THE PENNSYLVANIA STATE UNIVERSITY

UNIVERSITY PARK, PENNSYLVANIA

FINAL REPORT

March 15, 1971

Prepared by

Y. L. Su

Charles B. Manula

and

Thomas V. Falkie

DESIGNING AND PLANNING OPEN PIT MINING OPERATIONS WITH COMPUTER SIMULATION SOLUTIONS

United States Department of the Interior

Bureau of Mines

Grant No. G-0190439 (Min. 22)

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SUMMARY

Deterministic and stochastic simulation were combined to develop a computer model of an open pit mining system using bucket wheel excavators and related materials handling equipment. The model is closed and dynamic in the sense that information is fed back to control activities at various levels and reservoirs. The results of interaction between unit operations in one time interval determines overall system behavior for the next interval. Equipment performance curves and system profile characteristics rather than time studies are applied to determine the operation of each activity at any time period. For that part of system where performance is dictated by a random variable, subjective probabilities are employed.

Two stages of research were considered to formulate this model. Stage one involved the formulation of equipment sub-assemblies for the sequence of equipment moves along with related assignments and routines for information retrieval. The second stage of research combined all sub-assemblies into an integrated open pit mining simulator. The model is not tailored for any specific open pit operation but is readily adaptable to any system of surface mining, including operations having a high degree of complexity. Questions answered by the model include: 1) system design and selection of equipment for a new mining operation; 2) analysis of existing operations for possible changes, additions or general

improvements; and 3) analysis of equipment performance for the entire life of the mine.

The interim report (January 11, 1971) presented the complete model along with a computer program developed to test the model on Penn State's computer system. In the final report case studies have been added for the purposes of model testing and application. Interpretations of results and data input considerations are also listed.

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

General Introduction

Minerals are the basic ingredients for a country's industrialization. The importance of mineral resources in national development is well illustrated by the Hewett-Lovering model of national history (Figure 1). As a nation approaches the zenith of commercial power its mineral resources are fully utilized and much reliance is placed on foreign imports. The cost of raw materials is decreasing due to plentiful domestic and foreign supplies while the standard of living is increasing because of expanding markets both at home and abroad.

The depletion of a cheap supply of domestic raw materials coupled with increased dependence upon foreign mineral resources usually signals economic decline and internal political unrest. The country which started with an abundance of cheap mineral resources now becomes a "have not" nation or at least a "have less" one. Such a nation could improve its position in a variety of ways, the most common of which includes the acquisition of mineral resources by military conquest, political alliance, or economic domination (Cheney, 1969).

Although the United States still possesses a great variety of mineral resources, there is now deficiency in almost all of them (Figure 2). The United States is no longer self sufficient and must tolerate increased involvement in

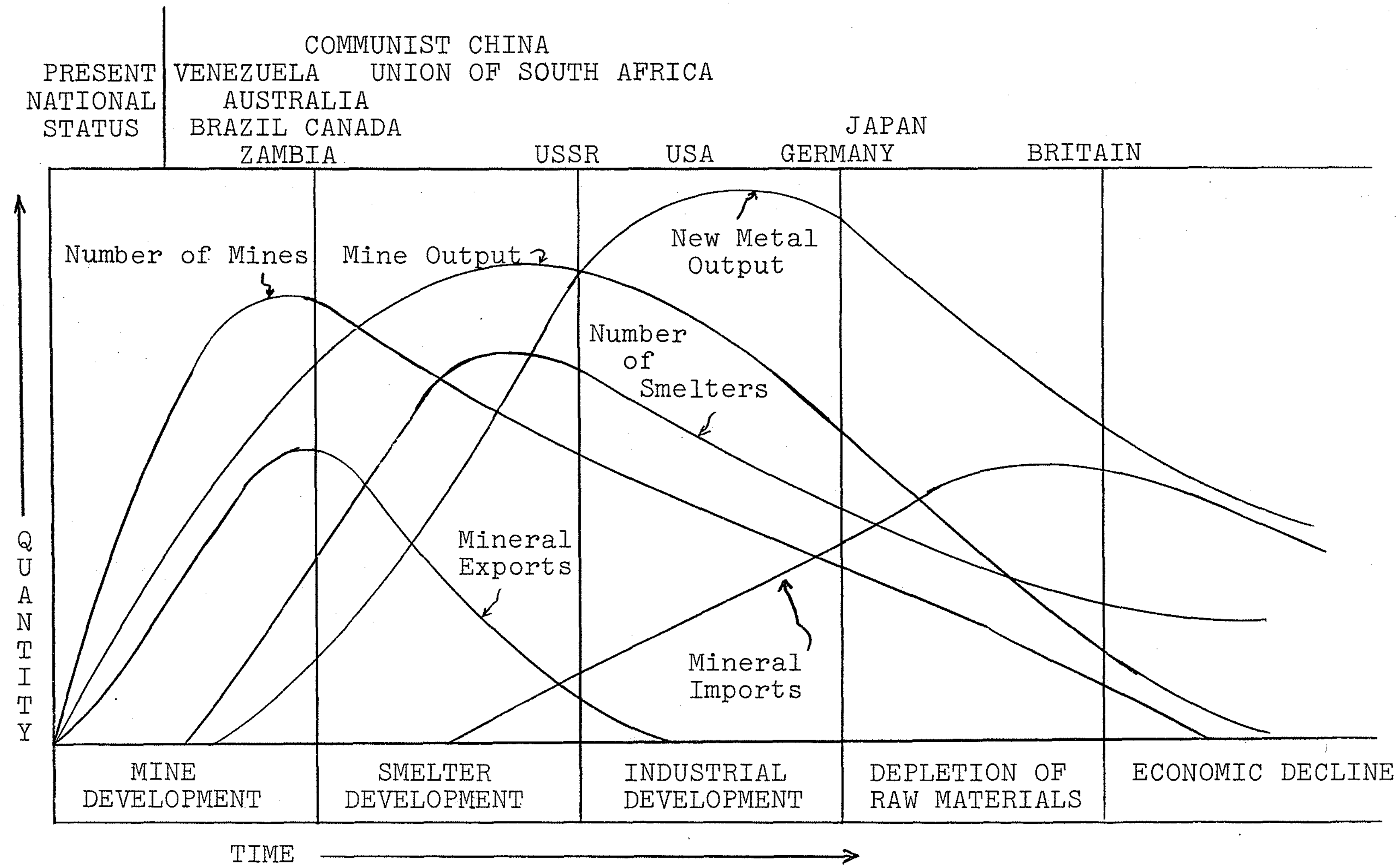


Figure 1 - Hewett-Lovering Model of the National Industrialization History (Cheney, 1967)

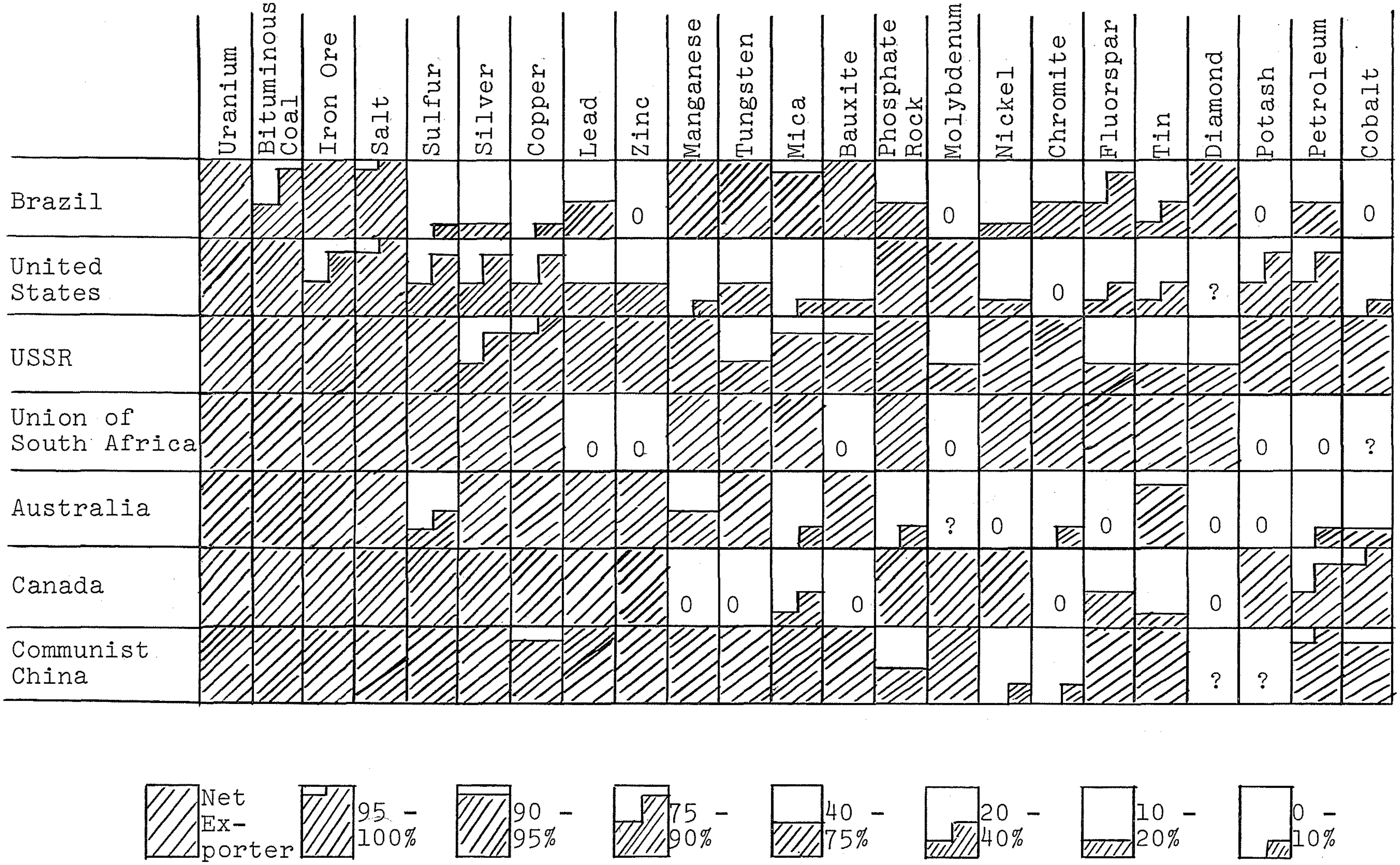


Figure 2 - Percentage of Commondities Produced by Countries for Their Own Consumption (Cheney, 1967)

international affairs. A natural solution for maintaining national self sufficiency without the need for acquiring foreign resources is to develop vast domestic resources of low grade ores by continued technological developments for converting these into mineable products.

An apparent solution to the problem of satisfying public demand from these high cost, low profit mineral deposits is mass material handling. A logical choice for mine development is the application of surface mining techniques where, with larger and faster equipment, the rising costs of labor can be readily reduced through automation and mechanization. Increased productivity and lower operating costs are currently being achieved with increases in the sizes of materials handling equipment (Table 1). Since most of the machines shown here are intermittent and must follow certain work cycles, further improvements can be expected if continuous excavation and loading practices are applied. The application of bucket wheel excavators and their related material handling equipment shows great promise and may well be the deciding factor in reversing the decline of domestic mineral production (Venkataramani, 1968).

Statement and Scope of the Problem

Due to the depletion of high grade, easily-mined ores, most of the basic raw material will need to come from low grade deposits in the foreseeable future. Apparent solutions to this problem include i) mass materials handling to meet increased productivity requirements ii) automation and

Table I

Increase in the Sizes of Equipment over the Years 1950 - 1969

	BWE (wheel diameter meter)	Truck (ton)	Loading shovel (cu. yd.)	Stripping Shovel (cu. yd.)	Dragline (cu. yd.)
1950-1955	10.0	35	6	60	80
1956-1959	11.1	50	8	60	80
1960-1964	11.5	85-100	8-15	115	85
1964-1969	17.5	160-200	15	180-200	130-240

mechanization to combat rising costs of labor and iii) the implementation of quantitative concepts to minimize management's risk in making decisions.

Because of the large capital investment and narrow profit margins in applying these systems, little margin for error can be tolerated. Every subjective conclusion which so often influences managerial decisions must be scrutinized carefully. Traditional trial-and-error methods in mine planning and design are no longer feasible and must be sidestepped in favor of more objective means. In order to aid management in passing from an area of subjective reasoning to one of objective reasoning in the operation of these systems, there is a tremendous need in mining for the development and application of Operations Research (O.R.) methods to mine planning and design.

This thesis will attempt to apply one facet of O.R., namely, simulation to develop a model of open pit mining using BWEs and their related materials handling equipment. The proposed model is closed and dynamic in the sense that information is fed back to control activities at various levels and reservoirs. This model can be regarded as a management laboratory where many ideas are tried on paper and the best of these selected prior to application. Questions to be answered by the model include:

1. Systems design and selection of equipment for a new mining operation;
2. Analysis of existing operations for possible

alterations, additions, or general improvements;

3. Analysis of equipment performance for the entire life of the mine.

Unit operations to be modeled consist of face and logistics activities with the previously mentioned BWEs, trucks, trains, conveyors or any combination of these. The operation of each activity at any given time is determined from equipment performance curves and the haulroad and soil profiles. Here deterministic simulation is employed in order to study equipment rather than operator performance. For that part of the system where performance is dictated by a random variable, stochastic simulation is applied using subjective probability. The model as outlined above is not tailored to any specific open pit operation but is readily adaptable to any system of surface mining with slight modification.

Since the concept of total systems simulation will be implemented, each unit operation will not be permitted to exist as an entity. Interrelationships are identified and listed and the system adjusted to provide mine management with an understanding of the goal-seeking, self-correcting interplay between them. Model construction as proposed will be applied to an IBM 360/67 computer and a program will be developed as part of research. Equipment performance is analyzed in a specific time period and can be readily applied over the life of an ore body using grid point simulation. The new concept to be tried would include information retrieval from the model itself as input to a Calcomp plotter to provide not only numerical but also graphical information in an attempt to simulate years of operation when this is used for long-range planning. The computer program and related routines along with a listing of variable names are given in subsequent chapters.

Computer Simulation

Because most problems amenable to systems simulation can be represented by a mathematical model, two series of computations are needed. First, the model must be tested in an experiment conducted in the actual situation, and the results of this must be compared with the model results. Second, once the model is adjusted it must be manipulated to determine the outcome under various conditions. The variables occurring in these problems are usually large in number and related through many complex equations. In an effort to cope with the mathematical tedium, electronic computing machines have been used for solution of simulation problems. Computers drastically reduce the time involved in computation and are so designed that mistakes in computation are practically impossible if programmed correctly. Furthermore, the computer is capable of generating the necessary random numbers in carrying out simulation.

Review of Related Literature

One notable application of simulation at work in industry is the VPI-OCR FACE SIMULATOR (Lucas, 1969). The model developed here has the purpose of allowing the comparison of methods for room-and-pillar face operations and observing their effect on mining prior to actual installation. Proposed changes are tried in the model and the best of these are selected as a guide for better mine management. IBM's own simulation package, the System 360 General Purpose Simulator has experienced heavy use in solving similar problems and other steady-state situations.

Simulation languages such as SIMSCRIPT and GASP have reduced the programming skills required to build a simulation model, but not to a level where they can be used by a busy engineer or manager unless he has extensive programming experience. In an attempt to make simulation a more readily available tool, C. E. Donaghey (1967) has structured a generalized materials handling model (MHSS). The majority of the materials handling system consists of a set of moves and a set of pieces of equipment required to execute the moves. MHSS gives a technique for describing and classifying the elements in these sets, and then a technique for simulating the interactions of these elements as the materials handling system operates. To apply the model the user simply furnishes data parameters to the computer for his own problem.

A model of material handling for open pit mining was also reported by W. C. Morgan and L. L. Peterson (1968) of the Caterpillar Co. The stochastic simulator developed here calculates haul and return times for trucks on a new profile. Adjustments are made in the computer for the interaction between shovels and trucks at the point of loading.

The development of a simulation model to evaluate a gold mining activity was reported by the Bureau of Mines as part of a program of research leading to a total mining systems concept (Johnson, 1968). Mining by model permits easy alteration of processing techniques to locate the high cost stages of operation.

A new philosophy of computer simulation as applied to a total systems concept was introduced in a paper by R. L. Sanford and C. B. Manula (1968). A dynamic model of underground coal mining was presented for the purposes of systems design and selection of equipment for a completely new operation and the analysis of existing operations for possible alterations, additions and general improvements. The main differences between this simulator and its predecessors is the ability to transport materials from multiple mine faces to multiple mine destinations and the ready adaptability to a wide variety of mine layouts. The second difference that characterizes the model is the deterministic simulation of equipment moves according to their mechanical capabilities and the physical profile of the mining system. Here the computer generates performance data in the absence of time studies to compare equipment rather than operator performance.

Since the early 1960's the development of dynamic models for economic systems has been given great impetus by the much publicized work of the Industrial Dynamics Group at M.I.T. headed by J. W. Forrester (1961). One criticism for using the standard methods of industrial dynamics, however, is the literally hundreds of assumptions that go into model development. These assumptions are oftentimes not characteristic of the actual systems they are to represent. To circumvent this difficulty, D. A. Wismer (1967) proposed a "sparse" model of industrial dynamics coupled with dynamic programming to obtain results in a quick and economical fashion. This economy is achieved by stating explicitly the objectives expected and tailoring the model toward the achievement of those objectives. Three specific and widely differing uses of the model are presented. These are called analysis, feasibility, and control and are demonstrated in terms of a dynamic model of savings for a cement company.

Venkataramani (1968) developed a computer model to simulate the digging component of a bucket wheel excavator (BWE). To reflect the dynamic characteristics of a BWE system, rate equations based on formulae from published literature were used to generate the goal-seeking, self-correcting interplay between the unit operations. As output, the model will print out a time study, production study and power consumption for mining a specified ore block.

II. SYSTEM CHARACTERISTICS AND METHODS OF SIMULATION

The open pit system to be modeled includes the operation of BWE's and their related materials handling equipment. The cutting action of the BWE and the time-varied movement of individual trucks and trains along with the steady transportation of material by conveyors are predicted with complete certainty from equations governing their performance characteristics. Mechanical availabilities of each machine and the service time distribution of mining equipment are random variables and are predicted by Monte-Carlo techniques. This chapter will discuss the required expressions related to equipment performance and the methods of formulating these into a complete simulation model.

Deterministic Simulation

Deterministic simulation as used in the model performs the sequentially simulated operation of equipment moves according to a fixed set of orders. The change of state from time to time is devoid of uncertainty and can be perfectly predicted. A formal definition of it is such that, if the state of the system at time t corresponds to a certain position of the point M which depends on the initial point M_o and t, then

$$M = M\ (M_o,\ t) \qquad (1)$$

when t varies but M_o remains fixed, M describes a curve which represents the evolution of the system starting from the initial condition defined by M_o; the simulation of this model

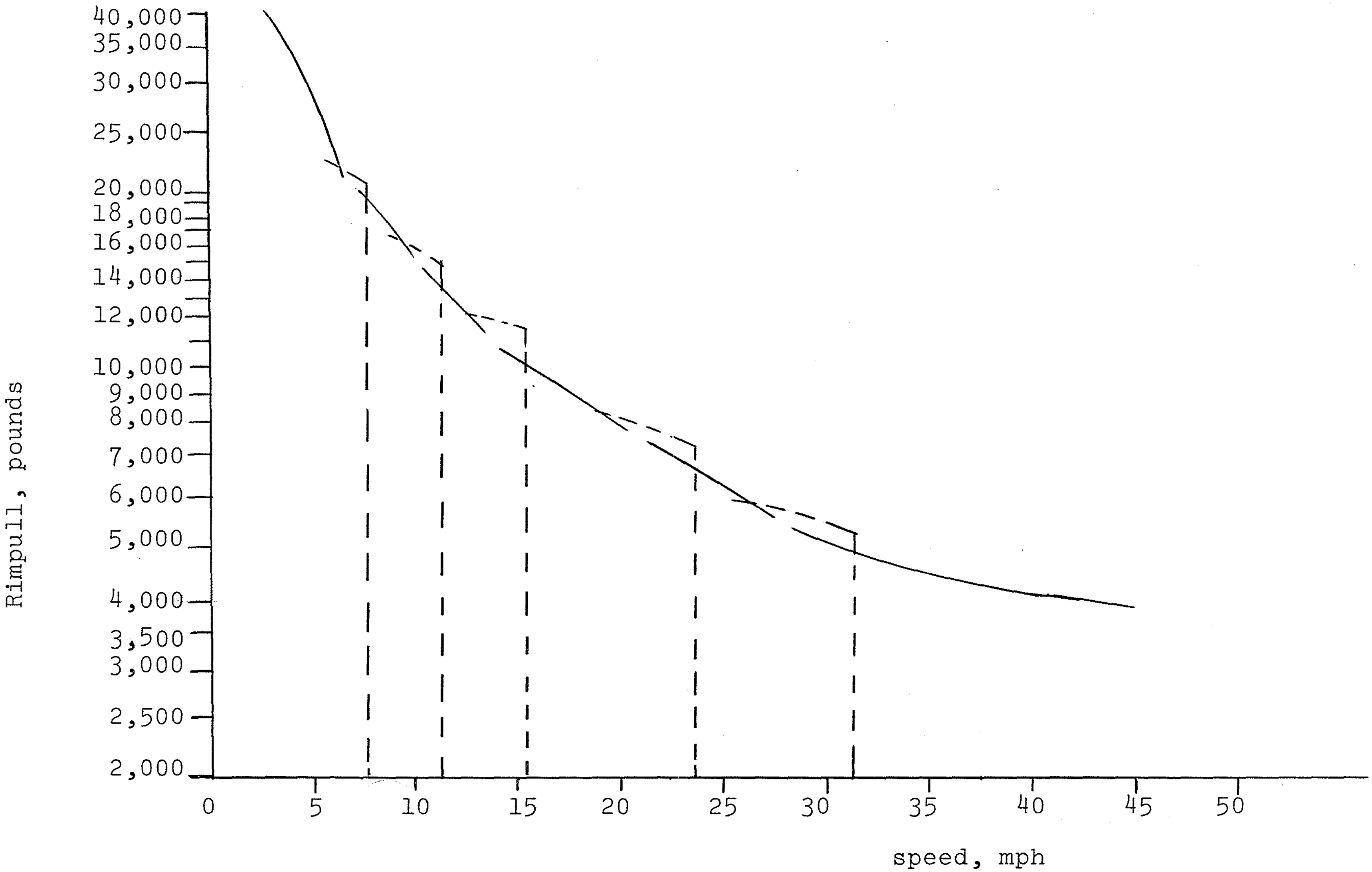
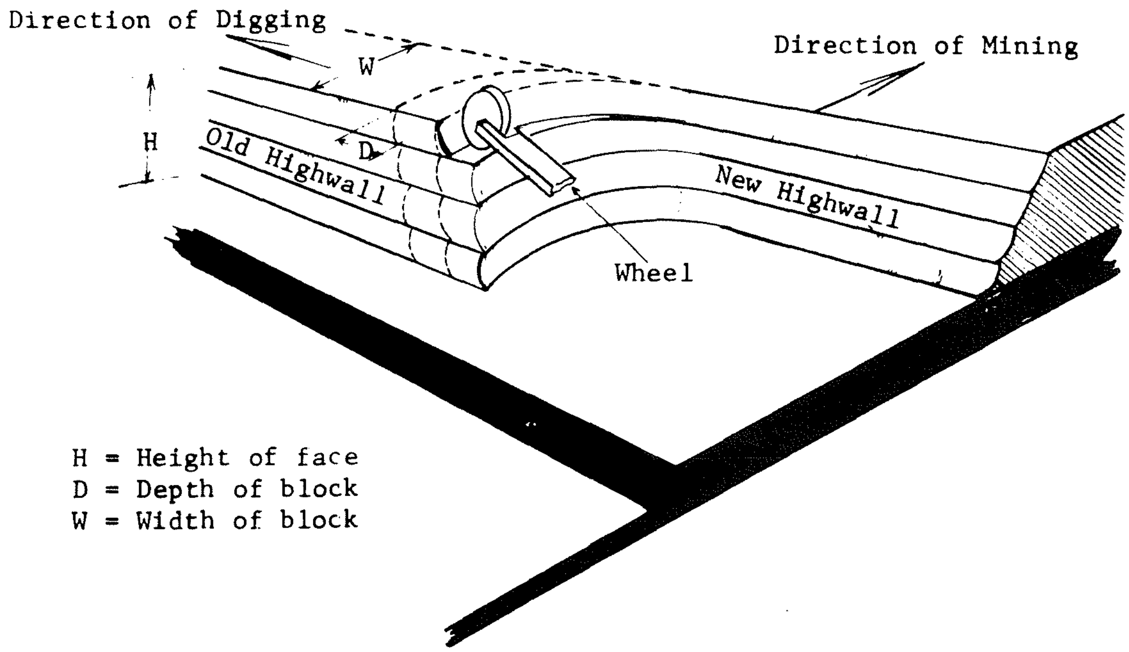


Figure 3 - Typical Speed-Rimpull Curve of Trucks



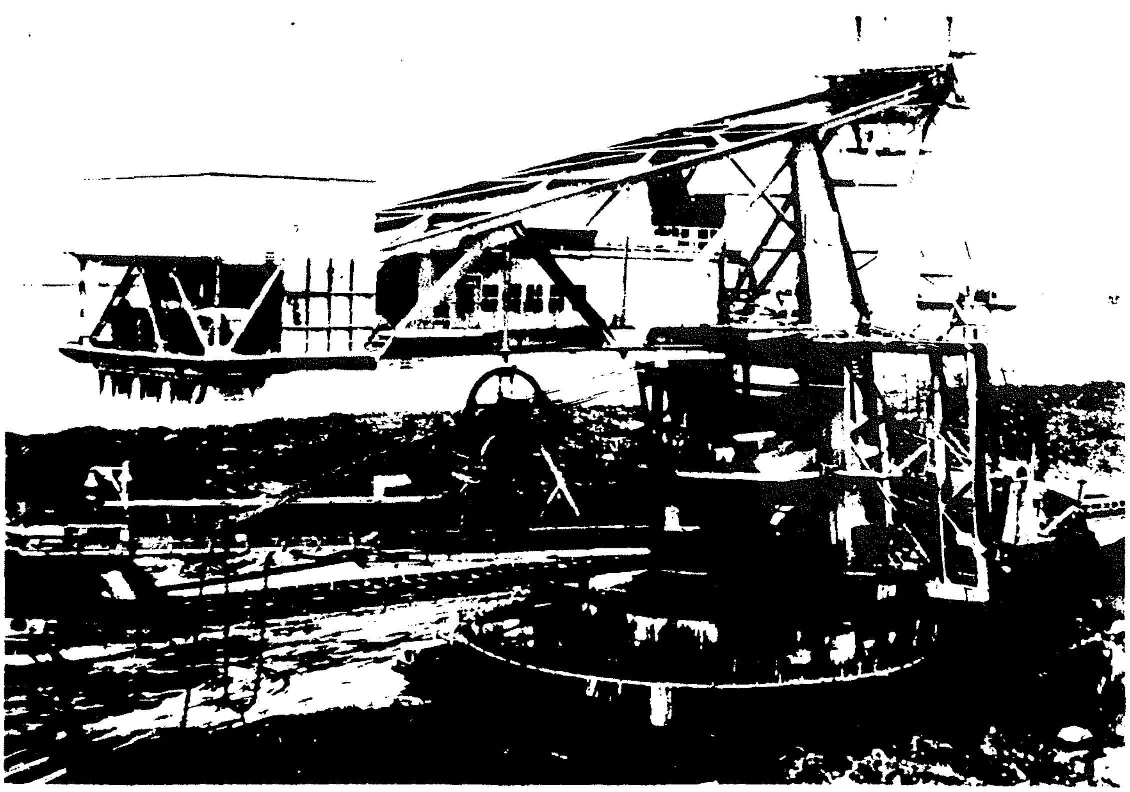


Figure 4 - Cutting, Slewing and Tramming of BWE's

operation, that is, $M'(M_o,t) = M_o'$. The maximum cutting speed is theoretically the speed which yields a centrifugal force equivalent to the gravitational force.

$$V_{max} = \sqrt{gD/2} \quad (7)$$

where,

g = gravity acceleration

D = diameter of wheel

The practical operating value of speed, V_1, lies between 0.4 to 0.6 of V_{max}.

2. BWE output. Output from a BWE is estimated by the following set of equations:

$$S = (V_1/\pi D) \times Z \quad (8)$$

where,

S = number of buckets discharged per second

D = diameter of the wheel in meters

Z = number of buckets on the wheel

V_1 = cutting speed of the wheel in meters per second

The actual output capacity of a BWE in a given soil is,

$$Q_a = I \times B_f \times S \quad (9)$$

where,

I = nominal bucket capacity in cubic meters

B_f = bucket filling capacity expressed as a fraction on the nominal bucket capacity.

Q_a = actual capacity of the BWE in cubic meters/second

3. Slewing. From the actual output, the slewing speed of a BWE is evaluated. The thickness of each slice of material excavated is theoretically computed from

$$d = 87.6 \times Q_a / D \times S \qquad (10)$$

d = thickness of slice in meters

and the slewing speed is, therefore,

$$V_s = \frac{Q_a}{d \times h} \qquad (11)$$

where,

V_s = slewing speed of BWE wheel in meters/second

h = height of bank excavated in meters

However, with a non-crowding machine, because of the fixed length of the wheel boom, the BWE moves forward bodily in the direction of the bench and the thickness of the slice at any point is approximated by

$$d_p = d(\cos\theta + \text{Sin}^2\,\theta/2p_i) \qquad (12)$$

where,

$p_i = R_s/d$

R_s = slewing radius in meters

θ = angle between the direction of advance and direction of p.

In order to maintain uniform output, the reduction in the thickness of the slice as the boom slews away from the center is compensated for by increasing the width of the slice cut. To increase the width, the slewing speed has to change according to,

$$V_p = V_s/\cos\theta \qquad (13)$$

V_p = slewing speed at the point p.

V_s = starting slewing speed at the center

4. Tramming of BWE. Tramming speed of a BWE is very slow, and is regarded to be constant and fixed.

5. Power consumption. The power requirement for a BWE connected with the cutting, slewing and tramming operations are theoretically computed from standard equations which are listed in Appendix I.

Movement of Conveyor Belt. Since the speed of a conveyor remains constant for the entire simulation period, deterministic simulation is accomplished simply by dividing the total length of the conveyor into elements with equal length and advancing one element during each time interval. Detailed discussions of related modeling techniques are presented in a later chapter.

Probabilistic Simulation of Stochastic Processes

When the state of the system at time, t, is, M, which depends on the initial condition, M_o, and, t, as shown in equation (1), and if, M_o, lies within a region, u, with a certain probability distribution, the set of curves, $M(M_o,t)$, represents a stochastic process. The Monte-Carlo method is the technique to obtain the expected values of these processes. In modeling the following conditions are considered to be stochastic.

Mechanical Availability. The failure of a piece of equipment and the required service time for each failure are random variables. As a result the working time of the machine is also a random variable. For example, let the required repair time be, X, with a probability density function, f(x), and the duration of continuous working time of the machine will be, Y, with p.d.f., g(y).

The mechanical availability is then defined as

$$\frac{E(Y)}{E(Y + X)} = \frac{\text{Expected working hours}}{\text{Expected working hours + Expected repair hours}}$$

which is usually regarded as a constant, c, for a machine. In the process of simulation, a random number is generated from a uniform distribution between [0,1] at the end of each work or failure cycle.

Soils Characteristics. Cutting resistance is a measuring unit which designates the mechanical properties of a soil against the cutting action of a BWE. Different authors suggest different methods to express this factor. Professor N. G. Dombrowsky (1964) at the Fifth International Earthmoving Conference used the unit of, kg/cm^2, to specify the digging forces for various types of ground. However, most technical publications and manufacturers' catalogs still prefer the unit, kg/cm, which is based on the required load per unit length of the cutters in contact with the ground. Table 2 shows some reference values for the cutting resistance of certain materials based on this unit. Because of the non-uniformity of soils, the cutting resistance varies greatly even for the same material at the same location and is, therefore, treated as a random variable in BWE simulation.

A second soil property which is considered to be random is the presence of boulders in the ground. The capacity of an excavator can be affected adversely in proportion to the

Table 2

Cutting Resistance of Soils for BWE Excavation

(Gartner, 1965)

SOIL TYPE	CUTTING RESISTANCE kg/cm
Earth	10-30
Loess	20-40
Sand	10-40
Clayey sand	10-50
Gravel fine	20-50
Gravel coarse	20-80
Sandy loam and wet loam	20-60
Dry loam	20-80
Clay wet	30-65
Clay dry	50-120
Clay schistose	35-120
Sandy clay	20-65
Clayey slate	50-160
Slate	70-200
Sandstone (easy digging)	70-160
Sandstone (hard digging)	160-280
Gypsum	50-130
Lime	30-120
Phosphate	80-200
Alluvial light consolidation	30-60
Alluvial medium consolidation	50-80
Alluvial heavy consolidation	70-150
Hard Coal	50-100
Lignite	20-70
Brown iron ore	190-210

frequency of boulder occurrence. These boulders are either too hard to cut or too difficult to handle.

The stochastic simulation of cutting resistance consists of generating a random number from a given density function at each time interval and using this value to denote the material properties at this specific time period. Similarly, a random number is generated from a uniform distribution between [0,1]; if this number is less than the probability of hitting boulders, it signifies that a boulder has been hit. The machine is then idled for the period required to restart the BWE.

Dynamic Modeling of the System

There are three essential components in a dynamic model: a) information flow, b) material flow and c) decision. These components form a complicated interconnected network within the system whereby a beginning decision causes the action of material flow. This in turn generates an information flow to affect consecutive decisions and the resulting amplification of system outputs.

The execution of information feedback among unit operations in the open pit materials handling model is accomplished by assigning reservoirs, or surge bins in this case, to the head and the tail of each sub-assembly. A conceptual flow model to describe the phenomena is shown in Figure 5.

The soil characteristics, mining profiles, bench information and the required reservoirs provide information to a decision center. If the reservoir can accept material and

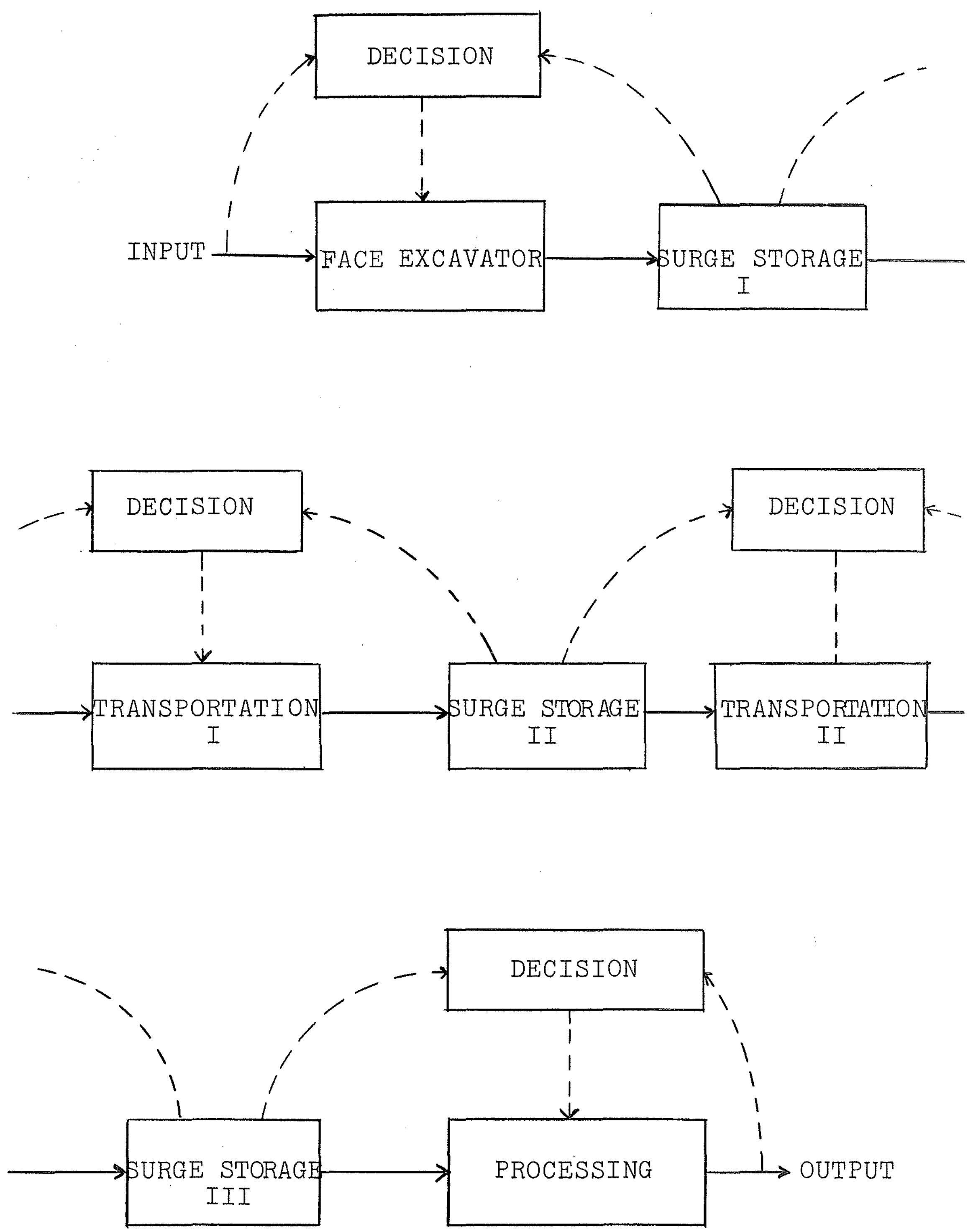


Figure 5 Conceptual Dynamic Modeling of Open Pit Materials Handling System

no idle time occurrence is listed, the face excavator will load material. Similarly, at the second decision center, Reservoirs I and II supply information to determine the action of Transportation I. Thus, the control decisions regulate the performance of each unit operation and therefore increase or decrease the rate of flow into and out of the storage facilities. When control decisions occur at discrete points, in Δt, these decisions regulate flow rates in the next time interval. Current flow rates affect future storage levels which in turn affect future decisions.

Other Computation Techniques

The potentialities of computation and experimentation as related to the application of simulation methods are restricted unless ways are developed to combine the elements of the mining model to meet those objectives as listed in Chapter I. One central requirement is the correct choice of a time interval to measure what has been done to compare with the objectives. For example in the deterministic simulation of equipment moves, the result in the period $M(t+\Delta t)$ could be adversely affected by other external variables including haulroad profiles. Only when, Δt, is assumed small enough can these other variables be taken as constants in this incremental time period. Decreasing incremental values of, Δt, however, monotonically increases computational times, and consequently, computer costs reach a point where these are no longer justified for the information received. A value of, Δt, based on errors from previous comparisons shows a bottom value of one (1) second necessary to synthesize the system to meet model requirements while at the same time satisfy the restrictions placed on time and money (O'Neil, 1966).

Grid Point Simulation

A second problem in the application of simulation models as related to the objectives proposed here deals with long range planning where large numbers of jobs have to be simulated. A day by day simulation in these cases is economically and physically impossible when twenty (20) to thirty (30) years in the operating life of the mine have to be considered. An alternative approach, and the one used in this research, is to allow for two distinct time periods for information retrieval. The first of these would allow a shift-by-shift operation for information retrieval related to daily scheduling and planning. The second time period would involve a one-cut sequence of the BWE operation at changing values of the input variables over the entire orebody and the results interpolated for the complete life of the mine. This proposed idea would operate by dividing the entire orebody into grids with simulation conducted at each grid point and the results represented graphically on a contour map. This would allow a quick and easy method for management to identify at what stages in mining should changes be made to meet the objectives of the firm.

As would be expected, the results of simulation at each grid point vary because of changing conditions at each point. To derive the production and related waiting time values from them a curve smoothing method is applied using interpolating techniques to obtain the required contours (Figure 6). The method operates in the following manner:

Let the result of simulation at a grid point be, $Z(x,y)$, with x,y being the coordinates of this point. Let, Z_1, be the value of a contour which intercepts "grid-lines" at I, I+1, I+2, and I+3. The coordinates of, I, are interpolated as follows,

$$x_i = x_m$$

$$y_i = y_m + \frac{Z_1 - Z(x_m, y_m)}{Z(x_m, y_{m+1}) - Z(x_m, y_m)} \times (y_{m+1} - y_m)$$

and coordinates of I+1 are,

$$x_{i+1} = x_m + \frac{Z_1 - Z(x_m, y_m)}{Z(x_m, y_{m+1}) - Z(x_m, y_{m+1})} \times (x_{m+1} - x_m)$$

$$y_{i+1} = y_{m+1}$$

A similar procedure is applied to obtain the coordinates of I+2 and I+3. Let (x_i, y_i), (x_{i+1}, y_{i+1}) and (x_{i+2}, y_{i+2}) be the coordinates of points I, I+1 and I+2. The smooth curve used to connect these points is given by the following,

$$x_\ell = x_i + \ell x \Delta x \qquad \ell = 0, 1, 2, \cdots, k-1$$

where, Δx, is small, i.e., one tenth of the distance between two grid points.

Next, by linear interpolation,

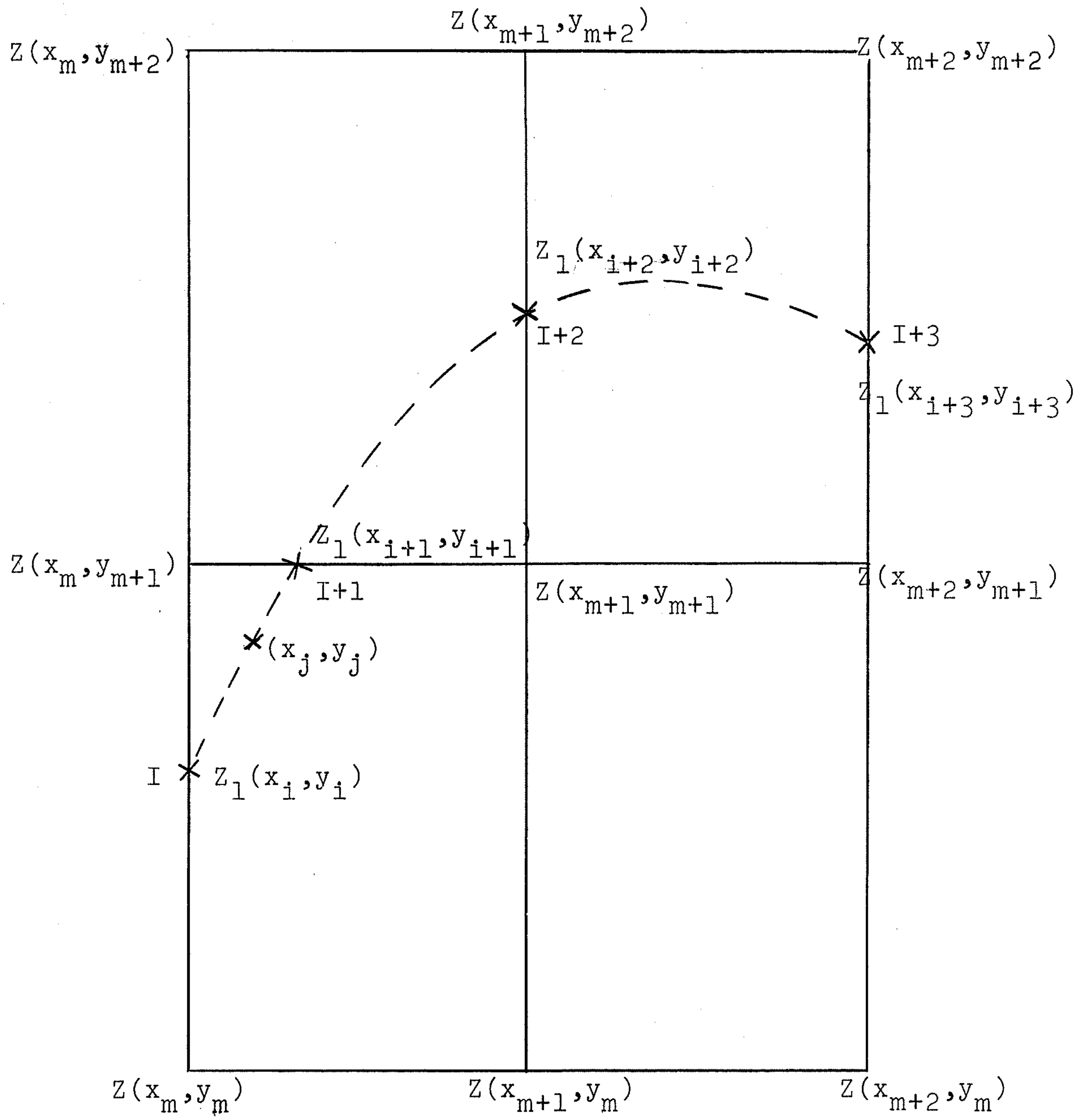


Figure 6 Curve Smoothing

$$y_\ell = y_i + \frac{Y_{i+1} - Y_i}{x_{i+1} - x_i} \times (\Delta x \times \ell)$$

and by taking the average of (x_ℓ, y_ℓ), the coordinates of the interpolated point, J, are obtained by,

$$x_j = \frac{1}{k} \sum_{\ell=0}^{k-1} x_\ell$$

$$y_j = \frac{1}{k} \sum_{\ell=0}^{k-1} y_\ell$$

where, (x_{j+1}, y_{j+1}), is again calculated by taking ℓ from 1 to k. When either x_ℓ or y_ℓ exceeds x_{i+1} or y_{i+1}, then (x_{i+2}, y_{i+2}) and (x_{i+1}, y_{i+1}) will be used for the interpolation of (x_ℓ, y_ℓ).

The above procedure is repeated until all the required contours are computed. Methods for obtaining the results of grid point simulation are listed in chapter IV as they are found to exist for an operating prototype.

III. MODEL FORMULATION

The basic aspects of the system to be modeled may be brought into focus by referring to Figure 7, a schematic diagram of a typical open pit mining operation. An n-stage materials handling scheme is employed to mine and move both ore and waste from face areas through intermediate zones to final destinations. Materials handling units are directed to a processing plant or stockpile if ore is mined, while waste and overburden are tranported to refuse disposal sites. At each face operation a bucket wheel excavator is employed to mine and load material.

Plan of work

Two stages of research were considered in modeling the above mentioned system. Stage one involved the formulation of equipment sub-assemblies which included the sequence of equipment moves along with related assignments and routines for information retrieval. The second stage of research combined all sub-assemblies into an integrated open-pit mining simulator that is able to execute two different analyses of mining operations. Provisions are made, depending on management's choice for the design and selection of equipment for a completely new operation. On the other hand, productivity can be measured and compared when changes are made to an existing system. A systems flow model is presented in Figure 8 to illustrate the flow of information and decision points along with related feedback loops and

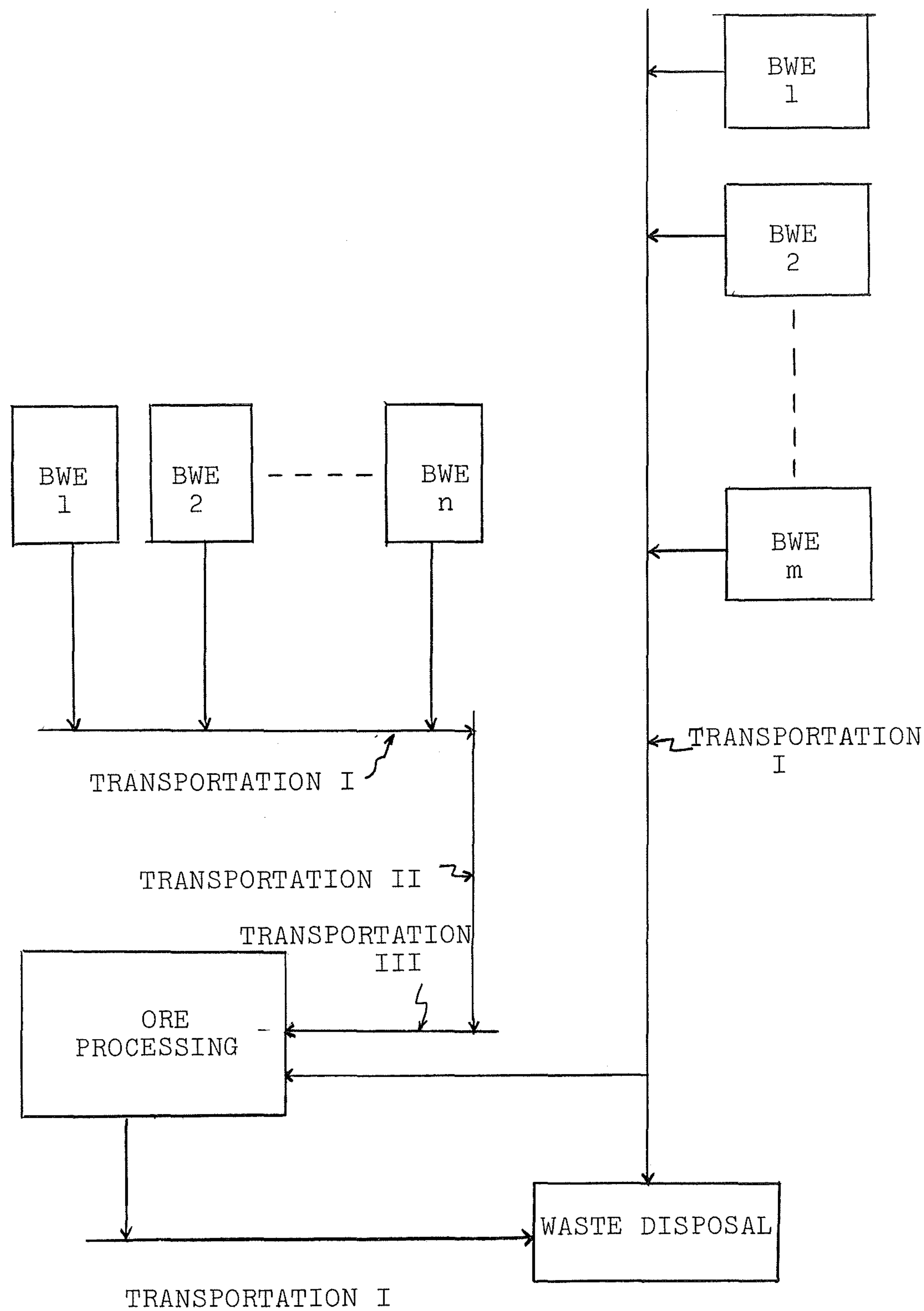


Figure 7 - Conceptual Operating System to be Modeled

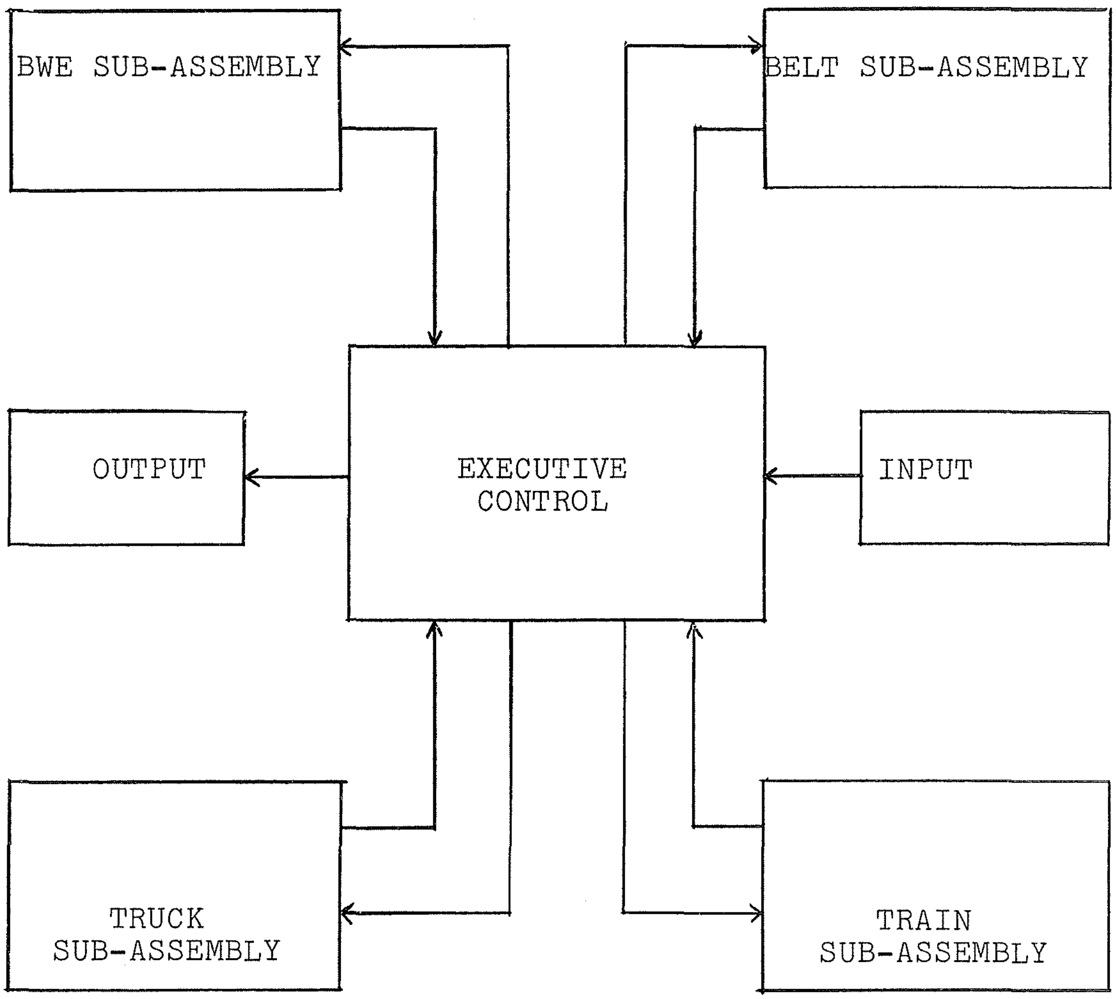


Figure 8 - Block Diagram of the System

interconnected networks.

