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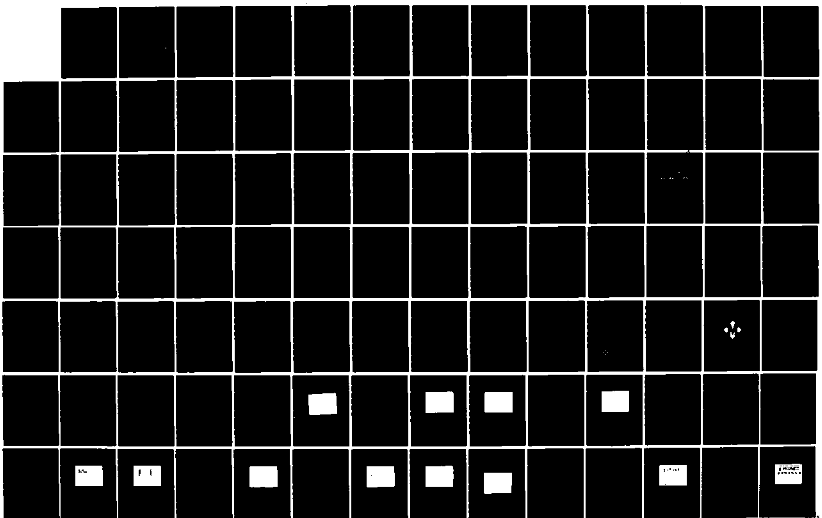

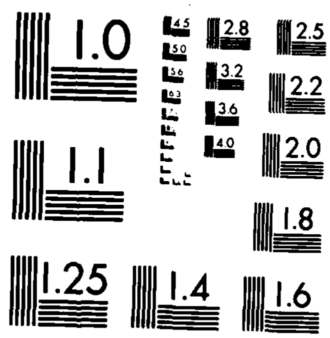

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A LINEAR-PROGRAMMING-BASED COAL PREPARATION AND BLENDING TECHNIQUE

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Final report, 10 April 1985

A thesis submitted to the Colorado School of Mines, Golden, CO, in partial fulfillment of the requirements for the degree of Master of Science (Mineral Economics).

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A LINEAR-PROGRAMMING-BASED COAL PREPARATION AND BLENDING TECHNIQUE

by

Steven L. Van Drew

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A thesis submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Master of Science (Mineral Economics).

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ABSTRACT

A model of the Martiki Coal Corporation blending and preparation process is developed with minimization of wash loss as the objective. Solution is by iterative linear programming using the Tucker Tableau algorithm on an Apple II microcomputer. Output serves as an aid to preparation plant personnel in making the daily specific gravity and tonnage decision. Each percentage reduction in Martiki's 1984 wash loss would have decreased disposal costs and increased revenues by approximately $550,700.

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For the second time in my life, I am indebted to the U.S. Army for providing me with the opportunity to pursue academic excellence. I view the incurred service obligation as an opportunity to express my gratitude by relaying my skills and enthusiasm for operations research to future officers, conducting detailed analyses for the Army, and serving as an example to junior officers of the benefits of an Army career. I am especially grateful to Colonel Allen F. Grum for selecting me as a West Point instructor and steering me towards the Colorado School of Mines.

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Chapter 1

INTRODUCTION

The purpose of this study is to formulate and code a mathematical model of the coal blending and preparation process at the Martiki Coal mine in Lovely, Kentucky, which will reduce wash loss by improving the daily tonnage and specific gravity decision. Martiki prepared, or washed, 4,742,607 tons of raw coal in 1984, with 3,073,799 tons produced as clean coal, and 1,668,808 tons, or 35.19 percent, discarded as reject. A reduction of one percent in this wash loss would have decreased reject disposal costs and increased revenues by approximately $550,700.

Several aspects of coal and its preparation suggest defining a general mathematical model for the coal preparation and blending process. Familiarization with these aspects is necessary prior to examining the site-specific differences which prohibit this type of generalization.

Coal Quality Characteristics

Coal is a heterogeneous mixture of inorganic crystalline minerals and organic phytogenic, noncrystalline materials that vary in physical and chemical composition from seam to seam and within seams. Two major reasons for the variety of physical components in coal are the diversity of the original plant materials and the degree of metamorphism, or coalification, that has affected these materials. The impurities occurring in coal may be categorized into those that are ash forming and those that contribute sulfur. Further impurities are frequently added to the mined product by the mining process itself.

> Of principal importance in determining the value of a given coal on the market is its quality measured in terms of use characteristics, ash and sulfur contents, and heating value. (Leonard and Mitchell 1968)

Heating value is usually expressed in British thermal units (Btu) per pound or kilocalories per kilogram. One Btu per pound is equivalent to .556 kilocalories per kilogram. The consumption necessary for each kilowatt hour of power generated is generally determined by the heating value of the coal burned.

Ash content, expressed as a percentage by weight, directly affects the heating value and thus limits the capacity of any given combustion unit. Not all ash-forming impurities can be separated from the coal by preparation, or washing, methods. Inherent ash content is a limiting minimum that consists of those ash-forming impurities that for coal preparation purposes can be considered structurally a part of the coal. Those ash-forming impurities that can from the two sources supplying coal to the Harmarville preparation plant. "All coal has approximately the same sizing, physical properties, and chemical properties" (Nelson 1966) since both sources are mining from the same seam. Optimum values do not necessarily minimize total mining costs, since the objective of the full model is to minimize total steel producing costs. CEIR Inc.'s C-E-I-R LP/90/94 linear programming code is used to solve the model.

Barbaro and Mutmansky (1983) have applied a nonlinear mixed integer goal programming model to the problem of supplying coal to power plants. The goal programming aspect of the model follows from contracts that specify a pricing schedule with bonuses or penalties for coal above or below multiple coal quality goals. Of the five quality characteristics considered, two have nonlinear payment schedules. Some of the decision variables are binary integer variables: whether a mine is operated, whether a market is supplied, or whether a blending preparation plant is used. The suppliers' expected net profit before tax is maximized in this model, subject to fourteen types of constraints. The formulation is then demonstrated for a scenario with three mines, two plants, and three markets. Under these conditions, the formulation yields an initial tableau with 42 equations and 113 variables, with solution costs, transport, and environmental limits. IBM's MPS-360 solution code is used and output is both numerical and cartographic. However, for full generation to be tenable on the Penn State IBM 370-168, "pre-processing limitations on numbers of activities and constraints" (Knight and Manula 1976) are necessary. While 67 counties, 7 external regions, 9 markets, and 10 seams are considered, coal characteristics for only ROM and two prepared grades are available.

Nelson (1966) describes a model of steel-making operations developed by the operations research section at Wheeling Steel Corporation. The Wheeling Steel model takes into account all relevant costs and production considerations from choice and use of raw materials to slabbing of ingots. As with coal utilized in power generation, coking coal utilized in metallurgical processes must meet strict quality specifications. These coal quality considerations are the most important nonlinear section of the model. The model is "a 'hybrid' linear program that handles non-linear relationships through the mechanism of separable variables" (Nelson 1966). The Harmarville mine, Wheeling's primary coal supplier and only preparation plant, is treated as a submodel. The objective of the Harmarville submodel is to identify the specific gravity to operate the preparation plant at and to specify what tonnage to request

Chapter II

LITERATURE REVIEW

As Nielsen (1984) points out, the more than twenty years of Application of Computers and Operations Research in the Mineral Industry (APCOM) symposia have been geared towards large-scale operations which have corporate mainframes available. This observation is also valid for papers presented at meetings of the Society of Mining Engineers (SME) of AIME. Despite this bias, previous linear programming and/or coal blending applications appearing in the mining literature merit examination for peculiarities that may be applicable to a small-scale operation such as Martiki.

Large-Scale Operations

Knight and Manula (1976) have developed the Pennsylvania Coal Model (PCM) "to simulate potential coal production and utilization systems in Pennsylvania." The PCM is a linear-programming-based, four-stage model that minimizes the cost of meeting demand subject to production, sulfur emission, capital, and transportation constraints. To evaluate the implications of various demand scenarios, the user may manipulate extensive data bases for demand, reserves, production, coal characteristics, production percent or more. Refuse disposal areas at Martiki are being filled in half the time they were designed for.

Taken together, these difficulties account for the inability of Martiki to meet contract specifications efficiently. Intuition is not an adequate tool for evaluating the infinite number of quality, tonnage, and specific gravity combinations from which to select the optimum blend and the specific gravity that will minimize wash loss.

This brief examination of the coal blending and preparation process at Martiki was necessary prior to reviewing the literature for similar applications. While several coal blending and/or preparation formulations appear in the literature, none is completely adaptable for this study, the purpose of which is to model Martiki in order to reduce wash loss by improving the daily tonnage and the specific gravity decision.

1. No consideration is given to the tonnage and quality of coal that is ahead of the ROM coal in both the clean and crushed coal silos. Enough of this coal may remain after loading two unit-trains to have an effect on the averaging nature of coal quality characteristics. Conversely, some of the washed ROM coal may be needed to complete a shipment having quality specifications significantly different than those currently under consideration.

2. As mentioned earlier, the raw coal blending is completely arbitrary. No control is exercised over the tonnage from each source fed to the crusher. Only one stockpile exists, and the decision to unload there is made by the drivers, based on the length of the crusher queue. No sample can reflect accurately the quality of one stockpile that has been fed by many sources.

3. The preparation plant is capable of washing at 20 gravities, ranging from 1.41 to 1.60 in increments of 0.01. Samples are analyzed at only one gravity, however, requiring the operator to make a decision based on estimated nonlinear extrapolations.

4. Coal is frequently overprepared to avoid violating contract specifications, resulting in reject losses of 40

individual load's movement through the process because of the continuous separating that occurs from the instant a load is dropped in the crusher chute.

In general, one "hand-picked" sample is taken each day from a load coming from each of the sources. Samples are analyzed at either a 1.45 or 1.50 specific gravity, a two-day process. For contract compliance purposes, final product samples are also analyzed. Each contract specifies maximum moisture, sulfur and ash percentages, and minimum Btu content. Some contracts contain ranges called deadbands in which the base price is paid, with penalties or bonuses awarded for being above or below the deadband depending on the coal characteristic. Each contract also contains a clause that allows the customer to cancel the contract if coal quality repeatedly violates specifications.

Martiki's current procedure for making the daily specific gravity decision relies on the "gut-feeling" or intuition of one person. That person obtains tonnage estimates for coal available from each of the sources for that day, evaluates the most recent sample analysis for each source's coal, considers which contract must be satisfied, and announces the specific gravity that the preparation plant will wash coal at for that day. There are several difficulties with this procedure:

tonnage to accept from each source and the specific gravity at which to operate the preparation plant. An incorrect decision would result in either underprepared coal (too high a specific gravity), where the contract specifications are violated, or overprepared coal (too low a specific gravity), where an excessive amount of reject must be disposed of. A mathematical model would aid the decision maker in avoiding making an incorrect decision. Site-specific peculiarities must be examined, however, prior to formulating a model for Martiki.

The Martiki Coal Mine

Martiki is a surface mine that produces over three million tons of bituminous steam coal each year. Martiki supplies as many as ten utilities, with long-term contracts and reserves potentially guaranteeing the mine's operation until 2010. ROM coal is available from five Martiki pits and five independent sources. Deliveries of 10,000 tons are loaded on unit-trains from a clean coal silo, generally for one customer per day. ROM coal is either stockpiled or fed to the preparation plant via an in-line crusher that empties into a crushed coal silo. The raw coal blending that occurs is completely arbitrary. This arbitrariness is introduced by the unpredictable arrival of different size loads from the ten distinct pits. It is impossible to trace an coal requirements, but overpreparation can be costly through reject losses" (Leonard and Mitchell 1968).

Refuse From Coal Preparation

Coal preparation refuse, or reject losses, represent not only lost revenues, but also the additional cost of refuse disposal. Refuse disposal is subject to laws and government regulations, and is costly enough to warrant consideration of all routes and methods of transportation to the disposal area and all possible methods of keeping the quantity of refuse to a minimum. Minimizing the quantity of misplaced float material caused by inefficient washing is an important factor in preventing spontaneous combustion in the refuse disposal area. The design of a mine and plant should include the location and the estimated capacity of the disposal areas for the life of the property or the plant.

The Coal Preparation Decision

The complexity of the daily decision making process involved in coal preparation and blending should be apparent at this point. Coal from multiple sources, each with its own quality attributes, must be blended and prepared to meet the specifications of a contract. Sample analyses performed provide the theoretical results for the preparation process. The decision maker must amass this data and decide the washing gravity to be used is based on raw coal washability data and clean coal specifications. According to Leonard and Mitchell (1968), for most bituminous coals,

> washing at 1.55 or 1.60 will usually (a) show an efficient separation of coal and refuse; (b) achieve high capacity performance from the cleaning equipment; (c) result in a fairly small loss of Btu in the refuse; (d) permit the use of simplified processes, and (e) prove more economical than washing at lower gravities.

The Economics of Coal Preparation

The preparation policy that enables an operator to make the most money for his efforts and investments is site dependent. Each individual mine or production group must calculate its economics of preparation based on several variables including present facilities, contract requirements, ability to make a product meeting requirements, probable costs, and possible future changes in raw coal or finished product. As stated by Leonard and Mitchell (1968),

> [p]reparation is the last production step that can offset cost shortcomings in mining and haulage, and thus raise the value of the finished product to command the highest possible realization.

Loss of previous mining cost advantages may occur, however, because of the cost of raw coal preparation from a material handling standpoint, or because of increased reject losses. "The raw coal must be prepared to meet the clean

When prepared, or washed, ROM coal is separated into refuse and salable clean coal. In preparing coal, technologists have numerous processes and machines available, ranging from extremely simple to complex. Each machine or process is designed to remove one or more of the impurities discussed earlier. For methods of gravity concentration, the most common method of preparation, the principles applied are directly related to measurable and controllable characteristics such as the following:

1. Dense impurities (inorganic minerals) have specific gravities ranging from 2.2 to 2.7 while "pure" coal (organic component) has a specific gravity of from 1.23 to 1.72, depending on the moisture and ash content.

2. There is a small apparent specific gravity difference (0.1) between particles composed of both coal and minerals in varying proportions.

3. A volume difference exists between equal weighted organic and inorganic particles.

4. There is a surface chemistry difference between organic particles and inorganic minerals.

For preparation plants that utilize methods of gravity concentration for washing, control over the process is exercised by regulating the specific gravity of the separating fluid, a suspension of sand or magnetite. The affected by extreme variations in raw coal characteristics, raw coal blending is practiced. Blending bins, proportioning techniques, and mobile rotary bucket wheels used as stockpile stackers and reclaimers are examples of methods being used to level out fluctuations in coal sulfur, ash and Btu content, and size.

Selective mining, or the care, effort, and cost expended by the mine operators, engineers, and miners to avoid breaking, handling, or shipping anything but usable coal, could conceivably produce a run-of-mine (ROM) coal product that minimizes downstream preparation and utilization problems and costs. This technique has economic limitations, however, in that it slows down operations, uses more men or machines, and generally decreases productivity. The concern for maximizing average mine productivity by increasing mechanization and avoiding placing stringent specifications on the miners and their capital intensive machines has increased the application of coal preparation machines and processes downstream.

Coal Preparation

Coal preparation is performed to minimize the amount of inorganic materials which constitute a coal feed such that total mining, preparation, and utilization costs are minimized while achieving acceptable hydrocarbon recovery.

product. Examples of both types of analysis are included as Appendix A.

A float and sink analysis is made by testing the coal sample at preselected, carefully controlled specific gravities.

> The specific-gravity fractions are dried, weighed and analyzed, generally for ash content. Other analyses, such as sulfur content are also conducted, depending on the end use of the washed coal. A table is compiled showing the weight percent of each specific-gravity fraction, together with the analyses of each fraction. The data are mathematically combined on a weighted basis into "cumulative float" and "cumulative sink," and used to develop the "washability curves" that are characteristic for the coal. (Leonard and Mitchell 1968)

The two most common chemical analyses are the proximate and ultimate analyses. The proximate analysis normally measures moisture, ash, volatile matter, and fixed carbon. The ultimate analysis normally measures the percentages of the elements present in the coal: hydrogen, carbon, oxygen, nitrogen, sulfur, and ash. The choice of analysis is based on the availability of laboratory facilities and the perceived need for analysis results. Representative analysis results are provided in Appendix A.

Raw Coal Blending and Selective Mining

Where a high degree of product quality control and/or where preparation plant efficiency and performance are both suitable and reasonably uniform. Continued economic boiler operation requires uniformity of feed containing inherent characteristics that permit efficient results when burned. For example, the corrosive effects associated with utilizing high sulfur coal greatly increase operation and maintenance costs. Best results are achieved when the coal has been prepared physically by crushing, sizing, blending, and removing the objectionable impurities discussed earlier.

Sampling and Analyzing Coal

The successful operation of a coal preparation plant requires that the operator have information on raw coal and final product characteristics, as well as reliable data on what is actually happening at each of the preparation stages. The recognized U.S. agency for the standardization of methods for sampling coal is The American Society for Testing and Materials (ASTM). ASTM Standard D-492 and Tentative D-2234 dictate methods for manual (hand) and automatic (mechanical) sampling, respectively, as well as procedures for sample preparation (Leonard and Mitchell 1968). Float and sink tests and/or chemical analyses are then done on the samples to determine raw coal washability characteristics, predict results, check plant performance, or determine analytical characteristics of the final be removed by washing are considered segregated.

Sulfur content in coal is also expressed as a percentage by weight and "is reported in detailed chemical analyses as sulfate sulfur, pyritic sulfur, and organic sulfur" (Leonard and Mitchell 1968). To be extracted, sulfate sulfur, which is usually only of minor importance, must be treated with hydrochloric acid. The limiting minimum for sulfur content after washing is organic sulfur, which cannot be removed unless the chemical bonds holding it are broken.

Moisture in coal, also expressed as a percentage by weight, replaces potential energy in proportion to the amount present, and is therefore considered an impurity. Physically held moisture in the coal pores is inherent moisture, while surface moisture is completely extraneous to the coal and is caused by rain, condensation, etc.

Coal Utilization in Power Generation

When a coal-burning, steam generating plant is designed and constructed, consideration is given to the types of coal economically available in an area. Long-term, large-quantity contracts are awarded benefiting both the utilities and coal producers. Quality criteria are normally included in these contracts to ensure that a coal feed is by IBM's MPSX code. The assignment of a binary decision variable to plant selection suggests that consideration is given only to the results of washing ROM coal at one specific gravity for each plant. This formulation ignores the fact that each mine's coal would exhibit different characteristics after washing, and that each plant is presumably capable of washing at a wide range of gravities. This limitation is addressed by the statement that adding a complete "preparation plant selection is more difficult and would require significant modification to the model" (Barbaro and Mutmansky 1983).

Bott and Badiozamani (1982) have incorporated the blending problem into a model that also determines the mining sequence and rate of advance along each bench. As formulated, only in-pit blending and sulfur limitations are considered, although "specification of limits on other quality parameters such as sodium, ash and/or other elements of concern" (Bott and Badiozamani 1982) are possible. A linear programming algorithm is used in the blending portion of the model, maximizing the value of coal shipped. Coal from each mining block can be blended into a product, stored as noncompliant coal for later use, or handled as refuse.

