED RESERVE DEEPHN= 20. DEEPTHK= 95. SURF= 2.
CMR=COMMITTED RESERVE  DEEP=250.90  SURF=000.20

TEXT  PROD PRCE SURF
C1HG CTR.01 7.079 18.81 0.00

ENDREGION********** SV $ W.VIRGINIA,SOUTH

TABLE VA $ VIRGINIA
RCL=RECLAMATION COST
1.56  2.91  4.28
5.65  7.10  8.48
12.65 21.38 25.34
16.61 25.20 30.18
4.56  5.60  6.59
9.59 18.06 21.63

OVR=OVERBURDEN RATIO DISTR 0 MIN=12.  MAX=46.
TSM=SEAM THICKNESS DISTR  0 MIN=28.  MAX=54.
MDM 3 4 4 3 4 4 3 4 3 4 3 4 3 4 3 2
DSM=SEAM DEPTH DISTR DR=05.0  D04=25.0  D07=35.0  D10=35.0
MSS=SURFACE MINE SIZE DISTR  SIX=33. 33.3 33.3 00.0 00.0 00.0
OVR T50=32.4  INS=16.  IND=31.  ISR=.20

ENDTABLE

COAL TYPE ZA $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEPHN= 115. DEEPTHK= 78. SURF= 42.
CMR=COMMITTED RESERVE  DEEP=131.56  SURF=013.82

OVR YTS=.70  YTD=.60

TEXT  PROD PRCE SURF
C1ZA CTR.01 3.436 19.16 0.12

ENDCOAL

COAL TYPE ZB $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
CMR=DEMONSTRATED RESERVE DEEPHN= 748. DEEPTHK= 95. SURF= 326.
CMR=COMMITTED RESERVE  DEEP=000.00  SURF=074.07

SUP04960
SUP04970
SUP04980
SUP04990
SUP05000
SUP05010
SUP05020
SUP05030
SUP05040
SUP05050
SUP05060
SUP05070
SUP05080
SUP05090
SUP05100
SUP05110
SUP05120
SUP05130
SUP05140
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SUP05220
SUP05230
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SUP05260
SUP05270
SUP05280
SUP05290
SUP05300
SUP05310
SUP05320
SUP05330
SUP05340
SUP05350
SUP05360
SUP05370
SUP05380
SUP05390
SUP05400
SUP05410
SUP05420
SUP05430
SUP05440
SUP05450
SUP05460
SUP05470
SUP05480
SUP05490
SUP05500
CONVERSATIONAL MONITOR SYSTEM

OVR YTS=.70  YTD=.60
TEXT PROD   PRCE  SURF
CIZB CTR.01 2.263 19.16 1.00
ENDCOAL

COAL TYPE ZC $ COAL
PR0=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 16.  DEEPTHK= 0.  SURF= 9.
OVR YTS=.70  YTD=.60
ENDCOAL

COAL TYPE ZD $ COAL
PR0=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)= 0.56
CMR=COMMITTED RESERVE DEEP=019.31 SURF=032.15
OVR YTS=.70  YTD=.60
TEXT PROD   PRCE  SURF
CIZD CTR.01 1.423 19.16 0.69
ENDCOAL

COAL TYPE ZE $ COAL
PR0=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN=  2.  DEEPTHK= 10.  SURF= 7.
ENDCOAL

COAL TYPE ZF $ COAL
PR0=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 133.  DEEPTHK= 55.  SURF= 39.
CMR=COMMITTED RESERVE DEEP=241.81 SURF=012.87
TEXT PROD   PRCE  SURF
CIZF CTR.01 5.930 16.78 0.07
ENDCOAL

COAL TYPE HA $ COAL
PR0=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 33.  DEEPTHK= 8.  SURF= 6.
CMR=COMMITTED RESERVE DEEP=018.35 SURF=001.89
TEXT PROD   PRCE  SURF
C1HA CTR.01 .478 15.00 0.12
ENDCOAL

COAL TYPE HB $ COAL
PR0=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14  (VARIABLE)= 0.56

CONVERSATIONAL MONITOR SYSTEM

DMR=Demonstrated Reserve DEEPTHN= 53. DEEPHK= 248. SURF= 6.
CMR=Committed Reserve DEEP=000.00 SURF=033.18
TEXT
PROD PRCE SURF
C1HB CTR.01 1.013 15.00 1.00
ENDCOAL

COAL TYPE HC $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
CMR=Committed Reserve DEEP=076.91 SURF=018.04
TEXT
PROD PRCE SURF
C1HD CTR.01 2.312 15.00 2.24
ENDCOAL

COAL TYPE HD $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
CMR=Committed Reserve DEEP=076.91 SURF=018.04
TEXT
PROD PRCE SURF
C1HD CTR.01 2.312 15.00 2.24
ENDCOAL

COAL TYPE ZB $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=Demonstrated Reserve DEEPTHN= 1610. DEEPHK= 1529. SURF= 240.46
CMR=Committed Reserve DEEP=000.00 SURF=240.46
TEXT
PROD PRCE SURF
C1ZB CTR.01 7.863 16.39 1.00
ENDCOAL

COAL TYPE ZC $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=Demonstrated Reserve DEEPTHN= 380. DEEPHK= 279. SURF= 79.
CONVERSATIONAL MONITOR SYSTEM

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<th>OVR</th>
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<th>YTD=0.60</th>
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COAL TYPE ZD $ COAL

PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.

KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.

ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST$/TON (FIXED) = 1.14 (VARIABLE)= 0.56

DMR=DEMONSTRATED RESERVE DEEP= 460. DEPTHK= 258. SURF= 273.

CMR=COMMITTED RESERVE DEEP= 000.00 SURF= 070.09

OVR YTS=0.70 YTD=0.60

ENDCOAL

COAL TYPE ZE $ COAL

PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.

KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.

ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST$/TON (FIXED) = 1.14 (VARIABLE)= 0.56

DMR=DEMONSTRATED RESERVE DEEP= 174. DEPTHK= 215. SURF= 90.

CMR=COMMITTED RESERVE DEEP= 068.19 SURF= 024.50

ENDCOAL

COAL TYPE ZF $ COAL

PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.

KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.

ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST$/TON (FIXED) = 1.14 (VARIABLE)= 0.56

DMR=DEMONSTRATED RESERVE DEEP= 0. DEPTHK= 0. SURF= 54.

CMR=COMMITTED RESERVE DEEP= 068.19 SURF= 024.50

ENDCOAL

COAL TYPE ZG $ COAL

PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.

KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.

ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST$/TON (FIXED) = 1.14 (VARIABLE)= 0.56

DMR=DEMONSTRATED RESERVE DEEP= 400. SURF= 127.22

CMR=COMMITTED RESERVE DEEP= 000.00 SURF= 068.19

ENDCOAL

COAL TYPE H6 $ COAL

PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.

KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.

ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST$/TON (FIXED) = 1.14 (VARIABLE)= 0.56

DMR=DEMONSTRATED RESERVE DEEP= 71. DEPTHK= 226. SURF= 460.

CMR=COMMITTED RESERVE DEEP= 000.00 SURF= 127.22

ENDCOAL

COAL TYPE HC $ COAL

PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.

KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.

ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST$/TON (FIXED) = 1.14 (VARIABLE)= 0.56

DMR=DEMONSTRATED RESERVE DEEP= 70. DEPTHK= 14. SURF= 35.

ENDCOAL

COAL TYPE HO $ COAL

PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.

KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.

ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.

CLEANING COST$/TON (FIXED) = 1.14 (VARIABLE)= 0.56

DMR=DEMONSTRATED RESERVE DEEP= 70. DEPTHK= 14. SURF= 35.

ENDCOAL

SUP06610

SUP06620

SUP06630

SUP06640

SUP06650

SUP06660

SUP06670

SUP06680

SUP06690

SUP06700

SUP06710

SUP06720

SUP06730

SUP06740

SUP06750

SUP06760

SUP06770

SUP06780

SUP06790

SUP06800

SUP06810

SUP06820

SUP06830

SUP06840

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SUP06880

SUP06890

SUP06900

SUP06910

SUP06920

SUP06930

SUP06940

SUP06950

SUP06960

SUP06970

SUP06980

SUP06990

SUP07000

SUP07010

SUP07020

SUP07030

SUP07040

SUP07050

SUP07060

SUP07070

SUP07080

SUP07090

SUP07100

SUP07110

SUP07120

SUP07130

SUP07140

SUP07150
FILE: ML20C SUPIN A CONVERSATIONAL MONITOR SYSTEM PAGE 014

PRT=1, THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.
SUP07160
KSW=0, THIS IS KSW.IF=1, PRINT BALANCE SHEETS.
SUP07170
ISN=0, THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
SUP07180
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE)=00.56
SUP07190
CMR=COMMITTED RESERVE DEEP=171. DEEPTHK= 189. SURF= 158.
SUP07200
TEXT
SUP07210
PROD PRCE SURF
SUP07220
CIHD CTR.01 5.878 13.24 1.00
SUP07230
ENDCOAL
SUP07240
COAL TYPE HE $ COAL
PRT=0
SUP07250
KSW=0,
SUP07260
ISN=0
SUP07270
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
SUP07280
CMR=COMMITTED RESERVE DEEP=171. DEEPTHK= 189. SURF= 158.
SUP07290
TEXT
SUP07300
PROD PRCE SURF
SUP07310
CIHF CTR.01 20.60 13.24 0.15
SUP07320
ENDCOAL
SUP07330
COAL TYPE HF $ COAL
PRT=1
SUP07340
KSW=0
SUP07350
ISN=0
SUP07360
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
SUP07370
CMR=COMMITTED RESERVE DEEP=171. DEEPTHK= 189. SURF= 158.
SUP07380
TEXT
SUP07390
PROD PRCE SURF
SUP07400
CIHG CTR.01 3.772 13.24 0.15
SUP07410
ENDCOAL
SUP07420
COAL TYPE HG $ COAL
PRT=2
SUP07430
KSW=0
SUP07440
ISN=0
SUP07450
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
SUP07460
CMR=COMMITTED RESERVE DEEP=171. DEEPTHK= 189. SURF= 158.
SUP07470
TEXT
SUP07480
PROD PRCE SURF
SUP07490
CIHG CTR.01 3.772 13.24 0.15
SUP07500
ENDCOAL
SUP07510
ENDREGION*********** EK $ KENTUCKY, EAST
SUP07520
TABLE TN $ TENNESSEE
SUP07530
RCL=RECLAMATION COST
SUP07540
1.24 2.28 3.14
4.12 4.94 5.89
8.75
1.31 2.06 2.67
3.38 3.97 4.66
6.71
SUP07550
SUP07560
SUP07570
SUP07580
SUP07590
OBR=OVERBURDEN RATIO DISTR 0 MIN=12. MAX=46.
SUP07600
TSN=SEAM THICKNESS DISTR 0 MIN=28. MAX=54.
SUP07610
MOD 3 3 3 3 3 3 3 3 3 3 3 3 3 3
SUP07620
DSM=SEAM DEPTH DISTR D=05.0 D04=25.0 D03=35.0 D10=35.0
SUP07630
MSS=SURFACE MINE SIZE DISTR SIX=33.4 33.3 33.3 33.3 33.3 33.3 33.3 00.0 00.0 00.0 00.0 00.0
SUP07640
OVR $SV=.18 TSD=32.4 INS=.6 IND=.5
SUP07650
SUP07660
ENDTABLE
SUP07670
COAL TYPE ZB $ COAL
PRT=3
SUP07680
KSW=0
SUP07690
ISN=0
SUP07700
FILE: ML20C SUPIN A CONVERSATIONAL MONITOR SYSTEM

ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 103. DEEPTHK= 30. SURF= 45.
CMR=COMMITTED RESERVE DEEP=016.02 SURF=026.11
OVR YTS=.70 YTD=.60
TEXT PROD PRCE SURF
C1ZB CTR.01 1.178 14.26 0.69
ENDCOAL

COAL TYPE ZC $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 24. DEEPTHK= 2. SURF= 17.
CMR=COMMITTED RESERVE DEEP=000.00 SURF=003.07
OVR YTS=.70 YTD=.60
TEXT PROD PRCE SURF
C1ZD CTR.01 .095 14.26 1.00
ENDCOAL

COAL TYPE ZD $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 36. DEEPTHK= 4. SURF= 19.
CMR=COMMITTED RESERVE DEEP=000.00 SURF=003.07
OVR YTS=.70 YTD=.60
TEXT PROD PRCE SURF
C1ZD CTR.01 .095 14.26 1.00
ENDCOAL

COAL TYPE ZF $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56
CMR=COMMITTED RESERVE DEEP=000.00 SURF=003.07
OVR YTS=.70 YTD=.60
TEXT PROD PRCE SURF
C1ZD CTR.01 .095 14.26 1.00
ENDCOAL

COAL TYPE ZG $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 48. DEEPTHK= 36. SURF= 34.
CMR=COMMITTED RESERVE DEEP=000.00 SURF=003.07
OVR YTS=.70 YTD=.60
TEXT PROD PRCE SURF
C1ZD CTR.01 .371 11.95 1.00
ENDCOAL

COAL TYPE HD $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56
CMR=COMMITTED RESERVE DEEP=000.00 SURF=0 9.9E
TEXT PROD PRCE SURF
C1HD CTR.01 .371 11.95 1.00
ENDCOAL

COAL TYPE HE $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 12. DEEPTHK= 1. SURF= 5.
ENDCOAL
COAL TYPE HF $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 63. DEEPTHK= 10. SURF= 29.
CMR=COMMITTED RESERVE DEEP=026.61 SURF=023.28
TEXT PROD PRCE SURF
CIHF CTR.01 1.349 11.95 0.54
ENDCOAL
COAL TYPE HG $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 49. DEEPTHK= 36. SURF= 38.
CMR=COMMITTED RESERVE DEEP=002.61 SURF=023.28
RCL=RECLAMATION COST
1.15 2.18 3.04
4.02 4.84 5.80
8.66 8.66 8.66
1.34 2.09 2.70
3.41 4.00 4.68
6.74 6.74 6.74
OBR=OVERBURDEN RATIO DISTR
0 MIN=20. MAX=92.
TSM=SEAM THICKNESS DISTR
0 MIN=28. MAX=48.
MDM 2 3 4 3 2 2 3 4 3 2 2 3 4 3 2 3 4 3 2
DSM=SEAM DEPTH DISTR DR=05.0 D0=25.0 D0=35.0 D10=35.0
HSS=SURFACE MINE SIZE DISTR
SIX=33.4 33.3 33.3 00.0 00.0 00.0
OVR INS=.31 TD=41.4 TDD=18.2 INS=5.
OVR IN=23. IS=.31
OVR IND=.23. ISR=.17
EN thirsty
COAL TYPE ZZ $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 48. DEEPTHK= 2. SURF= 6.
OVR YTS=.70 YTD=.60
ENDCOAL
COAL TYPE ZD $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 225. DEEPTHK= 380. SURF= 21.
CMR=COMMITTED RESERVE DEEP=000.00 SURF=024.73
OVR YTS=.70 YTD=.60
TEXT PROD PRCE SURF
CIZD CTR.01 .964 20.34 1.00
ENDCOAL
COAL TYPE ZE $ COAL
PR=0 THIS IS PRNTR. IF=1, PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW. IF=1, PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS. IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEPTHN= 18. DEEPTHK= 0. SURF= 2.
ENDCOAL
COAL TYPE ZF $ COAL
PR=0 THIS IS PRNTR. IF=1, PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW. IF=1, PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS. IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEPTHN= 104. DEEPTHK= 77. SURF= 13.
CMR=COMMITTED RESERVE DEEP=023.53 SURF=034.73
ENDCOAL
COAL TYPE HB $ COAL
PR=0 THIS IS PRNTR. IF=1, PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW. IF=1, PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS. IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEPTHN= 283. DEEPTHK= 105. SURF= 25.
ENDCOAL
COAL TYPE HD $ COAL
PR=0 THIS IS PRNTR. IF=1, PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW. IF=1, PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS. IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEPTHN= 31. DEEPTHK= 41. SURF= 14.
CMR=COMMITTED RESERVE DEEP=000.00 SURF=065.54
ENDCOAL
COAL TYPE HF $ COAL
PR=0 THIS IS PRNTR. IF=1, PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW. IF=1, PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS. IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)= 0.56
CMR=COMMITTED RESERVE DEEP=125.49 SURF=102.77
ENDCOAL
TEXT PROD PRCE SURF
C1HD CTR.01 2.558 15.42 1.00
ENDCOAL
C1HF CTR.01 7.194 16.42 0.49
ENDCOAL
ENDREGION AL $ ALABAMA
TABLE IL $ ILLINOIS
RCL=RECLAMATION COST
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RCL=RECLAMATION COST
**CONVERSATIONAL MONITOR SYSTEM**

**COAL TYPE MF** $ COAL

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<td>10</td>
<td>38</td>
<td>80</td>
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<tr>
<td>SURF</td>
<td>134</td>
<td>134</td>
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**COAL TYPE MG** $ COAL

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<tr>
<th>CTR.</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>04</th>
</tr>
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<tbody>
<tr>
<td>PROD</td>
<td>27</td>
<td>10</td>
<td>38</td>
<td>80</td>
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<tr>
<td>SURF</td>
<td>134</td>
<td>134</td>
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**COAL TYPE MH** $ COAL

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<th>CTR.</th>
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<th>02</th>
<th>03</th>
<th>04</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROD</td>
<td>27</td>
<td>10</td>
<td>38</td>
<td>80</td>
</tr>
<tr>
<td>SURF</td>
<td>134</td>
<td>134</td>
<td>134</td>
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</tbody>
</table>