Equipment Sub-assemblies

Before the implications of changes in management policies and associated production plans can be derived from the above representation, it is necessary that all machine activities be expressed in explicit quantitative form. The straight-forward but detailed formulation of equations describing these operations are listed for application with the principles of deterministic and stochastic simulation. Model building as explained here consists of tracing step by step the actual equipment moves and flow of information while at the same time observing the series of decisions that take place. Details of actual model construction for machine operations, including BWE's, trucks, trains, and belt conveyors, are provided for in the following discussions.

A summary of notations used in model construction are listed below,

- f: tramming, maneuvering variable of BWE's
- h: variable of hitting boulder of BWE's
- u: variable designating outby equipment
- g: variable designating the mechanical availability
- p: variable designating the position of transportation media
- s: variable designating the condition of truck at stations
- D: payload of truck
- b: Constraint factor for transportation media, truck and train

r: feeding rate of conveyor

c: variable designating condition of traffic control lights

I: variable designating the condition of haulroad intersection

R: variable designating train dispatching

<u>BWE's</u>. Basically there are four independent moving parts connected with this piece of equipment: the bucket wheel itself, boom, superstructure and the crawlers. A combination of these four activities yields the work output of the machine. The rotation of the wheel is the main activity while the vertical movement of the boom positions the wheel and a horizontal rotation of the superstructure provides the necessary slewing action. The crawler activity positions the machine for the next cut sequence.

Although BWE output during any time interval, Δt, is theoretically calculated by formulas presented in Chapter II, no output is obtained when the machine is maneuvering, in contact with boulders, experiencing mechanical failure or waiting on outby activities. In practice, therefore, total BWE production in time period, T, is expressed mathematically as follows:

$$T.P. = \sum_{i=1}^{n} Q_a \times \Delta t \times g_i \times h_i \times f_i \times u_i \times d$$

where,

$n = T/\Delta t$

$$f_i = \begin{cases} 0 & \text{if BWE is tramming, maneuvering} \\ 1 & \text{if BWE is cutting the soil} \end{cases}$$

$$h_i = \begin{cases} 0 & \text{if buckets hit boulders or when restarting power} \\ 1 & \text{otherwise} \end{cases}$$

$$u_i = \begin{cases} 0 & \text{if related equipment is not available} \\ 1 & \text{otherwise} \end{cases}$$

$$g_i = \begin{cases} 0 & \text{if machine fails mechanically} \\ 1 & \text{otherwise} \end{cases}$$

The actual capacity of the machine in cubic meters per second is defined by Q_a, while d defines the density of the soil in tons (short tons) per cubic meter. Figure 15 shows the flow model of BWE operations.

Related output measurement for information retrieval, which follows from the basic production equations, includes a) waiting times, TW; b) Mechanical delay times, TF; c) boulder contact delay times, TH; and d) Maneuvering times, TM. These are obtained from the computer using the following relationships,

$$TW = \sum_{i=1}^{n} (1-u_i) \times \Delta t$$

$$TF = \sum_{i=1}^{n} (1-g_i) \times \Delta t$$

$$TM = \sum_{i=1}^{n} (1-f_i) \times \Delta t$$

$$TH = \sum_{i=1}^{n} (1-h_i) \times \Delta t$$

The values of u_i, g_i, h_i and f_i are calculated at each time interval, Δt, using soil characteristics, machine performance curves, and the BWE assignment as input. A complete listing and definition of the input variables are provided in Appendix III.

Trucks. Truck performance is quantified not only in haulroad locations but also at any of the following operations; a) Ore and waste loading stations; b) plant disposal and refuse sites; and c) the ore discharge points. Information retrieval from the above locations includes total production and delay times along with amount of material carried. The values obtained in, Δt, and accumulated for the time period T, are given by,

$$(WT)_j = \sum_{i=1}^{n} P_{ijk} \, S_{ijk} \, \Delta t$$

i.e., the total waiting time of k^{th} truck at j^{th} station.

where,

$$n = T/\Delta t$$

and,

$$P_{ijk} = \begin{cases} 1 & \text{when the } k^{th} \text{ truck at } j^{th} \text{ station} \\ 0 & \text{otherwise} \end{cases}$$

$$S_{ijk} = \begin{cases} 1 & \text{if either the } k^{th} \text{ truck is on a waiting line of } j^{th} \text{ station or the station is out of service or both} \\ 0 & \text{otherwise} \end{cases}$$

Also,

$$(TP)_k = \sum_{i=1}^{n} P_{ijk} \, S_{ijk} \, \frac{D_k}{t_k} \, \Delta t \qquad j = \ell$$

where, $(TP)_k$ is the total material transported by k^{th} truck

ℓ: ℓ^{th} dumping station

D_k: payload of k^{th} truck

t_k: discharge time of k^{th} truck

When in a segment of the haulroad, truck performance traveling empty or loaded is calculated by the set of equations listed in Chapter II. The velocity in practice, however, is altered to read,

$$V(t+\Delta t) = V(t) + a(t+\Delta t) \times \Delta t \times g(\Delta t) \times b(\Delta t)$$

where,

$V(t)$ = velocity at time t

$a(t+\Delta t)$ = acceleration in $(t+\Delta t)$ from available rimpull at $V(t)$

$$g(\Delta t) = \begin{cases} 0 & \text{mechanical failure} \\ 1 & \text{otherwise} \end{cases}$$

$b(\Delta t)$ = allowable factor satisfying the following constraints;

i) $a(t+\Delta t)\, b(\Delta t) \leq$ maximum acceleration

ii) $V(t+\Delta t) \leq$ maximum speed, and

iii) $V(t+\Delta t) \leq$ limiting speed for mixed fleet operation.

The flow model for truck operations as described above is illustrated in Figure 16. Required input data to carry out the simulation for the sub-assembly includes speed-rimpull curves, maximum acceleration rates, a realistic deceleration rate, vehicular payload, discharge rates, haul-road conditions and truck assignments. A complete listing and definitions of the input variables are provided in Appendix III.

Belts. Components connected with this particular sub-assembly consist of primary and secondary gathering belts along with their required surge facilities. Information obtained and listed here includes production and out-of-service time because of belt overloading and mechanical failure. Although constant speeds are used during the simulation, delay times are experienced in actual practice. Total material transported, TP, is, therefore, expressed as,

$$TP = \sum_{i=k}^{n+k} r_i \times \Delta t \times u_i \times g_i$$

where,

$n = T/ t$

$k = L/(V \times \Delta t)$

L = Length of belt

V = speed of belt

r_i = feeding rate

$$u_i = \begin{cases} 0 & \text{if related gathering belt or surge is overloaded} \\ 1 & \text{no overloading or overloading is to be cumulated} \end{cases}$$

$$g_i = \begin{cases} 0 & \text{if belt fails mechanically} \\ 1 & \text{otherwise} \end{cases}$$

$0 \leq r_i \leq$ total material storage during step i

Related waiting time (W.T.) which follows from the above basic transportation equation is

$$W.T. = \sum_{i=1}^{n} (1-u_i) \times \Delta t$$

In a situation where overloading occurs in the absence of an automatic stopping device lost production is determined in the following way,

$$T.O. = \sum_{i=1}^{n} (1-u_i)\, r_i \Delta t$$

where,

$$u_i = \begin{cases} 0 & \text{no overloading occurs} \\ 1 & \text{otherwise} \end{cases}$$

and,

T.O. = total tons lost.

The belt flow model is shown in Figure 17.

Required input data for the execution of this sub-assembly includes belt speeds, capacities, assignments of belts and surge facilities, and feed rates. A complete listing and definition of input variables are presented in Appendix III.

Trains. The mathematics and logic for building this particular sub-assembly are nearly identical to that required for trucks. The main difference arises in the overlapping of haulroad segments from longer trip lengths and in the manner of equipment moves. The decisions and computations for a multiple trip network are shown in Figure 18. The average slope of the haulroad profile must be calculated for the entire trip length in order to determine its related force vector in Δt and consequently the acceleration.

A second difference results from the necessity of installing traffic control lights in the system. When a train enters a section of haulroad, the lights controlled by this section are turned on automatically to regulate other trains entering from the opposite direction. The waiting time of trains at haulage intersections is expressed mathematically as follows:

$$(WTI)_j = \sum_{i=1}^{n} \sum_{k=1}^{m} c_{ik} I_{ijk} \Delta t$$

where,

$(WTI)_j$ = total waiting time of j^{th} train at intersection

$$c_{ik} = \begin{cases} 1 & \text{when } k^{th} \text{ light is on} \\ 0 & \text{otherwise} \end{cases}$$

$$I_{ijk} = \begin{cases} 1 & \text{if the train is at the intersection where } k^{th} \text{ light is installed} \\ 0 & \text{otherwise} \end{cases}$$

m = total traffic lights in the system

$n = T/\Delta t$

This value is cumulated by the computer for T.

One final comment involves the application of a dispatcher in this sub-assembly. Here an empty trip is received by the loading station and a predetermined number of empty cars are placed in storage. The waiting time generated by this feature is obtained in the following way,

$$(WT)_{\ell} = \sum_{i=1}^{n} P_{i\ell} R_{i\ell} \Delta t$$

i.e., the total waiting time at ℓ^{th} dumping station,

where,

$$P_{i\ell} = \begin{cases} 1 & \text{if train is at } \ell^{th} \text{ dumping station} \\ 0 & \text{otherwise} \end{cases}$$

$$R_{i\ell} = \begin{cases} 1 & \text{If no loading station requests empty trip and/or traffic light at } \ell^{th} \text{ station is on and/or train is waiting for dumping} \\ 0 & \text{otherwise} \end{cases}$$

A complete list of variable names and definitions is presented in Appendix III.

<u>State II Development</u>

Because the proposed system is not a simple information feedback loop but a complex multi-looped one with interconnected networks, the sub-assemblies as developed in the previous section cannot exist as separate entities. Sub-assembly information generated in, Δt, affects subsequent decisions and consequently the execution of machine operations in the next time interval. All decision points must, therefore, be defined and coordinated in order to transfer new data and decision policies to the equipment in, $t+\Delta t$. An Executive Control System along with its related auxiliary functions has been developed to accomplish this purpose.

Executive Control. The central function of Executive Control is to determine and provide at each time step, Δt, the values of variables representing machine performance. The values u_i, g_i, f_i, h_i of BWE's; P_{ijk}, S_{ijk}, $g(\Delta t)$, $b(\Delta t)$ of trucks; r_i, u_i, g_i of belts; and the c_{ik}, I_{ijk}, $P_{i\ell}$, $R_{i\ell}$ of trains are stored, updated and compared in order to control the next sequence of activities specified by the input data. Also included are routines for entering and leaving the system. At the end of, T, the system requests data initialization for the next set of jobs. Data Control assigns input data as required while Data Reader and Printer are used to fulfill the input and output requirements.

Other Programming Considerations

Grid point simulation is introduced and applied for long-range planning as part of the program of research. This allows simulation of the complete ore body at preselected points involving parameter changes. Only a one-cut sequence is allowed at each discrete point with complete tabulation of all decision variables. The results are interpolated and displayed graphically as contours using the subroutine CONTOR which was applied for this purpose. Input data for the subroutine includes the output of the simulation model together with the number, location and soil profiles at each point in terms of the x,y coordinates.

Other subroutines and functions include OBSTOW which allows for the placement of an observation tower in the truck system to obtain maximum fleet utilization. SETBAS, CHCOMP and RAND were made available through the OS/360 Library at the Pennsylvania State University's Computation Center. The functions as related to model application are defined below:

SETBAS: to initialize the base for generating random numbers

RAND: to generate a random number from a uniform distribution

CHCOMP: to compare a string of characters

The model was developed for application on the University's IBM 360/67 system and coded in FORTRAN IV and is not considered suitable for execution on other systems unless modified. The program is listed in Appendix III along with definitions of subroutines, functions, and all exogeneous and endogenous variables.

IV. CASE STUDY AND MODEL IMPLEMENTATION

Since abstraction is the central ingredient in the process of building a mathematical model to describe a real operating system, it is essential that the model be tested in a real world situation before useful information can be obtained. The Alberta operations of the Great Canadian Oil Sands Corporation (GCOS)* at Athabasca were selected as the operating prototype to compare with model output. The hypothesis of equal productivity was tested using the productivety standard deviation of GCOS as the population estimator. Operational data such as these were given by GCOS personnel and are related to mining the Athabasca tarsands located near Fort McMurray. A map showing this location is listed in Figure 9.

Operating Prototype

The Athabasca tarsands is a single orebody covering 10,000 square miles and estimated to contain 600 billion barrels of oil. The average thickness is 150 feet with a covering of 60 feet of overburden. The overburden is removed by fourteen (14) 50-tons scrapers and the deposits excavated in two (2) 75 foot benches with BWE's. Material is moved by a bridge conveyor, which is mounted on crawlers and travels with the BWE, to a rail-mounted bench conveyor.

* All data in this report are disguised to protect the wishes of GCOS.

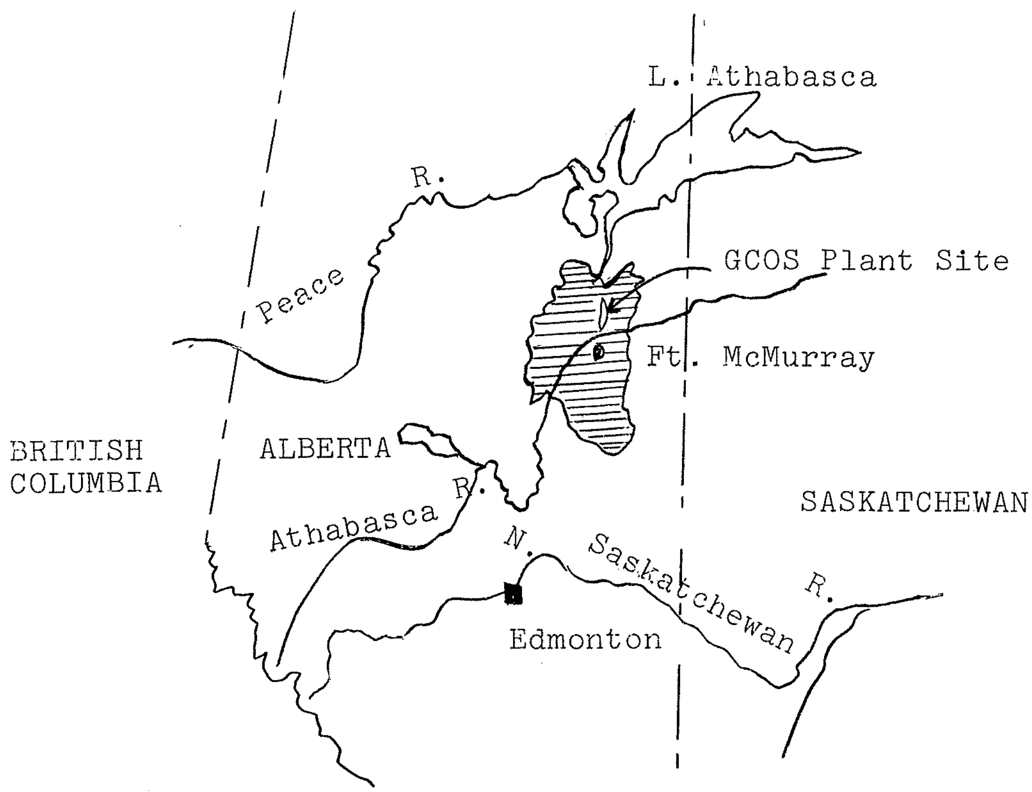


Figure 9 Location Map of GCOS Operation

From here a trunk conveyor located along the perimeter of the orebody accepts material for discharge onto a main conveyor which is connected to a central processing plant. A photograph showing the complete operation can be seen in Figure 10 while a schematic representation of the materials handling arrangement is illustrated in Figure 11. Mining and equipment terminology as referred to here is that which is commonly used by operating personnel.

Input Data. The performance characteristics of equipment are listed on Table 3. These include operating and engineering data, mechanical availability of machines and the soil properties of the orebody itself. Because of the high latitude location, mechanical availability and productivity rates obtained from company records are seasonal and for application to this thesis values are limited only to summer operations.

The cutting resistance of tarsands included as parts of the soil properties was not available from operating records. This was estimated by comparing the allowable BWE cutting speed with reference data given by Gartner (Table 2) for a value of 20-30 kg/cm in warm months. The method of estimating the bucket filling capacity of BWE's was simply one of comparing the weight conveyed by the belt, which could be directly observed from a weightometer, and the number of buckets discharged in a unit time. Average values taken from 50 observations were calculated at 0.80 and 0.70 for the #1300 and #1301 wheels, respectively.

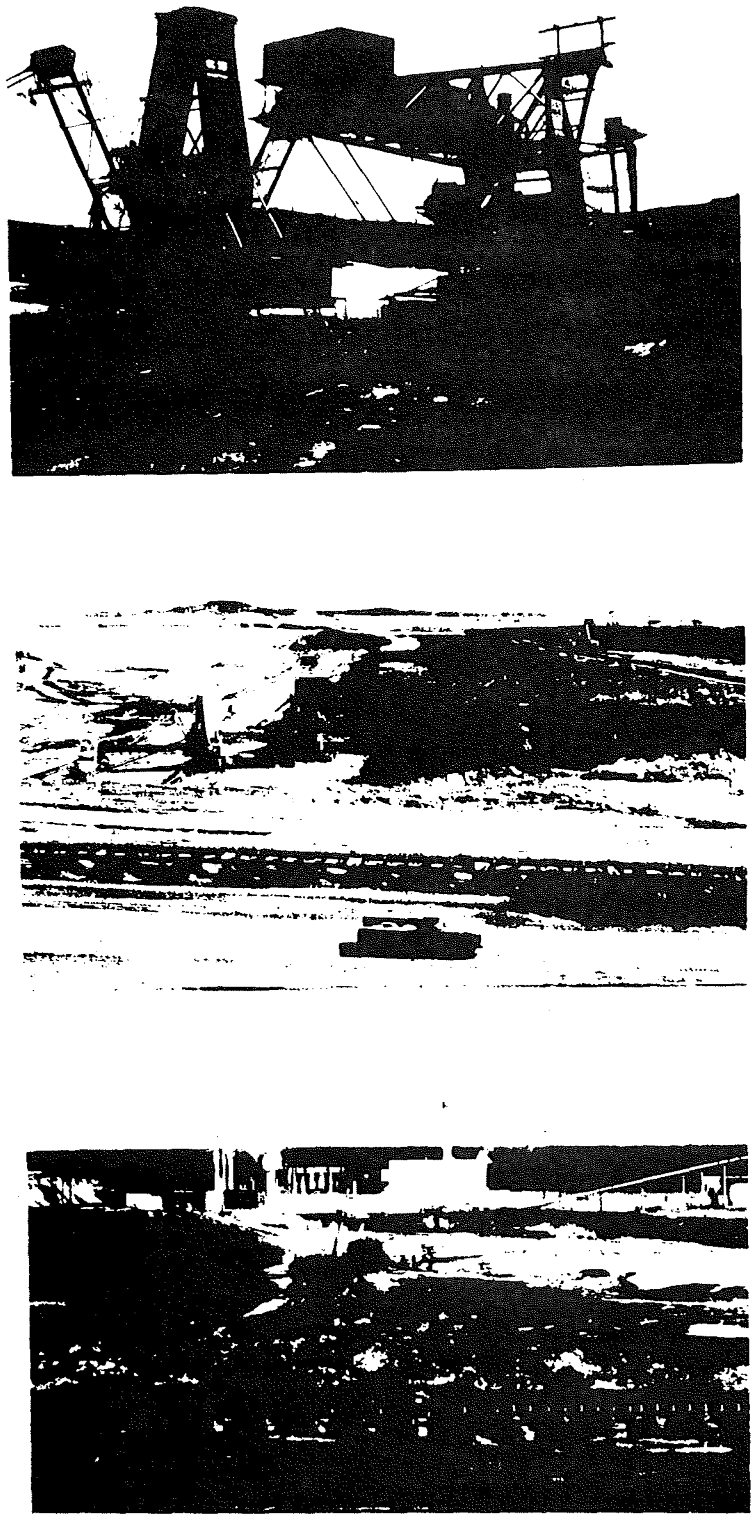


Figure 10   Complete GCOS Materials Handling System

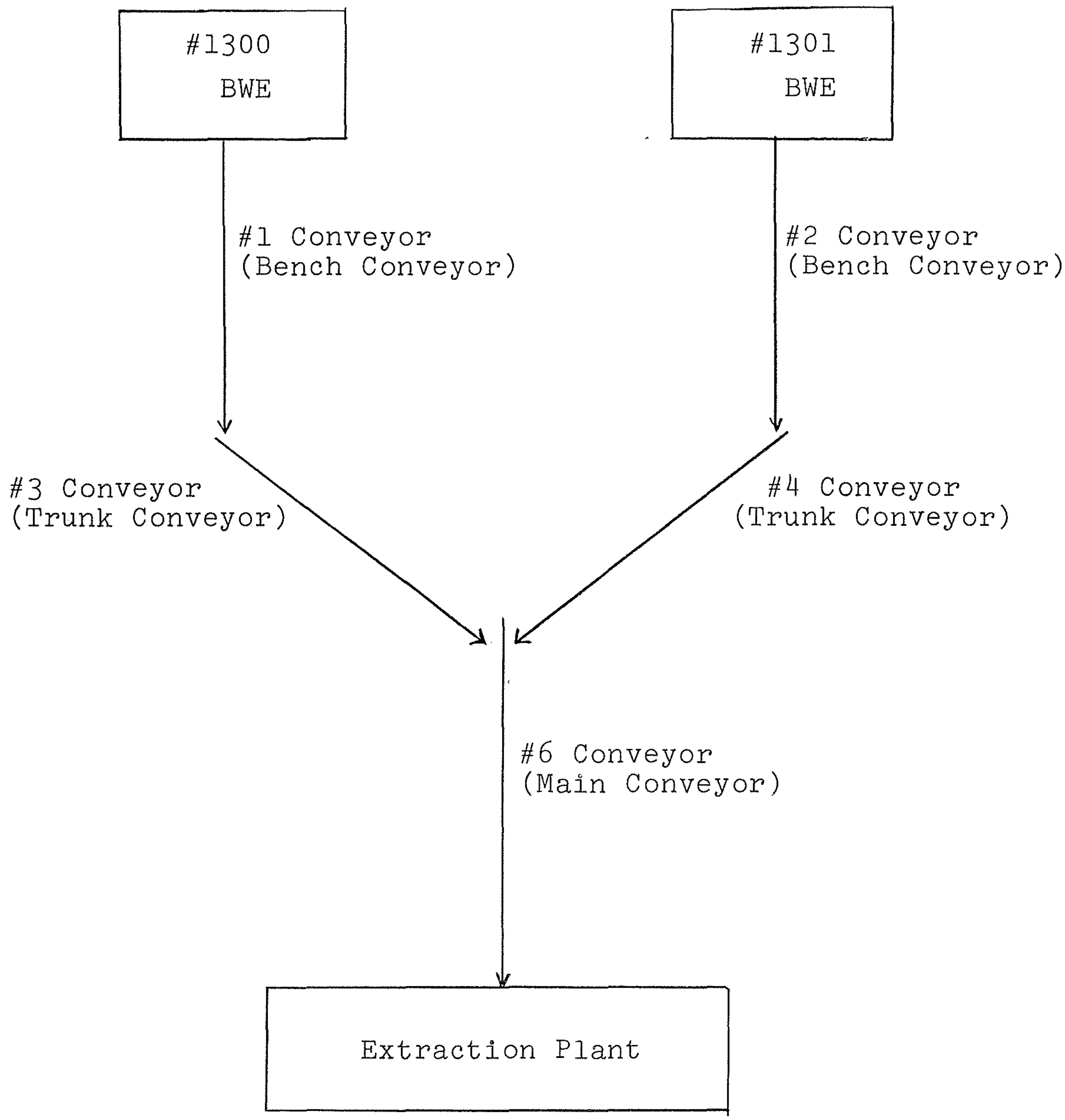


Figure 11 Schematic Representation of GCOS Materials Handling System

Table 3

Equipment Characteristics of GCOS Materials Handling System*

A. BWE

	#1300	#1301
capacity of bucket	1.1 cm.m.	1.1 cu.m.
number of buckets	10(10 pre-cutters)	10(10 pre-cutters)
diameter of wheel	9.0 meters	9.0 m.
length of wheel boom	30.0 m.	30.0 m.
service weight of machine	1,590,000 kg.	1,590,000 kg.
crawler speed	0.12 m/sec.	0.12 m/sec.
mechanical availability	0.60	0.70
number of cuts	5	5
height of each cut	4.57 m.	4.57 m
maximum advance	7.20 m.	7.20 m.
cutting angle (right)	1.0 radian	1.0 radian
cutting angle (left)	0.6 radian	0.6 radian
cutting resistance of tar-sands	20-30 kg./m.	20-30 kg./m.
bucket filling ratio	0.80	0.70
cutting speed of wheel	0.65 rpm	0.65 rpm
density of tarsands	1.92	1.92
frequency of hitting rock lens	0.0187	0.00
time to restart	1.2 min.	1.2 min.

B. Conveyors

	#1	#2	#3	#4	#6
size (inches)	60	60	60	60	72
speed (fpm)	1025	1025	1025	1025	1025
length (ft.)	4380	4000	2900	1170	1390
capacity (tph)	12000	12000	12000	12000	14000
mechanical availability	0.85	0.85	0.90	0.90	0.95
size of head bin (tons)	0	0	0	0	7000

C. Capacity of Extraction Plant — 4900 tons/hr.

* Data disguised for confidentiality purposes

Results. The data explained above and listed in Table 3 were coded for the IBM 360/67 as shown in Appendix IV for a format referred to in the READER portion of the program. These data were simulated in 60 seconds for a six-hour real world operation to obtain sufficient information for making the necessary comparisons. Output results are presented in Appendix IV and summarized in Table 4 with actual operating data. Here monthly production and machine delay times of the operating prototype were used to compute means and standard deviations of hourly production and waiting time probabilities of each machine.

Because the model was constructed based on the realistic potential of equipment rather than on performance, model output was expected to compare closely with that of the prototype. Examination of Table 4 clearly illustrates that model behavior is technologically identical to that of the operating system both in production and in the reliability of equipment. Other behavioral patterns which serve to further demonstrate model ability to replicate real world activities are equipment performance for assigned functions and the observance of system constraints such as waiting for outbye activities. Detailed printouts at regular time intervals have been accomplished to substantiate the acceptance of the above hypothesis.

Hypothetical Case Study

Since the actual operations for testing the model were comparatively simple in concept and design, it was not

Table 4

Comparisons of Model Output with Prototype Production

	Model Output	Prototype Output Mean*	Prototype Output Standard* deviation
A. #1300 BWE			
actual capacity (tons/hr)	5034	4990	
delay-mechanical (hrs/hr)	0.260	0.260	0.180
delay-waiting (hrs/hr)	0.201	0.240	0.130
cutting time (hrs/hr)	0.438	0.480	
actual production (tons/hr)	2433	2400	
B. #1301 BWE			
actual capacity (tons/hr)	4469	4080	
delay-mechanical (hrs/hr)	0.172	0.170	0.080
delay-waiting (hrs/hr)	0.230	0.240	0.140
cutting time (hrs/hr)	0.593	0.600	
actual production (tons/hr)	2650	2450	
C. #1 and #3 Conveyors			
delay-mechanical (hrs/hr)		0.080	0.100
delay-waiting (hrs/hr)	0.096	0.150	0.110
D. #2 and #4 Conveyors			
delay-mechanical (hrs/hr)		0.020	0.130
delay-waiting (hrs/hr)	0.096	0.180	0.180
E. #6 Conveyor			
delay-mechanical (hrs/hr)	0.043	0.050	0.020
delay-waiting (hrs/hr)	0.053	0.090	0.100

* Data disguised for confidentiality purposes

possible to demonstrate model sophistication and flexibility to any great degree. It is the intent, therefore, to create a hypothetical system and a complex one for the purposes of accommodating the simulation of a wide variety of job activities while at the same time demonstrating model application as a decision making method. Figure 12 illustrates a complex system where two ore bodies are mined simultaneously.

Orebody I has three (3) identical BWE's operating in the face areas. The first of these is a stripping machine with trucks to move overburden to a waste disposal site. Ore is excavated by the second and third BWE's onto section belts and moved to a unit train system for transport to a centralized processing plant. Plant refuse is removed by trucks to a tailings dump. At the same time three (3) BWE's with trucks are used in mining orebody II.

Input consideration. Table 5 lists the performance characteristics of equipment and the mining profiles for the proposed case. Data for BWE operations includes soil cutting resistance and machine capacities. All BWE's are assumed to be of the same design and size and working under identical conditions with only cutting resistance being altered.

Information for the truck system includes the truck types, capacities, haulroad profiles, and assignments. The speed-rimpull curves of each truck type are inputed in tabular format and are not listed since these are easily identified as part of the data set in Appendix V. All haulroads are numbered from six (6) to accommodate the movement of

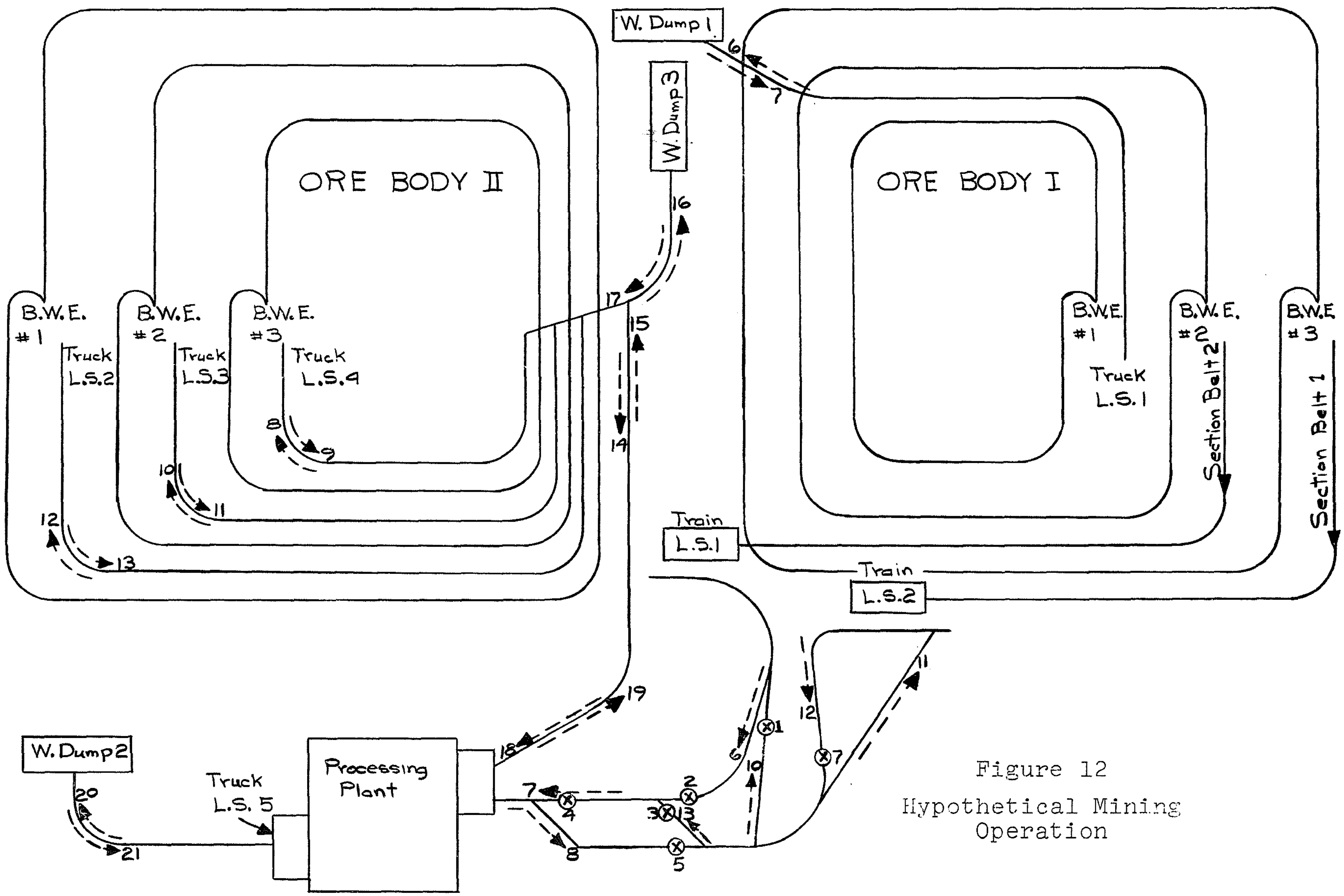


Figure 12

Hypothetical Mining Operation

Table 5

Equipment Characteristics and System Profiles for the Hypothetical Case Study

A. System Configuration

number of ore bodies: 2
number of processing plants: 1
number of waste area: 3
number of BWE's: ore body 1: 3
ore body 2: 3
number of belt conveyors: ore body 1: 2 section belts
ore body 2: 0
number of trucks: ore body 1: 6
ore body 2: 30
processing plant: 25
number of train: ore body 1: 4
ore body 2: 0

B. BWE

i. BWE Characteristics

capacity of buckets:	1.5 cu. m.
number of buckets:	14
diameter of wheel:	11.48 m.
length of wheel boom:	48 m.
service weight of machine:	3,267,000 kg.
crawler speed:	0.15 m/sec.
time to restart:	30 sec.
maximum advance:	24 m.
maximum cutting angle (right):	1 radian
maximum cutting angle (left):	1 radian
mechanical availability:	0.8
capacity of surge bins:	100 tons

ii. Soil Characteristics

	Ore body 1			Ore body 2		
	bench 1	bench 2	bench 3	bench 1	bench 2	bench 3
number of cuts	2	2	2	2	2	2
height of cuts (m)	7.5	7.5	7.5	7.5	7.5	7.5
chance of hitting boulder	0.001	0.001	0.001	0.001	0.001	0.001
density	2.5	2.5	2.5	2.5	2.5	2.5
ore/waste ratio	0.0	1.0	1.0	1.0	1.0	1.0
bucket filling ratio	0.5	0.8	0.8	0.9	0.8	0.8
cutting resistance (kg/cm)	90	60	60	30	60	60
allowable cutting speed (rpm)	0.4	0.6	0.6	0.6	0.6	0.6

Table 5 (Continued)

C. Truck

i. Truck Type

	Type 1	Type 2	Type 3	Type 4
payload tons	75	90	100	120
empty weight	41.5	77.6	80.4	100
maneuvering time (sec.)	10	10	10	10
dumping time (sec.)	10	10	10	10
number in ore body 1	0	3	1	2
number in ore body 2	0	0	30	0
number in processing plant	3	16	6	0
speed rimpull curves	see appendix V			

ii. Truck Assignment

number of loading station in the system: 5

ore body 1: 1
ore body 2: 3
processing plant: 1

number of trucks assigned to BWE:

ore body 1: BWE 1: 6
ore body 2: BWE 1: 10
BWE 2: 10
BWE 3: 10

mechanical availability = 0.90 for all trucks

iii. Haulroad Conditions

Coordinate #	Section #	Slope %	Resistance %	Distance (ft)	Speed Limit (ft/sec)
6	1	0.0	2.0	1000	10.0
7	1	0.0	2.0	1000	10.0
8	1	0.0	2.0	500	15.0
	2	0.0	2.0	800	15.0
9	1	0.0	2.0	500	15.0
	2	0.0	2.0	500	15.0
10	1	2.0	2.0	800	15.0
	2	1.0	2.0	200	15.0
11	1	-1.0	2.0	200	15.0
	2	-2.0	2.0	800	15.0
12	1	8.0	2.0	800	15.0
	2	4.0	2.0	600	15.0
13	1	-4.0	2.0	600	15.0
	2	-8.0	2.0	800	15.0
14	1	0.0	2.0	500	20.0
15	1	0.0	2.0	500	20.0
16	1	0.0	2.0	600	20.0
	2	5.0	2.0	300	10.0
17	1	-5.0	2.0	300	10.0
	2	0.0	2.0	600	20.0
18	1	0.0	2.0	500	10.0

Table 5 (Continued)

iii. Haulroad Conditions (cont'd)

Coordinate #	Section #	Slope %	Resistance %	Distance (ft)	Speed Limit (ft/sec)
19	1	0.0	2.0	500	10.0
20	1	2.0	2.0	1000	15.0
21	1	-2.0	2.0	1000	15.0

D. Belt

number of section belts: 2 number of groups belts: 0

	Section 1	Section 2
size (inches)	42	42
speed (fpm)	400	400
length (ft)	2000	2000
capacity (tons/sec)	4.5	4.5
feeding rate (tons/sec)	4.5	4.5
mechanical availability	0.8	0.8

E. Train

number of trains: 4
number of loading stations: 2
number of traffic control lights: 7
friction of car wheels (%): 0.5
length of car (ft): 30.0
weight of car (tons): 10.0
capacity of car (tons): 50.0
max. acceleration (ft/sec^2): 0.4
average deceleration (ft/sec^2): 0.4
weight of locomotive (tons): 30
friction of locomotive wheel (%): 0.75
max. cars per train: 60
mechanical availability: 0.95
mean dumping time of a train (sec): 60.0
standard deviation of dumping time (sec): 10
speed-tractive force curve: see appendix V
loading rate (tons/sec): 3.0
min. empty car at loading station: 40
train assignment: loading station 1: 2 trains
loading station 2: 2 trains

Haulroad Conditions

Coordinate	Section	Slope (%)	Distance (ft)	Speed limit (ft/sec)	Light number	Lights controlled
6	1	0.0	1,000	10.0	0	1
	2	0.0	5,000	30.0	0	0
	3	0.0	1,000	10.0	2	3

Table 5 (Continued)

Haulroad Conditions (cont'd)

Coordinate	Section	Slope (%)	Distance (ft)	Speed limit (ft/sec)	Light number	Lights controlled
7	1	0.0	50,000	50.0	0	0
	2	0.0	2,000	10.0	4	0
	3	0.0	1,000	10.0	0	4
8	1	0.0	1,000	10.0	0	4
	2	0.0	55,000	50.0	0	0
	3	0.0	1,000	10.0	5	7
9	1	0.0	2,000	20.0	0	7
10	1	0.0	3,000	30.0	0	0
	2	0.0	1,000	10.0	1	0
	3	0.0	1,000	10.0	0	1
11	1	0.0	6,000	30.0	0	0
	2	0.0	1,000	10.0	6	0
	3	0.0	1,000	10.0	0	6
12	1	0.0	1,000	10.0	0	6
	2	0.0	6,000	40.0	0	0
	3	0.0	1,000	10.0	7	0
13	1	0.0	3,000	30.0	0	5
	2	0.0	3,000	30.0	0	0
	3	0.0	1,000	10.0	3	2

trucks, with numbers one (1) to five (5) reserved for sources, destinations and transfer points. Each coordinate condition including the number of sections along with their related slopes, resistances, distances and speed restrictions are recorded accordingly.

The input requirements for trains are nearly identical to those used for trucks with one main exception. The conditions for haulroad sections are expanded to include provisions for traffic control signals. Added functions to be performed are best illustrated by the following example.

Referring to Figure 12 and Table 5 for trains, there are seven (7) traffic lights in this system. The first light is installed at the second section of the tenth coordinate and the second light at the third section of the sixth coordinate while the seventh light is at the third section of the twelfth coordinate. This last light is controlled by the third section of coordinate 8 and the first section of coordinate 9 as indicated by the last column of train haulroad conditions. Once a train enters these portions of the haulroad, number 7 light is automatically turned on and consequently, no other train is permitted to enter the third section of the twelfth coordinate.

For belts, the system is the same as that used for the GCOS study with the exception that no primary belt is applied here.

Results. Six hours of operation were simulated by the IBM 360/67 computer with input data recorded above. Output results are entered in Appendix V along with a summary listing in Table 6. Although no direct comparisons could be made with an actual operating system, confidence can be placed in the model where productivity comparisons are made of individual units subject to the constraints imposed by the system and specified as part of the input. The model will allow management to study system performance without disrupting a going operation.

In making choices within the wide range of alternatives available for problem solving, solid judgment, experience and a knowledge of local conditions must supplement model application. Only those strategies are selected which appear to yield the greatest improvement. For example, a preliminary analysis of Table 6 clearly indicates that the majority of BWE's have long delay times which are intolerable because of the large capital investment for this equipment. In order to minimize these times a logical choice would be to increase the capacity of the materials handling system. Closer scrutiny of results indicate, however, that a change in the truck fleet for ore body II or an increase in the number of trains for ore body I may not be a correct decision since delay times along these various haulage routes are already too high. A sound strategy for obtaining the same objective and the one utilized for demonstrating model application is the installation of smaller BWE's.

Strategy 1. Consider the following BWE specifications for reducing delay times for the same level of production:

Table 6

Model Output - Hypothetical Case Study

	Original	Strategy 1	Strategy 2	Strategy 3	Strategy 4
A. BWE outputs					
i. Theoretical Capacity (tons/hr)	27,512	20,214	20,214	20,214	20,214
ii. Actual Capacity (tons/hr)					
Ore body I					
BWE 1	7,360.4	7,360.4	7,360.4	7,360.4	7,360.4
BWE 2	9,953.4	7,391.5	7,391.5	7,391.5	7,391.5
BWE 3	9,953.4	7,391.5	7,391.5	7,391.5	7,391.5
Ore body II					
BWE 1	10,094.3	8,344.9	8,344.9	8,344.9	8,344.9
BWE 2	9,953.4	7,391.5	7,391.5	7,391.5	7,391.5
BWE 3	9,953.4	7,391.5	7,391.5	7,391.5	7,391.5
iii. Available Cutting Time (hrs/hr)					
Ore body I					
BWE 1	0.805	0.806	0.817	0.795	0.783
BWE 2	0.301	0.406	0.392	0.395	0.397
BWE 3	0.294	0.393	0.497	0.499	0.545
Ore body II					
BWE 1	0.489	0.759	0.756	0.745	0.771
BWE 2	0.741	0.774	0.772	0.784	0.762
BWE 3	0.639	0.649	0.639	0.783	0.791
Average (hrs/hr/BWE)	0.545	0.631	0.645	0.667	0.675
iv. Actual production (tons/hr)					
Ore body I					
BWE 1	5,924.1	5,930.9	6,016.1	5,652.5	5,760.5
BWE 2	2,997.6	3,004.5	2,895.0	2,922.4	2,936.0
BWE 3	2,926.1	2,905.3	3,670.1	3,685.4	4,031.1
Ore body II					
BWE 1	4,875.3	6,409.5	6,378.3	6,260.3	6,492.7
BWE 2	7,372.9	5,723.2	5,706.1	5,791.6	5,631.3
BWE 3	6,363.8	4,799.3	4,720.6	5,784.8	5,844.7
total ore (tons/hr)	24,535.6	22,841.8	23,270.1	24,444.6	24,929.4
total waste (tons/hr)	5.924.1	6,409.5	6,016.1	6,260.3	5,760.5

Table 6 (Continued)

	Original	Strategy 1	Strategy 2	Strategy 3	Strategy 4
v. Waiting time (hrs/hr)					
Ore body I					
BWE 1	0.0000	0.0000	0.0000	0.0002	0.007
BWE 2	0.6166	0.4740	0.5152	0.4970	0.508
BWE 3	0.6321	0.4937	0.3881	0.3811	0.303
Ore body II					
BWE 1	0.3877	0.0536	0.0777	0.0400	0.067
BWE 2	0.0233	0.0002	0.0032	0.0395	0.024
BWE 3	0.000	0.0000	0.0011	0.0039	0.024
Average (hrs/hr/BWE)	0.2766	0.1703	0.1642	0.1620	0.155
B. Truck					
i. Waiting at loading station (hrs/hr/truck)					
Ore body I					
Bench 1	0.1439	0.1337	0.1503	0.1578	0.139
Average	0.1439	0.1337	0.1503	0.1578	0.139
Ore body II					
Bench 1	0.0045	0.0604	0.0748	0.0588	0.0201
Bench 2	0.1044	0.0487	0.0984	0.0471	0.0480
Bench 3	0.3195	0.2691	0.1237	0.1066	0.0912
Average	0.1428	0.1539	0.0920	0.0657	0.0531
Processing Plant	0.2814	0.3010	0.2897	0.2695	0.270
ii. Waiting at ore dumping station (hrs/hr/truck)					
Ore body II					
Bench 1	0.0020	0.0009	0.0010	0.0018	0.0023
Bench 2	0.0021	0.0025	0.0017	0.0022	0.0027
Bench 3	0.0021	0.0026	0.0011	0.0039	0.0040
Average	0.0021	0.0017	0.0013	0.0024	0.0030
iii. Waiting at waste dumping station (hrs/hr/truck)					
Ore body I	0.0000	0.0000	0.0000	0.0000	0.0000
Processing Plant	0.0034	0.0047	0.0031	0.0037	0.0035
C. Belt					
i. Waiting time (hrs/hr)					
Section 1	0.3430	0.3314	0.1950	0.1604	0.049
Section 2	0.3453	0.3296	0.3516	0.3377	0.360

Table 6 (Continued)

	Original	Strategy 1	Strategy 2	Strategy 3	Strategy 4
D. Train					
i. Waiting time at loading station (hrs/hr)					
Train 1	0.0538	0.0491	0.0925	0.0508	0.0516
Train 2	0.0486	0.0369	0.0452	0.0875	0.0987
Train 3	0.1638	0.1591	0.1475	0.1605	0.1635
Train 4	0.1527	0.1469	0.2050	0.2397	0.2408
Train 5	--	--	--	--	0.1459
Average (hrs/hr/train)	0.1048	0.0980	0.1224	0.1346	0.1401
ii. Waiting at road intersection (hrs/hr)					
Train 1	0.6061	0.4388	0.2808	0.3702	0.3887
Train 2	0.3697	0.2847	0.0000	0.0138	0.2641
Train 3	0.5175	0.4463	0.5666	0.5302	0.5085
Train 4	0.0044	0.0063	0.2088	0.1855	0.2713
Train 5	--	--	--	--	0.2069
Average (hrs/hr/train)	0.3743	0.2939	0.2640	0.2749	0.3279
iii. Waiting at dumping station (hrs/hr)					
Train 1	0.0000	0.0000	0.0000	0.0000	0.0000
Train 2	0.0000	0.0034	0.0043	0.0000	0.0031
Train 3	0.0000	0.0000	0.0000	0.0000	0.0043
Train 4	0.0018	0.0000	0.0000	0.0006	0.0000
Train 5	--	--	--	--	0.0026
Average (hrs/hr/train)	0.0008	0.0009	0.0011	0.0002	0.0020
iv. Waiting for dispatching (hrs/hr)					
Train 1	0.0104	0.0261	0.0165	0.0071	0.0289
Train 2	0.0000	0.0000	0.0000	0.0000	0.0072
Train 3	0.0000	0.0000	0.0000	0.0000	0.0031
Train 4	0.0000	0.0000	0.0000	0.0000	0.0000
Train 5	--	--	--	--	0.0118
Average (hrs/hr/train)	0.0026	0.0065	0.0041	0.0018	0.0102
v. Cars loaded (#/hr)					
Loading Station 1					
Train 1	10	10	20	20	20
Train 2	10	10	30	30	30
Train 3	10	10	10	10	10
Train 4	20	20	10	10	10
Train 5	--	--	--	--	20

Table 6 (Continued)

	Original	Strategy 1	Strategy 2	Strategy 3	Strategy 4
v. Cars loaded (#/hr)					
Loading Station 2					
Train 1	10	10	10	10	10
Train 2	20	20	10	10	10
Train 3	10	10	10	10	10
Train 4	20	20	20	20	20
Train 5	--	--	--	--	10

bucket capacity: 1.2 cu. m.

number of buckets: 12

wheel diameter: 10 meters

maximum advance: 12 meters

service weight: 2,000,000 kg

The required changes for these new data are few and only occur in lines 25, 35, 47, 57 and 67 as shown in Appendix V.

The summary of output results, also in Table 6, show a reduction of 26% in both the theoretical and actual BWE capacities. Theoretical capacities are those based only on BWE specifications while actual capacities consider the soil characteristics; i.e., production in a unit cutting time. With smaller BWE's the available cutting time is increased while actual production is down 6.9%. A system decrease from 24,536 tons/hr. to 22,842 tons/hr. is the result with an average BWE waiting time dropping from 0.277 hrs/hr/BWE to a value of 0.170 hrs/hr/BWE. Although BWE waiting times have been cut 40% it is interesting to note that average delay times for trucks of ore body II have increased from 0.143 to 0.154 hrs/hr/truck.

<u>Strategy 2</u>. Since the objective for model application is to decrease total operating costs for the same level of production, a second alternative is considered whereby the truck fleet is reduced from the scheduled 30 units to 28. The attempt is to minimize truck waiting times at the BWE's and hence costs. Adjustments for doing this simply involve a change of 30 to 28 in line 121 while at the same time

changing values in lines 362 and 363 to reflect the new BWE assignments. The choice here is 14 and 7 units for BWE 1 and 2 respectively, with 7 units assigned to BWE 3 in the ore body II.

The results of this alternative are also listed in Table 6 and indicate that average truck waiting time decreases from 0.154 to 0.092 hrs/hr/truck with a 2.0% increase in BWE production, or, from 22,842 to a value of 23,270 tons/hr. Corresponding decreases in BWE waiting time are placed at 0.164 hrs/hr/BWE as compared to 0.170 hrs/hr/BWE in Strategy 1. The increases of BWE production was accomplished by a better assignment of the truck fleet.

Strategy 3. Since further changes in the fleet size would not show definite improvement as evidenced by the above results, it may be management's choice at this time to consider the method of dispatching trucks for reducing both truck and BWE waiting times with corresponding increases in production. This is accomplished by changing the value in line 45 from 0 to 1 which permits subroutine OBSTOW to enter as part of the main program. This subroutine simulates the operations of the truck dispatching activity.

The result of this strategy yields an average reassignment of ten (10) trucks during the six-hour operating period. Compared with strategy 3, ore production is increased 5.0% and waiting times decreased 1.3% and 7% for BWE and trucks, respectively. These are reflected in a new productivity of 24,445 tons/hr with a waiting time for trucks at 0.066 hrs/hr/

truck and for BWE at 0.162 hrs/hr/BWE. Other changes for decreasing waiting times and increasing production may be made with regard to mixed fleet operations.

Strategy 4. An apparent solution for improving overall productivity of BWEs is found to exist at ore body I; i.e., in the reduction of waiting times which have a value of 0.276 hrs/hr/BWE. This can be accomplished by redesigning the track layout to decrease train waiting times at intersections. However, for the purposes of illustrating model application, one (1) train will be added to the system. Data input for adding a train involves changing values in lines 399 to 411 and adding a speed-tractive force curve to specify the characteristics of the fifth train, at the same time adding a value of one (1) in line 630 to reflect this assignment to loading station 1.

Results of this alternative indicate that total ore production is increased 1.6% from a total value of 24,445 to 24,929 tons/hr; the average waiting time of trains is increased from 0.422 to 0.482 hrs/hr/train. A slight improvement of BWE waiting time, from 0.162 to 0.155 hrs/hr/BWE, is also experienced. No further improvements were tried here.

Other Applications

The concepts of long range planning with grid point simulation as discussed in Chapter II are applied using GCOS data as a case example. The objective is to project productivity rates and waiting times over a portion of the ore-body using trucks as part of the material handling scheme.

Grid points are selected on regular one thousand (1000) feet intervals for a total of twenty (20) points and an area of 400 acres. The details for inputing data at each grid point are not discussed here since these are identical in format as applied in the other examples. The only program change required is in the variable IGRID which takes on a value of one (1). This allows the computer to simulate the number of grid points for a one-cut sequence rather than the normal shift times.

Output for each grid point are arranged in an input format suitable for the CONTOR program as these are listed on Table 7. Upon execution of this input by CONTOR an output is obtained and used as input to the CALCOMP PLOTTER. The result is shown in Figure 13.