Gershon (1982) describes a linear programming application, Mine Scheduling Optimization (MSO), that will

(1) Determine the optimal operation of a mine, from mine to plant to market.

(2) Account for mine-plant-market interfaces.

(3) Optimize operations over the life of the mine.

(4) Accomplish long, intermediate, and short range planning.

MSO is a generalized formulation that simultaneously optimizes the ultimate pit, production scheduling, and transportation problems. "The blending problem, however, may require a complete reformulation for different ores" (Gershon 1982). Since Gershon (1982) considers coal to be "representative of a more difficult blending problem where the blend must be accomplished for multiple attributes," his example considers only in-pit blending. A matrix generator, PDS/MAGEN, is used to construct the model, and APEX-III, Control Data Corporation´s linear programming code, solves the problem. Full formulation of this problem requires as many as 8,000 constraints, and therefore, "a little foresight and engineering knowledge, brought to bear on the problem, will save thousands of dollars of computer expense" (Gershon 1982). This foresight and engineering knowledge comes in the form of a programmer capable of eliminating variables and constraints from the model as coal is mined.

Jerez (1984a) has incorporated mining, washing, and transportation into a model for the Lost Mountain mine near

Hazard, Kentucky. Costs are minimized in this formulation which is solved as a mixed integer linear programming model on an MVS/370 using IBM's MPSX solution code. The integer aspect of this formulation handles the decision to wash ROM coal at one of three specific gravities (Jerez 1984b). While the multiple seam, multiple contract requirements at the Lost Mountain mine are not unusual, the flexibility of the operation, as portrayed in a schematic of coal flow, is unique. ROM coal may be stockpiled as high or low quality raw coal, or sent directly to a contract stockpile. Washed coal is also segregated in stockpiles as either high or low quality. Clean coal is then transported to contract stockpiles, with one for each contract. A proportioning technique was adopted that constructs shipments according to the relative proportions of in place coal. This technique prevents both selective mining of only high quality coal and stockpiling of low quality coal. The MVS/370 is located in Chicago, and "an efficient telecommunication network allows different remote locations (Hazard, Kentucky; Middlesboro, Kentucky; Denver, Colorado) to share the information when complex scenarios need to be resolved by different departments" (Jerez 1984a).

Small-Scale Operations

The software and hardware necessary to adopt any of the formulations presented thus far give merit to Nielsen´s (1984) statement that

> combined costs for programs and computer equipment, may represent an initial investment of $100,000 to $200,000, plus training and operating expenses. It is not easy for the small-scale mine manager to convince himself, or others, about the cost effectiveness of such an installation.

Most small-scale operations still make their blending decisions in a manner similar to the Carter Mining Company, an Exxon subsidiary located in Gillete, Wyoming.

> As with other aspects of mining geology, there is an element of individual judgment factored into blending decisions. The coal quality engineer communicates the target blend to the production supervisor and specifies the number of truck loads of coal from each bench that should be loaded into a designated silo. (Brown, Dille, and Hand 1984)

Hooban and Camozzo (1981) offer hope for small-scale operations with a microcomputer. Although presented from the point of view of a coal buyer or broker, a specific shipment, with its associated quality requirements, is blended from 10 coals with varying quality and available only in limited quantities. An explanation of the linear programming software´s simplex procedure is offered in layman´s terms.

> It is not especially obvious from the results, but the program implicitly considers every possible combination of coals that could be devised from

> the mines on which it has information. It does not necessarily perform a computation for each one, but it does produce an answer that cannot be made better by an alternative allocation. (Hooban and Camozzo 1981)

The coal broker, however, is not concerned with preparing coal. His decision is concerned only with meeting contract specifications by blending already prepared coal provided by multiple suppliers.

While any one of the previous formulations may on the surface appear to be adaptable to this study, several peculiarities with Martiki's operation prevent direct adaptation. These pecularities will be outlined as the model is formulated in the next chapter. Significant aspects of coal blending and preparation, a brief description of Martiki's current operation, and several formulations appearing in the literature have been presented. This study will now formulate a model of Martiki's coal blending and preparation process that will reduce wash loss by improving the daily tonnage and the specific gravity decision.

Chapter III

MODELING MARTIKI

A general statement of the coal blending and preparation problem based on the brief examination of Martiki presented earlier would be: how many tons of ROM coal to accept from each source and what specific gravity to wash the coal at in order to meet a contract's quality specifications. This problem statement is not adequate for modeling purposes however. Formulation requires a well defined statement of the problem that includes an appropriate objective, considers external constraints, and acknowledges interrelationships with other organizational areas. It is these site-specific considerations which prohibit defining a mathematical model general enough to be applicable to all coal preparation facilities.

Formulating the Problem

Objective

The obvious objective of a Martiki model would be profit maximization. This choice would involve both revenues and costs. While revenues are well defined as a function of tonnage and quality delivered, costs at Martiki are not easily delineated. A more appropriate objective would be to minimize wash loss. Recognizing that the solution to a coal blending and preparation model is suboptimal to the overall coal producing operation, the objective used should be as specific as possible while still encompassing the main goals of the decision maker and maintaining a reasonable degree of consistency with the higher level objective (Hillier and Lieberman 1967). Minimizing wash loss meets this requirement by directly affecting profits.

The cost of a ton of ROM coal can be considered sunk by the time it reaches the preparation facility. The cost of preparing that ton is a function of the quality. How much of that ton is output as compliant coal, a function of the specific gravity necessary to prepare it, will directly affect revenues. The noncompliant coal output as wash loss represents both lost revenue and the additional cost of disposal. A one percent reduction in Martiki's 1984 wash loss would have decreased disposal costs and increased revenues by approximately $550,700.

External Constraint

For considerations of problem formulation, the only external constraint is the insistence by Martiki operating management that programs be written for an Apple II microcomputer. This constraint places limitations on the problem formulation by eliminating "sophisticated" solution algorithms that have sizable memory requirements. The integer and nonlinear aspects of most of the formulations presented in the literature review must therefore be avoided.

Interrelationships

As the last step in the production of coal, blending and preparation is a function of what has already been mined. Coal selection from a blending and preparation viewpoint involves the decision either to stockpile or to prepare tonnage delivered from each of the sources. Preparation plant personnel have no control over from where in a seam coal is being mined and, therefore, no control over the quality of coal being delivered. This functional relationship can only be eliminated by integrating blending and preparation into an overall mine plan. Operating management at Martiki, however, saw no immediate need for a complete renovation of operations.

Problem Statement

With a specific objective in mind, and with external constraints identified and interrelationships examined, a well-defined statement of the problem is: how can the Martiki preparation plant meet the quality requirements of a contract in such a way as to minimize wash loss, given that the only controls exercised over the process are the option to stockpile coal temporarily and to select a specific gravity at which to prepare coal. This problem statement must now be reformulated into a convenient form for analysis.

Model Construction

> A model is necessarily an abstract idealization of the problem, and approximations and simplifying assumptions generally are required if the model is to be tractable. Therefore, care must be taken to insure that the model remains a valid representation of the problem. (Hillier and Lieberman 1967)

For mathematical modeling purposes, the essence of the problem must be described by a system of equations and mathematical expressions.

Assumptions

Analysis results will be the foundation for model formulation. It must be assumed, therefore, that ASTM procedures are being followed by laboratory personnel when taking and analyzing samples. Even with this assumption, coefficients within the model will not be constants. Full float and sink tests are rarely conducted because they are costly and must be performed at an outside laboratory. The Martiki laboratory is capable only of performing proximate and ultimate chemical analyses at three specific gravities: 1.45, 1.50, and 1.55. While results of these analyses provide theoretical results for washing coal at the test specific gravity, the relationship between these results and results at other specific gravities is nonlinear and varies, as does quality, from seam to seam and within seams.

It must also be assumed that the most recent analysis results are representative of a current delivery. This assumption is necessary since samples are normally taken from delivery trucks instead of ahead of the shovel or dragline at the mine face, and two days are required to perform an analysis.

Decision Variables

The daily coal blending and preparation decision identified in the problem statement may be separated into two related decisions: the tonnage to accept from each source and the specific gravity at which to prepare the resulting blend. The decision variable chosen must be related and quantifiable. The obvious choice of decision variable for this model would be to let x_{ij} be the tons of coal from source i prepared at specific gravity j. Pits will be associated with i = 1 to 10, stockpiles with i = 11 to 20, and coal already prepared with i = 21. This last variable is necessary to accommodate the dynamic three-stage nature of the Martiki infrastructure shown in Figure 1.

This inflexible design allows no room for error. Once ROM coal is unloaded into the crusher chute, it will be output either as clean coal or as wash loss. There are no blending compartments within the silos so coal from the crushed coal silo is prepared in first-in first-out (FIFO) order and eventually shipped in FIFO order from the clean coal silo. Shipment of clean coal is treated as stage 1. Any coal remaining in the clean coal silo after loading a unit-train will be the first coal to be shipped on the next train. It must therefore be incorporated into any stage 2 calculations, where stage 2 is the preparation of ROM coal in the crushed coal silo. Coal remaining after the stage 2 shipment is complete must in turn be incorporated into the stage 3 calculations, where stage 3 is the preparation of ROM coal delivered to the crusher chute. This three-stage treatment is necessary for modeling purposes; operations are actually occurring simultaneously.

While the preparation plant is capable of adjusting its washing gravity almost instantaneously, coal can be prepared only at one gravity at a time. The three-stage treatment allows coal preparation at two specific gravities: one for stage 2 and one for stage 3. Tonnage processed is

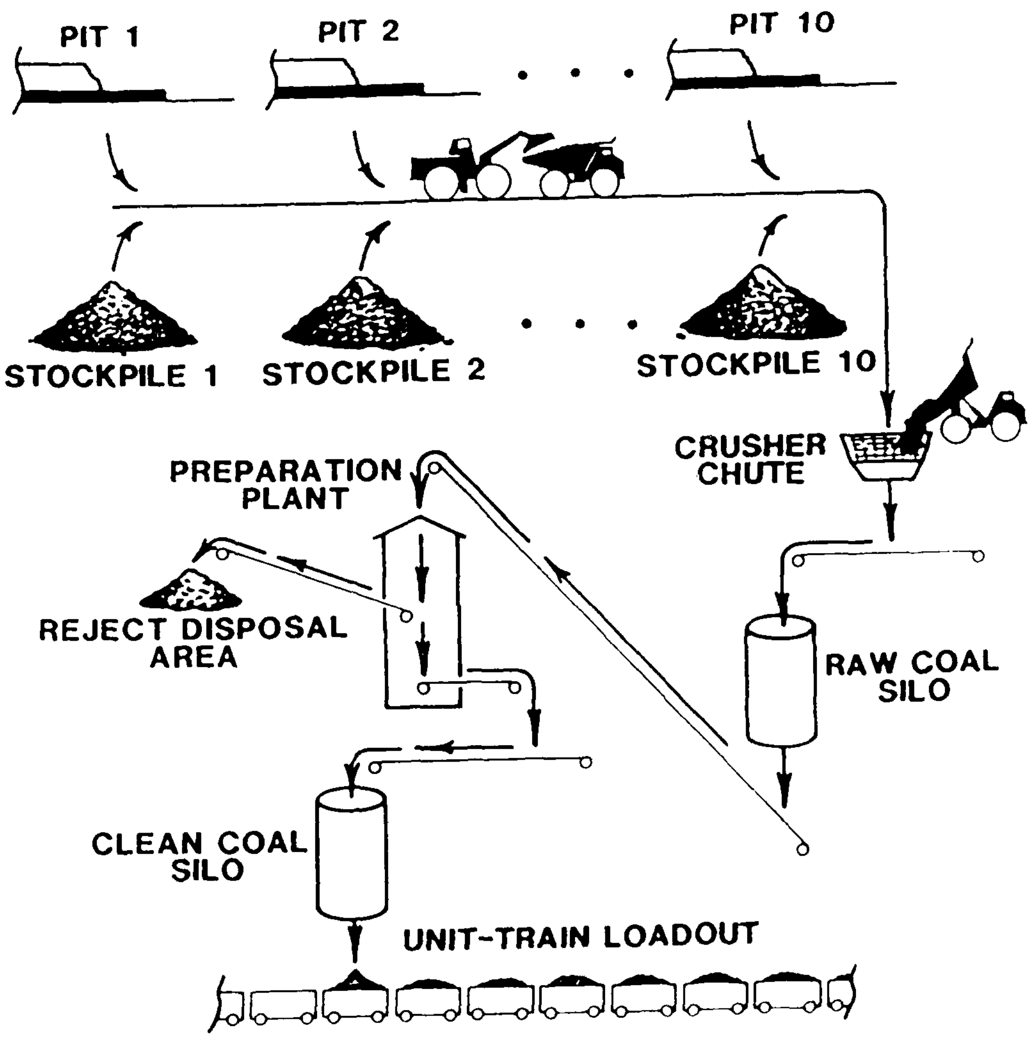


Figure 1

Schematic of Coal Flow

continuously monitored so a change of gravities at the completion of stage 2 is realistic and represents an improvement over the current procedure of maintaining a constant specific gravity during a shift.

This one specific gravity at a time restriction does present problems for model formulation however. The specific gravity, j, can take on 20 values ranging from 1.41 to 1.60. With 20 sources of coal available for preparing and 20 possible specific gravities, 400 primary decision variables are needed. An Apple II's memory is not adequate for performing calculations on an array this large or including additional integer variables needed to limit preparation to one specific gravity. This [illegible] will be addressed in the next chapter. For purposes of clarity, the objective function and constraints presented will still be in terms of x_{ij}.

Objective Function

Letting c_{ij} be the percentage wash loss in decimal form associated with preparing coal from source i at specific gravity j, the objective of minimizing wash loss may be expressed as a function of the decision variables by

$$\text{MIN } \Sigma c_{ij} x_{ij} \text{ for } i = 1 \text{ to } 21 \text{ and } j \in (1, 2, \ldots, 20),$$

where $c_{21,j} = 0$. The objective function coefficients are readily available from sample analysis results. An alternate objective function that maximizes yield, the converse of minimizing wash loss, would be

$$\text{MAX } \Sigma(1-c_{ij})x_{ij} \text{ for } i = 1 \text{ to } 21 \text{ and } j\epsilon(1,2,\ldots,20),$$

where $c_{21,j} = 0$.

Constraints

There are three types of restrictions on the values decision variables may be assigned. Each source will have an upper (bu) and lower (bl) limit based on the expected delivery or stockpile size and the flexibility the decision maker is willing to allow. These limits are independent of the specific gravity and may be expressed as

$$bl_i \leq x_{ij} \leq bu_i \text{ for } i = 1,2,\ldots,21 \text{ and } j\epsilon(1,2,\ldots,20).$$

where $bl_{21} = bu_{21} = x_{21,j}$ since this variable is a constant determined in the preceding stage.

Two capacity constraints exist. The first is for plant capacity. As designed, the preparation plant has a materials balance of 1,200 tons per hour. With two eight-hour shifts operating, the upper limit on plant production is 19,200 tons of ROM coal. This constraint may be expressed as success of this testing phase and the support of top and operating management. Both groups were involved in the initial formulation and so recognize the problem of excessive wash loss attributed to overpreparation and accept the validity of the model formulation. Unfortunately, the status quo, while costly, is comfortable.

As long as the intuition of the current decision maker is adequate for meeting contract quality specifications, the perceived risk of adopting a new procedure does not outweigh the potentially significant benefits. The loss of a contract may be the only situation capable of motivating an abandonment of the status quo. While drastic, a lost contract would represent

> a cost that is brought to light quite emphatically and will generally receive the immediate attention of all operating people concerned. However, the unnecessary daily losses that can so easily escape the operator´s attention unless pointed out factually . . . can be even more costly to the operator. (Leonard and Mitchell 1968)

That this model may never gain complete acceptance may be attributed to the failure of this analyst to identify a "shark" in the organization, someone "highly motivated to rise in the hierarchy, by any means necessary" (Woolsey and Swanson 1975). The means necessary in this case are the willingness to implement a model that has not sold itself

REPORT DATE: 01-28-85

FULL SCENARIO

	STAGE 1 CLEAN	STAGE 2 RAW	STAGE 3 ROM
CONTRACT:	DETROIT ED	MONONGAHLA	CAROLINA P
REQUIRED:			
% SULFUR	1.1	1.05	1.2
SULFUR DB	.1	.1	.1
%ASH	12.8	12.6	13.2
% MOISTURE	13.3	13.1	13.5
BTU	12050	12500	12000
BTU DB	250	500	150
TONS	10000	10000	10000
TONNAGE;			
SILO/ROM	12500	15000	30000
WASH LOSS		4500	8100
EXCESS	2500	3000	14900
SHORTAGE			
QUALITY;			
% SULFUR	1.02	1.14115385	1.20170528
% ASH	11.38	11.2346154	11.907785
% MOISTURE	10.62	12.4615385	13.1989805
BTU	12579	12070.9615	11876.6219
WASH GRAVITY		1.57	1.59
% LOSS		30	27

ROM SOURCES

PIT/PILE	ROM TONS	% LOSS	CLEAN TONS
MARY F#2	5000	27	3650
TAYLORBROS	5000	27	3650
AMBER	5000	27	3650
BLAZER	2650	27	1934.5
TRIPLE "B"	2000	27	1460
CBRG1CBRG2	2000	27	1460
CBRG3CBRG4	2000	27	1460
CBRG 2/3/4	2000	27	1460
CBRG 3/4	2000	27	1460
STOCKTON	2000	27	1460
BLAZER	100	27	73
STOCKTON	250	27	182.5

Figure 4

Sample Report

provided with suggestions for obtaining a stage 3 solution. This suggestion normally entails allowing more flexibility in the coal selection decision by raising or lowering a limit as appropriate.

When the program finds solutions at all stages, the report in Figure 4 is generated. This self-explanatory report lists the results of calculations at each stage. Contract quality specifications are listed in the upper section, blend and preparation quality values, with shortage or excess conditions accounted for, and specific gravities are listed in the middle section, and the lower section lists ROM coal selection values. This report format is used for all three possible scenarios. The values necessary to generate this report are also stored in a data file. More copies of the report may be generated by running the REPORT program.

Implementation

Hillier and Lieberman (1967) suggest that when testing a model it is "sometimes useful to continue the status quo" so that comparisons may be made between current procedures and output from the model. Martiki is currently undergoing this testing phase of implementation with an operator trained on the use of the software package. The likelihood of the model's eventual acceptance is a function of the optimum solution in terms of the objective of reducing wash loss. As with stage 1, calculations are then performed which identify an excess or shortage tonnage condition to input to stage 3.

Stage 3 calculations are performed to simultaneously identify an optimum ROM coal selection blend and specific gravity at which to prepare the blend. Subject to the selection limits specified by the user, iterations search downward from another user input suggested starting specific gravity until the first solution is found. As with the stage 2 iterations, the first specific gravity capable of meeting the stage 3 contract specifications, given an internally calculated blend, is the optimum solution in terms of the objective of minimizing wash loss.