**CLEANING COST** $/TON (FIXED) = 1.14, (VARIABLE) = 0.56

**DMR=DEMONSTRATED RESERVE DEPTH**

**CMR=COMMITTED RESERVE DEEP**

**TABLE IN $ ILLINOIS**

<table>
<thead>
<tr>
<th>RBR=OVERBURDEN RATIO DISTR</th>
<th>0 MIN=16. MAX=69.</th>
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</thead>
<tbody>
<tr>
<td>TSM=SEAM THICKNESS DISTR</td>
<td>0 MIN=28. MAX=66.</td>
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<tr>
<td>OSM</td>
<td>0 0 0 0 0 0 0 0</td>
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<tr>
<td>ODR</td>
<td>0 0 0 0 0 0 0 0</td>
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<tr>
<td>ORR</td>
<td>0 0 0 0 0 0 0 0</td>
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**TEXT**

PROD PRCE SURF

**ENDTABLE**

**ENDREGION*********** IL $ ILLINOIS**

**FILE: ML2OC**

**SUPIN A**

**CONVERSATIONAL MONITOR SYSTEM**

**PAGE 019**

**SUP09910**

**SUP09920**

**SUP09930**

**SUP09940**

**SUP09950**

**SUP09960**

**SUP09970**

**SUP09980**

**SUP09990**

**SUP10000**

**SUP10010**

**SUP10020**

**SUP10030**

**SUP10040**

**SUP10050**

**SUP10060**

**SUP10070**

**SUP10080**

**SUP10090**

**SUP10100**

**SUP10110**

**SUP10120**

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**SUP10140**

**SUP10150**

**SUP10160**

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**SUP10180**

**SUP10190**

**SUP10200**

**SUP10210**

**SUP10220**

**SUP10230**

**SUP10240**

**SUP10250**

**SUP10260**

**SUP10270**

**SUP10280**

**SUP10290**

**SUP10300**

**SUP10310**

**SUP10320**

**SUP10330**

**SUP10340**

**SUP10350**

**SUP10360**

**SUP10370**

**SUP10380**

**SUP10390**

**SUP10400**

**SUP10410**

**SUP10420**

**SUP10430**

**SUP10440**

**SUP10450**

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**ENDREGION*********** IL $ ILLINOIS**

**TABLE IN $ ILLINOIS**

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<th>RCL=RECLAMATION COST</th>
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<tr>
<td>0.30</td>
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<td>0.41</td>
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<td>0.33</td>
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<td>0.39</td>
<td>0.40</td>
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<tr>
<td>0.35</td>
<td>0.39</td>
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<tr>
<td>0.43</td>
<td>0.39</td>
<td>0.40</td>
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**OBR=OVERBURDEN RATIO DISTR**

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<tr>
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<tbody>
<tr>
<td>0.14</td>
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<td>0.30</td>
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**OVERBURDEN RATIO DISTR:**

<table>
<thead>
<tr>
<th>0 MIN=16. MAX=69.</th>
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<tbody>
<tr>
<td>0.14</td>
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<tr>
<td>0.30</td>
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<td>0.35</td>
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<tr>
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**OVERBURDEN RATIO DISTR:**

<table>
<thead>
<tr>
<th>0 MIN=16. MAX=69.</th>
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<tbody>
<tr>
<td>0.14</td>
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<td>0.30</td>
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<td>0.25</td>
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<td>0.35</td>
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**FILE: ML20C**

**SUPIN A**

**CONVERSATIONAL MONITOR SYSTEM**

<table>
<thead>
<tr>
<th>KSW</th>
<th>THIS IS KSW.IF=1,PRINT BALANCE SHEETS.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISN</td>
<td>THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.</td>
</tr>
<tr>
<td>CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56</td>
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<tr>
<td>DMR=DEMONSTRATED RESERVE DEEPTHN= 256. DEEPThK= 1506. SURF= 581.</td>
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</tr>
<tr>
<td>CMR=COMMITTED RESERVE DEEP=000.00 SURF=000.79</td>
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</tr>
<tr>
<td>TEXT</td>
<td>PROD PCRE SURF</td>
</tr>
<tr>
<td>C1HG CTR.01</td>
<td>0.032 10.04 1.00</td>
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</tbody>
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**ENDCOAL**

**COAL TYPE HH $ COAL**

<table>
<thead>
<tr>
<th>PRT</th>
<th>THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.</th>
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<tr>
<td>KSW</td>
<td>THIS IS KSW.IF=1,PRINT BALANCE SHEETS.</td>
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<td>ISN</td>
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<td>CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56</td>
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<tr>
<td>DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPThK= 0. SURF= 10.</td>
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<tr>
<td>CMR=COMMITTED RESERVE DEEP=001.93 SURF=003.40</td>
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<tr>
<td>TEXT</td>
<td>PROD PCRE SURF</td>
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<td>C1HG CTR.01</td>
<td>0.193 10.04 0.70</td>
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**ENDCOAL**

**COAL TYPE MB $ COAL**

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<td>THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.</td>
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<td>CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56</td>
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<tr>
<td>DMR=DEMONSTRATED RESERVE DEEPTHN= 289. DEEPThK= 158. SURF= 255.</td>
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**ENDCOAL**

**COAL TYPE ME $ COAL**

<table>
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<tr>
<td>ISN</td>
<td>THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.</td>
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<tr>
<td>CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56</td>
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<tr>
<td>DMR=DEMONSTRATED RESERVE DEEPTHN= 27. DEEPThK= 156. SURF= 61.</td>
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</tr>
<tr>
<td>CMR=COMMITTED RESERVE DEEP=000.00 SURF=000.79</td>
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<tr>
<td>TEXT</td>
<td>PROD PCRE SURF</td>
</tr>
<tr>
<td>C1MF CTR.01</td>
<td>0.032 9.57 1.00</td>
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**ENDCOAL**

**COAL TYPE MF $ COAL**

<table>
<thead>
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<td>ISN</td>
<td>THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.</td>
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<tr>
<td>CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56</td>
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<tr>
<td>DMR=DEMONSTRATED RESERVE DEEPTHN= 720. DEEPThK= 2257. SURF= 289.</td>
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**SUP10460**

**SUP10470**

**SUP10480**

**SUP10490**

**SUP10500**

**SUP10510**

**SUP10520**

**SUP10530**

**SUP10540**

**SUP10550**

**SUP10560**

**SUP10570**

**SUP10580**

**SUP10590**

**SUP10600**

**SUP10610**

**SUP10620**

**SUP10630**

**SUP10640**

**SUP10650**

**SUP10660**

**SUP10670**

**SUP10680**

**SUP10690**

**SUP10700**

**SUP10710**

**SUP10720**

**SUP10730**

**SUP10740**

**SUP10750**

**SUP10760**

**SUP10770**

**SUP10780**

**SUP10790**

**SUP10800**

**SUP10810**

**SUP10820**

**SUP10830**

**SUP10840**

**SUP10850**

**SUP10860**

**SUP10870**

**SUP10880**

**SUP10890**

**SUP10900**

**SUP10910**

**SUP10920**

**SUP10930**

**SUP10940**

**SUP10950**

**SUP10960**

**SUP10970**

**SUP10980**

**SUP10990**

**SUP11000**
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<td>PRCE SURF</td>
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<td>C1MG CTR.01 12.78 9.57 1.00</td>
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<tr>
<td>ENDRREGION********** IN $ INDIANA</td>
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<tr>
<td>TABLE WK $ KENTUCKY.WEST</td>
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<tr>
<td>RCL=RECLAMATION COST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>.13 .30 .40 .22 .33 .40</td>
<td></td>
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<tr>
<td>OBR=OVERBURDEN RATIO DISTR</td>
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</tr>
<tr>
<td>0 MIN=16. MAX=67.</td>
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<tr>
<td>TSM=SEAM THICKNESS DISTR</td>
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<tr>
<td>0 MIN=24. MAX=66.</td>
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<td></td>
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<tr>
<td>MDM 0 0 3 2 0 0 4 3 2 0 0 4 3 2 0 0 4 3 2 0 0 4 3 2</td>
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<td></td>
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<tr>
<td>DSM=SEAM DEPTH DISTR</td>
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</tr>
<tr>
<td>DR=00.0 D04=30.0 D07=35.0 D10=35.0</td>
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<td>MSS=SURFACE MINE SIZE DISTR</td>
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<tr>
<td>SIX=20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0</td>
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<tr>
<td>ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.</td>
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<tr>
<td>CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)=0.06</td>
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<tr>
<td>CMR=DEMONSTRATED RESERVE DEEPHN=5. DEEPHK=5 SURF=55.</td>
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<td>C1HF CTR.01 116 9.86 1.00</td>
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<td>ENDCOAL</td>
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<tr>
<td>COAL TYPE HG $ COAL</td>
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<td>PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.</td>
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<td>KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.</td>
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<td>ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.</td>
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<tr>
<td>CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)=0.06</td>
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<td>CMR=DEMONSTRATED RESERVE DEEPHN=53. DEEPHK=5028. SURF=1230.</td>
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<td>CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)=0.06</td>
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<td>COAL TYPE MG $ COAL</td>
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<tr>
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<td>ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.</td>
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| CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)=0.06
FILE: ML20C CONVERSATIONAL MONITOR SYSTEM

DMR=DEMONSTRATED RESERVE DEEPTHN= 101. DEEPTHK= 168. SURF= 450. SUP11560
CMR=COMMITTED RESERVE DEEP=428.34 SURF=287.00 SUP11570
TEXT PROD PRCE SURF SUP11580
C1MG CTR.01 24.12 9.32 0.47 SUP11590
ENDCOAL SUP11600
COAL TYPE MH $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 0. SURF= 28.
ENDCOAL SUP11610
ENDECOAL SUP11620
ENDREGION********** WK $ KENTUCKY, WEST
TABLE IA $ IOWA
RCL=RECLAMATION COST
.19 .25 .31
.35 .40 .43
.46 .24 .28 .32
.35 .38 .40
.42
OBR=OVERBURDEN RATIO DISTR 0 MIN=23. MAX=46.
TSM=SEAM THICKNESS DISTR 0 MIN=28. MAX=54.
MDM 0 9 0 0 0 5 5 4 3 2 5 5 4 3 2 5 5 4 3 5 4 3 2
DSM=SEAM DEPTH DISTR DR=33.0 D04=35.0 D07=35.0 D10=35.0
MSS=_SURFACE MINE SIZE DISTA SIX=33.4 33.3 33.3 00.0 00.0 00.0
OVR TSD=46.8 TDD=19.7 INS=7. IND=26.
OVR ISR=.15
ENDTABLE SUP11700
ENDETABLE SUP11710
COAL TYPE MG $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 248. DEEPTHK= 503. SURF= 0.
ENDCOAL SUP11720
ENDREGION********** IA $ IOWA
TABLE MO $ MISSOURI
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 248. DEEPTHK= 503. SURF= 0.
ENDCOAL SUP11730
ENDREGION********** IA $ IOWA
TABLE MO $ MISSOURI
OVR YTS=.95 YTD=.95
ENDCOAL SUP11740
ENDREGION********** IA $ IOWA
TABLE MO $ MISSOURI
OVR YTS=.95 YTD=.95
ENDCOAL SUP11750
ENDREGION********** IA $ IOWA
TABLE MO $ MISSOURI
OVR YTS=.95 YTD=.95
ENDCOAL SUP11760
## Conversational Monitor System

### Reclamation Cost

<table>
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<th>RCL</th>
<th>$/Ton (Fixed)</th>
<th>$/Ton (Variable)</th>
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<tbody>
<tr>
<td>.15</td>
<td>.21</td>
<td>.27</td>
</tr>
<tr>
<td>.31</td>
<td>.36</td>
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### Overburden Ratio Distribution
- **Min**: 23, **Max**: 107

### Seam Thickness Distribution
- **Min**: 28, **Max**: 54

### Seam Depth Distribution
- **Min**: 205, **Max**: 35

### Surface Mine Size Distribution
- **Min**: 33, **Max**: 100

### Other Parameters
- **TSD**: 46.8
- **TDD**: 19.7
- **Ind**
- **OVR**
- **DISR**: 0.15
- **DSM**: Cleaning Cost $/Ton (Fixed): 1.14, $/Ton (Variable): 0.56
- **DMR**: Demonstrated Reserve
- **SURF**: 284

### Coal Type

- **HG**
- **HH**
- **MG**
- **MH**

###Other Information

- **DMR**: Demonstrated Reserve
- **SURF**: 298
- **OVR TSD**: 46.8
- **TDD**: 19.7

### Table for Kansas

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<th>$/Ton (Variable)</th>
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### Table for Missouri

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FILE: ML20C  SUPIN A

CONVERSATIONAL MONITOR SYSTEM

MDM 0 0 0 0 5 5 5 4 2 5 5 3 2 5 5 4 3 2
DSM=SEAM DEPTH DISTR DR=00.0 D04=30.0 D07=35.0 D10=35.0
MSS=SURFACE MINE SIZE DISTR SIX=50.0 50.0 00.0 00.0 00.0 00.0
OVR TSD=46.8 TDD=19.7 INS=8. IND=33.
OVR ISR=.15
ENDTABLE

COAL TYPE ZG $ COAL
PRT=O THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=DEMONSTRATED RESERVE DEPTHN= 0. DEEPHK= 0. SURF= 42.
ENDCOAL

COAL TYPE HF $ COAL
PRT=O THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=DEMONSTRATED RESERVE DEPTHN= 0. DEEPHK= 0. SURF= 112.
ENDCOAL

COAL TYPE HG $ COAL
PRT=O THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=DEMONSTRATED RESERVE DEPTHN= 0. DEEPHK= 0. SURF= 321.
CMR=COMMITTED RESERVE DEEP=000.00 SURF=016.07
TEXT Prod Price Surf
C1HG CTR.01 .485 9.52 1.00
ENDCOAL

COAL TYPE MH $ COAL
PRT=O THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=DEMONSTRATED RESERVE DEPTHN= 0. DEEPHK= 0. SURF= 54.
ENDCOAL

ENDREGION************ KS $ KANSAS

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RCL=RECLAMATION COST
.15 .21 .27
.31 .36 .38
.41 .46 .50
.52 .56 .57
.6

OBR=OVERBURDEN RATIO DISTR 0 MIN=23. MAX=107.
TSM=SEAM THICKNESS DISTR 0 MIN=28. MAX=54.
MDM 0 0 0 0 5 5 5 4 3 2 5 5 4 2 5 5 4 3 2
DSM=SEAM DEPTH DISTR DR=00.0 D04=30.0 D07=35.0 D10=35.0
MSS=SURFACE MINE SIZE DISTR SIX=50.0 50.0 00.0 00.0 00.0 00.0
OVR TSD=46.8 TDD=19.7 INS=6. IND=23.
OVR ISR=.15
ENDTABLE

COAL TYPE ZA $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.

PAGE 024
FILE: ML20C SUPIN A CONVERSATIONAL MONITOR SYSTEM

FILE: ML20C SUPIN A CONVERSATIONAL MONITOR SYSTEM

KSW=0 THIS IS KSW.1F=1, PRINT BALANCE SHEETS.
SUP13210
ISN=0 THIS IS ISENS.1F=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
SUP13220
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.056
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DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 0. SURF= 8.
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CMR=COMMUNTED RESERVE DEEP=000.00 SURF=002.53
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OVR YTS=0.70 YTD=0.60
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TEXT PROD PRCE SURF
SUP13270
C12A CTR.01 .073 13.51 1.00
SUP13280
ENDCOAL SUP13290

COAL TYPE ZB $ COAL

PRT=0 THIS IS PRNTR.1F=1, PRINT PRODUCTION AND CUM PROD.
SUP13300
KSW=0 THIS IS KSW.1F=1, PRINT BALANCE SHEETS.
SUP13310
ISN=0 THIS IS ISENS.1F=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
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CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.056
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DMR=DEMONSTRATED RESERVE DEEPTHN= 89. DEEPTHK= 8. SURF= 42.
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CMR=COMMUNTED RESERVE DEEP=000.00 SURF=001.57
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OVR YTS=0.70 YTD=0.60
SUP13360
TEXT PROD PRCE SURF
SUP13370
C12B CTR.01 .045 13.51 1.00
SUP13380
ENDCOAL SUP13390

COAL TYPE ZC $ COAL

PRT=0 THIS IS PRNTR.1F=1, PRINT PRODUCTION AND CUM PROD.
SUP13400
KSW=0 THIS IS KSW.1F=1, PRINT BALANCE SHEETS.
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ISN=0 THIS IS ISENS.1F=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
SUP13420
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.056
SUP13430
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 0. SURF= 16.
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CMR=COMMUNTED RESERVE DEEP=000.00 SURF=002.22
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OVR YTS=0.70 YTD=0.60
SUP13460
TEXT PROD PRCE SURF
SUP13470
C12C CTR.01 .060 13.51 1.00
SUP13480
ENDCOAL SUP13490

COAL TYPE ZD $ COAL

PRT=0 THIS IS PRNTR.1F=1, PRINT PRODUCTION AND CUM PROD.
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KSW=0 THIS IS KSW.1F=1, PRINT BALANCE SHEETS.
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ISN=0 THIS IS ISENS.1F=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
SUP13520
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.056
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DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 0. SURF= 68.
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CMR=COMMUNTED RESERVE DEEP=000.00 SURF=002.22
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OVR YTS=0.70 YTD=0.60
SUP13560
TEXT PROD PRCE SURF
SUP13570
C12D CTR.01 .060 13.51 1.00
SUP13580
ENDCOAL SUP13590

COAL TYPE ZE $ COAL

PRT=0 THIS IS PRNTR.1F=1, PRINT PRODUCTION AND CUM PROD.
SUP13600
KSW=0 THIS IS KSW.1F=1, PRINT BALANCE SHEETS.
SUP13610
ISN=0 THIS IS ISENS.1F=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
SUP13620
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.056
SUP13630
DMR=DEMONSTRATED RESERVE DEEPTHN= 1. DEEPTHK= 13. SURF= 7.
SUP13640
ENDCOAL SUP13650

COAL TYPE ZF $ COAL

PRT=0 THIS IS PRNTR.1F=1, PRINT PRODUCTION AND CUM PROD.
SUP13660
KSW=0 THIS IS KSW.1F=1, PRINT BALANCE SHEETS.
SUP13670
ISN=0 THIS IS ISENS.1F=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
SUP13680
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.056
SUP13690
DMR=DEMONSTRATED RESERVE DEEPTHN= 125. DEEPTHK= 76. SURF= 32.
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CMR=COMMUNTED RESERVE DEEP=000.00 SURF=018.44
SUP13710
OVR YTS=0.70 YTD=0.60
SUP13720
TEXT PROD PRCE SURF
SUP13730
C12F CTR.01 .052 13.51 1.00
SUP13740
ENDCOAL SUP13750
ENDCOAL
COAL TYPE ZG $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 0. SURF= 3.
ENDCOAL.

