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SPOC

Simulated Processing of Ore and Coal

Chapter 6 Plant Simulators

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The SPOC Manual

Chapter 6 Plant Simulators

Plant Simulators for Mineral Dressing

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THE SPOC MANUAL

The **SPOC*** manual consists of eighteen chapters, published separately. Their numbers and short titles are as follows:

1. Summary
2. Sampling Methodology
2.1 SAMBA Computer Program
2.2 Grinding Circuit Sampling
3. Material Balance
3.1 BILMAT Computer Program
3.2 MATBAL Computer Program
4. Modelling and Simulation
4.1 Industrial Ball Mill Modelling
5. Unit Models: Part A
5.1 Unit Models: Part B
5.2 Unit Models: Part C
6. Flowsheet Simulators
7. Model Calibration
7.1 STAMP Computer Program
7.2 FINDBS Computer Program
7.3 RTD and MIXERS Computer Programs
8. Miscellaneous Computer Programs

These chapters are available from: CANMET, Energy, Mines and Resources Canada
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***S**imulated **P**rocessing of **O**re and **C**oal

FOREWORD

High energy costs and depleting ore reserves combine to make process evaluation and optimization a challenging goal in the 80's. The spectacular growth of computer technology in the same period has resulted in widely available computing power that can be distributed to the most remote mineral processing operations. The SPOC project, initiated at CANMET in 1980, has undertaken to provide Canadian industry with a coherent methodology for process evaluation and optimization assisted by computers. The SPOC Manual constitutes the written base of this methodology and covers most aspects of steady-state process evaluation and simulation. It is expected to facilitate industrial initiatives in data collection and model upgrading.

Creating a manual covering multidisciplinary topics and involving contributions from groups in universities, industry and government is a complex endeavour. The reader will undoubtedly notice some heterogeneities resulting from the necessary compromise between ideals and realistic objectives or, more simply, from oversight. Critiques to improve future editions are welcomed.

D. Laguitton
SPOC Project Leader
Canada Centre for Mineral and Energy Technology

AVANT-PROPOS

La croissance des coûts de l'énergie et l'appauvrissement des gisements ont fait de l'évaluation et de l'optimisation des procédés un défi des années 80 au moment même où s'effectuait la dissémination de l'informatique jusqu'aux concentrateurs les plus isolés. Le projet SPOC, a été lancé en 1980 au CANMET, en vue de développer pour l'industrie canadienne, une méthodologie d'application de l'informatique à l'évaluation et à l'optimisation des procédés minéralurgiques. Le Manuel SPOC constitue la documentation écrite de cette méthodologie et en couvre les différents éléments. Les retombées devraient en être une vague nouvelle d'échantillonnages et d'amélioration de modèles.

La rédaction d'un ouvrage couvrant différentes disciplines et rassemblant des contributions de groupes aussi divers que les universités, l'industrie et le gouvernement est une tâche complexe. Le lecteur notera sans aucun doute des ambiguïtés ou contradictions qui ont pu résulter de la diversité des sources, de la traduction ou tout simplement d'erreurs. La critique constructive est encouragée afin de parvenir au format et au contenu de la meilleure qualité possible.

D. Laguitton
Chef du projet SPOC,
Centre canadien de la technologie des minéraux et de l'énergie

ABSTRACT

This chapter describes five process flowsheet simulators: SPLITX, CRSHEX, GRNDEX, HCONEX, and FLOTEX.

SPLITX is a general simulator based on a split-coefficient model of two or three product separators and mixers. It features automatic flowsheet decomposition and tear-stream selection as well as a convergence acceleration method. CRSHEX is an interactive simulator for a crushing plant developed for an IBM-PC microcomputer. GRNDEX simulates grinding plants involving rod mill, ball mills, hydrocyclones, mixers, and extrapolation modules. HCONEX and FLOTEX simulate, respectively, multicycloning and flotation plants involving recycling and water addition.