The user is cautioned that if the program's solution to the stage 2 or 3 specific gravity decision is identical to the suggested starting specific gravity input for that stage, then it is possible that a higher specific gravity would yield an improved solution. In either case the BLEND program should be run again with a higher starting specific gravity suggested for the appropriate stage. If no solution is found at stage 2, the program stops and notifies the user. If no solution is found at stage 3, the user is notified of the stage 2 specific gravity solution and

If more tons are available than are needed, the excess is assigned to $x_{21,j}$ and input to the stage 2 calculations. If not enough tons are available to meet the first contract, stage 2 calculations must meet this shortage in terms of both tonnage and quality.

Stage 2 calculations are performed to identify the optimum specific gravity for washing the crushed coal silo contents. An adaption of Nevison's 1982 Simplex program performs the Tucker Tableau LP algorithm iteratively. The iterations search downward from a user input starting specific gravity until the first solution is found. At each iteration new quality and wash loss coefficients are read from the row in each gravity table corresponding to the current specific gravity under consideration. This iterative procedure was necessary to accommodate the strictly linear nature of the model. With a nonlinear or mixed integer linear formulation, these iterations would not be necessary, but the external constraint of solution by an Apple II prevented such "sophistication."

There is no coal selection decision involved at stage 2 since the crushed coal silo contents are fixed. Iterations continue until a solution is found, if one exists. It is intuitively obvious that the first specific gravity capable of meeting the stage 2 contract specifications is the included in gravity tables. Silo contents are identified by tonnage and quality. Contract specifications are dictated, and the order in which to consider contracts is listed. If a solution exists under these conditions, the BLEND program will identify the optimum specific gravity at which to prepare the crushed coal, stage 2, and the optimum tonnage of ROM coal to accept from each source and the optimum specific gravity at which to prepare the resulting blend, stage 3.

The BLEND Program

BLEND accepts the conditions established by DATA and AUTO and performs up to three stages of calculations. A menu is displayed at the beginning of the program that allows the user to specify the scenario to evaluate. The usual selection will be a complete three-stage scenario. If both silos are empty, the user selects the empty silo scenario allowing the program to begin with stage 3 calculations. On the rare occasion in which a raw coal blend is possible, the user selects the raw blend scenario allowing the program to perform modified (no preparation) stage 3 calculations. A listing of the BLEND program is provided in Appendix C.

The stage 1 calculations compare the contents of the clean coal silo with the first contract under consideration.

corresponding to a specific gravity. As mentioned earlier, analysis results are normally available for only one specific gravity, providing six "pieces" of data. At the user's suggestion, another data entry program was written to automatically complete the remainder of the gravity table.

The AUTO Program

AUTO is a curve fitting (piecewise linear) program that calculates quality parameters for a complete gravity table based on available analysis results for a source. If only one analysis is available, the user must input estimated increments for a linear relationship. With two analyses, increments are calculated internally for a linear relationship. Three analyses yield a piecewise linear fit. At the end of the AUTO program, the user is encouraged to return to DATA and to review the tables created by AUTO. User input increments that would yield unrealistic quality values are not allowed. While appearing crude on the surface, AUTO is completely representative of the current thought process required of laboratory personnel, the intended users.

Together, AUTO and DATA establish the conditions of the scenario under consideration. Names identify pits, stockpiles, and contracts. Theoretical washing results for quality parameters at each possible specific gravity are stockpile gravity tables, contract specifications, clean and crushed coal silo contents, upper and lower limits for ROM coal selection, and an ordering of the contracts to consider at each stage. The user reviews and edits these data files by first selecting the appropriate menu option. Displays are then presented in a format similar to current hard copy Martiki reporting formats. Self-explanatory prompts that guide the user through the editing process appear at the same place on the screen for each display. Data entries may be changed individually, by row, or by column at the user's discretion.

Ranging checks are performed as all data are entered to prevent obvious errors. In the coal selection section, the user is notified if a maximum entry is less than a minimum. In the crushed coal silo section, the user is notified of total tonnage input to ensure that source tonnage specifications have been entered accurately. A complete explanation of the DATA program is provided in Appendix B, The User's Manual, where sample displays and all prompts are explained to the user.

From the user's point of view, entering 120 "pieces" of data into each of the 20 gravity tables is the most time consuming aspect of DATA. A gravity table represents the results of a complete float and sink analysis, with each row

$$
\begin{array}{c|cccccc|c|c}
 & X_1 & X_2 & \cdot & \cdot & \cdot & X_n & -1 & \\
\hline
V_1 & t_{1,1} & t_{1,2} & \cdot & \cdot & \cdot & t_{1,n} & C_1 & = Y_1 \\
V_2 & t_{2,1} & t_{2,2} & \cdot & \cdot & \cdot & t_{2,n} & C_2 & = Y_2 \\
\cdot & \cdot & \cdot & & & & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & & & & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & & & & \cdot & \cdot & \cdot \\
V_m & t_{m,1} & t_{m,2} & \cdot & \cdot & \cdot & t_{m,n} & C_m & = Y_m \\
\hline
\end{array}
$$

$$
\begin{array}{|cccccc|}
\hline
b_1 & b_2 & \cdot & \cdot & \cdot & b_n \\
\hline
\end{array}
\quad \boxed{b_{n+1}}
$$

$$
\begin{array}{cccccc}
\shortparallel & \shortparallel & & & & \shortparallel \\
U_1 & U_2 & \cdot & \cdot & \cdot & U_n
\end{array}
$$

Figure 3

Symbolic Tucker Tableau

of maintaining a basis. A symbolic Tucker Tableau from Nevison (1982) is illustrated in Figure 3.

The Tucker Tableau requires all constraints in less than or equal to form, with negative right hand sides allowed. Gaver and Thompson (1973) outline the six steps of the algorithm as follows:

1. Set up the initial tableau and the indicator variables.

2. Find a pivot column by looking for negative indicators. If there are none, stop, a solution has been found.

3. Pivot as with the simplex procedure.

4. Replace the pivot column by the unique non-basic column of the pivot matrix.

5. Exchange the pivot row and column indicators.

6. Go to step 2.

The coefficients that constitute the initial tableau are stored in random-access data files updated by the user with the DATA program.

The DATA Program

Coding a customized data entry program for Martiki was the most time consuming aspect of this study. DATA maintains 10 random-access files that contain pit, stockpile, and contract names, complete 20 row pit and

CHAPTER IV

THE PROGRAMS AND THEIR IMPLEMENTATION

With a problem statement formulated and a mathematical model constructed, a solution technique must be chosen. Given the external constraint of solution on an Apple II and the nature of the model's analytical requirements, the obvious choice is linear programming (LP). As formulated, the proportionality, additivity, divisibility, and certainty assumptions of LP are all satisfied. The choice of an LP algorithm is not as obvious.

The LP Algorithm

Given the constant dimensions of the model formulation expressed in matrix form, 21 columns by 48 rows, the standard simplex algorithm would be computationally inefficient on an Apple II. The Tucker, or condensed, Tableau algorithm represents an efficient alternative in terms of both data storage requirements and programming simplicity. The Tucker Tableau is designed to solve maximization formulations without requiring the addition of slack or artificial variables. This eliminates the requirement to store and manipulate coefficients for 70 additional "dummy" variables. This is accomplished by updating indicator variables bordering the tableau instead

WITH $j \in (1,2,...,20)$, $l \in (1,2,...,10)$, and $c_{21,j} = 0$

MIN	$\Sigma c_{ij} x_{ij}$		for $i = 1$ to 21
ST	x_{ij}	$\leq bu_i$	for all i
	x_{ij}	$\geq bl_i$	for all i
	Σx_{ij}	$\leq 19{,}200$	for $i = 1$ to 20
	Σx_{ij}	$\leq 6{,}000$	for $i = 11$ to 20
	$\Sigma(1-c_{ij}) q_{ijk} x_{ij}$	$\leq \Sigma(1-c_{ij}) q_{kl} x_{ij}$	for $i = 1$ to 21 and $k = (1,2,3)$
	$\Sigma(1-c_{ij}) q_{ijk} x_{ij}$	$\geq \Sigma(1-c_{ij}) q_{kl} x_{ij}$	for $i = 1$ to 21 and $k = 4$

WHERE: x_{ij}-tons of coal from source i prepared at specific gravity j

c_{ij}-decimal form of percent wash loss associated with preparing coal from source i at specific gravity j

bl_i-source i delivery or stockpile lower limit

bu_i-source i delivery or stockpile upper limit

q_{ijk}-analysis result for quality parameter k from source i tested at specific gravity j

q_{kl}-quality parameter k as specified by contract l

Figure 2

The Model Formulation

distinction between preparation phases with excess tonnage from preceding stages incorporated into calculations. The complete model formulation is shown in Figure 2. A solution to this model will meet contract quality requirements, will not violate plant or rehandling capacities, will assign values to the coal selection decision variables within limits specified by the decision maker, and will be optimum in terms of minimum wash loss or maximum yield. Derivation of a solution to the Martiki coal blending and preparation problem will now be discussed.

$$\Sigma x_{ij} \leq 19{,}200 \text{ for } i = 1 \text{ to } 20 \text{ and } j \in (1,2,\ldots,20).$$

The second capacity constraint is for rehandling, or moving tons of stockpiled coal to the crusher chute. The upper limit on rehandling capacity is currently 6,000 tons of ROM coal. This constraint may be expressed as

$$\Sigma x_{ij} \leq 6{,}000 \text{ for } i = 11 \text{ to } 20 \text{ and } j \in (1,2,\ldots,20).$$

The last type of constraint deals with the contract quality specifications. Only one contract is considered at a time, so $l \in (1,2,\ldots,10)$. Letting $k = 1$ correspond to sulfur, $k = 2$ to ash, $k = 3$ to moisture, and $k = 4$ to Btu, the quality constraints may be expressed as

$$\Sigma(1-c_{ij})q_{ijk}x_{ij} \leq \Sigma(1-c_{ij})q_{kl}x_{ij} \text{ for } i = 1 \text{ to } 21,$$
$$j \in (1,2,\ldots,20),\ k \in (1,2,3), \text{ and } l \in (1,2,\ldots,10),$$

and

$$\Sigma(1-c_{ij})q_{ijk}x_{ij} \geq \Sigma(1-c_{ij})q_{kl}x_{ij} \text{ for } i = 1 \text{ to } 21,$$
$$j \in (1,2,\ldots,20),\ k = 4, \text{ and } l \in (1,2,\ldots,10),$$

where q_{ijk} is the analysis result for quality parameter k from source i tested at specific gravity j, and q_{kl} is quality parameter k as specified by contract l, with any deadband added or subtracted as applicable.

As constructed, the model is a valid representation of the problem. The three-stage treatment allows for a and the desire to adopt two apparently unacceptable features accompanying the model:

1. The necessity to obtain improved forecasts on expected daily deliveries from each source.

2. The necessity to exercise control over these deliveries by distributing them either to the crusher or to a stockpile.

Without model implementation this study may still claim limited success, however, since Martiki has adopted recommendations to segregate stockpiles and consider raw coal blending when possible.

CHAPTER V

SUMMARY AND RECOMMENDATIONS FOR FURTHER STUDY

Summary

The coal producer who supplies steam coal for power generation is faced with the dilemma of operating profitably while ensuring that coal supplied is reasonably uniform and meets several quality characteristics. Failure to meet these quality requirements results in the loss of a long-term mutually beneficial contract. In an effort to prevent this from occurring, raw coal blending and preparation is conducted. With gravity concentration methods of preparation, the primary controls over the process are the selection of ROM coal to input and the specific gravity at which to wash the resulting blend. Sample analyses conducted under ASTM standards provide the decision maker with theoretical washing results for preparing coal at a test specific gravity. Unless a site-specific model has been formulated, the decision maker must rely on intuition, an inadequate tool for considering the infinite number of quality, tonnage, and specific gravity combinations possible.

A review of the literature has revealed that previous coal blending models and submodels have been formulated for the large-scale producer with a corporate mainframe computer available. This luxury has allowed the modeler to adopt "sophisticated" analysis techniques capable of considering nonlinear revenue functions and washing results. Most of the authors have admitted that modeling blending and preparation was the most difficult aspect of their formulation, which would account for their failure to consider a full range of gravities.

The purpose of this study was to formulate a coal blending and preparation model for the Martiki Coal mine in Lovely, Kentucky, capable of being solved on an Apple II microcomputer, which would aid the decision maker by identifying the optimum tonnage to accept from each source and specific gravity at which to wash the resulting blend in order to minimize wash loss. Wash loss minimization was chosen as the objective function because overpreparation caused Martiki to experience a 35.19 percent wash loss in 1984. Each percentage reduction of this wash loss would have decreased disposal costs and increased revenues by approximately $550,700.

The model formulated in this study, at the insistence of Martiki management, evaluates the coal blending and preparation problem as a function of what has already been mined, a suboptimal condition. The model treats the Martiki preparation process as a dynamic three-stage process because of the inflexible design of the infrastructure. Once coal is input to the preparation process it is output in FIFO order as either clean compliant coal or noncompliant wash loss.

A Tucker Tableau LP algorithm was chosen as the solution technique because of its computational efficiency in terms of memory requirements and programming simplicity. Coefficients for initial tableaus are read from data files created by the user with the DATA and AUTO programs. The BLEND program performs three stages of calculations when the complete scenario is chosen by the user. Iterations of the Tucker Tableau LP algorithm are performed for stages 2 and 3 which search downward from a user-input suggested starting specific gravity until a solution, the optimum, is found. A report generated at the completion of the program lists contract quality specifications and resulting prepared coal quality values for the three stages, specific gravities to prepare the stage 2 and 3 coal blends at, and ROM tonnage to accept from up to 20 sources.

The model is currently in a testing phase of implementation. It appears unlikely, however, that the model will gain complete acceptance until a contract is lost under the current decision-making procedure.

Recommendations for Further Study

If or when the model is accepted there are several extensions that may be adopted. The first possible extension would be to add a sensitivity analysis report to the current model. The data needed to generate this report are already available from the Tucker Tableau solution. Its inclusion in the existing report would have been nonsensical, however, since preparation plant personnel have no control over either quality or tonnage delivered.

A second extension would require Martiki's management to alter the preparation plant's interrelationship with other organizational areas and obtain costs for all functional areas. An all encompassing model with a profit maximization objective, similar to Gershon's MSO, could then be developed. Ultimate pit, production scheduling, specific gravity, and transportation problems would be optimized simultaneously with a model of this nature.

A third extension would be to formulate a model that blends output from Martiki with that from Pontiki, a sister mine. While this would require considerable logistics planning, one potential benefit is the possibility that the need to prepare Martiki coal may be eliminated.

REFERENCES CITED

Barbaro, Ralph W. and Jan M. Mutmansky. 1983. "A Goal Programming Model for Determining the Optimal Production Schedule Considering Penalties or Bonuses Dependent on Quality." Paper read at the SME-AIME fall meeting and exhibit, 19-21 October, at Salt Lake City, Utah.

Bott, Donald L. and Khosrow Badiozamani. 1982. "Optimal Blending of Coal to Meeting Quality Compliance Standards." Proceedings, 17th Application of Computer Methods in the Mineral Industry. Golden, Colorado, pp. 15-23.

Brown, J. D., J. A. Dille, and J. P. Hand. 1984. "Quality Control and Shipment Planning at the Carter Mining Company." Paper read at the SME-AIME fall meeting, 24-26 October, at Denver, Colorado.

Gaver, Donald P. and Gerald L. Thompson. 1973. Programming and Probability Models in Operations Research. Monterey, California: Brooks/Cole Publishing Co., p. 217.

Gershon, Mark. 1982. "A Linear Programming Approach to Mine Scheduling Optimization." Proceedings, 17th Application of Computer Methods in the Mineral Industry. Golden, Colorado, pp. 483-493.

Hillier, Frederick S. and Gerald J. Lieberman. 1967. Introduction to Operations Research. San Francisco, California: Holden-Day, Inc., pp. 12-19.

Hooban, Michael and Robert Camozzo. 1981. "Blending Coal with a Small Computer." Coal Age. July, pp. 102-104.

Jerez, Rodrigo. 1984a. "Coal Production Scheduling Model." Paper read at the SME-AIME fall meeting, 24-26 October, at Denver, Colorado.

________. 1984b. Personal interview. Denver, Colorado. 15 November.

Knight, C. Gregory and Charles B. Manula. 1976. "The Pennsylvania Coal Model." Proceedings, 14th Application of Computer Methods in the Mineral Industry. State College, Pennsylvania, pp. 655-666.

Leonard, Joseph W. and David R. Mitchell, eds. 1968. Coal Preparation. 3rd Edition. Baltimore, Maryland: Port City Press, Inc., pp. 1-3 - 6-37.

Nelson, Floyd J. 1966. "Determination of Optimum Washing of Metallurgical Coal at the Harmarville Mine." Proceedings, 6th International Symposium on Computers and

Operations Research. State College, Pennsylvania, pp. D1 - D19.

Nevison, J. M. 1982. Executive Computing: How to Get it Done on Your Own. Reading, Massachusetts: Addison-Wesley Publishing Co., pp. 173-200.

Nielsen, Kai. 1984. "APCOM .... What Next?" International Mining. September, pp. 90-91.

Woolsey, Robert E. D. and Huntington S. Swanson. 1975. Operations Research for Immediate Application: A Quick & Dirty Manual. San Francisco, California: Harper & Row, Publishers, p. 66.

Appendix A

TYPICAL SAMPLE ANALYSES

MAPCO, INCORPORATED
Tulsa, Oklahoma

Composite of
DDH M-29 350' 5-1/2", 359' 1-3/4"
DDH M-30 320' 7-1/4", 329' 7-1/4"
DDH M-31 326' 1-3/4", 340' 3-3/4"

Lab No. C-368533, 534, 535

FLOAT & SINK ANALYSIS

February 1974

1	2	3	4	5	6	7	8	9	10	11	12	13	14
SPECIFIC GRAVITY			DRY BASIS			CUM. RECOVERY (FLOAT)				CUM. REJECT (SINK)			
SINK	FLOAT	% Wt	% Ash	% Sul	Btu	% Wt	% Ash	% Sul	Btu	% Wt	% Ash	% Sul	Btu
	1.30	45.8	3.98	0.77	14253	45.8	3.98	0.77	14253	100.0	14.44	0.93	12517
1.30	1.40	28.1	9.98	0.96	13202	73.9	6.26	0.84	13853	54.2	23.28	1.06	11019
1.40	1.45	6.7	17.18	1.05	12038	80.6	7.17	0.86	13702	26.1	37.59	1.16	9731
1.45	1.50	3.3	21.52	0.99	11320	83.9	7.73	0.86	13609	19.4	44.64	1.20	7590
1.50	1.55	1.7	26.85	1.23	10475	85.6	8.11	0.87	13547	16.1	49.38	1.24	6825
1.55	1.60	2.3	33.98	1.06	9368	87.9	8.79	0.88	13437	14.4	52.04	1.24	6294
1.60	1.70	3.4	40.53	1.17	8292	91.3	9.97	0.89	13246	12.1	55.47	1.28	5823
1.70		8.7	61.31	1.32	4866	100.0	14.44	0.93	12517	8.7	61.31	1.32	4266

COMMERCIAL TESTING & ENGINEERING CO.

MC-1024

MARTIKI COAL CORPORATION

A SUBSIDIARY OF MAPCO INC.