COAL TYPE HA $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 0. SURF= 3.

COAL TYPE HB $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 0. SURF= 3.

COAL TYPE HG $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 26. DEEPTHK= 58. SURF= 0.

COAL TYPE MG $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 0. SURF= 3.

ENDCOAL.

ENDREGION*********** OK $ OKLAHOMA
TABLE AR $ ARKANSAS
RCL=RECLAMATION COST
.18 .25 .31
.35 .36 .38
.41
.40 .44 .48
.51 .54 .56
.58
QBD=OVERBURDEN RATIO DISTR 0 MIN=23. MAX=46.
TSM=SEAM THICKNESS DISTR 0 MIN=28. MAX=54.
MOM 0 0 0 0 0 5 5 4 3 2 5 5 4 3 2 5 5 4 3 2
DSM=SEAM DEPTH DISTR DR=00.0 D04=30.0 D07=35.0 D10=35.0
MSS=SURFACE MINE SIZE DISTR SIX=50.0 50.0 00.0 00.0 00.0 00.0
OVR $SV=.02 TSD=46.8 TDD=19.7 INS= 9.
OVR IND=22. ISR=.15
ENDTABLE
CONVERSATIONAL MONITOR SYSTEM

COAL TYPE ZB $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1 ,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=DEMONSTRATED RESERVE DEPTHN= 0. DEEPThK= 0. SURF= 25.
GVR YTS=0.70 YTD=0.60
ENDCOAL

COAL TYPE ZD $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=3 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=DEMONSTRATED RESERVE DEPTHN= 10. DEEPThK= 30. SURF= 05.
GVR YTS=0.70 YTD=0.60
ENDCOAL

COAL TYPE ZE $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=* THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=DEMONSTRATED RESERVE DEPTHN= 136. DEEPThK= 133. SURF= 58.
GVR YTS=0.70 YTD=0.60
ENDCOAL

COAL TYPE ZF $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=3 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 1.14 (VARIABLE)=00.56
DMR=DEMONSTRATED RESERVE DEPTHN= 78. DEEPThK= 0. SURF= 01.
GVR YTS=0.70 YTD=0.60
ENDCOAL

ENDREGION******w****

FILE: ML20C SUPIN A

SUP14310
SUP14320
SUP14330
SUP14340
SUP14350
SUP14360
SUP14370
SUP14380
SUP14390
SUP14400
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SUP14420
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SUP15780
SUP15790
SUP15800

ENDTABLE

COAL TYPE LA $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 0.00 (VARIABLE)=00.00
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OVBDR=1  SEVEN=60.0 40.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
TEXT=PRICE SURF
CILD=498 3.10 1.00
ENDCOAL
ENDREGION
TABLE  MTNAST
RCL=RECLAMATION COST
.11  .17  .23
.27  .32  .34
.38  .14  .18
.20  .24  .28
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COAL TYPE MB $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEP=0.  DEPTHK=3357.  SURF=110.
OVR YTS=.85  YTD=.80
OVTSM=0  MIN=28.  MAX=102.
ENDCOAL
COAL TYPE MF $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEP=113.  DEPTHK=622.  SURF=0.
OVR YTS=.85  YTD=.80
OVTSM=0  MIN=28.  MAX=102.
ENDCOAL
COAL TYPE MG $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)=0.56
DMR=DEMONSTRATED RESERVE DEEP=75.  DEPTHK=234.  SURF=0.
OVR YTS=.85  YTD=.80
OVTSM=0  MIN=28.  MAX=102.
ENDCOAL
COAL TYPE SA $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)=0.00 (VARIABLE)=0.00
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CMR=COMMITTED RESERVE  DEEP=000.00  SURF=138.91
OVRBR=1 SEVEN=80.0 15.0 5.0 0.0 0.0 0.0 0.0
TEXT PROD PRICE SURF
CISA CTR.01 7096 3.38 1.00
ENDCOAL
COAL TYPE SB $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 18969. SURF= 7513.
CLEANING COST $/TON (FIXED)= 0.00 (VARIABLE)=00.00
CMR=COMMITTED RESERVE DEEP=000.00 SURF=269.46
OVRBR=1 SEVEN=80.0 15.0 5.0 0.0 0.0 0.0 0.0
TEXT PROD PRICE SURF
CISA CTR.01 13766 3.38 1.00
ENDCOAL
COAL TYPE SF $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 127. SURF= 0.
OVRBR=1 SEVEN=80.0 15.0 5.0 0.0 0.0 0.0 0.0
OVTSM=0 MIN=28. MAX=102.
ENDCOAL
ENREGION********** WM $ MONTANA,WEST
TABLE WY $ WYOMING
RCL=RECLAMATION COST
.11 .17 .23
.27 .32 .35
.38 .09 .13 .17
.20 .23 .25
.20
OVR=OVERBURDEN RATIO DISTR 0 MIN= 2. MAX=36.
TSM=SEAM THICKNESS DISTR 0 MIN=60. MAX=102.
MDM 0 0 0 0 0 5 5 4 3 2 5 5 3 2 5 5 4 3 2
DSM=SEAM DEPTH DISTR DR=00.0 DO=33.3 D0=33.3 D10=33.4
MSS=SURFACE MINE SIZE DISTR SIX=0.0 0.0 10.0 20.0 30.0 40.0
OVR SWT=.105 TSD=50.4 TDD=18.8 SWL=0.00
OVR DWL=0.00 YTS=.095 YTD=.095 INS=.14.
OVR ISD=24.0 ISR=.14 FSS=.125 FSD=.080
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COAL TYPE HB $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
DMR=DEMONSTRATED RESERVE DEEPTHN= 49. DEEPTHK= 507. SURF= 1000.
OVR YTS=.95 YTD=.80
OVTSM=0 MIN=28. MAX=102.
ENDCOAL
COAL TYPE MB $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)= 0.56
ENDCOAL
CONVERSATIONAL MONITOR SYSTEM

DMR=DEMONSTRATED RESERVE DEEPTHN= 9. DEEPTHK= 1815. SURF= 467. 
CMR=COMMUTTED RESERVE DEEP=000.00 SURF=147.28 
OVR YTS=.85 YTD=.60 
OVTSM=1 SIX=64.0 17.9 17.9 0.2 42.9 57.1 
TEXT PROD PRCE SURF 
C1MD CTR.01 7426 4.84 1.00 
ENDCOAL 

COAL TYPE MD $ COAL 
PRM=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD. 
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS. 
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE. 
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)= 0.56 
DMR=DEMONSTRATED RESERVE DEEPTHN= 788. DEEPTHK= 2887. SURF= 1116. 
CMR=COMMUTTED RESERVE DEEP=000.00 SURF=052.46 
OVR YTS=.85 YTD=.80 
OVTSM=1 SIX=50.3 20.3 20.3 9.1 42.9 57.1 
TEXT PROD PRCE SURF 
C1MD CTR.01 2645 4.84 1.00 
ENDCOAL 

COAL TYPE MF $ COAL 
PRM=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD. 
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS. 
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE. 
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)= 0.56 
DMR=DEMONSTRATED RESERVE DEEPTHN= 18. DEEPTHK= 6.9. SURF= 
OVR YTS=.85 YTD=.80 
OVTSM=1 SIX=49.4 21.5 21.5 7.6 42.9 57.1 
ENDCOAL 

COAL TYPE MH $ COAL 
PRM=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD. 
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS. 
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE. 
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)= 0.56 
DMR=DEMONSTRATED RESERVE DEEPTHN= 10. DEEPTHK= 48. SURF= 
OVR YTS=.85 YTD=.80 
OVTSM=1 SIX=49.9 25.8 25.8 2.5 42.9 57.1 
ENDCOAL 

COAL TYPE SA $ COAL 
PRM=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD. 
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS. 
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE. 
CLEANING COST $/TON (FIXED)= 0.00 (VARIABLE)=00.00 
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 11035. SURF= 1812. 
CMR=COMMUTTED RESERVE DEEP=000.00 SURF=000.95 
OVR YTS=1 SEVEN=80.0 15.0 5.0 0.0 0.0 0.0 0.0 
TEXT PROD PRCE SURF 
C1SA CTR.01 4B 3.82 1.00 
ENDCOAL 

COAL TYPE SB $ COAL 
PRM=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD. 
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS. 
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE. 
CLEANING COST $/TON (FIXED)= 0.00 (VARIABLE)=00.00 
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 3716. SURF= 32. 
CMR=COMMUTTED RESERVE DEEP=000.00 SURF=163.03 

FILE: ML120C SUPIN A CONVERSATIONAL MONITOR SYSTEM PAGE 032
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**Coal Type HC**

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**Coal Type HD**

- PRODUCT PRICE: $/MTR
- CLEANING COST:
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**Coal Type HF**

- PRODUCT PRICE: $/MTR
- CLEANING COST:
  - FIXED: 1.14
  - VARIABLE: 0.56

**Coal Type MA**

- PRODUCT PRICE: $/MTR
- CLEANING COST:
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  - VARIABLE: 0.56

**Coal Type M3**

- PRODUCT PRICE: $/MTR
- CLEANING COST:
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**Coal Type MF**

- PRODUCT PRICE: $/MTR
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FILE: ML20C  SUPIN  A  CONVERSATIONAL MONITOR SYSTEM

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FILE: ML20C SUPIN A CONVERSATIONAL MONITOR SYSTEM

PRT=0 THIS IS PRTNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)= 0.55
DMR=DEMONSTRATED RESERVE DEEPHTH= 4. DEEPTHK= 3. SURF= 0.
OVR YTS=.85 YTD=.70
ENDCOAL

COAL TYPE HA $ COAL

PRT=0 THIS IS PRTNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPHTH= 431. DEEPTHK= 950. SURF= 0.
OVR YTS=.85 YTD=.80
ENDCOAL

COAL TYPE H3 $ COAL

PRT=0 THIS IS PRTNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPHTH= 6. DEEPTHK= 1. SURF= 0.
OVR YTS=.85 YTD=.80
ENDCOAL

COAL TYPE HD $ COAL

PRT=0 THIS IS PRTNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPHTH= 8. DEEPTHK= 3. SURF= 0.
OVR YTS=.85 YTD=.80
ENDCOAL

COAL TYPE MB $ COAL

PRT=0 THIS IS PRTNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)= 0.56
DMR=DEMONSTRATED RESERVE DEEPHTH= 0. DEEPTHK= 114. SURF= 250.
CMR=COMMITTED RESERVE DEEP=000.00 SURF=010.64
OVR YTS=.85 YTD=.80
TEXT PROD PRCE SURF
C1MBCTR.01 528 4.19 1.00
ENDCOAL

COAL TYPE MC $ COAL

PRT=0 THIS IS PRTNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)=1.14 (VARIABLE)= 0.56
CMR=COMMITTED RESERVE DEEP=026.84 SURF=151.73
OVR YTS=.85 YTD=.80
OVTSM=1 SIX=45.0 26.9 26.9 0.2 42.9 57.1
ENDCOAL

COAL TYPE MD $ COAL

PRT=0 THIS IS PRTNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
COAL TYPE MF $ COAL

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## Clean-up Costs

- **$/TON (Fixed)** = 1.14
- **$/TON (Variable)** = 0.56

## Reserve Information

- **DEEPTHN** = 0
- **DEEPTHK** = 12

## Surf Information

- **OVR YTS** = 0.80
- **YTD** = 0.70

---

## Coal Type HS $ COAL

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## Clean-up Costs

- **$/TON (Fixed)** = 1.14
- **$/TON (Variable)** = 0.56

## Reserve Information

- **DEEPTHN** = 2
- **DEEPTHK** = 76

## Surf Information

- **OVR YTS** = 0.80
- **YTD** = 0.70

---

## Coal Type MA $ COAL

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## Clean-up Costs

- **$/TON (Fixed)** = 1.14
- **$/TON (Variable)** = 0.56

## Reserve Information

- **DEEPTHN** = 28
- **DEEPTHK** = 102

## Surf Information

- **OVR YTS** = 0.95
- **YTD** = 0.95
CONVERSATIONAL MONITOR SYSTEM

COAL TYPE MB $ COAL
PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED) = 1.14 (VARIABLE) = 0.00
DMR=DEMONSTRATED RESERVE DEPTHPH= 0. DEPTHK= 1. SURF= 0.
CVR YST= .80 YTD= .70
ENDCOAL

COAL TYPE SA $ COAL
PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED) = 0.00 (VARIABLE) = 0.00
DMR=DEMONSTRATED RESERVE DEPTHPH= 0. DEPTHK= 2. SURF= 0.
ENDCOAL

COAL TYPE SD $ COAL
PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED) = 0.00 (VARIABLE) = 0.00
DMR=DEMONSTRATED RESERVE DEPTHPH= 0. DEPTHK= 0. SURF= 0.
ENDCOAL

COAL TYPE SG $ CCAL
PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED) = 0.00 (VARIABLE) = 0.00
DMR=DEMONSTRATED RESERVE DEPTHPH= 0. DEPTHK= 0. SURF= 0.
ENDCOAL

ENDREGION********* WA $ WASHINGTON

TABLE TX $ TEXAS
RCL=RECLAMATION COST

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<th>OVR DWL</th>
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OVR=OVERBURDEN RATIO DISTR 0 MIN= 4. MAX=16.
TSM=SEAM THICKNESS DISTR 0 MIN= 20. MAX=54.
MOM=0 0 0 0 0 5 5 4 3 2 5 5 4 3 2 5 4 3 2
OVR=OVERBURDEN DISTR DR=0.0 00=30. 007=35.0 D10=35.0
MS=SEAM THICKNESS DISTR 0 MIN= 20. MAX=54.

ENDTABLE

COAL TYPE LF $ COAL
PRT=0 THIS IS PRNTR.IF=1, PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1, PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1, PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED) = 0.00 (VARIABLE) = 0.00
DMR=DEMONSTRATED RESERVE DEPTHPH= 0. DEPTHK= 0. SURF= 2828.
CMR=COMMITTED RESERVE DEEP= 0.00 SURF= 187.50
ENDCOAL
**FILED ML20C SUPIN A CONVERSATIONAL MONITOR SYSTEM PAGE 041**

VOBR=1 SEVEN=60.0 40.0 0.0 0.0 0.0 0.0 0.0 0.0 TEXT=PROD PICE SURF C1LFCTR.01 10007 2.47 1.00 ENDCOAL ENDREGION******** TX $ TEXAS TABLE CN $ COLORADO,NORTH RCL=RECLAMATION COST

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OBR=OVERBURNED RATIO DISTR 0 MIN= 2. MAX=21.
TSM=SEAM THICKNESS DISTR 0 MIN=60. MAX=102.
MDM 0 0 0 0 0 0 5 5 4 3 2 5 5 4 3 2 5 4 3 2
DSM=SEAM DEPTH DISTR DR=00.0 D04=33.3 D07=33.3 D10=33.4
MSS=SURFACE MINE SIZE DISTR SIX=00.0 5.0 10.0 20.0 30.0 30.0 40.0 0.0

OVR $SV=.26 TSD=54.0 TDD=18.8 SWL=0.0 OVR DWL=0.0
OVR DLY=.09 INS=8. IND=22. YTS=.09 YTD=.09

ENDTABLE

COAL TYPE SA $ COAL
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 0.00 (VARIABLE)=0.00
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEPTHK= 295. SURF= 115.
CMR=COMMITTED RESERVE DEEPTHN= 9.30 DEEP=0 SURF=0 9.25

OVOBR=1 SEVEN=80.0 15.0 5.0 0.0 0.0 0.0

TEXT=PROD PICE SURF C1SACTR.01 1031 3.82 0.58

ENDCOAL

**COAL TYPE SD $ COAL**
PRT=0 THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0 THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0 THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED)= 0.00 (VARIABLE)=0.00
DMR=DEMONSTRATED RESERVE DEEPTHN= 0. DEEP=249.
CMR=COMMITTED RESERVE DEEPTHN= 9.30 SURF=0 9.30