RÉSUMÉ

Ce chapitre décrit cinq simulateurs d'unités de traitement des minerais: SPLITX, CRSHEX, GRNDEX, HCONEX et FLOTEX.

Le SPLITX est un simulateur général conçu d'après le modèle du coefficient de partage de deux ou trois séparateurs et mélangeurs. Les caractéristiques de ce simulateur sont la décomposition automatique de l'organigramme, la sélection par flux séparé et une méthode de convergence. Le CRSHEX est un simulateur interactif d'une installation de broyage mis au point pour un micro-ordinateur IBM-PC. Le GRNDEX simule des installations de broyage comprenant des broyeurs à barres et à boulets, des hydrocyclones, des mélangeurs ainsi que des modules d'extrapolation. Le HCONEX et le FLOTEX simulent respectivement des installations de classification et de flottation comprenant la recirculation et l'addition d'eau.

ACKNOWLEDGEMENTS

The SPOC project has benefited from such a wide range of contributions throughout the industry, the university, and the government sectors that a nominal acknowledgement would be bound to make unfair omissions. The main groups that contributed are: the various contractors who completed project elements; the Industrial Steering Committee members who met seven times to provide advice to the project leader; the various users of project documents and software who provided feedback on their experience; the CANMET Mineral Sciences Laboratories staff members who handled the considerable in-house task of software development, maintenance, and documentation; the EMR Computer Science Centre staff who were instrumental in some software development; and the CANMET Publications Section. Inasmuch as in a snow storm, every flake is responsible, their contributions are acknowledged.

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INTRODUCTION

Computer simulation of industrial processes has been recognized as a powerful design tool for many years, especially in the petrochemical engineering industries (1). More recently, simulation packages have been developed for the mineral processing industries where they seem to be on the verge of achieving a high economic return in several concentrators (2,3).

Process simulation is often referred to as a *material balance problem* because estimating the mass distribution of materials in a given flowsheet for given model variables and parameters is the most frequent objective of the calculation. (Material balance computation differs from the computation of the *predictive material balance*: the computation of predictive material balance is performed routinely in most plants to assess circulating loads and calculate production tonnages from selected assays. Predictive material computation — unlike material balance computation — is not generally designed to question the circuit configuration or the set points of the individual process units.) Material balance computations are usually carried out by solving simultaneously the quadratic mass-assay relationships across all or selected process units (4). Process simulation can also be done by the simultaneous solution of all model equations. However, this method becomes increasingly rigid as models depart from linearity and the number of equations increases; it also requires costly and complex overhead costs for sparse-matrix computation.

The sequential modular method, in which computations are routed successively through the required unit simulators, is more analogous to the actual flow of materials through the plant and is therefore more accessible to most industrial users. This method has been the object of numerous investigations dealing mainly with optimizing the computation path of complex flowsheets and accelerating computation convergence (5,6). After seriously considering the acquisition of one of the major process simulation packages at the beginning of the SPOC project (7), project personnel decided that the modest computation power, either available or in the process of being acquired, in most Canadian concentrators requires a much smaller type of simulator. To avoid costly overhead features of a general program, a more specific type of approach had to be taken, where the applications would be strictly limited to mineral processing. It was further decided that a division of the simulator into smaller programs, each specific to an area of the concentrator, is sufficient until mineral liberation measurements can be done routinely and on a large scale. The SPOC executive programs are therefore divided into five groups:

1. A general mixer-splitter flowsheet simulator, SPLITX.
2. A crushing plant simulator, CRSHEX.
3. A grinding plant simulator, GRNDEX.
4. A multicyclone flowsheet simulator, HCONEX.
5. A flotation circuit simulator, FLOTEX.

These programs correspond to the process evaluation, sector by sector, which is currently applied in most concentrators.

This user's guide is therefore divided into five sections describing each of these five executive programs.

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SPLITX

PREDICTIVE MATERIAL BALANCE BY SPLIT COEFFICIENT SIMULATION EXECUTIVE

E. Ter Heijden

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FIGURES

1. PROGRAM IDENTIFICATION

Program Title: Predictive Material Balance by **SPLIT** Coefficient Simulation **EX**ecutive.