CERTIFICATE OF COAL ANALYSIS

SHIPPED TO:

N W K

Volatile	33.33	35.52
Fix. Carbon	52.81	56.28

MINE: MARTIKI

DATE SAMPLE 3-6-85

NO. OF CARS 120

APPROX. TONNAGE 11,535 (CAPACITY WEIGHTS)

ANALYSIS NO. 85-3-32

	% MOISTURE	% ASH	% SULPHUR	BTU
AS REC'D	6.17	7.69	.96	12,688
DRY BASIS	XXXXXXXXXXXX	8.20	1.02	13,522
MAF	XXXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX	14,730

DATE: 3-7-85

I HEREBY CERTIFY THAT THE QUALITY LISTED ABOVE WAS DETERMINED IN LABORATORY TESTS ACCORDING TO A.S.T.M PROCEDURES.

ADDRESS INQUIRIES TO–

MAPCO COALS INC.
1437 South Boulder Ave
Tulsa, Oklahoma 74119
PHONE (918) 592-7269

E Keith Chaffin

CHEMIST

Appendix B

THE USER'S MANUAL

USER'S MANUAL

MARTIKI COAL CORPORATION

BLENDING & PREPARATION SOFTWARE PACKAGE

USER'S MANUAL

MARTIKI COAL CORPORATION
BLENDING & PREPARATION
SOFTWARE PACKAGE

STEVEN L. VAN DREW
COLORADO SCHOOL OF MINES
GOLDEN, CO

Option 4
Edit Stockpile Gravity Tables

When menu option 4 is selected, you will see the display in Figure 2.2 except the the title will be PILES AVAILABLE FOR GRAVITY DISPLAY, and the prompt will be ENTER THE PILE # FOR TABLE TO EXAMINE **. Type a number between 1 and 10 corresponding to the stockpile whose float and sink gravity table you want to examine. Press RETURN. You will then see the display in Figure 2.3, with the current quality values for the stockpile you have selected. The stockpile name will be in the upper right hand corner.

Prompts

Identical to prompts 5-14.

Option 5
Edit Contract Specifications

When menu option 5 is selected, you will see the display in Figure 2.3 except that the title will be ENTER/REVIEW/CHANGE CONTRACT DATA. This phase of DATA allows you to name up to 10 contracts, and set the quality specifications for each. Each name can be up to 10 characters long, and any characters may be used. Names already in memory will be displayed.

Prompts

Identical to prompts 2-4. When no more contract names are to be changed, you will see prompt #16.

13. WHAT COLUMN? (1-6) *
Type a number between 1 and 6 corresponding to the column with the value(s) you want to change.

14. CHANGE ANOTHER COLUMN? (Y/N) *
Type Y or y if you want to change the values for another column.
Type N or n if you want to examine another table or return to the menu display.

Option 3
Name Stockpiles

When menu option 3 is selected, you will see the display in Figure 2.2 except that the title will be ENTER/REVIEW/CHANGE PILE NAMES. This phase of DATA allows you to name up to 10 stockpiles. Each name can be up to 10 characters long, and any characters may be used. Names already in memory will be displayed.

Prompts

15. NAME STOCKPILES WITH PIT NAMES? *
Type Y or y if you want the stockpile names to match the pit names. If you have separate stockpiles for each pit, this is a good way to identify them.
Type N or n if you want to give the stockpiles different names.Other prompts will be identical to prompts 2-4.

8. CHANGE DOWN COLUMN? (Y/N) *
Type Y or y if you want to change values a column at a time.
Type N or n if you are through making changes or want to go back to one of the other methods of changing values.

9. ANY MORE CHANGES? (Y/N) *
Type Y or y if you want to change any more values for the displayed pit. You will then see prompts 6-8 again until you select a method for changing values.
Type N or n if you are through making changes to the displayed pit´s values.

10. EXAMINE ANOTHER TABLE? (Y/N) *
Type Y or y if you want to review the data for another pit. You will then see Figure 2.2 again and be asked to enter a new pit #.
Type N or n if you are through making changes to pit gravity tables. This will return you to the menu display.

11. WHAT SPECIFIC GRAVITY? ****
Type a number between 1.41 and 1.60, the specific gravity of the row with the value(s) you want to change. The value(s) will be replaced with *´s. Type the new value over the *´s, then press RETURN.

12. CHANGE ANOTHER ROW? (Y/N) *
Type Y or y if you want to change the values for another specific gravity.
Type N or n if you want to start changing by columns, examine another table, or return to the menu display.

```
MULTIPLE GRAVITY ANALYSIS FOR **********
SPGR %LOSS MOIST  ASH  SULF  BTU   MAF
1.60 ***** ***** ***** **** ***** *****
1.59 *   * *   * *   * *  * *   * *   *
1.58 *   * *   * *   * *  * *   * *   *
1.57 *   * *   * *   * *  * *   * *   *
1.56 *   * *   * *   * *  * *   * *   *
1.55 *   * *   * *   * *  * *   * *   *
1.54 *   * *   * *   * *  * *   * *   *
1.53 *   * *   * *   * *  * *   * *   *
1.52 *   * *   * *   * *  * *   * *   *
1.51 *   * *   * *   * *  * *   * *   *
1.50 *   * *   * *   * *  * *   * *   *
1.49 *   * *   * *   * *  * *   * *   *
1.48 *   * *   * *   * *  * *   * *   *
1.47 *   * *   * *   * *  * *   * *   *
1.46 *   * *   * *   * *  * *   * *   *
1.45 *   * *   * *   * *  * *   * *   *
1.44 *   * *   * *   * *  * *   * *   *
1.43 *   * *   * *   * *  * *   * *   *
1.42 *   * *   * *   * *  * *   * *   *
1.41 ***** ***** ***** **** ***** *****
DO YOU WANT TO CHANGE ANY VALUES? *
```

Figure 2.3
Gravity Tables Display

6. CHANGE ONE VALUE ONLY? (Y/N) *
Type Y or y if you want to change values one at a time.
Type N or n if you would rather change values a row or column at a time.

7. CHANGE ACROSS ROW? (Y/N) *
Type Y or y if you want to change values a row at a time.
Type N or n if you would rather change values by column.

**********. Type the new name over the *'s and press RETURN when finished. You do not have to use all 10 spaces. If you make a mistake while typing the new name, the left arrow (<--) or delete (DEL) keys will backspace, or the CONTROL and X keys pressed simultaneously will restart the entry.

4. ENTER OR CHANGE ANOTHER? (Y/N) *
Type Y or y if you want to change another name. This will return you to prompt #3.
Type N or n if you are through changing names. This will return you to the menu display.

Option 2
Edit Pit Gravity Tables

When option 2 is selected, you will see the display in Figure 2.2 except that the title will be PITS AVAILABLE FOR GRAVITY DISPLAY, and the prompt will be ENTER PIT # FOR TABLE TO EXAMINE **. Type a number between 1 and 10 corresponding to the pit whose float and sink gravity table you want to examine. Press RETURN. You will then see the display in Figure 2.3, with the current quality values for the pit you have selected. The pit name will be in the upper right hand corner.

Prompts

5. DO YOU WANT TO CHANGE ANY VALUES? *
Type Y or y after reviewing the current data if you want to change any values.
Type N or n if you are satisfied with the current data. Your next prompt will be prompt #10.

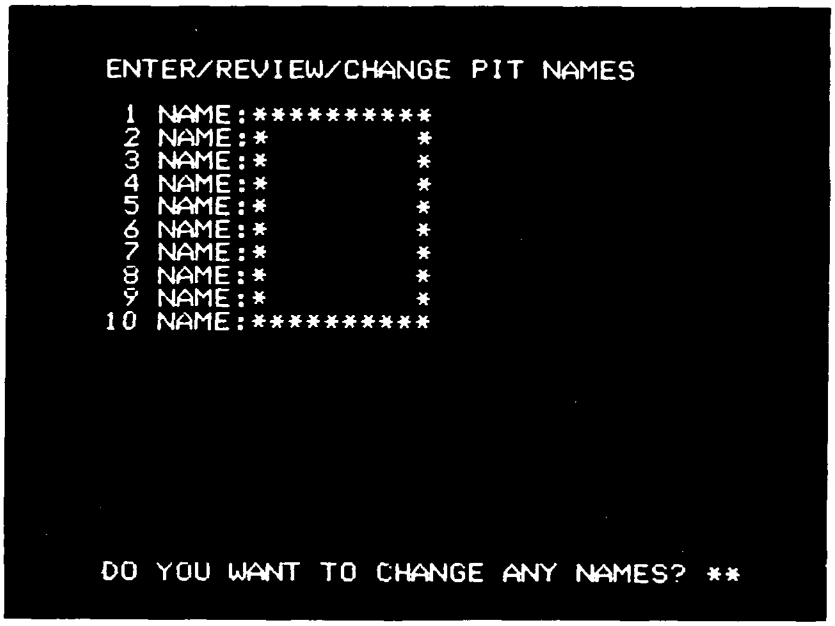


Figure 2.2
Names Display

Prompts

2. DO YOU WANT TO CHANGE ANY NAMES? *
Type Y or y after reviewing existing names, if you want to change any.
Type N or n if you do not want to change any names. This will return you to the menu display.

3. ENTER NUMBER OF NAME TO CHANGE **
Type a number between 1 and 10 corresponding to the name you want to change. Press RETURN. The name you want to change will be replaced by

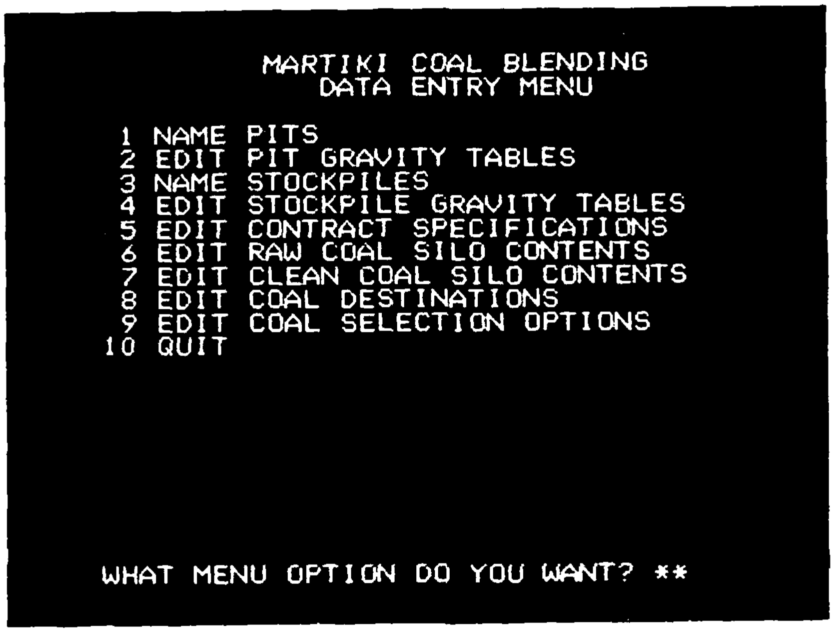


Figure 2.1
DATA Menu Display

Option 1
Name Pits

When menu option 1 is selected, you will see the display in Figure 2.2. This phase of DATA allows you to enter, review, or change up to 10 pit names. Each name can be up to 10 characters long, and any characters may be used. If names are already in memory, they will be displayed. Names chosen should be unique and have some relationship to the pit they identify so that others will recognize them later.

CHAPTER 2
THE DATA PROGRAM

Purpose

The DATA program is the most important phase of the package. Without accurate and current data, any solution that the BLEND program gives will be of no use. DATA allows the user to review and update all of the data needed by BLEND. Pit, stockpile and contract names, float and sink gravity tables and contract specifications are examples of the type of data manipulated with DATA.

The DATA Entry Menu

Once DOS 3.3 is booted, the System Master disk can be removed. Select the disk labeled DATA, insert it into drive 1, and close the door. Type

]RUN DATA

then press RETURN. The IN USE lamp should light, and after a few seconds you will see the display in Figure 2.1. This is the menu display which you will see throughout the program. You have 10 options available which will each be explained in the following sections.

Prompt

1. WHAT MENU OPTION DO YOU WANT? **
Type a number between 1 and 10 corresponding to the option you want to select. If you make a mistake while typing, use the left arrow (<--) or delete (DEL) key to backspace. Press RETURN when finished.

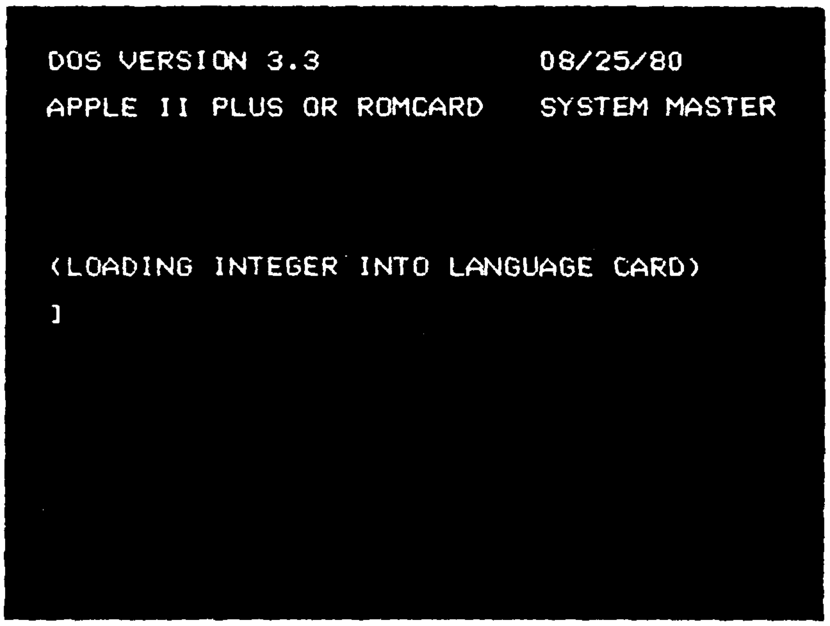


Figure 1.1
Start-up Display

designed to be as similar to current Martiki report formats as possible. Questions that require responses, called prompts, are always located at the bottom of the screen. Prompts are self-explanatory and simple checks are made on numeric responses to ensure that they are within range. If you type a character that is not allowed, you will hear a bell. Pressing RETURN is not necessary for (Y/N) responses.

Getting Started

With the Apple II set up properly (consult owner´s manual), turn on the monitor. Select the disk labeled DOS 3.3 System Master, insert it into drive 1, close the door, and turn on the power switch for the Apple II. You should hear a beep from inside the Apple II and see the display in Figure 1.1. The flashing square on the screen is the cursor, which marks where the next character you type will appear. The square bracket (]) is the Applesoft prompt. If the only message on the screen is Apple][and the disk is whirring with the IN USE lamp lit, you have either inserted the wrong disk, or have inserted the System Master upside down. Turn off the console and repeat these procedures.

CHAPTER 1
INTRODUCTION

Purpose

The Martiki Coal Blending software package is a set of customized Applesoft programs designed to be used by Martiki Coal Corporation preparation plant and laboratory personnel as an aid in making the daily specific gravity and tonnage decision. This manual may be used as both a handy reference for operators trained on the use of the package, or as a tutorial for future operators.

Organization

This manual presents material in the same sequence that it will be encountered when running the programs. Chapter 2 covers the DATA program, Chapter 3 covers the AUTO program, and Chapter 4 covers the BLEND program. Chapter 5 presents methods of configuring the data so that other variations may be evaluated. Figures in each chapter represent the various monitor displays. Accompanying each figure is a list of the prompts that can be encountered and an explanation of the responses expected. At the end of each chapter is a section on error handling. While the programs have error trapping routines built in, not every error can be handled within a program.

General

The package has been written for any Apple II series computer with 128k of memory that can be booted with DOS 3.3. A terminal, monitor, printer, and two disk drives are needed. No knowledge of programming is necessary to run these programs. The displays and output have been

LIST OF FIGURES

TABLE OF CONTENTS

16. ENTER # OF CONTRACT TO EXAMINE **
Type a number between 1 and 10 corresponding to the contract whose specifications you want to examine. Press RETURN. You will then see the display in Figure 2.4 with prompt #5.

17. ENTER # OF VALUE TO CHANGE *
Type a number between 1 and 6 corresponding to the row that the value you wart to change is in. If you want to change all values you will have to repeat this step each time. The next prompt will be prompt #9.

18. EXAMINE ANOTHER CONTRACT? *
Type Y or y if you want to examine the specifications for another contract.
Type N or n if you want to return to the menu display.

```
CONTRACT SPECIFICATIONS FOR **********

 1 MAX % SULFUR           ****
 2 MAX % ASH             *****
 3 MAX % MOISTURE        *****
 4 AVERAGE BTU/LB   *****
 5 SULFUR DEADBAND         ***
 6 BTU/LB DEADBAND      ***

DO YOU WANT TO CHANGE ANY VALUES? *
```

Figure 2.4
Contract Specifications Display

Option 6
Edit Raw Coal Silo Contents

When menu option 6 is selected, you will see the display in Figure 2.5, first for pits, and then for stockpiles. This phase of DATA allows you to list the tons for each pit and stockpile that are in the raw coal silo.

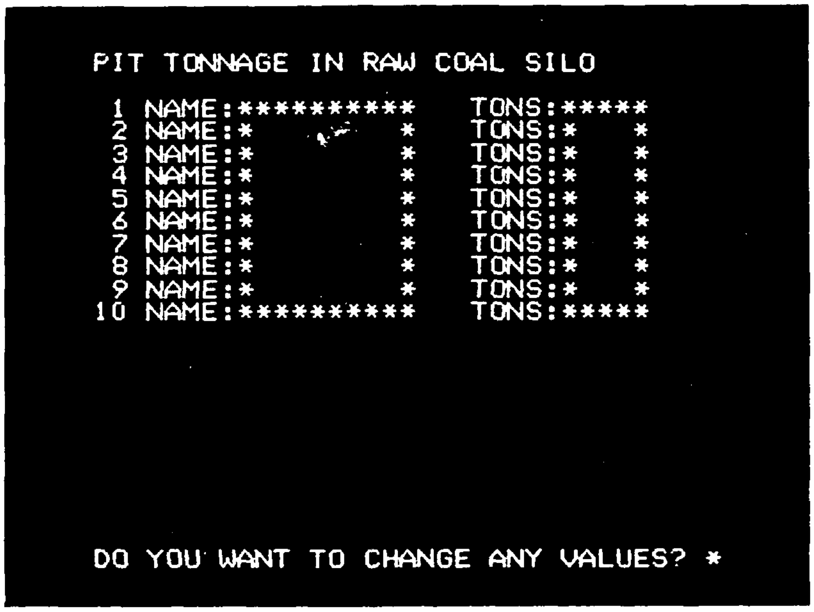


Figure 2.5
Raw Coal Silo Display

Prompts

The first prompt you will see is prompt #5, followed by prompt #6. If you type Y or y for prompt #6, you will see prompt #19 next. If you type N or n for prompt #6, you must change all values.

19. ENTER THE # FOR THE TONS TO CHANGE ** Type a number between 1 and 10 corresponding to the pit or stockpile whose tons you want to change. The next prompt will be prompt #9.