Since any decisions to be made are based on a productivity figure of 5000 tons/hr, the results show that an increase in the truck fleet is necessary when the working face of the first BWE reaches point A in the ore body. At this point the production and waiting times of BWEs are as follows:

Actual production of BWEs (tons/hr)

First BWE: 2274.5

Second BWE: 2678.9

Waiting times of BWEs (hrs/hr)

First BWE: 0.125

Second BWE: 0.061

The new system is tried again to locate the next critical point. No further work was tried with grid point simulation

Table 7

Results of Grid Point Simulation

no.	Coordinates (ft) BWE 1 X	BWE 1 Y	BWE 2 X	BWE 2 Y	Grid Cutting Time BWE 1 (mins)	BWE 2 (mins)	*Production Rate BWE 1 (tons/hr)	BWE 2 (tons/hr)	Total (tons/hr)
1	0	0	1000	1000	83.58	90.33	4433.6	4127.3	8560.9
2	0	1000	1000	2000	97.83	94.92	3787.8	3927.8	7715.5
3	0	2000	1000	3000	114.08	105.25	3248.2	3542.3	6790.5
4	0	3000	1000	4000	131.92	117.33	2808.9	3177.6	5986.5
5	0	4000	1000	5000	147.17	129.42	2517.9	2880.7	5398.6
6	0	5000	2000	0	163.58	90.33	2265.3	4127.3	6392.6
7	1000	0	2000	1000	89.58	95.33	4136.3	3910.9	8047.5
8	1000	1000	2000	2000	115.83	106.58	3199.2	3498.1	6697.2
9	1000	2000	2000	3000	132.50	117.92	2796.7	3161.7	5958.3
10	1000	3000	2000	4000	149.67	130.00	2475.8	2867.9	5343.7
11	1000	4000	2000	5000	165.58	142.08	2237.9	2624.0	4862.0
12	1000	5000	3000	0	181.92	95.33	2036.9	3910.9	5947.8
13	2000	0	3000	1000	101.92	103.67	3635.8	3596.2	7232.0
14	2000	1000	3000	2000	129.08	115.75	2870.8	3220.9	6091.7
15	2000	2000	3000	3000	145.25	127.08	2551.2	2933.8	5484.9
16	2000	3000	3000	4000	162.92	139.17	2274.5	2678.9	4953.4
17	2000	4000	3000	5000	178.92	151.25	2071.1	2464.9	4536.0
18	2000	5000	4000	0	194.92	103.67	1901.1	3596.2	5497.3
19	3000	0	4000	1000	116.75	114.92	3173.9	3244.2	6418.1
20	3000	1000	4000	2000	143.58	127.00	2580.8	2935.6	5516.5
21	3000	2000	4000	3000	161.17	138.33	2299.2	2695.2	4994.3
22	3000	3000	4000	4000	178.50	150.42	2076.0	2478.5	4554.5
23	3000	4000	4000	5000	194.67	162.50	1903.5	2294.3	4197.8
24	3000	5000	5000	0	211.67	114.92	1750.6	3244.2	4994.8

* Materials at each grid point are 6175.96 tons and 6213.72 tons for BWE1 and BWE2 respectively.

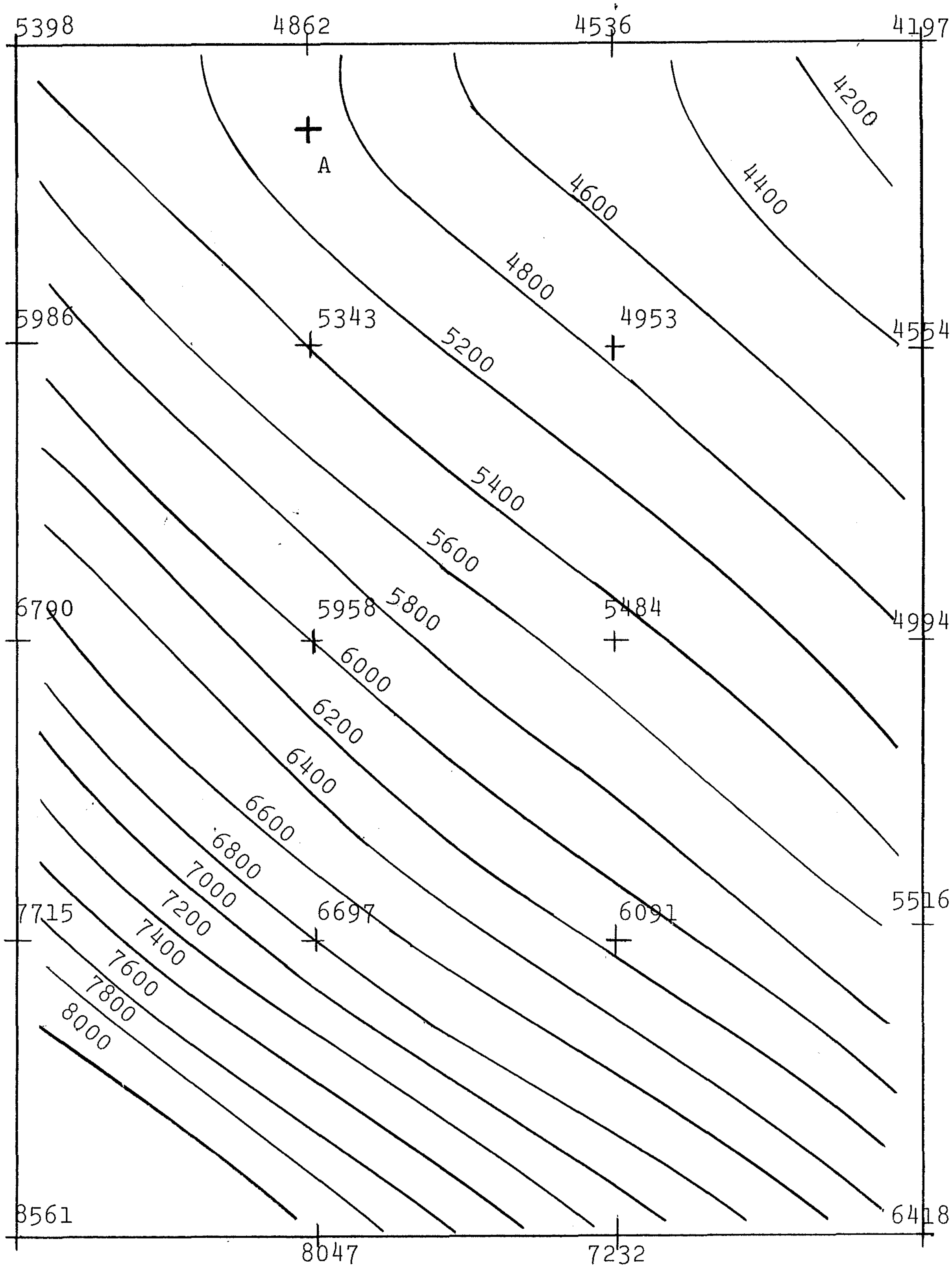


Figure 13 Contour Map of BWE Productions

since the application is left to management with actual data and a problem to solve. A wide range of choices is available for information retrieval.

V. CONCLUSIONS

Remarks

This investigation is primarily concerned with the mathematical modeling of various job activities connected with the excavation and transportation of materials in open pit mining. These unit operations, however, were not permitted to exist as separate entities but rather programmed into a closed-loop, total systems simulator for application on an IBM 360/67 digital computer. More specifically, the job activities related to the operations of bucket wheel excavators, trucks, trains and conveyor belts are combined for multi-mining operations. The work involved to accomplish this included: a) problem definition and mathematical formulation b) model building and testing and c) applying the model in practice.

It may be well to mention at this point that traditional time and motion studies were side-stepped in favor of a deterministic approach using equipment performance characteristics and the haulroad and soil profiles. This allows the simulation of a completely new operation where equipment rather than operator performance is the important criteria for making comparisons. The problem of equipment reliability is recognized, however, and provisions are made using methods of subjective probability. The value of managerial experience has, therefore, been preserved which allows results more closely related to real world problems.

Each unit operation has been properly developed as an independent sub-assembly of the total systems model. This permits easy changes, refinements and additions of individual job activities without affecting the operation of other sub-assemblies as part of the overall model. This flexibility has been well demonstrated in its application to a hypothetical mining situation. Here a high degree of complexity was defined with multi-stage transportation schemes and multi-orebody operations which were easily analyzed with a minimum of effort.

A new concept referred to as grid point simulation was introduced as a part of the research for application to long range planning problems. A distinct time period for a one-cut sequence is employed for information retrieval which makes the simulation of a large set of jobs economically and physically possible for the operating life of the mine. The presentation of results is also unique since these are portrayed graphically as output from a calcomp plotter and provides management with a direct method for making comparisons.

Finally in conjunction with model application, the following extensions are listed:

1. Although the face excavator was limited to bucket wheel operations, other types of machines including shovels and draglines can be readily incorporated with slight modifications. Although mathematical models for this equipment are not available, stochastic simulation can be readily applied for equipment

loading and tramming times. Other equipment can also be conceptually modeled. Pipeline operations can be simulated and substituted for belt conveyors.

2. Provisions have been made in the model to execute a wide variety of functions. Portions of jobs can be bypassed with a proper choice of data and a minimum of effort. For example, mechanical availabilities can be selected and the stochastic simulation of this part of the activity eliminated. A second example is the installation of observation towers for dispatching and the use of signals in traffic control.
3. The model is not limited to the investigation of equipment performance but readily applicable to the design of haulroads and bench configurations.
4. Finally, the computer program was written to utilize available library programs; subroutines and functions, for reasons of efficiency and as a result, is not applicable for other computing systems. The problem is not a formidable one since these are easily divorced from the main program and can be universally written.

Future Research

Because of the many input requirements, it is somewhat tedious to compile essential data especially by busy management whose programming experience may be limited. There is a need to develop input routines which would include storage potential and easy access for commonly used equipment. A single label to specify each type is desired. A second contribution and one already mentioned is for research leading to the development of mathematical models of other excavators and materials handling systems. Pneumatic and hydraulic transport should be considered here.

Finally, further work is required in the development of an objective function for model application. Since the simulation provides only engineering and performance data no cost or profit optimization is conducted. A cost analysis model of the following form is essential for these purposes.

$$\text{Min. } CT = \sum_{i=1}^{n} C_i t_i$$

where,

C_i = cost of waiting for i^{th} equipment type

t_i = waiting time of the i^{th} equipment type

for $CT_{j-1} > CT_j < CT_{j+1}$

and,

CT_j = total cost at j^{th} computation

A routine needs to be written and added to the main program for proper application in industry.

Summary

An apparent solution to the problem of satisfying public demand from high cost, low profit mineral deposits is mass materials handling. Increased productivity and lower operating costs can be achieved by increases in the sizes of materials handling equipment. Bucket wheel excavators with their related materials handling units appear to have great potential for this purpose. Because of the large capital investment and narrow profit margins in applying this equipment, little margin for error can be tolerated. There exists, therefore, a tremendous need in the industry for the development and application of operations research methods to reduce risks in mine design and planning.

This thesis applied one facet of O.R., namely simulation, to develop a model of surface mining with BWE's. The model developed here is closed and dynamic in the sense that information is fedback to control activities at various levels and reservoirs. This model can be regarded as a management laboratory where many ideas are tried on paper and the best of these selected prior to application.

Two stages of research were applied in modeling this system. Stage one involved the formulation of equipment sub-assemblies which involved the sequence of equipment moves along with related assignments and routines for information retrieval. The second stage of research combined all sub-assemblies into an integrated open pit mining simulator. The complete model is able to execute two different analyses of mining operations. Questions related to: 1) system design and selection of equipment for a new mining operation; 2) analysis of existing operations for possible alternatives, additions or general improvements; and 3) analysis of equipment performance for the entire life of the mine, can be answered.

The validity of the model has been verified with actual operating data. Since actual operations for testing were comparatively simple in concept and design, a hypothetical case study was created to demonstrate model sophistication and flexibility. The concept of a management laboratory was also demonstrated here.

The computer program itself is an effort to make mine production more efficient. It offers mining management a basis for designing and planning the excavation and material handling of low grade ores. The main objective is to develop the country's vast domestic resources of low grade ores by continued technological improvements for converting these into mineable products. Because the United States is no longer self sufficient in mineral resources; she must tolerate increased involvement in international affairs. The most important contribution as result of this study is for maintaining national self sufficiency without the need for acquiring foreign resources.

BIBLIOGRAPHY

Cheney, E. S. (1967), "Mineral Resources in National and International Affairs", Mining Engineering, December 1967, pp. 47-54.

Dombrowsky, N. G. (1964), "The New Bucket Wheel Excavator and Its Construction Problems", Bergbautechnik, Vol. 14, 1964, pp. 277.

Donaghey, C. E. (1967), "A Generalized Material Handling Simulation System", Ph.D. Thesis, University of Pittsburgh, Pa. 1967.

Forrester, J. W. (1961), Industrial Dynamics, The M.I.T. Press, Cambridge, Mass. 1961.

Gartner, K. (1965), "Bucket Wheel Excavator on Building Sites", Forden und Heben, Vol. 3, No. 6, November 1965.

Johnson, E. E. and H. J. Bennett (1968), "An Engineering and Economic Study of a Gold Mining Operation", Bureau of Mines IC No. 8374, 1968.

Kiviat, P. J. (1963), "GASP - A General Activity Simulation Program", Project No. 90 17-019(2), Applied Research Laboratory United States Steel, Monroeville, Pa. July 1963.

Krumrey, A. (1965), "Krupp Bucket Wheel Excavators with Stacker Boom", Krupp Technical Review, Vol. 23, No. 1 1965.

Lucas, R. J. (1964), "Optimization of Underground Mining", Office of Coal Research, Research and Development No. 6, Vols. I, II, & III.

Markowitz, H. M. (1962), B. Hauser and H. W. Karr. SIMSCRIPT-A Simulation Programming Language, The Rand Corporation RM-3310, November, 1962.

Morgan, W. C. and L. L. Peterson (1968), "Comparison of Estimating Technique for Determining Shovel - Truck Productivity" Society of Mining Engineers, Minneapolis, 1968.

O'Neil, T. J. (1966), "Computer Simulation of Materials Handling in Open-pit Mines", M. S. Thesis, The Pennsylvania State University, 1966.

Sanford, R. L. and C. B. Manula (1968), "A Complete Coal Mining Simulator" Society of Mining Engineers, New York 1968.

Venkataramani, R. (1968), "Bucket Wheel Simulator", M. S. Thesis, Department of Mining Engineering, Pennsylvania State University.

Wismer, D. A. (1967), "On the Uses of Industrial Dynamic Models" Operations Research, Vol. 15, No. 4, July - August, 1967, pp. 752-767.

APPENDIX I

POWER CONSUMPTION OF BWE'S

The power requirements of a bucket wheel excavator are composed of the following individual ratings,

1. Cutting power, which consists of two portions: digging and lifting

   Digging power $N_G = K \times \Sigma L \times V_1/102$

   Lifting power $N_H = F_t \times R/367$

   Total cutting power = $(N_G + N_H)/\eta$

where,

K = specific digging resistance in kg/cm

ΣL = total length of the cutters in the soil

T_t = the BWE capacity in tons/hr.