Program Code Name: SPLITX.

Authors: E. Ter Heijden.

Organization: Energy, Mines and Resources, Canada Centre for Mineral and Energy Technology, Mineral Processing Laboratory.

Date: July 1985.

Updates: This is the first version of this system and is designated VERSION 1.0. Major updates may be necessary to adapt the program to advances in technology.

Source Language: CDC FORTRAN Extended 4.8. The code was written as close as was practical to ANSI standard. Installation-dependent code is minimal and identified with comments in the code.

Availability: Complete program listing is available from:

CANMET,
Energy, Mines and Resources,
Technology Information Division,
555 Booth Street
Ottawa, Ontario,
K1A 0G1.

2. ENGINEERING DOCUMENTATION

2.1 NARRATIVE DESCRIPTION

The SPLITX program is a general interactive linear split coefficient simulation of flowsheet analysis. The program uses the sequential modular approach and convergence acceleration by the Aitkins Delta Squared (ADS) method. SPLITX is a system of three programs called ENTRY, FLOWAN, and MATFLO.

ENTRY performs interactive plant data entry and modification of the stream connection matrix (SCM), unit parameters, and feed description.

FLOWAN performs flowsheet analysis on the data provided by ENTRY and outputs the streams comprising recycle loops, the streams comprising complex nodes, the node SCM, the node calculation order, and each complex node decomposition. A complex node decomposition consists of the minimum cost tear set, the node calculation order, and all paths between tear streams.

The concepts of tear sets and complex nodes are discussed in SPLITX Section 2.2.2.

MATFLO performs predictive material balance calculations on the data provided by both ENTRY and FLOWAN. The program incorporates a linear split coefficient model and, for complex nodes, performs direct substitution iterations until the conditions for applying the ADS method to a given accuracy have been satisfied. This method is discussed further in SPLITX Section 2.2.4. The output for each node is an iteration report that shows for each tear stream the flow rate by direct substitution, the predicted flow rate by ADS acceleration, the variation in the predicted flow rate relative to the previous iteration, and the estimated number of iterations to convergence by direct substitution. For each iteration the median equivalent simple loop split factor for the complex node is output. Final output consists of the material balance in all streams of the plant. Units permitted by the simulator are separators and mixers. A separator can have up to three feeds and three products; a mixer or junction can have up to three feeds and one product.

2.2 METHOD OF SOLUTION

A flowsheet simulation is performed in three steps involving three different programs: ENTRY, FLOWAN, and MATFLO. The algorithms of each program are discussed in detail in the following section.

2.2.1 ENTRY Program

Four categories of data are required to perform a simulation:

- — a flowsheet description
- — a feed material description
- — a unit model description
- — unit model options (if necessary).

Each category must be clearly understood by the user to utilize the program successfully.

2.2.1.1 Flowsheet description

A flowsheet must be described by a stream connection matrix. This is a four-column table in which the rows correspond to the flowsheet streams and the columns correspond to the flowsheet units or nodes. Before defining the SCM, the user must represent a flowsheet in terms of nodes, i.e., separators and junctions.

Each node and stream is given a unique arbitrary number, but which must be a positive non-zero integer.

Column one of the SCM contains a stream number. Column two contains either the number of the node from which the stream originates, or zero for a feed stream. Column three contains either the number of the node to which the stream flows, or zero for a product stream. Column four contains the *weight* or *cost* of the stream. This concept of weight is discussed in more detail in SPLITX Section 2.2.2.5. It gives the user the option of influencing the selection of the tear streams, i.e., the streams that must be initialized in a recycle loop to initiate the iterative computation.