20. ARE ALL VALUES CORRECT? *
Type Y or y if you are satisfied with all of the changes you just made. This is a check at the end of changing all values, so review what you have just typed in.
Type N or n if you notice a mistake. The next prompt will be prompt #6.

21. RAW TONS IN SILO TOTAL TO *****
IS THIS TOTAL CORRECT? *
Type Y or y if this total is correct and you want to return to the menu display. The total is the sum of pit and stockpile tons in the raw coal silo.
Type N or n if this total is not correct. You will have to repeat all steps of this phase again to find the mistake.

Option 7
Edit Clean Coal Silo Contents

When menu option 7 is selected, you will see the display in Figure 2.6. This phase of DATA allows you to list the quality characteristics and tons in the clean coal silo.

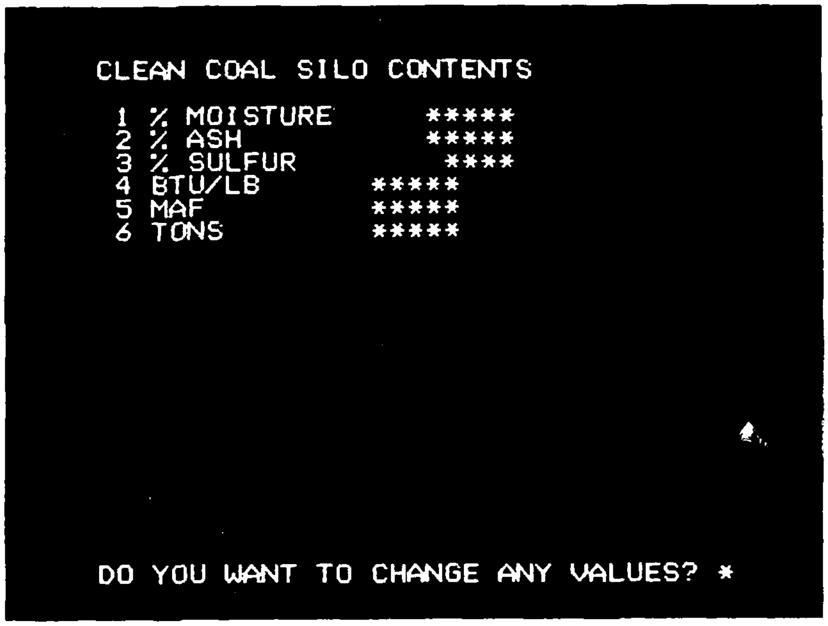


Figure 2.6
Clean Coal Silo Display

Prompts

You will see prompt #5 first, followed by prompt #6 if you type Y or y for prompt #5. If you type Y or y for prompt #6, you will see prompt #22. If you type N or n, you will have to change all values, and then you will see prompt #20.

22. ENTER THE # OF THE VALUE TO CHANGE *
Type a number between 1 and 6 corresponding to the row that the value you want to change is in. After making the change, you will see prompt #9.

Option 8
Edit Coal Destinations

When menu option 8 is selected, you will see the display in Figure 2.7. The 10 contract names are listed again for your reference. This phase of DATA allows you to set the destinations (contract #) and tonnage for each of the 3 stages.

Prompts

You will see prompt #5 first, followed by prompt #6 if you type Y or y for prompt #5. If you type Y or y for prompt #6, you will see prompt #23. If you type N or n, you will see prompt #24.

23. ENTER THE STAGE ROW # *
Type a number between 1 and 3 corresponding to the row of the stage whose value you want to change, then you will see prompt #25.

24. REPLACE WITH NEXT STAGES? *
Type Y or y if you want the contract # and tons for stage 2 to replace those in stage 1, and the contract # and tons for stage 3 to replace those in stage 2. You will have to enter the new stage 3 values.
Type N or n if you want to change all values yourself. After making the changes you will see prompt #20.

25. IS THE VALUE A CONTRACT #? *
Type Y or y if the value you want to change is in the contract # column.
Type N or n if the value you want to change is in the tons column.
After making the change you will see prompt #9.

```
SET COAL DESTINATIONS AND TONNAGES

 1 NAME:**********
 2 NAME:*        *
 3 NAME:*        *
 4 NAME:*        *
 5 NAME:*        *
 6 NAME:*        *
 7 NAME:*        *
 8 NAME:*        *
 9 NAME:*        *
10 NAME:**********

   STAGE           CONTRACT #    TONS
 1 CLEAN COAL          **        *****
 2 RAW COAL            **        *****
 3 ROM COAL            **        *****



DO YOU WANT TO CHANGE ANY VALUES? *
```

Figure 2.7
Coal Destinations Display

Option 9
Edit Coal Selection Options

When menu option 9 is selected, you will see the display in Figure 2.8, first for pits, and then for stockpiles. This phase of DATA allows you to list the minimum and maximum tons available from each of the pits and stockpiles. If no coal is available for the current blend, make both the minimum and maximum 0. If you want to force the blend to have a certain amount of coal from one of

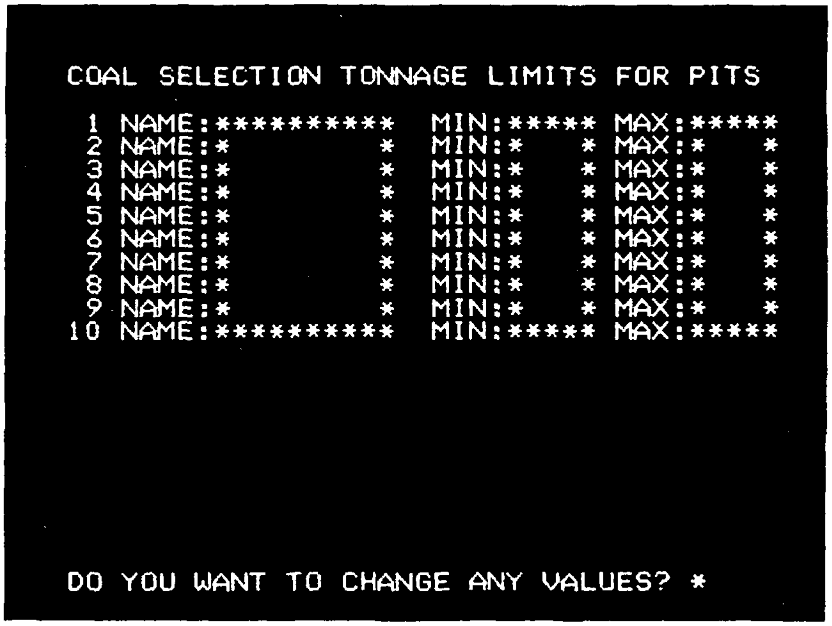


Figure 2.8
Coal Selection Display

the sources, make both the minimum and maximum that amount of tons.

Prompt

The only prompt you will see is prompt #5. If you type Y or y you will have to change all values on the display. If you type N or n you will go from the pit to the stockpile display, and then return to the menu display.

Option 10
Quit

When menu option 10 is selected, the program will end after saving all changes you have made. The display in Figure 2.9 will appear.

Figure 2.9
End of DATA Display

Error Handling

The following list of error messages and how to handle them does not include every possible error, only those that are most likely to be encountered. For a more detailed list or explanation, consult an Apple User´s Manual.

1. MAX IS LESS THAN MIN IN ROW # **

This message will appear in the coal selection phase (option 9) if you have entered values for a pit or stockpile with the minimum value greater than the maximum. DATA will return you to the display so that you can correct the error.

2. DISK DEFECTIVE OR DRIVE NOT READY!
CORRECT THE PROBLEM, THEN PRESS
THE RETURN KEY TO TRY AGAIN

Either the disk drive door is open or the disk was not inserted correctly. Remove the disk, reinsert it and close the door. Press RETURN. If the error message appears again, the disk is defective. Try using another copy of DATA. You may have to reboot the System Master disk first.

3. FILE NOT ON THIS DISK!
CORRECT THE PROBLEM, THEN PRESS
THE RETURN KEY TO TRY AGAIN

The wrong disk was inserted into the drive, or you have typed the program name wrong. Check your spelling first. If that was not the problem, remove the disk, insert the correct one, then press RETURN.

4. ***** FILE LOCKED!

A data file has been locked, preventing changes. The file´s name is *****. Type]UNLOCK *****, then press RETURN. You will now have to rerun DATA.

CHAPTER 3
THE AUTO PROGRAM

The AUTO program is a way of quickly completing gravity tables. This is especially convenient when the only data available is from a 1.50 laboratory analysis. You cannot review gravity tables from AUTO, it is only designed to take the data you provide and complete entire gravity tables. To review changes you have made with AUTO, you should run DATA.

The AUTO Menu

AUTO is on the same disk as DATA, so select the disk labeled DATA, insert it into drive 1, and close the door. Type

]RUN AUTO

then press RETURN. The IN USE lamp should light, and after a few seconds you will see the display in Figure 3.1. This is the menu display for AUTO. The top half of the screen stays the same throughout the entire program. You have five options available which will be explained in the following sections.

Prompts

26. WHAT AUTO ENTRY METHOD DO YOU WANT? * Type a number between 1 and 5 corresponding to the option you want to select. If you make a mistake while typing, use the left arrow (<--) or delete (DEL) key to backspace. Press RETURN when finished. Unless you type 5 you will then see prompt #27.

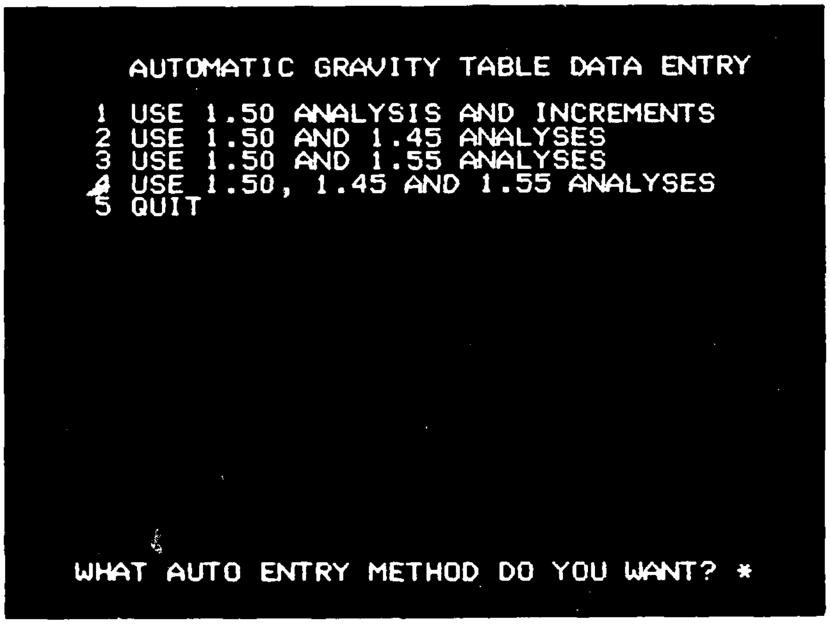


Figure 3.1
AUTO Menu Display

27. IS THIS ANALYSIS FOR A PIT? (Y/N) *
Type Y or y if the gravity table you want to automatically complete is for a pit. Pit names will then be displayed and you will see prompt #28.
Type N or n if the gravity table you want to automatically complete is for a stockpile. Stockpile names will then be displayed and you will see prompt #29.

28. ENTER THE PIT # **
Type a number between 1 and 10 corresponding to the name of the pit whose gravity table you want to automatically load.

29. ENTER THE STOCKPILE # **
Type a number between 1 and 10 corresponding to the name of the stockpile whose gravity table you want to automatically load.

AUTO Options

Prompts 26-29 tell AUTO which pit or stockpile gravity table you want to complete automatically and which method you want to use. If you choose method 1 and either a pit or stockpile, you will see Figure 3.2. Methods 2,3, and 4 have displays identical tc Figure 3.2 except for the INCR row which will be 1.45 for method 2, 1.55 for method 3, or 1.45 and 1.55 for method 4. Each method requires the results from a 1.50 analysis. When using method 1, AUTO will sound a bell and erase an entry if the increment provided would give unrealistic data. Normally, increments should all be positive values since AUTO uses the general trend that as the specific gravity gets lower, % loss, BTU, and MAF get higher, and % moisture, % ash, and % sulfur get lower.

After AUTO saves the completed table, you will see prompt #26. Continue automatically completing tables by selecting method 1,2,3, or 4. To end AUTO, choose method 5, QUIT. The screen will be erased and you will see the message

RUN DATA TO REVIEW THESE CHANGES

The DATA disk is already in drive 1, so to do this, type

]RUN DATA

then press RETURN. Reviewing the new gravity tables is important since BLEND uses whatever is there, right or wrong.

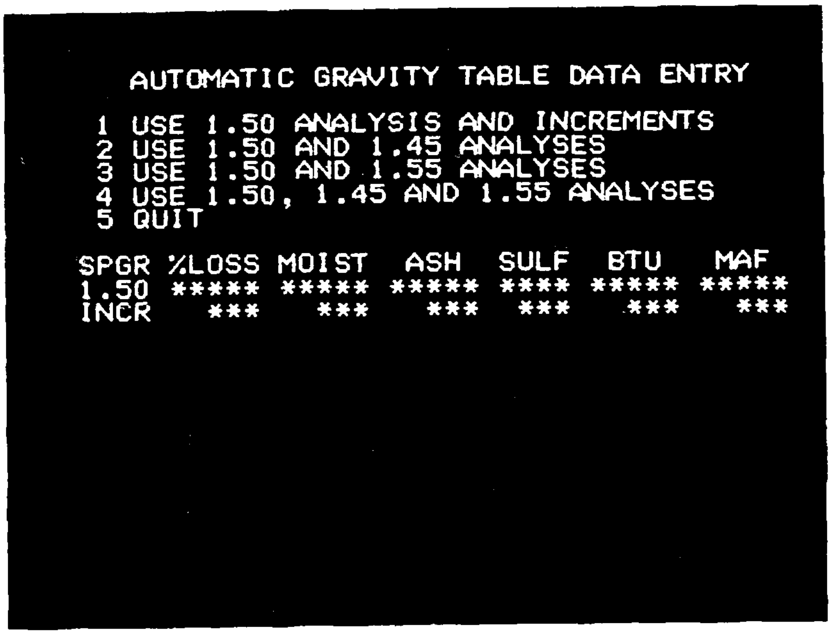
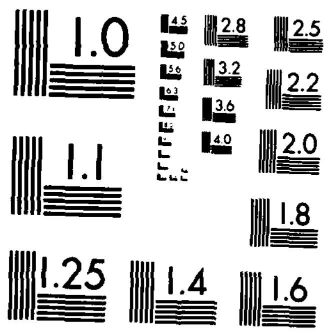


Figure 3.2
AUTO Method Display

AD-A154 797 A LINEAR-PROGRAMMING-BASED COAL PREPARATION AND BLENDING TECHNIQUE(U) ARMY MILITARY PERSONNEL CENTER ALEXANDRIA VA S L VAN DREW 10 APR 85 2/2

UNCLASSIFIED F/G 9/2 NL

END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963 A

CHAPTER 4
THE BLEND PROGRAM

Purpose

The BLEND program uses data from DATA and AUTO to calculate specific gravities for preparing raw coal silo and ROM coal, and tonnage to accept from pits and stockpiles as ROM coal. BLEND treats the preparation process as three separate stages. Stage 1 handles the clean coal silo, stage 2 prepares coal in the raw coal silo, and stage 3 blends ROM coal from pits and stockpiles and prepares it. The answers BLEND gives will be the best, under the conditions established by DATA and AUTO, for minimizing the percent reject, or wash loss.

The BLEND Scenario Menu

Once you have established the conditions with DATA and AUTO, place the DATA disk in drive 2 and the BLEND disk in drive 1. Close both drive doors. Make sure that the printer is on and ready. Type

```
]RUN BLEND
```

then press RETURN. The IN USE lamp should light, and after a few seconds you will see the display in Figure 4.1. This is the scenario menu which allows you to choose a scenario for BLEND to evaluate. You have three scenarios available which will be explained in the scenario section.

Prompt

30. WHAT SCENARIO DO YOU WANT TO USE? *
Type a number between 1 and 3 corresponding to the scenario you want BLEND to evaluate.

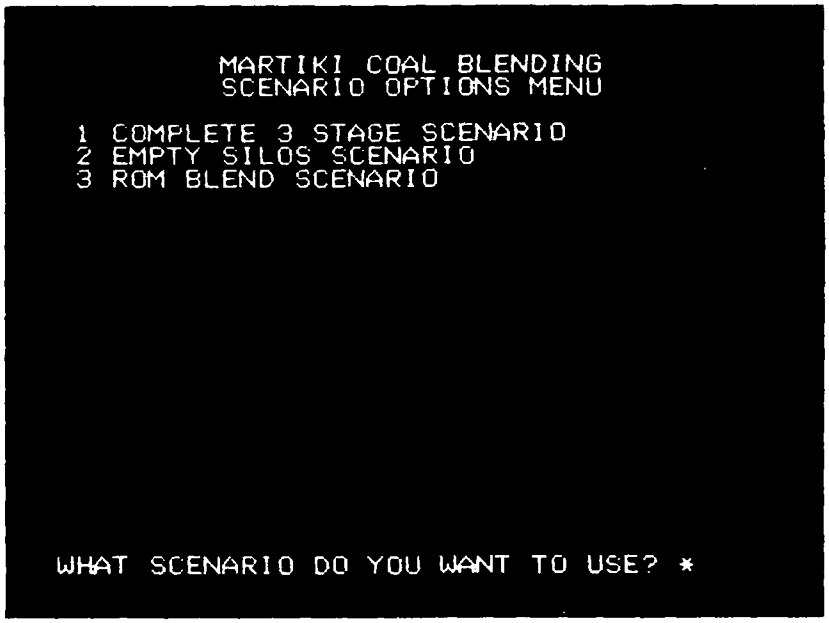


Figure 4.1
BLEND Menu Display

<u>Scenarios</u>

1. Scenario 1, COMPLETE 3 STAGE SCENARIO, will be the normal scenario to select. This scenario evaluates the entire preparation process as three separate stages.

2. Scenario 2, EMPTY SILOS SCENARIO, should be chosen when <u>both</u> silos are empty. This scenario ignores both silos and immediately begins calculating ROM tonnage and specific gravity. It is not necessary to "empty" the silos first with DATA, BLEND does not even read silo data for this scenario.

3. Scenario 3, ROM BLEND SCENARIO, should be chosen when it may be possible to meet contract specifications with a ROM blend. When running DATA, ROM quality should be put in the gravity table´s 1.60 specific gravity row for each source under consideration for this blend. % loss is ignored since no preparation is involved.

Date Entry

After selecting a scenario, you will be asked to

ENTER THE DATE BELOW

Month, day, and year should be typed in as two-digit numbers, for example

```
MONTH 02
DAY   21
YEAR  85
```

Starting Specific Gravities

After entering the date, if you selected scenario 1 or 2 you will be asked to

ENTER YOUR SUGGESTIONS BELOW FOR
SPECIFIC GRAVITIES TO START WITH

A caution statement will also be displayed.