OVOBR=1 SEVEN=80.0 15.0 5.0 0.0 0.0 0.0

ENDCOAL

ENDREGION******** CN $ COLORADO,NORTH

**TABLE AK $ ALASKA**

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OBR=OVERBURNED RATIO DISTR 0 MIN= 2. MAX=92.
TSM=SEAM THICKNESS DISTR 0 MIN=60. MAX=102.
DM 0 0 0 0 0 0 5 5 4 3 2 5 5 4 3 2 5 4 3 2
DSM=SEAM DEPTH DISTR DR=00.0 D04=33.3 D07=33.3 D10=33.4
MSS=SURFACE MINE SIZE DISTR SIX=05.0 5.0 30.0 30.0 30.0 00.0

OVR SV=.02 TSD=54.0 TDD=18.8 SWL=0.0 OVR DWL=0.0
OVR DLY=.09 INS=13. IND=36. YTS=.09 YTD=.09

ENDTABLE
FILE: ML20C  SUPIN  A  CONVERSATIONAL MONITOR SYSTEM  PAGE 042

DVR YTD=0.95
ENDTABLE
COAL TYPE SA $ COAL
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
CLEANING COST $/TON (FIXED) = 0.00 (VARIABLE) = 00.00
CMR=Demonstrated Reserve DEEP=0. DEPTHK= 2348. SURF= 38.
CMR=Committed Reserve DEEP=000.00 SURF=015.62
TEXT PROD PRCE SURF
ENDCOAL
ENDREGION********** AK $ ALASKA
ENDDATA
PRT=0  THIS IS PRNTR.IF=1,PRINT PRODUCTION AND CUM PROD.
KSW=0  THIS IS KSW.IF=1,PRINT BALANCE SHEETS.
ISN=0  THIS IS ISENS.IF=1,PRINT LOOK-AHEAD PRICES FOR MINE LIFE.
**CONVERSATIONAL MONITOR SYSTEM**

```fortran
REAL ISRC, ISRR, ISRG, IDRC, IDRR, IDRG
REAL MDM
INTEGER PRKTR

C
COMMON /COEF,CCEFL,CCF2,PIES
DIMENSION ICASE(5),S,M/NS(5,5),RECFCT(2),A(4),B(25),C(25),
2 CDFPR(25),CFSPCF(5),COMPT(4),CARO(20),HDTAB(8),
3 TEXT(9),BRDNR(6),SMTHR(6),SMDPR(4),SIZER(6),DEMR(3),
4 CINTD(2),BRDNC(7),SNTCH(6),SMDPC(4),SICE(6),ALPHA(4),
5 VALUE(4),TYPE(4),PROD(3),T2(8),T3(13),T4(10),
6 BB(6),SZELET(6),BDNLET(7),THKLET(5),
7 DIPLET(4),RESREQ(2,6),INTER(33),TEPSZ(5),
8 TEMP2(6),THKKN(6),
9 TDARG(5,5,4),KMARG(4,5)
DIMENSION DPSIDT(5,6)

C
COMMON /COST/,SIZMIN(6),RECL(14),MLIFE(2,2),CLEAN(2),ASZ(2,6),
2 RUT,ISENS,APFAC
C
DATA MDM,FSDS,FSDO/'MDM','FSD'/
C
DATA IN,KIO,KOUT,IPRT,KINTER/21,22,23,31,32/
C
DATA ENDPRM,ENDTEN,'END''EPR','END''EPR'
C
DATA ENDPB,ENDTAB,ENDRGN,ENDCOL,ENDALL,TOPLER,OBJ,THKSM,
2 RIDE,BLNK,COAL
3 /'ENDP','ENDD'/'ENR',/ 'ENDC',/ 'ENDD',/ 'TABLE',/ 'OBJ',/ 'TSM',
4 'OVR',/ 'COAL'/
C
DATA MXOVR/25/
C
DATA COMP/'ISR','ECP','EMP','EPS','ROR',
5 /'N/A','SVT','SSD','FD0','TSD','TDD','PSS','PDS',
6 'LIC','RTL','SWL','DWA','SWD','DWD','CTX','IDR',
7 'INS','IND','YTS','YTD'/
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C
DATA COMPC/'OVOB','OVTS','OVDS','OVMS','TEXT'/
C
DATA COMPT/'C','S','X','E'/,'RCL'/'RCL'/
C
DATA AXE,DSM,SWITCH,XISN,XPRH/X','DSM','KSW','ISN,'
C
EQUIVALENCE (T3(1),BRDNC(1)),(T3(8),SICE(1)),
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C
EQUIVALENCE (B(1),ISRG), (C(1),ISRR), (B(21),IDRG), (C(21),IDRR),
2 (A(1),CAPIS),(A(2),CAPID),(A(3),CAPDS),(A(4),CAPDD),
```
PROGRAM NAME FSRAMC

AUTHOR PAL KHERA OF THC, AND PHIL CHILDRESS OF FEA

DATE FEBRUARY 1976

PURPOSE CALCULATE POSSIBLE NEW MINES AND PREPARE PARTIAL INPUT FOR LP TO DEVELOP THE COAL MODEL

SUBROUTINES CALLED

OBDN (BY PAL) ASSIGN DISTRIBUTION OF OVERBURDEN RATIOS FOR SURFACE MINES FOR PARAMS SEE THE SUBROUTINE INC

STHK (BY PAL) ASSIGN SEAM THICKNESS RATIOS FOR DEEP MINES FOR PARAMS SEE THE SUBROUTINE INC

MC (BY PHIL) COSTING AND SELECTION OF NEW MINES BASED ON THEIR ASSIGNED COSTS FOR PARAMS SEE BELOW

INPUT SEE FILE RP2.SUPIN.DATA

OUTPUT IN A FORMAT SUITABLE FOR LP

LIST OF PARAMS FOR SUBROUTINE 'MC' FOR MINE COSTING

CALL MC(ICASE,KSW,KIO,KOUT,CT,ECAP,EMP,EPAS,ROR,IBASYS,
ICASYR,SEVT,SVT$C,TPMD5,TPMDD,TPMDC,P3$,$P3D,
CAPIS,CAPID,CAPDS,CAPDD,TXIC,ROY,SWEL,DWEL,CTAX,
MCYR,ESCALI,CUM,PRNTR,XINSS,XINSD,YIELD5,YIELDDD)

PARAM INFORMATION

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C LIST OF PARAMS FOR SUBROUTINE 'MC' FOR MINE COSTING

CALL MC(ICASE,KSW,KIO,KOUT,CT,ECAP,EMP,EPAS,ROR,IBASYS,
ICASYR,SEVT,SVT$C,TPMD5,TPMDD,TPMDC,P3$,$P3D,
CAPIS,CAPID,CAPDS,CAPDD,TXIC,ROY,SWEL,DWEL,CTAX,
MCYR,ESCALI,CUM,PRNTR,XINSS,XINSD,YIELD5,YIELDDD)

PARAM INFORMATION

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FILE: RAMCC FORTRAN A 
CONVERSATIONAL MONITOR SYSTEM

CT COAL TYPE (MC, SF, ETC) A2 NEI01110
MLIFE MINE LIFE IN YEARS SURF/DEEP NEI01130
ECAP ESCALATOR FOR CAPITAL NEI01140
EMP ESCALATOR FOR HUMAN RESOURCES NEI01150
EPAS ESCALATOR FOR POWER AND SUPPLY NEI01160
ROR RATE OF RETURN NEI01170
IBASYR BASE YEAR (E.G., 1975) NEI01180
ICASYR CASE YEAR (E.G., 1980) NEI01190
RECL RECLAMATION COST $/TON NEI01200
CLEAN CLEANING COST (FIXED AND VARIABLE) NEI01210
RUT UTILITY DISCOUNT RATE NEI01220
ISENS SWITCH TO PRINT COSTS FOR ALL YEARS NEI01230
APFAC ANNUITY PRICE FACTOR FOR ANNUITY NEI01240
SEVT SEVERANCE TAX (FIXED) / COST/ NEI01250
SEVT$C SEVERANCE TAX $/CLEAN TON OF COAL NEI01260
SMDS $/MAN DAY SURFACE MINES NEI01270
SPMDD $/MAN DAY DEEP MINES NEI01280
TPMDS TONS/MAN DAY SURFACE MINES NEI01290
TPMDD TONS/MAN DAY DEEP MINES NEI01300
PSD POWER & SUPPLIES SURFACE MINES NEI01310
PSD POWER & SUPPLIES DEEP MINES NEI01320
CAPIS INITIAL CAPITAL SURFACE MINES NEI01330
CAPID INITIAL CAPITAL DEEP MINES NEI01340
CAPDS DEFFERED CAPITAL SURFACE MINES NEI01350
CAPDD DEFFERED CAPITAL DEEP MINES NEI01360
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NEI011500
NEI011510
NEI011520
NEI011530
NEI011540
NEI011550
NEI011560
NEI011570
NEI011580
NEI011590
NEI011600
NEI011610
NEI011620
NEI011630
NEI011640
NEI011650
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C XLIC  LICENSE FEE PER TON  F4.2  C(14)  NE101660
C ROY  ROYALTY FEE PER TON  F4.2  C(15)  NE101670
C SWEL  WELFARE FUND SURFACE MINES  F4.2  C(16)  NE101690
C DWEL  WELFARE FUND DEEP MINES  F4.2  C(17)  NE101700
C CTAX  CORPORATE TAX  F4.2  C(18)  NE101720
C MCYR  CONTRACT TERM, YEARS  I2  NE101730
C ESCAL1  ESCALATOR TO CASE YEAR  NE101740
C PRNTR  SWITCH TO PRINT PRODUCTION, 1-YES, 0-NO  NE101750
C XINSS  EXPOSURE INSURANCE SURF  F5.2  C(22)  NE101760
C XINSD  EXPOSURE INSURANCE DEEP  F5.2  C(23)  NE101770
C YIELDS  CLEAN COAL YIELD FRACTION SURF  F4.2  C(24)  NE101780
C YIELDD  CLEAN COAL YIELD FRACTION DEEP  F4.2  C(25)  NE101790
C
DATA  BDWLET/'05','10','15','20','25','30','45'/, NE101800
2  THKLET/'72','60','48','36','28'/, NE101810
3  DIPLLET/'00','04','07','10'/, NE101820
4  THKMN/'72','60','48','42','36','28'/, NE101830
C  SWEL  WELFARE FUND SURFACE MINES  F4.2  C(16)  NE101690
C  DIEL  DEEP MINES  F4.2  C(17)  NE101700
C  CTAX  CORPORATE TAX  F4.2  C(18)  NE101710
C  MCYR  CONTRACT TERM, YEARS  I2  NE101720
C  ESCAL1  ESCALATOR TO CASE YEAR  NE101730
C  PRNTR  SWITCH TO PRINT PRODUCTION, 1-YES, 0-NO  NE101740
C  XINSS  EXPOSURE INSURANCE SURF  F5.2  C(22)  NE101750
C  XINSD  EXPOSURE INSURANCE DEEP  F5.2  C(23)  NE101760
C  YIELDS  CLEAN COAL YIELD FRACTION SURF  F4.2  C(24)  NE101770
C  YIELDD  CLEAN COAL YIELD FRACTION DEEP  F4.2  C(25)  NE101780
C  KSTD = 20
C  LOOK FOR PRINT SWITCH
C  1 IN COL 20 OF 1ST CARD MEANS PRINT ALL
C  1 IN COL 30 OF 1ST CARD MEANS PIES DATA (OUTPUT ICAP & DCAP)
C
READ(IN,198)II,IPIES
198 FORMAT(19X,I1,9X,II)
   IF(II.NE.1) GO TO 19
   REWIND IN
   PRINT 199
199 FORMAT(1H1)
   READ(IN,9050,END=19)CARD
   PRINT 201,CARD
   GO TO 18
   19 REWIND IN
C  GLOBAL PARAMS
C
20 READ(IN,8010,END=2650,ERR=40) ICASE,((STHMNS(I,J),J=1,5),I=1,5), NE101800
   RECFC1.1,M1F2.E1,MCYR,A,B(21),(B(I),=1.5),IBS1YR,ICAS1YR, NE101810
   SVT$G,(B(I),I=7,20),RUT,APFAC  NE101820
READ RATES FOR EXPOSURE INSURANCE AND YIELD OF CLEAN TONS

DO 21 I = 22, MXOVR
21   B(I) = 0.0

22   KSTT = 22
       READ(IN,5070,END=2650,ERR=40) AA
       BACKSPACE IN

DO 23 I = 22, MXOVR
23   CONTINUE
       IF (AA .EQ. COMPR(I)) GO TO 24

24   KSTT = 24
       READ(IN,8012,END=2650,ERR=40) B(I)
       GO TO 22

4020 CONTINUE

XNYR = ICASYR - IBASYR
ECAP = B(2)
ALC = ALOG(1. + ECAP)
ALC1 = ALC * (XNYR/2.)
ALC2 = ALC * (XNYR/4.) + ALOG(XNYR/40.)
PRINT 19711, ECAP, XNYR, ALC, ALC1, ALC2
19711 FORMAT(' ECAP=',FIO.3,' XNYR=',FIO.3, ' ALC=',FIO.3, ' ALC1=',FIO.3, ' ALC2=',FIO.3)

THE FACTORS COEF1 & COEF2 RELATE TO AN OLDER VERSION
OF THE CODE AND HAVE NO DIRECT RELATIONSHIP
TO THE CURRENT PRODUCTION AND PRICE (RACP) OUTPUT OF RAMC
COEF1 = EXP(ALC1)
COEF2 = EXP(ALC2)
PRINT 19712, COEF1, COEF2
19712 FORMAT(' COEF1 ',2E10.3)

READ MINESIZE AND LETTER ASSOCIATED THEREWITH

DIMENSION IDTTT(18)
WRITE(6,7701)
7701 FORMAT('PLEASE ENTER RUN IDENTIFIER: /)
       READ(5,7702) IDTTT
       WRITE(KOUT,7702) IDTTT
7702 FORMAT(18A4)

(END OF MIT INSERT)

WRITE(KOUT,197) COEF1, COEF2
197 FORMAT('ELEMENT GDS',10X,'$ COEF1 ',FIO.3,' COEF2 ',FIO.3)

READ MINE SIZE AND LETTER ASSOCIATED THEREWITH
NOTE: ISEN, WHICH WAS READ HERE, NO IN INPUT FOR COAL

TYPR FOLLOWING COAL TYPE HEADER CARD.

READ(IN,8015,END=2650,ERR=40) SZEMIN
READ(IN,8020,END=2650,ERR=40) SZELET

TRANSFER MINE SIZE AND MINE LETTER TO ARRAY 'ASZ' FOR USE BY 'MC'

DO 25 I = 1, 6
   ASZ(1,I) = SZEMIN(I)
   ASZ(2,I) = SZELET(I)
25 CONTINUE

DO 26 I=1,5
   CALL STHK(SMTHR,LMIN,LMAX)
   DO 27 J=1,6
      DPSMDT(I,J)=SMTHR(J)
   27
   LIVAX=LMAX-12
   IF(I .EQ. 1) LMAX=LMAX-13
26 CONTINUE

GO TO 80

CALL GLOBAL PARAMETERS.

WRITE(IPRT,9175) ICASE, IBASYR, ICASVR, IBASYR, TEMPSZ,
2       ((STHMS(I,J),J=1,5),I=1,5), SZEMIN, RECFCFT,
3       MLIFE, MCYR, A, (B(I),I=2,5)

WRITE(IPRT,9175) ICASE, IBASYR, ICASVR, IBASYR, TEMPSZ,
2       ((STHMS(I,J),J=1,5),I=1,5), SZEMIN, RECFCFT,
3       MLIFE, MCYR, A, (B(I),I=2,5)
WRITE(IPRT,9177) RUT, APFAC
C INITIALIZE OUTPUT FILE
C WRITE(KOUT,9170)
C REGIONAL PARAMETERS
C TRANSFER GLOBAL PARAMS TO REGIONAL PARAMS
C WHERE OVER-RIDE IS PERMISSIBLE
C RETURN HERE FOR NEW REGION
--------------------
200 DO 202 I = 1,6
C SMTHR(I) = 0.0
C SIZER(I) = 0.0
202 CONTINUE
C MIT CORRECTION
C ORIGINAL DO 204 I =1,4
DO 204 I = 1,7
C 204 3RDNR(I) = 0.0
C DO 206 I = 1,4
C SMDPR(I) = 0.0
C DO 207 I = 1,14
C RECLAMATION COST
C 207 RECL(I) = 0.0
C SVTSR = SVT$G
C DO 220 I = 1,MXOVR
220 C(I) = G(I)
FEDS=0.
FEED*0.
C NOTE THAT LINES 355 TO 359 ARE COMPLETELY OVER-RIDDEN
C BY THE CODE ON LINES 456 469
C COMPUTE ESCALATION FACTOR
C ESCAL = .38+ECAP+.38*EMP+.24*EPAS
C MIT CORRECTION
C ORIGINAL VERSION:
ESCAL = .32+EMP+.53*EPAS
C ESCAL1=(1+ESCAL)**MMM
ESCAL1= .32*(1+EMP)**10 + .53*(1+EPAS)**10
PRINT 8999,ESCAL,MMM,ESCAL1
8999 F0M1AT(' 'ESCALATOR=','F9.3,',' **','15,' YEARS=','F9.3)
C
C TABLE HEADING
C
KSTT = 222
READ(IN,8050,END=2650,ERR=40) HDTAB
IF(HDTAE(1) .NE. TABLER) GO TO 280
IF (IPIES.NE.0) WRITE(KOUT,9190) HDTAB
IF (IPIES.EQ.0) WRITE(KOUT,9191) HDTAB
C
C READ RECLAMATION COST, OVERBURDEN RATIO, SEAM THICKNESS,
C SEAM DEPTH, AND SURFACE MINE SIZE RATIO.
C
255 KSTT = 260
260 READ(IN,8070,END=2650,ERR=40) TEXT, I
BACKSPACE IN
C
IF(TEXT(1) .EQ. RCL) GO TC 310
C
IF(TEXT(1) .EQ. OBR) GO TO 320
C
IF(TEXT(1) .EQ. THKSM) GO TO 480
C
IF(TEXT(1) .EQ. DSM) GO TO 580
C
IF(TEXT(1) .EQ. MDM) GO TO 525
GO TO 300
C
C ERROR - INCORRECT INPUT CARD
C
290 BACKSPACE IN
300 READ(IN,8050) CARD
WRITE(IPRT,9020) KSTT,CARD
STOP 300
C
C RECLAMATION COST. - - -
C
310 KSTT = 311
311 READ(IN,8060,END=2650,ERR=40) RECL
C
GO TO 255
C
C OVERBURDEN RATIO. - - -
C
320 IF(I .EQ. 0) GO TO 370
IF(I .EQ. 1) GO TO 420
C
C ERROR
C
340 READ(IN,8050) CARD
WRITE(IPRT,9030) CARD, I
STOP 340
C
MINIMUM AND MAXIMUM VALUES..