2.2.1.2 Stream description

Each stream is defined by a unique number. The material constituting a stream consists of solid particles or water, or both. The description of this material follows some conventions that must be understood. The solid is described as a collection of classes and subclasses for which a number of characteristics are given. The classes and subclasses allowed in the program pertain to size fractions and density fractions. Each size class can be divided into several density subclasses. For each subclass, the material is defined by some characteristics, the first of which is its weight or weight fraction. Other characteristics can be any mass conservative assay such as chemical or mineralogical assay. The following notation is used:

NS:	number of classes in the size distribution
NG:	number of classes in the gravity distribution
NC:	number of characteristics
FLOW (I,J,1):	absolute value of the weight or flow rate of material in size interval I and gravity interval J
FLOW (I,J,K):	absolute value of characteristic K (beginning with 2) in size interval I and gravity interval J; e.g.: Cu, Ash, Btu, etc.

Water is simply described by its flow rate in any given stream.

This stream description is quite general and is also used in most unit simulators described in Chapters 5, 5.1, and 5.2 of the SPOC Manual.

2.2.1.3 Model parameters

The SPLITX program does not use the unit simulators of Chapters 5, 5.1, and 5.2. It is limited to a general material splitter or mixer model in which each class of solid is handled separately and in parallel with others. There is no class transformation or interaction; the split coefficients must describe the individual distribution of each characteristic and of the water across the flowsheet separators. This restricts the simulator applications to predictive material balance with hypothetical split factors dictated by design set-points or constraints because few units separate solids and water in a linear fashion without interclass transformation. In addition, the determination of split coefficients would require large-scale experiments but would not provide any phenomenological description of the actual process. It is still, however, useful for design engineers and students.

The program requires NS*NG*NC split coefficients, one for each characteristic in each subclass, 1 for water. These parameters are stored in a vector in an order corresponding to nested variations of the three subscripts: I = 1 to NS, J = 1 to NG, K = 1 to NC. For example, if NS = 3, NG = 4, and NC = 2, the order of storage of the 25 split coefficients is as follows: SC(1,1,1), SC(2,1,1), SC(3,1,1), SC(1,2,1), SC(2,2,1), SC(3,2,1), SC(1,3,1),...,SC(3,4,1), SC(1,1,2), SC(2,1, 2),...,SC(3,4,2), SC(water).

An important convention is that the split factor of a separator is the fraction of the separator feed material that passes to the lowest numbered product stream. For a separator with three products, two split-factors are required. The first split-factor applies to the lowest numbered product stream, the second to the middle numbered product stream, and the complement of the two split-factors applies to the highest numbered product stream.

2.2.1.4 Program options

The ENTRY program does not ask the user to enter any program options. These are requested during the execution of the FLOWAN and MATFLO programs. The ENTRY program uses the name *option* during the unit data entry to allow selection of particular model options such as the type of classification model for a hydrocyclone. These unit model options are described in Chapters 5, 5.1 and 5.2. These should not be confused with the general program options referred to in this section, namely the amount of output printed by FLOWAN and MATFLO, the option of initializing the tear streams, the accuracy of the convergence method, and the frequency of iteration printouts.

The ENTRY program generates a data file which is read by the FLOWAN program. An example is given with the sample run.

2.2.2 The Flowsheet Analysis Technique: FLOWAN Program

The flowsheet analysis technique used in the FLOWAN program is presented here as a computation path optimization for sequential simulation. This description appears in the *Proceedings of the 4th Symposium on Automation in Mining, Mineral and Metal Processing (IFAC)*, Helsinki, 1983.

2.2.2.1 Introduction

Process simulation by computer has been common practice in chemical engineering for the past 15 years. Applications of mineral and coal process simulation have been more limited in scope and number during the same period. The difference between the two disciplines can be explained by the availability of fundamental parameters in chemical process theory compared to the difficulty of characterizing these parameters in mineral and coal process theory. The remote location of mineral and coal plants from urban centers with large academic and specialized workforces has also delayed progress in computer applications in the mineral sector. This late start-up, however, has the advantage that several techniques, resulting from years of efforts in chemical plant simulation, can be readily applied to give the first generation of mineral plant simulator features that have appeared only recently in simulations of chemical processes. This is the case with computation path optimization, the science of arranging computations in the most efficient sequence for simulating a complex flowsheet. Publications on computation path optimization date from the early 1960s (1) and research is still being conducted. (See, for example, Pibouleau (2) on the subject.) This chapter illustrates how user-friendly computer programs can be developed by transferring state-of-the-art graph theory from its traditional chemical engineering context to that of mineral and coal engineering.