CAUTION! IF A SOLUTION IS FOUND AT A
SPECIFIC GRAVITY THAT YOU SUGGESTED,
YOU SHOULD RUN THE PROGRAM AGAIN WITH
A HIGHER SUGGESTED SPECIFIC GRAVITY

BLEND is designed to search down in increments of .01 from your suggestion for a starting specific gravity until a specific gravity is found that is capable of preparing either the raw coal silo coal or ROM coal to contract specifications. If you suggest 1.60 as the specific gravity to start stage 2 or 3 at, every specific gravity from 1.60

down to the answer will be evaluated. To speed up the calculations, you can suggest specific gravities closer to where you think the answer might be. However, as the caution statement warns, if BLEND stops with your suggested specific gravity for either stage 2 or 3, you cannot be sure that a higher specific gravity would not work also. You should run BLEND again with a higher suggestion for the appropriate stage. If scenario 1 was chosen you will see prompts 31 and 32. If scenario 2 was chosen you will only see prompt #32.

Prompts

31. STAGE 2 (RAW SILO) SUGGESTIONS? ****
Type a number between 1.60 and 1.41 corresponding to the specific gravity you want the stage 2 calculations to begin with. After entering your suggestion press RETURN.

32. STAGE 3 (ROM) SUGGESTION? ****
Type a number between 1.60 and 1.41 corresponding to the specific gravity you want the stage 3 calculations to begin with. After entering your suggestion press RETURN.

BLEND While Calculating

After entering your suggestion(s) for starting you will see a display similar to Figure 4.2. This display will remain on the screen while BLEND performs its calculations. The display is updated as the search for specific gravities drops down. You can check the status of calculations at any time by reading the stage 2 and/or stage 3

Figure 4.2
BLEND in Progress Display

"SG=" value. For example, the sample display in Figure 4.2 shows that BLEND has found a specific gravity of 1.52 for stage 2 and is currently evaluating 1.47 as a stage 3 specific gravity. If scenario 2 was chosen there will be no value for stage 2. If scenario 3 was chosen there will be no values for stage 2 or 3. Each time BLEND changes to a new specific gravity, a bell will sound and the new value will be displayed under the appropriate stage.

The BLEND Report

When BLEND completes calculations for the scenario you have chosen, a report similar to Figure 4.3 will be printed. The format is the same for all three scenarios, only the values change. For example, if scenario 2 or 3 was chosen, the report would have "0" for stage 1 and stage 2 entries. There would also be no stage 3 wash gravity or % loss if scenario 3 was chosen. The sample report is for scenario 1.

The sample report shows that stage 1 is shipping 10,000 tons to Detroit Ed, stage 2 is shipping 10,000 tons to Monongahla, and stage 3 is shipping 10,000 tons to Carolina P. For each stage, contract quality requirements are listed as "CONTRACT REQUIRED;", and actual shipped quality as "QUALITY;". The tonnage for each stage is listed as "TONNAGE;". For example, stage 2 had 15,000 tons in the raw coal silo, lost 4,500 tons as reject, used 2,500 tons of excess from stage 1, shipped 10,000 tons to Monongahla, and was left with 3,000 tons of excess for stage 3, (15000 - 4500 + 2500 -10000 = 3000). Raw coal silo coal should be prepared at 1.57 with a 30% wash loss. ROM coal from the 12 sources should be prepared at 1.59 with a 27% wash loss. For each of the 12 sources, the ROM tons to blend, the individual % loss, and the resulting clean tons are listed.

The DATA needed to generate this report is saved before BLEND ends. After the report is printed the display will erase and you will see the message

DONE! RUN REPORT TO GET ANOTHER COPY

At any time, to get another copy of the most recent report, the BLEND disk should be in drive 1 and the printer should be ready. Type

]RUN REPORT

then press RETURN.

REPORT DATE: 01-28-85

FULL SCENARIO

	STAGE 1 CLEAN	STAGE 2 RAW	STAGE 3 ROM
CONTRACT;	DETROIT ED	MONONGAHLA	CAROLINA P
REQUIRED;			
% SULFUR	1.1	1.05	1.2
SULFUR DB	.1	.1	.1
%ASH	12.8	12.6	13.2
% MOISTURE	13.3	13.1	13.5
BTU	12050	12500	12000
BTU DB	250	500	150
TONS	10000	10000	10000
TONNAGE;			
SILO/ROM	12500	15000	30000
WASH LOSS		4500	8100
EXCESS	2500	3000	14900
SHORTAGE			
QUALITY;			
% SULFUR	1.02	1.14115385	1.20170528
% ASH	11.38	11.2346154	11.907785
% MOISTURE	10.62	12.4615385	13.1989805
BTU	12579	12070.9615	11876.6219
WASH GRAVITY		1.57	1.59
% LOSS		30	27

		ROM SOURCES	
PIT/PILE	ROM TONS	% LOSS	CLEAN TONS
MARY F#2	5000	27	3650
TAYLORBROS	5000	27	3650
AMBER	5000	27	3650
BLAZER	2650	27	1934.5
TRIPLE "B"	2000	27	1460
CBRG1CBRG2	2000	27	1460
CBRG3CBRG4	2000	27	1460
CBRG 2/3/4	2000	27	1460
CBRG 3/4	2000	27	1460
STOCKTON	2000	27	1460
BLAZER	100	27	73
STOCKTON	250	27	182.5

Figure 4.3
Sample Report

No BLEND Solution

If BLEND is not able to find a solution for stage 2, the screen will be erased, a bell will ring 10 times, and the message

THE PROGRAM COULD NOT FIND A SOLUTION
FOR WASHING THE RAW COAL!

will appear. Since the raw coal silo contents are fixed, you have no choice but to wash it anyway at 1.41. To get BLEND to go ahead and calculate a full scenario, you should change the quality requirements for the stage 2 contract, and suggest 1.41 as the stage 2 starting gravity. This will allow BLEND to process stage 2 and go on to stage 3. Keep in mind that the stage 2 contract quality requirements are not correct.

If BLEND is not able to find a solution for stage 3, the screen will be erased, a bell will ring 10 times, and the message

THE PROGRAM COULD NOT FIND A SOLUTION
FOR WASHING THE ROM COAL!

RAW COAL CAN BE WASHED AT ****

will appear. The most likely reason is that BLEND did not have enough flexibility for finding a ROM blend that it could prepare. Rerun DATA and lower as many coal selection minimums as possible. Then rerun BLEND and suggest **** as the stage 2 starting gravity.

If BLEND is not able to find a solution for blending ROM coal, scenario 3, the screen will be erased, a bell will ring 10 times, and the message

THE PROGRAM COULD NOT FIND A SOLUTION
FOR BLENDING THE ROM COAL!

will appear. This either means that not enough compliant coal is available, you are forcing BLEND to use too much non-compliant coal, or there is no way to meet the contract without preparation.

Rerun DATA and lower the coal selection minimums or raise the maximums, whichever seems appropriate. Then rerun BLEND.

Error Handling

The following list of error messages and how to handle them does not include every possible error, only those that are most likely to be encountered. For a more detailed list or explanation, consult an Apple User's Manual.

1. YOU ARE TRYING TO FORCE THE PROGRAM TO BLEND MORE THAN PLANT CAPACITY! RERUN THE DATA PROGRAM AND LOWER THE SELECTION MINIMUMS BY AT LEAST ****

This message will appear if the minimum tons specified in DATA's coal selection section add up to more than 20,000, the plant capacity. You should run DATA again and lower enough minimums to bring the minimums total down to 20,000 or lower. Chapter 5 discusses another method for handling this error.

2. YOU ARE TRYING TO FORCE THE PROGRAM TO BLEND MORE THAN REHANDLING CAPACITY! RERUN THE DATA PROGRAM AND LOWER THE SELECTION PILE MINIMUMS BY AT LEAST ****

This message will appear if the minimum tons for stockpiles specified in DATA's coal selection section add up to more than 6,000, the rehandling capacity. You should run DATA again and lower enough stockpile minimums to bring the total down to 6,000 or less. Another method for handling this error is discussed in Chapter 5.

3. END OF DATA
RERUN THE DATA PROGRAM AND
REVIEW THE DISPLAYS FOR MISSING OR BAD
DATA, INSERT THE PROPER VALUE,
THEN TRY AGAIN

This message will appear if BLEND has a problem trying to read data created by DATA or AUTO. You should run DATA and look for an obvious mistake in one of the displays.

Other possible errors and messages are similar to the Error Handling section in Chapter 2.

CHAPTER 5
VARIATIONS ON USE

While the software package was designed to aid in making the daily specific gravity and tonnage decision, the variations on its use are limited only by the imagination of someone familiar enough with Martiki´s preparation process. The easiest way to test a new idea is just to try it and examine the results to see if they are consistent with the actual situation.

One fairly obvious variation is to examine the effects of a change in contract requirements. To do this you should run a "typical day´s" scenario with the old contract requirements, and then run the same scenario with only the contract requirements changed. Comparing the two reports will show what effects, if any, this contract change will have.

Another variation is to examine the effects of adding a new pit or stockpile. Again, run a "typical day´s" scenario without the new source, and then run the same scenario with the new source available for coal selection. Comparing the two reports will show what effects, if any, this new source will have.

Another variation is to raise the plant and/or rehandling capacity. To do this, place the BLEND disk in drive 1, close the door, then type

```
]LOAD BLEND              (press RETURN)
]LIST 8380
```

and press RETURN. You will see

```
8380 C(22)=20000:C(23)=6000:REM PLANT &
        REHANDLING CAPACITY
```

You can temporarily change either capacity by retyping line 8380 with new values. For example, type

```
8380 C(22)=30000:C(23)=8000:REM PLANT &
        REHANDLING CAPACITY
```

then press RETURN. If you run BLEND now, the plant capacity will be 30,000 tons, and the rehandling capacity will be 8,000 tons. This change is only temporary, however, and will be lost as soon as you run a different program or turn off the Apple. To make the change permanent, after typing your new line 8380 type

```
]UNLOCK BLEND          (press RETURN)
]SAVE BLEND            (press RETURN)
]LOCK BLEND
```

then press RETURN.

You can examine the effects of a different capacity by running a "typical day's" scenario with the old capacity, changing line 8380 as shown above, then rerunning the same scenario. Comparing the two reports will show what effects, if any, the capacity change will have.

Changing the plant capacity will also allow you to look at a long-range projection. Run BLEND's empty silos scenario with a "typical" contract for stage 3, capacities raised to appropriate long-range total values, "typical" float and sink results for each source, and coal selection maximums raised to reflect the most available from each source during the long-range period. By preparing a long-range blend, the report will show the "average" specific gravity needed to meet the "typical" contract, average % loss, and relative proportions of ROM coal from each source.