V_1 = peripheral cutting speed in m/sec

R = radius of the bucket wheel in meters

η = efficiency of electrical and mechanical components of the BWE drive

2. Slewing motor power

   $= (m_f + m_s) \times V_s/(102 \times \eta)$

where,

$m_f = DW\mu/L$

$m_s = md/V_d \times V_s$

m_d = cutting torque exerted by the wheel drive in kg-meters

m_s = cutting torque exerted by the slewing motor

V_d = cutting speed of the wheel in meters/second

V_s = slewing speed of the wheel boom in meters/second

W = weight of the superstructure in kg

u = friction coefficient at the ball race on which the superstructure revolves

D = diameter of the ball race in meters

L = length of cutting boom in meters

η = efficiency of the slewing motor drive

3. Tram motor power

$$= 1/\eta \times (W_t \times r + W_t/50 \times g_r) \times V_t/102$$

where,

W_t = total weight of the BWE in kg

r = ground resistance in fraction

g_r = slope of the ground in fraction

V_t = tram velocity in meters/second

APPENDIX II

SYSTEMS FLOW MODEL

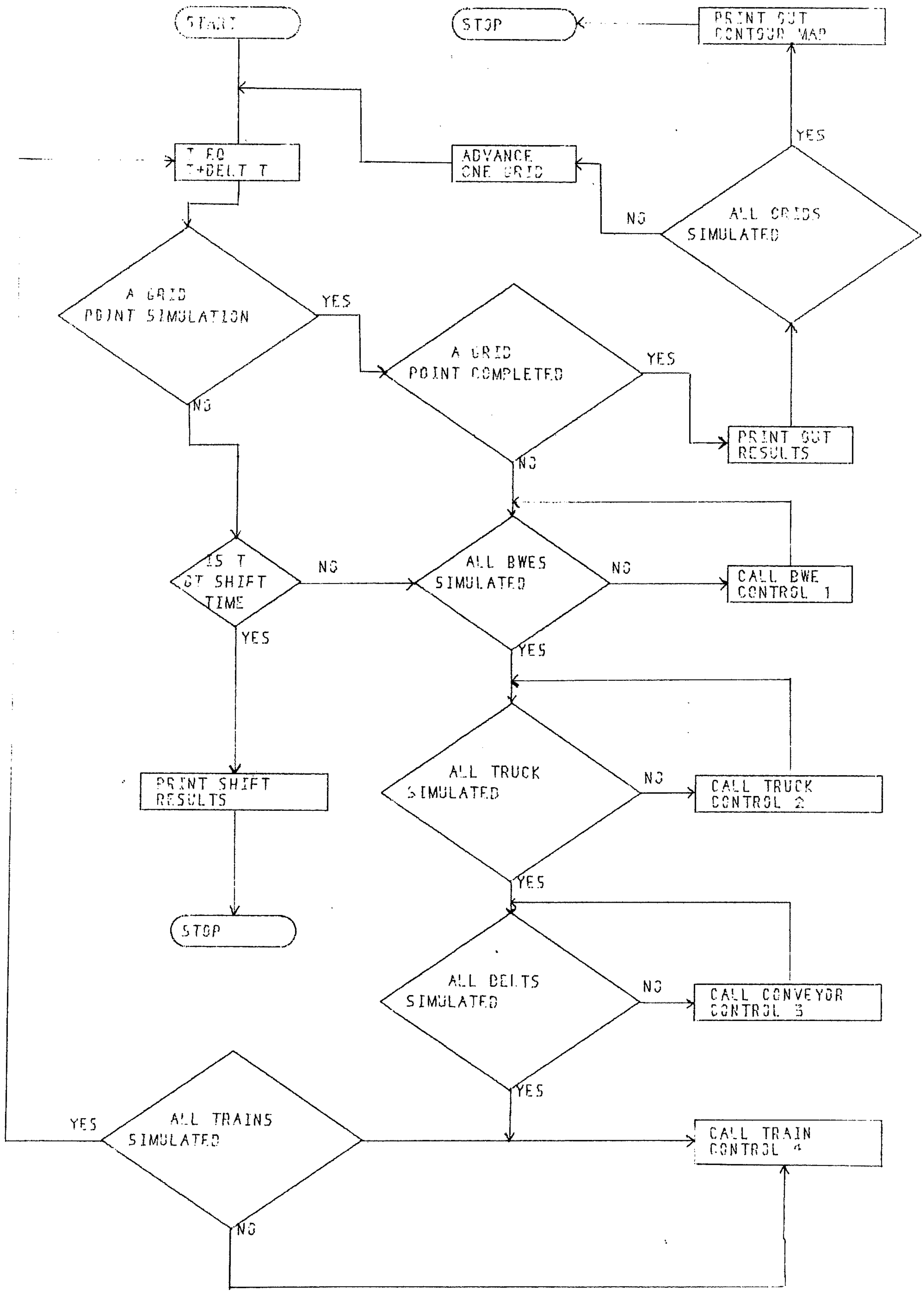


Figure 14 - Executive Control

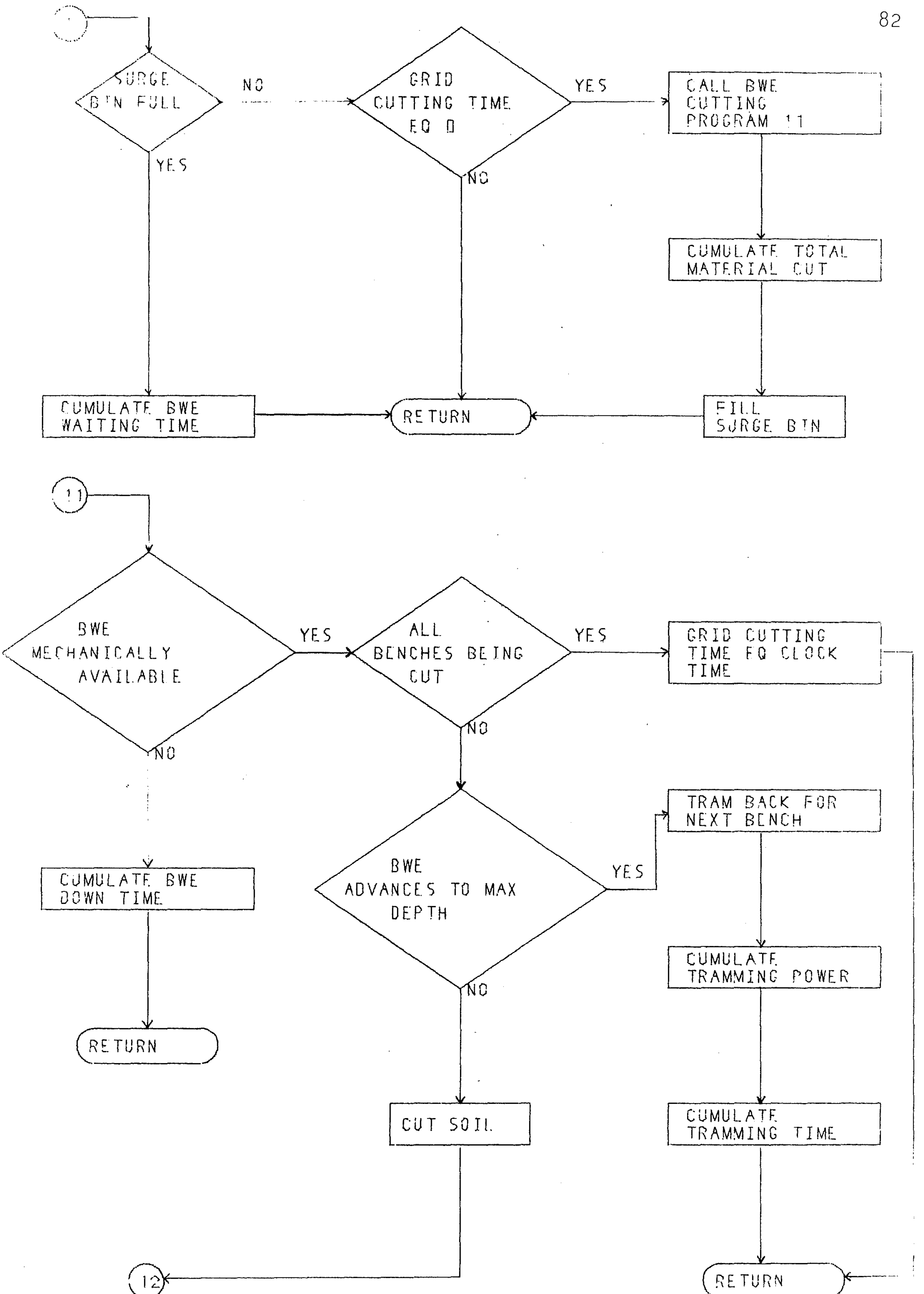


Figure 15 - BWE Sub-assembly

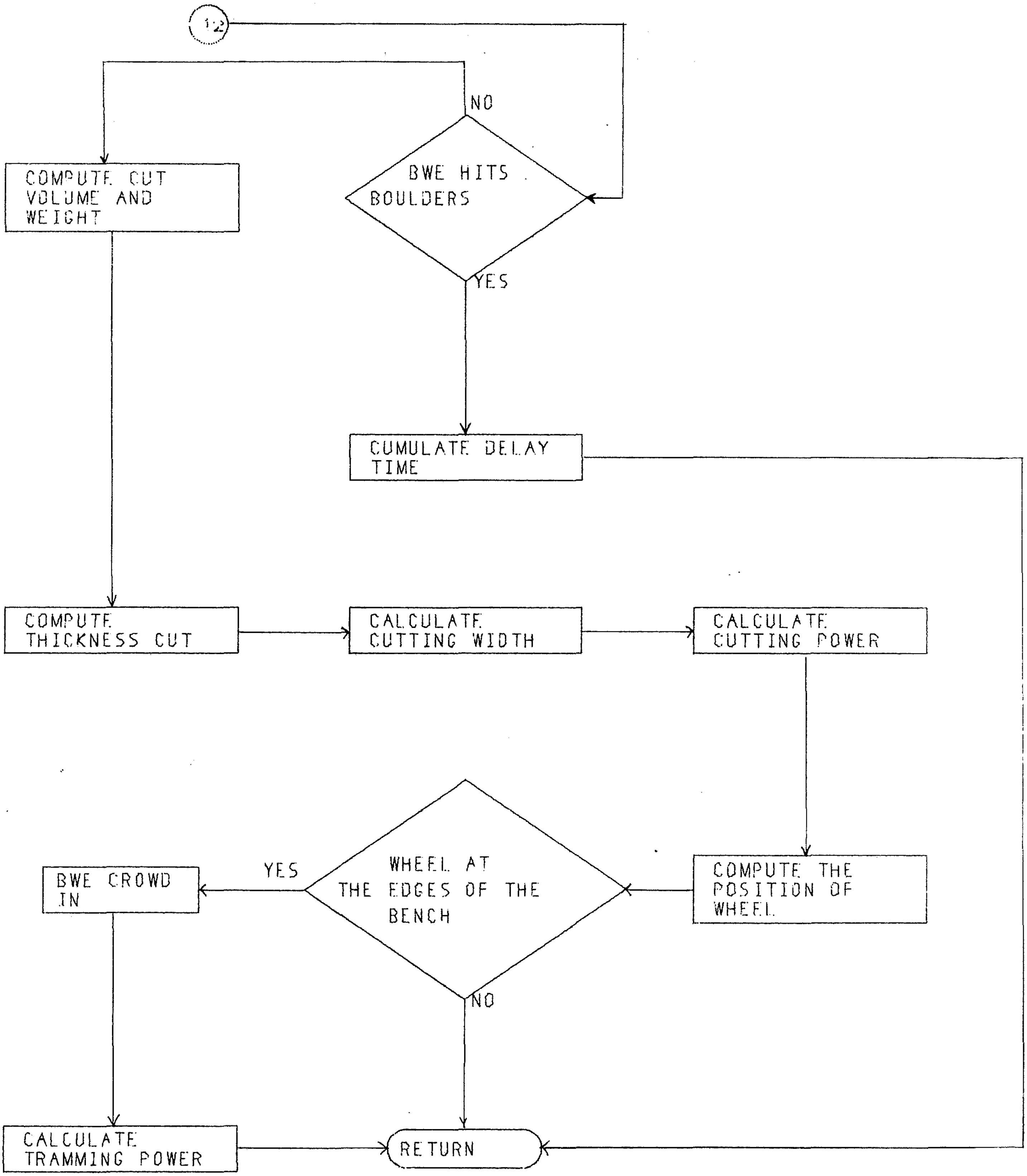


Figure 15 - Continued

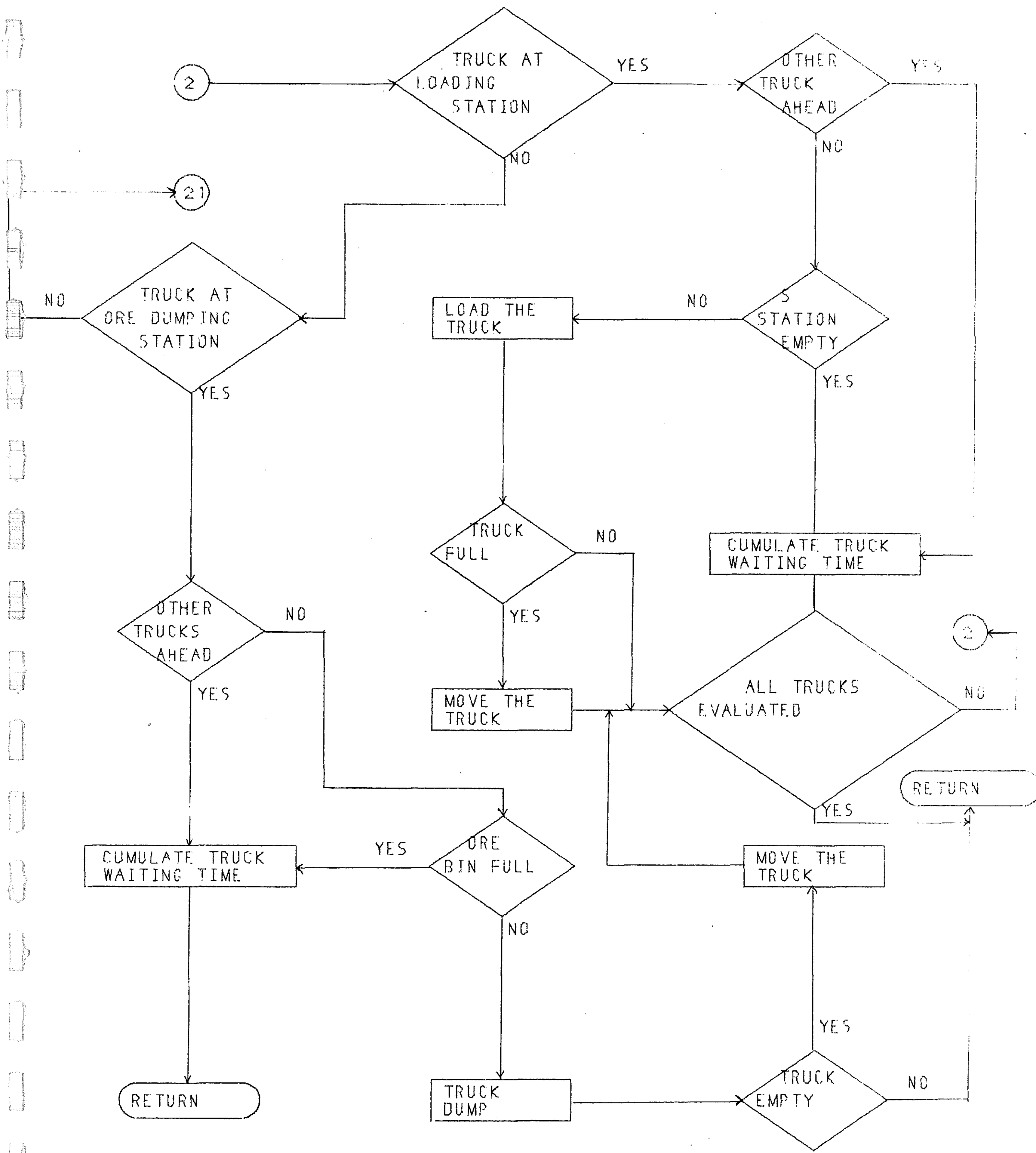


Figure 16 - Truck Sub-assembly

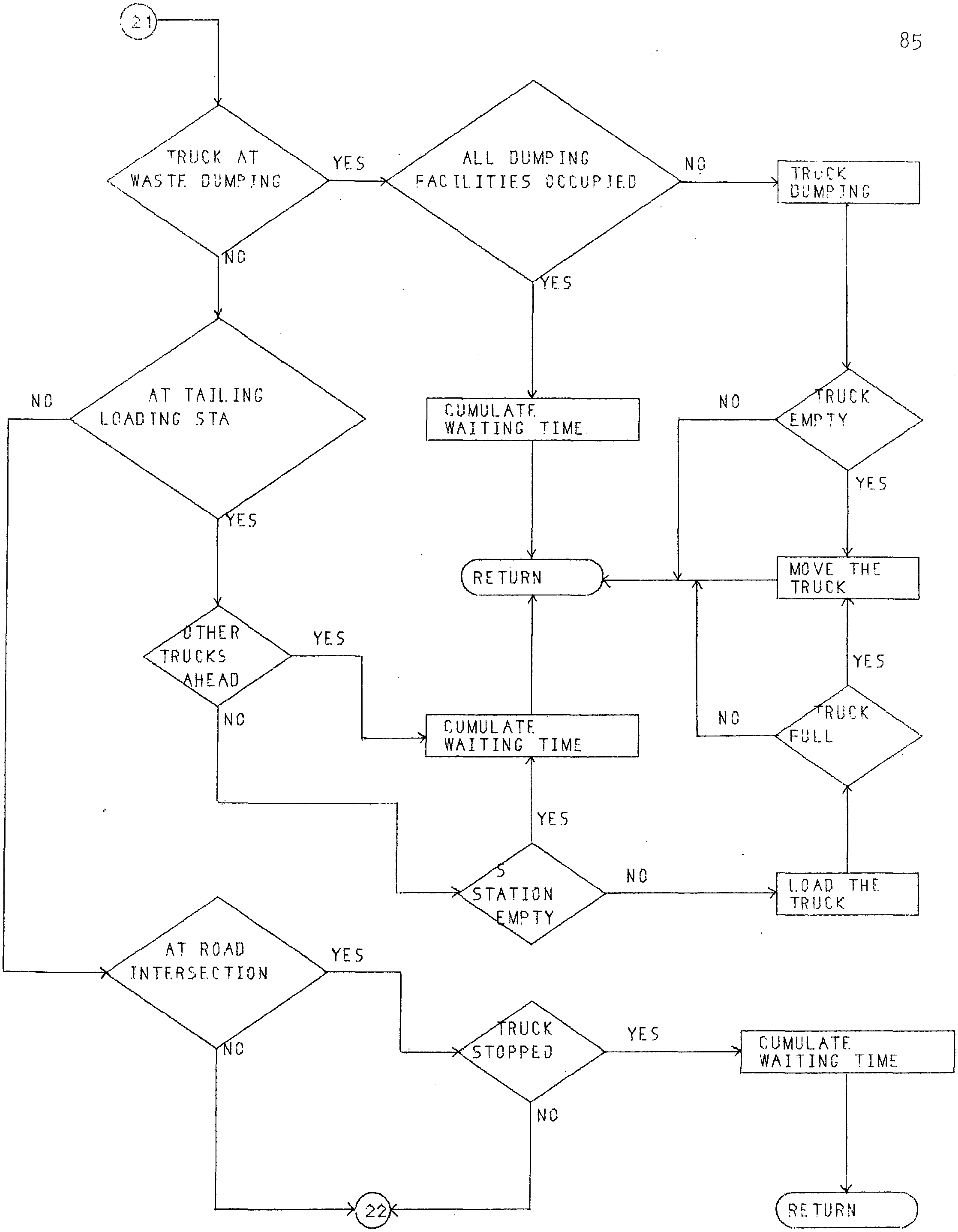


Figure 16 - Continued

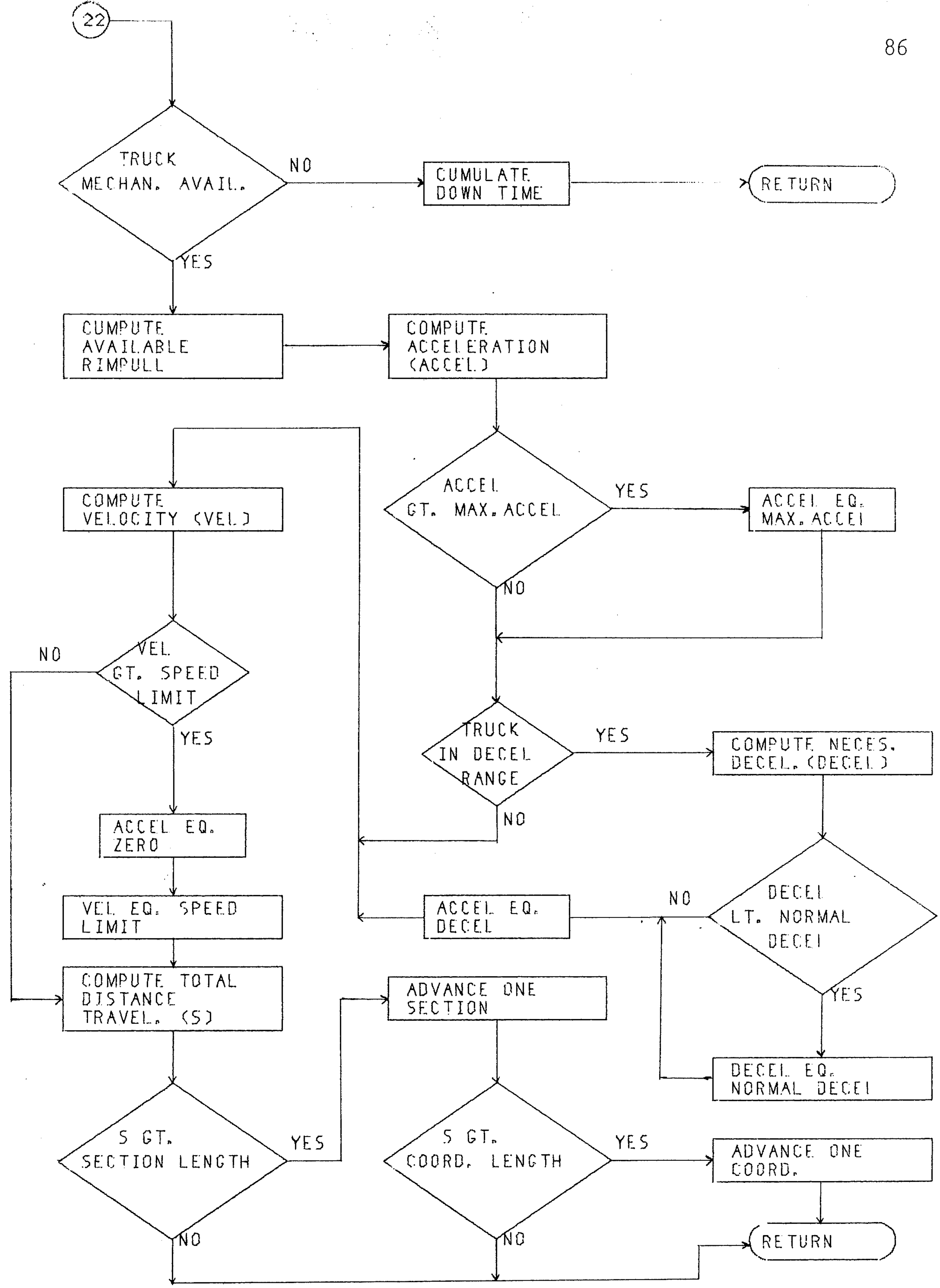


Figure 16 - Continued

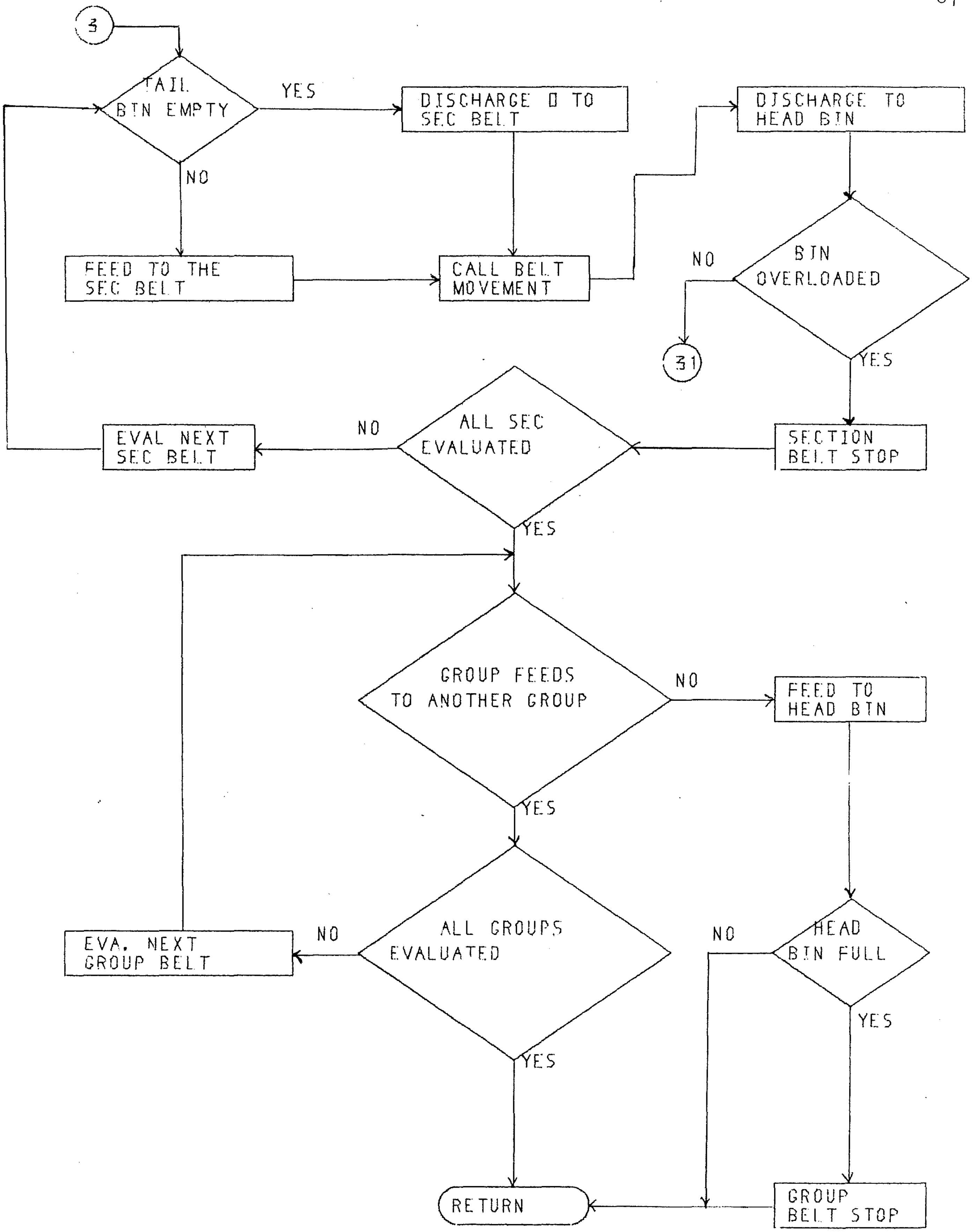


Figure 17 - Belt Sub-assembly

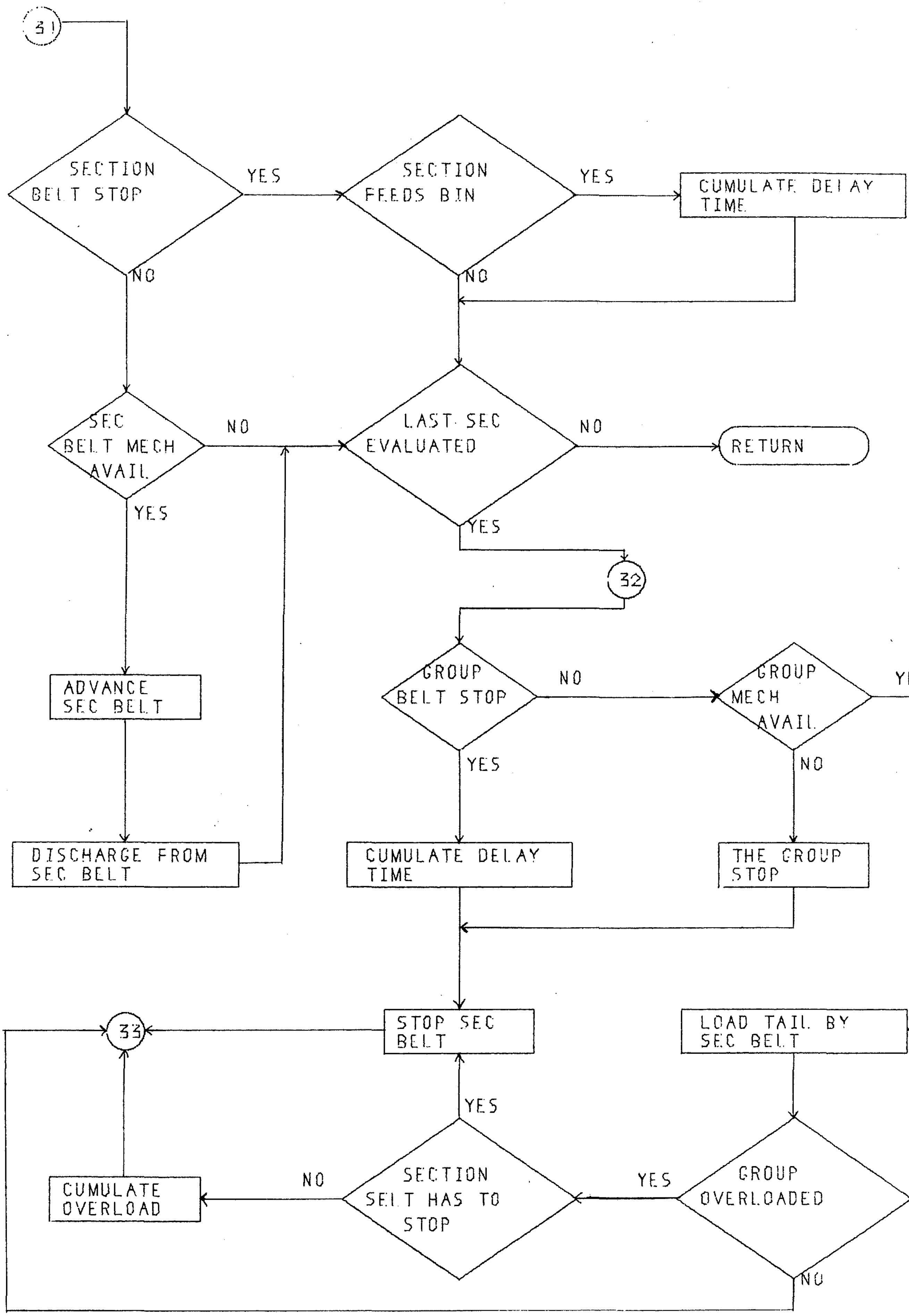


Figure 17 - Continued

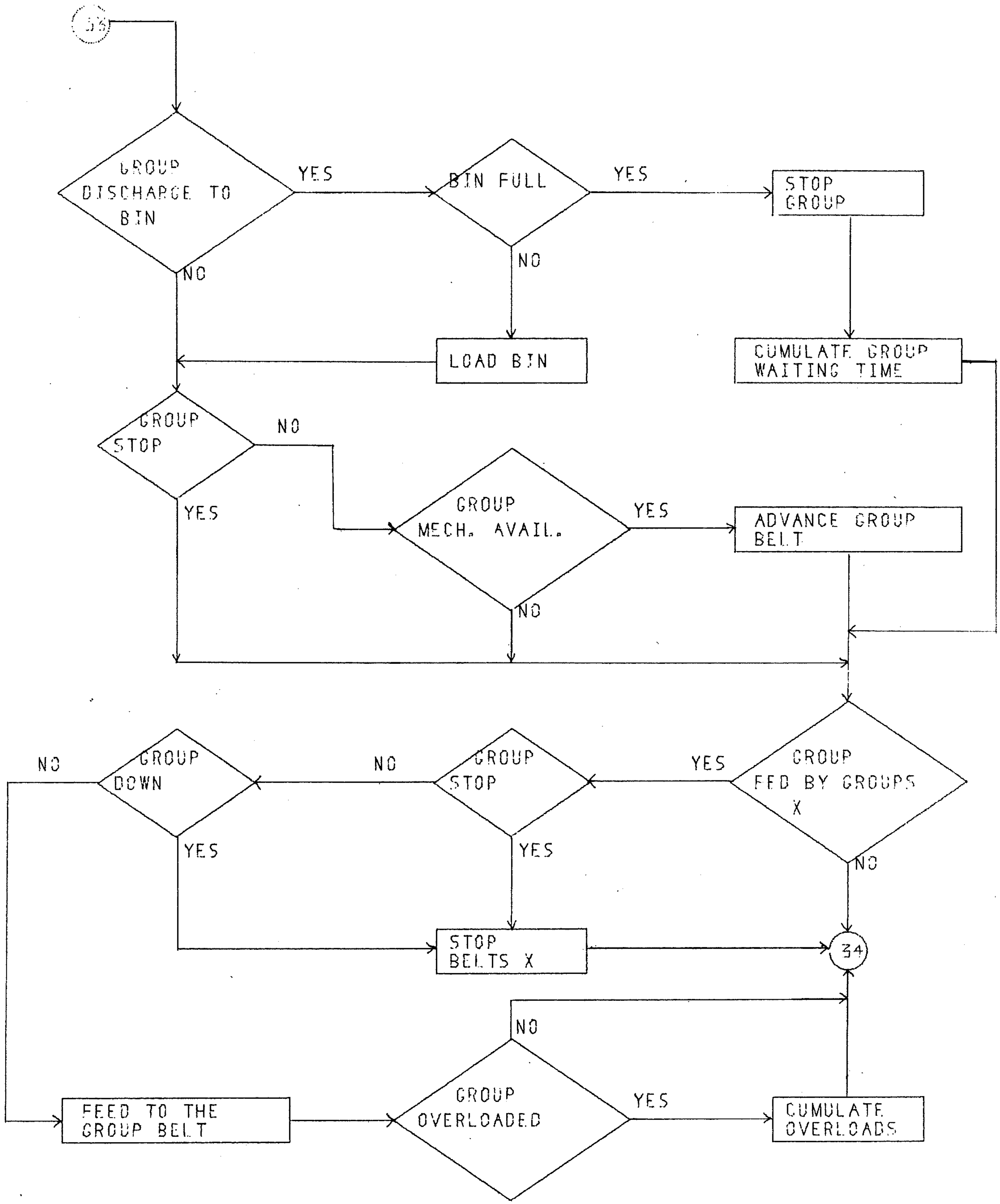


Figure 17 - Continued

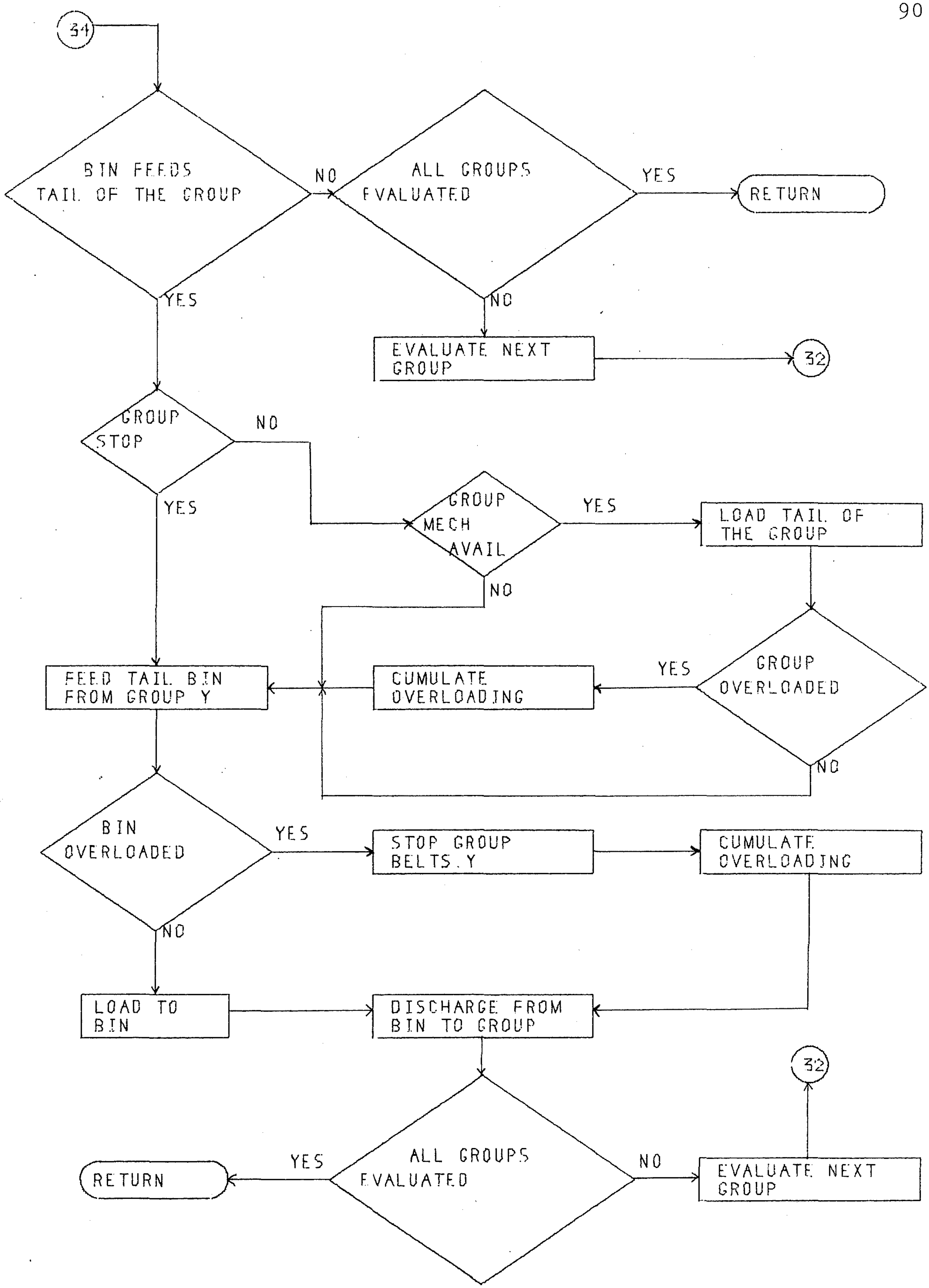


Figure 17 - Continued

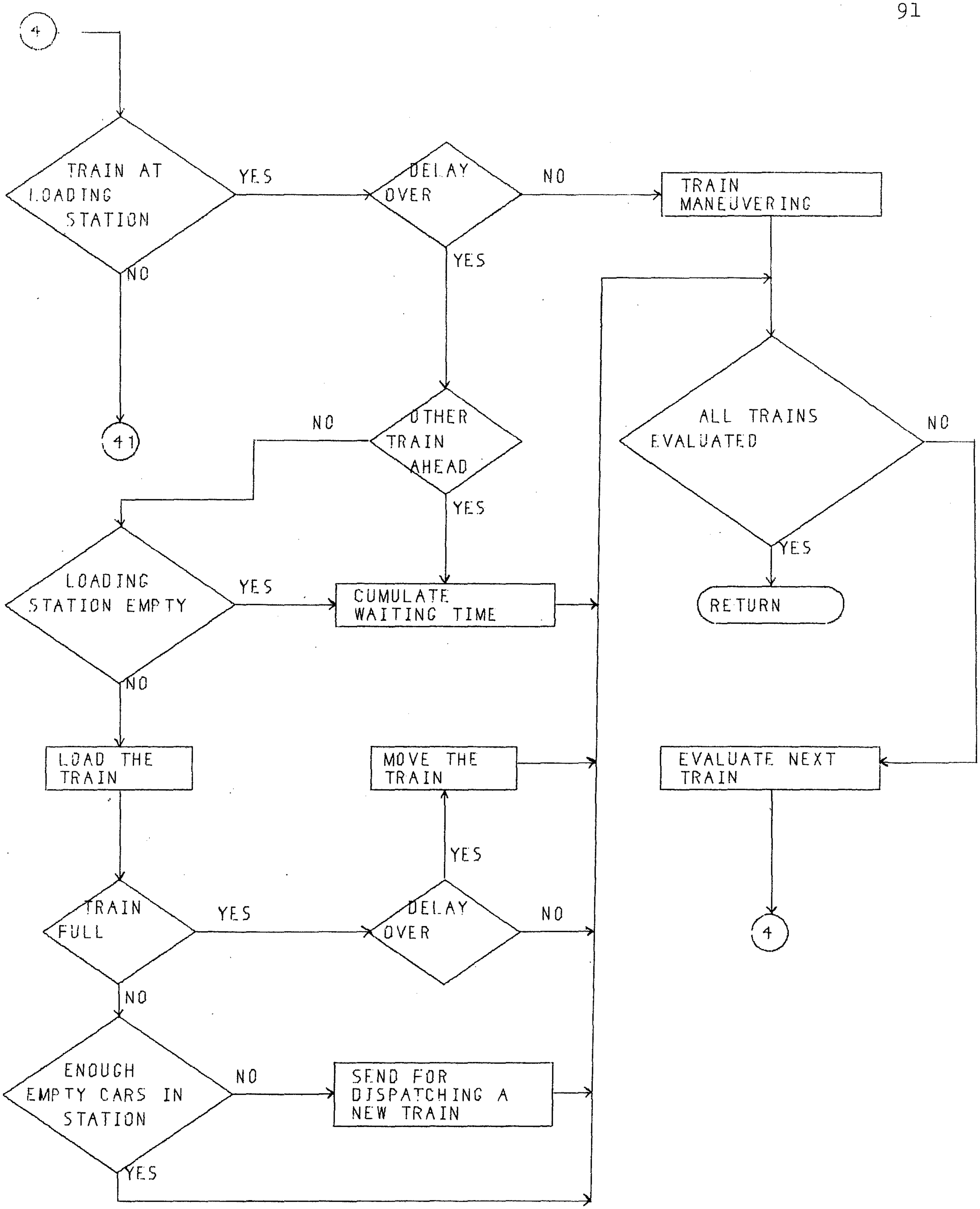


Figure 18 - Train Sub-assembly

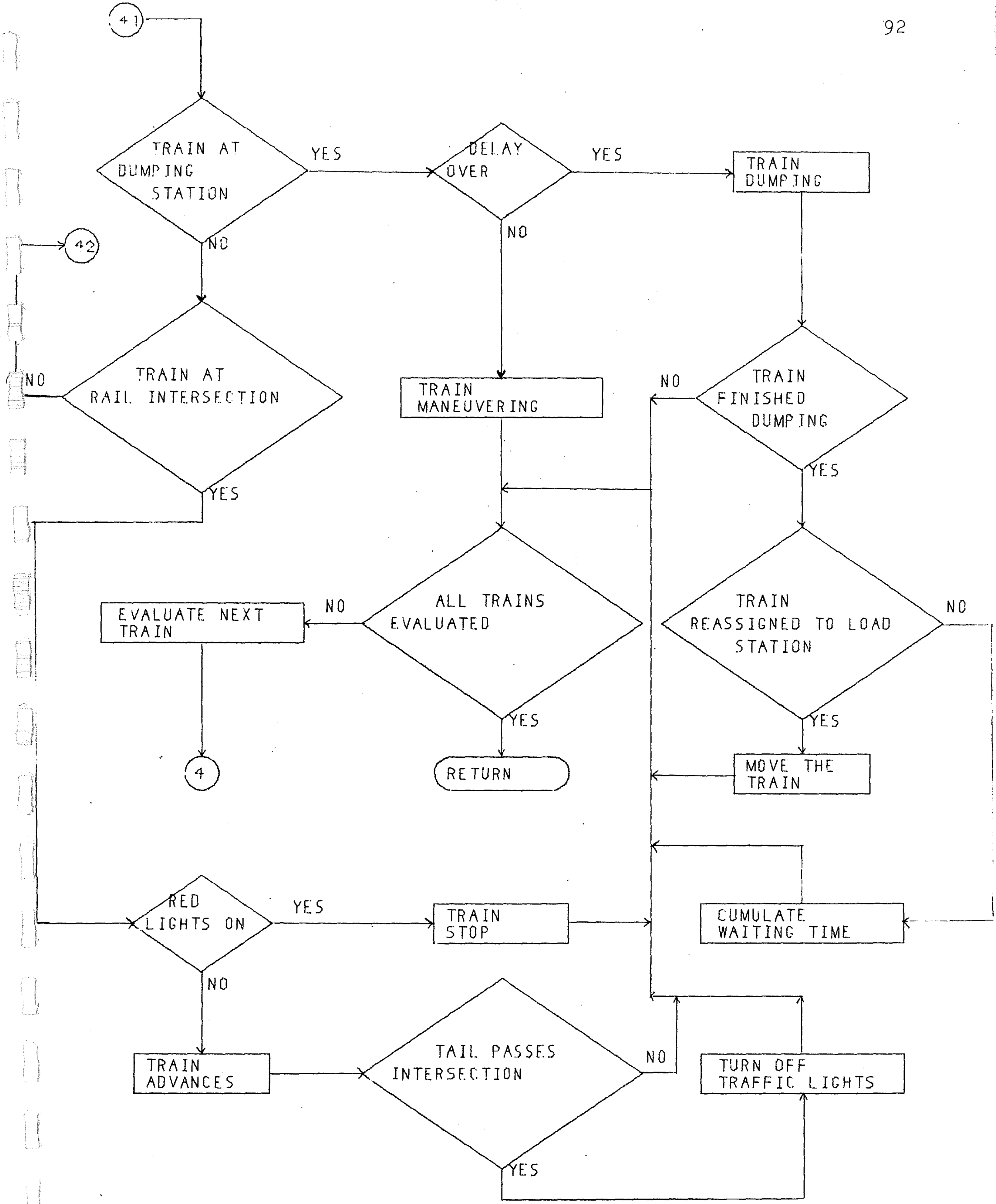


Figure 18 - Continued

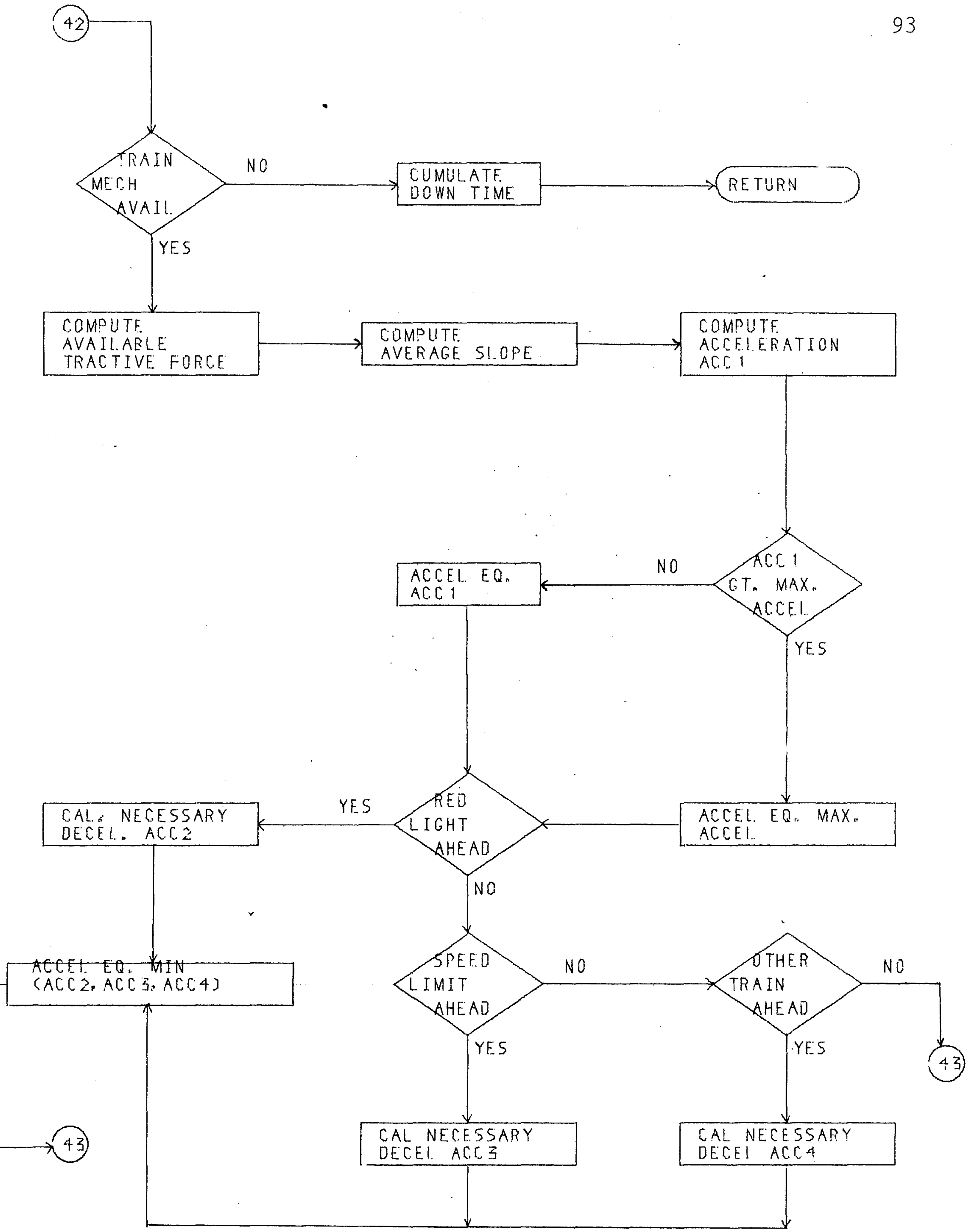


Figure 18 - Continued

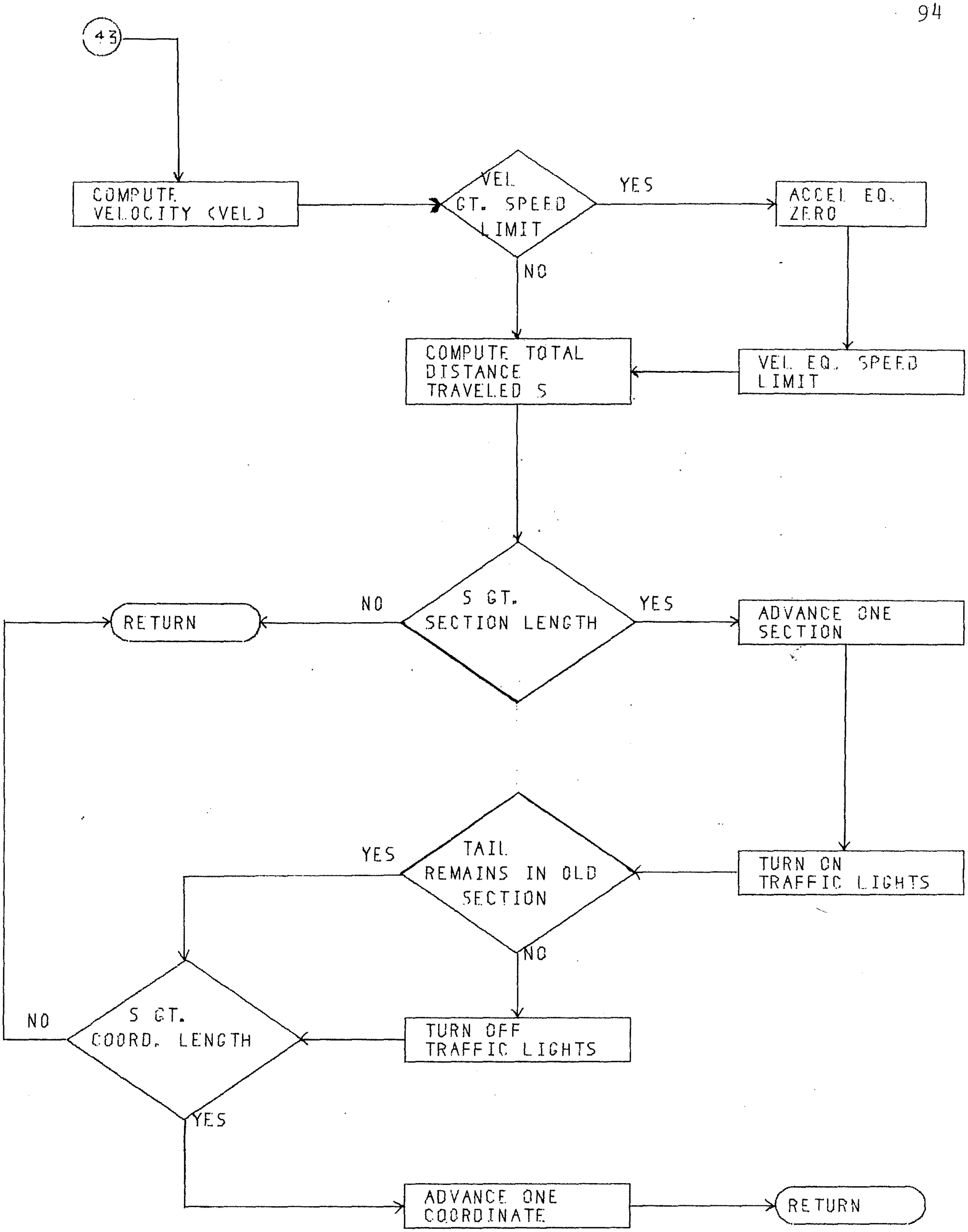


Figure 18 - Continued

APPENDIX III

DEFINITION OF VARIABLES AND PROGRAM LISTING

DEFINITION OF VARIABLES

Input Variables

I. BWE Input

subscripts (I,J) indicate J^{th} BWE in I^{th} ore body

BCAPSG(I,J,K): capacity of surge bins k = 1 ore, K = 2 waste

BCOB(I,J): capacity of bucket

BCS(I,J): crawler speed

BCTMAX(I,J): maximum advance in a bench before cutting the lower bench

BDENST(I,J,M): material density of M^{th} bench

BDIA(I,J): diameter of the wheel

BDMEAN(I,J): mean down time when hitting boulders

BFRS(I,J): frictional resistance at the ball race

BGRADE(I,J): slope of the floor

BHEIGT(I,J,M,N): heights of M^{th} bench
N = 1 left hand side N = 2 right hand side

BKFILL(JJ): bucket filling capacity of JJ^{th} soil type

BKRES(JJ): cutting resistance of JJ^{th} soil type

BLENBM(I,J): length of wheel boom

BNOB(I,J): number of buckets on the wheel

BOWM(I,J): overall weight of the machine

BPROB(I,J,M): probability that BWE does not hit boulder at M^{th} bench

BRATIO(I,J,M): ore to waste ratio of M^{th} bench

BRORI(I,J): floor resistance

BRPM(I,J): allowable cutting speed in JJ^{th} soil type as a ratio of maximum cutting speed

BRS(I,J): radius of the ball race

BSETTM(I,J): mean maneuvering time

BVINE(I,J): swell factor of JJ^{th} soil type

BWAVIL(I,J): mechanical availability of the BWE

BWLANG(I,J): maximum slewing angle to the left of line of advance

BWRANG(I,J): maximum slewing angle to the right of line of advance

BWS(I,J): weight of superstructure

IASBTS(I,J): = n n^{th} surge bin to be used by the BWE

ISTOP: total number of soil types in the system

LSOIL(I,J,M): soil type at M^{th} bench

NBWBEN(I,J): total benches to be cut by the BWE

NBWE(I): total number of BWE in I^{th} ore body

SLPBEN(I,J): slope of bench

II. TRUCK Input

Subscripts (IBOD, NTK) indicate NTK^{th} truck in $IBOD^{th}$ ore body

ACELMA: maximum acceleration rate of a truck

COOLEN(I): length of I^{th} haulroad

CORDRS(I,J): road resistance of J^{th} section of I^{th} Coordinate

COSECL(I,J): length of J^{th} section of I^{th} Coordinate

COSLOP(I,J): slope of J^{th} section of I^{th} Coordinate

COSPLM(I,J): speed limit of J^{th} section of I^{th} coordinate

IASIGN(IBOD,NTK): = n assigning the truck to n^{th} loading station

IASLTW(I): = n n^{th} waste dumping station to be used by I^{th} loading station

IASMTT(I): material at I^{th} loading station
= 1 ore = 2 waste

IASTHB(I): = n n^{th} ore dumping station to be used by I^{th} loading station

IASTTB(I): = n n^{th} ore loading bin equivalent to I^{th} loading station

KINDT(IBOD, NTK): type of the truck

NCOOR: total number of coordinates in the truck system

NCOOSC(I): total number of sections in I^{th} coordinate

NOBSTW(IBOD): = 1 observation tower in the ore body = 0 no observation tower

NPOCKT(I): number of loading facilities in I^{th} loading station

NPOCKT3(I): number of dumping facilities in I^{th} ore dumping station

NPATH(IBOD, J, M,K): truck path from one destination to the other
= 1 loading station = 2 waste dumping station
= 3 ore dumping station = 4 tailing loading station = 5 road intersection = 6 haulroad coordinates

NPHTK(IBOD, J,M): total number of coordinates a truck has to travel when it is assigned to J^{th} loading station
m = 1 from loading station to ore dumping station
m = 2 from loading station to waste dumping station
m = 3 from ore dumping station to loading station
m = 4 from waste dumping station to loading station

NTASBD(J): = n J^{th} loading station be in n^{th} ore body

NTKDPS: total number of truck dumping stations in the system

NTKLDS: total number of truck loading stations in the system

NTKSYS: total number of truck types in the system

NTRUCK(IBOD): number of trucks in the ore body

RATFED(I): loading rate of I^{th} loading station

TBKT(I): mean maneuvering time of I^{th} truck type

TKAVIL(IBOD,NTK): mechanical availability of the truck

TKDMT(I): mean dumping time of I^{th} truck type

TKGVW(I): empty weight of I^{th} truck type

TKMEAN(I): payload of I^{th} truck type

TKRIMP(I,J)
TKSPED(I,J) } speed - rimpull curve of I^{th} truck type

TKTP(I,J): type of I^{th} truck

III. <u>BELT input</u>

CBINCP(I): capacity of head bin of I^{th} group belt

CCAPGR(I): capacity of I^{th} group belt

CCAPSC(J): capacity of J^{th} section belt

CGDAVL(I): mechanical availability of I^{th} group belt

CGRLEN(I): length of I^{th} group belt

CGRSPD(I): speed of I^{th} group belt

CRATFD(I): discharging rate of the head bin of I^{th} group belt

CSCAVL(J): mechanical availability of J^{th} section belt

CSCFDT(J): discharging rate of tail bin of J^{th} section belt

CSCLEN(J): length of J^{th} section belt

CSCSPD(J): speed of J^{th} section belt

CSEPLN(I,K): spacing of section belts along I^{th} group belt assuming that head of group I is 0 ft.

IASCTB(J): = n n^{th} tail bin feeding J^{th} section belt

IASMTC(J): material at tail bin of J^{th} section belt = 1 ore = 2 waste

ICDISG(I): = n I^{th} group belt feeding n^{th} head bin

ICDISS(J): = n J^{th} section belt feeding n^{th} head bin

ICGRFB(I,K): groups feeding head bin of I^{th} group belt

ICGRFT(I,J): groups feeding tail of I^{th} group belt

ICSTOP(J): = 1 stopping J^{th} section belt when overloading occurs
= 0 overloading to be cumulated

NCASBD(J): = n J^{th} section belt in n^{th} ore body

NCGRFB(I): total number of group belts feeding head bin of I^{th} group belt

NCGRFT(I): total number of group belts feeding tail of I^{th} group belt

NCGRP: total number of group belts in the system

NCGRS8(I): size of I^{th} group belt

NCSEPG(I): number of section belts in I^{th} group

NCSCS8(J): size of J^{th} section belt

NGASBD(I): = n I^{th} group belt in n^{th} ore body

NSEC1S: number of section belts in the system

IV. <u>TRAIN input</u>

CARFRI: friction resistance of car wheels

CARLEN: length of a car

CARLOD(I): payload of a car I = 1 ore
I = 2 waste

CARWTE: empty weight of a car

IASMTR(I): material at I^{th} loading station = 1 ore = 2 waste

IASRHB(I): = n n^{th} ore dumping station station to be used by I^{th} loading station

IASRTB(I); = n n^{th} ore loading bin being used by I^{th} loading station

LGTCON(I,J,K): traffic lights to be turned on when a train is at J^{th} section of I^{th} coordinate

MECRLS(L): minimum number of empty cars allowed at L^{th} loading station

MTRASG(K): = n K^{th} train being assigned to n^{th} loading station at the beginning of simulation

MXCRTR(K): maximum number of car for K^{th} train

NPHRL(J,M): total number of coordinate traveled by the train which is assigned to J^{th} loading station m = 1 loaded with ore m = 2 loaded with waste m = 3 empty train from ore dump m = 4 empty from waste dump

NRCOOR: total number of coordinates in train system

NRCOSC(I): number of sections in I^{th} coordinate

NREDLT(I,J): = 0; no traffic light in J^{th} section of I^{th} coordinate = n n^{th} traffic light in this section

NRPATH(J,M,K): train path from one destination to another = 1 loading station = 2 waste dumping station = 3 ore dumping station = 4 tailing loading station = 5 road intersection = 6 haulroad coordinates

NUMLDS: number of train loading stations in the system

NUMTR: number of trains in the system

NUTRLT: number of traffic control lights in the system

RAUL(KTR,J): mechanical availability of the train

RATELS(L): loading rate of L^{th} loading station

RCELEL(I,J): length of J^{th} section of I^{th} coordinate

RCSECL(I): length of I^{th} coordinate

RCSLOP(I,J): slope of J^{th} section of I^{th} coordinate

RCSPLM(I,J): speed limit of J^{th} section of I^{th} coordinate

RDECEL(K,J): normal deceleration of K^{th} train

RDUDPT(K): standard deviation of dumping time of K^{th} train

RECAR(L): total empty car at L^{th} loading station at the beginning of simulation

RLOCFR(K,J): friction resistance of K^{th} locomotive

RMAXAC(K,J): maximum acceleration of K^{th} train

RMEDPT(K): mean dumping time of K^{th} train

RSPEED(K,J,N)
RTRAEF(K,J,N) } speed vs. tractive force curve of K^{th} train

RWTLOC(K,J): weight of K^{th} locomotive

V. GENERAL input

CAPHBN(I,J): capacity of J^{th} surge bin being used as a dumping bin of I^{th} transportation medium

CAPM1L(I): bin capacity of I^{th} crusher

DATAT(I): characters used to indicate various input deck

DELTT: time increment

IBASE: base for generating random number

ICRASC(I): = n tailing bin of I^{th} crusher equivalent to n^{th} tail bin of section belt
= 0 the tailing not being transported by belt

ICRASR(I): = n tailing bin of I^{th} crusher equivalent to n^{th} train loading station
= 0 the tailing not being transported by train

ICRAST(I): = n tailing bin of I^{th} crusher equivalent to n^{th} truck loading station
= 0 the tailing not being transported by truck

LOCM1L(I): = n n^{th} crusher being used by the activities of I^{th} ore body

NBODY: number of ore bodies in the system

NCRUSH: number of ore dumping stations (crushers) in the system

NDUMP: number of waste dumping areas in the system

NELEMN(I,K): transportation media used in I^{th} ore body BWE = 1, TRUCK = 2, TRAIN = 3, BELT = 4, CRUSHER = 5

NELEMT(I): total number of transportation media used to transport ore from face to crusher in I^{th} ore body

NGRID: = 0 shift simulation = 1 grid point simulation

NPOCK2(I): number of dumping facilities at I^{th} dumping area

NPOCK4(I): number of tailing loading pockets (facilities) at I^{th} crusher

NSHIFT: number of shifts to be simulated

NTAIL: number of tailing loading stations in the system

RATM1L(I): processing rate of I^{th} processing plant (crusher)

SHIFTT: shift length to be simulated

Output Variables

I. BWE output

subscripts (I,J) indicate J^{th} BWE in I^{th} ore body

ACTU: actual capacity of a BWE

BDGKWH(I,J): digging power consumption

BPRDOW(I,J): delay time due to hitting boulders

BSLKWH(I,J): slewing power consumption

BTHO: theoretical capacity of a BWE

BTRAM2(I,J): total maneuvering time

BTRKWH(I,J): crowding power consumption

BWCTSH(I,J): total cutting time

BWEWT(I,J): total waiting time

BWTTHK(I,J): total advance in a bench

BWTTMD(I,J): total delay time (mechanical failure)

NCTBEN(I,J): final position of the wheel

PRODTB(I,J,K): total tonnages produced K = 1, K = 2 waste

TRKWH2(I,J): total maneuvering power consumption

II. <u>TRUCK outputs</u>

subscripts (I,K) indicate K^{th} truck in I^{th} ore body

CUMWT2(I,K): total tailing moved

LODTK(I,K,J): total number of trip made, J = 1 ore J = 2 waste

OREMV(I,K): total amount of ore moved

TKWTBW(I,K): total waiting time at loading station

TKWTCR(I,K): total waiting time at ore dumping station

TKWTDP(I,K): total waiting time at waste dumping station

TKWTTL(I,K): total waiting time at tailing loading

WASTMV(I,K): total tonnage of waste moved

III. BELT output

CBNOVI(I): total tonnage overloaded to the surge at the tail of I^{th} group belt

CGROVL(I): total tonnage overloaded to I^{th} group belt

CGRWMC(K): total waiting time of I^{th} group belt to prevent overloading K^{th} surge bin
K = ID1SG(I)

CGRWT(I): total waiting time of I^{th} group belt

CSBWTK(K): total waiting time of J^{th} section belt to prevent overloading K^{th} head bin
K = ID1SS(J)

CSEOVL(J): total tonnage contributing to overload gathering belt by J^{th} section belt

CSEWT(J): total waiting time of J^{th} section belt

CTWTSC(J): total tonnage transported by J^{th} section belt

IV. TRAIN output

RCARLD(L): total cars loaded by L^{th} loading station

RLDSDL(L): total idle time of L^{th} loading station

RTOTLD(K): total tonnage hauled by K^{th} train

RWTA1N(K): total waiting time of K^{th} train at road intersection

RWTD1S(K): total waiting time of K^{th} train at dumping station

Endogenous Variables

I. BWE variables

subscripts (I,J) indicate J^{th} BWE in I^{th} ore body

ACP: actual output from wheel per second

AGBCWT(I,J): average cutting rate of the BWE in Δt

ALPHA: angle between line of advance and slewing boom

BAT: bucket arrival time

BCAB: actual capacity of a bucket in the given material

BCLOCK(I,J): total required time for cutting a grid point

BCOUNT(I,J): = 1 bucket hitting boulders
= 0 otherwise

BDTIME(I,J): down time from the beginning of hitting boulders to the present time period

BDTH: slewing width

BLOT: total cutter length of buckets in the bench

BPOS1T(I,J): position of wheel in the bench

BTODOT(I,J): down time when hitting boulders

BSURGE(L,K): amount of material in L^{th} surge bin

BVLANG(I,J): slewing angle to the left of line of advance

BVRANG(I,J): slewing angle to the right of line of advance

BWBACK(I,J): distance tramming back after finishing a bench

BWECWT(I,J): amount of material cut

BWTMD(I,J): > 0 mechanically availability
< 0 mechanically fail
= 0 to be generating a new random number

BWTTHK(I,J): total advance in a bench

CSPEED: actual cutting speed of the wheel in a given material

D1SP: cutting power consumption

EFFE: electrical efficiency of motors

EFFM: mechanical efficiency of transmissions

IBCMAT(I,J): = 1 excavating ore = 2 excavating waste

ISECT(I,J): = 1 slewing outward from line of advance = 0 slewing from edges of the bench toward line of advance

ISET(I,J): = 1 at right segment of the line of advance = 0 at left segment

NCTBEN(I,J): = n cutting n^{th} bench

NCTSET(I,J): = 0 completing a grid point = 1 cutting the same grid point

R1SP: power consumption for lifting buckets

SNT1K: thickness of cut at any point of the bench

TH1CK: thickness of cut at the center

TRUVOL: quantity in bench

VMAX: theoretical maximum cutting speed

VOLUME: actual output

XFRPM: rpm of the wheel

II. TRUCK variables

subscripts (I,K) indicate K^{th} truck of I^{th} ore body

ACCEL: available acceleration rate

AV1LRP: available rimpull at the given velocity

B1NCRU(J): amount of material in the bin of J^{th} crusher

DEACC: necessary deceleration rate

DECEL: normal deceleration rate of the truck

FRM1LB: amount of tailing loaded into truck at Δt

ICOOST(I,K): = m at m^{th} section of a coordinate

LDQUE(L,K): queuing number of the truck at L^{th} loading station

LTCOOR(I,K): = n at n^{th} coordinate

MATER(I,K): material carried = 1 ore = 2 waste

TON(I,K): total weight of the truck

TRAELE(I,K): length of section travelled by the truck

TRASEC(I,K): length of coordinate travelled by the truck

TVEL(I,K): velocity of the truck

WTTK(I,K): amount of material loaded to the truck

YY: range of haulroad section for deceleration

III. BELT variables

subscripts J = J^{th} section belt, IB = IB^{th} ore body, I = I^{th} group belt

BSURGE(L,2): amount of material at L^{th} surge bin of the BWE's. '2' indicate waste, which is directly transported to waste dump

CARYGP(I,L): amount of material at L^{th} segment of the group belt

CARYSC(J,L): amount of material at L^{th} segment of the section belt

B1NCRU(L): amount of material in the bin of L^{th} crusher

CB1NFL(I): amount of material in the tail bin of the group belt

CBNDCH(I): amount of material feeding to I^{th} group belt from tail bin

CBNOUF(I): amount overloading the tail bin of the group belt

CD1SMC(I): amount of material discharging from the group belt

CD1SRF(J): amount of material feeding the section belt

CGDOWN(I): > 0 the group belt mechanically available
< 0 mechanically fail
= 0 to be generating a new random number

CGRD1S(I): amount of material discharging

CGSTOP(I): = 1 the group belt stop = 0 do not stop

CLDMC(L): = 0 L^{th} bin at the head of group belt being full = 1 otherwise

CLOAD: total amount of material feeding to a segment of the group belt

CSCD1S(J): amount of material discharging from the section belt

CSCHDB(L): amount of material discharging to L^{th} head bin from the section belt

CSDOWN(J): > 0 the section belt mechanically available
< 0 mechanically fail
= 0 to be generating a new random number

CSESTP(J): = 1 stopping the section belt = 0 otherwise

IARYPG(I,J): = n the section belt feeding n^{th} segment of the group belt

NARYGP(I): total segments in the group belt

NARYSC(J): total segments in the section belt

IV. <u>TRAIN variables</u>

K: K^{th} train in the system

L: L^{th} loading station in the system

AV1LRP: available tractive force

B1NCRU(I): amount of material at I^{th} tailing bin of the crusher

GRADE: average slope of the haulroad lying by the train

IRCOOT(K): = n at n^{th} section of a coordinate

KRAVDP(K): = 1 available for reassignment = 0 otherwise

MAXDPQ(L): total number of trucks waiting at L^{th} waste dumping station

MAXCRQ(L): total number of trucks waiting at L^{th} ore dumping station

MAXMLQ(L): total number of trucks waiting at L^{th} tailing loading station

MAXLD(L): total number of trucks waiting at L^{th} loading station

MCRQUE(L,I,K): queuing number of the truck at L^{th} ore dumping station

MDMQUE(L,I,K): queuing number of the truck at L^{th} waste dumping station

M1LQUE(L,I,K): queuing number of the truck at L^{th} tailing loading station

MTR(I,K): = 1 ore in surge of loading station = 2 waste in surge of loading station

NEW(L): = 1 no truck being newly loaded at L^{th} loading station = 0 some trucks being loaded and ready to move

NEW2(L): = 1 no truck newly complete dumping at L^{th} waste dumping station = 0 some trucks complete dumping

NEW3(L): = 1 no truck finishing dumping at L^{th} ore dumping station = 0 some trucks finishing dumping ore

NEW4(L): = 1 no truck being loaded at L^{th} tailing loading station = 0 some trucks being loaded and ready to move

RATAGB: loading rate

S: travel distance

SPDL1M: speed limit

TBACKT(I,K): maneuvering time at loading station

TKDOWN(I,K): > 0 mechanically available
< 0 mechanically fail
= 0 to be generating a new random number

TKDNT: amount of material dumped in Δt

KMATER(K): material in the cars = 1 ore = 2 waste = 3 after dumping ore = 4 after dumping waste

LRCOOR(K): = n at n^{th} coordinate

LREDLT(I): = 1 I^{th} traffic light on = 0 the light off

NASGLS(L): = 1 a new train being dispatched to the loading station = 0 no train being dispatched to this station

NDUMPG(K): = 1 the train being dumping, = -1 waiting at intersection = 0 finishing dumping

NLOCO(K): = 1 a loaded train = 0 empty train

NRF1RT(K): = 0 calculating total weight of the train = 1 weight already being calculated

RACCEL: acceleration rate at the given conditions

RACC1: deceleration rate due to approaching an intersection

RACC2: deceleration rate due to approaching another train

RDOWN(K): > 0 mechanically available
< 0 mechanically fail
= 0 generating new condition

RLEFT(K): length of the train left at the old section of haulroad

RFR1C(K): total frictional resistance of the train

RLOAD(K): amount of material in the train

RLOAD1(L): number of loaded cars at the loading station

RMASS(K): total mass of the train

RSENDE(L): calling for dispatching a new train

RTDOWN(K): total down time of the train

RTCARL(K): length of the train

RTRELE(K): length of section traveled by the train

RTRSEC(K): length of coordinate traveled by the train

RTOTWT(K): total weight of the train

RTWTLD(K): waiting time of the train at loading station

RTWTDP(K): waiting time of the train at ore dumping station

RVEL(K): velocity of the train

S: distance traveled in Δt

SMALL: determining the loading station for sending a new train

SPDL1M: speed limit

X: length of the train in new section of haulroad

YY: range of a section of haulroad where the train decelerates

V. OTHER variables

CLOCK: clock time in simulation process

EQU1VL(II,J): amount of material at J^{th} bin of II^{th} sub-assembly. II = 1 BWE, II = 2 truck, II = 3 train, II = 4 belt, II= 5 crusher