2.2.2.2 Reasons for having optimal computation paths

Two general approaches have prevailed in process simulation by computer. These are usually referred to as the *global* or *simultaneous* solution and the *sequential modular* solution.

In the global solution, all mathematical equations representing the unit models in the process flowsheet are solved simultaneously. The nonlinearity of most models requires iterations of large and often sparse systems to arrive at a solution. Upgrading a model in this type of system can be a delicate programming task.

The sequential modular approach is usually preferred because conceptually it approaches the actual processing of materials more closely: each process unit is simulated by a separate subroutine. The numeric data representing the material in the streams are processed through these subroutines in a sequence similar to that followed by a real particle or molecule in the plant. The replacement of one module by another is user-transparent if the data interface of the new module is compatible. However, the existence of recycling streams requires the initialization of some downstream variables before activating upstream modules. Furthermore, several routes between the circuit feed and products are usually possible. The simulation cost is a function of the execution cost of all unit simulators and the number of times they are called. The rate of convergence of the iterative simulation and the sequence of module calls therefore contribute to the simulation cost. The cost becomes an important factor if a simulator is used in an *optimization* mode, i.e., to search for the best model parameters or the best flowsheet configuration to achieve a given product from a given feed. Therefore an optimal computation path in process simulation is needed. An optimal path is one of the many facets of computation efficiency. Other facets include code efficiency and data-routing efficiency (3).

2.2.2.3 Components of an optimal computation path

In the sequential modular simulation of a complex plant, the optimal computation path is such that the flowsheet is divided into subplants between which there are no recycle paths. These subplants or nodes can be either complex, i.e., they include several process units connected by recycling streams, or simple, i.e., they include only one or several process units without recycle.

When a flowsheet is reduced to nodes (complex or simple), there is only a feed forward of material that determines the sequence of simulation. Within each complex node a feed forward of information can only be obtained if a number of recycling streams are given an approximation value that permits simulation of the output variables of the unit they enter.

This is illustrated on the simple flowsheet in Figure 1, which shows two complex nodes and one simple node. The first complex node includes model Nos. 1 and 2. The variables of stream 3 are required as input to unit model No. 1 to simulate stream 2. Since stream 3 is normally calculated by unit model No. 2, a suitable initialization value of stream 3 must be used and iteration continued until a convergence is obtained for stream 3 variables (Figure 1). This is equivalent to cutting or *tearing* stream 3 into two parts: 3′ entering unit 1, and 3 exiting unit 2. In complex nodes, the choice of torn streams is not unique, and a tearing algorithm is needed that ensures the optimal simulation path is taken subsequently, i.e., the fastest convergence.

Since it is not always easy to group cycles into complex nodes by visual inspection, algorithms have been developed so that grouping can be done by computer. These will be referred to as STEP 1 algorithms. The complex nodes identified in STEP 1 can be decomposed into torn cycles by STEP 2 algorithms. An extensive review of the various algorithms proposed in the literature of the past 20 years is given by Pibouleau (2) and Ford (4).