READ(IN,6095,END=2650,ERR=40) AA
IF(AA .EQ. AXL) GO TO 255
BACKSPACE IN
KSTT = 375
READ(IN,6050,END=2650,ERR=40) XMIN, XMAX
LMIN = XMIN
LMAX = XMAX
CALL DCMN(BRDNR,LMIN,LMAX)
GO TO 255

ACTUAL PERCENTAGE..

READ(IN,8115,END=2650,ERR=40) AA
IF(AA .EQ. AXL) GO TO 255
BACKSPACE IN
KSTT = 425
READ(IN,8110,END=2650,ERR=40) BRDNR
GO TO 255

IF(I .EQ. 0) GO TO 550
IF(I .NE. 1) GO TO 340

SEAM THICKNESS. - - - -

ACTUAL PERCENTAGE..

READ(IN,8115,END=2650,ERR=40) AA
IF(AA .EQ. AXL) GO TO 255
BACKSPACE IN
KSTT = 524
READ(IN,8110,END=2650,ERR=40) SMTHR
GO TO 255

525 READ(IN,8147,END=2650,ERR=40) ((KMARG(L,J),J=1,5),L=1,4)
8147 FORMAT(3X,2012)
DO 526 0=1,5
DO 526 L=1,4
00
527 r=t,5 NE104820
527 TMARG(J,KK,L)=0.
K4=KMARG(L,J)
IF(K4.EQ.0) GO TO 526
DO 528 KK=1,K4
528 TMARG(J,KK,L)=100/K4
526 CONTINUE
WRITE(IPRT,8311) (((TMARG(II,KK,LL),KK=1,5),II=1,5),LL=I,4)
8311 FORMAT(' MINE SIZE DIST BY SEAM BY DEPTH://'/(SE20.5))
GO TO 255

MINIMUM AND MAXIMUM VALUES..

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550 KSTT = 551
READ(IN,8095,END=2650,ERR=40) AA
IF(AA .EQ. AXE) GO TO 255
BACKSPACE IN
KSTT = 555
READ(IN,8090,END=2650,ERR=40) XMIN,XMAX
LMIN = XMIN
LMAX = XMAX
CALL STHK(SMTHR,LMIN,LMAX)
GO TO 255
C
C SEAM DEPTH(DSM)=SMDPR, AND MINE SIZE DISTRIBUTIONS(MSS)=SIZER
C
580 KSTT = 581
READ(IN,8130,END=2650,ERR=40) SMDPR, SIZER
C
C OVER-RIDE PARAMETERS -- -- -- OVER.RIDE --
C
600 KSTT = 600
READ(IN,8030,END=2650,ERR=40) AAA
IF(AAA .NE. ORIDE) GO TO 780
C
C OVER-RIDE PARAMS, IF ANY, OVER GLOBAL PARAMS
C
BACKSPACE IN
KSTT = 620
620 READ(IN,8150,END=2650,ERR=40) ((ALPHA(I),VALUE(I)),I=1,4)
DO 740 J = 1,4
IF(ALPHA(J) .EQ. BLNK) GO TO 740
IF(ALPHA(J) .EQ. $SVT) GO TO 730
IF(ALPHA(J) .EQ. $FDS) GO TO 731
IF(ALPHA(J) .EQ. $FSD) GO TO 732
DO 720 I = 1,MXOVR
C(I) = VALUE(J)
GO TO 720
720 CONTINUE
GO TO 740
730 SVT$R = VALUE(J)
GO TO 740
731 FEDS=VALUE(J)
GO TO 740
732 FEDD=VALUE(J)
740 CONTINUE
GO TO 600
C
C 780 IF(AAA .NE. ENDTAS) GO TO 280
C
C PRINT REGIONAL PARAMETERS
C
WRITE(IPRT,823)
WRITE(IPRT,9195) ICASE, (HDTAB(J),J=4,8), ISRR, IDRR, SEVT, SVT$R
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WRITE(IPRT,9197) RECL, XINSS, XINSD, YIELDS, YIELDD
WRITE(IPRT,9198) RECL, XINSS, XINSD, YIELDS, YIELDD

9198 FORMAT(' FEDERAL ROYALTY SURFACE, DEEP=',12F8.3)
YSTEM=YIELDS
YIDTEM=YIELDDD

C
C COAL PARAMS
C
KSTT = 782
READ(IN,B030,END=2650,ERR=40) AAA
IF(AAA .NE. COAL) GO TO 280
WRITE(IPRT,823)
FORMAT(///)
CM = 0.0
SVT$C = SVT$R

KSTT = 822

C
C COAL TYPE
C
READ(IN,B170,END=2650,ERR=40) CT
PRNTR=O
KSW=0
ISENS=0
READ(IN,B200,END=2650,ERR=40) PRNTR
READ(IN,B200,END=2650,ERR=40) KSW
READ(IN,B200,END=2650,ERR=40) ISENS

C
C COAL PARAMETERS. PRINT HEADING.
C
WRITE(IPRT,835) ICASE, (HOTAB(J),J=4,8), CT
835 FORMAT(1H1,10X,5A4,1//, 4X,'----- COAL PARAMETERS FOR ',5A4,
2 ' , COAL TYPE -',A2,':-',//)
837 FORMAT(/,9X, 15H MINE TYPE, 7X,22HPROD PRICE CUM PROD.,/)

C
C CLEANING COST
C
C CLEANING COST, DEMONSTRATED RESERVES, COMMITTED RESERVES,
C AND PRINT SWITCH FOR INTERMEDIATE RESULTS.
C
KSTT = 850
READ(IN,B190,END=2650,ERR=40) CLEAN, DEMR
CMTD(1)=0.
CMTD(2)=0.
READ(IN,B030,END=2650,ERR=40) AABB
BACKSPACE IN
DATA CMIT/'CMR='/
IF (AABB.NE.COMIT) GO TO 890
READ(IN,8192,END=2650,ERR=40)CMTD
890 CONTINUE
C
C TRANSFER REGIONAL PARAMS TO COAL PARAMS
C
ISRC = ISRR
IDRC=IDRR
TPMDCSC = TPMDC
TPMDDC = TPMDD
YIELDS=YYSTEM
YIELDD=YIYTDEM
DO 900 I = 1,"
C 900 3RDNC(I) = BRDNR(I)
DO 940 I = 1,6
C
SMTHC(I) = SMTHR(I)
C
SIZEC(I) = SIZER(I)
940 CONTINUE
C
C OVER-RIDE PARAMS, IF ANY, OVER GLOBAL AND/OR REGIONAL PARAMS
C
1000 KSTT = 1001
READ(IN,B030,END=2650,ERR=40) AAA
IF(AAA .EQ. COMPC(5)) GO TO 1500
BACKSPACE IN
IF(AAA .NE. ORIDE) GO TO 1130
KSTT = 1040
1040 READ(IN,B145,END=1650,ERR=40) AA
IF(AA .EQ. AXE) GO TO 1000
BACKSPACE IN
KSTT = 1050
C
1050 READ(IN,B150,END=2650,ERR=40) ((ALPHA(I),VALUE(I)),I=1,4)
DO 1060 I = 1, 4
C .SEVERANCE TAX $/TON OF CLEAN COAL
IF(ALPHA(I) .EQ. $SVT) SVTSC = VALUE(I)
C .ILLEGAL SURFACE RESERVE FRACTION
IF(ALPHA(I) .EQ. COMPR(11)) ISRC = VALUE(I)
C .INACCESSIBLE DEEP RESERVE FRACTION
IF(ALPHA(I) .EQ. COMPR(21)) IDRC = VALUE(I)
C .TONS/MANDAY SURFACE
IF(ALPHA(I) .EQ. COMPR(10)) TPMDCS= VALUE(I)
C .TONS/MANDAY DEEP
IF(ALPHA(I) .EQ. COMPR(11)) TPMDDC= VALUE(I)
IF(ALPHA(I) .EQ.COMPR(24)) YIELDS=VALUE(I)
IF(ALPHA(I) .EQ.COMPR(25)) YIELDD=VALUE(I)
1080 CONTINUE
  GO TO 1000
C C
1130  DO 1160 II = 1,4
  IF(AAA .EQ. COMIPC(II)) GO TO(1210,1310,1410,1450), II
C CONTINUE
  IF(AAA .EQ. ENDCOL) GO TO 1500
 C CONTINUE
  GO TO 300
C OVERBURDEN RATIO DISTRIBUTION -- --
C
1210  KSTT = 1211
  READ(IN,8210,END=2650,ERR=40) TEXT(1), TEXT(2), I
  BACKSPACE IN
C
  IF(I .EQ. 0) GO TO 1280
  IF(I .NE. 1) GO TO 300
C
  KSTT = 1250
  1250 READ(IN,8225,END=2650,ERR=40) AA
  IF(AA .EQ. AXE) GO TO 1000
  BACKSPACE IN
C
  ACTUAL PERCENTAGE...
C
  KSTT = 1260
  1260 READ(IN,8230,END=2650,ERR=40) BRDNC
  GO TO 1000
C
  KSTT = 1281
  1280 READ(IN,8245,END=2650,ERR=40) AA
  IF(AA .EQ. AXE) GO TO 1000
  BACKSPACE IN
C
  MINIMUM AND MAXIMUM VALUES..
C
  KSTT = 1285
  1285 READ(IN,8250,END=2650,ERR=40) XMIN, XMAX
  LMIN = XMIN
  LMAX = XMAX
  CALL OBDN(BRDNC,LMIN,LMAX)
  GO TO 1000
C
  .SEAM THICKNESS DISTRIBUTION. -- --
C
  KSTT = 1311
  1310 READ(IN,8210,END=2650,ERR=40) TEXT(1), TEXT(2), I
  BACKSPACE IN
  IF(I .EQ. 0) GO TO 1380
  IF(I .NE. 1) GO TO 300
C
  KSTT = 1316
  1316 READ(IN,8225,END=2650,ERR=40) AA
  IF(AA .EQ. AXE) GO TO 1000
BACKSPACE IN
KSTT = 1360
1360 READ(IN,B230,END=2650,ERR=40) SMTHC
C C ACTUAL PERCENTAGE..
C C GO TO 1000
C 1380 KSTT = 1381
   READ(IN,B245,END=2650,ERR=40) AA
   IF(AA .EQ. AXE) GO TO 1000
   BACKSPACE IN
   KSTT = 1385
C C MINIMUM AND MAXIMUM VALUES..
C C READ(IN,B250,END=2650,ERR=40) XMIN, XMAX
   LMIN = XMIN
   LMAX = XMAX
   CALL STHK(SMTHC,LMIN,LMAX)
   GO TO 1000
C C SEAM DEPTH DISTRIBUTION -- ACTUAL PERCENTAGE..
C 1410 KSTT = 1411
   READ(IN,B145,END=2650,ERR=40) AA
   IF(AA .EQ. AXE) GO TO 1000
   BACKSPACE IN
   KSTT = 1415
   READ(IN,B270,END=2650,ERR=40) SMDPC
   GO TO 1000
C C SURFACE MINE DISTRIBUTION RATIO -- ACTUAL PERCENTAGE..
C 1450 KSTT = 1451
   READ(IN,B225,END=2650,ERR=40) AA
   IF(AA .EQ. AXE) GO TO 1000
   BACKSPACE IN
   READ(IN,B230,END=2650,ERR=40) SIZEC
   KSTT = 1455
   GO TO 1000
C C PRINT COAL PARAMETERS
C ----- C
C 1500 WRITE(IPRT,9200) DEMR, CMTD, ((TEMP2(I),SIZEC(I)),I=1,6),
   2 BRDNC, ((THKMN(I),SMTHC(I)),I=1,6),
   3 SMDPC, SEVT, SVT$C, CLEAN
C IF(PRNT .EQ. 1) WRITE(IPRT,837)
C C READ AND PRINT PRESENT PRODUCTION
C C 1510 KSTT = 1511
READ(IN,8290,END=2650,ERR=40) TYPE, PROD
DO 1560 IK = 1,4
   IF(TYPE(1) .EQ. COMPT(IK)) GO TO(1610,1610,1650,1,1650), IK
1530 CONTINUE
   GO TO 280

C EXISTING PRODUCTION PRICE ESCALTED HERE
1610 PROD(2)=PROD(2)*ESCAL1
WRITE(KOUT,9210) TYPE, PROD
C PRINT PRODUCTION AND CUMULATIVE PRODUCTION HERE, IF DESIRED
   IF(PRNTR.NE.1) GO TO 1510
   CUM = CUM +. PROD(1)
   PROD(3) = CUM
   TYPE(1) = BLVK
   TYPE(2) = BLVK
   WRITE(IPRT,9215) TYPE, PROD
   GO TO 1510
C CALCULATE NEW MINES
C CALCULATE VARIOUS ELEMENTS OF TABLE - 2
C TRANSFER DEMONSTRATED AND COMMITTED RESERVES
C SURFACE DEMO
1650 T2(1) = DEMR(3) * (1.-ISRC)
C1650 T2(1) = DEMR(3)
C DEEP THICK DEMO
   T2(4) = DEMR(2)*(1.-IDRC)
C DEEP THIN DEMO
   T2(7) = DEMR(1)*(1.-IDRC)
C SURFACE COMMITTED
   T2(2) = CMTD(2)
C DEEP COMMITTED
   T2(5) = CMTD(1)
C CALCULATE RESERVE AVAILABLE FOR NEW MINES
C TEMP = 0.0
C SURFACE
   T2(3) = T2(1) - T2(2)
   T2(3) = (T2(1) - T2(2)) * (1.0 - ISRC)
   IF(T2(3) .LT. 0.0) T2(3) = 0.0
C DEEP THICK
   T2(6) = T2(4) - T2(5)
   IF(T2(6) .GE. 0.0) GO TO 1780
   TEMP = T2(6)

T2(6) = 0.0

C DEEP THIN
1780 T2(8) = T2(7) + TEMP
   IF(T2(8) .LT. 0.0) T2(8) = 0.0
C
C NAMELIST /BUGP2/ T2, T3, T4
C WRITE(IPRT,BUGP2)
C
C CALCULATE MINE SIZES, AND WRITE THEM ON FILE
C
C WRITE NEW SURFACE MINES, FOLLOWED BY DEEP MINES.
C
C SURFACE MINES.

C REWIND KIO
C 'NEWMIN' IS THE SWITCH TO DETERMINE IF NEW MINES WERE OPENED
C
   NEWMIN = 0
   DO 1790 I = 1, 6
       BB(I) = 0.0
   1790 CONTINUE
C
   IF(T2(3) .LT. 0.01) GO TO 2010
C
   DO 1970 J = 1, 7
       IF(T3(J) .EQ. 0.0) GO TO 1970
       XX = T3(J) * T2(3) / 100.0
   1800 BB(M) = T3(M2) * XX / 100.0
   1950 TEMP = 0.0
   DO 1950 M = 1, 6
       IF(BB(M) .EQ. 0.0) GO TO 1950
       TEMP = TEMP + BB(M)
   1970 DIV = RESREQ(1,M) * YIELDS
       IF(DIV .LT. 1.0) DIV = 99.9E+20
       K = TEMP / DIV
       IF(K .EQ. 0.0) GO TO 1950
       TEMP = TEMP - K * DIV
   1990 PSODN = K * SZMIN(M) * YIELDS
   2000 NEWMIN = NEWMIN + 1
   WRITE(KIO,9130) SDNLET(J),SZELET(M),PSODN

C WRITE ON FILE FOR LATER USE
C
   WRITE(KIO,9130) SDNLET(J),SZELET(M),PRODN
   1950 CONTINUE
   1970 CONTINUE
C
C DEEP MINES.
C
   DO 2000 I = 1, 6
   2000 BB(I) = 0.0
```
C 2010 DO 2310 L3=7,10
     L4 = L3 - 6
     IF(T4(L3) .EQ. 0.0) GO TO 2310
     IF (MARGW.EQ.0) GO TO 2011
     IF (MARGW.EQ.0) GO TO 2316
     DC 2315 LL=1.5
     IF (TMARG(LL,1,L4).LE.0.)GO TO 2320
     IF(J ,LT. 4) GC TO 2040
     IF(J .EQ. 4) GO TO 2030
     IF(T4(6) .EQ. 0.0) GO TO 2320
     XX = T4(6) + T2(6)
C 2050 IF(XX .LT. .1E-02) GO TO 2320
     ZZ = T4(L3) * XX / 10000.0
     DO 2100 M = 2,6
     M2 = 7 -. M
     BB(M) = STHMNS(J,M2) C ZZ / 100.0
     C2100 BB(M) = TMARG(J,M2,L4) * ZZ / 100.0
     TEMP = 0.0
     DO 2300 M = 1,6
     IF(BB(M) .EQ. 0.0) GO TO 2300
     TEMP = TEMP + BB(M)
     DIV = RESREQ(2,M) *YIELDD
     IF(DIV .LT. 1.0) DIV = 99.9E+20
     K = TEMP / DIV
C A1 = BB(M)
NAMELIST /BUGP3/ A1, TEMP, DIV, K
C WRITE(IPRT,BUGP3)
C IF(K .EQ. 0.0) GO TO 2300
     TEMP = TEMP - K * DIV
     PRODN = K * SZEMIN(M) * YIELDD
C NAMELIST /BUGP4/ M, PRODN, TEMP
C WRITE(IPRT,BUGP4)
C NEWMIN = NEWMIN + 1
C WRITE ON FILE FOR LATER USE.
```
WRITE(KIO,9150) THKLET(J),DIPLET(L4),SZELET(M),PRODN

CONTINUE
CONTINUE
IF(NEWMIN.LT.1) GO TO 2370

CALL MINE COSTING SUBROUTINE

THIS SUBROUTINE COSTS NEW MINES, SORTS THEM ON PRICE,
AND WRITES THEM ON 'KOUT' FILE.
ENDFILE KIO
REWORK KIO

IF SEVERANCE TAX $/TON IS TO BE USED, SET
SEVERANCE TAX FRACTION = 0.