ISHF: = n, n^{th} shift to be simulated

```
C       MAIN PROGRAM
C
        COMMON /GENIN1/CAPBIN(5),RATMIL(5),CAPMIL(5),DELTT,SHI
       +FTT,CAPHBN(5,15),EQUIVL(5,15),CLOCK,BSURGE(15,2),BWEWT
       +(3,5),TKWTBW(3,30),PRODTB(3,5,2),WASTMV(4,30),TKWTDP(4
       +,30),BINCRU(5),DREMV(4,30),TKWTCR(4,30),CUMWT2(4,30),T
       +KWTTL(4,30),WTTK(4,30)
        COMMON /BWEIN1/BCS(3,5),BLENBM(3,5),BCOB(3,5),BNOB(3,5
       +),BDIA(3,5),BCTMAX(3,5),BWS(3,5),BOWM(3,5),BFRS(3,5),B
       +RS(3,5),BWAVIL(3,5),BDMEAN(3,5),BWLANG(3,5),BWRANG(3,5
       +),BSETTM(3,5),BCAPSG(3,5,2),BKFILL(10),BKRES(10),BRPM(
       +10),BVINC(10),BRORI(3,5),BGRADE(3,5),BPROB(3,5,5),BHEI
       +GT(3,5,5,2),BDENST(3,5,5),BRATIO(3,5,5),BCLOCK(3,5),BP
       +RDOW(3,5),BCOUNT(3,5)
        COMMON /BWEIN2/SLPBEN(3,5),BWTMD(3,5),BWECWT(3,5),BWTT
       +MD(3,5),BWCTFR(3,5),BWTTHK(3,5),BWFDD(3,5),
       +            AGBCWT(3,5),BSLKWH(3,5),BTRKWH(3,5),BWCTS
       +H(3,5),EFFM,EFFE,BPOSIT(3,5),BWBACK(3,5),BTRAM2(3,5),T
       +RKWH2(3,5),BVLANG(3,5),BVRANG(3,5),BTODOT(3,5),BDTIME(
       +3,5),BWIDTH(3,5),BDGKWH(3,5)
        COMMON /TRKIN1/TKMEAN(10),TKGVW(10),TKSPED(10,20),TKRI
       +MP(10,20),COSPLM(50,5),COSLOP(50,5),CORDRS(50,5),COSEC
       +L(50,5),COOLEN(50),TKDHIL(20),TKTP(10,20),RATFED(15),T
       +BKT(10),TKDMT(10),ACELMA,TKAVIL(4,30),TVEL(4,30),TON(4
       +,30),TRASEC(4,30),TRAELE(4,30),TBACKT(4,30),TKTDOW(4,3
       +0),TKFDD(4,30),TKDOWN(4,30)
        COMMON /BELIN1/CGRLEN(4),CGRSPD(4),CCAPGR(4),CSCLEN(20
       +),CSCSPD(20),CSEPLN(4,5),CRATFD(4),CBINCP(4),CSCFDT(20
       +),CCPSHB(20),CCAPSC(20),CDISRF(20),CTLBIN(20),CBINFL(4
       +),CSESTP(20),CSCDIS(20),CTWTSC(20),CARYSC(20,400),CGRW
       +MC(4),CARYGP(4,400),CGSTOP(4),CGRWT(4),CSEWT(20),CSEOV
       +L(20),CLDMC(4),CDISMC(4),CGRDIS(4),CGROVL(4),CBNDCH(4)
        COMMON /BELIN2/CBNOVF(4),CSCHDB(20),CSBWTK(20),CSCAVL(
       +20),CSCFDD(20),CSDOWN(20),CGPAVL(4),CGPFDD(4),CGDOWN(4
       +)
        COMMON /TRNIN1/CARFRI,CARLEN,CARWTE,CARLOD(2),RMAXAC(6
       +,2),RDECEL(6,2),RWTLOC(6,2),RLOCFR(6,2),RMEDPT(6),RDVD
       +PT(6),              RSPEED(6,2,20),RTRAEF(6,2,20),RCSP
       +LM(30,5),RCSLOP(30,5),RCELEL(30,5),RCSECL(30),RATELS(5
       +),RTCARL(6)
        COMMON /TRNIN2/RMASS(6),RFRIC(6),RVEL(6),RLEFT(6),RTOT
       +WT(6),RTRELE(6),RTRSEC(6),RLDSDL(5),RECAR(5),RSENDE(6)
       +,RDLSMN(6),RLOAD(6),RDLALS(6),RARIDP(6),RTLTDP(6),RTWT
       +DP(6),RLOADI(6),RDLADP(6),RWTDIS(6),RWTAIN(6),RTOTLD(6
       +),RCARLD(6),RTWTLD(6),RAVL(6,2),RFDD(6,2),       RDOWN(
       +6,2),RTDOWN(6,2)
        COMMON /GENIN2/IBOD,JBWE,NTK,NEXTEN(3,5),ISHF,NPOCK3(5
       +),KTR,NLS,NSC,NBODY,NSHIFT,NDUMP,NCRUSH,NTAIL,NOBSTW(3
       +),IBASE,LOCMIL(5),NPOCK2(5),NPOCK4(5),ICRASC(5),ICRASR
       +(5),NELEMT(4),NELEMN(4,5),ICRAST(5),LDQUE(15,30),MAXLD
```

```
+(15),NEW(15),LODTK(4,30,2),MDMQUE(5,4,30),NEW2(5),MAXD
+PQ(5),MCRQUE(5,4,30),MAXCRQ(5),NEW3(5),MILQUE(5,4,30),
+NGRID
 COMMON /GENIN3/MAXMLQ(5),NEW4(5),LODTK2(4,30),MTR(4,30
+)
 COMMON /BWEIN4/NBWE(3),IASBTS(3,5),NBWBEN(3,5),NCTSET(
+3,5),IBCMAT(3,5),ISET(3,5),ISECT(3,5),LSOIL(3,5,5),NCT
+BEN(3,5)
 COMMON /TRKIN2/NTRUCK(4),KINDT(4,30),NTASBD(15),IASMTT
+(15),IASTTB(15),NPATH(4,15,4,10),IASTHB(15),NCOOSC(50)
+,IASIGN(4,30),NPHTK(4,15,4),NPOCKT(15),NTKDPS,NTKLDS,I
+ASLTW(15),MATER(4,30),ICOOST(4,30),LTCOOR(4,30)
 COMMON /BELIN3/NCGRP,NSECIS,ICDISG(4),NCSEPG(4),NCSCSZ
+(20),NCGRSZ(4),IASMTC(20),NCGRFT(4),ICGRFT(4,5),NCGRFB
+(4),ICGRFB(4,5),ICSTOP(20),ICDISS(20),NARYIG(4),IARYPG
+(4,5),NARYSC(20),IASCTB(20),IASCHB(4),NGASBD(4),NCASBD
+(20)
 COMMON /TRNIN3/NUMTRN,NUMLDS,NUTRLT,IASRHB(6),IASRTB(6
+),MXCRTR(6),NRCOOR,NRCOSC(30),NREDLT(30,5),LGTCON(30,5
+,5),NRPATH(5,4,10),NPHRL(5,4),MTRASG(6),IASMTR(5),IASR
+HS(5),NRTDPS,NRASBD(5),NRFIRT(6),NLOCO(6),KMATER(6),IR
+COOT(6),LRCOOR(6),LREDLT(10),NASGLS(6),LDSCNT(6),MTOTL
+D(6),KRAVDP(6),NDLBDP(6),NDUMDP(6),NDUMPG(6),MECRLS(5)
 CALL READER
 DO 15 I=1,5
 DO 5 J=1,5
 COSPLM(I,J)=0.
 COSLOP(I,J)=0.
 CORDRS(I,J)=0.
5 COSECL(I,J)=0.
15 COOLEN(I)=0.
 DO 25 I=1,5
 DO 25 J=1,15
25 EQUIVL(I,J)=0.
 NBODY1=NBODY+1
 DO 45 IBOD=1,NBODY
 JJ=NBWE(IBOD)
 DO 35 JBWE=1,JJ
 BPRDOW(IBOD,JBWE)=0.
 BCOUNT(IBOD,JBWE)=0
 BWTMD(IBOD,JBWE)=0.
 BWECWT(IBOD,JBWE)=0.
 BWTTMD(IBOD,JBWE)=0.
 BWCTFR(IBOD,JBWE)=0
 NEXTEN(IBOD,JBWE)=0
 NCTSET(IBOD,JBWE)=1
 NCTBEN(IBOD,JBWE)=1
 BWTTHK(IBOD,JBWE)=0.
 IBCMAT(IBOD,JBWE)=1
 AGBCWT(IBOD,JBWE)=0.
 BPOSIT(IBOD,JBWE)=0.
```

```
      ISET(IBOD,JBWE)=1
      ISECT(IBOD,JBWE)=1
      BWBACK(IBOD,JBWE)=0.
      TRKWH2(IBOD,JBWE)=0.
      BVLANG(IBOD,JBWE)=0.
      BVRANG(IBOD,JBWE)=0.
      BTODOT(IBOD,JBWE)=0.
      BDTIME(IBOD,JBWE)=0.
      BWIDTH(IBOD,JBWE)=0.
      BDGKWH(IBOD,JBWE)=0.
      BSLKWH(IBOD,JBWE)=0.
      BTRAM2(IBOD,JBWE)=0.
      BTRKWH(IBOD,JBWE)=0.
      BWCTSH(IBOD,JBWE)=0.
      BWEWT(IBOD,JBWE)=0.
      PRODTB(IBOD,JBWE,1)=0.
      PRODTB(IBOD,JBWE,2)=0.
   35 CONTINUE
   45 CONTINUE
      DO 115 IBOD=1,NBODY1
      NN=NTRUCK(IBOD)
      IF (NN.EQ.0) GO TO 115
      DO 105 NTK=1,NN
      MATER(IBOD,NTK)=4
      MIL=IASIGN(IBOD,NTK)
      IF (MIL.EQ.0) GO TO 55
      LTCOOR(IBOD,NTK)=NPHTK(IBOD,MIL,4)
   55 ICOOST(IBOD,NTK)=1
      TBACKT(IBOD,NTK)=0.
      TKDOWN(IBOD,NTK)=0.
      TKTDOW(IBOD,NTK)=0.
      TVEL(IBOD,NTK)=0.
      TON(IBOD,NTK)=0.
      WTTK(IBOD,NTK)=0.
      TRASEC(IBOD,NTK)=0.
      TRAELE(IBOD,NTK)=0.
      TKWTBW(IBOD,NTK)=0.
      LODTK(IBOD,NTK,1)=0
      LODTK(IBOD,NTK,2)=0
      WASTMV(IBOD,NTK)=0.
      TKWTDP(IBOD,NTK)=0.
      OREMV(IBOD,NTK)=0.
      LODTK2(IBOD,NTK)=0
      CUMWT2(IBOD,NTK)=0.
      TKWTTL(IBOD,NTK)=0.
      TKWTCR(IBOD,NTK)=0.
      DO 65 JBWE=1,NTKLDS
      LDQUE(JBWE,NTK)=0
   65 CONTINUE
      DO 75 MIL=1,NTAIL
   75 MILQUE(MIL,IBOD,NTK)=0
```

```
      DO 85 ICR=1,NCRUSH
      MCRQUE(ICR,IBOD,NTK)=0
   85 CONTINUE
      DO 95 KDP=1,NDUMP
   95 MDMQUE(KDP,IBOD,NTK)=0
  105 CONTINUE
  115 CONTINUE
      DO 125 I=1,NTKLDS
      BSURGE(I,1)=0
      BSURGE(I,2)=0
      MAXLD(I)=0
  125 NEW(I)=1
      DO 135 ICR=1,NCRUSH
      NEW3(ICR)=1
      BINCRU(ICR)=0.
      MAXCRQ(ICR)=0
      MAXMLQ(ICR)=0
      NEW4(ICR)=1
  135 CONTINUE
      DO 145 KDP=1,NDUMP
      NEW2(KDP)=1
      MAXDPQ(KDP)=0
  145 CONTINUE
      IF (NSECIS.EQ.0) GO TO 185
      DO 175 IC=1,NSECIS
      IF (ICDISS(IC).EQ.0) GO TO 155
      CSBWTK(ICDISS(IC))=0
      CSCHDB(ICDISS(IC))=0.
  155 CDISRF(IC)=0.
      CTLBIN(IC)=0.
      CSESTP(IC)=0
      CSCDIS(IC)=0.
      CTWTSC(IC)=0.
      CSEWT(IC)=0.
      CSEOVL(IC)=0.
      CSDOWN(IC)=0.
      DO 165 I=1,400
  165 CARYSC(IC,I)=0.
  175 CONTINUE
  185 DO 205 NC=1,NCGRP
      CBINFL(NC)=0.
      CGDOWN(NC)=0.
      CGSTOP(NC)=0
      CGRWT(NC)=0.
      CLDMC(NC)=1
      CGRWMC(NC)=0
      CDISMC(NC)=0.
      CGRDIS(NC)=0.
      CGROVL(NC)=0.
      DO 195 N=1,400
  195 CARYGP(NC,N)=0.
```

```
  205 CONTINUE
C *** INITIALIZE TRAIN VARIABLES
      IF (NUMTRN.EQ.0) GO TO 275
      DO 225 I=1,5
      DO 225 J=1,5
      RCSPLM(I,J)=0.
      RCSLOP(I,J)=0.
      NREDLT(I,J)=0
  225 RCELEL(I,J)=0.
      DO 235 KTR=1,NUMTRN
      RTWTLD(KTR)=0.
      LDSCNT(KTR)=1
      RLEFT(KTR)=0.
      NDUMPG(KTR)=1
      IRCOOT(KTR)=1
      LRCOOR(KTR)=1
      NRFIRT(KTR)=0
      RTRELE(KTR)=0.
      RTRSEC(KTR)=0.
      RDLSMN(KTR)=0.
      RLOAD(KTR)=0.
      RDLALS(KTR)=0.
      RTOTLD(KTR)=0.
      KRAVDP(KTR)=0
      NDLBDP(KTR)=1
      RARIDP(KTR)=0.
      NDUMDP(KTR)=0
      RTLTDP(KTR)=0.
      RDLADP(KTR)=0.
      MTOTLD(KTR)=0
      RWTDIS(KTR)=0.
      RWTAIN(KTR)=0.
      KMATER(KTR)=4
      RVEL(KTR)=0.
      RDOWN(KTR,1)=0.
      RDOWN(KTR,2)=0.
      RTDOWN(KTR,1)=0.
      RTDOWN(KTR,2)=0.
  235 CONTINUE
      DO 245 NLT=1,NUTRLT
  245 LREDLT(NLT)=0
      DO 265 NLS=1,NUMLDS
      RLDSDL(NLS)=0.
      DO 255 KTR=1,NUMTRN
      IF (MTRASG(KTR).NE.NLS) GO TO 255
      RECAR(NLS)=RECAR(NLS)+MXCRTR(KTR)
      LRCOOR(KTR)=NPHRL(NLS,4)
  255 CONTINUE
      RCARLD(NLS)=0.
      NASGLS(NLS)=0
      RLOADI(NLS)=0.
```

```
      RSENDE(NLS)=0.
  265 CONTINUE
  275 EFFM=0.8
      EFFE=0.9
      IBOD=1
      JBWE=1
      CLOCK=0.
      ISHF=1
      NSC=1
      CALL CONTRL
      END
C
C
      SUBROUTINE PRINTR
C
C
C *** PRINTING ROUTINE
C
      COMMON /GENIN1/CAPBIN(5),RATMIL(5),CAPMIL(5),DELTT,SHI
     +FTT,CAPHBN(5,15),EQUIVL(5,15),CLOCK,BSURGE(15,2),BWEWT
     +(3,5),TKWTBW(3,30),PRODTB(3,5,2),WASTMV(4,30),TKWTDP(4
     +,30),BINCRU(5),OREMV(4,30),TKWTCR(4,30),CUMWT2(4,30),T
     +KWTTL(4,30),WTTK(4,30)
      COMMON /BWEIN1/BCS(3,5),BLENBM(3,5),BCOB(3,5),BNOB(3,5
     +),BDIA(3,5),BCTMAX(3,5),BWS(3,5),BOWM(3,5),BFRS(3,5),B
     +RS(3,5),BWAVIL(3,5),BDMEAN(3,5),BWLANG(3,5),BWRANG(3,5
     +),BSETTM(3,5),BCAPSG(3,5,2),BKFILL(10),BKRES(10),BRPM(
     +10),BVINC(10),BRORI(3,5),BGRADE(3,5),BPROB(3,5,5),BHEI
     +GT(3,5,5,2),BDENST(3,5,5),BRATIO(3,5,5),BCLOCK(3,5),BP
     +RDOW(3,5),BCOUNT(3,5)
      COMMON /BWEIN2/SLPBEN(3,5),BWTMD(3,5),BWECWT(3,5),BWTT
     +MD(3,5),BWCTFR(3,5),BWTTHK(3,5),BWFDD(3,5),
     +              AGBCWT(3,5),BSLKWH(3,5),BTRKWH(3,5),BWCTS
     +H(3,5),EFFM,EFFE,BPOSIT(3,5),BWBACK(3,5),BTRAM2(3,5),T
     +RKWH2(3,5),BVLANG(3,5),BVRANG(3,5),BTODOT(3,5),BDTIME(
     +3,5),BWIDTH(3,5),BDGKWH(3,5)
      COMMON /TRKIN1/TKMEAN(10),TKGVW(10),TKSPED(10,20),TKRI
     +MP(10,20),COSPLM(50,5),COSLOP(50,5),CORDRS(50,5),COSEC
     +L(50,5),COOLEN(50),TKDHIL(20),TKTP(10,20),RATFED(15),T
     +BKT(10),TKDMT(10),ACELMA,TKAVIL(4,30),TVEL(4,30),TON(4
     +,30),TRASEC(4,30),TRAELE(4,30),TBACKT(4,30),TKTDOW(4,3
     +0),TKFDD(4,30),TKDOWN(4,30)
      COMMON /BELIN1/CGRLEN(4),CGRSPD(4),CCAPGR(4),CSCLEN(20
     +),CSCSPD(20),CSEPLN(4,5),CRATFD(4),CBINCP(4),CSCFDT(20
     +),CCPSHB(20),CCAPSC(20),CDISRF(20),CTLBIN(20),CBINFL(4
     +),CSESTP(20),CSCDIS(20),CTWTSC(20),CARYSC(20,400),CGRW
     +MC(4),CARYGP(4,400),CGSTOP(4),CGRWT(4),CSEWT(20),CSEOV
     +L(20),CLDMC(4),CDISMC(4),CGRDIS(4),CGROVL(4),CBNDCH(4)
      COMMON /BELIN2/CBNOVF(4),CSCHDB(20),CSBWTK(20),CSCAVL(
     +20),CSCFDD(20),CSDOWN(20),CGPAVL(4),CGPFDD(4),CGDOWN(4
     +)
```

```
      COMMON /TRNIN1/CARFRI,CARLEN,CARWTE,CARLOD(2),RMAXAC(6
     +,2),RDECEL(6,2),RWTLOC(6,2),RLOCFR(6,2),RMEDPT(6),RDVD
     +PT(6),              RSPEED(6,2,20),RTRAEF(6,2,20),RCSP
     +LM(30,5),RCSLOP(30,5),RCELEL(30,5),RCSECL(30),RATELS(5
     +),RTCARL(6)
      COMMON /TRNIN2/RMASS(6),RFRIC(6),RVEL(6),RLEFT(6),RTOT
     +WT(6),RTRELE(6),RTRSEC(6),RLDSDL(5),RECAR(5),RSENDE(6)
     +,RDLSMN(6),RLOAD(6),RDLALS(6),RARIDP(6),RTLTDP(6),RTWT
     +DP(6),RLOADI(6),RDLADP(6),RWTDIS(6),RWTAIN(6),RTOTLD(6
     +),RCARLD(6),RTWTLD(6),RAVL(6,2),RFDD(6,2),       RDOWN(
     +6,2),RTDOWN(6,2)
      COMMON /GENIN2/IBOD,JBWE,NTK,NEXTEN(3,5),ISHF,NPOCK3(5
     +),KTR,NLS,NSC,NBODY,NSHIFT,NDUMP,NCRUSH,NTAIL,NOBSTW(3
     +),IBASE,LOCMIL(5),NPOCK2(5),NPOCK4(5),ICRASC(5),ICRASR
     +(5),NELEMT(4),NELEMN(4,5),ICRAST(5),LDQUE(15,30),MAXLD
     +(15),NEW(15),LODTK(4,30,2),MDMQUE(5,4,30),NEW2(5),MAXD
     +PQ(5),MCRQUE(5,4,30),MAXCRQ(5),NEW3(5),MILQUE(5,4,30),
     +NGRID
      COMMON /GENIN3/MAXMLQ(5),NEW4(5),LODTK2(4,30),MTR(4,30
     +)
      COMMON /BWEIN4/NBWE(3),IASBTS(3,5),NBWBEN(3,5),NCTSET(
     +3,5),IBCMAT(3,5),ISET(3,5),ISECT(3,5),LSOIL(3,5,5),NCT
     +BEN(3,5)
      COMMON /TRKIN2/NTRUCK(4),KINDT(4,30),NTASBD(15),IASMTT
     +(15),IASTTB(15),NPATH(4,15,4,10),IASTHB(15),NCOOSC(50)
     +,IASIGN(4,30),NPHTK(4,15,4),NPOCKT(15),NTKDPS,NTKLDS,I
     +ASLTW(15),MATER(4,30),ICOOST(4,30),LTCOOR(4,30)
      COMMON /BELIN3/NCGRP,NSECIS,ICDISG(4),NCSEPG(4),NCSCSZ
     +(20),NCGRSZ(4),IASMTC(20),NCGRFT(4),ICGRFT(4,5),NCGRFB
     +(4),ICGRFB(4,5),ICSTOP(20),ICDISS(20),NARYIG(4),IARYPG
     +(4,5),NARYSC(20),IASCTB(20),IASCHB(4),NGASBD(4),NCASBD
     +(20)
      COMMON /TRNIN3/NUMTRN,NUMLDS,NUTRLT,IASRHB(6),IASRTB(6
     +),MXCRTR(6),NRCOOR,NRCOSC(30),NREDLT(30,5),LGTCON(30,5
     +,5),NRPATH(5,4,10),NPHRL(5,4),MTRASG(6),IASMTR(5),IASR
     +HS(5),NRTDPS,NRASBD(5),NRFIRT(6),NLOCO(6),KMATER(6),IR
     +COOT(6),LRCOOR(6),LREDLT(10),NASGLS(6),LDSCNT(6),MTOTL
     +D(6),KRAVDP(6),NDLBDP(6),NDUMDP(6),NDUMPG(6),MECRLS(5)
C
C *** PRINT OUT SHIFT RESULT
C
      WRITE (6,15)
   15 FORMAT (1H1//////////)
      WRITE (6,25) ISHF
   25 FORMAT (1H ,120(1H.)/1H ,'.',118X,'.'/1H ,'.',39X,'SHI
     +FT',I4,' REPORT',63X,'.'/2H .,118X,'.'/1H ,120(1H.))
      TIME=CLOCK/60.
      WRITE (6,35) TIME,DELTT
   35 FORMAT (///30X,'SHIFT TIME =',F10.2,' MINUTE'/30X,'TIM
     +E INCREMENT =',F10.2,' SECONDS')
      NBODY1=NBODY+1
```

```
      DO 45 IBOD=1,NBODY1
      IF (NTRUCK(IBOD).NE.0) GO TO 55
   45 CONTINUE
      GO TO 195
C
C ***** TRUCK
C
   55 WRITE (6,65)
   65 FORMAT (///'1',40X,'      TRUCK PRODUCTION STATISTICS'
     +)
      WRITE (6,75)
   75 FORMAT (//5X,'ASSIGNED',6X,'TRUCK',10X,'TRUCK TYPE',3X
     +,'CAPACITY',8X,'LOADS',7X,'LOADS',8X,'TONS',7X,'TONS',
     +8X,'TONS'/5X,'ORE BODY',6X,'NUMBER',22X,'(TON)',11X,'O
     +RE',9X,'WASTE',8X,'ORE',8X,'WASTE',7X,'TAILING'/)
      TOTAL1=0
      TOTAL2=0.
      TOTAL3=0.
      NBODY1=NBODY+1
      DO 115 IBOD=1,NBODY1
      NN=NTRUCK(IBOD)
      IF (NN.EQ.0) GO TO 115
      SUBT1=0.
      SUBT2=0.
      SUBT3=0.
      DO 95 NTK=1,NN
      KND=KINDT(IBOD,NTK)
      WRITE (6,85) IBOD,NTK,(TKTP(KND,K1),K1=1,8),TKMEAN(KND
     +),LODTK(IBOD,NTK,1),LODTK(IBOD,NTK,2),OREMV(IBOD,NTK),
     +WASTMV(IBOD,NTK),CUMWT2(IBOD,NTK)
   85 FORMAT (1H ,7X,I1,13X,I2,11X,8A1,6X,F6.0,11X,I3,9X,I3,
     +F13.1,F11.1,F12.1)
      SUBT1=SUBT1+OREMV(IBOD,NTK)
      SUBT2=SUBT2+WASTMV(IBOD,NTK)
      SUBT3=SUBT3+CUMWT2(IBOD,NTK)
      LODTK(IBOD,NTK,1)=0
      LODTK(IBOD,NTK,2)=0
      OREMV(IBOD,NTK)=0.
      WASTMV(IBOD,NTK)=0.
      CUMWT2(IBOD,NTK)=0.
   95 CONTINUE
      WRITE (6,105) SUBT1,SUBT2,SUBT3
  105 FORMAT (/5X,'SUBTOTAL',72X,F9.1,F11.1,F12.1/)
      TOTAL1=TOTAL1+SUBT1
      TOTAL2=TOTAL2+SUBT2
      TOTAL3=TOTAL3+SUBT3
  115 CONTINUE
      WRITE (6,125) TOTAL1,TOTAL2,TOTAL3
  125 FORMAT (/5X,'TOTAL PRODUCTION IN THE WHOLE SYSTEM',44X
     +,F9.1,F11.1,F12.1)
      WRITE (6,135)
```

```
  135 FORMAT (/////40X,'     TRUCK WAITING TIME'//)
      WRITE (6,145)
  145 FORMAT (' ','ASSIGNED',2X,'TRUCK ',3X,'WAIT AT BWE FOR
     +',4X,'WAIT AT MILL FOR',3X,'WAIT FOR DUMPING',3X,'WAIT
     + FOR DUMPING'/' ','ORE BODY',2X,'NUMBER',3X,'LOADING(M
     +INUTES)',3X,'LOADING(MINUTES)',3X,'      ORE(MINUTES)',
     +6X,'WASTE(MINUTES)'/)
      DO 185 IBOD=1,NBODY1
      NN=NTRUCK(IBOD)
      IF (NN.EQ.0) GO TO 185
      DO 165 NTK=1,NN
      TKWTBW(IBOD,NTK)=TKWTBW(IBOD,NTK)/60.
      TKWTTL(IBOD,NTK)=TKWTTL(IBOD,NTK)/60.
      TKWTCR(IBOD,NTK)=TKWTCR(IBOD,NTK)/60.
      TKWTDP(IBOD,NTK)=TKWTDP(IBOD,NTK)/60.
      WAITTK=TKWTBW(IBOD,NTK)+TKWTTL(IBOD,NTK)+TKWTCR(IBOD,N
     +TK)+TKWTDP(IBOD,NTK)
      WRITE (6,155) IBOD,NTK,TKWTBW(IBOD,NTK),TKWTTL(IBOD,NT
     +K),TKWTCR(IBOD,NTK),TKWTDP(IBOD,NTK)
  155 FORMAT (' ',I4,6X,I4,5X,F14.2,5X,F14.2,5X,F14.2,5X,F14
     +.2)
      TKWTBW(IBOD,NTK)=0.
      TKWTTL(IBOD,NTK)=0.
      TKWTCR(IBOD,NTK)=0.
      TKWTDP(IBOD,NTK)=0.
  165 CONTINUE
      WRITE (6,175)
  175 FORMAT ('0')
  185 CONTINUE
C
C ***** BWES
C
  195 WRITE (6,205)
  205 FORMAT (1H1,45X,'BUCKET WHEEL EXCAVATORS OUTPUT STATIS
     +TICS'////)
      DO 415 IBOD=1,NBODY
      WRITE (6,215) IBOD
  215 FORMAT ('0',55X,'ORE BODY',I5//)
      NBB=NBWE(IBOD)
      DO 415 JBWE=1,NBB
      IF (BDIA(IBOD,JBWE).EQ.0) GO TO 415
      BTHEO=(SQRT(4.9*BDIA(IBOD,JBWE)))*60./(3.1416*BDIA(IBO
     +D,JBWE))*0.7*BCOB(IBOD,JBWE)*BNOB(IBOD,JBWE)*60.*BDENS
     +T(IBOD,JBWE,1)
      WRITE (6,225) JBWE
  225 FORMAT ('0',40X,'BUCKET WHEEL EXCAVATOR NUMBER',I4/)
      WRITE (6,235)
  235 FORMAT ('0',40X,'WHEEL SPECIFICATIONS'//)
      WRITE (6,245) BDIA(IBOD,JBWE),BNOB(IBOD,JBWE),BCOB(IBO
     +D,JBWE),BLENBM(IBOD,JBWE),BTHEO
  245 FORMAT (' ',25X,'WHEEL DIAMETER',F20.2,'  METERS'/' ',
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   +25X,'NUMBER OF BUCKETS',F17.0/' ',25X,'BUCKET CAPACITY
   +',F19.2,'  CU.MTS.'/' ',25X,'CUT LENGTH',F24.2,'  METE
   +RS'/' ',25X,'THEORETICAL CAPACITY',F14.2,' TON/HOUR'//
   +)
    WRITE (6,255)
255 FORMAT (/' ',40X,'OPERATING CONDITIONS'/)
    WRITE (6,265)
265 FORMAT ('0',30X,'SP.CUT.RESIS',5X,'INITIAL HEIGHT',3X,
   +'FINAL HEIGHT',3X,'FLOOR SLOPE'/31X,'(KG/CM)',10X,'(ME
   +TER)',14X,'(METER)',7X,'(%)'/)
    NBEN=NBWBEN(IBOD,JBWE)
    DO 285 KC=1,NBEN
    X=1.2*BKRES(LSOIL(IBOD,JBWE,KC))
    Y=0.8*BKRES(LSOIL(IBOD,JBWE,KC))
    WRITE (6,275) KC,Y,X,(BHEIGT(IBOD,JBWE,KC,N),N=1,2)
275 FORMAT (' ',18X,'  BENCH',I3,3X,F4.1,'--',F5.1,F12.2,F
   +17.2)
285 CONTINUE
    WRITE (6,295) BGRADE(IBOD,JBWE)
295 FORMAT (80X,F7.3)
    WRITE (6,305)
305 FORMAT (///50X,'PRODUCTION STUDY'/)
    ACTU=(PRODTB(IBOD,JBWE,1)+PRODTB(IBOD,JBWE,2))/(BWCTSH
   +(IBOD,JBWE)/3600.)
    WRITE (6,315) PRODTB(IBOD,JBWE,1),PRODTB(IBOD,JBWE,2),
   +ACTU
315 FORMAT (' ',30X,'ORE EXCAVATED',F22.2,'  TONS'/' ',30X
   +,'WASTE EXCAVATED',F20.2,'  TONS'/' ',30X,'ACTUAL CAPA
   +CITY',F19.2,' TONS PER HOUR')
    PRBWE=PRODTB(IBOD,JBWE,1)+PRODTB(IBOD,JBWE,2)
    PRODTB(IBOD,JBWE,1)=0.
    PRODTB(IBOD,JBWE,2)=0.
    WRITE (6,325)
325 FORMAT (///50X,'TIME STUDY'/)
    WRITE (6,335)
335 FORMAT (19X,'CUT',17X,'TRAM',10X,'DELAY(WAITING)',4X,'
   +DELAY(MECH.)',6X,'DELAY(OTHER)'/19X,'(MINUTES)',11X,'(
   +MINUTES)',5X,'(MINUTES)',9X,'(MINUTES)',9X,'(MINUTES)'
   +)
    TT6=BPRDOW(IBOD,JBWE)/60.
    TT5=BWTTMD(IBOD,JBWE)/60.
    TT4=BWEWT(IBOD,JBWE)/60.
    TT1=BWCTSH(IBOD,JBWE)/60.
    TT3=BTRAM2(IBOD,JBWE)/60.
    WRITE (6,345) TT1,TT3,TT4,TT5,TT6
345 FORMAT (19X,F8.2,10X,F8.2,6X,F8.2,10X,F8.2,10X,F8.2)
    WTBWE=TT4
    WRITE (6,355)
355 FORMAT (///50X,'POWER CONSUMPTION'/)
    WRITE (6,365)
365 FORMAT (21X,'CUT',10X,'CROWD',11X,'SLEW',8X,'TRAM'/21X
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```
     +,'KWH',11X,'KWH',13X,'KWH',10X,'KWH'/)
      PT1=BDGKWH(IBOD,JBWE)/3600.
      PT2=BTRKWH(IBOD,JBWE)*BWCTSH(IBOD,JBWE)/3600.
      PT3=BSLKWH(IBOD,JBWE)/3600.
      PT5=TRKWH2(IBOD,JBWE)*BTRAM2(IBOD,JBWE)/3600.
      KWHBWE=PT1+PT2+PT3+PT5
      WRITE (6,375) PT1,PT2,PT3,PT5
  375 FORMAT (9X,4F15.2)
      PT6=BDGKWH(IBOD,JBWE)/BWCTSH(IBOD,JBWE)
      PT7=BSLKWH(IBOD,JBWE)/BWCTSH(IBOD,JBWE)
      PT8=(BTRKWH(IBOD,JBWE)+TRKWH2(IBOD,JBWE))/(BTRAM2(IBOD
     +,JBWE)/3600.)
      WRITE (6,385) PT6,PT7,PT8
  385 FORMAT (//20X,'KW RATING OF THE DIGGING MOTOR',F10.1/2
     +0X,'KW RATING OF THE SLEW MOTOR',F12.1/20X,'KW RATING
     +OF THE CRAWLER MOTORS',F9.1)
      BWEWT(IBOD,JBWE)=0.
      BWTTMD(IBOD,JBWE)=0.
      BPRDOW(IBOD,JBWE)=0.
      BTRAM2(IBOD,JBWE)=0.
      BWCTSH(IBOD,JBWE)=0.
      BDGKWH(IBOD,JBWE)=0.
      BSLKWH(IBOD,JBWE)=0.
      BTRKWH(IBOD,JBWE)=0.
      TRKWH2(IBOD,JBWE)=0.
      WRITE (6,395)
  395 FORMAT (////50X,'POSITION OF BUCKET WHEEL EXCAVATOR'/)
      KC=NCTBEN(IBOD,JBWE)
      WRITE (6,405) KC,BWTTHK(IBOD,JBWE)
  405 FORMAT (//40X,'WHEEL IS IN BENCH',I5,'    ADVANCE',F8.2
     +)
  415 CONTINUE
C
C ***** CONVEYORS
C
      IF (NSECIS.EQ.0) GO TO 615
      WRITE (6,435)
  435 FORMAT (1H1,50X,'CONVEYORS OUTPUT STATISTICS'////)
      NSEC=NCSEPG(1)
      K=1
      J=0
      DO 605 IC=1,NCGRP
      IF (NCGRP.EQ.0) GO TO 455
      WRITE (6,445) IC
  445 FORMAT (1H0,'BELT GROUP',I3)
      IF (NCSEPG(IC).EQ.0) GO TO 525
  455 WRITE (6,465)
  465 FORMAT (1H0,5X,'SECTION BELT',4X,'TOTAL TONNAGE',4X,'T
     +ONNAGE CONTRIBUTING',4X,'DOWN TIME FOR OVERLOAD',4X,'D
     +OWN TIME FOR',4X,'DOWN TIME FOR'/1H ,21X,'PRODUCED',9X
     +,'TO OVERLOAD MAIN',8X,'PREVENTION, (MIN)',9X,'NO MINE
```

```
     + CARS',5X,'STOPPED MAIN BELT')
  475 DO 515 JJ=K,NSEC
      J=J+1
      X=(CSEWT(J)-CGRWT(IC))/60.
      IF (ICDISS(J).NE.0) GO TO 485
      Y=0.
      GO TO 495
  485 Y=CSBWTK(ICDISS(J))/60.
  495 Z=CGRWT(IC)/60.
      WRITE (6,505) J,CTWTSC(J),CSEOVL(J),X,Y,Z
  505 FORMAT (1H ,I10,F23.1,F23.2,F26.2,F17.2,F17.2)
      CTWTSC(J)=0.
      CSEOVL(J)=0.
  515 CSEWT(J)=0.
      IF (NCGRP.EQ.0) GO TO 605
  525 LL=NCGRFT(IC)
      WRITE (6,535) IC,CGROVL(IC),(ICGRFT(IC,L),L=1,LL)
  535 FORMAT (1H0,5X,'GROUP',I3,2X,'WAS OVERLOADED',F7.1,2X,
     +'TONS BY GROUPS',5I3///)
      CGROVL(IC)=0.
      IF (CBINCP(IC).LE.0) GO TO 555
      WRITE (6,545) CBINCP(IC),IC,CBNOVF(IC)
  545 FORMAT (1H0,5X,F4.0,2X,'TON OF SURGE AT TAIL OF GROUP'
     +,I3,2X,'WAS OVERLOADED BY',F10.2,2X,'TONS')
      CBNOVF(IC)=0.
  555 IF (ICDISG(IC).EQ.0) GO TO 575
      X=CGRWMC(IC)/60.
      WRITE (6,565) X
  565 FORMAT (1H0,'TOTAL DELAY TIME WAITING FOR EMPTY CAR',F
     +7.2,2X,'MINUTES')
  575 Y=CGRWT(IC)/60.
      WRITE (6,585) Y
  585 FORMAT (1H0,'TOTAL DELAY TIME FOR OVERLOADING PREVENTI
     +ON',F7.2,2X,'MINUTES'///)
      CGRWT(IC)=0.
      IF (IC.NE.NCGRP) GO TO 595
      IF (NSEC.EQ.NSECIS) GO TO 605
      K=NSEC+1
      NSEC=NSECIS
      GO TO 475
  595 IF (NCSEPG(IC+1).EQ.0) GO TO 605
      K=NSEC+1
      NSEC=NCSEPG(IC+1)+K-1
  605 CONTINUE
C *****
C ***** TRAINS
C *****
  615 IF (NUMTRN.EQ.0) GO TO 715
      WRITE (6,625)
  625 FORMAT (1H1,50X,'TRAINS OUTPUT STATISTICS'///)
      DO 665 NLS=1,NUMLDS
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      WRITE (6,635) NLS
  635 FORMAT (1H0,'LOADING STATION',I3)
      II=RCARLD(NLS)
      WRITE (6,645) II
  645 FORMAT (1H0,5X,'TOTAL CARS LOADED',I6)
      RCARLD(NLS)=0.
      X=RLDSDL(NLS)/60.
      WRITE (6,655) X
  655 FORMAT (1H0,5X,'WAIT TIME FOR EMPTY MINE CARS',F7.2,2X
     +,'MINUTES'////)
      RLDSDL(NLS)=0.
  665 CONTINUE
      DO 705 KTR=1,NUMTRN
      WRITE (6,675) KTR
  675 FORMAT (1H0,'TRAIN',I3)
      WRITE (6,685) RTOTLD(KTR)
  685 FORMAT (1H0,5X,'TONNAGE HAULED',F10.1)
      RTOTLD(KTR)=0.
      X=RWTAIN(KTR)/60.
      Y=RWTDIS(KTR)/60.
      WRITE (6,695) X,Y
  695 FORMAT (1H0,5X,'DELAY TIME AT INTERSECTIONS',F7.2,2X,'
     +MINUTES'/1H0,5X,'WAITING FOR DISPATCH TO SECTION',F7.2
     +,2X,'MINUTES')
      RWTAIN(KTR)=0.
      RWTDIS(KTR)=0.
  705 CONTINUE
  715 ISHF=ISHF+1
      IF (ISHF.LE.NSHIFT) GO TO 735
      CALL SAVBAS(IBASE)
      WRITE (6,725) IBASE
  725 FORMAT (1H1,'IBASE FOR NEXT RUN IS',I15)
      STOP
  735 CLOCK=0.
      IBOD=1
      JBWE=1
      NEXTEN(IBOD,JBWE)=0
      RETURN
      END
      SUBROUTINE TRAIN
C
      COMMON /GENIN1/CAPBIN(5),RATMIL(5),CAPMIL(5),DELTT,SHI
     +FTT,CAPHBN(5,15),EQUIVL(5,15),CLOCK,BSURGE(15,2),BWEWT
     +(3,5),TKWTBW(3,30),PRODTB(3,5,2),WASTMV(4,30),TKWTDP(4
     +,30),BINCRU(5),OREMV(4,30),TKWTCR(4,30),CUMWT2(4,30),T
     +KWTTL(4,30),WTTK(4,30)
      COMMON /BWEIN1/BCS(3,5),BLENBM(3,5),BCOB(3,5),BNOB(3,5
     +),BDIA(3,5),BCTMAX(3,5),BWS(3,5),BOWM(3,5),BFRS(3,5),B
     +RS(3,5),BWAVIL(3,5),BDMEAN(3,5),BWLANG(3,5),BWRANG(3,5
     +),BSETTM(3,5),BCAPSG(3,5,2),BKFILL(10),BKRES(10),BRPM(
     +10),BVINC(10),BRORI(3,5),BGRADE(3,5),BPROB(3,5,5),BHEI
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+GT(3,5,5,2),BDENST(3,5,5),BRATIO(3,5,5),BCLOCK(3,5),BP
+RDOW(3,5),BCOUNT(3,5)
 COMMON /BWEIN2/SLPBEN(3,5),BWTMD(3,5),BWECWT(3,5),BWTT
+MD(3,5),BWCTFR(3,5),BWTTHK(3,5),BWFDD(3,5),
+             AGBCWT(3,5),BSLKWH(3,5),BTRKWH(3,5),BWCTS
+H(3,5),EFFM,EFFE,BPOSIT(3,5),BWBACK(3,5),BTRAM2(3,5),T
+RKWH2(3,5),BVLANG(3,5),BVRANG(3,5),BTODOT(3,5),BDTIME(
+3,5),BWIDTH(3,5),BDGKWH(3,5)
 COMMON /TRKIN1/TKMEAN(10),TKGVW(10),TKSPED(10,20),TKRI
+MP(10,20),COSPLM(50,5),COSLOP(50,5),CORDRS(50,5),COSEC
+L(50,5),COOLEN(50),TKDHIL(20),TKTP(10,20),RATFED(15),T
+BKT(10),TKDMT(10),ACELMA,TKAVIL(4,30),TVEL(4,30),TON(4
+,30),TRASEC(4,30),TRAELE(4,30),TBACKT(4,30),TKTDOW(4,3
+0),TKFDD(4,30),TKDOWN(4,30)
 COMMON /BELIN1/CGRLEN(4),CGRSPD(4),CCAPGR(4),CSCLEN(20
+),CSCSPD(20),CSEPLN(4,5),CRATFD(4),CBINCP(4),CSCFDT(20
+),CCPSHB(20),CCAPSC(20),CDISRF(20),CTLBIN(20),CBINFL(4
+),CSESTP(20),CSCDIS(20),CTWTSC(20),CARYSC(20,400),CGRW
+MC(4),CARYGP(4,400),CGSTOP(4),CGRWT(4),CSEWT(20),CSEOV
+L(20),CLDMC(4),CDISMC(4),CGRDIS(4),CGROVL(4),CBNDCH(4)
 COMMON /BELIN2/CBNOVF(4),CSCHDB(20),CSBWTK(20),CSCAVL(
+20),CSCFDD(20),CSDOWN(20),CGPAVL(4),CGPFDD(4),CGDOWN(4
+)
 COMMON /TRNIN1/CARFRI,CARLEN,CARWTE,CARLOD(2),RMAXAC(6
+,2),RDECEL(6,2),RWTLOC(6,2),RLOCFR(6,2),RMEDPT(6),RDVD
+PT(6),              RSPEED(6,2,20),RTRAEF(6,2,20),RCSP
+LM(30,5),RCSLOP(30,5),RCELEL(30,5),RCSECL(30),RATELS(5
+),RTCARL(6)
 COMMON /TRNIN2/RMASS(6),RFRIC(6),RVEL(6),RLEFT(6),RTOT
+WT(6),RTRELE(6),RTRSEC(6),RLDSDL(5),RECAR(5),RSENDE(6)
+,RDLSMN(6),RLOAD(6),RDLALS(6),RARIDP(6),RTLTDP(6),RTWT
+DP(6),RLOADI(6),RDLADP(6),RWTDIS(6),RWTAIN(6),RTOTLD(6
+),RCARLD(6),RTWTLD(6),RAVL(6,2),RFDD(6,2),      RDOWN(
+6,2),RTDOWN(6,2)
 COMMON /GENIN2/IBOD,JBWE,NTK,NEXTEN(3,5),ISHF,NPOCK3(5
+),KTR,NLS,NSC,NBODY,NSHIFT,NDUMP,NCRUSH,NTAIL,NOBSTW(3
+),IBASE,LOCMIL(5),NPOCK2(5),NPOCK4(5),ICRASC(5),ICRASR
+(5),NELEMT(4),NELEMN(4,5),ICRAST(5),LDQUE(15,30),MAXLD
+(15),NEW(15),LODTK(4,30,2),MDMQUE(5,4,30),NEW2(5),MAXD
+PQ(5),MCRQUE(5,4,30),MAXCRQ(5),NEW3(5),MILQUE(5,4,30),
+NGRID
 COMMON /GENIN3/MAXMLQ(5),NEW4(5),LODTK2(4,30),MTR(4,30
+)
 COMMON /BWEIN4/NBWE(3),IASBTS(3,5),NBWBEN(3,5),NCTSET(
+3,5),IBCMAT(3,5),ISET(3,5),ISECT(3,5),LSOIL(3,5,5),NCT
+BEN(3,5)
 COMMON /TRKIN2/NTRUCK(4),KINDT(4,30),NTASBD(15),IASMTT
+(15),IASTTB(15),NPATH(4,15,4,10),IASTHB(15),NCOOSC(50)
+,IASIGN(4,30),NPHTK(4,15,4),NPOCKT(15),NTKDPS,NTKLDS,I
+ASLTW(15),MATER(4,30),ICOOST(4,30),LTCOOR(4,30)
 COMMON /BELIN3/NCGRP,NSECIS,ICDISG(4),NCSEPG(4),NCSCSZ
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     +(20),NCGRSZ(4),IASMTC(20),NCGRFT(4),ICGRFT(4,5),NCGRFB
     +(4),ICGRFB(4,5),ICSTOP(20),ICDISS(20),NARYIG(4),IARYPG
     +(4,5),NARYSC(20),IASCTB(20),IASCHB(4),NGASBD(4),NCASBD
     +(20)
      COMMON /TRNIN3/NUMTRN,NUMLDS,NUTRLT,IASRHB(6),IASRTB(6
     +),MXCRTR(6),NRCOOR,NRCOSC(30),NREDLT(30,5),LGTCON(30,5
     +,5),NRPATH(5,4,10),NPHRL(5,4),MTRASG(6),IASMTR(5),IASR
     +HS(5),NRTDPS,NRASBD(5),NRFIRT(6),NLOCO(6),KMATER(6),IR
     +COOT(6),LRCOOR(6),LREDLT(10),NASGLS(6),LDSCNT(6),MTOTL
     +D(6),KRAVDP(6),NDLBDP(6),NDUMDP(6),NDUMPG(6),MECRLS(5)
C *** SEE WHETHER THE TRAIN IS A LOADED TRIP OR EMPTY TRIP A
C *** WHETHER THIS SUBROUTINE IS THE FIRST TIME BEING ENTERE
      NDUMPG(KTR)=0
      IF (NRFIRT(KTR).NE.0) GO TO 25
      IF (KMATER(KTR).LE.2) GO TO 5
C TRAIN IS AN EMPTY TRIP
      RTONS=CARWTE*MXCRTR(KTR)
      NLOCO(KTR)=2
      GO TO 15
C    TRAIN IS A LOADED TRIP
    5 RTONS=(CARWTE+CARLOD(KMATER(KTR)))*MXCRTR(KTR)
      NLOCO(KTR)=1
   15 RTCARL(KTR)=CARLEN*MXCRTR(KTR)
      RTOTWT(KTR)=RTONS+RWTLOC(KTR,1)+RWTLOC(KTR,2)
      RMASS(KTR)=RTOTWT(KTR)*2000./32.2
      NRFIRT(KTR)=1
C     CALCULATE THE FRICTION OF THE WHOLE TRIP
      RFRIC(KTR)=RWTLOC(KTR,1)*RLOCFR(KTR,1)+RWTLOC(KTR,2)*R
     +LOCFR(KTR,2)+RTONS*CARFRI
C    TURN TRAFFIC LIGHTS ON
      I=NRPATH(NLS,KMATER(KTR),LRCOOR(KTR))
      DO 10 KK=1,5
      IF(LGTCON(I,1,KK).EQ.0) GO TO 10
      LREDLT(LGTCON(I,1,KK))=1
   10 CONTINUE
C    FIND THE AVAILABLE RIMPULL AT SPEED OF TIME T
   25 LL=NLOCO(KTR)
      I=NRPATH(NLS,KMATER(KTR),LRCOOR(KTR))
      IF(LRCOOR(KTR).EQ.NPHRL(NLS,KMATER(KTR))-1) GO TO 30
      L=NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)+2)
      GO TO 32
   30 L=NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)+1)
   32 J=IRCOOT(KTR)
      X=RDOWN(KTR,LL)
      A=RDOWN(KTR,LL)
      B=RFDD(KTR,LL)
      CC=RAVL(KTR,LL)
      CALL PROCES(A,B,CC,IBASE,DELTT)
      RDOWN(KTR,LL)=A
      IF (X.GE.0) GO TO 35
      RTDOWN(KTR,LL)=RTDOWN(KTR,LL)+DELTT
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      RACCEL=0.
      GO TO 175
   35 DO 45 I=1,20
      IF (RVEL(KTR)-RSPEED(KTR,LL,I))  75,65,45
   45 CONTINUE
      WRITE (6,55)
   55 FORMAT ('0','TRAIN SPEED TOO HIGH')
   65 AVILRP=RTRAEF(KTR,LL,I)
      GO TO 85
C   INTERPOLATE THE AVAILABLE RIMPULL
   75 IF (I.EQ.1) GO TO 65
      AVILRP=RTRAEF(KTR,LL,I-1)+(RVEL(KTR)-RSPEED(KTR,LL,I-1
     +))/(RSPEED(KTR,LL,I)-RSPEED(KTR,LL,I-1))*(RTRAEF(KTR,L
     +L,I)-RTRAEF(KTR,LL,I-1))
C   SEE WHETHER THE WHOLE TRIP IS ON THE SAME ELEMENT OF COO
   85 X=RTCARL(KTR)-RLEFT(KTR)
      I=NRPATH(NLS,KMATER(KTR),LRCOOR(KTR))
      IF (LRCOOR(KTR).EQ.NPHRL(NLS,KMATER(KTR))-1) GO TO 95
      L=NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)+2)
      GO TO 105
   95 L=NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)+1)
  105 J=IRCOOT(KTR)
      IF (LRCOOR(KTR).EQ.1) GO TO 115
      K=NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)-2)
  115 IF (RLEFT(KTR).LE.0) GO TO 145
      IF (J.EQ.1) GO TO 125
      HH=RLEFT(KTR)*RCSLOP(I,J-1)+X*RCSLOP(I,J)
      GO TO 135
  125 HH=RLEFT(KTR)*RCSLOP(K,NRCOSC(K))+X*RCSLOP(I,J)
  135 GRADE=HH/RTCARL(KTR)
      GO TO 155
  145 GRADE=RCSLOP(I,J)
  155 IF (GRADE.GE.5.) STOP 130
C     CALCULATE FRICTION FORCE, GRAVITY FORCE, ETC.
      RGFORC=20.0*GRADE*RTOTWT(KTR)
      RSTSTE=RGFORC+RFRIC(KTR)
      RACCEL=(AVILRP-RSTSTE)/RMASS(KTR)
      IF (RACCEL.GT.0.) GO TO 175
C   TRAIN REDUCES SPEED BECAUSE OF SLOPE
      RVEL(KTR)=RVEL(KTR)-0.2*RMAXAC(KTR,NLOCO(KTR))*DELTT
      IF (RVEL(KTR).GE.0) GO TO 25
      WRITE (6,165) I,J
  165 FORMAT (1HO,'AT COORDINATE',I5,' SECTION',I5,' SLOPE T
     +OO LARGE')
      STOP 1030
  175 IF (RACCEL.LE.RMAXAC(KTR,NLOCO(KTR))) GO TO 185
      RACCEL=RMAXAC(KTR,NLOCO(KTR))
C   CALCULATE THE NECESSARY DECELERATION TO SATISFY THE SPEE
C   NEXT ELEMENT
  185 Y=RCELEL(I,J)-RTRELE(KTR)
      S=RVEL(KTR)*DELTT+0.5*RACCEL*DELTT*DELTT
```

```
      YY=RCSPLM(I,J)**2/(2.*RDECEL(KTR,NLOCO(KTR)))
      IF (Y-S.GT.YY) GO TO 325
      IF (J.EQ.NRCOSC(I)) GO TO 205
      IF (NREDLT(I,J+1).EQ.0) GO TO 195
      IF (LREDLT(NREDLT(I,J+1)).EQ.1) GO TO 225
  195 SPDLIM=RCSPLM(I,J+1)
      GO TO 235
  205 IF (NREDLT(L,1).EQ.0) GO TO 215
      IF (LREDLT(NREDLT(L,1)).EQ.1) GO TO 225
  215 SPDLIM=RCSPLM(L,1)
      GO TO 235
  225 SPDLIM=0.
      NDUMPG(KTR)=-1
  235 RACC1=(SPDLIM**2-RVEL(KTR)**2)/(2.*Y)
C    SEE WHETHER THE OTHER TRAIN IS ONE ELEMENT AHEAD
      DO 275 NTR=1,NUMTRN
      IF (KTR.EQ.NTR) GO TO 275
      MLS=MTRASG(NTR)
      MMM=NRPATH(MLS,KMATER(NTR),LRCOOR(NTR))
      IF (MMM.NE.I) GO TO 265
      IF (IRCOOT(NTR).NE.IRCOOT(KTR)+1) GO TO 275
  255 Z=RTRELE(NTR)-RTCARL(NTR)
      YY=RCELEL(I,J)-RTRELE(KTR)+Z
      SPDLIM=RVEL(NTR)
      RACC2=(SPDLIM**2-RVEL(KTR)**2)/(2.*YY)
      GO TO 285
  265 IF (MMM.NE.L) GO TO 275
      IF (IRCOOT(KTR).NE.NRCOSC(I)) GO TO 275
      GO TO 255
  275 CONTINUE
      RACC2=10.E30
  285 IF (RACC1.GT.RACC2) GO TO 295
      RACC=RACC1
      GO TO 305
  295 RACC=RACC2
  305 IF (RACC.GE.-RDECEL(KTR,NLOCO(KTR))) GO TO 315
      RACC=-RDECEL(KTR,NLOCO(KTR))
  315 IF (RACC.GE.RACCEL) GO TO 325
      RACCEL=RACC
  325 RVEL(KTR)=RVEL(KTR)+RACCEL*DELTT
      IF (RVEL(KTR).LE.RCSPLM(I,J)) GO TO 335
      RVEL(KTR)=RCSPLM(I,J)
      RACCEL=(RCSPLM(I,J)-(RVEL(KTR)-RACCEL*DELTT))/DELTT
      GO TO 345
  335 IF (RVEL(KTR).GT.0.) GO TO 345
      RVEL(KTR)=0.
  345 S=RVEL(KTR)*DELTT-0.5*RACCEL*DELTT*DELTT
      IF (S.GE.0.4*DELTT) GO TO 355
      S=0.4*DELTT
  355 RTRELE(KTR)=RTRELE(KTR)+S
      RTRSEC(KTR)=RTRSEC(KTR)+S
```

```
      IF (RLEFT(KTR).LE.0.) GO TO 365
      RLEFT(KTR)=RLEFT(KTR)-S
      IF (RLEFT(KTR).GT.0) GO TO 365
      RLEFT(KTR)=0.
  365 IF (RTRSEC(KTR).GT.RCSECL(I)) GO TO 405
      IF (RTRELE(KTR).LT.RCELEL(I,J)) GO TO 435
      IF (NDUMPG(KTR).EQ.-1) GO TO 395
      RTRELE(KTR)=0.
      IRCOOT(KTR)=IRCOOT(KTR)+1
      IF (IRCOOT(KTR).GT.NRCOSC(I)) GO TO 405
      RLEFT(KTR)=RCELEL(I,J)+RTCARL(KTR)-RTRSEC(KTR)
C   TURN ON TRAFFIC LIGHT TO PREVENT OTHER TRAIN ENTERING
  375 J=IRCOOT(KTR)
      JJ=J-1
      DO 385 KK=1,5
      IF(JJ.LE.0) GO TO 384
      IF(LGTCON(I,JJ,KK).EQ.0) GO TO 384
      LREDLT(LGTCON(I,JJ,KK))=0
  384 IF (LGTCON(I,J,KK).EQ.0) GO TO 385
      LREDLT(LGTCON(I,J,KK))=1
  385 CONTINUE
      RETURN
C   TRAFFIC LIGHT IS ON
  395 RTRELE(KTR)=RTRELE(KTR)-S
      RTRSEC(KTR)=RTRSEC(KTR)-S
      RWTAIN(KTR)=RWTAIN(KTR)+DELTT
      RETURN
  405 IF (NDUMPG(KTR).EQ.-1) GO TO 445
      LRCOOR(KTR)=LRCOOR(KTR)+1
      IRCOOT(KTR)=1
      RTRSEC(KTR)=0.
      RTRELE(KTR)=0.
      RLEFT(KTR)=RTCARL(KTR)
      NRFIRT(KTR)=0
      NDUMPG(KTR)=1
      IF (LRCOOR(KTR).EQ.NPHRL(NLS,KMATER(KTR))) GO TO 415
      I=L
      GO TO 375
  415 RVEL(KTR)=0.
      RLEFT(KTR)=0.
C TURN OFF TRAFFIC LIGHTS
      I=NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)-1)
      JJ=NRCOSC(I)
      DO 425 J=1,JJ
      DO 425 KK=1,5
      IF (LGTCON(I,J,KK).EQ.0) GO TO 425
      LREDLT(LGTCON(I,J,KK))=0
  425 CONTINUE
  435 RETURN
C   TRAFFIC LIGHT IS ON
  445 RTRSEC(KTR)=RTRSEC(KTR)-S
```

```
      RTRELE(KTR)=RTRELE(KTR)-S
      RWTAIN(KTR)=RWTAIN(KTR)+DELTT
      RETURN
      END
C
      SUBROUTINE READER
      LOGICAL*1 DATAT(10)
      COMMON /GENIN1/CAPBIN(5),RATMIL(5),CAPMIL(5),DELTT,SHI
     +FTT,CAPHBN(5,15),EQUIVL(5,15),CLOCK,BSURGE(15,2),BWEWT
     +(3,5),TKWTBW(3,30),PRODTB(3,5,2),WASTMV(4,30),TKWTDP(4
     +,30),BINCRU(5),OREMV(4,30),TKWTCR(4,30),CUMWT2(4,30),T
     +KWTTL(4,30),WTTK(4,30)
      COMMON /BWEIN1/BCS(3,5),BLENBM(3,5),BCOB(3,5),BNOB(3,5
     +),BDIA(3,5),BCTMAX(3,5),BWS(3,5),BOWM(3,5),BFRS(3,5),B
     +RS(3,5),BWAVIL(3,5),BDMEAN(3,5),BWLANG(3,5),BWRANG(3,5
     +),BSETTM(3,5),BCAPSG(3,5,2),BKFILL(10),BKRES(10),BRPM(
     +10),BVINC(10),BRORI(3,5),BGRADE(3,5),BPROB(3,5,5),BHEI
     +GT(3,5,5,2),BDENST(3,5,5),BRATIO(3,5,5),BCLOCK(3,5),BP
     +RDOW(3,5),BCOUNT(3,5)
      COMMON /BWEIN2/SLPBEN(3,5),BWTMD(3,5),BWECWT(3,5),BWTT
     +MD(3,5),BWCTFR(3,5),BWTTHK(3,5),BWFDD(3,5),
     +              AGBCWT(3,5),BSLKWH(3,5),BTRKWH(3,5),BWCTS
     +H(3,5),EFFM,EFFE,BPOSIT(3,5),BWBACK(3,5),BTRAM2(3,5),T
     +RKWH2(3,5),BVLANG(3,5),BVRANG(3,5),BTODOT(3,5),BDTIME(
     +3,5),BWIDTH(3,5),BDGKWH(3,5)
      COMMON /TRKIN1/TKMEAN(10),TKGVW(10),TKSPED(10,20),TKRI
     +MP(10,20),COSPLM(50,5),COSLOP(50,5),CORDRS(50,5),COSEC
     +L(50,5),COOLEN(50),TKDHIL(20),TKTP(10,20),RATFED(15),T
     +BKT(10),TKDMT(10),ACELMA,TKAVIL(4,30),TVEL(4,30),TON(4
     +,30),TRASEC(4,30),TRAELE(4,30),TBACKT(4,30),TKTDOW(4,3
     +0),TKFDD(4,30),TKDOWN(4,30)
      COMMON /BELIN1/CGRLEN(4),CGRSPD(4),CCAPGR(4),CSCLEN(20
     +),CSCSPD(20),CSEPLN(4,5),CRATFD(4),CBINCP(4),CSCFDT(20
     +),CCPSHB(20),CCAPSC(20),CDISRF(20),CTLBIN(20),CBINFL(4
     +),CSESTP(20),CSCDIS(20),CTWTSC(20),CARYSC(20,400),CGRW
     +MC(4),CARYGP(4,400),CGSTOP(4),CGRWT(4),CSEWT(20),CSEOV
     +L(20),CLDMC(4),CDISMC(4),CGRDIS(4),CGROVL(4),CBNDCH(4)
      COMMON /BELIN2/CBNOVF(4),CSCHDB(20),CSBWTK(20),CSCAVL(
     +20),CSCFDD(20),CSDOWN(20),CGPAVL(4),CGPFDD(4),CGDOWN(4
     +)
      COMMON /TRNIN1/CARFRI,CARLEN,CARWTE,CARLOD(2),RMAXAC(6
     +,2),RDECEL(6,2),RWTLOC(6,2),RLOCFR(6,2),RMEDPT(6),RDVD
     +PT(6),                RSPEED(6,2,20),RTRAEF(6,2,20),RCSP
     +LM(30,5),RCSLOP(30,5),RCELEL(30,5),RCSECL(30),RATELS(5
     +),RTCARL(6)
      COMMON /TRNIN2/RMASS(6),RFRIC(6),RVEL(6),RLEFT(6),RTOT
     +WT(6),RTRELE(6),RTRSEC(6),RLDSDL(5),RECAR(5),RSENDE(6)
     +,RDLSMN(6),RLOAD(6),RDLALS(6),RARIDP(6),RTLTDP(6),RTWT
     +DP(6),RLOADI(6),RDLADP(6),RWTDIS(6),RWTAIN(6),RTOTLD(6
     +),RCARLD(6),RTWTLD(6),RAVL(6,2),RFDD(6,2),       RDOWN(
     +6,2),RTDOWN(6,2)
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```
      COMMON /GENIN2/IBOD,JBWE,NTK,NEXTEN(3,5),ISHF,NPOCK3(5