Ford, after comparing the various algorithms in ore-dressing plant simulation, recommends Johnson's algorithm (5) for complex node identification, and Upadye and Grens (6) for tearing streams. Pibouleau's work (2) is more theoretical and aimed at finding algorithms that cannot be defeated by the most intricate networks. Pibouleau therefore resorts to hybrid

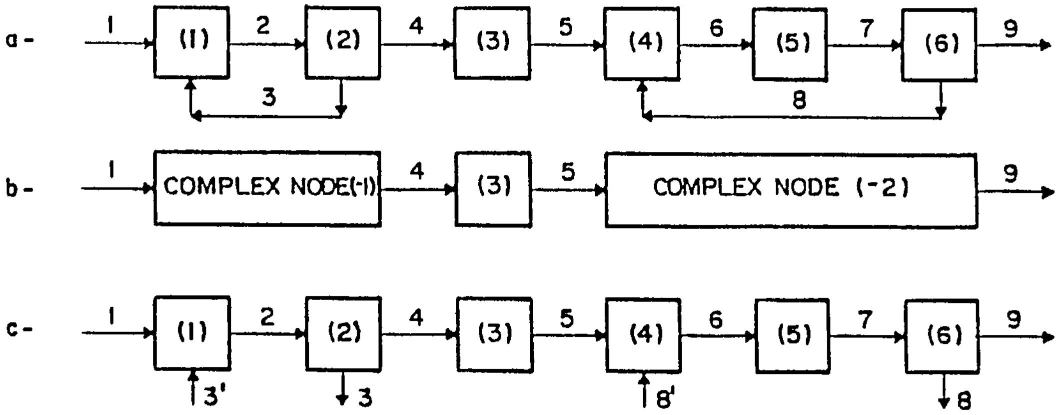


Fig. 1 — Illustration of the tear stream algorithm

algorithms in which several back-up methods can be used if the previous ones fail. This requires a larger core but offers greater potential for identifying the best practical algorithms through experience on several real flowsheet simulations. For STEP 1 algorithms, Pibouleau prefers those of Christensen and Rudd (7), in sequence with those of Kehat and Shacham (8) and Sargent and Westerberg (9). His preliminary testing on seven very complex flowsheets showed that Christensen and Rudd's method gave better overall performance (7). For STEP 2 algorithms, Pibouleau prefers those of Pho and Lapidus (10) with minor modifications. Since the objective of this work was to develop a workable tool for flowsheet analysis in a mineral and coal process simulator, no effort was made to enter the debate on graph theory and prove or disprove the algorithms. Ford's test flowsheets (4) are based on realistic mineral plants whereas Pibouleau's (2) examples, although spectacular, are not. The Johnson (5) and Upadye (6) algorithms were therefore implemented with minor modifications that will be described in this section.

2.2.2.4 STEP 1 algorithms: flowsheet reduction into nodes

The objective of these methods is to describe the flowsheet as an acyclic set of nodes connected by streams. A node-stream connection matrix is produced as well as a node calculation order that follows a feed forward of material.

Matrix Representation of a Flowsheet

Of the many methods in which a network of units and streams (also referred to as nodes and arcs) can be represented in numerical form, the stream connection matrix (SCM) has the advantage of being dense, of fixed dimensions (NS by 3, where NS is the number of streams), and directly legible from the flowsheet. After an arbitrary but unique number has been assigned to each stream and to each unit, the SCM contains the stream number list in column one, the origin unit number of stream (i,1) in position (i,2) and the termination unit number of stream (i,1) in position (i,3). All subsequent flowsheet reduction proceeds from this matrix. Table 1 is the SCM of Figure 1. Zero indices represent origins and destinations outside the flowsheet.

Table 1 — Stream connection matrix for Figure 1

1	0	1
2	1	2
3	2	1
4	2	3
5	3	4
6	4	5
7	5	6
8	6	4
9	6	0

Cycle Finding

Johnson's method (5) is as follows:

- Pick the next stream in SCM as root stream "r" (start by first).
- Search for a stream k such as OU(k) = TU(r) in SCM, where OU = origin unit and TU = termination unit.
- Search for a stream k′ such as OU(k′) = TU(k).
- Replace k by k′ and repeat d until k′ = r: a cycle has been found.
- Repeat until all SCM have been scanned.