These suggestions for variations on use are only examples of what can be done. Keep in mind that these variations use "typical" data, so any decision made based on the results should be done with caution. The normal method of use should still be a complete 3 stage scenario.

```
12380 FA(2)=(ST*FA(2)-FX(2)*FA(3))/T2
12390 FM(2)=(ST*FM(3)-FX(2)*FM(3))/T2
12400 FB(2)=(ST*FB(3)-FX(2)*FB(3))/T2
12410 IF FS(2) > CS(2) + DS(2) THEN 12460
12420 IF FA(2) > CA(2) THEN 12460
12430 IF FM(2) > CM(2) THEN 12460
12440 IF FB(2) < CB(2) - DB(2) THEN 12460
12450 GOTO 12470
12460 POP:GOTO 400:REM NEXT K
12470 RETURN
12996 REM
12997 REM   SUBROUTINE 13000
12998 REM FIX SILO CONTENTS
12999 REM
13000 D$= CHR$ (4)
13010 PRINT:PRINT D$;"OPEN CONTRACTNAMES,L11"
13020 PRINT:PRINT D$;"READ CONTRACTNAMES,R";C1
13030 INPUT C1$:PRINT D$
13040 PRINT:PRINT D$;"READ CONTRACTNAMES,R";C2
13050 INPUT C2$:PRINT D$
13060 FT(1)=T1
13070 FR(1)=ST
13080 FS(1)=PS(21)
13090 FA(1)=PA(21)
13100 FM(1)=PM(21)
13110 FB(1)=PB(21)
13120 FX(1)=ST-T1
13130 FOR I=1 TO M
13140 IF V(I) > = 0 THEN 13170
13150 X(-V(I))=C(I)
13160 GOTO 13180
13170 Y(V(I))=C(I)
13180 NEXT I
13190 FT(2)=T2
13200 FR(2)=TN
13210 FS(2)=-Y(26)/-B(22)+CS(2)+DS(2)
13220 FA(2)=-Y(25)/-B(22)+CA(2)
13230 FM(2)=-Y(24)/-B(22)+CM(2)
13240 FB(2)=Y(27)/-B(22)+CB(2)-DB(2)
13250 IF FX(1) < 0 THEN 13280
13260 FX(2)=-B(22)-FT(2)
13270 GOTO 13290
13280 FX(2)=-B(22)+FX(1)-FT(2)
13290 FG(2)=1.61-K*.01
13300 FL(2)=100-((-B(22)-X(21))/TN)*100
13310 FW(2)=TN+X(21)+B(22)
13320 IF ST-T1 > = 0 THEN 13430
13330 FS(1)=(ST*FS(1)-FX(1)*FS(2))/T1
```

```
11230 T(P1,P2)=1/P
11240 REM 7. EXCHANGE THE ANSWER INDICATORS
11250 X=H(P2)
11260 H(P2)=V(P1)
11270 V(P1)=X
11280 RETURN
11996 REM
11997 REM   SUBROUTINE 12000
11998 REM ADJUST FOR ROM
11999 REM
12000 D$= CHR$ (4)
12010 PRINT:PRINT D$;"READ CONTRACTNAMES,R";C3
12020 INPUT C3$:PRINT D$
12030 PRINT D$;"OPEN PITNAMES,L11"
12040 FOR RN=1 TO 10
12050 PRINT:PRINT D$;"READ PITNAMES,R";RN
12060 INPUT NM$(RN):NEXT RN:PRINT D$
12070 PRINT D$;"OPEN PILENAMES,L11"
12080 FOR RN=1 TO 10
12090 PRINT:PRINT D$;"READ PILENAMES,R";RN
12100 INPUT NMS(RN+10):#RN:PRINT D$
12110 TN=0
12120 FOR I=1 TO M
12130 IF V(I) > = 0 THEN 12170
12140 X(-V(I))=C(I)
12150 TN=TN+X(-V(I))
12160 GOTO 12180
12170 Y(V(I))=C(I)
12180 NEXT I
12190 FT(3)=T3
12200 FR(3)=TN-X(21)
12210 FS(3)=-Y(26)/-B(22)+CS(3)+DS(3)
12220 FA(3)=-Y(25)/-B(22)+CA(3)
12230 FM(3)=-Y(24)/-B(22)+CM(3)
12240 FB(3)=Y(27)/-B(22)+CB(3)-DB(3)
12250 IF FX(2) < 0 THEN 12280
12260 FX(3)=-B(22)-FT(3)
12270 GOTO 12290
12280 FX(3)=-B(22)+FX(2)-FT(3)
12290 FG(3)=1.61-K*.01:IF SO=3 THEN FG(3)=0
12300 FL(3)= 100-((-B(22)-X(21))/FR(3))*100
12310 FW(3)=TN+B(22)
12320 FOR I=1 TO 20
12330 FC(I)=X(I)-X(I)*(PL(I)/100)
12340 NEXT I
12350 IF FX(2) > = 0 THEN 12470
12360 ST=FT(2)+FX(2)
12370 FS(2)=(ST*FS(2)-FX(2)*FS(3))/T2
```

```
10130 P1=0
10140 FOR I=1 TO M
10150 S(I)=T(I,P2):REM STORE COPY FOR STEP 6
10160 IF T(I,P2) < = .00001 THEN 10200
10170 IF C(I)/T(I,P2) > M2 THEN 10200
10180 M2= C(I)/T(I,P2)
10190 P1=I
10200 NEXT I
10210 S(M+1)=B(P2):REM STORE COPY FOR STEP 6
10220 IF P1 > < 0 THEN 10250
10230 G$="RETRY"
10240 GOTO 10320
10250 P=T(P1,P2):REM PIVOT ELEMENT
10260 GOSUB 11000:REM STEPS 4-7
10270 REM 8. REPEAT STEPS 2-8
10280 NEXT L
10290 G$="RETRY"
10300 GOTO 10320
10310 G$="OKAY"
10320 RETURN
10995 REM
10996 REM    SUBROUTINE 11000
10997 REM STEPS 4-7
10998 REM 4. DIVIDE PIVOT ROW BY PIVOT ELEMENT
10999 REM
11000 FOR J=1 TO N
11010 T(P1,J)=T(P1,J)/P
11020 NEXT J
11030 C(P1)=C(P1)/P
11040 REM 5. READJUST ROWS TO NEW PIVOT ROW
11050 FOR I=1 TO M
11060 IF I=P1 THEN 11120
11070 X=T(I,P2)
11080 FOR J=1 TO N
11090 T(I,J)=T(I,J)-X*T(P1,J)
11100 NEXT J
11110 C(I)=C(I)-X*C(P1)
11120 NEXT I
11130 X=B(P2)
11140 FOR J=1 TO N
11150 B(J)=B(J)-X*T(P1,J)
11160 NEXT J
11170 B(N+1)=B(N+1)-X*C(P1)
11180 REM 6. RE-DO THE PIVOT COLUMN
11190 FOR I=1 TO M
11200 T(I,P2)=-S(I)/P
11210 NEXT I
11220 B(P2)=-S(M+1)/P
```

```
8997 REM    SUBROUTINE 9000
8998 REM TABLEAU AND QUICK QUALITY CHECKS
8999 REM
9000 G$="OKAY"
9010 FOR I=M TO 1 STEP -1
9020 IF C(I) > = -.00001 THEN 9060
9030 GOSUB 14000:REM TABLEAU REWORK
9040 G$="RETRY"
9050 IF FG$="NO SOLUTION" THEN 9270
9060 NEXT I
9070 IF G$="OKAY" THEN 9090:REM QUALITY CHECKS
9080 GOTO 9000
9090 NQ=20
9100 IF C(21) > 0 THEN NQ=21
9110 FOR J=1 TO NQ
9120 IF T(24,J) < = 0 THEN 9150
9130 NEXT J
9140 FG$="NO SOLUTION":GOTO 9270
9150 FOR J=1 TO NQ
9160 IF T(25,J) < = 0 THEN 9190
9170 NEXT J
9180 FG$="NO SOLUTION":GOTO 9270
9190 FOR J=1 TO NQ
9200 IF T(26,J) < = 0 THEN 9230
9210 NEXT J
9220 FG$="NO SOLUTION":GOTO 9270
9230 FOR J=1 TO NQ
9240 IF T(27,J) < = 0 THEN 9270
9250 NEXT J
9260 FG$="NO SOLUTION"
9270 RETURN
9996 REM
9997 REM   SUBROUTINE 10000
9998 REM STEPS 2-8
9999 REM
10000 FOR L=1 TO 1000
10010 REM 2. FIND PIVOT COLUMN
10020 M1=0
10030 P2=0
10040 FOR J=1 TO N
10050 IF B(J) < = M1 THEN 10080
10060 M1=B(J)
10070 P2=J
10080 NEXT J
10090 IF M1 > 0 THEN 10110
10100 GOTO 10310:REM FOUND SOLUTION
10110 REM 3. FIND PIVOT ROW
10120 M2=1000000
```

```
8310 MN=0:SM=0
8320 FOR RN=1 TO 20:RM=RN+27
8330 PRINT:PRINT D$;"READ SELECTION,R";RN
8340 INPUT MN(RN),C(RN):C(RM)=-MN(RN)
8350 MN=MN+MN(RN)
8360 IF RN>10 THEN SM=SM+MN(RN)
8370 NEXT RN:PRINT D$
8380 C(22)=20000:C(23)=6000:REM  PLANT & REHANDLING CAPACITY
8390 IF C(22)-MN > = 0 THEN 8450
8400 TEXT:HOME:PRINT "YOU ARE TRYING TO FORCE THE PROGRAM"
8410 PRINT "TO BLEND MORE THAN PLANT CAPACITY!"
8420 PRINT:PRINT "RERUN THE DATA PROGRAM AND LOWER THE"
8430 PRINT "SELECTION MINIMUMS BY AT LEAST ";MN-C(22)
8440 POP:GOTO 840
8450 IF C(23)-SM > = 0 THEN 8510
8460 TEXT:HOME:PRINT "YOU ARE TRYING TO FORCE THE PROGRAM"
8470 PRINT "TO BLEND MORE THAN REHANDLING CAPACITY!"
8480 PRINT:PRINT "RERUN THE DATA PROGRAM AND LOWER THE"
8490 PRINT "SELECTION PILE MINIMUMS BY AT LEAST ";SM-C(23)
8500 POP:GOTO 840
8510 FOR J=1 TO 10:RN=J*20+K
8520 PRINT:PRINT D$;"READ PITTABLES,R";RN
8530 INPUT PL(J),PM(J),PA(J),PS(J),PB(J),PF(J):NEXT J:PRINT
     D$
8540 FOR J=11 TO 20:RN=(J-10)*20+K
8550 PRINT:PRINT D$;"READ PILETABLES,R";RN
8560 INPUT PL(J),PM(J),PA(J),PS(J),PB(J),PF(J):NEXT J: PRINT
     D$
8570 IF FX(2) > = 0 THEN C(21)=FX(2):GOTO 8590
8580 C(21)=0
8590 C(48)=-C(21)
8600 PL(21)=0
8630 PM(21)=FM(2)
8640 PA(21)=FA(2)
8650 PS(21)=FS(2)
8640 PB(21)=FB(2)
8650 B(22)=0
8660 FOR J=1 TO N
8670 IF SO=3 THEN PL(J)=0
8680 B(J)=1-PL(J)/100:REM YIELD INDICATORS
8690 IF C(J) < = 0 THEN B(J)=0
8700 T(24,J)=(PM(J)-CM(3))*B(J):REM MOISTURE COEFFICIENT
8710 T(25,J)=(PA(J)-CA(3))*B(J):REM ASH COEFFICIENT
8720 T(26,J)=(PS(J)-CS(3)-DS(3))*B(J):REM SULFUR COEFFICIENT
8730 T(27,J)=(CB(3)-DB(3)-PB(J))*B(J):REM BTU COEFFICIENT
8740 NEXT J
8750 RETURN
8996 REM
```

```
7490 FOR J=1 TO N
7500 B(J)=1-PL(J)/100:REM YIELD INDICATORS
7510 IF C(J) < = 0 THEN B(J)=0
7520 T(24,J)=(PM(J)-CM(2))*B(J): REM MOISTURE COEFFICIENT
7530 T(25,J)=(PA(J)-CA(2))*B(J):REM ASH COEFFICIENT
7540 T(26,J)=(PS(J)-CS(2)-DS(2))*B(J):REM SULFUR COEFFICIENT
7550 T(27,J)=(CB(2)-DB(2)-PB(J))*B(J):REM BTU COEFFICIENT
7560 NEXT J
7570 RETURN
7993 REM
7994 REM    SUBROUTINE 8000
7995 REM STEP 1 (ROM)
7996 REM SET UP ANSWER GUIDES AND TUCKER TABLEAU
7997 REM ROWS WITH NEGATIVE ENTRIES IN THE LAST COLUMN
7998 REM ( > =  CONSTRAINTS) ARE AT THE BOTTOM OF THE
     TABLEAU
7999 REM
8000 D$= CHR$ (4)
8010 FOR I=1 TO M
8020 V(I)=I
8030 Y(I)=0
8040 NEXT I
8050 FOR J=1 TO N
8060 H(J)=-J
8070 X(J)=0
8080 NEXT J
8090 FOR I=1 TO N
8100 FOR J=1 TO N
8110 IF I=J THEN T(I,J)=1:GOTO 8130
8120 T(I,J)=0
8130 NEXT J
8140 NEXT I
8150 FOR J=1 TO 20
8160 T(22,J)=1
8170 IF J > = 11 THEN T(23,J)=1:GOTO 8190
8180 T(23,J)=0
8190 NEXT J
8200 T(22,21)=0:T(23,21)=0
8210 FOR I=28 TO 48
8220 FOR J=1 TO N
8230 IF I-27=J THEN T(I,J)=-1:GOTO 8250
8240 T(I,J)=0
8250 NEXT J
8260 NEXT I
8270 FOR I=24 TO 27
8280 C(I)=0
8290 NEXT I
8300 PRINT:PRINT D$;"OPEN SELECTION,L12"
```

```
7030 Y(I)=0
7040 NEXT I
7050 FOR J=1 TO N
7060 H(J)=-J
7070 X(J)=0
7080 NEXT J
7090 FOR I=1 TO N
7100 FOR J=1 TO N
7110 IF I=J THEN T(I,J)=1:GOTO 7130
7120 T(I,J)=0
7130 NEXT J
7140 NEXT I
7150 FOR J=1 TO 20
7160 T(22,J)=1
7170 IF J > = 11 THEN T(23,J)=1:GOTO 7190
7180 T(23,J)=0
7190 NEXT J
7200 T(22,21)=0:T(23,21)=0
7210 FOR I=28 TO 48
7220 FOR J=1 TO N
7230 IF I-27=J THEN T(I,J)=-1:GOTO 7250
7240 T(I,J)=0
7250 NEXT J
7260 NEXT I
7270 FOR I=24 TO 27
7280 C(I)=0:NEXT I
7290 TN=0
7300 PRINT:PRINT D$;"OPEN CRUSHEDTONS,L6"
7310 FOR RN=1 TO 20:RM=RN+27
7320 PRINT:PRINT D$;"READ CRUSHEDTONS,R";RN
7330 INPUT C(RN):C(RM)=-C(RN):TN=TN+C(RN)
7340 NEXT RN: PRINT D$
7350 IF ST-T1 > = 0 THEN C(21)=ST-T1:GOTO 7370
7360 C(21)=0
7370 C(48)=-C(21 )
7380 C(22)=TN:C(23)=TN:REM CRUSHED SILO TONS
7390 PRINT D$;"OPEN PITTABLES,L35"
7400 FOR J=1 TO 10:RN=J*20+K
7410 PRINT:PRINT D$;"READ PITTABLES,R";RN
7420 INPUT PL(J),PM(J),PA(J),PS(J),PB(J),PF(J):NEXT J:PRINT
     D$
7430 PRINT D$;"OPEN PILETABLES,L35"
7440 FOR J=11 TO 20:RN=(J-10)*20+K
7450 PRINT:PRINT D$;"READ PILETABLES,R";RN
7460 INPUT PL(J),PM(J),PA(J),PS(J),PB(J),PF(J):NEXT J: PRINT
     D$
7470 PL(21)=0
7480 B(22)=0
```

```
5210 VTAB 23:HTAB 1:POKE 34,23
5220 RETURN
5996 REM
5997 REM    SUBROUTINE 6000
5998 REM SET STANDARD VALUES FOR SCENARIO 1
5999 REM
6000 D$= CHR$ (4)
6010 PRINT:PRINT D$;"OPEN DESTINATION,L8,D2"
6020 PRINT:PRINT D$;"READ DESTINATION,R1"
6030 INPUT C1,T1:PRINT D$
6040 PRINT D$;"READ DESTINATION,R2"
6050 INPUT C2,T2:PRINT D$
6060 PRINT D$;"READ DESTINATION,R3"
6070 INPUT C3,T3:PRINT D$
6080 PRINT D$;"OPEN CONTRACTDATA,L31"
6090 PRINT:PRINT D$;"READ CONTRACTDATA,R";C1
6100 INPUT CS(1),CA(1),CM(1),CB(1),DS(1),DB(1):PRINT D$
6110 PRINT D$;"READ CONTRACTDATA,R";C2
6120 INPUT CS(2),CA(2),CM(2),CB(2),DS(2),DB(2):PRINT D$
6130 PRINT D$;"READ CONTRACTDATA,R";C3
6140 INPUT CS(3),CA(3),CM(3),CB(3),DS(3),DB(3):PRINT D$
6150 PRINT D$;"OPEN CLEANCOAL,L35"
6160 PRINT:PRINT D$;"READ CLEANCOAL,R1"
6170 INPUT PM(21),PA(21),PS(21),PB(21),PF(21),ST:PRINT D$
6180 RETURN
6196 REM
6197 REM    SUBROUTINE 6200
6198 REM SET STANDARD VALUES FOR SCENARIO 2 OR 3
6199 REM
6200 D$= CHR$ (4)
6210 PRINT:PRINT D$;"OPEN DESTINATION,L8,D2"
6220 PRINT:PRINT D$;"READ DESTINATION,R3"
6230 INPUT C3,T3:PRINT D$
6240 PRINT:PRINT D$;"OPEN CONTRACTDATA,L31"
6250 PRINT:PRINT D$;"READ CONTRACTDATA,R";C3
6260 INPUT CS(3),CA(3),CM(3),CB(3),DS(3),DB(3):PRINT D$
6270 RETURN
6993 REM
6994 REM    SUBROUTINE 7000
6995 REM STEP 1 (SILOS)
6996 REM SET UP ANSWER GUIDES AND TUCKER TABLEAU
6997 REM ROWS WITH NEGATIVE ENTRIES IN THE LAST COLUMN
6998 REM ( > =  CONSTRAINTS) ARE AT THE BOTTOM OF THE
     TABLEAU
6999 REM
7000 D$= CHR$ (4)
7010 FOR I=1 TO M
7020 V(I)=I
```

```
1700 PRINT "ENTER YOUR SUGGESTIONS BELOW FOR"
1710 PRINT "SPECIFIC GRAVITIES TO START WITH":PRINT
1720 INVERSE:PRINT "CAUTION!";:NORMAL:PRINT " IF A SOLUTION
     IS FOUND AT A"
1730 PRINT "SPECIFIC GRAVITY THAT YOU SUGGESTED,"
1740 PRINT "YOU SHOULD RUN THE PROGRAM AGAIN WITH"
1750 PRINT "A HIGHER SUGGESTED SPECIFIC GRAVITY"
1760 ON SO GOTO 1770,1790
1770 VTAB 20:HTAB 1:QU$="STAGE 2 (RAW SILO) SUGGESTION? "
1780 LO=1.41:HI=1.6:LN=4:GOSUB 1400:K1=INT((1.61-NM)*100)
1790 VTAB 21:HTAB 2 :QU$="STAGE 3 (ROM) SUGGESTION? "
1800 LO=1.41:HI=1.6:LN=4:GOSUB 1400:K2=INT((1.61-NM)*100)
1810 POKE 34,0:HOME:RETURN
4996 REM
4997 REM    SUBROUTINE 5000
4998 REM DISPLAY MARTIKI "M"
4999 REM
5000 TEXT:HOME:INVERSE
5010 HTAB 21:PRINT SPC(1):VTAB 2:HTAB 20:PRINT SPC(3)
5020 VTAB 3:HTAB 19:PRINT SPC(5):VTAB 4:HTAB 18:PRINT SPC(7)
5030 VTAB 5:HTAB 17:PRINT SPC(9):VTAB 6:HTAB 19:PRINT SPC(5)
5040 VTAB 7:HTAB 15:PRINT SPC(1);:HTAB 20:PRINT SPC(3);:HTAB
     27:PRINT SPC(1)
5050 VTAB 8:HTAB 14:PRINT SPC(2);:HTAB 21:PRINT SPC(1);:HTAB
     27:PRINT SPC(2)
5060 VTAB 9:HTAB 13:PRINT SPC(3);:HTAB 27:PRINT SPC(3)
5070 VTAB 10:HTAB 12:PRINT SPC(5);:HTAB 26:PRINT SPC(5)
5080 VTAB 11:HTAB 11:PRINT SPC(6);:HTAB 26:PRINT SPC(6)
5090 VTAB 12:HTAB 12:PRINT SPC(5);:HTAB 26:PRINT SPC(5)
5100 VTAB 13:HTAB 13:PRINT SPC(3);:HTAB 27:PRINT SPC(3)
5110 VTAB 14:HTAB 14:PRINT SPC(2);:HTAB 20:PRINT
     SPC(1);:HTAB 22:PRINT SPC(1);:HTAB 27:PRINT SPC(2)
5120 VTAB 15:HTAB 15:PRINT SPC(1);:HTAB 20:PRINT
     SPC(1);:HTAB 22:PRINT SPC(1);:HTAB 27:PRINT SPC(1)
5130 VTAB 16:HTAB 20:PRINT SPC(3):VTAB 17:HTAB 17:PRINT
     SPC(9)
5140 VTAB 18:HTAB 18:PRINT SPC(7):VTAB 19:HTAB 19:PRINT
     SPC(5)
5150 VTAB 20:HTAB 20:PRINT SPC(3):VTAB 21:HTAB 21:PRINT
     SPC(1)
5160 VTAB 22:HTAB 1:NORMAL:PRINT "PROGRAM IN PROGRESS
     DON´T INTERRUPT!"
5170 VTAB 1:HTAB 2:PRINT "PRINTER";:HTAB 32:PRINT "DATA
     DISK"
5180 VTAB 2:HTAB 2:PRINT "SHOULD BE";:HTAB 32:PRINT "SHOULD
     BE"
5190 VTAB 3:HTAB 2:PRINT "READY";:HTAB 32:PRINT "IN DRIVE"
5200 VTAB 4:HTAB 35:PRINT "#2"
```

```
1320 GET YN$:IF NOT (YN$="Y" OR YN$="y" OR YN$="N" OR
     YN$="n") THEN PRINT CHR$(7);:GOTO 1320
1330 PRINT YN$;:REM ECHO RESPONSE
1340 RETURN
1394 REM
1395 REM    SUBROUTINE 1400
1396 REM ASK FOR NUMERIC ENTRY (PROMPT IS QU$)
1397 REM RETURN RESPONSE IN NM
1398 REM NM MUST BE  < = HI AND  > = LO
1399 REM
1400 GOSUB 1200:REM CLEAR ENTRY LINE
1410 PRINT QU$;:REM DISPLAY PROMPT
1420 GOSUB 1000:NM=VAL(CC$)
1430 REM CHECK THAT ENTRY IS IN RANGE
1440 IF NM<LO OR NM>HI THEN PRINT CHR$(7);:HTAB (HT):GOTO
     1420
1450 RETURN
1496 REM
1497 REM    SUBROUTINE 1500
1498 REM MENU DISPLAY AND SELECTION
1499 REM
1500 HOME:HTAB 10:PRINT "MARTIKI COAL BLENDING"
1510 HTAB 10:PRINT "SCENARIO OPTIONS MENU":PRINT
1520 INVERSE:FOR I=1 TO 3:HTAB 2:PRINT I:NEXT I:NORMAL
1530 VTAB 4:HTAB 4:PRINT "COMPLETE 3 STAGE SCENARIO"
1540 HTAB 4:PRINT "EMPTY SILOS SCENARIO"
1550 HTAB 4:PRINT "ROM BLEND SCENARIO"
1560 VTAB 23:HTAB 1:QU$="WHAT SCENARIO DO YOU WANT TO USE?"
1570 LO=1:HI=3:LN=1
1580 GOSUB 1400:SO=NM
1590 RETURN
1597 REM    SUBROUTINE 1600
1598 REM DATE ENTRY AND VERIFICATION
1599 REM
1600 VTAB 23:HTAB 1:GOSUB 1200
1610 VTAB 19:HTAB 1:PRINT "ENTER THE DATE BELOW"
1620 VTAB 20:HTAB 1:QU$="MONTH "
1630 LO=1:HI=12:LN=2:GOSUB 1400:MM=NM
1640 VTAB 21:HTAB 1:QU$="DAY   "
1650 LO=1:HI=31:LN=2:GOSUB 1400:DD=NM
1660 VTAB 22:HTAB 1:QU$="YEAR  "
1670 LO=0:HI=99:LN=2:GOSUB 1400:YY=NM
1680 DT$=STR$(MM) + "-" + STR$(DD) + "-" + STR$(YY)
1690 POKE 34,7:HOME:RETURN
1696 REM
1697 REM    SUBROUTINE 1700
1698 REM GET STARTING GRAVITY SUGGESTIONS
1699 REM
```

```
    ANOTHER COPY"
820 GOTO 840
830 GOSUB 18000:REM NO SOLUTION
840 PRINT:PRINT D$;"CLOSE"
850 END
989 REM    SUBROUTINE 1000
990 REM ENTER STRING DATA INTO A FIELD WITH LN CHARACTERS
991 REM THE RETURN KEY WILL END DATA ENTRY
992 REM THE LEFT ARROW AND DELETE KEYS BACKSPACE
993 REM THE ENTERED STRING IS RETURNED IN CC$
994 REM CTRL-X RESTARTS ENTRY
1000 HT=POS(0) + 1:REM START OF FIELD POSITION
1010 REM DISPLAY INVERSE ENTRY VIDEO MASK
1020 FOR I=1 TO LN:PRINT "*";:NEXT I
1030 HTAB (HT):REM REPOSITION TO START OF FIELD
1040 REM ENTER DATA
1050 CC$="":REM INITIALIZE OUTPUT TO NULL
1060 GET C$
1070 IF C$= CHR$ (24) THEN HTAB (HT):GOTO 1020:REM CTRL-X
1080 IF (C$= CHR$ (8) OR C$= CHR$ (127)) THEN 1110
1090 IF LEN(CC$)=1 THEN PRINT CHR$(8);:PRINT "*";:PRINT CHR$
     (8);:CC$="":GOTO 1060
1100 IF LEN(CC$)>0 THEN PRINT CHR$(8);:PRINT "*";:PRINT CHR$
     (8);:CC$=LEFT$(CC$,LEN(CC$)-1):GOTO 1060
1110 IF C$= CHR$(13) THEN GOTO 1170:REM <CR> - END OF ENTRY
1120 IF (C$<CHR$(32) OR C$>CHR$(126) OR C$= CHR$ (44)) THEN
     PRINT CHR$(7);:GOTO 1060
1130 REM WHEN ENTRY IS FULL WAIT FOR <CR> OR CTRL-X
1140 IF LEN (CC$)=LN THEN PRINT CHR$(7);:GOTO 1060
1150 PRINT C$;:REM ECHO KEYSTROKE
1160 CC$=CC$+C$:GOTO 1060
1170 REM REDISPLAY ENTRY AND CLEAR TO END OF FIELD
1180 HTAB(HT):PRINT CC$;SPC(LN-LEN(CC$)):RETURN
1196 REM
1197 REM    SUBROUTINE 1200
1198 REM CLEAR ROW THAT CURSOR IS ON
1199 REM
1200 HTAB 1:REM START OF BEGINNING OF ROW
1210 PRINT SPC(39)
1220 HTAB 1:REM LEAVE CURSOR AT BEGINNING OF LINE
1230 RETURN
1296 REM
1297 REM    SUBROUTINE 1300
1298 REM ASK A QUESTION(QU$) AND RETURN A Y/N RESPONSE IN
     YN$
1299 REM
1300 GOSUB 1200:REM CLEAR ENTRY LINE
1310 PRINT QU$;:REM DISPLAY PROMPT
```

```
350 GOSUB 8000:REM STEP 1 (ROM)
360 GOSUB 9000:REM CHECK TABLEAU
370 IF FG$="NO SOLUTION" THEN 400
380 GOSUB 10000:REM STEPS 2-8
390 IF G$="OKAY" THEN 420
400 NEXT K
410 POKE 34,0:GOTO 830
420 GOSUB 12000:REM ADJUST FOR ROM
430 GOTO 790
440 REM
450 REM SCENARIO 2 SECTION
460 GOSUB 1700:REM STARTING GRAVITY
470 GOSUB 6200:REM STANDARD VALUES
480 GOSUB 5000:REM DISPLAY "M"
490 PRINT:PRINT D$;"OPEN PITTABLES,L35"
500 PRINT:PRINT D$;"OPEN PILETABLES,L35"
510 PRINT:PRINT D$;"OPEN CONTRACTNAMES,L11"
520 SC=2:FOR K=K2 TO 20:FG$=""
530 VTAB 15:HTAB 32:PRINT "STAGE #3":VTAB 16:HTAB 32:PRINT
    "SG=       ";:HTAB 36:PRINT 1.61-K*.01;CHR$(7)
540 VTAB 23:POKE 34,23
550 GOSUB 8000:REM STEP 1 (ROM)
560 GOSUB 9000:REM CHECK TABLEAU
570 IF FG$="NO SOLUTION" THEN 600
580 GOSUB 10000:REM STEPS 2-8
590 IF G$="OKAY" THEN 620
600 NEXT K
610 POKE 34,0:GOTO 830
620 GOSUB 12000:REM ADJUST FOR ROM
630 GOTO 790
640 REM
650 REM SCENARIO 3 SECTION
660 GOSUB 6200:REM STANDARD VALUES
670 GOSUB 5000:REM DISPLAY "M"
680 PRINT:PRINT D$;"OPEN PITTABLES,L35"
690 PRINT:PRINT D$;"OPEN PILETABLES,L35"
700 PRINT:PRINT D$;"OPEN CONTRACTNAMES,L11"
710 SC=3:K=1:FG$=""
720 GOSUB 8000:REM STEP 1 (ROM)
730 GOSUB 9000:REM CHECK TABLEAU
740 IF FG$="NO SOLUTION" THEN 770
750 GOSUB 10000:REM STEPS 2-8
760 IF G$="OKAY" THEN 780
770 POKE 34,0:GOTO 830
780 GOSUB 12000:REM ADJUST FOR ROM
790 GOSUB 16000:REM SAVE REPORT DATA
800 GOSUB 15000:REM PRINT RESULTS
810 TEXT:HOME:VTAB 10:HTAB 1:PRINT "DONE!  RUN REPORT TO GET
```

```
1   REM  BLEND   JANUARY 1985   STEVEN L. VAN DREW
2   REM  THIS PROGRAM WAS DEVELOPED TO SOLVE THE
3   REM  DAILY TONNAGE AND SPECIFIC GRAVITY DECISIONS
4   REM  FOR COAL BLENDING AND PREPARATION AT THE
5   REM  MARTIKI COAL MINE IN LOVELY,KY.
6   REM  SOLUTION IS BY ITERATIVE LINEAR PROGRAMMING
7   REM  USING THE TUCKER TABLEAU AND SIMPLEX METHOD.
8   REM  REFERENCE:   T-2982   CO SCHOOL OF MINES
9   REM                        GOLDEN,CO  80401
10  REM  MAIN PROGRAM
20  ONERR  GOTO 20000: REM  ENABLE ERROR TRAPPING
30  DATA  104,168,104,166,223,154,72,152,72,96
40  FOR ML=768 TO 777:READ MC:POKE ML,MC:NEXT ML
50  D$ = CHR$ (4):REM  CONTROL-D CHAR
60  PRINT D$;"MAXFILES 11":PRINT D$
70  DIM B(22),C(48),CA(3),CB(3),CM(3),CS(3),DB(3),DS(3),
    FA(3)
80  DIM FB(3),FC(20),FG(3),FL(3),FM(3),FR(3),FS(3),FT(3),
    FW(3),FX(3)
90  DIM H(21),MN(20),NM$(20),PA(21),PB(21),PF(21),PL(21),
    PM(21),PS(21)
100 DIM S(49),SG(2),SW(2),T(48,21),U(21),V(48),X(21),Y(48)
110 GOSUB 1500:REM DISPLAY MENU
120 GOSUB 1600:REM DATE ENTRY
130 M=48:REM # OF ROWS (CONSTRAINTS)
140 N=21:REM # OF COLUMNS (VARIABLES)
150 ON SO GOTO 180,460,660
160 REM
170 REM  SCENARIO 1 SECTION
180 GOSUB 1700:REM STARTING GRAVITIES
190 GOSUB 6000:REM STANDARD VALUES
200 GOSUB 5000:REM DISPLAY "M"
210 SC=1:FOR K=K1 TO 20:FG$=""
220 VTAB 15:HTAB 2:PRINT "STAGE #2":VTAB 16:HTAB 2:PRINT
    "SG=       ";:HTAB 6:PRINT 1.61-K*.01;CHR$(7)
230 VTAB 23:POKE 34,23
240 GOSUB 7000:REM STEP 1 (SILOS)
250 GOSUB 9000:REM CHECK TABLEAU
260 IF FG$="NO SOLUTION" THEN 290
270 GOSUB 10000:REM STEPS 2-8
280 IF G$="OKAY" THEN 310
290 NEXT K
300 POKE 34,0:GOTO 830
310 GOSUB 13000:REM FIX SILO CONTENTS
320 SC=2:FOR K=K2 TO 20:FG$=""
330 VTAB 15:HTAB 32:PRINT "STAGE #3":VTAB 16:HTAB 32:PRINT
    "SG=       ";:HTAB 36:PRINT 1.61-K*.01;CHR$(7)
340 VTAB 23:POKE 34,23
```