IF(SVT$C .GT. 0.0) SEVT = 0.0

NAMELIST(DBG5) T,KSW,KIO,KOUT,CT,MYR,ECAP,EMP,EPAS,ROR,
1 ICASYR,RECL,SEVT,$PMDS,$PMDD,TPMDS,TPMDD,PSS,
2 PSD,CAPIS,CAPID,CAPDS,CAPDD,XLIC,ROY,SWEL,DDEL,CTX
WRITE(6(DBG5)
CALL MGCICASE,KSW,KIO,KOUT,CT,ECAP,EMP,EPAS,ROR,IBASYR,ICASYR,
2 SEVT,SVT$C,$PMDS,$PMDD,TPMDS,TPMDD,PSS,PSD,CAPIS,CAPID,
3 CAPDS,CAPDD,ALIC,ROY,SWEL,DDEL,SWEL,DDLDEL,CTX,MCYR,
4 ESCAL1,CUM,PRNTR,XINS5,XINS6,YIELDS,YIELDDD,FEDS,FEDDD
WRITE REMAINING MINES, IF ANY.

SINCE THE COUNTER IK MUST EQUAL 4 (SEE LINES 750-752)
THEREFORE, LINES 947-963 COULD BE OMITTED
IK = IK - 2
GO TO(2400,2450), IK

PRINT DEEP MINES, AND THEIR PRODUCTION HERE

IF(PRNR .NE. 1) GO TO 2403
CLM = CLM + PROD(1)
PROD(3) = PROD(1)
TYPE(1) = BLN
TYPE(2) = BLN
WRITE(IPRT,9210) TYPE, PROD

2408 XSTT = 2410
2410 READ(IN,290,END=2560,ERR=40) TYPE, PROD
IF(TYPE(1) .EQ. COMPT(3)) GO TO 2400

END COAL
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2450 BACKSPACE IN
READ(IN,8030,END=2650,ERR=40) AAA
IF(AAA .NE. ENDCOL) GO TO 280
KSTT = 2490
2490 READ(IN,8030,END=2650,ERR=40) AAA
REWRITE KIO
C NEW COAL TYPE
C IF(AAA .EQ. COAL) GO TO 820
C END REGION
C IF(AAA .NE. ENDCOL) GO TO 280
KSTT = 2550
2550 READ(IN,8030,END=2650,ERR=40) AAA
IF(AAA .EQ. ENDCALL) GO TO 2700
C NEW REGION
C IF(AAA .NE. TABLER) GO TO 280
BACKSPACE IN
GO TO 200
C PHYSICAL END OF FILE ENCOUNTERED BEFORE LOGICAL END
C 2650 WRITE(IPRT,9080)
STOP 2650
C ALL DONE
C 2700 CONTINUE
WRITE(KOUT,9230)
WRITE(IPRT,9100)
CALL EXIT
C FORMATS
-------- INPUT --------
C 8010 FORMAT(/,T6,5A4,/,5(/,T7,F4.1),/T23,F4.2,T32,F4.2.
1 2(/,T33,12,T50,12),/T21,12,/
2 4110X,F7.0,1X),2(/,T38,F4.2),/T12,F5.3,T27,F5.3,T43,F5.3.
3 T52,F5.3,./T11,I4,T26,14,/,T25,F5.2,T49,F7.4,./T15,F6.3.
4 T35,F6.2.
C MIT CORRECTION
C ORIGINAL VERSION ....(/,T23,F4.2,T50,F4.2)......
6 T30,F4.2,2(/,T23,F5.3,T50,F5.3),./T15,F4.2,./T27,F6.3.
7 ./T28,F6.3)
C 8012 FORMAT(T49,F5.2)
C 8015 FORMAT(18X,6(F3.1,1X))
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8020 FORMAT (18X, 6(A2, 1X))

C
8025 FORMAT (T7, I1)
C
8030 FORMAT (A4)
C
8050 FORMAT (20A4)
C
8060 FORMAT (33X, 3(F5.2, 6X), /, 33X, F5.2, /,
2           33X, 3(F5.2, 6X), /, 33X, F5.2)
C
8070 FORMAT (9A3, I1)
C
8090 FORMAT (T34, F4.0, T42, F4.0)
C
8095 FORMAT (T34, A1)
8100 FORMAT (T36, 7(F4.1, 1X))
C
8115 FORMAT (T36, A1)
C
8130 FORMAT (T25, 4(F4.1, 5X), /, T36, 6(F4.1, 1X))
C
8145 FORMAT (T11, A1)
C
8150 FORMAT (T7, 4(A3, 1X, F11.3))
C
8170 FORMAT (T11, A2)
C
8190 FORMAT (T29, F5.2, T47, F5.2, /, T34, F7.0, T50, F7.0, T63, F7.0)
C
8192 FORMAT (T34, F7.0, T50, F7.0)
C
8195 FORMAT (A3, 1X, A1)
C
8200 FORMAT (T5, I1)
C
8210 FORMAT (2A3, I1)
C
8225 FORMAT (T16, A1)
C
8230 FORMAT (T16, 7(F4.1, 1X))
C
8245 FORMAT (T13, A1)
C
8250 FORMAT (T13, F4.0, T21, F4.0)
C
8270 FORMAT (T11, 4(F4.1, 5X))
C
8290 FORMAT (A1, 2A4, A3, 1X, 3F7.3)
8290 FORMAT (A1, 2A4, A3, F5.3, 1X, F5.2, 1X, F4.2)
C
8300 FORMAT (33A4)
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C FILE: RAMCC FORTRAN A
C C FORMATS ------- OUTPUT -------
C
C 9010 FORMAT(/,1X,'('), 'READ ERROR - PROCESSING STOPPED',//, 14X,'READ STATEMENT IN PROCESS IS = ',14)
C 9020 FORMAT(/,1X,'('), 'INPUT ERROR - WRONG CARD ENCOUNTERED', 14X,'READ STATEMENT LAST PROCESSED = ',14,/, 14X,'FURTHER PROCESSING STOPPED',//,1X,20A4)
C 9030 FORMAT(/,1X,'('), 'INPUT ERROR - COL 28 = ',11,' Instead OF', 0 OR 1,/,1X,10X.20A4)
C 9050 FORMAT(/,1X,'('), 'INPUT ERROR -(',A3,' ') EXPECTED -(',A3, ' ENCOUNTERED', 14X,'INPUT REJECTED')
C 9060 FORMAT(/,1X,'MAXIMUM OVERBURDEN RATIO EXCEEDS 45:1, SURFACE', 14X,'MINE NOT CALCULATED',//,4X,'MAXIMUM OVERBURDEN RATIO EXCEEDS 45:1, DEEP',//,4X,'MINE NOT CALCULATED',//)
C 9080 FORMAT(/,1X,'(.'), 'PHYSICAL END OF INPUT FILE REACHED', 14X,'BEFORE LOGICAL END. PROCESSING INTERRUPTED')
C 9100 FORMAT(/,1X,6('<>'), 'ALL DONE ',6('<>'))
C 9130 FORMAT('S',2A2,3X,F10.2)
C 9150 FORMAT('D',3A2,1X,F10.2)
C 9170 FORMAT('ELEMENT SUPPLY')
C
C 9175 FORMAT(/,'H1,10X,5A4, //,T20,'---- GLOBAL PARAMETERS ----',//, 4X,'ALL INPUT PRICES ARE IN JANUARY 1, ',14,' DOLLARS', 4X,'CASE YEAR = ',14, 'BASE YEAR = ',14, //, 4X,'SEAM THICKNESS VS MINE SIZE', //, 4X,(PERCENT DISTRIBUTION) - DEEP MINES',//,4X,'MINE-SIZE', //, (MATONS),T25,5(F3.1,2X),//,4X,(SEAM THICK', 14X,'MINE LIFE IN YEARS', //,4X,'MINE CONTRACT LIFE IN YEARS = ',13, 4X,'MINE LIFE IN YEARS = ',13, //, 4X,'CAPITAL - INITIAL - SURFACE = ',F8.1,/,T25,'DEEP', //, 4X,'MINE CONTRACT LIFE IN YEARS = ',14, //, 4X,'UTILITY DISCOUNT RATE',T33,'= ',F5.3,/,24X,'ANNUITY PRICE FACTOR',T33,'= ',F6.3,/)
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9190 FORMAT (4X,2A4, R=500, C=6, T=12, ZERO', 6A4, /)
2 9X,19H = T
3 PROD PRCE SURF ICAP DCAP DRAG)

9191 FORMAT (4X,2A4, R=500, C=5, T=12, ZERO', 6A4, /)
2 9X,19H = T
3 PROD PRCE SURF CAPL DRAG')

9195 FORMAT (1H1,10X, 5A4, //, 12X, '---- REGIONAL PARAMETERS FOR', 5A4, /
2 '-----', //, 4X, 'ILLEGAL SURFACE RESERVE FRACTION = ', F4.2, //
3 //, 4X, 'INACCESSIBLE DEEP RESERVE FRACTION = ', F4.2, //
4 //, 4X, 'SEVERANCE TAX RATE = ', F6.4, 4X, //, 4X, 'LICENSE FEE',
5 'OR $1', 'F5.2, 'PER TON', //, 4X, 'ROYALTY FEE', T24, ' ', F4.2, //, 4X,
6 'CORPORATE TAX', T24, ' ', F4.2, //, 4X, 'WELFARE FUND', //
7 '($ PER TON) - SURFACE = ', F5.2, //, T3 4, 'DEEP = ', F5.2, //
8 T20, '($ PER DAY)', //
9 'SURFACE = ', F5.2, //, T34, 'DEEP = ', F5.2, //, 4X, 'POWER &',
10 'SUPPLY - SURFACE = ', F6.1, //, T22, 'DEEP = ', F6.1, //, 4X
11 'TONS PER MANDAY - SURFACE = ', F6.2, //, T23, 'DEEP', T33, =
13 A 'DEEP = ', F6.2, //

9197 FORMAT (4X, 'RECLAMATION COST $/TON (5)= ',
2 'F5.2, (10)= ' F5.2, (15)= ' F5.2, (20)= ' F5.2, //
3 'F5.2, (25)= ' F5.2, (30)= ' F5.2, //
4 'F5.2, (45)= ' F5.2, (50)= ' F5.2, //,
5 'F5.2, (10)= ' F5.2, (15)= ' F5.2, (20)= ' F5.2, //,
6 'F5.2, (25)= ' F5.2, (30)= ' F5.2, (45)= ' F5.2, //,
7 'F5.2, (50)= ' F5.2, //, 4X, 'POWER &',
8 'SUPPLY - SURFACE = ', F6.1, //, T22, 'DEEP = ', F6.1, //, 4X
9 'TONS PER MANDAY - SURFACE = ', F6.2, //, T23, 'DEEP', T33, =
11 A 'DEEP = ', F6.2, //

9200 FORMAT (4X, 'DEMONSTRATED RESERVES - DEEP THIN', T40, = 'F9.2, //, T29, NEI1190
2 'DEEP THICK = ', F9.2, //, T29, 'SURFACE = ', F9.2, //, 4X,
3 'COMMITTED RESERVES - DEEP', T40, = 'F9.2, //,
4 T29, 'SURFACE', T40, = 'F9.2, //, 4X,
5 'SURFACE MINE SIZE DISTR (F3.1)= ', F6.2, //, (F3.1)=',
6 F6.2, //, ('F3.1)=', F6.2, //, T19, 'PERCENT', T29, ',
7 F3.1, = ', F6.2, //, ('F3.1)=', F6.2, //, (F3.1)=',
8 F6.2, //, ('F3.1)=', F6.2, //, ('F3.1)=', F6.2, //,
A 'F3.1, = ', F6.2, //, ('F3.1)=', F6.2, //, (F3.1)=',
B T29, 'SURFACE MINE SIZE DISTR (5)= ', F6.2, //, (10)=',
C 'THICKNESS DISTR', T29, '('A2)= ', F6.2, //, ('A2)=',
D F6.2, //, ('A2)= ', F6.2, //, T8, 'PERCENT', T29, ',
E T29, 'SURFACE MINE SIZE DISTR (15)= ', F6.2, //,
F T29, 'SURFACE MINE SIZE DISTR (20)= ', F6.2, //,
G T29, 'SURFACE MINE SIZE DISTR (25)= ', F6.2, //,
H T29, 'SURFACE MINE SIZE DISTR (30)= ', F6.2, //,
I T29, 'SURFACE MINE SIZE DISTR (45)= ', F6.2, //,
J T29, 'SURFACE MINE SIZE DISTR (50)= ', F6.2, //,
K T29, 'SURFACE MINE SIZE DISTR (60)= ', F6.2, //,
L T29, 'SURFACE MINE SIZE DISTR (75)= ', F6.2, //,
M T29, 'SURFACE MINE SIZE DISTR (90)= ', F6.2, //,
9210 FORMAT (T10, A1, A4, 1X, A4, A3, T30, F7.3, 2(1X, F6.2))
C
9215 FORMAT (T10, A1, A4, 1X, A4, A3, T30, F7.3, 2(F7.2, 2X))
C NEI12110
9230 FORMAT('ENDATA')
C NEI12120
C END
C* SUBROUTINE STHK(ARY,LMIN,LMAX)
C* GIVE: MINIMUM AND MAXIMUM SEAM THICKNESSES FOR DEEP MINABLE RESERVES
C* THIS SUBROUTINE ASSIGN: PERCENTAGE DISTRIBUTION OF RESERVES TO
C* SEAM THICKNESS CATEGORIES USING EVEN DISTRIBUTION.
C* IF MINIMUM THICKNESS IS LESS THAN 42 INCHES, MINIMUM IS ASSUMED
C* TO BE 42 INCHES, FOR THICK RESERVES.
C* IF MINIMUM AND MAXIMUM ARE ZERO, OR MINIMUM IS GREATER OR EQUAL TO
C* MAXIMUM, PERCENTAGE ASSIGNED IS ZERO.
C* THIN RESERVES ARE ALWAYS ASSIGNED 57.1% TO 28-36, AND 42.9%
C* TO 36-42 INCHES SEAM THICKNESSES RESPECTIVELY.
C* ----- INPUT -----
C* LMIN MINIMUM SEAM THICKNESS
C* LMAX MAXIMUM SEAM THICKNESS
C* ----- OUTPUT -----
C* ARY ARRAY CONTAINING PERCENTAGES OF ASSIGNED DISTRIBUTION
C* INTEGER THIK(6)
C* DIMENSION ARY(1), AA(6), ITHK(4)
C* DATA AA/4*0.0,42.9,57.1/, THIK/72,60,48,42,36,28/
C* SET RETURN ARRAY 'ARY' = 0.
C* DO 20 I = 1,6
C* 20 ARY(I) = 0.0
C* IF(LMIN+LMAX .EQ. 0 .OR. LMIN .GE. LMAX) RETURN
C* DO 40 J = 1,4
C* 40 AA(J) = THIK(J)
C* IF(LMIN - THIK(J)) 80,100,100
C* 80 CONTINUE
C* J = 4
C*C
C* 100 LIM = J
C*  ITHK(J) = LMIN
C*  IF(ITHK(J) .LT. 42) ITHK(J) = 42
C*  JSET = 1
C*  TOT = 0.0
C*  SET = 1
C*C
C*C  DO 240 J = 1,LIM
C*   GO TO(150,200), JSET
C*C  150 IF(ITHK(J) .GE. LMAX) GO TO 240
C*   AA(J) = LMAX - ITHK(J)
C*   TOT = TOT + AA(J)
C*   JSET = 2
C*   GO TO 240
C*C
C*C  200 AA(J) = ITHK(J-1) - ITHK(J)
C*   TOT = TOT + AA(J)
C*C  240 CONTINUE
C*C
C*C  IF(TOT .LT. 1.0) TOT = 100.0
C*   TIHD = 1000.0 / TOT
C*   NTOT = 0
C*C
C*C  DO 350 J = 1,4
C*   NEXT = AA(J) = THOU + .5
C*   ARY(J) = NEXT / 10.0
C*C  350 NTOT = NTOT + NEXT
C*   IF(IABS(NTOT - 1000) .GT. 0) ARY(LIM) = ARY(LIM)=100.0-NT0T/10.0
C*C
C*C  RETURN
C*C  END