     +),KTR,NLS,NSC,NBODY,NSHIFT,NDUMP,NCRUSH,NTAIL,NOBSTW(3
     +),IBASE,LOCMIL(5),NPOCK2(5),NPOCK4(5),ICRASC(5),ICRASR
     +(5),NELEMT(4),NELEMN(4,5),ICRAST(5),LDQUE(15,30),MAXLD
     +(15),NEW(15),LODTK(4,30,2),MDMQUE(5,4,30),NEW2(5),MAXD
     +PQ(5),MCRQUE(5,4,30),MAXCRQ(5),NEW3(5),MILQUE(5,4,30),
     +NGRID
      COMMON /GENIN3/MAXMLQ(5),NEW4(5),LODTK2(4,30),MTR(4,30
     +)
      COMMON /BWEIN4/NBWE(3),IASBTS(3,5),NBWBEN(3,5),NCTSET(
     +3,5),IBCMAT(3,5),ISET(3,5),ISECT(3,5),LSOIL(3,5,5),NCT
     +BEN(3,5)
      COMMON /TRKIN2/NTRUCK(4),KINDT(4,30),NTASBD(15),IASMTT
     +(15),IASTTB(15),NPATH(4,15,4,10),IASTHB(15),NCOOSC(50)
     +,IASIGN(4,30),NPHTK(4,15,4),NPOCKT(15),NTKDPS,NTKLDS,I
     +ASLTW(15),MATER(4,30),ICOOST(4,30),LTCOOR(4,30)
      COMMON /BELIN3/NCGRP,NSECIS,ICDISG(4),NCSEPG(4),NCSCSZ
     +(20),NCGRSZ(4),IASMTC(20),NCGRFT(4),ICGRFT(4,5),NCGRFB
     +(4),ICGRFB(4,5),ICSTOP(20),ICDISS(20),NARYIG(4),IARYPG
     +(4,5),NARYSC(20),IASCTB(20),IASCHB(4),NGASBD(4),NCASBD
     +(20)
      COMMON /TRNIN3/NUMTRN,NUMLDS,NUTRLT,IASRHB(6),IASRTB(6
     +),MXCRTR(6),NRCOOR,NRCOSC(30),NREDLT(30,5),LGTCON(30,5
     +,5),NRPATH(5,4,10),NPHRL(5,4),MTRASG(6),IASMTR(5),IASR
     +HS(5),NRTDPS,NRASBD(5),NRFIRT(6),NLOCO(6),KMATER(6),IR
     +COOT(6),LRCOOR(6),LREDLT(10),NASGLS(6),LDSCNT(6),MTOTL
     +D(6),KRAVDP(6),NDLBDP(6),NDUMDP(6),NDUMPG(6),MECRLS(5)
C
C
C *** READ IN THE NUMBER OF ORE BODY TO BE SIMULATED,NUMBER
C *** MULTIPLE PRINTER, NUMBER OF BWE IN EACH ORE BODY
C
      READ (5,465) NBODY,NSHIFT,NDUMP,NCRUSH,NTAIL,NGRID
      READ (5,5) IBASE
    5 FORMAT (I10)
      CALL SETBAS(IBASE)
      READ (5,475) DELTT,SHIFTT
      NCGRP=0
      NSECIS=0
C ASSUME THE CAPCITY OF HEAD BIN EQUAL 120 TONS
      NBODY1=NBODY+1
      DO 15 IBOD=1,NBODY1
   15 NTRUCK(IBOD)=0
      NTKDPS=0
      NUTRLT=0
      NTKLDS=0
      NUMLDS=0
      NUMTRN=0
      NRTDPS=0
C
C *** READ DATA OF EACH SUB-MODEL
```

```
C
   25 READ (5,485) (DATAT(I),I=1,10)
      CALL CHCOMP(DATAT,'LAST',4,&35,&55,&35)
   35 WRITE (6,45) (DATAT(I),I=1,10)
   45 FORMAT (' ',10A1)
      GO TO 65
   55 RETURN
C
C *** FIND OUT WHICH SUB-MODEL TO BE READ NEXT
C
   65 CALL CHCOMP(DATAT,'BWES',4,&75,&135,&75)
   75 CALL CHCOMP(DATAT,'CONVEYORS',9,&85,&275,&85)
   85 CALL CHCOMP(DATAT,'TRAINS',6,&95,&355,&95)
   95 CALL CHCOMP(DATAT,'TRUCKS',6,&105,&195,&105)
  105 CALL CHCOMP(DATAT,'OTHERS',6,&115,&435,&115)
  115 WRITE (6,125)
  125 FORMAT (1H1,'THIS IS A BRANCH FOR READING MORE DATA,ER
     +ROR')
      STOP
C
C *****
C***** BWES(BUCKET WHEEL EXCAVATORS) AND BENCH INFORMATIONS
C *****
C
C
C *** READ TOTAL NUMBER OF DIFFERENT SOIL TYPE IN THE SYSTEM
C
  135 READ (5,465) ISOTP
      DO 145 JJ=1,ISOTP
      READ (5,475) BKFILL(JJ),BKRES(JJ),BRPM(JJ),BVINC(JJ)
  145 CONTINUE
      NBODY1=NBODY+1
      DO 175 I=1,NBODY
C
C *** READ OBSERVATION TOWER IN THIS ORE BODY
C
      READ (5,465) NOBSTW(I)
C
C   NUMBER OF BWE IN EACH ORE BODY
C
      READ (5,465) NBWE(I)
      JJ=NBWE(I)
      DO 165 J=1,JJ
C
C   READ BWE CHARACTERISTICS
C
      READ (5,475) BCS(I,J),BLENBM(I,J),BCOB(I,J),BNOB(I,J),
     +BDIA(I,J),BCTMAX(I,J),BWS(I,J),BOWM(I,J)
      IF (BDIA(I,J).EQ.0) GO TO 165
      READ (5,475) BFRS(I,J),BRS(I,J),BDMEAN(I,J),BSETTM(I,J
     +),BWLANG(I,J),BWRANG(I,J),SLPBEN(I,J)
```

```
      READ (5,475) BWAVIL(I,J),BWFDD(I,J)
C
C *** CAPACITY OF SURGE
C
      READ (5,475) (BCAPSG(I,J,K),K=1,2)
C
C   READ SOIL INFORMATION AND CONFIGURATION
C
C
C *** TOTAL BENCHES TO BE CUT
C
      READ (5,465) NBWBEN(I,J)
      MM=NBWBEN(I,J)
C
C *** READ SOIL CHARACTERISTICS AND CONFIGURATION IN THIS BE
C
      DO 155 M=1,MM
      READ (5,475) (BHEIGT(I,J,M,N),N=1,2),BPROB(I,J,M),BDEN
     +ST(I,J,M),BRATIO(I,J,M)
      READ (5,465) LSOIL(I,J,M)
  155 CONTINUE
      READ (5,475) BRORI(I,J),BGRADE(I,J)
  165 CONTINUE
  175 CONTINUE
C
C *** ASSIGN THE BWE TO THE SURGE BIN NUMBER
C
      DO 185 I=1,NBODY
      JJ=NBWE(I)
  185 READ (5,465) (IASBTS(I,J),J=1,JJ)
      GO TO 25
C****** TRUCKS
C *****
C
C
C *** TOTAL DIFFERENT KIND OF TRUCK IN THE SYSTEM AND READ E
C
  195 READ (5,465) NTKSYS
      DO 215 I=1,NTKSYS
      READ (5,495) TKMEAN(I),TKGVW(I),TBKT(I),TKDMT(I),(TKTP
     +(I,J),J=1,20)
      READ (5,475) (TKSPED(I,J),J=1,20)
      READ (5,475) (TKRIMP(I,J),J=1,20)
      DO 205 J=1,20
  205 TKSPED(I,J)=TKSPED(I,J)*5280./3600.
  215 CONTINUE
      READ (5,475) (TKDHIL(II),II=1,20)
      READ (5,475) ACELMA
C
C *** ASSIGN NUMBER AND TYPE OF TRUCK TO EACH ORE BODY
C
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```
      DO 235 IBOD=1,NBODY1
      READ (5,465) NTRUCK(IBOD)
      MTK=NTRUCK(IBOD)
      READ (5,465) (KINDT(IBOD,NTK),NTK=1,MTK)
      DO 225 NTK=1,MTK
  225 READ (5,475) TKAVIL(IBOD,NTK),TKFDD(IBOD,NTK)
  235 CONTINUE
C
C ******
C ***** COORDINATES (PATHS)
C *****
C
C    ASSIGN COORDINATE NUMBER, READ HAULAGE INFORMATIONS FOR
C    A SPECIFIC COORDINATE(INCLUDING SPEED LIMIT,SLOPE,ROAD R
C    SECTION LENGTH, TOTAL LENGTH OF THE COORDINATE)
C
      READ (5,465) NCOOR
      DO 245 I=6,NCOOR
      READ (5,465) NCOOSC(I)
      M=NCOOSC(I)
      READ (5,475) (COSPLM(I,J),J=1,M)
      READ (5,475) (COSLOP(I,J),J=1,M)
      READ (5,475) (CORDRS(I,J),J=1,M)
      READ (5,475) (COSECL(I,J),J=1,M)
      READ (5,475) COOLEN(I)
  245 CONTINUE
C
C *** READ NUMBER OF TRUCK LOADING STATION AND DUMPING STATI
      READ (5,465) NTKDPS,NTKLDS
C ASSIGN TRUCK LOADING STATION TO ORE BODY,
C VALUE OF NTASBD MUST BE SMALLER OR EQUAL TO NBODY
      READ (5,465) (NTASBD(J),J=1,NTKLDS)
C
C *** ASSIGN TRUCK PATH,IF THE TRUCKS ARE FROM THE SAME LOAD
C *** THEY WILL HAVE THE SAME PATH FOR ORE,WASTE AND EMPTY
C *****
      DO 255 J=1,NTKLDS
      I=NTASBD(J)
      DO 255 M=1,4
      READ (5,465) MM,(NPATH(I,J,M,K),K=1,MM)
      NPHTK(I,J,M)=MM
  255 CONTINUE
C
C *** ASSIGN TRUCK TO LOADING STATION
C
      DO 265 I=1,NBODY1
      JJ=NTRUCK(I)
  265 READ (5,465) (IASIGN(I,J),J=1,JJ)
C ASSIGN MATERIAL (ORE=1 AND WASTE=2) TO EACH LOADING STATIO
      READ (5,465) (IASMTT(J),J=1,NTKLDS)
C *** ASSIGN WASTE DUMPING STATION TO EACH LOADING STATION
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```
      READ (5,465) (IASLTW(I),I=1,NTKLDS)
C *** NUMBER THE TAIL BIN (LOADING BIN) FOR EACH LOADING STA
      READ (5,465) (IASTTB(I),I=1,NTKLDS)
C *** NUMBER THE ORE DUMPING BIN FOR EACH LOADING STATION
      READ (5,465) (IASTHB(I),I=1,NTKLDS)
C READ THE LOADING RATE (TON/SEC) AT EACH TRUCK LOADING STAT
      READ (5,475) (RATFED(I),I=1,NTKLDS)
C READ NUMBER OF POCKET AT EACH TRUCK LOADING STATION
      READ (5,465) (NPOCKT(I),I=1,NTKLDS)
C *** READ NUMBER OF POCKETS AT EACH ORE DUMPING STATION
      READ (5,465) (NPOCK3(I),I=1,NTKDPS)
      GO TO 25
C *****
C ***** CONVEYORS
C *****
C *****
  275 READ (5,465) NCGRP,NSECIS
      READ (5,465) (NCSEPG(IC),IC=1,NCGRP)
      READ (5,475) (CGRLEN(IC),IC=1,NCGRP)
      READ (5,475) (CGRSPD(IC),IC=1,NCGRP)
      READ (5,475) (CCAPGR(IC),IC=1,NCGRP)
      READ (5,465) (NCGRSZ(IC),IC=1,NCGRP)
      READ (5,475) (CCAPSC(JC),JC=1,NSECIS)
      READ (5,465) (NCSCSZ(JC),JC=1,NSECIS)
      READ (5,475) (CSCSPD(JC),JC=1,NSECIS)
      READ (5,465) (ICSTOP(JC),JC=1,NSECIS)
      READ (5,475) (CSCLEN(JC),JC=1,NSECIS)
C *** ASSIGN (LOCATE) THE POSITION OF SECTION BELT AND GROUP
      READ (5,465) (NGASBD(IC),IC=1,NCGRP)
      READ (5,465) (NCASBD(I),I=1,NSECIS)
C
C *** READ NUMBER OF HEAD BEN AND TAIL BIN IN THE SYSTEM
C *** ASSIGN THE TAIL BIN TO EACH SECTION BELT AND HEAD BIN
C
      READ (5,465) (IASCTB(I),I=1,NSECIS)
      READ (5,465) (ICDISS(JC),JC=1,NSECIS)
      READ (5,465) (ICDISG(IC),IC=1,NCGRP)
C *** ASSIGN MATERIAL (ORE=1 AND WASTE=2) TO TAIL BIN OF SEC
      READ (5,465) (IASMTC(I),I=1,NSECIS)
C    READ AVAILABILITY(CC) OF EACH BELT AND THE FAILURE DURAT
C    DISTRIBUTION (WORKING DURATION CAN BE OBTAINED FROM STAT
C    TRANSFORMATION Y=CC/1-CC*X)
C    1 = NORMAL DISTRIBUTION 2 PARAMETERS 2 = UNIFORM DISTRIB
      DO 285 JC=1,NSECIS
  285 READ (5,475) CSCAVL(JC),CSCFDD(JC)
      DO 295 IC=1,NCGRP
  295 READ (5,475) CGPAVL(IC),CGPFDD(IC)
C
C *** READ POSITION (FEET) OF SECTION BELTS ALONG MAIN BELT
C *** ASSUMING HEAD OF GROUP I IS 0 FT
C
```

```
      DO 305 IC=1,NCGRP
      KK=NCSEPG(IC)
  305 READ (5,475) (CSEPLN(IC,K),K=1,KK)
C
C *** READ DISCHARGE PLAN OF GROUPS, THE MAIN BELT WHICH HAS
C *** BEEN FEEDED THE TAIL BY OTHER GROUPS AND  MAIN BELTS W
C *** FEED THE SURGE BIN OF THIS GROUP AND BINS CAPACITY
C
      DO 315 I=1,NCGRP
      READ (5,465) NCGRFT(I),(ICGRFT(I,J),J=1,4)
  315 READ (5,505) NCGRFB(I),CRATFD(I),CBINCP(I),(ICGRFB(I,J
     +),J=1,4)
      READ (5,475) (CSCFDT(IC),IC=1,NSECIS)
C
C
C *** AFTER READ CONVEYOR INPUT DATA RETURN TO MAIN PROGRAM
C *** ARRAYS OFR BELTS
C
C
C
C *** CALCULATE ARRAYS FOR BELTS
C
      DO 335 I=1,NCGRP
      IF (NCGRP.EQ.0) GO TO 335
      NARYIG(I)=CGRLEN(I)/CGRSPD(I)/(DELTT/60.)
      JJ=NCSEPG(I)
      IF (JJ.LE.0) GO TO 335
      DO 325 J=1,JJ
      X=CSEPLN(I,J)
      IARYPG(I,J)=X/CGRSPD(I)/(DELTT/60.)
  325 CONTINUE
  335 CONTINUE
      DO 345 K=1,NSECIS
  345 NARYSC(K)=CSCLEN(K)/CSCSPD(K)/(DELTT/60.)
      GO TO 25
C
C *****
C ***** TRAINS
C *****
C
  355 READ (5,465) NUMTRN,NUMLDS,NUTRLT,NRTDPS
      READ (5,475) CARFRI,CARLEN,CARWTE,(CARLOD(I),I=1,2)
      READ (5,475) (RMAXAC(KTR,1),KTR=1,NUMTRN)
      READ (5,475) (RMAXAC(KTR,2),KTR=1,NUMTRN)
      READ (5,475) (RDECEL(KTR,1),KTR=1,NUMTRN)
      READ (5,475) (RDECEL(KTR,2),KTR=1,NUMTRN)
      READ (5,475) (RWTLOC(KTR,1),KTR=1,NUMTRN)
      READ (5,475) (RWTLOC(KTR,2),KTR=1,NUMTRN)
      READ (5,475) (RLOCFR(KTR,1),KTR=1,NUMTRN)
      READ (5,475) (RLOCFR(KTR,2),KTR=1,NUMTRN)
      READ (5,465) (MXCRTR(KTR),KTR=1,NUMTRN)
```

```
      READ (5,475) (RMEDPT(KTR),KTR=1,NUMTRN)
      READ (5,475) (RDVDPT(KTR),KTR=1,NUMTRN)
      READ (5,475) (RATELS(NLS),NLS=1,NUMLDS)
      READ (5,465) (MECRLS(NLS),NLS=1,NUMLDS)
      READ (5,475) (RECAR(NLS),NLS=1,NUMLDS)
      DO 365 KTR=1,NUMTRN
      DO 365 J=1,2
  365 READ (5,475) RAVL(KTR,J),RFDD(KTR,J)
C   READ THE CHARACTERISTIC CURVE (IN TABLE FORM) OF LOCOMOT
      DO 375 KTR=1,NUMTRN
      DO 375 J=1,2
      DO 375 K=1,20
  375 READ (5,475) RSPEED(KTR,J,K),RTRAEF(KTR,J,K)
C   READ THE LAYOUT OF RAILS  GRADE, DISTANCE, COORDINATE NO
C   ELEMENTS IN COORDINATE, TRAFFIC CONTROL LIGHTS AND NO. O
C   TRAFFIC LIGHT
      READ (5,465) NRCOOR
      DO 405 I=6,NRCOOR
      READ (5,465) NRCOSC(I)
      M=NRCOSC(I)
      DO 395 J=1,M
      READ (5,385) RCSPLM(I,J),RCSLOP(I,J),RCELEL(I,J),NREDL
     +T(I,J),(LGTCON(I,J,K),K=1,5)
  385 FORMAT (3F10.2,6I5)
  395 CONTINUE
      READ (5,475) RCSECL(I)
  405 CONTINUE
C   ASSIGN TRAIN PATH, IF TRAINS COME FROM THE SAME LOADING
C   THEY WILL HAVE THE SAME PATH FOR ORE, WASTE, AND EMPTY
      DO 415 J=1,NUMLDS
      DO 415 M=1,4
      READ (5,465) KK,(NRPATH(J,M,K),K=1,KK)
      NPHRL(J,M)=KK
  415 CONTINUE
C   ASSIGN TRAINS TO LOADING STATION
C
C *** READ NUMBER OF TRAIN DUMPING STATION
C *** ASSIGN TRAIN TO LOADING STATIONS AT THE BEGINNING OF S
C *** AND ASSIGN ORE DUMPING STATION TO EACH LOADING STATION
C
      READ (5,465) (MTRASG(KTR),KTR=1,NUMTRN)
C *** NUMBER TRAIN HEAD BIN (ORE DUMPING BIN FOR ITH TRAIN L
      READ (5,465) (IASRHB(I),I=1,NUMLDS)
C *** NUMBER TAIL BIN (LOADING BIN OF ORE) TO ITH TRAIN LOAD
      READ (5,465) (IASRTB(I),I=1,NUMLDS)
C
C *** ASSIGN (LOCATE) THE POSITION OF TRAIN LOADING STATION
      READ (5,465) (NRASBD(NLS),NLS=1,NUMLDS)
C *** ASSIGN MATERIAL AT EACH LOADING STATION FOR TRAIN
C *** ORE = 1  WASTE = 2
C
```

```
      READ (5,465) (IASMTR(LD),LD=1,NUMLDS)
C   CONVERT ACCEL. FROM MILE/HR/SEC TO FT/SEC/SEC
      DO 425 I=1,NUMTRN
      DO 425 J=1,2
  425 RMAXAC(I,J)=RMAXAC(I,J)*5280./3600.
      GO TO 25
C *****
C ***** GENGEAL INPUT DATA
C *****
C
C *** THERE ARE MORE THAN 48 POSSIBLE COMBINATIONS IN TRANSP
C *** MATERIAL FROM BWE TO CRUSHER   SO THAT SOME SIMPLIFICA
C *** 1. ASSUME THAT IF THE TRANSPORTATION MEDUMM IS LOADED
C ***    IT HAS TO GO DIRECTLY TO DUMPING FACILITY
C *** 2. DEFIN BWE=1, TRUCK=2, TRAIN=3, CONVEYOR=4,CRUSHER=5
C
C
C *** READ NUMBER OF TRANSPRRTATION MEDIUM (LESS THAN 6) IN
C *** SYSTEM AND ASSIGN THEN TO ORDER FOR EXAMPLE 1 4 3 5
C *** MEANS FROM BWE TO CONVETOR TO TRAIN TO CRUSHER
C
  435 DO 445 IBOD=1,NBODY
      READ (5,465) KK,(NELEMN(IBOD,K),K=1,KK)
  445 NELEMT(IBOD)=KK
      DO 455 I=1,5
  455 READ (5,475) (CAPHBN(I,J),J=1,15)
      READ (5,475) (CAPMIL(I),I=1,NCRUSH)
      READ (5,475) (RATMIL(I),I=1,NCRUSH)
      READ (5,465) (NPOCK2(I),I=1,NDUMP)
      READ (5,465) (NPOCK4(I),I=1,NCRUSH)
C ***
C *** ASSIGN THE CRUSHER TO EACH ORE BODY
C ***
      READ (5,465) (LOCMIL(MIL),MIL=1,NBODY)
C
C *** ASSIGN THE RELATION BETWEEN CRUSHER AND BINS OF TAILIN
C
C ASSIGN TAIL BIN OF SECTION BELT TO CRUSHER
      READ (5,465) (ICRASC(I),I=1,NCRUSH)
C ASSIGN TRAIN LOADING STATION TO CRUSHER
      READ (5,465) (ICRASR(I),I=1,NCRUSH)
C ASSIGN TRUCK LOADING STATION TO CRUSHER
      READ (5,465) (ICRAST(I),I=1,NCRUSH)
      GO TO 25
  465 FORMAT (16I5)
  475 FORMAT (8F10.2)
  485 FORMAT (10A1)
  495 FORMAT (4F10.2,20A1)
  505 FORMAT (I10,2F10.2,4I10)
      END
      SUBROUTINE TRUCK
```

```
C
      COMMON /GENIN1/CAPBIN(5),RATMIL(5),CAPMIL(5),DELTT,SHI
     +FTT,CAPHBN(5,15),EQUIVL(5,15),CLOCK,BSURGE(15,2),BWEWT
     +(3,5),TKWTBW(3,30),PRODTB(3,5,2),WASTMV(4,30),TKWTDP(4
     +,30),BINCRU(5),OREMV(4,30),TKWTCR(4,30),CUMWT2(4,30),T
     +KWTTL(4,30),WTTK(4,30)
      COMMON /BWEIN1/BCS(3,5),BLENBM(3,5),BCOB(3,5),BNOB(3,5
     +),BDIA(3,5),BCTMAX(3,5),BWS(3,5),BOWM(3,5),BFRS(3,5),B
     +RS(3,5),BWAVIL(3,5),BDMEAN(3,5),BWLANG(3,5),BWRANG(3,5
     +),BSETTM(3,5),BCAPSG(3,5,2),BKFILL(10),BKRES(10),BRPM(
     +10),BVINC(10),BRORI(3,5),BGRADE(3,5),BPROB(3,5,5),BHEI
     +GT(3,5,5,2),BDENST(3,5,5),BRATIO(3,5,5),BCLOCK(3,5),BP
     +RDOW(3,5),BCOUNT(3,5)
      COMMON /BWEIN2/SLPBEN(3,5),BWTMD(3,5),BWECWT(3,5),BWTT
     +MD(3,5),BWCTFR(3,5),BWTTHK(3,5),BWFDD(3,5),
     +               AGBCWT(3,5),BSLKWH(3,5),BTRKWH(3,5),BWCTS
     +H(3,5),EFFM,EFFE,BPOSIT(3,5),BWBACK(3,5),BTRAM2(3,5),T
     +RKWH2(3,5),BVLANG(3,5),BVRANG(3,5),BTODOT(3,5),BDTIME(
     +3,5),BWIDTH(3,5),BDGKWH(3,5)
      COMMON /TRKIN1/TKMEAN(10),TKGVW(10),TKSPED(10,20),TKRI
     +MP(10,20),COSPLM(50,5),COSLOP(50,5),CORDRS(50,5),COSEC
     +L(50,5),COOLEN(50),TKDHIL(20),TKTP(10,20),RATFED(15),T
     +BKT(10),TKDMT(10),ACELMA,TKAVIL(4,30),TVEL(4,30),TON(4
     +,30),TRASEC(4,30),TRAELE(4,30),TBACKT(4,30),TKTDOW(4,3
     +0),TKFDD(4,30),TKDOWN(4,30)
      COMMON /BELIN1/CGRLEN(4),CGRSPD(4),CCAPGR(4),CSCLEN(20
     +),CSCSPD(20),CSEPLN(4,5),CRATFD(4),CBINCP(4),CSCFDT(20
     +),CCPSHB(20),CCAPSC(20),CDISRF(20),CTLBIN(20),CBINFL(4
     +),CSESTP(20),CSCDIS(20),CTWTSC(20),CARYSC(20,400),CGRW
     +MC(4),CARYGP(4,400),CGSTOP(4),CGRWT(4),CSEWT(20),CSEOV
     +L(20),CLDMC(4),CDISMC(4),CGRDIS(4),CGROVL(4),CBNDCH(4)
      COMMON /BELIN2/CBNOVF(4),CSCHDB(20),CSBWTK(20),CSCAVL(
     +20),CSCFDD(20),CSDOWN(20),CGPAVL(4),CGPFDD(4),CGDOWN(4
     +)
      COMMON /TRNIN1/CARFRI,CARLEN,CARWTE,CARLOD(2),RMAXAC(6
     +,2),RDECEL(6,2),RWTLOC(6,2),RLOCFR(6,2),RMEDPT(6),RDVD
     +PT(6),                RSPEED(6,2,20),RTRAEF(6,2,20),RCSP
     +LM(30,5),RCSLOP(30,5),RCELEL(30,5),RCSECL(30),RATELS(5
     +),RTCARL(6)
      COMMON /TRNIN2/RMASS(6),RFRIC(6),RVEL(6),RLEFT(6),RTOT
     +WT(6),RTRELE(6),RTRSEC(6),RLDSDL(5),RECAR(5),RSENDE(6)
     +,RDLSMN(6),RLOAD(6),RDLALS(6),RARIDP(6),RTLTDP(6),RTWT
     +DP(6),RLOADI(6),RDLADP(6),RWTDIS(6),RWTAIN(6),RTOTLD(6
     +),RCARLD(6),RTWTLD(6),RAVL(6,2),RFDD(6,2),       RDOWN(
     +6,2),RTDOWN(6,2)
      COMMON /GENIN2/IBOD,JBWE,NTK,NEXTEN(3,5),ISHF,NPOCK3(5
     +),KTR,NLS,NSC,NBODY,NSHIFT,NDUMP,NCRUSH,NTAIL,NOBSTW(3
     +),IBASE,LOCMIL(5),NPOCK2(5),NPOCK4(5),ICRASC(5),ICRASR
     +(5),NELEMT(4),NELEMN(4,5),ICRAST(5),LDQUE(15,30),MAXLD
     +(15),NEW(15),LODTK(4,30,2),MDMQUE(5,4,30),NEW2(5),MAXD
     +PQ(5),MCRQUE(5,4,30),MAXCRQ(5),NEW3(5),MILQUE(5,4,30),
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     +NGRID
      COMMON /GENIN3/MAXMLQ(5),NEW4(5),LODTK2(4,30),MTR(4,30
     +)
      COMMON /BWEIN4/NBWE(3),IASBTS(3,5),NBWBEN(3,5),NCTSET(
     +3,5),IBCMAT(3,5),ISET(3,5),ISECT(3,5),LSOIL(3,5,5),NCT
     +BEN(3,5)
      COMMON /TRKIN2/NTRUCK(4),KINDT(4,30),NTASBD(15),IASMTT
     +(15),IASTTB(15),NPATH(4,15,4,10),IASTHB(15),NCOOSC(50)
     +,IASIGN(4,30),NPHTK(4,15,4),NPOCKT(15),NTKDPS,NTKLDS,I
     +ASLTW(15),MATER(4,30),ICOOST(4,30),LTCOOR(4,30)
      COMMON /BELIN3/NCGRP,NSECIS,ICDISG(4),NCSEPG(4),NCSCSZ
     +(20),NCGRSZ(4),IASMTC(20),NCGRFT(4),ICGRFT(4,5),NCGRFB
     +(4),ICGRFB(4,5),ICSTOP(20),ICDISS(20),NARYIG(4),IARYPG
     +(4,5),NARYSC(20),IASCTB(20),IASCHB(4),NGASBD(4),NCASBD
     +(20)
      COMMON /TRNIN3/NUMTRN,NUMLDS,NUTRLT,IASRHB(6),IASRTB(6
     +),MXCRTR(6),NRCOOR,NRCOSC(30),NREDLT(30,5),LGTCON(30,5
     +,5),NRPATH(5,4,10),NPHRL(5,4),MTRASG(6),IASMTR(5),IASR
     +HS(5),NRTDPS,NRASBD(5),NRFIRT(6),NLOCO(6),KMATER(6),IR
     +COOT(6),LRCOOR(6),LREDLT(10),NASGLS(6),LDSCNT(6),MTOTL
     +D(6),KRAVDP(6),NDLBDP(6),NDUMDP(6),NDUMPG(6),MECRLS(5)
C *****
C *****
C *****
C
C *** DECEL CAN BE AN INPUT CONSTANT
C
      IA=0
      DECEL=0.5
      X=TKDOWN(IBOD,NTK)
      A=TKDOWN(IBOD,NTK)
      B=TKFDD(IBOD,NTK)
      CC=TKAVIL(IBOD,NTK)
      CALL PROCES(A,B,CC,IBASE,DELTT)
      TKDOWN(IBOD,NTK)=A
      IF (X.GE.0.) GO TO 5
      TKTDOW(IBOD,NTK)=TKTDOW(IBOD,NTK)+DELTT
      ACCEL=0.
      IA=1
    5 M=MATER(IBOD,NTK)
      LL=ICOOST(IBOD,NTK)
      JBWE=IASIGN(IBOD,NTK)
      K=NPATH(IBOD,JBWE,M,LTCOOR(IBOD,NTK))
      IF (K.LT.6) GO TO 215
      IF (LTCOOR(IBOD,NTK).EQ.1.OR.LTCOOR(IBOD,NTK).EQ.NPHTK
     +(IBOD,JBWE,M)-1) GO TO 15
      K1=NPATH(IBOD,JBWE,M,LTCOOR(IBOD,NTK)+2)
      GO TO 25
   15 K1=NPATH(IBOD,JBWE,M,LTCOOR(IBOD,NTK)+1)
   25 IF (IA.EQ.1) GO TO 105
      KND=KINDT(IBOD,NTK)
```

```
C
C *** FIND THE AVAILABLE RIMPULL OF TRUCK AT THIS TIME INTER
C
   35 DO 45 KK=2,20
      IF (TVEL(IBOD,NTK)-TKSPED(KND,KK))  75,65,45
   45 CONTINUE
C
C
C
      WRITE (6,55)
   55 FORMAT ('0','TRUCK VELOCITY TOO HIGH')
      STOP
   65 AVILRP=TKRIMP(KND,KK)
      GO TO 85
   75 AVILRP=TKRIMP(KND,KK-1)+(TVEL(IBOD,NTK)-TKSPED(KND,KK-
     +1))/(TKSPED(KND,KK)-TKSPED(KND,KK-1))*(TKRIMP(KND,KK)-
     +TKRIMP(KND,KK-1))
C
C *** FROM AVAILABLE RIMPULL FIND THE POSSIBLE ACCELERATION
C
   85 ACCEL=(AVILRP-((COSLOP(K,LL)+CORDRS(K,LL))*20.*TON(IBO
     +D,NTK)))/(TON(IBOD,NTK)*2000./32.2)
      IF (ACCEL.GT.0.) GO TO 95
      TVEL(IBOD,NTK)=TVEL(IBOD,NTK)-0.2*DELTT*DECEL
      IF (TVEL(IBOD,NTK).GE.0.) GO TO 35
      STOP 125
   95 IF (ACCEL.LE.ACELMA) GO TO 105
      ACCEL=ACELMA
C    CALCULATE THE NECESSARY DECELERATION TO SATISFY THE SPEE
C    LIMIT OF NEXT ELEMENT
  105 Y=COSECL(K,LL)-TRAELE(IBOD,NTK)
      S=TVEL(IBOD,NTK)*DELTT+0.5*ACCEL*DELTT*DELTT
      YY=COSPLM(K,LL)**2/(2.*DECEL)
      IF (Y-S.GT.YY) GO TO 135
      IF (LL.LT.NCOOSC(K)) GO TO 115
      SPDLIM=COSPLM(K1,1)
      GO TO 125
  115 SPDLIM=COSPLM(K,LL+1)
  125 DEACC=(SPDLIM*SPDLIM-TVEL(IBOD,NTK)**2)/(2.*Y)
      IF (DEACC.LT.-DECEL)DEACC=-DECEL
      IF (DEACC.GT.ACCEL) GO TO 135
      ACCEL=DEACC
  135 TVEL(IBOD,NTK)=TVEL(IBOD,NTK)+ACCEL*DELTT
      IF (TVEL(IBOD,NTK).LE.COSPLM(K,LL)) GO TO 155
      TVEL(IBOD,NTK)=COSPLM(K,LL)
      ACCEL=(COSPLM(K,LL)-(TVEL(IBOD,NTK)-ACCEL*DELTT))/DELT
     +T
      GO TO 165
  155 IF (TVEL(IBOD,NTK).GT.0.) GO TO 165
      TVEL(IBOD,NTK)=0.
  165 S=TVEL(IBOD,NTK)*DELTT-0.5*ACCEL*DELTT*DELTT
```

```
      IF (S.GE.0.4*DELTT) GO TO 175
      S=0.4*DELTT
  175 TRASEC(IBOD,NTK)=TRASEC(IBOD,NTK)+S
      TRAELE(IBOD,NTK)=TRAELE(IBOD,NTK)+S
      IF (TRASEC(IBOD,NTK).GE.COOLEN(K)) GO TO 185
      IF (TRAELE(IBOD,NTK).LT.COSECL(K,LL)) GO TO 205
      ICOOST(IBOD,NTK)=ICOOST(IBOD,NTK)+1
      TRAELE(IBOD,NTK)=0.
      GO TO 205
C
C *** TRUCK AT THE INTERSECTION OF TWO COORDINATES
C
  185 LTCOOR(IBOD,NTK)=LTCOOR(IBOD,NTK)+1
      ICOOST(IBOD,NTK)=1
      TRAELE(IBOD,NTK)=0.
      TRASEC(IBOD,NTK)=0.
      DO 195 II=1,4
      IF (LTCOOR(IBOD,NTK).NE.NPHTK(IBOD,JBWE,II).OR.LTCOOR(
     +IBOD,NTK)-1.NE.1) GO TO 195
      TVEL(IBOD,NTK)=0.
  195 CONTINUE
  205 RETURN
C
C *** TRUCK REACHES THE LOADING OR DUMPING PLACE  MANEUVE TR
C
  215 TBACKT(IBOD,NTK)=TBACKT(IBOD,NTK)+DELTT
      RETURN
      END
C
      SUBROUTINE OBSTOW
C
C
C ***
C *** OBSERVATION TOWER TO CONTROL THE PATH OF TRUCKS
C ***
      COMMON /GENIN1/CAPBIN(5),RATMIL(5),CAPMIL(5),DELTT,SHI
     +FTT,CAPHBN(5,15),EQUIVL(5,15),CLOCK,BSURGE(15,2),BWEWT
     +(3,5),TKWTBW(3,30),PRODTB(3,5,2),WASTMV(4,30),TKWTDP(4
     +,30),BINCRU(5),OREMV(4,30),TKWTCR(4,30),CUMWT2(4,30),T
     +KWTTL(4,30),WTTK(4,30)
      COMMON /BWEIN1/BCS(3,5),BLENBM(3,5),BCOB(3,5),BNOB(3,5
     +),BDIA(3,5),BCTMAX(3,5),BWS(3,5),BOWM(3,5),BFRS(3,5),B
     +RS(3,5),BWAVIL(3,5),BDMEAN(3,5),BWLANG(3,5),BWRANG(3,5
     +),BSETTM(3,5),BCAPSG(3,5,2),BKFILL(10),BKRES(10),BRPM(
     +10),BVINC(10),BRORI(3,5),BGRADE(3,5),BPROB(3,5,5),BHEI
     +GT(3,5,5,2),BDENST(3,5,5),BRATIO(3,5,5),BCLOCK(3,5),BP
     +RDOW(3,5),BCOUNT(3,5)
      COMMON /BWEIN2/SLPBEN(3,5),BWTMD(3,5),BWECWT(3,5),BWTT
     +MD(3,5),BWCTFR(3,5),BWTTHK(3,5),BWFDD(3,5),
     +             AGBCWT(3,5),BSLKWH(3,5),BTRKWH(3,5),BWCTS
     +H(3,5),EFFM,EFFE,BPOSIT(3,5),BWBACK(3,5),BTRAM2(3,5),T
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+RKWH2(3,5),BVLANG(3,5),BVRANG(3,5),BTODOT(3,5),BDTIME(
+3,5),BWIDTH(3,5),BDGKWH(3,5)
 COMMON /TRKIN1/TKMEAN(10),TKGVW(10),TKSPED(10,20),TKRI
+MP(10,20),COSPLM(50,5),COSLOP(50,5),CORDRS(50,5),COSEC
+L(50,5),CODLEN(50),TKDHIL(20),TKTP(10,20),RATFED(15),T
+BKT(10),TKDMT(10),ACELMA,TKAVIL(4,30),TVEL(4,30),TON(4
+,30),TRASEC(4,30),TRAELE(4,30),TBACKT(4,30),TKTDOW(4,3
+0),TKFDD(4,30),TKDOWN(4,30)
 COMMON /BELIN1/CGRLEN(4),CGRSPD(4),CCAPGR(4),CSCLEN(20
+),CSCSPD(20),CSEPLN(4,5),CRATFD(4),CBINCP(4),CSCFDT(20
+),CCPSHB(20),CCAPSC(20),CDISRF(20),CTLBIN(20),CBINFL(4
+),CSESTP(20),CSCDIS(20),CTWTSC(20),CARYSC(20,400),CGRW
+MC(4),CARYGP(4,400),CGSTOP(4),CGRWT(4),CSEWT(20),CSEOV
+L(20),CLDMC(4),CDISMC(4),CGRDIS(4),CGROVL(4),CBNDCH(4)
 COMMON /BELIN2/CBNOVF(4),CSCHDB(20),CSBWTK(20),CSCAVL(
+20),CSCFDD(20),CSDOWN(20),CGPAVL(4),CGPFDD(4),CGDOWN(4
+)
 COMMON /TRNIN1/CARFRI,CARLEN,CARWTE,CARLOD(2),RMAXAC(6
+,2),RDECEL(6,2),RWTLOC(6,2),RLOCFR(6,2),RMEDPT(6),RDVD
+PT(6),              RSPEED(6,2,20),RTRAEF(6,2,20),RCSP
+LM(30,5),RCSLOP(30,5),RCELEL(30,5),RCSECL(30),RATELS(5
+),RTCARL(6)
 COMMON /TRNIN2/RMASS(6),RFRIC(6),RVEL(6),RLEFT(6),RTOT
+WT(6),RTRELE(6),RTRSEC(6),RLDSDL(5),RECAR(5),RSENDE(6)
+,RDLSMN(6),RLOAD(6),RDLALS(6),RARIDP(6),RTLTDP(6),RTWT
+DP(6),RLOADI(6),RDLADP(6),RWTDIS(6),RWTAIN(6),RTOTLD(6
+),RCARLD(6),RTWTLD(6),RAVL(6,2),RFDD(6,2),        RDOWN(
+6,2),RTDOWN(6,2)
 COMMON /GENIN2/IBOD,JBWE,NTK,NEXTEN(3,5),ISHF,NPOCK3(5
+),KTR,NLS,NSC,NBODY,NSHIFT,NDUMP,NCRUSH,NTAIL,NOBSTW(3
+),IBASE,LOCMIL(5),NPOCK2(5),NPOCK4(5),ICRASC(5),ICRASR
+(5),NELEMT(4),NELEMN(4,5),ICRAST(5),LDQUE(15,30),MAXLD
+(15),NEW(15),LODTK(4,30,2),MDMQUE(5,4,30),NEW2(5),MAXD
+PQ(5),MCRQUE(5,4,30),MAXCRQ(5),NEW3(5),MILQUE(5,4,30),
+NGRID
 COMMON /GENIN3/MAXMLQ(5),NEW4(5),LODTK2(4,30),MTR(4,30
+)
 COMMON /BWEIN4/NBWE(3),IASBTS(3,5),NBWBEN(3,5),NCTSET(
+3,5),IBCMAT(3,5),ISET(3,5),ISECT(3,5),LSOIL(3,5,5),NCT
+BEN(3,5)
 COMMON /TRKIN2/NTRUCK(4),KINDT(4,30),NTASBD(15),IASMTT
+(15),IASTTB(15),NPATH(4,15,4,10),IASTHB(15),NCOOSC(50)
+,IASIGN(4,30),NPHTK(4,15,4),NPOCKT(15),NTKDPS,NTKLDS,I
+ASLTW(15),MATER(4,30),ICOOST(4,30),LTCOOR(4,30)
 COMMON /BELIN3/NCGRP,NSECIS,ICDISG(4),NCSEPG(4),NCSCSZ
+(20),NCGRSZ(4),IASMTC(20),NCGRFT(4),ICGRFT(4,5),NCGRFB
+(4),ICGRFB(4,5),ICSTOP(20),ICDISS(20),NARYIG(4),IARYPG
+(4,5),NARYSC(20),IASCTB(20),IASCHB(4),NGASBD(4),NCASBD
+(20)
 COMMON /TRNIN3/NUMTRN,NUMLDS,NUTRLT,IASRHB(6),IASRTB(6
+),MXCRTR(6),NRCOOR,NRCOSC(30),NREDLT(30,5),LGTCON(30,5
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```
     +,5),NRPATH(5,4,10),NPHRL(5,4),MTRASG(6),IASMTR(5),IASR
     +HS(5),NRTDPS,NRASBD(5),NRFIRT(6),NLOCO(6),KMATER(6),IR
     +COOT(6),LRCOOR(6),LREDLT(10),NASGLS(6),LDSCNT(6),MTOTL
     +D(6),KRAVDP(6),NDLBDP(6),NDUMDP(6),NDUMPG(6),MECRLS(5)
      NTK=0
    5 NTK=NTK+1
      IF (NTK.GT.NTRUCK(IBOD)) RETURN
      JBWE=IASIGN(IBOD,NTK)
C
C *** TRUCK IS EMPTY AND ON THE HAUL ROAD
C
C *** THIS TRUCK IS FROM THE LOADING STATION WHICH HAS NO MA
C
      IF (LTCOOR(IBOD,NTK).EQ.NPHTK(IBOD,JBWE,MATER(IBOD,NTK
     +))-1) GO TO 5
C
C ** THIS TRUCK IS AT THE LAST COORDINATE OF THE PATH NO NEW
C
C
      IF (NPATH(IBOD,JBWE,MATER(IBOD,NTK),LTCOOR(IBOD,NTK)).
     +LE.4) GO TO 5
      IF (MATER(IBOD,NTK).LE.2) GO TO 5
C *** THIS TIME OR THERE ARE TOO MANY TRUCKS WAITING
      NN=NELEMT(IBOD)
      DO 15 II=1,NN
      IF (NELEMN(IBOD,II).EQ.2) GO TO 25
   15 CONTINUE
      STOP 80
   25 IF (EQUIVL(II-1,JJ).LT.1.) GO TO 35
      IF (MAXLD(JJ).LT.2) GO TO 5
   35 JBWE=0
   45 JBWE=JBWE+1
      IF (JBWE.GT.NTKLDS) GO TO 5
      IF (NTASBD(JBWE).NE.IBOD) GO TO 45
      IF (MAXLD(JJ).GE.2) GO TO 45
C
C *** ASSIGN TRUCK PATH
C
      JJ=IASIGN(IBOD,NTK)
      IF (JBWE.EQ.JJ) GO TO 45
      NPK=NPHTK(IBOD,JBWE,MATER(IBOD,NTK))
      DO 55 I=1,NPK
      IF (NPATH(IBOD,JJ,MATER(IBOD,NTK),LTCOOR(IBOD,NTK)).EQ
     +.NPATH(IBOD,JBWE,MATER(IBOD,NTK),I)) GO TO 65
   55 CONTINUE
C
C *** TRUCK ALREADY PASSED THIS BWE  FINDING ANOTHER TRUCK
C
      GO TO 5
C
C *** IF ONE TRUCK ALREADY REASSIGNED TO THIS LOADING STATIO
```

```
C *** WILL BE REASSIGNED TO THIS BWE
C
   65 IF (EQUIVL(II-1,JJ).EQ.0) GO TO 45
C
C *** TRUCK BEING ASSIGNED A NEW PATH
      LTCOOR(IBOD,NTK)=I
      IASN=IASIGN(IBOD,NTK)
      IASIGN(IBOD,NTK)=JBWE
      WRITE (6,75) NTK,IBOD,IASN,IASIGN(IBOD,NTK)
   75 FORMAT (' ',I4,' TRUCK FROM',I3,' ORE BODY ORIGINAL AS
     +SIGNED TO',I3,' BWE AT THIS TIME REASIGNED TO ',I3,' B
     +WE')
      EQUIVL(II-1,JJ)=0.
      GO TO 5
      END
C
      SUBROUTINE BWECUT
C
      COMMON /GENIN1/CAPBIN(5),RATMIL(5),CAPMIL(5),DELTT,SHI
     +FTT,CAPHBN(5,15),EQUIVL(5,15),CLOCK,BSURGE(15,2),BWEWT
     +(3,5),TKWTBW(3,30),PRODTB(3,5,2),WASTMV(4,30),TKWTDP(4
     +,30),BINCRU(5),OREMV(4,30),TKWTCR(4,30),CUMWT2(4,30),T
     +KWTTL(4,30),WTTK(4,30)
      COMMON /BWEIN1/BCS(3,5),BLENBM(3,5),BCOB(3,5),BNOB(3,5
     +),BDIA(3,5),BCTMAX(3,5),BWS(3,5),BOWM(3,5),BFRS(3,5),B
     +RS(3,5),BWAVIL(3,5),BDMEAN(3,5),BWLANG(3,5),BWRANG(3,5
     +),BSETTM(3,5),BCAPSG(3,5,2),BKFILL(10),BKRES(10),BRPM(
     +10),BVINC(10),BRORI(3,5),BGRADE(3,5),BPROB(3,5,5),BHEI
     +GT(3,5,5,2),BDENST(3,5,5),BRATIO(3,5,5),BCLOCK(3,5),BP
     +RDOW(3,5),BCOUNT(3,5)
      COMMON /BWEIN2/SLPBEN(3,5),BWTMD(3,5),BWECWT(3,5),BWTT
     +MD(3,5),BWCTFR(3,5),BWTTHK(3,5),BWFDD(3,5),
     +               AGBCWT(3,5),BSLKWH(3,5),BTRKWH(3,5),BWCTS
     +H(3,5),EFFM,EFFE,BPOSIT(3,5),BWBACK(3,5),BTRAM2(3,5),T
     +RKWH2(3,5),BVLANG(3,5),BVRANG(3,5),BTODOT(3,5),BDTIME(
     +3,5),BWIDTH(3,5),BDGKWH(3,5)
      COMMON /TRKIN1/TKMEAN(10),TKGVW(10),TKSPED(10,20),TKRI
     +MP(10,20),COSPLM(50,5),COSLOP(50,5),CORDRS(50,5),COSEC
     +L(50,5),COOLEN(50),TKDHIL(20),TKTP(10,20),RATFED(15),T
     +BKT(10),TKDMT(10),ACELMA,TKAVIL(4,30),TVEL(4,30),TON(4
     +,30),TRASEC(4,30),TRAELE(4,30),TBACKT(4,30),TKTDOW(4,3
     +0),TKFDD(4,30),TKDOWN(4,30)
      COMMON /BELIN1/CGRLEN(4),CGRSPD(4),CCAPGR(4),CSCLEN(20
     +),CSCSPD(20),CSEPLN(4,5),CRATFD(4),CBINCP(4),CSCFDT(20
     +),CCPSHB(20),CCAPSC(20),CDISRF(20),CTLBIN(20),CBINFL(4
     +),CSESTP(20),CSCDIS(20),CTWTSC(20),CARYSC(20,400),CGRW
     +MC(4),CARYGP(4,400),CGSTOP(4),CGRWT(4),CSEWT(20),CSEOV
     +L(20),CLDMC(4),CDISMC(4),CGRDIS(4),CGROVL(4),CBNDCH(4)
      COMMON /BELIN2/CBNOVF(4),CSCHDB(20),CSBWTK(20),CSCAVL(
     +20),CSCFDD(20),CSDOWN(20),CGPAVL(4),CGPFDD(4),CGDOWN(4
     +)
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```
      COMMON /TRNIN1/CARFRI,CARLEN,CARWTE,CARLOD(2),RMAXAC(6
     +,2),RDECEL(6,2),RWTLOC(6,2),RLOCFR(6,2),RMEDPT(6),RDVD
     +PT(6),                 RSPEED(6,2,20),RTRAEF(6,2,20),RCSP
     +LM(30,5),RCSLOP(30,5),RCELEL(30,5),RCSECL(30),RATELS(5
     +),RTCARL(6)
      COMMON /TRNIN2/RMASS(6),RFRIC(6),RVEL(6),RLEFT(6),RTOT
     +WT(6),RTRELE(6),RTRSEC(6),RLDSDL(5),RECAR(5),RSENDE(6)
     +,RDLSMN(6),RLOAD(6),RDLALS(6),RARIDP(6),RTLTDP(6),RTWT
     +DP(6),RLOADI(6),RDLADP(6),RWTDIS(6),RWTAIN(6),RTOTLD(6
     +),RCARLD(6),RTWTLD(6),RAVL(6,2),RFDD(6,2),       RDOWN(
     +6,2),RTDOWN(6,2)
      COMMON /GENIN2/IBOD,JBWE,NTK,NEXTEN(3,5),ISHF,NPOCK3(5
     +),KTR,NLS,NSC,NBODY,NSHIFT,NDUMP,NCRUSH,NTAIL,NOBSTW(3
     +),IBASE,LOCMIL(5),NPOCK2(5),NPOCK4(5),ICRASC(5),ICRASR
     +(5),NELEMT(4),NELEMN(4,5),ICRAST(5),LDQUE(15,30),MAXLD
     +(15),NEW(15),LODTK(4,30,2),MDMQUE(5,4,30),NEW2(5),MAXD
     +PQ(5),MCRQUE(5,4,30),MAXCRQ(5),NEW3(5),MILQUE(5,4,30),
     +NGRID
      COMMON /GENIN3/MAXMLQ(5),NEW4(5),LODTK2(4,30),MTR(4,30
     +)
      COMMON /BWEIN4/NBWE(3),IASBTS(3,5),NBWBEN(3,5),NCTSET(
     +3,5),IBCMAT(3,5),ISET(3,5),ISECT(3,5),LSOIL(3,5,5),NCT
     +BEN(3,5)
      COMMON /TRKIN2/NTRUCK(4),KINDT(4,30),NTASBD(15),IASMTT
     +(15),IASTTB(15),NPATH(4,15,4,10),IASTHB(15),NCOOSC(50)
     +,IASIGN(4,30),NPHTK(4,15,4),NPOCKT(15),NTKDPS,NTKLDS,I
     +ASLTW(15),MATER(4,30),ICOOST(4,30),LTCOOR(4,30)
      COMMON /BELIN3/NCGRP,NSECIS,ICDISG(4),NCSEPG(4),NCSCSZ
     +(20),NCGRSZ(4),IASMTC(20),NCGRFT(4),ICGRFT(4,5),NCGRFB
     +(4),ICGRFB(4,5),ICSTOP(20),ICDISS(20),NARYIG(4),IARYPG
     +(4,5),NARYSC(20),IASCTB(20),IASCHB(4),NGASBD(4),NCASBD
     +(20)
      COMMON /TRNIN3/NUMTRN,NUMLDS,NUTRLT,IASRHB(6),IASRTB(6
     +),MXCRTR(6),NRCOOR,NRCOSC(30),NREDLT(30,5),LGTCON(30,5
     +,5),NRPATH(5,4,10),NPHRL(5,4),MTRASG(6),IASMTR(5),IASR
     +HS(5),NRTDPS,NRASBD(5),NRFIRT(6),NLOCO(6),KMATER(6),IR
     +COOT(6),LRCOOR(6),LREDLT(10),NASGLS(6),LDSCNT(6),MTOTL
     +D(6),KRAVDP(6),NDLBDP(6),NDUMDP(6),NDUMPG(6),MECRLS(5)
C *****
C ***** BUCKET WHEEL EXCAVATOR SUB-MODEL
C *****
C
C
C *** SLEWMX    MAXIMUM SLEW SPEED  CAN BE AN INPUT CONSTANT
C
      SLEWMX=0.35
      X=BWTMD(IBOD,JBWE)
      A=BWTMD(IBOD,JBWE)
      B=BWFDD(IBOD,JBWE)
      CC=BWAVIL(IBOD,JBWE)
      CALL PROCES(A,B,CC,IBASE,DELTT)
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```
      BWTMD(IBOD,JBWE)=A
      IF (X.GE.0.) GO TO 15
      BWTTMD(IBOD,JBWE)=BWTTMD(IBOD,JBWE)+DELTT
      BWECWT(IBOD,JBWE)=0.
      RETURN
C
C *** DETERMINE WHETHER A BENCH CUT OR FALL CUT
C
   15 IF (BWCTFR(IBOD,JBWE).EQ.1.) GO TO 75
C
   25 KC=NCTBEN(IBOD,JBWE)
      IF (BWTTHK(IBOD,JBWE).LT.BCTMAX(IBOD,JBWE)) GO TO 85
      IF (NBWBEN(IBOD,JBWE).NE.KC) GO TO 55
C     THE BWE HAS FINISHED CUTTING ONE GRID POINT
C     THE RESULTS ARE READY TO BE PRINTED OUT
      IF (NGRID.EQ.1) GO TO 45
      NCTBEN(IBOD,JBWE)=0
      GO TO 65
   45 NCTSET(IBOD,JBWE)=0
      BCLOCK(IBOD,JBWE)=CLOCK
      RETURN
C     TRAM THE BWE BACK TO CUT NEXT BENCH
   55 IF (BWBACK(IBOD,JBWE).GE.BWTTHK(IBOD,JBWE)) GO TO 65
      BTRAM2(IBOD,JBWE)=BTRAM2(IBOD,JBWE)+DELTT
      BWBACK(IBOD,JBWE)=BWBACK(IBOD,JBWE)+BCS(IBOD,JBWE)*DEL
     +TT
      TRKWH2(IBOD,JBWE)=TRKWH2(IBOD,JBWE)+(BOWM(IBOD,JBWE)*B
     +RORI(IBOD,JBWE)+BOWM(IBOD,JBWE)/50.*BGRADE(IBOD,JBWE)*
     +BCS(IBOD,JBWE)*DELTT)/(367100.*EFFE*EFFM)
      BWECWT(IBOD,JBWE)=0.
      RETURN
   65 BWBACK(IBOD,JBWE)=0.
      NCTBEN(IBOD,JBWE)=NCTBEN(IBOD,JBWE)+1
C
C *** INITIATE CUTTING POSITION AND SET THE SLOPE OF BENCH
C
      KC=NCTBEN(IBOD,JBWE)
      BVLANG(IBOD,JBWE)=BWLANG(IBOD,JBWE)+(BWRANG(IBOD,JBWE)
     +-BWLANG(IBOD,JBWE))/NBWBEN(IBOD,JBWE)*SLPBEN(IBOD,JBWE
     +)
      BVRANG(IBOD,JBWE)=BWRANG(IBOD,JBWE)-(BWRANG(IBOD,JBWE)
     +-BWLANG(IBOD,JBWE))/NBWBEN(IBOD,JBWE)*SLPBEN(IBOD,JBWE
     +)
      BPOSIT(IBOD,JBWE)=0.
      ISET(IBOD,JBWE)=1
      ISECT(IBOD,JBWE)=1
      BWTTHK(IBOD,JBWE)=0.
      GO TO 85
C     THIS IS A BRANCH FOR THE FALL CUT
   75 BWCTFR(IBOD,JBWE)=0
      GO TO 25
```

```
C
C *** BWE IS CUTTING
C
   85 IF (BCOUNT(IBOD,JBWE).NE.0) GO TO 265
      CF=BPROB(IBOD,JBWE,KC)/DELTT
      CCF=(1.-BPROB(IBOD,JBWE,KC))+CF
      XX=RAND(CCF)
      IF (XX.GT.CF) GO TO 255
   95 JJ=LSOIL(IBOD,JBWE,KC)
  105 X=RAND(1.3)
      IF (X.LT.0.7) GO TO 105
C
C *** GENERATE WHETHER THE MATERIAL BEING CUT IS ORE OR WAST
C ***=1 ORE  =2 WASTE
C
      YY=RAND(1.0)
      IF (YY.GT.BRATIO(IBOD,JBWE,KC)) GO TO 115
      IBCMAT(IBOD,JBWE)=1
      GO TO 125
  115 IBCMAT(IBOD,JBWE)=2
  125 BCAB=BKFILL(JJ)*BCOB(IBOD,JBWE)*BVINC(JJ)
      VMAX=SQRT(0.5*9.8*BDIA(IBOD,JBWE))
      CSPEED=VMAX*BRPM(JJ)
      XFRPM=CSPEED*60./(BDIA(IBOD,JBWE)*3.1416)
      ACP=BCAB*BNOB(IBOD,JBWE)*XFRPM*60.
      THICK=0.133*SQRT(ACP/(0.5*BDIA(IBOD,JBWE)*XFRPM*BNOB(I
     +BOD,JBWE)))
      VOLUME=ACP*DELTT/3600.
      TRUVOL=VOLUME/BVINC(JJ)
C
C**** CALCULATING THE CUTTING THICKNESS, WEIGHT OF CUTTING I
C
      ALPHA=BPOSIT(IBOD,JBWE)/BLENBM(IBOD,JBWE)
      PET=BLENBM(IBOD,JBWE)/THICK
      SNTIK=THICK*(COS(ALPHA)+SIN(ALPHA)*SIN(ALPHA)/(2.*PET)
     +)
      WIDTH=(BLENBM(IBOD,JBWE)*(BWLANG(IBOD,JBWE)+BWRANG(IBO
     +D,JBWE)))
      HEIGT=(BHEIGT(IBOD,JBWE,KC,2)-BHEIGT(IBOD,JBWE,KC,1))/
     +WIDTH
      HEIGT=HEIGT*BWIDTH(IBOD,JBWE)+BHEIGT(IBOD,JBWE,KC,2)
      BBBB=VOLUME/(THICK*HEIGT)
      IF (BBBB.LE.SLEWMX*DELTT) GO TO 135
      BBBB=SLEWMX*DELTT
      VOLUME=THICK*HEIGT*BBBB
  135 BDTH=VOLUME/(SNTIK*HEIGT)
      BWECWT(IBOD,JBWE)=VOLUME*BDENST(IBOD,JBWE,KC)
      AGBCWT(IBOD,JBWE)=BWECWT(IBOD,JBWE)
C
C *** CALCULATING DIGGING POWER, SLEWING POWER
C
```

```
      BETANG=6.2832/BNOB(IBOD,JBWE)
      NNBID=0.25*BNOB(IBOD,JBWE)
C
C *** CALCULATE THE CUTTER LENGTH IN THE BENCH
C
      BLOT=0.
      DO 145 II=1,100
      IF (NNBID.LT.II) GO TO 155
      BLOT=BLOT+2.*THICK*COS(BETANG*II)
  145 CONTINUE
  155 TTTR=1.5708+ATAN((HEIGT-BDIA(IBOD,JBWE)/2.)/(BDIA(IBOD
     +,JBWE)/2.))
      NBID=(TTTR/6.2832)*BNOB(IBOD,JBWE)+0.5
      CUTRES=BKRES(JJ)
      BAT=3.1416*BDIA(IBOD,JBWE)/BNOB(IBOD,JBWE)/CSPEED
      ALOT=2.*THICK*(NBID-NNBID)
      DIGP=CUTRES*(ALOT+BLOT)*100.*3.1416*BDIA(IBOD,JBWE)/BN
     +OB(IBOD,JBWE)
      RISP=BCAB*BDENST(IBOD,JBWE,KC)*1000.*BDIA(IBOD,JBWE)
      TOTPER=(DIGP+RISP)/367100.*(1./BAT)*3600./EFFE/EFFM
      SLP=BBBB/BAT
      FRIFOR=BFRS(IBOD,JBWE)*BWS(IBOD,JBWE)*BRS(IBOD,JBWE)/B
     +LENBM(IBOD,JBWE)
      SLEP=(CUTRES*(ALOT+BLOT)*100.*SLP/CSPEED+FRIFOR)*BBBB
      SLEPKW=SLEP/367100.*3600./BAT/EFFE/EFFM
      BDGKWH(IBOD,JBWE)=BDGKWH(IBOD,JBWE)+TOTPER*DELTT
      BSLKWH(IBOD,JBWE)=BSLKWH(IBOD,JBWE)+SLEPKW*DELTT
      BWCTSH(IBOD,JBWE)=BWCTSH(IBOD,JBWE)+DELTT
C
C *** POSITIONING THE BUCKET IN THE BENCH
C
      IF (ISECT(IBOD,JBWE).NE.1) GO TO 175
      IF (BPOSIT(IBOD,JBWE)-BVLANG(IBOD,JBWE)*BLENBM(IBOD,JB
     +WE))  185,245,245
  175 IF (BPOSIT(IBOD,JBWE)-BVRANG(IBOD,JBWE)*BLENBM(IBOD,JB
     +WE))  185,245,245
C
C
  185 IF (ISET(IBOD,JBWE).NE.0) GO TO 225
      BPOSIT(IBOD,JBWE)=BPOSIT(IBOD,JBWE)-BDTH
      IF (BPOSIT(IBOD,JBWE).GT.0.) RETURN
      IF (ISECT(IBOD,JBWE).EQ.0) GO TO 205
      ISECT(IBOD,JBWE)=0
      GO TO 215
  205 ISECT(IBOD,JBWE)=1
  215 ISET(IBOD,JBWE)=1
      RETURN
  225 BPOSIT(IBOD,JBWE)=BPOSIT(IBOD,JBWE)+BDTH
      RETURN
C
C *** BUCKET REACHES THE RIGHT OR LEFT EDGE LIMIT, CROWD IN
```