Appendix C

BLEND PROGRAM LISTING

```
13340 FA(1)=(ST*FA(1)-FX(1)*FA(2))/T1
13350 FM(1)=(ST*FM(1)-FX(1)*FM(2))/T1
13360 FB(1)=(ST*FB(1)-FX(1)*FB(2))/T1
13370 IF FS(1) > CS(1)+DS(1) THEN 13420
13380 IF FA(1) > CA(1) THEN 13420
13390 IF FM(1) > CM(1) THEN 13420
13400 IF FB(1) < CB(1)-DB(1) THEN 13420
13410 GOTO 13430
13420 POP:GOTO 400:REM NEXT K
13430 RETURN
13996 REM
13997 REM    SUBROUTINE 14000
13998 REM TABLEAU REWORK
13999 REM
14000 P1=I
14010 FOR J=1 TO N
14020 IF T(P1,J) > = -.00001 THEN 14040
14030 GOTO 14060:REM OKAY EXIT
14040 NEXT J
14050 FG$="NO SOLUTION":RETURN
14060 P2=J
14070 FOR I=1 TO M
14080 S(I)=T(I,P2):REM STORE FOR STEP 6
14090 NEXT I
14100 S(M+1)=B(P2)
14110 M2=C(P1)/T(P1,P2)
14120 FOR I=P1 TO M
14130 IF T(I,P2)<=.00001 THEN 14170
14140 IF (C(I)/T(I,P2)) > M2 THEN 14170
14150 P1=I
14160 M2=C(I)/T(I,P2)
14170 NEXT I
14180 P=T(P1,P2)
14190 GOSUB 11000:REM STEPS 4-7
14200 RETURN
14996 REM
14997 REM    SUBROUTINE 15000
14998 REM PRINT RESULTS
14999 REM
15000 PRINT:PRINT D$;"PR#1":REM ACTIVATE PRINTER
15010 PRINT CHR$(9);"80N";:REM LINE WIDTH 80
15020 PRINT:PRINT "REPORT DATE: ";DT$:PRINT
15030 ON SO GOTO 15040,15060,15080
15040 PRINT "FULL SCENARIO":PRINT:PRINT
15050 GOTO 15090
15060 PRINT "EMPTY SILOS SCENARIO":PRINT:PRINT
15070 GOTO 15090
15080 PRINT "ROM BLEND SCENARIO":PRINT:PRINT
```

```
15090 HTAB 20:PRINT "STAGE 1";:HTAB 40:PRINT "STAGE 2";:POKE
      36,60:PRINT "STAGE 3"
15100 HTAB 21:PRINT "CLEAN";:HTAB 42:PRINT "RAW";:POKE
      36,62:PRINT "ROM":PRINT
15110 PRINT "CONTRACT";:HTAB 20:PRINT C1$;:HTAB 40:PRINT
      C2$;:POKE 36,60:PRINT C3$
15120 PRINT "REQUIRED;"
15130 PRINT "  % SULFUR";:HTAB 20:PRINT CS(1);:HTAB 40:PRINT
      CS(2);:POKE 36,60:PRINT CS(3)
15140 PRINT "  SULFUR DB";:HTAB 20:PRINT DS(1);:HTAB
      40:PRINT DS(2);:POKE 36,60:PRINT DS(3)
15150 PRINT "  % ASH";:HTAB 20:PRINT CA(1);:HTAB 40:PRINT
      CA(2);:POKE 36,60:PRINT CA(3)
15160 PRINT "  % MOISTURE";:HTAB 20:PRINT CM(1);:HTAB
      40:PRINT CM(2);:POKE 36,60:PRINT CM(3)
15170 PRINT "  BTU";:HTAB 20:PRINT CB(1);:HTAB 40:PRINT
      CB(2);:POKE 36,60:PRINT CB(3)
15180 PRINT "  BTU DB";:HTAB 20:PRINT DB(1);:HTAB 40:PRINT
      DB(2);:POKE 36,60:PRINT DB(3)
15190 PRINT "  TONS";:HTAB 20:PRINT T1;:HTAB 40:PRINT
      T2;:POKE 36,60:PRINT T3:PRINT
15200 PRINT "TONNAGE;"
15210 PRINT "SILO/ROM";:HTAB 20:PRINT FR(1);:HTAB 40:PRINT
      FR(2);:POKE 36,60:PRINT FR(3)
15220 PRINT "  WASH LOSS";:HTAB 40:PRINT FW(2);:POKE
      36,60:PRINT FW(3)
15230 PRINT "  EXCESS";
15240 IF FX(1) > = 0 THEN HTAB 20:PRINT FX(1);
15250 IF FX(2) > = 0 THEN HTAB 40:PRINT FX(2);
15260 IF FX(3) > = 0 THEN POKE 36,60:PRINT FX(3):GOTO 15280
15270 PRINT
15280 PRINT "  SHORTAGE";
15290 IF FX(1) < 0 THEN HTAB 20:PRINT -FX(1);
15300 IF FX(2) < 0 THEN HTAB 40:PRINT -FX(2);
15310 IF FX(3) < 0 THEN POKE 36,60:PRINT -FX(3):GOTO 15330
15320 PRINT
15330 PRINT:PRINT "QUALITY;"
15340 PRINT "  % SULFUR";:HTAB 20:PRINT FS(1);:HTAB 40:PRINT
      FS(2);:POKE 36,60:PRINT FS(3)
15350 PRINT "  % ASH";:HTAB 20:PRINT FA(1);:HTAB 40:PRINT
      FA(2);:POKE 36,60:PRINT FA(3)
15360 PRINT "  % MOISTURE";:HTAB 20:PRINT FM(1);:HTAB
      40:PRINT FM(2);:POKE 36,60:PRINT FM(3)
15370 PRINT "  BTU";:HTAB 20:PRINT FB(1);:HTAB 40:PRINT
      FB(2);:POKE 36,60:PRINT FB(3)
15380 PRINT:PRINT "WASH GRAVITY";:HTAB 40:PRINT FG(2);:POKE
      36,60:PRINT FG(3)
15390 PRINT "% LOSS";:HTAB 40:PRINT FL(2);:POKE 36,60:PRINT
```

```
      FL(3)
15400 PRINT:PRINT
15410 HTAB 37:PRINT "ROM SOURCES"
15420 PRINT "PIT/PILE";:HTAB 20:PRINT "ROM TONS";:HTAB
      40:PRINT "% LOSS";:POKE 36,60:PRINT "CLEAN TONS"
15430 PRINT:FOR I=1 TO 20
15440 IF X(I)=0 THEN 15460
15450 PRINT NM$(I);:HTAB 20:PRINT X(I);:HTAB 40:PRINT
      PL(I);:POKE 36,60:PRINT FC(I)
15460 NEXT I
15470 PRINT CHR$(9);"I":REM SCREEN WIDTH 40
15480 PRINT:PRINT D$;"PR#0":REM PRINTER OFF
15490 RETURN
15996 REM
15997 REM   SUBROUTINE 16000
15998 REM SAVE REPORT DATA ON SEQUENTIAL ACCESS FILE
15999 REM
16000 D$= CHR$(4)
16010 PRINT D$;"OPEN REPORTDATA,D1"
16020 PRINT D$;"DELETE REPORTDATA"
16030 PRINT D$;"OPEN REPORTDATA"
16040 PRINT D$;"WRITE REPORTDATA"
16050 PRINT DT$;",";SO;",";C1$;",";C2$;",";C3$;",";CS(1)
      ;",";CS(2);",";CS(3);",";DS(1);",";DS(2);",";DS(3)
      ;",";CA(1);",";CA(2);",";CA(3);",";CM(1);",";CM(2)
      ;",";CM(3)
16060 PRINT D$;"APPEND REPORTDATA"
16070 PRINT D$;"WRITE REPORTDATA"
16080 PRINT CB(1);",";CB(2);",";CB(3);",";DB(1);",";DB(2)
      ;",";DB(3);",";T1;",";T2;",";T3;",";FR(1);",";FR(2)
      ;",";FR(3);",";FW(2);",";FW(3);",";FX(1);",";FX(2)
      ;",";FX(3)
16090 PRINT D$;"APPEND REPORTDATA"
16100 PRINT D$;"WRITE REPORTDATA"
16110 PRINT FS(1);",";FS(2);",";FS(3);",";FA(1);",";FA(2)
      ;",";FA(3);",";FM(1);",";FM(2);",";FM(3);",";FB(1)
      ;",";FB(2);",";FB(3);",";FG(2);",";FG(3);",";FL(2)
      ;",";FL(3)
16120 PRINT D$;"APPEND REPORTDATA"
16130 PRINT D$;"WRITE REPORTDATA"
16140 PRINT X(1);",";X(2);",";X(3);",";X(4);",";X(5);",";
      X(6);",";X(7);",";X(8);",";X(9);",";X(10);",";X(11)
      ;",";X(12);",";X(13);",";X(14);",";X(15);",";X(16)
      ;",";X(17);",";X(18);",";X(19);",";X(20)
16150 PRINT D$;"APPEND REPORTDATA"
16160 PRINT D$;"WRITE REPORTDATA"
16170 PRINT PL(1);",";PL(2);",";PL(3);",";PL(4);",";PL(5)
      ;",";PL(6);",";PL(7);",";PL(8);",";PL(9);",";PL(10)
```

```
      ;",";PL(11);",";PL(12);",";PL(13);",";PL(14);",";
      PL(15);",";PL(16);" ,";PL(17);",";PL(18);",";PL(19)
      ;",";PL(20)
16180 PRINT D$;"APPEND REPORTDATA"
16190 PRINT D$;"WRITE REPORTDATA"
16200 PRINT FC(1);",";FC(2);",";FC(3);",";FC(4);",";FC(5)
      ;",";FC(6);",";FC(7);",";FC(8);",";FC(9);",";FC(10)
      ;",";FC(11);",";FC(12);",";FC(13);",";FC(14);",";
      FC(15);",";FC(16);",";FC(17);",";FC(18);",";FC(19)
      ;",";FC(20)
16210 PRINT D$
16220 RETURN
17996 REM
17997 REM   SUBROUTINE 18000
17998 REM NO SOLUTION DISPLAY
17999 REM
18000 HOME
18010 FOR B=1 TO 10:PRINT CHR$(7):NEXT B:REM 10 BELLS
18020 PRINT "THE PROGRAM COULD NOT FIND A SOLUTION"
18030 ON SC GOTO 18040,18060,18100
18040 PRINT "FOR WASHING THE RAW COAL!"
18050 GOTO 18110
18060 PRINT "FOR WASHING THE ROM COAL!"
18070 IF SO=2 THEN 18110
18080 PRINT:PRINT "RAW COAL CAN BE WASHED AT ";
18090 INVERSE:PRINT FG(2):NORMAL:GOTO 18110
18100 PRINT "FOR BLENDING THE ROM COAL!"
18110 RETURN
19997 REM
19998 REM   ++ERROR-HANDLING ROUTINE++
19999 REM
20000 EN=PEEK(222):REM GET ERROR NUMBER
20010 EL=PEEK(219)*256+PEEK(218):REM ERROR LINE
20020 CALL 768:REM FIX ONERR-GOTO PROBLEM
20030 IF EN=5 THEN E$="END OF DATA":GOTO 20200
20040 IF EN=4 THEN E$="WRITE PROTECTED DISK":GOTO 20090
20050 IF EN=9 THEN E$="DISK FULL":GOTO 20090
20060 IF EN=8 THEN E$="I/O ERROR":GOTO 20130
20070 IF EN=6 THEN E$="FILE NOT ON DISK":GOTO 20130
20080 IF EN=10 THEN E$="FILE LOCKED"
20090 REM UNRECOVERABLE ERROR ENCOUNTERED
20100 POKE 34,0:HOME:PRINT E$
20110 POKE 216,0:REM DISABLE ERROR TRAP
20120 RESUME:REM AND RE-EXECUTE ERROR
20130 REM RECOVERABLE ERROR
20140 POKE 34,0:HOME:PRINT E$
20150 IF E$="I/O ERROR" THEN PRINT "CHECK THE DISK DRIVE AND
      PRINTER"
```

```
20160 PRINT "CORRECT THE PROBLEM, THEN PRESS"
20170 PRINT "THE RETURN KEY TO TRY AGAIN"
20180 INPUT "";CC$:REM WAIT FOR RETURN KEY
20190 RESUME
20200 REM END OF DATA ERROR
20210 POKE 34,0:HOME:PRINT E$
20220 PRINT "RERUN THE DATA PROGRAM AND"
20230 PRINT "REVIEW THE DISPLAYS FOR MISSING OR BAD"
20240 PRINT "DATA, INSERT THE PROPER VALUE,"
20250 PRINT "THEN TRY AGAIN"
20260 POP:GOTO 840
```

END

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