SUBROUTINE OBDN(ARY,LMIN,LMAX)

C  GIVEN MINIMUM AND MAXIMUM OVERBURDEN RATIOS FOR SURFACE MINABLE
C  RESERVES, THIS SUBROUTINE ASSIGNS PERCENTAGE DISTRIBUTION OF
C  RESERVES TO OVERBURDEN RATIO CATEGORIES FROM 5:1 TO 45:1 USUING
C  EVEN DISTRIBUTION BETWEEN LIMITS SET BY LMIN AND LMAX WITH STEPS
C  OF 5 FROM 5 TO 30, AND OF 15 FROM 30 TO 45.
C
C  IF MINIMUM AND MAXIMUM ARE ZERO, OR MINIMUM IS GREATER OR EQUAL TO
C  MAXIMUM, PERCENTAGE ASSIGNED IS ZERO.
C
C  IF THE MAXIMUM OVERBURDEN RATIO IS GREATER THAN 45:1,
C  A RECOVERY FACTOR IS CALCULATED = (45-LMIN)/(LMAX-LMIN), AND
C  LMAX IS SET = 45. THIS RECOVERY FACTOR IS USED TO CALCULATE THE
C  PERCENTAGES OF DISTRIBUTION RATIOS.
--- INPUT ---
LMIN  MINIMUM OVERBURDEN RATIO
LMAX  MAXIMUM OVERBURDEN RATIO

--- OUTPUT ---
ARY  ARRAY CONTAINING PERCENTAGE OF ASSIGNED EVEN DISTRIBUTION

INTEGER  BDNCLS(7)
DIMENSION  IBDN(7), AA(7), ARY(1)
DATA  IBDN/5,10,15,20,25,30,45/

TOT = 0.0

DO 80 J = 1,7
  BDNCLS(J) = IBDN(J)
  ARY(J) = 0.0
80  AA(J) = 0.0

IF(LMIN + LMAX .EQ. 0 .OR. LMIN .GE. LMAX) RETURN

RECFR = 1
DO 120 J = 1,7
  IF(LMAX - BDNCLS(J)) 160,160,120
120 CONTINUE

LMAX GREATER THAN 45. MODIFY RECOVERABLE FRACTION RECFR.
RECFR = FLOAT(45-LMIN)/FLOAT(LMAX-LMIN)
LMAX = 45
J = 7

ASSIGN DISTRIBUTION

160  LIM = J
  JSET = 1
  BDNCLS(J) = LMAX

DO 280 J = 1,LIM
  GO TO(200,250), JSET
200  IF(BDNCLS(J) .LE. LMIN) GO TO 280
    AA(J) = BDNCLS(J) - LMIN + 1
    TOT = TOT + AA(J)
    JSET = 2
    GO TO 280
250  AA(J) = BDNCLS(J) - BDNCLS(J-1)
    TOT = TOT + AA(J)
280 CONTINUE
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IF (TOT .LT. 1.0)     TOT = 100.0
       THOU = 1000.0 / TOT
       NTOT = 0

DO 380 J = 1, 7
       NEXT = AA(J) * THOU + .5
       ARY(J) = (NEXT / 10.0) * RECFR

380 NTOT = NTOT + NEXT
RETURN
END

SUBROUTINE MC(T,KSA,KIO,KOUT,CT,ECAP,EMP,EPAS,ROR,
               IBASYR,ICASVR,SEVTR,SEVT,SLAB,DLAB,TPMDBS,TPMDBD,PASaS.
               PASBD,XICBS,XICsD,DCBS,DCBO,XLIC,ROY,SWEL,DWEL,SWELD,CTAX,
               MCYR,ESCAL1,CUMUL,PRNTR,XINSS,XINSD,YIELDS,YIELDD,FEDS,FEDD)

C****PICEM MINE COSTING SUBROUTINE
C FEA/CHILDRESS/FEBRUARY. 1976
C
C THIS PROGRAM DETERMINES MINIMUM ACCEPTABLE SELLING
C PRICES FOR MODEL COAL MINES ACCORDING TO FORMULAE
C ESTABLISHED IN BUM IC832 AND IC935 FOR SURFACE AND DEEP
C MINES. IT INTERPOLATES FOR CAPITAL, POWER AND SUPPLIES, AND TONS
C PER MINE DAY, ACCORDING TO RULES DEVELOPED BY ICF CORP. IT
C IS PASSED INPUT PARAMETERS AND MINE TYPES FOR WHICH
C COSTING IS REQUESTED FROM THE MAIN PROGRAM, PERFORMS THE
C REQUIRED CASH FLOW ANALYSIS, AND IF KSW IS 1, CREATES A PRINT
C FILE ON LOGICAL UNIT MPRT. IT THEN WRITES ON KOUT THE NEW MINE
C INFORMATION IN GAMMA FORMAT, SORTED BY PRICE, FOR USE IN THE
C PICEM MODEL. THIS SUBROUTINE IS CALLED IN THE MAIN PROGRAM EACH
C TIME A NEW COAL TYPE IS PROCESSED.
C
C****ARRAYS****
C A(4,25) TEXT FOR MINE COSTS
C B(25,166) DATA FOR MINE COSTS
C P(15) PARAMETER BUFFER
C BUF(2,166) SURFACE OR DEEP TEXT BUFFER
C D(4,166) MINE TYPE HEADER INFORMATION

DOUBLE PRECISION A,D,UMY,RMINE
DIMENSION A(4,25),B(26,166),T(5)
DIMENSION C(2,166),SF(2),D(2),D(4,166),DUMMY(4,10),AC(2)
COMMON /COST/ SZEAMIN(6),RECL(14),MILE(2,2),CLEAN(2),ASZ(2,6),
               RUT,ISENS,APAC
DATA IPRT,MPRT,KSC,31,32,12/
REAL BLACKL(2)
DATA BLACKL/.25,.50/
DATA DDRAG/0.0/
C
C MINE CORRECTION
C ORIGINAL VERSION
C REAL IC,IC1
REAL IC,IC1,LAB
REAL TLIG(8)
DATA TLIG//'LA', 'LB', 'LC', 'LD', 'LE', 'LF', 'LG', 'LH'/
INTEGER DR, PRNTR
DIMENSION B/JF(11,160), AST(2,7) , ADP(2,7), AOB(2,7)
DATA AST//0,0,0,28,28,36,36,48,48 /
X 30, 60, 72, 72, 0, 0 /
DATA ADP/400,0,0,0,0,0,0,0 /
DATA AOB/5,0,10,15,15,20,20 /
X 25, 25, 30, 30, 45, 45 /
DFTA BLK/
DATA BUF/1750,0 /
DATA ZRO/0,0 /
EQUIVALENCE (A(53), DUMY(1))
X 25, 30, 45, 45, 0, 0 /
DATA BLK/' /
DATA BUF/1750,0 /
DATA ZRO/0,0 /
DATA AC/'S ','D' /
DATA A/SHINITIAL,8H CAPITAL,8H,8H
C SHDEFERRED,8H CAPITAL,8H,8H,8HPRESENT,
C SHVALUE,CA,8HPITALI IN,8HV,8H CASH FLO,8HW /
C SH,8H,8HSALIES,8H,8H /
C SHB,8H,8HOPERATIN,8HBG COSTS,8H,8H /
C SHGROSS PR,8HOFIT,8H,8H,8HDEPLETIO, /
C SHH,8H,8H /
C SHPROFIT B,8HBEFORE TA,8HXES,8H,8H FEDERAL /
C SHINCOME T,8HAX,8H,8HNET PROF,8HIT /
C SH,8H /
C SHB,8HSELLING,8HPRICE ($,8H/TON),8H /
C SHB,8H LABOR,8H,8H /
DATA DUMY/8H POWER,8H AND SUP, /
DATA DUMY/8H PAYRO,8HLL OVERH, /
C SH:EAD,8H,8H UNION,8H WELFARE,8H /
C SH,8H ROYAL,8HTY,8H,8H /
C SH LICEN,8HSES,8H,8H,8H WARE,8H /
C SH,8H,8HCOST,8HS,8H,8HTAXES,8H AND INS, /
C SHURANCE,8H,8H DEPRE,8HICATION,8H,8H /
C SH,8HM,8HTAL OPER,8HATING CO,8HS,8HOUTPUT P, /
C SHER MAN-D,8HAY (TONS,8H) /
DATA SF,DS,DD/'SURF','ACE', 'DP/S', 'HAFT', 'DP/D', 'RIFT' /
C
301 FORMAT(A1) / 
302 FORMAT(1H1,' CONTROL STMT-','A4,' WRGB..STOPPING') /
303 FORMAT(1X,2F2.0,3X,F10.2,7I4) / 
305 FORMAT(1X,3F2.0,1X,F10.2,7I4) /
306 FORMAT(1X,3F2.0,1X,F10.2,7I4) /
307 FORMAT(1X,3F2.0,1X,F10.2,7I4) /
308 FORMAT(1X,3F2.0,1X,F10.2,7I4) /
309 FORMAT(1X,3F2.0,1X,F10.2,7I4) /
310 FORMAT(1H1,' CASE:','A4,' PAGE:','13,' OF '13) /
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329 FORMAT(11X,5A4) NEI14860
330 FORMAT(36X,12./,6X,12) NEI14870
331 FORMAT(15(6X,F10.2,/)) NEI14880
324 FORMAT(1H .55X,'(THOUSANDS OF DOLLARS)',/,,/) NEI14890
326 FORMAT(1H .33X,6('TP=',2A4,3X)) NEI14900
327 FORMAT(1H .33X,6('SZ=',3F3.1, ' MMT/YR ')) NEI14910
328 FORMAT(1H .33X,6('OS=',F4.0,7X)) NEI14920
329 FORMAT(1H .33X,6('ST=',F4.0, ' IN. ')) NEI14930
330 FORMAT(1H .33X,6('DP=',F5.0, ' FT. '),/,,/) NEI14940
332 FORMAT(1H .4AB,6(F10.0,4X)) NEI14950
300 FORMAT(1H) NEI14960
340 FORMAT(1H ,/,,/) NEI14970
341 FORMAT(1H ) NEI14980
362 FORMAT(1H .4AB,6(F10.2,4X),/.1H ,'OPERATING COSTS') NEI14990
372 FORMAT(1H .4AB,6(F10.1,4X)) NEI15000

C REWIND KSC
NAMELIST /BUGC/ MDIV
SMAL= .0000001
MDIV=100
IF(ROR.LT.SMAL) WRITE(6,BUGC)

C 'KK' DEFINES THE NUMBER OF THE PRESENT MINE UNDER CALCULATION.
C MAXIMUM LIMIT AT PRESENT IS 160 MINES.
C
C KK=0
C
C CALCULATE PRESENT VALUE FACTOR FOR DEFERRED CAPITAL DIST'N
C ACCORDING TO ICF'S RECOMMENDATION
C
C SEE SUBROUTINE 'PRVAL' FOR THIS.
C
C X1=KICBS
X2=KICBD
X3=DCBS
X4=DCBD
NAMELIST /DBUG3/ X1,X2,X3,X4
WRITE(6,BUG3)

C****BEGIN READING INPUT****
10 READ(KIO,301,END=999) ACONT
BACKSPACE KIO
DO 15 K=1,2
IF(ACONT.EQ.AC(K)) GO TO (100,200),K
15 CONTINUE
WRITE(6,302) ACONT
NAMELIST /DSUG2/ K,KK,AC,ACONT
WRITE(6,DSUG2)
STOP
C
C 100=STRIP,200=DEEP
C MAKE CALCULATIONS FOR SURFACE MINES
C ------- -------
C
100 READ(KIO,303) OB,SZ,PROD,RMINE
C
C
C MINE LIFE IN YEARS.
C
AMR=.25
BLUNG=BLACKL(1)
DO 101 K=1,8
IF (CT.EQ.TLIG(K)) AMR=.25
IF (CT.EQ.TLIG(K)) BLUNG=0
101 CONTINUE
MYR = MLIFE(2,1)
IF(SZ .LT. 10.0) MYR = MLIFE(1,1)
CALL PRVAL(MYR,ROR,PVFAC,DCFRAC)
C
SZ=SZ/10.
C
RECLAMATION COST - $/TON.
C
DO 35 II = 1, 7
IF(AOS(1,II) .GE. OB-SMAL) GO TO 37
35 CONTINUE
II = 7
37 XRECL = RECL(II)
YRECL = RECL(II+7)
C
EMPLOYMENT INSURANCE RATE - $/$100 OF PAYROLL COST
XFINSG = XINSG
C
YIELD DC CLEAN TONS - FRACTION OF RAW TONS
YIELD = YIELDS
FED=FEDS
C
CALCULATE SEVT$ HERE
SEVT$ = SEVT * 1000. * SZ * YIELD
C
KK=KK+1
NAMELIST/DBUG8/ KK,OB,SZ,PROD
C
WRITE(6,DBUG8)
C
CALCULATE ALL COSTS FOR STRIP MINE.
DO 42 J=1,2
42 CJ,J,KK)=SF(J)
D(1,KK)=SZ
D(2,KK)=OB
D(3,KK)=0.
D(4,KK)=0.
IF(SZ.LT.1.) GO TO 47
C
MINES WITH CAPACITY OF 1 MILLION TONS OR MORE.
IC=(XICBS+1.20*(OB-10.)*1000)*SZ*1.000)*SZ*1.0000)*SZ*(1.-(SZ-1.)/20)
DC=(DCBS+0.25*(OB-10.)*1000)*SZ*1.0000)*SZ*1.0000)*SZ*(1.-(SZ-1.)/20)
GO TO 49
C
MINES WITH CAPACITY OF LESS THAN 1 MILLION TONS.
47 IC=(XICBS+1.20*(OB-10.)*1000)*SZ*1.0000)*SZ*1.0000)*SZ*1.0000)*SZ*(1.-(SZ-1.)/20)
DC=(DCBS+0.25*(OB-10.)*1000)*SZ*1.0000)*SZ*1.0000)*SZ*1.0000)*SZ*(1.-(SZ-1.)/20)
49 CONTINUE
TFMD=(TPMBS+3*(SZ-1.0)/0.1)*(1.0-0.1*(OB-10.)/5)
LAB=(SZ*1000/TPMD)*SLAB
PON=400.
PAS=(PASBS+30.*(OB-10.))*SZ
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WEL=SWEL
WPD=SWELD
SURF=1.0

FILL OUT REST OF BUFFER ITEMS, ALL MINES

--- -----

800 CONTINUE

C DEFERRED CAPITAL = 0, IF MINE LIFE <= 10 YEARS,
C   = 2 * VALUE OF 20 YEARS, IF MINE LIFE = 30 YEARS,
C   = LINEAR INTERPOLATED VALUE, IF MINE LIFE > 10 YEARS, BUT < 30 YEARS.

DC = DC * (FLOAT(MYR-10)/10.)

IF(MYR .LE. 10) DC = 0.0

C NOTE HERE THAT THE CALCULATION OF PVFAC IN SUBROUTINE PVAL IGNORES
C INFLATION, REAL CAPITAL ESCALATION, AND ASSUMES THAT THE THE
C DISCOUNT RATE, ROR, IS REAL

B(1, KK)=IC
B(2, KK)=DC
B(3, KK)=IC+PVFAC*DC
XXX=(1-(1.+ROR)**(-MYR))/ROR
MDIV=110

IF(XXX.LT.SMAL) WRITE(6,BUGDC)
B(4, KK)=B(3, KK)/XXX
B(13, KK)=LAB
B(14, KK)=PAS
B(15, KK)=0.2*LAB

C MIT CORRECTION

C ORIGINAL VERSION:

B(16, KK)=1000.*SZ*(WEL+WPD/TPMD)*YIELD
B(15, KK)=1000.*SZ*(WEL+YIELD*WPD/TPMD)

B(16, KK)=EL*1000.*SZ*YIELD
B(17, KK)=RO*1000.*SZ*YIELD
B(18, KK)=XIC*1000.*SZ*YIELD
POV=PO-SZ
SUP=PAS-POV
B(19, KK)=0.15*(LAB+SUP)
B(20, KK)=0.02*IC
B(21, KK)=IC+DC/MYR
B(22, KK)=0.

DO 810 J=13,21

810 B(J, KK)=B(J, KK)-B(J, KK)

C TEST IF DEPL GT 1/2*GROSS PROFIT.
SAL=3(B(22, KK))/2.0+B(4, KK)-B(21, KK))/J.55
DEPL=0.1*SALES
GROP=SALES-B(22, KK)
XX=GROP/2.
IF(DEPL.LE.XX) GO TO 900

C
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GROPR=(B(4,KK)-B(21,KK))*4./3.  NE116510
SALES=GROPR+B(22,KK)  NE116520
DEPL=0.5*GROPR  NE116530
CONTINUE  NE116540
C  NE116550
C  NE116560
C  NE116570
C  NE116580
C  NE116590
C  NE116600
C  NE116610
C  NE116620
C  NE116630
C  NE116640
C  NE116650
C  NE116660
C  NE116670
C  NE116680
C  NE116690
C  NE116700
C  NE116710
C  NE116720
C  NE116730
C  NE116740
C  NE116750
C  NE116760
C  NE116770
C  NE116780
C  NE116790
C  NE116800
C  NE116810
C  NE116820
C  NE116830
C  NE116840
C  NE116850
C  NE116860
C  NE116870
C  NE116880
C  NE116890
C  NE116900
C  NE116910
C  NE116920
C  NE116930
C  NE116940
C  NE116950
C  NE116960
C  NE116970
C  NE116980
C  NE116990
C  NE117000
C  NE117010
C  NE117020
C  NE117030
C  NE117040
C  NE117050
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C EXPENSES TO BE USED TO CALCULATE CURRENT DEPRECIATION.