```
C
  245 BWTTHK(IBOD,JBWE)=BWTTHK(IBOD,JBWE)+THICK
      BPOSIT(IBOD,JBWE)=BPOSIT(IBOD,JBWE)-BDTH
      ISET(IBOD,JBWE)=0
      BTRAM2(IBOD,JBWE)=BTRAM2(IBOD,JBWE)+THICK/BCS(IBOD,JBW
     +E)
      BTRKWH(IBOD,JBWE)=BTRKWH(IBOD,JBWE)+(BOWM(IBOD,JBWE)*B
     +RORI(IBOD,JBWE)+BOWM(IBOD,JBWE)/50.*BGRADE(IBOD,JBWE)/
     +100.)*THICK/(367100.*EFFE*EFFM)
C
C
      RETURN
C
C *** BWE HITS THE BOULDER
C
  255 BTODOT(IBOD,JBWE)=BDMEAN(IBOD,JBWE)
      BCOUNT(IBOD,JBWE)=1
  265 IF (BDTIME(IBOD,JBWE).GE.BTODOT(IBOD,JBWE)) GO TO 275
      BDTIME(IBOD,JBWE)=BDTIME(IBOD,JBWE)+DELTT
      BPRDOW(IBOD,JBWE)=BPRDOW(IBOD,JBWE)+DELTT
      BWECWT(IBOD,JBWE)=0.
      RETURN
  275 BDTIME(IBOD,JBWE)=0.
      BCOUNT(IBOD,JBWE)=0.
      GO TO 95
      END
C
      SUBROUTINE RTGNDP(A,B,C,IBASE,*,*)
C
C *** DUMPING RATE GENERATOR FOR TRAIN DUMPING
      CALL RANDN(IBASE,RX)
      A=A-(C+B*RX)
      IF (A.GT.0.) RETURN 1
      RETURN 2
      END
C    PROCESS GENERATORS
      SUBROUTINE PROCES(A,B,CC,IBASE,DELTT)
      IF (A.NE.0.) GO TO 25
      X=RAND(1.0)
      IF(X.GT.0.5) GO TO 5
      B=B*CC/(1-CC)
      XX=1
      GO TO 15
    5 XX=-1
   15 A=B*XX
   25 IF (A.LT.0.) GO TO 35
C    THE MACHINE IS WORKING AT THIS TIME INTERVAL
      A=A-DELTT
      IF (A.LE.0.)A=0.
      RETURN
C    THE MACHINE IS DOWN AT DELTT
```

```
   35 A=A+DELTT
      IF (A.GE.0.)A=0.
      RETURN
      END
      SUBROUTINE CONTRL
C
C ***
C *** EXECUTIVE CONTROL SYSTEM
C ***
      COMMON /GENIN1/CAPBIN(5),RATMIL(5),CAPMIL(5),DELTT,SHI
     +FTT,CAPHBN(5,15),EQUIVL(5,15),CLOCK,BSURGE(15,2),BWEWT
     +(3,5),TKWTBW(3,30),PRODTB(3,5,2),WASTMV(4,30),TKWTDP(4
     +,30),BINCRU(5),OREMV(4,30),TKWTCR(4,30),CUMWT2(4,30),T
     +KWTTL(4,30),WTTK(4,30)
      COMMON /BWEIN1/BCS(3,5),BLENBM(3,5),BCOB(3,5),BNOB(3,5
     +),BDIA(3,5),BCTMAX(3,5),BWS(3,5),BOWM(3,5),BFRS(3,5),B
     +RS(3,5),BWAVIL(3,5),BDMEAN(3,5),BWLANG(3,5),BWRANG(3,5
     +),BSETTM(3,5),BCAPSG(3,5,2),BKFILL(10),BKRES(10),BRPM(
     +10),BVINC(10),BRORI(3,5),BGRADE(3,5),BPROB(3,5,5),BHEI
     +GT(3,5,5,2),BDENST(3,5,5),BRATIO(3,5,5),BCLOCK(3,5),BP
     +RDOW(3,5),BCOUNT(3,5)
      COMMON /BWEIN2/SLPBEN(3,5),BWTMD(3,5),BWECWT(3,5),BWTT
     +MD(3,5),BWCTFR(3,5),BWTTHK(3,5),BWFDD(3,5),
     +              AGBCWT(3,5),BSLKWH(3,5),BTRKWH(3,5),BWCTS
     +H(3,5),EFFM,EFFE,BPOSIT(3,5),BWBACK(3,5),BTRAM2(3,5),T
     +RKWH2(3,5),BVLANG(3,5),BVRANG(3,5),BTODOT(3,5),BDTIME(
     +3,5),BWIDTH(3,5),BDGKWH(3,5)
      COMMON /TRKIN1/TKMEAN(10),TKGVW(10),TKSPED(10,20),TKRI
     +MP(10,20),COSPLM(50,5),COSLOP(50,5),CORDRS(50,5),COSEC
     +L(50,5),COOLEN(50),TKDHIL(20),TKTP(10,20),RATFED(15),T
     +BKT(10),TKDMT(10),ACELMA,TKAVIL(4,30),TVEL(4,30),TON(4
     +,30),TRASEC(4,30),TRAELE(4,30),TBACKT(4,30),TKTDOW(4,3
     +0),TKFDD(4,30),TKDOWN(4,30)
      COMMON /BELIN1/CGRLEN(4),CGRSPD(4),CCAPGR(4),CSCLEN(20
     +),CSCSPD(20),CSEPLN(4,5),CRATFD(4),CBINCP(4),CSCFDT(20
     +),CCPSHB(20),CCAPSC(20),CDISRF(20),CTLBIN(20),CBINFL(4
     +),CSESTP(20),CSCDIS(20),CTWTSC(20),CARYSC(20,400),CGRW
     +MC(4),CARYGP(4,400),CGSTOP(4),CGRWT(4),CSEWT(20),CSEOV
     +L(20),CLDMC(4),CDISMC(4),CGRDIS(4),CGROVL(4),CBNDCH(4)
      COMMON /BELIN2/CBNOVF(4),CSCHDB(20),CSBWTK(20),CSCAVL(
     +20),CSCFDD(20),CSDOWN(20),CGPAVL(4),CGPFDD(4),CGDOWN(4
     +)
      COMMON /TRNIN1/CARFRI,CARLEN,CARWTE,CARLOD(2),RMAXAC(6
     +,2),RDECEL(6,2),RWTLOC(6,2),RLOCFR(6,2),RMEDPT(6),RDVD
     +PT(6),                RSPEED(6,2,20),RTRAEF(6,2,20),RCSP
     +LM(30,5),RCSLOP(30,5),RCELEL(30,5),RCSECL(30),RATELS(5
     +),RTCARL(6)
      COMMON /TRNIN2/RMASS(6),RFRIC(6),RVEL(6),RLEFT(6),RTOT
     +WT(6),RTRELE(6),RTRSEC(6),RLDSDL(5),RECAR(5),RSENDE(6)
     +,RDLSMN(6),RLOAD(6),RDLALS(6),RARIDP(6),RTLTDP(6),RTWT
     +DP(6),RLOADI(6),RDLADP(6),RWTDIS(6),RWTAIN(6),RTOTLD(6
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```
      +),RCARLD(6),RTWTLD(6),RAVL(6,2),RFDD(6,2),      RDOWN(
      +6,2),RTDOWN(6,2)
       COMMON /GENIN2/IBOD,JBWE,NTK,NEXTEN(3,5),ISHF,NPOCK3(5
      +),KTR,NLS,NSC,NBODY,NSHIFT,NDUMP,NCRUSH,NTAIL,NOBSTW(3
      +),IBASE,LOCMIL(5),NPOCK2(5),NPOCK4(5),ICRASC(5),ICRASR
      +(5),NELEMT(4),NELEMN(4,5),ICRAST(5),LDQUE(15,30),MAXLD
      +(15),NEW(15),LODTK(4,30,2),MDMQUE(5,4,30),NEW2(5),MAXD
      +PQ(5),MCRQUE(5,4,30),MAXCRQ(5),NEW3(5),MILQUE(5,4,30),
      +NGRID
       COMMON /GENIN3/MAXMLQ(5),NEW4(5),LODTK2(4,30),MTR(4,30
      +)
       COMMON /BWEIN4/NBWE(3),IASBTS(3,5),NBWBEN(3,5),NCTSET(
      +3,5),IBCMAT(3,5),ISET(3,5),ISECT(3,5),LSOIL(3,5,5),NCT
      +BEN(3,5)
       COMMON /TRKIN2/NTRUCK(4),KINDT(4,30),NTASBD(15),IASMTT
      +(15),IASTTB(15),NPATH(4,15,4,10),IASTHB(15),NCOOSC(50)
      +,IASIGN(4,30),NPHTK(4,15,4),NPOCKT(15),NTKDPS,NTKLDS,I
      +ASLTW(15),MATER(4,30),ICOOST(4,30),LTCOOR(4,30)
       COMMON /BELIN3/NCGRP,NSECIS,ICDISG(4),NCSEPG(4),NCSCSZ
      +(20),NCGRSZ(4),IASMTC(20),NCGRFT(4),ICGRFT(4,5),NCGRFB
      +(4),ICGRFB(4,5),ICSTOP(20),ICDISS(20),NARYIG(4),IARYPG
      +(4,5),NARYSC(20),IASCTB(20),IASCHB(4),NGASBD(4),NCASBD
      +(20)
       COMMON /TRNIN3/NUMTRN,NUMLDS,NUTRLT,IASRHB(6),IASRTB(6
      +),MXCRTR(6),NRCOOR,NRCOSC(30),NREDLT(30,5),LGTCON(30,5
      +,5),NRPATH(5,4,10),NPHRL(5,4),MTRASG(6),IASMTR(5),IASR
      +HS(5),NRTDPS,NRASBD(5),NRFIRT(6),NLOCO(6),KMATER(6),IR
      +COOT(6),LRCOOR(6),LREDLT(10),NASGLS(6),LDSCNT(6),MTOTL
      +D(6),KRAVDP(6),NDLBDP(6),NDUMDP(6),NDUMPG(6),MECRLS(5)
C
C *** IN ORE MOVING DIFFERENT TRANSPORTATION MEDIUM CAN BE P
C *** IN WASTE MOVING NO SECONDARY TRANSPORTATION IS ALLOWED
C
       IF (NEXTEN(IBOD,JBWE).EQ.0) GO TO 15
       NEXTEN(IBOD,JBWE)=0
       GO TO 35
   15  I=0
       IBOD=0
   25  IBOD=IBOD+1
       JBWE=0
       IF (IBOD-(NBODY+1))  35,65,645
C *****
C *****
C ***** CONTROL BWE
C *****
C *****
   35  JBWE=JBWE+1
       IF (JBWE.GT.NBWE(IBOD)) GO TO 65
       IF (BDIA(IBOD,JBWE).EQ.0.) GO TO 35
       IF (NCTSET(IBOD,JBWE).EQ.0) GO TO 35
C      THIS BWE HAS FINISHED CUTTING ONE GRID POING OG THE OR
```

```
      I=I+1
      JBW=IASBTS(IBOD,JBWE)
      BSURGE(JBW,1)=EQUIVL(1,JBW)
      IF (BSURGE(JBW,IBCMAT(IBOD,JBWE)).GT.BCAPSG(IBOD,JBWE,
     +IBCMAT(IBOD,JBWE))) GO TO 55
      CALL BWECUT
      BSURGE(JBW,IBCMAT(IBOD,JBWE))=BSURGE(JBW,IBCMAT(IBOD,J
     +BWE))+BWECWT(IBOD,JBWE)
      EQUIVL(1,JBW)=BSURGE(JBW,1)
      PRODTB(IBOD,JBWE,IBCMAT(IBOD,JBWE))=PRODTB(IBOD,JBWE,I
     +BCMAT(IBOD,JBWE))+BWECWT(IBOD,JBWE)
      IF (NEXTEN(IBOD,JBWE).NE.0) RETURN
      GO TO 35
C
C *** THE SURGE OF THE BWE IS FULL, BWE HAS TO WAIT
C
   55 BWEWT(IBOD,JBWE)=BWEWT(IBOD,JBWE)+DELTT
      GO TO 35
C *****
C *****
C ***** CONTROL TRUCKS
C *****
C *****
   65 IF (I.EQ.0) GO TO 1555
      NTK=0
   75 NTK=NTK+1
      IF (NTK.GT.NTRUCK(IBOD)) GO TO 25
C
C
C  STATEMENT 10 HERE IS A BRANCH FOR CONVEYOR AND TRAIN
C
C
C
C *** FIND THE COORDINATE WHERE THE TRUCK IS ON
C
      JBW=IASIGN(IBOD,NTK)
      IF (NPATH(IBOD,JBW,MATER(IBOD,NTK),LTCOOR(IBOD,NTK)).E
     +Q.1) GO TO 85
      IF (NPATH(IBOD,JBW,MATER(IBOD,NTK),LTCOOR(IBOD,NTK)).E
     +Q.3) GO TO 375
      IF (NPATH(IBOD,JBW,MATER(IBOD,NTK),LTCOOR(IBOD,NTK)).E
     +Q.2) GO TO 285
      IF (NPATH(IBOD,JBW,MATER(IBOD,NTK),LTCOOR(IBOD,NTK)).E
     +Q.5) GO TO 505
      IF (NPATH(IBOD,JBW,MATER(IBOD,NTK),LTCOOR(IBOD,NTK)).E
     +Q.4) GO TO 515
C
C ***
C ***
C *** TRUCK IS ON THE HAULT ROAD
C ***
```

```
C
      CALL TRUCK
      GO TO 75
C
C ***
C *** TRUCK IS AT BWE READY FOR LOADING FROM SURGE
C ***
C
C
C *** TRUCK AT NLSTH LOADING STATION (AT JBWETH TAIL BIN)
C
   85 NLS=IASIGN(IBOD,NTK)
      JBWE=IASTTB(NLS)
   95 IF (LDQUE(NLS,NTK).NE.0) GO TO 115
C
C *** TRUCK JUST ARRIVES AT BWE
C
      LDQUE(NLS,NTK)=MAXLD(NLS)+1
      MAXLD(NLS)=MAXLD(NLS)+1
      GO TO 95
  115 IF (LDQUE(NLS,NTK).GT.NPOCKT(NLS)) GO TO 175
C
C *** TRUCK AT JBWETH LOADING STATION NO OTHER TRUCK AHEAD
C
      IF (TBACKT(IBOD,NTK).GE.TBKT(KINDT(IBOD,NTK))) GO TO 1
     +35
      CALL TRUCK
      GO TO 75
C
C *** SURGE DOES NOT HAVE ENOUGH MATERIAL FOR TRUCK, TRUCK W
C
  135 RATAGB=RATFED(NLS)*DELTT
      IF (IASMTT(NLS).EQ.2) GO TO 165
      NN=NELEMT(IBOD)
      DO 145 II=1,NN
      IF (NELEMN(IBOD,II).EQ.2) GO TO 155
  145 CONTINUE
      STOP 151
  155 IF (EQUIVL(II-1,JBWE).GE.RATAGB) GO TO 185
      IF (II-1.GT.1) GO TO 175
  165 IF (BSURGE(JBWE,2).GE.RATAGB) GO TO 265
  175 TKWTBW(IBOD,NTK)=TKWTBW(IBOD,NTK)+DELTT
      GO TO 75
C
C *** TRUCK LOAD ORE FROM LOADING STATION
C
  185 MTR(IBOD,NTK)=1
  195 IF (RATAGB.GT.1.1*TKMEAN(KINDT(IBOD,NTK))) GO TO 245
      WTTK(IBOD,NTK)=WTTK(IBOD,NTK)+RATAGB
      IF (MTR(IBOD,NTK).EQ.2) GO TO 205
      EQUIVL(II-1,JBWE)=EQUIVL(II-1,JBWE)-RATAGB
```

```
      GO TO 215
  205 BSURGE(JBWE,MTR(IBOD,NTK))=BSURGE(JBWE,MTR(IBOD,NTK))-
     +RATAGB
  215 IF (RATAGB.GT.0.7*TKMEAN(KINDT(IBOD,NTK))) GO TO 235
      IF (WTTK(IBOD,NTK).LE.TKMEAN(KINDT(IBOD,NTK))) GO TO 7
     +5
C
C *** TRUCK IS FULL READY TO MOVE
C
  235 MATER(IBOD,NTK)=MTR(IBOD,NTK)
      NEW(NLS)=NEW(NLS)-1
      LDQUE(NLS,NTK)=0
      TON(IBOD,NTK)=WTTK(IBOD,NTK)+TKGVW(KINDT(IBOD,NTK))
      LODTK(IBOD,NTK,MATER(IBOD,NTK))=LODTK(IBOD,NTK,MATER(I
     +BOD,NTK))+1
      ICOOST(IBOD,NTK)=1
      LTCOOR(IBOD,NTK)=1
      TBACKT(IBOD,NTK)=0.
      GO TO 75
  245 WRITE (6,255)
  255 FORMAT (' ','TIME INCREMENT IS TOO LARGE')
      STOP
C
C *** TRUCK LOAD WASTE FROM SURGE
C
  265 MTR(IBOD,NTK)=2
      GO TO 195
C
C ***
C *** TRUCK IS AT WASTE DUMP
C ***
C
C
C *** FIND THE DUMP PLACE WHERE THIS TRUCK IS AT
C
  285 I=IASIGN(IBOD,NTK)
      KDP=IASLTW(I)
C
C *** TRUCK JUST ARRIVES AT DUMPING FACILITY
C
  295 IF (MDMQUE(KDP,IBOD,NTK).NE.0) GO TO 315
      MDMQUE(KDP,IBOD,NTK)=MAXDPQ(KDP)+1
      MAXDPQ(KDP)=MAXDPQ(KDP)+1
      GO TO 295
  315 IF (MDMQUE(KDP,IBOD,NTK).GT.NPOCK2(KDP)) GO TO 365
C
C *** TRUCK AT DUMPING FACILITY NO OTHER TRUCK AHEAD
C
      IF (TBACKT(IBOD,NTK).GE.TBKT(KINDT(IBOD,NTK))) GO TO 3
     +35
      CALL TRUCK
```

```
      GO TO 75
C
C *** TRUCK IS DUMPING
C
  335 TKDWT=WTTK(IBOD,NTK)*DELTT/TKDMT(KINDT(IBOD,NTK))
      IF (TKDWT.GT.2.0*TKMEAN(KINDT(IBOD,NTK))) GO TO 245
      TON(IBOD,NTK)=TON(IBOD,NTK)-TKDWT
      IF (TKDWT.GT.0.9*TKMEAN(KINDT(IBOD,NTK))) GO TO 345
      IF (TON(IBOD,NTK)-TKGVW(KINDT(IBOD,NTK)))  345,355,75
C
C *** TRUCK IS EMPTY, READY TO MOVE
C
  345 TON(IBOD,NTK)=TKGVW(KINDT(IBOD,NTK))
  355 NEW2(KDP)=NEW2(KDP)-1
      MDMQUE(KDP,IBOD,NTK)=0
      ICOOST(IBOD,NTK)=1
      LTCOOR(IBOD,NTK)=1
      TBACKT(IBOD,NTK)=0.
      WASTMV(IBOD,NTK)=WASTMV(IBOD,NTK)+WTTK(IBOD,NTK)
      MATER(IBOD,NTK)=4
      WTTK(IBOD,NTK)=0.
      GO TO 75
C
C *** SOME OTHER TRUCKS AHEAD, HAS TO WAIT
C
  365 TKWTDP(IBOD,NTK)=TKWTDP(IBOD,NTK)+DELTT
      GO TO 75
C
C ***
C *** TRUCK AT ORE DUMP
C ***
C
C
C *** FIND THE DUMPING STATION WHERE THIS TRU K IS AT
C
  375 I=IASIGN(IBOD,NTK)
      LCR=IASTHB(I)
      NN=NELEMT(IBOD)
      DO 385 II=1,NN
      IF (NELEMN(IBOD,II).EQ.2) GO TO 395
  385 CONTINUE
      STOP 375
C
C *** TRUCK JUST ARRIVES THE DUMPING STATION
C
  395 IF (MCRQUE(LCR,IBOD,NTK).NE.0) GO TO 415
      MCRQUE(LCR,IBOD,NTK)=MAXCRQ(LCR)+1
      MAXCRQ(LCR)=MAXCRQ(LCR)+1
      GO TO 395
  415 IF (MCRQUE(LCR,IBOD,NTK).GT.NPOCK3(LCR)) GO TO 495
C
```

```
C *** TRUCK AT CRUSHER NO OTHER TRUCKS AHEAD  BACK UP THE TR
C
      IF (TBACKT(IBOD,NTK).GE.TBKT(KINDT(IBOD,NTK))) GO TO 4
     +35
      CALL TRUCK
      GO TO 75
C
C *** TRUCK IS READY TO UNLOAD
C
  435 IF (NELEMN(IBOD,II+1).EQ.5) GO TO 445
      IF (WTTK(IBOD,NTK).GE.CAPHBN(II,LCR)-EQUIVL(II,LCR)) G
     +O TO 495
      GO TO 455
  445 IF (WTTK(IBOD,NTK).GE.CAPMIL(LOCMIL(IBOD))-BINCRU(LOCM
     +IL(IBOD))) GO TO 495
  455 TKDWT=WTTK(IBOD,NTK)*DELTT/TKDMT(KINDT(IBOD,NTK))
      IF (TKDWT.GT.2.0*TKMEAN(KINDT(IBOD,NTK))) GO TO 245
      TON(IBOD,NTK)=TON(IBOD,NTK)-TKDWT
      IF (TKDWT.GT.0.9*TKMEAN(KINDT(IBOD,NTK))) GO TO 465
      IF (TON(IBOD,NTK)-TKGVW(KINDT(IBOD,NTK)))  465,475,75
C
C *** TRUCK IS EMPTY  READY TO MOVE
C
  465 TON(IBOD,NTK)=TKGVW(KINDT(IBOD,NTK))
  475 NEW3(LCR)=NEW3(LCR)-1
      MCRQUE(LCR,IBOD,NTK)=0
      ICOOST(IBOD,NTK)=1
      LTCOOR(IBOD,NTK)=1
      TBACKT(IBOD,NTK)=0.
      OREMV(IBOD,NTK)=OREMV(IBOD,NTK)+WTTK(IBOD,NTK)
      MATER(IBOD,NTK)=3
      IF (NELEMN(IBOD,II+1).EQ.5) GO TO 485
      EQUIVL(II,LCR)=EQUIVL(II,LCR)+WTTK(IBOD,NTK)
      WTTK(IBOD,NTK)=0.
      GO TO 75
  485 BINCRU(LOCMIL(IBOD))=BINCRU(LOCMIL(IBOD))+WTTK(IBOD,NT
     +K)
      WTTK(IBOD,NTK)=0.
      GO TO 75
C
C ****SOME OTHER TRUCK AHEAD OR THE BIN IS FULL, TRUCK WAITS
C
  495 TKWTCR(IBOD,NTK)=TKWTCR(IBOD,NTK)+DELTT
      GO TO 75
C
C ***
C *** TRUCK AT ROAD INTERSECTION
C ***
C
  505 LTCOOR(IBOD,NTK)=LTCOOR(IBOD,NTK)+1
      GO TO 75
```

```
C
C ***
C *** TRUCK IS AT MILL TO LOAD TAILING
C ***
C
  515 I=IASIGN(IBOD,NTK)
      DO 525 II=1,NCRUSH
      IF (I.EQ.ICRAST(II)) GO TO 535
  525 CONTINUE
      STOP 410
  535 MIL=II
C
C *** TRUCK JUST ARRIVES AT TAILING LOADING POINT
C
  545 IF (MILQUE(MIL,IBOD,NTK).NE.0) GO TO 565
      MILQUE(MIL,IBOD,NTK)=MAXMLQ(MIL)+1
      MAXMLQ(MIL)=MAXMLQ(MIL)+1
      GO TO 545
  565 IF (MILQUE(MIL,IBOD,NTK).GT.NPOCK4(MIL)) GO TO 635
C
C *** TRUCK AT TAILING LOADING POINT NO TRUCKS AHEAD , MANER
C
      IF (TBACKT(IBOD,NTK).GE.TBKT(KINDT(IBOD,NTK))) GO TO 5
     +85
      CALL TRUCK
      GO TO 75
C
C *** TRUCK IS READY TO BE LOADED
C
  585 IF (BINCRU(MIL).LT.TKMEAN(KINDT(IBOD,NTK))) GO TO 635
      FRMILB=RATMIL(MIL)*DELTT
      IF (FRMILB.LE.TKMEAN(KINDT(IBOD,NTK))) GO TO 595
      FRMILB=TKMEAN(KINDT(IBOD,NTK))
  595 WTTK(IBOD,NTK)=WTTK(IBOD,NTK)+FRMILB
      BINCRU(MIL)=BINCRU(MIL)-FRMILB
      IF (FRMILB.GT.0.8*TKMEAN(KINDT(IBOD,NTK))) GO TO 615
      IF (WTTK(IBOD,NTK).LE.TKMEAN(KINDT(IBOD,NTK))) GO TO 7
     +5
C
C *** TRUCK IS FULL READY TO MOVE
C
  615 MATER(IBOD,NTK)=2
      NEW4(MIL)=NEW4(MIL)-1
      MILQUE(MIL,IBOD,NTK)=0
      TON(IBOD,NTK)=WTTK(IBOD,NTK)+TKGVW(KINDT(IBOD,NTK))
      LODTK(IBOD,NTK,2)=LODTK(IBOD,NTK,2)+1
      CUMWT2(IBOD,NTK)=CUMWT2(IBOD,NTK)+WTTK(IBOD,NTK)
      ICOOST(IBOD,NTK)=1
      TBACKT(IBOD,NTK)=0.
      IF (LTCOOR(IBOD,NTK).LT.NPHTK(IBOD,IASIGN(IBOD,NTK),MA
     +TER(IBOD,NTK))) GO TO 625
```

```
      LTCOOR(IBOD,NTK)=1
      GO TO 75
  625 LTCOOR(IBOD,NTK)=LTCOOR(IBOD,NTK)+1
      GO TO 75
C
C *** SOME OTHER TRUCKS AHEAD OR THERE ARE NO MATERIAL AVAIL
C
  635 TKWTTL(IBOD,NTK)=TKWTTL(IBOD,NTK)+DELTT
      GO TO 75
C
C***
C *** RESET QUEUING SITUATION OF TRUCK AT LOADING STATION
C ***
C
  645 JBWE=0
  655 JBWE=JBWE+1
      IF (JBWE.GT.NTKLDS) GO TO 675
      IF (MAXLD(JBWE).LE.0) GO TO 655
      IF (NEW(JBWE).GT.0) GO TO 655
      IBOD=NTASBD(JBWE)
      NN=NTRUCK(IBOD)
      DO 665 NTK=1,NN
      IF (LDQUE(JBWE,NTK).LT.NPOCKT(JBWE)) GO TO 665
      IF (LDQUE(JBWE,NTK).EQ.1) GO TO 665
      LDQUE(JBWE,NTK)=LDQUE(JBWE,NTK)-(1-NEW(JBWE))
  665 CONTINUE
      MAXLD(JBWE)=MAXLD(JBWE)-(1-NEW(JBWE))
      NEW(JBWE)=1
      GO TO 655
C
C *** RESET QUEUING SITUATION OF TRUCK AT WASTE DUMP
C
  675 IBOD=0
  685 IBOD=IBOD+1
      IF (IBOD.GT.NBODY+1) GO TO 775
      KDP=0
  695 KDP=KDP+1
      IF (KDP.GT.NDUMP) GO TO 715
      IF (MAXDPQ(KDP).LE.0) GO TO 695
      IF (NEW2(KDP).GT.0) GO TO 695
      NN=NTRUCK(IBOD)
      DO 705 NTK=1,NN
      IF (MDMQUE(KDP,IBOD,NTK).LT.NPOCK2(KDP)) GO TO 705
      IF (MDMQUE(KDP,IBOD,NTK).EQ.1) GO TO 705
      MDMQUE(KDP,IBOD,NTK)=MDMQUE(KDP,IBOD,NTK)-(1-NEW2(KDP)
     +)
  705 CONTINUE
      IF (IBOD.NE.NBODY+1) GO TO 695
      MAXDPQ(KDP)=MAXDPQ(KDP)-(1-NEW2(KDP))
      NEW2(KDP)=1
C
```

```
C *** RESET QUEUING SITUATION OF TRUCK AT ORE DUMP
C
  715 LCR=0
  725 LCR=LCR+1
      IF (LCR.GT.NTKDPS) GO TO 745
      IF (MAXCRQ(LCR).LE.0) GO TO 725
      IF (NEW3(LCR).GT.0) GO TO 725
      NN=NTRUCK(IBOD)
      DO 735 NTK=1,NN
      IF (MCRQUE(LCR,IBOD,NTK).LT.NPOCK3(LCR)) GO TO 735
      IF (MCRQUE(LCR,IBOD,NTK).EQ.1) GO TO 735
      MCRQUE(LCR,IBOD,NTK)=MCRQUE(LCR,IBOD,NTK)-(1-NEW3(LCR)
     +)
  735 CONTINUE
      IF (IBOD.NE.NBODY+1) GO TO 725
      MAXCRQ(LCR)=MAXCRQ(LCR)-(1-NEW3(LCR))
      NEW3(LCR)=1
C
C *** RESET QUEUING SITUATION OF TRUCK AT TAILING LOADING PO
  745 MIL=0
  755 MIL=MIL+1
      IF (MIL.GT.NTAIL) GO TO 685
      IF (MAXMLQ(MIL).LE.0) GO TO 755
      IF (NEW4(MIL).GT.0) GO TO 755
      NN=NTRUCK(IBOD)
      DO 765 NTK=1,NN
      IF (MILQUE(MIL,IBOD,NTK).LT.NPOCK4(MIL)) GO TO 765
      IF (MILQUE(MIL,IBOD,NTK).EQ.1) GO TO 765
      MILQUE(MIL,IBOD,NTK)=MILQUE(MIL,IBOD,NTK)-(1-NEW4(MIL)
     +)
  765 CONTINUE
      IF (IBOD.NE.NBODY+1) GO TO 755
      MAXMLQ(MIL)=MAXMLQ(MIL)-(1-NEW4(MIL))
      NEW4(MIL)=1
      GO TO 685
C
C *** OBSERVATION TOWER TO RESET TRUCK HAULT ROAD
C
  775 IBOD=0
  785 IBOD=IBOD+1
      IF (IBOD.GT.NBODY) GO TO 795
      IF (NOBSTW(IBOD).NE.1) GO TO 785
      CALL OBSTOW
      GO TO 785
C *****
C *****
C ***** CONTROL CONVEYORS
C *****
C *****
  795 IF (NSECIS.EQ.0) GO TO 975
      NSC=0
```

```
  805 NSC=NSC+1
      IF (NSC.GT.NSECIS) GO TO 875
      ICNT=IASCTB(NSC)
      IBOD=NCASBD(NSC)
      NN=NELEMT(IBOD)
      DO 815 II=1,NN
      IF (NELEMN(IBOD,II).EQ.4) GO TO 825
  815 CONTINUE
      STOP 740
  825 IF (II.EQ.1) GO TO 935
      IF (IASMTC(NSC).EQ.2) GO TO 965
      CDISRF(NSC)=CSCFDT(NSC)*DELTT
      IF (EQUIVL(II-1,ICNT).LE.CDISRF(NSC))CDISRF(NSC)=EQUIV
     +L(II-1,ICNT)
      IF (EQUIVL(II-1,ICNT).LE.0.)CDISRF(NSC)=1.0E-10
      X=CDISRF(NSC)
      CALL CONVEY
      IF (CDISRF(NSC).NE.0.) GO TO 845
      EQUIVL(II-1,ICNT)=EQUIVL(II-1,ICNT)-X
  835 IF (ICDISS(NSC).EQ.0) GO TO 805
      IF (II.EQ.NN-1) GO TO 865
      EQUIVL(II,ICDISS(NSC))=EQUIVL(II,ICDISS(NSC))+CSCDIS(N
     +SC)
      IF (EQUIVL(II,ICDISS(NSC)).GT.CAPHBN(II,ICDISS(NSC)))
     +GO TO 855
      CSESTP(NSC)=0.
      GO TO 805
  845 CSCDIS(NSC)=0.
      GO TO 835
  855 CSESTP(NSC)=1
      GO TO 805
C
C SECTION BELT DUMPS TO CRUSHER
C
  865 BINCRU(LOCMIL(IBOD))=BINCRU(LOCMIL(IBOD))+CSCDIS(NSC)
      IF (BINCRU(LOCMIL(IBOD)).GT.CAPMIL(LOCMIL(IBOD))) GO T
     +O 855
      CSESTP(NSC)=0
      GO TO 805
  875 IF (NCGRP.EQ.0) GO TO 975
      DO 925 ICNH=1,NCGRP
      IBOD=NGASBD(ICNH)
      IF (ICDISG(ICNH).EQ.0) GO TO 925
      NN=NELEMT(IBOD)
      DO 885 II=1,NN
      IF (NELEMN(IBOD,II).EQ.4) GO TO 895
  885 CONTINUE
      STOP 747
  895 IF (II.EQ.NN-1) GO TO 915
      EQUIVL(II,ICDISG(ICNH))=EQUIVL(II,ICDISG(ICNH))+CDISMC
     +(ICNH)
```

```
      IF (EQUIVL(II,ICDISG(ICNH)).LE.CAPHBN(II,ICDISG(ICNH))
     +) GO TO 905
      CLDMC(ICDISG(ICNH))=0
      CGSTOP(ICNH)=1
      GO TO 925
  905 CLDMC(ICDISG(ICNH))=1
      CGSTOP(ICNH)=0
      GO TO 925
C
C GROUP BELT DUMPS TO CRUSHER
C
  915 BINCRU(LOCMIL(IBOD))=BINCRU(LOCMIL(IBOD))+CDISMC(ICNH)
      IF (BINCRU(LOCMIL(IBOD)).LE.CAPMIL(LOCMIL(IBOD))) GO T
     +O 905
      CGSTOP(ICNH)=1
      CLDMC(ICDISG(ICNH))=0
  925 CONTINUE
      GO TO 975
C
C SECTION BELT LOADS TAILING FROM TAILING LOADING STATION
  935 DO 945 II=1,NCRUSH
      IF (ICNT.EQ.ICRASC(II)) GO TO 955
  945 CONTINUE
      STOP 792
  955 CDISRF(NSC)=CSCFDT(NSC)*DELTT
      IF (BINCRU(II).LE.CDISRF(NSC))CDISRF(NSC)=BINCRU(II)
      IF (BINCRU(II).LE.0.)CDISRF(NSC)=1.0E-10
      X=CDISRF(NSC)
      CALL CONVEY
      IF (CDISRF(NSC).NE.0.) GO TO 805
      BINCRU(II)=BINCRU(II)-X
      GO TO 805
  965 CDISRF(NSC)=CSCFDT(NSC)*DELTT
      IF (BSURGE(ICNT,2).LE.CDISRF(NSC))CDISRF(NSC)=BSURGE(I
     +CNT,2)
      IF (BSURGE(ICNT,2).LT.0.)CDISRF(NSC)=1.0E-10
      X=CDISRF(NSC)
      CALL CONVEY
      IF (CDISRF(NSC).NE.0.) GO TO 805
      BSURGE(ICNT,2)=BSURGE(ICNT,2)-X
      GO TO 805
C *****
C *****
C ***** CONTROL TRAIN
C *****
C *****
  975 IF (NUMTRN.EQ.0) GO TO 1545
      NLS=0
  985 NLS=NLS+1
      IF (NLS.GT.NUMLDS) GO TO 1085
      IF (RECAR(NLS).GT.0) GO TO 1005
```

```
      RLDSDL(NLS)=RLDSDL(NLS)+DELTT
      RECAR(NLS)=0.
      GO TO 1055
C   LOAD THE TRAIN AT LOADING STATIONS
C SEE WHETHER THERE ARE ENOUGH MATERIAL AT BIN
C LOAD THE TRAIN AT LOADING STATIONS
 1005 IBOD=NRASBD(NLS)
      NN=NELEMT(IBOD)
      DO 1015 II=1,NN
      IF (NELEMN(IBOD,II).EQ.3) GO TO 1025
 1015 CONTINUE
      STOP 842
 1025 IF (II.EQ.1) GO TO 1065
      IF (II.NE.2) GO TO 1075
      IF (IASMTR(NLS).EQ.1) GO TO 1075
      IF (BSURGE(IASRTB(NLS),2).LT.RATELS(NLS)*DELTT) GO TO
     +985
      BSURGE(IASRTB(NLS),2)=BSURGE(IASRTB(NLS),2)-RATELS(NLS
     +)*DELTT
 1045 RCARLD(NLS)=RCARLD(NLS)+RATELS(NLS)*DELTT/CARLOD(IASMT
     +R(NLS))
      RECAR(NLS)=RECAR(NLS)-RATELS(NLS)*DELTT/CARLOD(IASMTR(
     +NLS))
      RLOADI(NLS)=RLOADI(NLS)+RATELS(NLS)*DELTT/CARLOD(IASMT
     +R(NLS))
C   DISPATCH TRAIN TO LOADING STATION
 1055 IF (RECAR(NLS).GT.MECRLS(NLS)) GO TO 985
      IF (RSENDE(NLS).NE.0.) GO TO 985
      RSENDE(NLS)=CLOCK
      GO TO 985
C     TRAAIN LOADS FROM TAILING BINS
 1065 IF (BINCRU(LOCMIL(IBOD)).LT.RATELS(NLS)*DELTT) GO TO 9
     +85
      BINCRU(LOCMIL(IBOD))=BINCRU(LOCMIL(IBOD))-RATELS(NLS)*
     +DELTT
      GO TO 1045
C   TRAIN IS NOT THE FIRST TRANSPORTATION MEDIUM IN SERIES
 1075 IF (EQUIVL(II-1,IASRTB(NLS)).LT.RATELS(NLS)*DELTT) GO
     +TO 985
      EQUIVL(II-1,IASRTB(NLS))=EQUIVL(II-1,IASRTB(NLS))-RATE
     +LS(NLS)*DELTT
      GO TO 1045
 1085 KTR=0
 1095 KTR=KTR+1
      IF (KTR.GT.NUMTRN) GO TO 1545
      NLS=MTRASG(KTR)
      IBOD=NRASBD(NLS)
      IF (NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)).EQ.1) GO TO 11
     +05
      IF (NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)).EQ.2) GO TO 12
     +45
```

```
      IF (NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)).EQ.3) GO TO 14
     +65
      IF (NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)).EQ.4) GO TO 14
     +75
      IF (NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)).EQ.5) GO TO 15
     +05
C    TRAIN IS TRAVELLING
      CALL TRAIN
      GO TO 1095
C    TRAIN IS AT LOADING STATION, SEE WHETHER IT IS A NEWLY
 1105 IF (LDSCNT(KTR).EQ.1) GO TO 1135
 1125 RDLSMN(KTR)=0.
      LDSCNT(KTR)=1
      RECAR(NLS)=RECAR(NLS)+MXCRTR(KTR)
      NASGLS(NLS)=0
C
C   SEE WHETHER THE LOADING STATION IS OCCUPIED
 1135 DO 1145 NTR=1,NUMTRN
      MLS=MTRASG(NTR)
      IF (MLS.NE.NLS) GO TO 1145
      IF (NTR.EQ.KTR) GO TO 1145
      IF (NRPATH(MLS,KMATER(NTR),LRCOOR(NTR)).NE.1) GO TO 11
     +45
      IF (LDSCNT(NTR).NE.1) GO TO 1145
      IF (RLOAD(KTR).LT.RLOAD(NTR)) GO TO 1155
 1145 CONTINUE
      KIS=IASRTB(NLS)
      NN=NELEMT(IBOD)
      IF (RLOAD(KTR).GT.0.) GO TO 1165
      IRLOAD=RLOADI(NLS)
      IF (IRLOAD.LT.MXCRTR(KTR)) GO TO 1155
      RLOADI(NLS)=RLOADI(NLS)-MXCRTR(KTR)
      RLOAD(KTR)=CARLOD(IASMTR(NLS))*MXCRTR(KTR)
      GO TO 1165
 1155 RTWTLD(KTR)=RTWTLD(KTR)+DELTT
      GO TO 1095
C    CALL DELAY GENERATOR BEFORE TRAMMING TO DUMP
 1165 IF (MTOTLD(KTR).EQ.1) GO TO 1195
      A=RDLALS(KTR)
 1185 MTOTLD(KTR)=1
 1195 NNN=NRPATH(NLS,IASMTR(NLS),1)
      IF (NREDLT(NNN,1).EQ.0) GO TO 1205
      IF (LREDLT(NREDLT(NNN,1)).EQ.0) GO TO 1205
      RWTAIN(KTR)=RWTAIN(KTR)+DELTT
      GO TO 1095
 1205 RTOTLD(KTR)=RTOTLD(KTR)+RLOAD(KTR)
      KMATER(KTR)=IASMTR(NLS)
      LDSCNT(KTR)=0
      RDLALS(KTR)=0.
      MTOTLD(KTR)=0
      IRCOOT(KTR)=1
```

```
      IF (LRCOOR(KTR).LT.NPHRL(NLS,KMATER(KTR))) GO TO 1235
      LRCOOR(KTR)=1
C
C   TURN ON TRAFFIC LIGHTS
 1215 I=NRPATH(NLS,KMATER(KTR),1)
      DO 1225 K=1,5
      IF (LGTCON(I,1,K).EQ.0) GO TO 1225
      LREDLT(LGTCON(I,1,K))=1
 1225 CONTINUE
      GO TO 1095
 1235 LRCOOR(KTR)=LRCOOR(KTR)+1
      GO TO 1215
 1245 LAZY=4
C
C    TRAIN IS AT WASTE DUMP, SEE WHETHER TRAIN IS READY TO D
 1255 IF (KRAVDP(KTR).EQ.1) GO TO 1405
      IF (NDLBDP(KTR).EQ.0) GO TO 1285
 1265 RARIDP(KTR)=0.
      NDLBDP(KTR)=0
      GO TO 1095
 1275 RARIDP(KTR)=A
      GO TO 1095
 1285 IF (NDUMPG(KTR).EQ.0) GO TO 1375
C    TRAIN IS DUMPING
      ILS=IASRHB(NLS)
      IF (LAZY.EQ.4) GO TO 1325
      NN=NELEMT(IBOD)
      DO 1295 II=1,NN
      IF (NELEMN(IBOD,II).EQ.3) GO TO 1305
 1295 CONTINUE
      STOP 1236
 1305 IF (NELEMN(IBOD,II+1).EQ.5) GO TO 1315
      IF (EQUIVL(II,ILS).LE.CAPHBN(II,ILS)) GO TO 1325
      RTWTDP(KTR)=RTWTDP(KTR)+DELTT
      GO TO 1095
C TRAIN DUMPS TO CRUSHER
 1315 IF (BINCRU(LOCMIL(IBOD)).LE.CAPMIL(LOCMIL(IBOD))) GO T
     +O 1325
      RTWTDP(KTR)=RTWTDP(KTR)+DELTT
      GO TO 1095
 1325 A=RLOAD(KTR)
      D=RLOAD(KTR)
      B=RDVDPT(KTR)
      C=RMEDPT(KTR)
      CALL RTGNDP(A,B,C,IBASE,&1335,&1365)
 1335 RLOAD(KTR)=A
 1345 IF (KMATER(KTR)/2*2.EQ.KMATER(KTR)) GO TO 1095
      IF (NELEMN(IBOD,II+1).EQ.5) GO TO 1355
      EQUIVL(II,ILS)=EQUIVL(II,ILS)+D-A
      GO TO 1095
 1355 BINCRU(LOCMIL(IBOD))=BINCRU(LOCMIL(IBOD))+D-A
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```
      GO TO 1095
 1365 NDUMPG(KTR)=0
      RLOAD(KTR)=0.
      A=0.
      GO TO 1345
 1375 NDLBDP(KTR)=1
      KRAVDP(KTR)=1
      NDUMPG(KTR)=1
      RDLADP(KTR)=0.
C     TRAIN IS AVAILABLE FOR REASSIGNMENT
 1405 NI=1
      SMALL=RSENDE(1)
      IF (NUMLDS.LE.1) GO TO 1425
      DO 1415 N=2,NUMLDS
      IF (RSENDE(N).EQ.0) GO TO 1415
      IF (RSENDE(N).GE.SMALL) GO TO 1415
      NI=N
      SMALL=RSENDE(NI)
 1415 CONTINUE
 1425 IF (SMALL.EQ.0.) GO TO 1455
C SEE WHETHER THE TRAFFIC LIGHT IS ON, IF YES, TRAIN WAITS
      NNN=NRPATH(NI,LAZY,1)
      IF (NREDLT(NNN,1).EQ.0) GO TO 1445
      IF (LREDLT(NREDLT(NNN,1)).EQ.0) GO TO 1445
      RWTAIN(KTR)=RWTAIN(KTR)+DELTT
      GO TO 1095
 1445 KRAVDP(KTR)=0
      NASGLS(NI)=1
      RSENDE(NI)=0.
C    ASSIGN NEW PATH TO THIS TRAIN
      MTRASG(KTR)=NI
      IRCOOT(KTR)=1
      LRCOOR(KTR)=1
      KMATER(KTR)=LAZY
      GO TO 1095
 1455 RWTDIS(KTR)=RWTDIS(KTR)+DELTT
      GO TO 1095
C
C    TRAIN IS AT ORE DUMP
 1465 LAZY=3
      GO TO 1255
C TRAIN IS AT TAILING LOADING STATION
 1475 DO 1485 II=1,NCRUSH
      IF (NLS.EQ.ICRASR(II)) GO TO 1495
 1485 CONTINUE
      STOP 912
 1495 LCR=II
      GO TO 1105
C    TRAIN AT ROAD INTERSECTION
C    SEE WHETHER THERE IS A TRAFFIC LIGHT
 1505 NNN=NRPATH(NLS,KMATER(KTR),LRCOOR(KTR)+1)
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```
      IF (NREDLT(NNN,1).EQ.0) GO TO 1515
      IF (LREDLT(NREDLT(NNN,1)).EQ.0) GO TO 1515
      RWTAIN(KTR)=RWTAIN(KTR)+DELTT
      GO TO 1095
C   TRAIN DOES NOT STOP
 1515 LRCOOR(KTR)=LRCOOR(KTR)+1
      IRCOOT(KTR)=1
      CALL TRAIN
      IF (RLEFT(KTR).LE.0.) GO TO 1525
      LRCOOR(KTR)=LRCOOR(KTR)-1
      GO TO 1095
C   AFTER TAIL OF THE TRAIN PASSED THE INTERSECTION
C   TURN OFF RED LIGHTS
 1525 I=NRPATH(NLS,NLOCO(KTR),LRCOOR(KTR)-2)
      J=NRCOSC(I)
      DO 1535 KK=1,5
      IF (LGTCON(I,J,KK).EQ.0) GO TO 1535
      LREDLT(LGTCON(I,J,KK))=0
 1535 CONTINUE
      GO TO 1095
C
C ***
C *** ONE CYCLE OF SIMULATION IS COMPLETED
C ***
C
 1545 CLOCK=CLOCK+DELTT
C     SEE WHETHER ONE SHIFT OR ONE GRID POING SIMULATION IS
      IF (NGRID.EQ.1) GO TO 15
      IF (CLOCK.LE.SHIFTT) GO TO 15
 1555 CALL PRINTR
      END
C
      SUBROUTINE CONVEY
C
C ***
C *** CONVEYOR CONTROL SUBROUTINE
C ***
      COMMON /GENIN1/CAPBIN(5),RATMIL(5),CAPMIL(5),DELTT,SHI
     +FTT,CAPHBN(5,15),EQUIVL(5,15),CLOCK,BSURGE(15,2),BWEWT
     +(3,5),TKWTBW(3,30),PRODTB(3,5,2),WASTMV(4,30),TKWTDP(4
     +,30),BINCRU(5),OREMV(4,30),TKWTCR(4,30),CUMWT2(4,30),T
     +KWTTL(4,30),WTTK(4,30)
      COMMON /BWEIN1/BCS(3,5),BLENBM(3,5),BCOB(3,5),BNOB(3,5
     +),BDIA(3,5),BCTMAX(3,5),BWS(3,5),BOWM(3,5),BFRS(3,5),B
     +RS(3,5),BWAVIL(3,5),BDMEAN(3,5),BWLANG(3,5),BWRANG(3,5
     +),BSETTM(3,5),BCAPSG(3,5,2),BKFILL(10),BKRES(10),BRPM(
     +10),BVINC(10),BRORI(3,5),BGRADE(3,5),BPROB(3,5,5),BHEI
     +GT(3,5,5,2),BDENST(3,5,5),BRATIO(3,5,5),BCLOCK(3,5),BP
     +RDOW(3,5),BCOUNT(3,5)
      COMMON /BWEIN2/SLPBEN(3,5),BWTMD(3,5),BWECWT(3,5),BWTT
     +MD(3,5),BWCTFR(3,5),BWTTHK(3,5),BWFDD(3,5),
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+              AGBCWT(3,5),BSLKWH(3,5),BTRKWH(3,5),BWCTS
+H(3,5),EFFM,EFFE,BPOSIT(3,5),BWBACK(3,5),BTRAM2(3,5),T
+RKWH2(3,5),BVLANG(3,5),BVRANG(3,5),BTODOT(3,5),BDTIME(
+3,5),BWIDTH(3,5),BDGKWH(3,5)
 COMMON /TRKIN1/TKMEAN(10),TKGVW(10),TKSPED(10,20),TKRI
+MP(10,20),COSPLM(50,5),COSLOP(50,5),CORDRS(50,5),COSEC
+L(50,5),COOLEN(50),TKDHIL(20),TKTP(10,20),RATFED(15),T
+BKT(10),TKDMT(10),ACELMA,TKAVIL(4,30),TVEL(4,30),TON(4
+,30),TRASEC(4,30),TRAELE(4,30),TBACKT(4,30),TKTDOW(4,3
+0),TKFDD(4,30),TKDOWN(4,30)
 COMMON /BELIN1/CGRLEN(4),CGRSPD(4),CCAPGR(4),CSCLEN(20
+),CSCSPD(20),CSEPLN(4,5),CRATFD(4),CBINCP(4),CSCFDT(20
+),CCPSHB(20),CCAPSC(20),CDISRF(20),CTLBIN(20),CBINFL(4
+),CSESTP(20),CSCDIS(20),CTWTSC(20),CARYSC(20,400),CGRW
+MC(4),CARYGP(4,400),CGSTOP(4),CGRWT(4),CSEWT(20),CSEOV
+L(20),CLDMC(4),CDISMC(4),CGRDIS(4),CGROVL(4),CBNDCH(4)
 COMMON /BELIN2/CBNOVF(4),CSCHDB(20),CSBWTK(20),CSCAVL(
+20),CSCFDD(20),CSDOWN(20),CGPAVL(4),CGPFDD(4),CGDOWN(4
+)
 COMMON /TRNIN1/CARFRI,CARLEN,CARWTE,CARLOD(2),RMAXAC(6
+,2),RDECEL(6,2),RWTLOC(6,2),RLOCFR(6,2),RMEDPT(6),RDVD
+PT(6),              RSPEED(6,2,20),RTRAEF(6,2,20),RCSP
+LM(30,5),RCSLOP(30,5),RCELEL(30,5),RCSECL(30),RATELS(5
+),RTCARL(6)
 COMMON /TRNIN2/RMASS(6),RFRIC(6),RVEL(6),RLEFT(6),RTOT
+WT(6),RTRELE(6),RTRSEC(6),RLDSDL(5),RECAR(5),RSENDE(6)
+,RDLSMN(6),RLOAD(6),RDLALS(6),RARIDP(6),RTLTDP(6),RTWT
+DP(6),RLOADI(6),RDLADP(6),RWTDIS(6),RWTAIN(6),RTOTLD(6
+),RCARLD(6),RTWTLD(6),RAVL(6,2),RFDD(6,2),       RDOWN(
+6,2),RTDOWN(6,2)
 COMMON /GENIN2/IBOD,JBWE,NTK,NEXTEN(3,5),ISHF,NPOCK3(5
+),KTR,NLS,NSC,NBODY,NSHIFT,NDUMP,NCRUSH,NTAIL,NOBSTW(3
+),IBASE,LOCMIL(5),NPOCK2(5),NPOCK4(5),ICRASC(5),ICRASR
+(5),NELEMT(4),NELEMN(4,5),ICRAST(5),LDQUE(15,30),MAXLD
+(15),NEW(15),LODTK(4,30,2),MDMQUE(5,4,30),NEW2(5),MAXD
+PQ(5),MCRQUE(5,4,30),MAXCRQ(5),NEW3(5),MILQUE(5,4,30),
+NGRID
 COMMON /GENIN3/MAXMLQ(5),NEW4(5),LODTK2(4,30),MTR(4,30
+)
 COMMON /BWEIN4/NBWE(3),IASBTS(3,5),NBWBEN(3,5),NCTSET(
+3,5),IBCMAT(3,5),ISET(3,5),ISECT(3,5),LSOIL(3,5,5),NCT
+BEN(3,5)
 COMMON /TRKIN2/NTRUCK(4),KINDT(4,30),NTASBD(15),IASMTT
+(15),IASTTB(15),NPATH(4,15,4,10),IASTHB(15),NCOOSC(50)
+,IASIGN(4,30),NPHTK(4,15,4),NPOCKT(15),NTKDPS,NTKLDS,I
+ASLTW(15),MATER(4,30),ICOOST(4,30),LTCOOR(4,30)
 COMMON /BELIN3/NCGRP,NSECIS,ICDISG(4),NCSEPG(4),NCSCSZ
+(20),NCGRSZ(4),IASMTC(20),NCGRFT(4),ICGRFT(4,5),NCGRFB
+(4),ICGRFB(4,5),ICSTOP(20),ICDISS(20),NARYIG(4),IARYPG
+(4,5),NARYSC(20),IASCTB(20),IASCHB(4),NGASBD(4),NCASBD
+(20)
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      COMMON /TRNIN3/NUMTRN,NUMLDS,NUTRLT,IASRHB(6),IASRTB(6
     +),MXCRTR(6),NRCOOR,NRCOSC(30),NREDLT(30,5),LGTCON(30,5
     +,5),NRPATH(5,4,10),NPHRL(5,4),MTRASG(6),IASMTR(5),IASR
     +HS(5),NRTDPS,NRASBD(5),NRFIRT(6),NLOCO(6),KMATER(6),IR
     +COOT(6),LRCOOR(6),LREDLT(10),NASGLS(6),LDSCNT(6),MTOTL
     +D(6),KRAVDP(6),NDLBDP(6),NDUMDP(6),NDUMPG(6),MECRLS(5)
C *** SEE IF BELT WILL ACCEPT LOAD
C ***
      IF (CSESTP(NSC).NE.0) GO TO 25
      IF (CSDOWN(NSC).LT.0.) GO TO 55
C
C *** BELT NOT STOPPED. ADVANCE BELT
C ***
      CSCDIS(NSC)=CARYSC(NSC,1)
      CTWTSC(NSC)=CTWTSC(NSC)+CSCDIS(NSC)
      II=NARYSC(NSC)-1
      DO 15 I=1,II
   15 CARYSC(NSC,I)=CARYSC(NSC,I+1)
      CARYSC(NSC,II+1)=CDISRF(NSC)
      CDISRF(NSC)=0.
      IF (ICDISS(NSC).EQ.0) GO TO 55
      CSCHDB(ICDISS(NSC))=CSCHDB(ICDISS(NSC))+CSCDIS(NSC)
      GO TO 55
C ***
C *** IF LAST PANEL EVALUATED, ADVANCE MAIN BELT
C ***
   25 IF (ICDISS(NSC).EQ.0) GO TO 45
      CSBWTK(ICDISS(NSC))=CSBWTK(ICDISS(NSC))+DELTT
   45 CSESTP(NSC)=1
      IF (CSDOWN(NSC).GE.0.) GO TO 65
   55 A=CSDOWN(NSC)
      CC=CSCAVL(NSC)
      B=CSCFDD(NSC)
      CALL PROCES(A,B,CC,IBASE,DELTT)
      CSDOWN(NSC)=A
   65 IF (NSC.NE.NSECIS) RETURN
      NUML=1
      NUMH=NCSEPG(1)
      IS=0
C ***
C *** EVALUATE MAIN BELTS IN EACH GROUP
C ***
      IF (NCGRP.EQ.0) RETURN
      DO 325 IC=1,NCGRP
      IF (CGSTOP(IC).EQ.1)CGRWT(IC)=CGRWT(IC)+DELTT
      IF (NCSEPG(IC).EQ.0) GO TO 115
      DO 105 J=NUML,NUMH
      IS=IS+1
      IF (CGSTOP(IC).EQ.1) GO TO 85
      IF (CGDOWN(IC).LT.0.) GO TO 85
      CSESTP(J)=0
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```
      CLOAD=CSCDIS(J)+CARYGP(IC,IARYPG(IC,IS))
      CARYGP(IC,IARYPG(IC,IS))=CLOAD
      IF (CSCDIS(J).GT.CCAPGR(IC)*DELTT) WRITE (6,75)
   75 FORMAT (' ','SECTION FEEDING RATE TOO HIGH')
      IF (CLOAD.GT.CCAPGR(IC)*DELTT) GO TO 95
C ***
C *** MAIN BELT NOT OVERLOADED
C ***
      GO TO 105
C ***
C *** PANEL BELT STOP
C ***
   85 CSESTP(J)=1
      CSEWT(J)=CSEWT(J)+DELTT
      GO TO 105
   95 IF (ICSTOP(J).EQ.1) GO TO 85
C ***
C *** THIS SECTION BELT DOES NOT STOP, CUMULATE OVERLOAD
C ***
      CSEOVL(J)=CSEOVL(J)+CLOAD-CCAPGR(IC)*DELTT
  105 CONTINUE
  115 IS=0
      IF (NCSEPG(IC+1).EQ.0) GO TO 125
      NUML=NUMH+1
      NUMH=NCSEPG(IC+1)+NUML-1
C ***
C *** ADVANCE MAIN BELT IN GROUP
C ***
C ***
  125 IF (ICDISG(IC))  145,145,135
C *** LOADING TO MINE CAR
  135 IF (CLDMC(ICDISG(IC)).EQ.0) GO TO 165
      IF (CGDOWN(IC).LT.0.) GO TO 165
      CDISMC(IC)=CARYGP(IC,1)
      CGRDIS(IC)=CARYGP(IC,1)
  145 IF (CGSTOP(IC).EQ.1) GO TO 175
      IF (CGDOWN(IC).LT.0.) GO TO 175
      CGRDIS(IC)=CARYGP(IC,1)
C *** ADVANCE GROUP BELT
      LL=NARYIG(IC)-1
      DO 155 L=1,LL
  155 CARYGP(IC,L)=CARYGP(IC,L+1)
      CARYGP(IC,NARYIG(IC))=0.
      GO TO 175
C ***
C *** GROUP BELT WAITS FOR MINE CAR
C ****
  165 CGRDIS(IC)=0
      CDISMC(IC)=0.
      CGRWMC(IC)=CGRWMC(IC)+DELTT
C *** AT GROUPS INTERSECTIONS
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C *** ASSUME SURGE ALWAYS FEEDS TAIL OF NEXT GROUP
C ***(BIN AT HEAD OF GROUP IC FEEDS TAIL OF GROUP IC-1)
C *** IF THERE IS NO SURGE BIN SEE WHETHER GROUP I FEEDS TAI
  175 LL=NCGRFT(IC)
      KK=NCGRFB(IC)
      IF (LL.EQ.0) GO TO 215
      DO 205 L=1,LL
      IF (CGSTOP(IC).NE.0) GO TO 185
      IF (CGDOWN(IC).GE.0.) GO TO 195
  185 CGSTOP(ICGRFT(IC,L))=1
      GO TO 205
  195 CGSTOP(ICGRFT(IC,L))=0
      CGRDIS(ICGRFT(IC,L))=CARYGP(ICGRFT(IC,L),1)
      CARYGP(IC,NARYIG(IC))=CARYGP(IC,NARYIG(IC))+CGRDIS(ICG
     +RFT(IC,L))
  205 CONTINUE
C ***
C *** ACCUMULATE OVERLOAD
C ***
      IF (CGSTOP(IC).NE.0) GO TO 215
      IF (CGDOWN(IC).LT.0.) GO TO 215
      IF (CARYGP(IC,NARYIG(IC)).LE.CCAPGR(IC)*DELTT) GO TO 2
     +15
      CGROVL(IC)=CGROVL(IC)+CARYGP(IC,NARYIG(IC))-CCAPGR(IC)
     +*DELTT
C ***
C *** EITHER NO OVERLOAD OR SURGE BIN FEEDS TAIL OF GROUP IC
C ***
  215 IF (KK.EQ.0) GO TO 295
      IF (CGSTOP(IC).NE.0) GO TO 225
      IF (CGDOWN(IC).LT.0.) GO TO 225
      CARYGP(IC,NARYIG(IC))=CARYGP(IC,NARYIG(IC))+CBNDCH(IC)
      IF (CARYGP(IC,NARYIG(IC)).LE.CCAPGR(IC)*DELTT) GO TO 2
     +25
      CGROVL(IC)=CGROVL(IC)+CARYGP(IC,NARYIG(IC))-CCAPGR(IC)
     +*DELTT
C *** FILL BIN AT TAIL OF GROUP IC
  225 IF (CBINFL(IC).LT.CBINCP(IC)) GO TO 245
      DO 235 K=1,KK
  235 CGSTOP(ICGRFB(IC,K))=1
      GO TO 295
  245 DO 255 K=1,KK
  255 CGSTOP(ICGRFB(IC,K))=0
      DO 265 K=1,KK
  265 CBINFL(IC)=CBINFL(IC)+CGRDIS(ICGRFB(IC,K))
      CBINFL(IC)=CBINFL(IC)-CRATFD(IC)*DELTT
      IF (CBINFL(IC).LE.CBINCP(IC)) GO TO 275
C ***
C *** BIN OVERFLOW
      CBNOVF(IC)=CBNOVF(IC)+CBINFL(IC)-CBINCP(IC)
C *** BIN DISCHARGE
```

```
275 IF (CBINFL(IC).GT.CRATFD(IC)*DELTT) GO TO 285
    CBNDCH(IC)=0.
    GO TO 295
285 CBNDCH(IC)=CRATFD(IC)*DELTT
295 IF (CGSTOP(IC).EQ.0.) GO TO 315
    IF (CGDOWN(IC).GE.0.) GO TO 325
315 A=CGDOWN(IC)
    CC=CGPAVL(IC)
    B=CGPFDD(IC)
    CALL PROCES(A,B,CC,IBASE,DELTT)
    CGDOWN(IC)=A
325 CONTINUE
    RETURN
    END
```

APPENDIX IV

COMPUTER INPUT AND OUTPUT OF GCOS OPERATION

```
    1    1    1    1    1    0
1532206189
5.0       43200.
BWES
    2
0.80      20.0      0.60      1.00
0.63      30.0      0.55      1.00
    0
    2
0.12      30.0      1.10      10.0      9.00      7.20      1270000.  1590000.
0.03      8.00      5.00      0.00      0.60      1.00      1.00
0.60      30.
0.00      0.00
    5
4.57      4.57      0.9813    1.92      1.00
    1
4.57      4.57      0.9813    1.92      1.00
    1
4.57      4.57      0.9813    1.92      1.00
    1
4.57      4.57      0.9813    1.92      1.00
    1
4.57      4.57      0.9813    1.92      1.00
    1
0.03      0.05
0.12      30.0      1.10      10.0      9.00      7.20      1270000.  1590000.
0.03      8.00      5.00      0.00      0.60      1.00      1.00
0.70      30.0
0.00      0.00
    5
4.57      4.57      1.00      1.92      1.00
    2
4.57      4.57      1.00      1.92      1.00
    2
4.57      4.57      1.00      1.92      1.00
    2
```

```
4.57      4.57      1.00      1.92      1.00
    2
4.57      4.57      1.00      1.92      1.00
    2
0.03      0.05
    1    2
CONVEYORS
    1    3
    2
1390.
1025.
4.0
   72
3.33      3.33      3.33
   60   60   60
1025.     1025.     1025.
    1    1    0
4380.     4000.     5000.
    1
    1    1    2
    1    2    4
    0    0    0
    3
    1    1    2
0.75      30.
0.80      30.
0.95      30.
0.95      30.
1000.     1350.
    0

3.00      3.00      1.40
OTHERS
    3    1    4    5
```

```
0.0       0.C       100.







100.
1.36
    1
    1
    1    0
    4


LAST
```

```
SHIFT   1 REPCRT

SHIFT TIME =    360.08 MINUTE
TIME INCREMENT =      5.00 SECONDS
```

FACE EXCAVATORS OUTPUT STATISTICS

ORE BODY 1

BUCKET WHEEL EXCAVATOR NUMBER 1

WHEEL SPECIFICATIONS

WHEEL DIAMETER	9.00	METERS
NUMBER OF BUCKETS	10.	
BUCKET CAPACITY	1.10	CU.MTS.
CUT LENGTH	30.00	METERS
THEORETICAL CAPACITY	12500.28	TON/HOUR

OPERATING CONDITIONS

	SP.CUT.RESIS (KG/CM)	INITIAL HEIGHT (METER)	FINAL HEIGHT (METER)	FLOOR SLOPE (%)
BENCH 1	16.0-- 24.0	4.57	4.57	
BENCH 2	16.0-- 24.0	4.57	4.57	
BENCH 3	16.0-- 24.0	4.57	4.57	
BENCH 4	16.0-- 24.0	4.57	4.57	
BENCH 5	16.0-- 24.0	4.57	4.57	
				0.050

PRODUCTION STUDY

ORE EXCAVATED	14601.55	TONS
WASTE EXCAVATED	0.0	TONS
ACTUAL CAPACITY	5035.02	TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
174.00	10.61	72.33	93.00	15.33

POWER CONSUMPTION

CUT KWH	CROWD KWH	SLEW KWH	TRAM KWH
1453.55	19.56	1222.13	2.11

KW RATING OF THE DIGGING MOTOR 501.2
KW RATING OF THE SLEW MOTOR 421.4
KW RATING OF THE CRAWLER MOTORS 105.8

POSITION OF BUCKET WHEEL

WHEEL IS IN CUT 2 ADVANCE 3.19 METERS

BUCKET WHEEL EXCAVATOR NUMBER 2

WHEEL SPECIFICATIONS

WHEEL DIAMETER	9.00	METERS
NUMBER OF BUCKETS	10.	
BUCKET CAPACITY	1.10	CU.MTS.
CUT LENGTH	30.00	METERS
THEORETICAL CAPACITY	12500.28	TON/HOUR

OPERATING CONDITIONS

	SP.CUT.RESIS (KG/CM)	INITIAL HEIGHT (METER)	FINAL HEIGHT (METER)	FLOOR SLOPE (%)
BENCH 1	24.0-- 36.0	4.57	4.57	
BENCH 2	24.0-- 36.0	4.57	4.57	

BENCH 3	24.0-- 36.0	4.57	4.57
BENCH 4	24.0-- 36.0	4.57	4.57
BENCH 5	24.0-- 36.0	4.57	4.57

0.050

PRODUCTION STUDY

ORE EXCAVATED	15902.90 TONS
WASTE EXCAVATED	0.0 TONS
ACTUAL CAPACITY	4469.20 TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
213.50	11.09	67.83	73.33	0.0

POWER CONSUMPTION

CUT KWH	CROWD KWH	SLEW KWH	TRAM KWH
1658.94	26.23	1461.14	2.21

KW RATING OF THE DIGGING MOTOR 466.2
KW RATING OF THE SLEW MOTOR 410.6
KW RATING OF THE CRAWLER MOTORS 104.6

POSITION OF BUCKET WHEEL

WHEEL IS IN CUT 2 ADVANCE 6.87 METERS

BWE SUMMARY

	PRODUCTION(TONS) ORE	WASTE	LOADING (MINUTES)	WAITING (MINUTES)
ORE BODY 1				
BENCH 1	14601.6	0.0	174.00	72.33
BENCH 2	15902.9	0.0	213.50	67.83
SUBTOTAL	30504.4	0.0	387.50	140.17
GRAND TOTAL	30504.4	0.0	387.50	140.17
STATISTICS-TONS/HR/B,HRS/HR/B	2541.45	0.0	0.5381	0.1946

CONVEYORS OUTPUT STATISTICS

BELT GROUP 1

SECTION BELT	TOTAL PRODUCTION (TON)	OVERLOAD MAIN BELT (TON)	OVERLOAD PREVENTION (MIN)	WAIT FOR SURGE BIN (MIN)	WAIT FOR MAIN BELT (MIN)
1	14664.5	0.0	0.0	0.0	34.5
2	15797.4	0.0	0.0	0.0	34.5

GROUP 1 WAS OVERLOADED 0.0 TONS BY GROUPS 0
DELAY TIME(WAITING) 19.17 MINUTES
TOTAL DELAY TIME (WAITING+MECH.) 34.50 MINUTES

3	28583.8	0.0	0.0	0.0	0.0

APPENDIX V

COMPUTER INPUT AND OUTPUT OF HYPOTHETICAL CASE STUDY

```
   2     1     3     1     1
1292744850
5.0        216CC.
BWES        -- BWE INPUT DATA --
    6
0.90       30.C       0.40       1.0
0.80       60.C       0.40       0.8
0.50       9C.C       0.60       0.70
0.40       120.       0.60       0.7
0.30       15C.       C.70       0.7
0.20       18C.       C.70       0.7
0
    3       -- 3 BWES IN THE FIRST ORE BODY --
0.15       48.C       1.50       14.0       11.48      24.0       2500000.  3267000.
0.03       10.C       30.0       1800.      1.0        1.0        1.0
0.80       3C.C
400.       40C.
    2
7.5        7.5        0.999      2.5        0.0
    3
7.5        7.5        0.999      2.5        0.0
    3
0.02        0.C5
0.15       48.C       1.50       14.0       11.48      24.C       2500000.  3267000.
0.03       10.C       30.0       1800.      1.0        1.0        1.0
0.80       30.C
400.       40C.
    2
7.5        7.5        0.999      2.5        1.0
    2
7.5        7.5        0.999      2.5        1.0
    2
0.02        0.C5
0.15       48.C       1.50       14.0       11.48      24.0       2500000.  3267000.
0.03       10.0       30.0       1800.      1.0        1.0        1.0
0.80       30.C
```

```
400.      400.
    2
7.5       7.5       0.999     2.5       1.0
    2
7.5       7.5       0.999     2.5       1.0
    2
0.02       0.05

    3      -- 3 BWE IN THE SECOND ORE BODY  --
0.15      48.0      1.50      14.0      11.48     24.0      2500000.  3267000.
0.03      10.0      30.0      1800.     1.0       1.0       1.0
0.80      30.0
400.      400.
    2
7.5       7.5       0.999     2.5       1.0
    1
7.5       7.5       0.999     2.5       1.0
    2
0.02       0.05
0.15      48.0      1.50      14.0      11.48     24.0      2500000.  3267000.
0.03      10.0      30.0      1800.     1.0       1.0       1.0
0.80      30.0
400.      400.
    2
7.5       7.5       0.999     2.5       1.0
    2
7.5       7.5       0.999     2.5       1.0
    2
0.02       0.05
0.15      48.0      1.50      14.0      11.48     24.0      2500000.  3267000.
0.03      10.0      30.0      1800.     1.0       1.0       1.0
0.80      30.0
400.      400.
    2
7.50      7.50      0.99      2.50      1.00
    2
```

```
7.50       7.5C       0.99       2.50       1.00
   2
0.02        C.C5
   1    2    3
   4    5    6
TRUCKS           **** TRUCKS INPUT DATA ******
   4
      75.0       41.5        10.       10.HAULPAK READ CUMP 75B GM 16V71 ENGINE
       C.0        2.0        4.0        6.0        8.0       10.0       12.0       14.0
      16.0       2C.C       24.0       28.0       32.0       44.0

    66C00.     540CC.     41500.     30500.     21800.     18000.     16000.     13000.
    12000.      9400.      7700.      6500.      5700.      5000.      4500.

      9C.0       77.6        10.       10.HAULPAKBOTTOM DUMP MODEL 90 CUMMINS VT
       0.0        2.0        4.0        6.0        8.0       10.0       12.0       14.0
      16.0       20.C       24.0       28.0       32.0       38.0       44.0

    5120C.     405C0.     31000.     21000.     18500.     13000.     11800.     10000.
     6800.      5400.      5000.      4600.      3500.      3300.

      100.       8C.4        10.       10.HAULPAK BOTTOM DUMP MODEL 100 CUMMINS VT
       C.0        2.0        4.0        6.0        8.0       10.0       12.0       14.0
      16.0       2C.C       24.0       28.0       32.0       38.0       44.0

    512C0.     405C0.     300C0.     21000.     18500.     13500.     12000.      9500.
     9000.      6900.      5500.      4900.      4400.      3480.      3300.

      120.       1C0.        10.       10.HAULPAK BOTTOM DUMP MODEL 120 GM 16V
       C.0        2.0        4.0        6.0        8.0       10.0       12.0       14.0
      16.0       2C.C       24.0       28.0       32.0       38.0       44.0

    530CC.     460C0.     36000.     26000.     19000.     16500.     13000.     12000.
     9600.      8300.      6400.      6200.      4800.      4300.      4000.

51.5       47.C       42.6       38.2       35.3       32.3       29.4       27.9
```

26.5		25.0		23.5		22.1		20.6		19.1		17.6				109
																110
0.5																111
6																112
4	2	3	4	2	2											113
0.90		300.														114
0.90		300.														115
0.90		300.														116
0.90		300.														117
0.90		300.														118
0.90		300.														119
30																120
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	121
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		122
0.90		300.														123
0.90		300.														124
0.90		300.														125
0.90		300.														126
0.90		300.														127
0.90		300.														128
0.90		300.														129
0.900		300.														130
0.900		300.														131
0.900		300.														132
0.90		300.														133
0.90		300.														134
0.90		300.														135
0.90		300.														136
0.90		300.														137
0.90		300.														138
0.90		300.														139
0.90		300.														140
0.90		300.														141
0.90		300.														142
0.90		300.														143
0.90		300.														144

```
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
    25
     1    1    2    1    2    2    2    2    2    2    2    2    2    2    2    2
     2    2    2    3    3    3    3    3    3    3
  0.900      30C.
  0.900      3CC.
  0.900      3CC.
  0.900      30C.
  0.900      30C.
  0.900      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      300.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      300.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
  0.90      30C.
```

```
   21
    1             CCORDINATE 6
10.0
0.0
2.0
1000.
1000.
    1       CCORDINATE 7
 10.0
0.0
2.0
1000.
1000.
    2       CCORDINATE 8
15.0       15.C
0.0        0.C
2.0        2.C
500.       80C.
1300.
    2       CCORDINATE 9
15.0       15.0
0.0        0.C
2.0        2.C
800.       50C.
1300.
    2       CCRDINATE 10
15.0       15.0
2.C        1.C
2.0        2.C
800.0      20C.
1000.
    2       CCRDINATE 11
15.0       15.C
-1.0       -2.C
2.0        2.C
200.       80C.
```

```
1000.
    2       COORDINATE 12
15.0      15.0
8.0       4.0
2.0       2.0
800.      600.
1400.
    2       COORDINATE 13
15.0      15.0
-4.0      -8.0
2.0       2.0
600.      800.
1400.
    1       COORDINATE 14
20.0
0.0
2.0
500.
500.
    1       COORDINATE 15
20.0
0.0
2.0
500.
500.
    2       COORDINATE 16
20.0      10.0
0.0       5.0
2.0       2.0
600.      300.
900.
    2       COORDINATE 17
10.0      20.0
-5.0      0.0
2.0       2.0
300.      600.
```

```
900.
   1       COORDINATE 18
10.0
0.0
2.0
500.
500.0
   1       COOTDINATE 19
10.0
0.0
2.0
500.0
500.0
   1       CCCRDINATE 20
15.0
2.0
2.0
1000.
1000.
   1       CCCRDINATE 21
15.0
-2.0
2.0
1000.
1000.
   1    5
   1    2    2    2    3
   2    6    2     -- TRUCK PATH FROM 1ST TRUCK LOADING STATION  --
   2    6    2
   2    7    1
   2    7    1
   6   12    5   14    5   18    3
   6   12    5   14    5   16    2
   6   19    5   15    5   13    1
   6   17    5   15    5   13    1
   6   10    5   14    5   18    3
```

```
    6   10    5   14    5   16    2
    6   19    5   15    5   11    1
    6   17    5   15    5   11    1
    4    8    5   18    3      -- TRUCK PATH FROM 4TH TRUCK LOADING STATION --
    4    8    5   16    2
    4   19    5    9    1
    4   17    5    9    1
    2   20    2                -- TRUCK PATH FROM 5TH TRUCK LOADING STATION --
    2   20    2
    2   21    4
    2   21    4
    1    1    1    1    1    1
    2    2    2    2    2    2    2    2    2    2    3    3    3    3    3    3
    3    3    3    3    4    4    4    4    4    4    4    4    4    4
    5    5    5    5    5    5    5    5    5    5    5    5    5    5    5    5
    5    5    5    5    5    5    5    5    5    5    5    5    5    5
    2    1    1    1    2
    1    3    3    3    2
    1    4    5    6    5
    0    1    1    1    0
5.0       5.0       5.0       5.0       5.0       5.0       5.0
    2    2    2    2    5
    3
CONVEYORS      -- CONVEYOR INPUT DATA --
    0    2          -- TWO SECTION BELT  NO GROUP BELT --
    2       -- NUMBER OF SECTION BELT IN GROUP --
0.        0.
0.        0.
    0.    0.
    0    0          -- SIZE OF GROUP BELT --
9.5       9.5
   42   42
400.      400.
    0    0
2000.0    2000.             -- LENGTH OF SECTION BELT --
    0    0
```

```
     1     1          -- ASSIGN SECTION BELT TO ORE BODY --
     3     2
     2     3          -- DISCHARGE TO NUMBER 2 AND NUMBER 3 BIN --
     0     0
     1     1          -- MATERIAL AT THIS SECTION IS ORE --
0.80      30.C
0.80      30.C
          300.
0.
    0
    0
1.5       1.5
TRAINS     -- TRAIN INPUT DATA --
    4     2     7     1
 10.C      3C.0       10.0       50.0       50.0
0.4       0.4       0.4       0.4       --MAX ACCELERATION FOR 1ST LOCO --
0.4       0.4       0.4       0.4
0.4       0.4       0.4       0.4        -- AVERAGE DECELERATION RATE --
0.4       0.4       0.4       0.4
30.0      3C.C      30.0      30.0
30.C      30.C      30.0      30.0
15.0      15.C      15.0      15.0
15.0      15.C      15.0      15.0
   60    60    60    6C
60.0      6C.C      60.0      60.0
10.0      10.C      10.C      10.0
3.0       3.C
   40    40
80.C      80.C          -- ASSIGN EMPTH CARS TO L.S. AT BEGINNING --
0.95      30C.
0.95      30C.
0.95      30C.
0.95      30C.
0.95      300.
0.95      30C.
0.95      30C.
```

0.95	300.
0.0	81000.
1.0	80000.
2.0	78000.
4.0	75000.
6.0	72000.
8.0	68000.
10.0	63000.
12.5	58000.
15.0	53000.
17.5	48000.
20.0	42000.
25.0	33000.
30.0	25000.
40.0	10000.
45.0	5000.
50.0	3000.
55.0	2000.
60.0	1000.
70.0	1000.
0.0	81000.
1.0	80000.
2.0	78000.
4.0	75000.
6.0	72000.
8.0	68000.
10.0	63000.
12.5	58000.
15.0	53000.
17.5	48000.
20.0	42000.
25.0	33000.
30.0	25000.
40.0	10000.
45.0	5000.

50.0	3000.
55.0	2000.
60.0	1000.
70.0	1000.
0.0	81000.
1.0	80000.
2.0	78000.
4.0	75000.
6.0	72000.
8.0	68000.
10.0	63000.
12.5	58000.
15.0	53000.
17.5	48000.
20.0	42000.
25.0	33000.
30.0	25000.
40.0	10000.
45.0	5000.
50.0	3000.
55.0	2000.
60.0	1000.
70.0	1000.
0.0	81000.
1.0	80000.
2.0	78000.
4.0	75000.
6.0	72000.
8.0	68000.
10.0	63000.
12.5	58000.
15.0	53000.
17.5	48000.
20.0	42000.

25.0	33000.
30.0	25000.
40.0	10000.
45.0	5000.
50.0	3000.
55.0	2000.
60.0	1000.
70.0	1000.

0.0	81000.
1.0	80000.
2.0	78000.
4.0	75000.
6.0	72000.
8.0	68000.
10.0	63000.
12.5	58000.
15.0	53000.
17.5	48000.
20.0	42000.
25.0	33000.
30.0	25000.
40.0	10000.
45.0	5000.
50.0	3000.
55.0	2000.
60.0	1000.
70.0	1000.

0.0	81000.
1.0	80000.
2.0	78000.
4.0	75000.
6.0	72000.
8.0	68000.
10.0	63000.

12.5	58000.
15.0	53000.
17.5	48000.
20.0	42000.
25.0	33000.
30.0	25000.
40.0	10000.
45.0	5000.
50.0	3000.
55.0	2000.
60.0	1000.
70.0	1000.
0.0	81000.
1.0	80000.
2.0	78000.
4.0	75000.
6.0	72000.
8.0	68000.
10.0	63000.
12.5	58000.
15.0	53000.
17.5	48000.
20.0	42000.
25.0	33000.
30.0	25000.
40.0	10000.
45.0	5000.
50.0	3000.
55.0	2000.
60.0	1000.
70.0	1000.
0.0	81000.
1.0	80000.
2.0	78000.

```
4.0        75000.
6.0        72000.
8.0        68000.
10.0       63000.
12.5       58000.
15.0       53000.
17.5       48000.
20.0       42000.
25.0       33000.
30.0       25000.
40.0       10000.
45.0       5000.
50.0       3000.
55.0       2000.
60.0       1000.
70.0       1000.

   13
    3                   COORDINATE 6
10.0       0.0          1000.         0     1
30.0       0.0          5000.         0     0
10.0       0.0          1000.         2     3
7000.
    3                   COORDINATE 7
50.0       0.0          50000.        0     0
10.0       0.0          2000.         4     0
10.0       0.0          1000.         0     4
53000.
    3                   COORDINATE 8
10.0       0.0          1000.         0     4
50.0       0.0          55000.        0     0
10.0       0.0          1000.         5     7
57000.
    1                   COORDINATE 9
20.0       0.0          2000.         0     7
2000.
```

```
     3                  COORDINATE 10
30.0        0.0         3000.        0     0
10.0        0.0         1000.        1     0
10.0        0.0         1000.        0     1
5000.
     3                  COORDINATE 11
30.0        0.0         6000.        0     0
10.0        0.0         1000.        6     0
10.0        0.0         1000.        0     6
8000.
     3                  COORDINATE 12
10.0        0.0         1000.        0     6
40.0        0.0         6000.        0     0
10.0        0.0         1000.        7     0
8000.
     3                  COORDINATE 13
30.0        0.0         3000.        0     5
30.0        0.0         3000.        0     0
10.0        0.0         1000.        3     2
7000.
     4     6     5     7     3                   TRAIN FROM 1ST LOADING STATION
     4     6     5     7     3
     6     8     5     9     5    10     1
     6     8     5     9     5    10     1
     6    12     5    13     5     7     3       TRAIN FROM 2ND LOADING STATION
     6    12     5    13     5     7     3
     6     8     5     9     5    11     1
     6     8     5     9     5    11     1
     1     2     1     2       -- ASSIGN TRAIN TO LOADING STATION AT BEFINNING --
     1     1                -- ASSIGN HEAD BIN TO EACH LOADINGSTATION --
     2     3                -- ASSIGN TAIL BIN TO EACH LOADING STATION --
     1     1
     1     1
OTHERS                      -- GENERAL INPUT DATA --
     4     1     4     3     5
     3     1     2     5
```

```
100.    100.    100.    100.    100.    100.    100.    100.
100.    100.    100.    100.    100.    100.    100.    100.
100.    100.    100.    100.    100.    100.    100.    100.
100.    100.    100.    100.    100.    100.    100.    100.
100.    100.    100.    100.    100.    100.    100.    100.
100.    100.    100.    100.    100.    100.    100.    100.
100.    100.    100.    100.    100.    100.    100.    100.
100.    100.    100.    100.    100.    100.    100.    100.
100.    100.    100.    100.    100.    100.    100.    100.
100.    100.    100.    100.    100.
3000.0
50.0
    3    3    3    3    3    3
    4    4
    1    1         -- 1ST AND 2ND ORE BODY USE CRUSHER 1 --
    0    0
    0    0
    5      -- TAILING LOADING IS THE 5TH TRUCK L.S. IN THE SYSTEM --
LAST
```

SHIFT 1 FEPCRT

SHIFT TIME = 360.08 MINUTE
TIME INCREMENT = 5.00 SECONDS

TRUCK PRODUCTION STATISTICS

ASSIGNED ORE BODY	TRUCK NUMBER	TRUCK TYPE	CAPACITY (TON)	LOADS ORE	LOADS WASTE	TONS ORE	TONS WASTE	TONS TAILING
1 - 1	1	HAULP	120.	0	57	0.0	7000.0	0.0
1 - 1	2	HAULP	90.	0	56	0.0	5500.0	0.0
1 - 1	3	HAULP	100.	0	54	0.0	6875.0	0.0
1 - 1	4	HAULP	120.	0	51	0.0	6375.0	0.0
1 - 1	5	HAULP	90.	0	51	0.0	5100.0	0.0
1 - 1	6	HAULP	90.	0	46	0.0	4600.0	0.0
BENCH TOTAL						0.0	35450.0	0.0
SUBTOTAL						0.0	35450.0	0.0
2 - 1	1	HAULP	100.	24	0	3125.0	0.0	0.0
2 - 1	2	HAULP	100.	24	0	2875.0	0.0	0.0
2 - 1	3	HAULP	100.	22	0	2750.0	0.0	0.0
2 - 1	4	HAULP	100.	25	0	3000.0	0.0	0.0
2 - 1	5	HAULP	100.	22	0	2875.0	0.0	0.0
2 - 1	6	HAULP	100.	24	0	3000.0	0.0	0.0
2 - 1	7	HAULP	100.	24	0	3000.0	0.0	0.0
2 - 1	8	HAULP	100.	23	0	2875.0	0.0	0.0
2 - 1	9	HAULP	100.	24	0	3000.0	0.0	0.0
2 - 1	10	HAULP	100.	22	0	2875.0	0.0	0.0
BENCH TOTAL						29375.0	0.0	0.0
2 - 2	11	HAULP	100.	38	0	4750.0	0.0	0.0
2 - 2	12	HAULP	100.	37	0	4625.0	0.0	0.0
2 - 2	13	HAULP	100.	38	0	4750.0	0.0	0.0
2 - 2	14	HAULP	100.	35	0	4375.0	0.0	0.0
2 - 2	15	HAULP	100.	36	0	4500.0	0.0	0.0
2 - 2	16	HAULP	100.	32	0	3875.0	0.0	0.0
2 - 2	17	HAULP	100.	36	0	4375.0	0.0	0.0
2 - 2	18	HAULP	100.	35	0	4250.0	0.0	0.0
2 - 2	19	HAULP	100.	36	0	4375.0	0.0	0.0
2 - 2	20	HAULP	100.	31	0	3875.0	0.0	0.0
BENCH TOTAL						43750.0	0.0	0.0
2 - 3	21	HAULP	100.	32	0	4000.0	0.0	0.0
2 - 3	22	HAULP	100.	34	0	4250.0	0.0	0.0

2 - 3	23	HAULP	100.	34	0	4125.0	0.0	0.0
2 - 3	24	HAULP	100.	33	0	4125.0	0.0	0.0
2 - 3	25	HAULP	100.	32	0	3875.0	0.0	0.0
2 - 3	26	HAULP	100.	34	0	4125.0	0.0	0.0
2 - 3	27	HAULP	100.	31	0	3875.0	0.0	0.0
2 - 3	28	HAULP	100.	32	0	3875.0	0.0	0.0
2 - 3	29	HAULP	100.	23	0	2750.0	0.0	0.0
2 - 3	30	HAULP	100.	21	0	2625.0	0.0	0.0
BENCH TOTAL						37625.0	0.0	0.0
SUBTOTAL						110750.0	0.0	0.0
3 - 0	1	HAULP	75.	0	63	0.0	4725.0	4725.0
3 - 0	2	HAULP	75.	0	62	0.0	4725.0	4650.0
3 - 0	3	HAULP	90.	0	65	0.0	5940.0	5850.0
3 - 0	4	HAULP	75.	0	62	0.0	4575.0	4650.0
3 - 0	5	HAULP	90.	0	62	0.0	5490.0	5580.0
3 - 0	6	HAULP	90.	0	58	0.0	5130.0	5220.0
3 - 0	7	HAULP	90.	0	57	0.0	5040.0	5130.0
3 - 0	8	HAULP	90.	0	60	0.0	5400.0	5400.0
3 - 0	9	HAULP	90.	0	60	0.0	5400.0	5400.0
3 - 0	10	HAULP	90.	0	62	0.0	5580.0	5580.0
3 - 0	11	HAULP	90.	0	61	0.0	5490.0	5490.0
3 - 0	12	HAULP	90.	0	59	0.0	5310.0	5310.0
3 - 0	13	HAULP	90.	0	61	0.0	5490.0	5490.0
3 - 0	14	HAULP	90.	0	62	0.0	5670.0	5580.0
3 - 0	15	HAULP	90.	0	62	0.0	5580.0	5580.0
3 - 0	16	HAULP	90.	0	59	0.0	5310.0	5310.0
3 - 0	17	HAULP	90.	0	57	0.0	5130.0	5130.0
3 - 0	18	HAULP	90.	0	60	0.0	5400.0	5400.0
3 - 0	19	HAULP	90.	0	61	0.0	5400.0	5490.0
3 - 0	20	HAULP	100.	0	54	0.0	5500.0	5400.0
3 - 0	21	HAULP	100.	0	56	0.0	5700.0	5600.0
3 - 0	22	HAULP	100.	0	55	0.0	5600.0	5500.0
3 - 0	23	HAULP	100.	0	56	0.0	5500.0	5600.0
3 - 0	24	HAULP	100.	0	47	0.0	4700.0	4700.0
3 - 0	25	HAULP	100.	0	40	0.0	4000.0	4000.0

SUBTOTAL	0.0	131785.0	131765.0
TOTAL PRODUCTION IN THE WHOLE SYSTEM	110750.0	167235.0	131765.0

TRUCK WAITING TIME

ASSIGNED ORE BODY	TRUCK NUMBER	WAIT AT BWE FOR LOADING(MINUTES)	WAIT AT MILL FOR LOADING(MINUTES)	WAIT FOR DUMPING ORE(MINUTES)	WAIT DUMPING WASTE(MINUTES)
1 - 1	1	31.08	0.0	0.0	0.0
1 - 1	2	41.17	0.0	0.0	0.0
1 - 1	3	35.75	0.0	0.0	0.0
1 - 1	4	54.50	0.0	0.0	0.0
1 - 1	5	62.00	0.0	0.0	0.0
1 - 1	6	86.50	0.0	0.0	0.0
BENCH TOTAL		311.00	0.0	0.0	0.0
SUBTOTAL		311.00	0.0	0.0	0.0
HRS/HR/TRUCK		0.1439	0.0	0.0	0.0
2 - 1	1	2.42	0.0	0.67	0.0
2 - 1	2	1.83	0.0	2.08	0.0
2 - 1	3	2.00	0.0	1.92	0.0
2 - 1	4	1.00	0.0	0.50	0.0
2 - 1	5	0.0	0.0	0.0	0.0
2 - 1	6	3.58	0.0	0.0	0.0
2 - 1	7	0.0	0.0	0.17	0.0
2 - 1	8	0.0	0.0	0.08	0.0
2 - 1	9	5.25	0.0	1.67	0.0
2 - 1	10	0.0	0.0	0.08	0.0
BENCH TOTAL		16.08	0.0	7.17	0.0

2 - 2	11	28.50	0.0	0.58	0.0
2 - 2	12	29.50	0.0	0.25	0.0
2 - 2	13	28.83	0.0	0.0	0.0
2 - 2	14	29.50	0.0	1.25	0.0
2 - 2	15	27.58	0.0	1.83	0.0
2 - 2	16	39.00	0.0	0.58	0.0
2 - 2	17	33.25	0.0	0.08	0.0
2 - 2	18	36.75	0.0	0.0	0.0
2 - 2	19	56.33	0.0	0.0	0.0
2 - 2	20	66.75	0.0	3.08	0.0
BENCH TOTAL		376.00	0.0	7.67	0.0
2 - 3	21	92.17	0.0	4.42	0.0
2 - 3	22	91.17	0.0	0.17	0.0
2 - 3	23	94.83	0.0	1.00	0.0
2 - 3	24	96.33	0.0	0.0	0.0
2 - 3	25	94.50	0.0	0.08	0.0
2 - 3	26	98.33	0.0	0.75	0.0
2 - 3	27	101.67	0.0	1.00	0.0
2 - 3	28	111.67	0.0	0.0	0.0
2 - 3	29	179.42	0.0	0.0	0.0
2 - 3	30	190.25	0.0	0.0	0.0
BENCH TOTAL		1150.33	0.0	7.42	0.0
SUBTOTAL		1542.42	0.0	22.25	0.0
HRS/HR/TRUCK		0.1428	0.0	0.0021	0.0
3 - 0	1	0.0	83.75	0.0	0.83
3 - 0	2	0.0	88.50	0.0	0.92
3 - 0	3	0.0	86.42	0.0	1.58
3 - 0	4	0.0	84.50	0.0	1.00
3 - 0	5	0.0	90.92	0.0	0.67
3 - 0	6	0.0	85.67	0.0	1.00
3 - 0	7	0.0	85.50	0.0	1.92
3 - 0	8	0.0	92.75	0.0	2.00
3 - 0	9	0.0	90.17	0.0	0.67
3 - 0	10	0.0	91.75	0.0	1.08

3 - C	11	C.0	97.17	0.0	2.17
3 - 0	12	C.0	95.58	0.0	1.17
3 - 0	13	C.0	95.25	0.0	0.58
3 - C	14	C.0	101.33	0.0	0.92
3 - 0	15	C.0	102.25	0.0	1.00
3 - C	16	C.0	100.17	0.0	1.33
3 - C	17	0.0	95.17	0.0	1.50
3 - 0	18	C.0	105.67	0.0	0.83
3 - 0	19	C.0	101.25	0.0	1.00
3 - 0	20	C.0	111.92	0.0	0.83
3 - 0	21	C.0	105.42	0.0	0.67
3 - 0	22	C.0	112.75	0.0	0.83
3 - 0	23	C.0	121.17	0.0	1.50
3 - 0	24	C.0	132.67	0.0	0.83
3 - C	25	C.0	175.42	0.0	3.50
SUBTOTAL		C.0	2533.08	0.0	30.33
HRS/HR/TRUCK		0.0	0.2814	0.0	0.0034

FACE EXCAVATORS OUTPUT STATISTICS

ORE BODY 1

BUCKET WHEEL EXCAVATOR NUMBER 1

WHEEL SPECIFICATIONS

WHEEL DIAMETER	11.48	METERS
NUMBER OF BUCKETS	14.	
BUCKET CAPACITY	1.50	CU.MTS.
CUT LENGTH	48.00	METERS
THEORETICAL CAPACITY	27512.87	TON/HOUR

OPERATING CONDITIONS

	SP.CUT.RESIS (KG/CM)	INITIAL HEIGHT (METER)	FINAL HEIGHT (METER)	FLOOR SLOPE (%)
BENCH 1	72.0--108.0	7.50	7.50	
BENCH 2	72.0--108.0	7.50	7.50	
				0.050

PRODUCTION STUDY

ORE EXCAVATED	0.0	TONS
WASTE EXCAVATED	35544.37	TONS
ACTUAL CAPACITY	7360.35	TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
289.75	5.42	0.0	59.58	8.00

POWER CONSUMPTION

CUT KWH	CROWD KWH	SLEW KWH	TRAM KWH
6290.25	28.65	5244.71	0.76

KW RATING OF THE DIGGING MOTOR 1302.6
KW RATING OF THE SLEW MOTOR 1086.0
KW RATING OF THE CRAWLER MOTORS 159.5

POSITION OF BUCKET WHEEL

WHEEL IS IN CUT 2 ADVANCE 22.43 METERS

BUCKET WHEEL EXCAVATOR NUMBER 2

WHEEL SPECIFICATIONS

WHEEL DIAMETER	11.48	METERS
NUMBER OF BUCKETS	14.	
BUCKET CAPACITY	1.50	CU.MTS.
CUT LENGTH	48.00	METERS
THEORETICAL CAPACITY	27512.87	TON/HOUR

OPERATING CONDITIONS

	SP.CUT.RESIS (KG/CM)	INITIAL HEIGHT (METER)	FINAL HEIGHT (METER)	FLOOR SLOPE (%)
BENCH 1	48.0-- 72.0	7.50	7.50	
BENCH 2	48.0-- 72.0	7.50	7.50	
				0.050

PRODUCTION STUDY

ORE EXCAVATED 17985.31 TONS
WASTE EXCAVATED 0.0 TONS
ACTUAL CAPACITY 9953.44 TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
108.42	4.34	222.00	25.42	1.50

POWER CONSUMPTION

CUT KWH	CROWD KWH	SLEW KWH	TRAM KWH
1814.92	6.40	1256.63	0.61

KW RATING OF THE DIGGING MOTOR 1004.4
KW RATING OF THE SLEW MOTOR 695.4
KW RATING OF THE CRAWLER MOTORS 165.9

POSITION OF BUCKET WHEEL

WHEEL IS IN CUT 2 ADVANCE 10.95 METERS

BUCKET WHEEL EXCAVATOR NUMBER 3

WHEEL SPECIFICATIONS

WHEEL DIAMETER	11.48	METERS
NUMBER OF BUCKETS	14.	
BUCKET CAPACITY	1.50	CU.MTS.
CUT LENGTH	48.00	METERS
THEORETICAL CAPACITY	27512.87	TON/HOUR

OPERATING CONDITIONS

SP.CUT.RESIS (KG/CM)	INITIAL HEIGHT (METER)	FINAL HEIGHT (METER)	FLOOR SLOPE (%)

BENCH 1	48.0-- 72.0	7.50	7.50
BENCH 2	48.0-- 72.0	7.50	7.50

0.050

PRODUCTION STUDY

ORE EXCAVATED	17556.76 TONS
WASTE EXCAVATED	0.0 TONS
ACTUAL CAPACITY	9953.44 TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
105.83	4.53	227.58	19.92	4.0(

POWER CONSUMPTION

CUT KWH	CROWD KWH	SLEW KWH	TRAM KWH
1771.68	6.98	1226.69	0.64

KW RATING OF THE DIGGING MOTOR	1004.4
KW RATING OF THE SLEW MOTOR	695.4
KW RATING OF THE CRAWLER MOTORS	164.6

POSITION OF BUCKET WHEEL

WHEEL IS IN CUT 2 ADVANCE 10.53 METERS

ORE BODY 2

BUCKET WHEEL EXCAVATOR NUMBER 1

WHEEL SPECIFICATIONS

WHEEL DIAMETER	11.48	METERS
NUMBER OF BUCKETS	14.	
BUCKET CAPACITY	1.50	CU.MTS.
CUT LENGTH	48.00	METERS
THEORETICAL CAPACITY	27512.87	TON/HOUR

OPERATING CONDITIONS

	SP.CUT.RESIS (KG/CM)	INITIAL HEIGHT (METER)	FINAL HEIGHT (METER)	FLOOR SLOPE (%)
BENCH 1	24.0-- 36.0	7.50	7.50	
BENCH 2	48.0-- 72.0	7.50	7.50	
				0.050

PRODUCTION STUDY

ORE EXCAVATED	29251.68	TONS
WASTE EXCAVATED	0.0	TONS
ACTUAL CAPACITY	9967.45	TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
176.08	5.03	139.58	34.17	7.50

POWER CONSUMPTION

CUT KWH	CROWD KWH	SLEW KWH	TRAM KWH
2946.48	14.91	2038.52	0.71

KW RATING OF THE DIGGING MOTOR 1004.0
KW RATING OF THE SLEW MOTOR 694.6
KW RATING OF THE CRAWLER MOTORS 161.5

POSITION OF BUCKET WHEEL

WHEEL IS IN CUT 2 ADVANCE 18.54 METERS

BUCKET WHEEL EXCAVATOR NUMBER 2

WHEEL SPECIFICATIONS

WHEEL DIAMETER	11.48	METERS
NUMBER OF BUCKETS	14.	
BUCKET CAPACITY	1.50	CU.MTS.
CUT LENGTH	48.00	METERS
THEORETICAL CAPACITY	27512.87	TON/HOUR

OPERATING CONDITIONS

	SP.CUT.RESIS (KG/CM)	INITIAL HEIGHT (METER)	FINAL HEIGHT (METER)	FLOOR SLOPE (%)
BENCH 1	48.0-- 72.0	7.50	7.50	
BENCH 2	48.0-- 72.0	7.50	7.50	
				0.050

PRODUCTION STUDY

ORE EXCAVATED	44237.50	TONS
WASTE EXCAVATED	0.0	TONS
ACTUAL CAPACITY	9953.44	TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
266.67	6.89	8.42	68.75	12.50

POWER CONSUMPTION

CUT KWH	CROWD KWH	SLEW KWH	TRAM KWH
4464.03	31.03	3090.75	1.32

KW RATING OF THE DIGGING MOTOR 1004.4
KW RATING OF THE SLEW MOTOR 695.4
KW RATING OF THE CRAWLER MOTORS 161.4

POSITION OF BUCKET WHEEL

WHEEL IS IN CUT 1 ADVANCE 4.21 METERS

BUCKET WHEEL EXCAVATOR NUMBER 3

WHEEL SPECIFICATIONS

WHEEL DIAMETER	11.48	METERS
NUMBER OF BUCKETS	14.	
BUCKET CAPACITY	1.50	CU.MTS.
CUT LENGTH	48.00	METERS
THEORETICAL CAPACITY	27512.87	TON/HOUR

OPERATING CONDITIONS

	SP.CUT.RESIS (KG/CM)	INITIAL HEIGHT (METER)	FINAL HEIGHT (METER)	FLOOR SLOPE (%)
BENCH 1	48.0-- 72.0	7.50	7.50	
BENCH 2	48.0-- 72.0	7.50	7.50	
				0.050

PRODUCTION STUDY

ORE EXCAVATED 38182.49 TONS
WASTE EXCAVATED 0.0 TONS
ACTUAL CAPACITY 9953.44 TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
230.17	5.63	0.0	62.50	64.50

POWER CONSUMPTION

CUT KWH	CROWD KWH	SLEW KWH	TRAM KWH
3853.02	23.18	2667.71	0.84

KW RATING OF THE DIGGING MOTOR 1004.4
KW RATING OF THE SLEW MOTOR 695.4
KW RATING OF THE CRAWLER MOTORS 160.0

POSITION OF BUCKET WHEEL

WHEEL IS IN CUT 1 ADVANCE 0.42 METERS

BWE SUMMARY

	PRODUCTION(TONS) ORE	WASTE	LOADING (MINUTES)	WAITING (MINUTES)
ORE BODY 1				
BENCH 1	0.0	35544.4	289.75	0.0
BENCH 2	17985.3	0.0	108.42	222.00
BENCH 3	17556.8	0.0	105.83	227.58
SUBTOTAL	35542.1	35544.4	504.00	449.58
ORE BODY 2				
BENCH 1	29251.7	0.0	176.08	139.58
BENCH 2	44237.5	0.0	266.67	8.42
BENCH 3	38182.5	0.0	230.17	0.0
SUBTOTAL	111671.6	0.0	672.92	148.00
GRAND TOTAL	147213.6	35544.4	1176.92	597.58
STATISTICS-TONS/HR/B,HRS/HR/B	4088.32	987.12	0.5447	0.2766

CONVEYORS OUTPUT STATISTICS

SECTION BELT	TOTAL PRODUCTION (TON)	OVERLOAD MAIN BELT (TON)	OVERLOAD PREVENTION (MIN)	WAIT FOR SURGE BIN (MIN)	WAIT FOR MAIN BELT (MIN)
1	17542.5	0.0	0.0	123.5	0.0
2	17992.5	0.0	0.0	124.3	0.0

TRAINS OUTPUT STATISTICS

LOADING STATION 1
    TOTAL CARS LOADED 348
    WAIT TIME FOR EMPTY MINE CARS 130.00 MINUTES

LOADING STATION 2
    TOTAL CARS LOADED 359
    WAIT TIME FOR EMPTY MINE CARS 127.33 MINUTES

TRAIN 1
    TONNAGE HAULED 6000.0
    AT LOADING STATION 1
        DELAY TIME 19.4 MINUTES
        CARS LOADED 60
    AT LOADING STATION 2
        DELAY TIME 0.0 MINUTES
        CARS LOADED 60

AT INTERSECTIONS	1	2	3	4	5	6	7
DELAY (MIN)	0.0	0.0	0.0	0.0	0.0	0.0	218.2

        TOTAL 218.2 MINUTES
    WAITING FOR DISPATCHING 3.75 MINUTES
    DELAY AT DUMPING STATION 0.0 MINUTES

TRAIN 2
    TONNAGE HAULED 9000.0
    AT LOADING STATION 1
        DELAY TIME 0.0 MINUTES
        CARS LOADED 60
    AT LOADING STATION 2
        DELAY TIME 17.5 MINUTES
        CARS LOADED 120

AT INTERSECTIONS	1	2	3	4	5	6	7
DELAY (MIN)	0.0	0.0	0.9	0.2	0.0	0.0	132.0

        TOTAL 133.1 MINUTES
    WAITING FOR DISPATCHING 0.0 MINUTES
    DELAY AT DUMPING STATION 0.50 MINUTES

TRAIN 3

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     TONNAGE HAULED    6000.0
     AT LOADING STATION  1
         DELAY TIME   59.0 MINUTES
         CARS LOADED    60
     AT LOADING STATION  2
         DELAY TIME    0.0 MINUTES
         CARS LOADED    60
     AT INTERSECTIONS      1      2      3      4      5      6      7
          DELAY (MIN)    0.0    0.0    0.0    0.0    0.0    0.0  186.3
                TOTAL   186.3 MINUTES
     WAITING FOR DISPATCHING   0.0  MINUTES
     DELAY AT DUMPING STATION   0.0  MINUTES

TRAIN  4
     TONNAGE HAULED   12000.0
     AT LOADING STATION  1
         DELAY TIME    0.0 MINUTES
         CARS LOADED   120
     AT LOADING STATION  2
         DELAY TIME   55.0 MINUTES
         CARS LOADED   120
     AT INTERSECTIONS      1      2      3      4      5      6      7
          DELAY (MIN)    0.0    0.0    0.0    0.0    0.0    0.0    1.6
                TOTAL      1.6 MINUTES
     WAITING FOR DISPATCHING   0.0  MINUTES
     DELAY AT DUMPING STATION   0.67 MINUTES


TOTAL
     DELAY TIME AT INTERSECTIONS 539.17  MIN            0.3743 HRS/HR/TRAIN
     WAITING FOR DISPATCHING   3.75  MIN            0.0026 HRS/HR/TRAIN
     WAITING AT LOADING STATION 150.92  MIN            0.1048 HRS/HR/TRAIN
     DELAY AT DUMPING STATION   1.17  MIN            0.0008 HRS/HR/TRAIN
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