C Y(3,1) NOW CONTAINS P.V. OF ALL CAPITAL FLOWS

C

DO 1104 JJ=1, MCYR

DO 1104 JJ=1, MYR

C

C ORIGINAL VERSION

C

LL=JJ+NYR-1

Y(4, JJ) = Y(3,1)/XXX

Y(13, JJ) = LAB*(1+EMP)**LL

Y(14, JJ) = PAS*(1+EPAS)**LL

Y(15, JJ) = 0.20*Y(13, JJ)

3 = XINS+Y(13, JJ)*.01

CAPT = (1+ECAP)**LL

Y(16, JJ) = B(16, KK) *(1+EMP)**LL

Y(17, JJ) = B(17, KK) *CAPT

Y(18, JJ) = B(18, KK) *CAPT

XSUP= Y(14, JJ) - POW*(1+EPAS)**LL

Y(19, JJ) = 0.15*(Y(13, JJ)+XSUP)

C

C ORIGINAL VERSION

C

Y(20, JJ) = .02*Y(1, JJ) *CAPT

C DEPRECIATION IS CALC'D. AS STRAIGHT LINE

Y(20, JJ) = .02*(Y(11,1)/((1+EPAS)**(2./3.)))*(1+ECAP)**

& (JJ-2./3.)

C BASED ON ACTUAL CURRENT DOLLARS SPENT.

C

Y(21, JJ) = (Y(6, JJ)+Y(1, 1))/MYR

C

C ORIGINAL VERSION

C

Y(21, JJ) = (Y(6, MYR)+Y(1, 1))/MYR

Y(22, JJ) = 0.

DO 1105 MM=3,21

Y(22, JJ) = Y(22, JJ)+Y(MM, JJ)

C

C ADD RECLAMATION AND CLEANING COSTS DULY INFLATED

C AT CAPITAL AND LABOR OR POWER & SUPPLY ESCALATION RATES.

C ALSO ADD EXPOSURE INSURANCE COST.

C

C IT CORRECTION

C

Y(22, JJ) = (Y(22, JJ)+((XRECL+CLEAN(1))*(1+ECAP)**(NYR+1))+

2 YRECL*(1+EMP)**LL+CLEAN(2)*(1+EPAS)**LL)

3 +AMR-BLNG)*SZ*1000*YIELD

C

Y(23, JJ) = B(23, KK)

XSALES=X(22, JJ)/2.+Y(4, JJ)-Y(21, JJ))

1(1.55-(1.-SEVTR-FED))

2+SEVT/(2.+55)

XCEPL=0.1*XSALES

XGROPR=XSALES-Y(22, JJ)-XSALES*(SEVTR+FED)-SEVT$.

XY=XGROPR/2.

IF(XDEPL.LE.XY) GO TO 1202

XSALES=((Y(4, JJ)-Y(21, JJ))/2.*Y(22, JJ))/(1.-SEVTR+FED)+SEVT$

XGROPR=XSALES-Y(22, JJ)-XSALES*(SEVTR+FED)-SEVT$

NE117060

NE117070

NE117080

NE117090

NE117100

NE117110

NE117120

NE117130

NE117140

NE117150

NE117160

NE117170

NE117180

NE117190

NE117200

NE117210

NE117220

NE117230

NE117240

NE117250

NE117260

NE117270

NE117280

NE117290

NE117300

NE117310

NE117320

NE117330

NE117340

NE117350

NE117360

NE117370

NE117380

NE117390

NE117400

NE117410

NE117420

NE117430

NE117440

NE117450

NE117460

NE117470

NE117480

NE117490

NE117500

NE117510

NE117520

NE117530

NE117540

NE117550

NE117560

NE117570

NE117580

NE117590

NE117600
XDEPL=0.5*XGROPR

1202 CONTINUE
Y(5,J,J)=XSALES

C ADJUST FOR SEVERANCE TAX.
C
Y(12,J,J)=Y(5,J,J)/(SZ*1000.*YIELD)
C Y(12,J,J) CONTAIN THE UNADJUSTED PRICES FOR YEAR JJ, EXCEPT FOR
C UTILITY DISCOUNT RATE - ADDED BELOW
PTOT=PTOT+Y(12,J,J)*(1+RUT)**(-JJ)

1104 CONTINUE
C CAULATE FINAL PRICE.
INDIV=130
IF(ABS(1-SEVT).LT.SMAL) WRITE(6,BUGDC)
INDIV=140
IF(ABS(APFAC).LT.SMAL) WRITE(6,BUGDC)
3(25,KK)+PTOT/APFAC

C PRINT VALUES FOR ALL YEARS FOR SENSITIVILY ANALYSIS,
C IF SENSITIVITY SWITCH IS SET = 1.
C
IF(ISENS .EQ. 1) WRITE(MPRT,1145) RMINE, B(25,KK),
2 ((JKJ,Y(12,JKJ)),JKJ=1,MYR)
3 'LIFE OF THE MINE:','/','/5(15,','/2X,F12.2))

C
4(25,KK) = SURF
IF (ISENS.EQ.1) WRITE (MPRT,1234) NYR,Y(1,1),(Y(K,1),K=3,6).
1 (Y(K2,1),K2=12,22),XRECL,CLEAN(1),ECAP,YRECL,EMP,CLEAN(2),
2EPAS,XPINS,SEVTS,SEVTR
1234 FORMAT('NYR Y 1 3-6 12-22 XRECL,CLEAN(1),ECAP YRECL,EMP ',
1 'CLEAN(2) EPAS,XPINS,SEVTS,SEVTR','/','/5(15,','/2X,F12.2))

C MAKE CALCS FOR DEEP MINES
C ----- -----

200 READ(KIO,305) ST,DP,SZ,PROD,RMINE
DP=DP+100.

C MINE LIFE IN YEARS.
C
MYR = MLIFE(2.2)
IF(SZ .LT. 10.0) MYR = MLIFE(1.2)
CALL PRVAL(MYR,ROR,PVFAC,DCFRAC)

C
4(SZ=SZ/10.
DP=0
SURF=0.
XRECL=0.
YRECL=0.

C .EXPOSURE INSURANCE $/$100 OF PAYROLL COST
XPINS = XINSDF
C CLEAN TONS YIELD - FRACTION OF RAW TONS
YIELD = YIELDD
FED=FEDD
AM3=.15
BLUNG=BLACKL(2)
C CALCULATE SEVT$ HERE
SEVT$ = SEVT * 1000. * SZ * YIELD
C
IF(DP.LE.0.1) DR=1
KK=KK+1
NAMELIST/DBG9/ KK,ST,DP,SZ,PROD
WRITE(6,DBG9)
C MIT CORRECTION: NEXT LINE COMMENTED OUT
C
IF(ST.EQ.28.1) ST=24.
DO 204 J=1,2
204 C(J,KK)=DS(J)
GO TO 210
209 C(J,KK)=DD(J)
210 CONTINUE
D(1,KK)=SZ
D(2,KK)=0.
D(3,KK)=ST
D(4,KK)=DP
CALC IC,DC,LAB,PAS FOR DEEP MINES
IF(SZ.LT.1.) GO TO 260
IC=(XICBD+500*(DP-700.)/100.-6000*DR)*(1.+0.06*(72.-ST)/12)*
(1.+0.30-(SZ-1.))
DC=(DCBD-3000*DR)*(1.+0.06*(72.-ST)/12)*SZ
GO TO 280
260 CS=500*DP/100.
CSB=3500.
CI=(XICBD+CS-CSB-6000*DR)*(1.+0.06*(72.-ST)/12)
IC=(IC+CS)*SZ+CS
DC=(DCBD-3000*DR)*(1.+0.06*(72.-ST)/12)+SZ
GO TO 280
280 CONTINUE
TPMD=(TPMDBD-1.0*(72.-ST)/12+0.5*(SZ-1.)/0.1)
MDIV=150
IF(TF30.LT.SMAL) WRITE(6,BUGDC)
LAB=(SZ*1300/TPMD)*DLAB
PAS=(PASEP-0.15*1000.*(72-ST)/12)*SZ
POW=500.
WEL=WdEL
WPD=WdELD
GO TO 800
999 CONTINUE
C PRINT ALL PAGES
PRINT ALL PAGES
IF(KS#EQ.0) GO TO 701
KPAGE=KK/G +1
DO 700 KP=1,KPAGE
K=KP*6-5
700 CONTINUE
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C  K2=K1+5
C  WRITE(NFRT,1310) Y
C  NAMELIST ,DBUG1/ KPAGE,KK,K1,K2,KP,D
C  WRITE(6,DBG1)
C  WRITE(NFRT,320) T,KP,KPAGE
C  WRITE(NFRT,322)
C  WRITE(NFRT,324)
C  WRITE(NFRT,326) ((C(J,I),J=1,2),I=K1,K2)
C  WRITE(NFRT,327) (D(1,I),I=K1,K2)
C  WRITE(NFRT,328) (D(2,I),I=K1,K2)
C  WRITE(NFRT,329) (D(3,I),I=K1,K2)
C  WRITE(NFRT,330) (D(4,I),I=K1,K2)
C  DC 650 KO=1.4
C  650 WRITE(NFRT,332) (A(J,KQ),J=1,4),(B(KQ,I),I=K1,K2)
C  WRITE(NFRT,340)
C  DC 660 KQ=5,11
C  660 WRITE(NFRT,332) (A(J,KQ),J=1,4),(B(KQ,I),I=K1,K2)
C  WRITE(NFRT,341)
C  WRITE(NFRT,332) (A(J,12),J=1,4),(B(12,I),I=K1,K2)
C  DC 670 KQ=13,22
C  670 WRITE(NFRT,332) (A(J,KQ),J=1,4),(B(KQ,I),I=K1,K2)
C  WRITE(NFRT,341)
C  WRITE(NFRT,332) (A(J,23),J=1,4),(B(23,I),I=K1,K2)
C  700 CONTINUE
C  701 CONTINUE
C  353 FORMAT(1H ,5X,'S',2A2,2X,7F7.2)
C  354 FORMAT(1H ,5X,'D',3A2,7F7.2)
C  888 FORMAT(6X,A1,3A2,7F7.2)
C  889 FORMAT(1H ,':',N',A1,A2,' NEW.',A1,3A2,3X,F7.3,1X,
C  890 FORMAT(1A0,F6.2,F1X))
C  891 FORMAT(' NEW.',A1,3A2,3X,F7.3,4(F7.2,2X))
C  C NOW LOOP THRU B AND D AND STACK UP UNSORTED MINE DATA
C  1310 FORMAT(3(1H ,6(F10.2,1X))/,1H ,F10.2,1X,F10.2,1X,F10.2,1X,
C  1320 FORMAT(3(1H ,6(F10.2,1X))/,1H ,F10.2,1X,F10.2,1X,F10.2,1X,
C  COMMON /COEFS/COEF1,COEF2,PIES
C  DC 970 N=1,WINTOT
C  MDIV=200+N
C  IF(D(1,N).LT.SMAL) WRITE(6,BUGDC)
C  IF(D(1,N).LT.SMAL) WRITE(6,7982) D(1,N)
C  IF(D(1,N).LT.SMAL) WRITE(6,7983) D(1,N)
C  7984 FORMAT (F7.4)
C  IF(C(1,N).NE.SF(1)) GO TO 997
C  7983 FORMAT (F7.4)
C  C IT'S A SURFACE MINE. WRITE INFO TO XD.
C  XDB= BLK
C  XSZ= BLK
C  PRC=0.
C  PROD=0.
C  DD 720 J=1,7
C  IF(D(2,N).EQ.AOB(1,J)) XDB=AOB(2,J)
C  IF(J.EQ.7) GO TO 720
C  XDB=AOB(1,J)
C  IF(AOB(1,N)=ASZ(1,J)) LE...001) XSZ=ASZ(2,J)
C  720 CONTINUE
C  PRC=B(25,N)
C  PROD=B(24,N)
SURF=B(26,N)
YICS=((B1,N)/1000.)/D(1,N))
YDCS=((B2,N)/1000.)/D(1,N))
C RECALL THAT THE USE OF COEF1 & COEF2 RELATE TO AN OLDER
C VERSION OF THE RAMC CODE.
SCAP=YICS*COEF1+YDCS*COEF2
CC DCAP=YICS*(1+ECAP)*=(NYR/2) + YDCS*(NYR/40)*(1+ECAP)*=(NYR/4)
SDRAG=0.0
IF(D(1,N).GT.0.99) SDRAG=D(2,N)
WRITE(KSC,353) XOB,XSZ,PROD,PRC,SURF,YICS,YDCS,SDRAG,SCAP
GO TO 970
C IT'S A DEEP MINE. WRITE INFO TO K0.
997 XDP=ZRO
PRC=0.
PROD=0.
XSZ=BLK
DO 920 J=1,7
IF (J.EQ.7) GO TO 921
IF(ABS(D(1,N)-ASZ(1,J)).LE..001) XSZ=ASZ(2,J)
921 IF(ABS(D(3,N)-AST(1,J)).LT.0.001) XST=AST(2,J)
IF(ABS(D(4,N)-ADP(1,J)).LT.0.001) XDP=ADP(2,J)
920 CONTINUE
PRC=B(25,N)
SURF=3(26,N)
FICS=((B1,N)/1000.)/D(1,N))
YDCS=((B2,N)/1000.)/D(1,N))
DCAP=YICS*COEF1*YDCS*COEF2
CC DCAP=YICS*(1+ECAP)**(NYR/2) + YDCS*(NYR/40)*(1+ECAP)**(NYR/4)
WRITE(KSC,354) XST,XDP,XSZ,PROD,PRC,SURF,YICS,YDCS,DDRAG,DCAP
970 CONTINUE
NAMELIST/D:DEBUG/ Y
C WRITE(6,D1BUG)
REVERSE IS C
READ(KSC,88,END=733) BUF
WRITE(6,222)
222 FORMAT(1H,'I GOT THERE...')
733 CONTINUE
C BUF(6,*) IS PRICE KEY
MM=MINTOT
CALL SHELLR(BF,MM,MINT,11,6,1)
M=MINT
IF(M.MT.GT.35) MM=35
DO 1300 J=1,MM
IF (IPIES.NE.0) WRITE(KOUT,889) ORD(J),CT,(BUF(I,J),I=1,10)
IF (IPIES.EQ.0) WRITE(KOUT,889) ORD(J),CT,(BUF(I,J),I=1,7),
X BUF(I,J)=BUF(I,J)
1300 CONTINUE
C IF(PIRNT.EQ.1) GO TO 1300
CLJL = CLJUL + BUF(5,J)
BUF(7,J) = CHEL
WRITE(IPRT,890) (BUF(I,J),I=1,7)
1300 CONTINUE
RETURN
CSEE EVERETT FOR SOURCE OF THIS SORT ROUTINE
   DIMENSION A(NC, NR)
   M = N
   M = M/2
   RETURN
C
I = I + M
IF (I .LE. 0) RETURN
DO 109 J = 1, L
   I = I - M
   IF (I - NS + 1 .LE. 0) GO TO 109
   IF (A(NK, I + M) .GE. A(NK, I)) GO TO 109
   DO 200 JJ = 1, NC
      X = A(JJ, I)
      A(JJ, I + M) = X
      A(JJ, I) = A(JJ, I + M)
   200 CONTINUE
   GO TO 104
109 CONTINUE
   GO TO 104
END
SUBROUTINE PRVAL(MYR, ROR, PVFAC, DCFRAC)
   DIMENSION DCFRAC(1)
   C
   PVFAC - PRESENT VALUE FACTOR IS DERIVED TO CALCULATE
   DEFERRED CAPITAL ON THE FOLLOWING BASES
   NOTE HERE THAT THE CALCULATION OF PVFAC IN THIS SUBROUTINE
   IGNORES INFLATION, REAL CAPITAL ESCALATION, AND ASSUMES THAT
   THE DISCOUNT RATE, ROR, IS REAL
   C
   FIRST 25% OF MINE LIFE = 5% OF DEFERRED CAPITAL
   NEXT 50% OF MINE LIFE = 90% OF DEFERRED CAPITAL
   LAST 25% OF MINE LIFE = 5% OF DEFERRED CAPITAL
   LAST YEAR OF MINE LIFE = 0.
   C
   M25 = MYR/4
   M50 = MYR/2
   M75 = M25 + M50
   M99 = M25 - 1
   C MIT INSERT
   IF ((MYR - (M75 + M99)) .NE. 2) GO TO 120
      M50 = M50 + 1
      M75 = M75 + 1
   120 CONTINUE
   IF ((MYR - (M75 + M99)) .NE. 3) GO TO 130
      M25 = M25 + 1
      M75 = M75 + 1
      M99 = M99 + 1
   130 CONTINUE
   C END MIT INSERT
   C
   C
PVFACT = (.05/M25)*(1-(1+ROR)**(-M25))/ROR +
2 (.9/M50)*((1-(1+ROR)**(-M50))/ROR)*((1+ROR)**(-M25)) +
3 (.05/M99)*((1-(1+ROR)**(-M99))/ROR)*((1+ROR)**(-M75))

C
A = .05/M25

C
DO 25 I = 1, M25
25 DCFRAC(I) = A

C
A = .9/M50
NEXT = M25 + 1

C
DO 50 I = NEXT, M75
50 DCFRAC(I) = A

C
A = .05/M99
NEXT = M75 + 1
LAST = MYR - 1

C
DO 75 I = NEXT, LAST
75 DCFRAC(I) = A

C
DCFRAC(MYR) = 0.0

C
RETURN

C
END