This algorithm would generate all rotations of any existing cycle [e.g., (6,7,8), (7,8,6), (8,6,7)] and it is therefore necessary to reject paths meeting one of the following criteria:

- By convention, if the sequence number of a stream is larger than r, the path leading to that stream from the root stream is rejected. This means that all cycles have their highest numbered stream as a root.
- A stream with a destination unit of zero (output stream) cannot belong to a cyclic path.
- If a stream k already belongs to a path, or if TU(k) is already in the path, this path is rejected as a cycle.

In general, there is more than one output stream from any termination unit TU(k) reached by the path. To explore all possible routes, one at a time, all output streams from a unit, together with the unit position in the current path, are stored in a *Branch Point Stack* (BPS). The path is extended by always removing the top (last entered) stream in the BPS. This may lead to a new branch point of streams which are then added to the stack. The possible paths are thus explored in an orderly manner until the BPS is empty. The next root stream is then selected.

Complex Nodes' Identification

A complex node is made up of a collection of cycles that are connected by streams or units. The objective is to group all the plant cycles into complex nodes that do not share streams or units. The algorithm is one of absorption. Initially, all cycles are considered as separate complex nodes. The streams and units in each cycle are compared with those of every other cycle for common elements. When cycle Na finds a common element in cycle Nb, then Na absorbs Nb to form a longer list of streams. The comparison is pursued between the elements of the new inflated Na and another Nb until the only remaining nodes or cycles are disjoint. These are called complex nodes and given sequential negative numbers to distinguish them from the original unit numbers (Fig. 1).

Construction of the Reduced SCM and Order of Computation

The objective is to redefine a stream connection matrix of the reduced flowsheet in which all material flows forward between the complex nodes and open-circuit units that do not belong to cycles. Each unit in the plant is first associated with the number of the complex node to which it belongs (zero, if it does not belong to a complex node). The reduced SCM is then filled with the origin and destination units of all streams that do not belong to a complex node. These origin and destination unit numbers are checked to see if they belong to a complex node. If they do, they are replaced by the negative number of the complex node. The resulting reduced SCM is acyclic, and its rows can be permuted so that all streams with a given destination node occur before those originating from that node. The list of origin nodes is a possible calculation order if repeated nodes and zeroes are ignored.

2.2.2.5 STEP 2 algorithms: tear stream method for solving complex nodes

The complex nodes are collections of intersecting cycles that can only be calculated by iterative techniques. The tear stream method breaks all cycles in a node by *tearing* a chosen set of streams so that the output segment of a torn stream can be computed from a given value of the input segment. When both segments become equivalent within a preset tolerance, the cycle is completely defined.

Even for the simple case shown in Figure 1, there are several ways of tearing cycles. For example, in node (−1) either stream 2 or 3 could be torn. If 2 is torn, 3 can be computed from 2′, and 2 can in turn be calculated from 3 and 1. If 3 is torn, 2 can be computed from 3′ and 1, then 3 from 2. For more complex nodes the number of possibilities can be high. A set of rules defining the best set must therefore be established. The ultimate objective is to achieve convergence in the shortest computation time. This is impossible to quantify exactly because it is not known if iterating on a path that contains costly modules, but converges fast, is preferable to iterating on a path that contains inexpensive modules, but converges slowly. If a weighting factor that represents the overall cost of computing a stream is associated with each stream of a node (the higher the factor, the higher the cost), the best tear set should have the lowest sum of weighting factors.

The major problem lies in selecting the weighting factors. Various methods have been proposed (2). For some methods, the weight is equal to the number of unknown parameters in a stream; for others, all weights are equal, and the best tear set contains the smallest number of torn streams. The authors think that a solution to this problem consists of associating with each stream a weight that is proportional to the costs of a single run of the simulator module required to compute that stream. The convergence behaviour observed as the flowsheet simulator applied to solve various configurations should be recorded, and the weighting factors updated periodically to reflect the contribution of the convergence speed. Streams that can be initialized with a good accuracy can be given the lowest weight to force them into the tear set, if they are eligible.

To explore all possible ways of opening the cycles of a complex node, it is necessary to keep track of each and its sum of weights. This is done by introducing the notion of state of a complex node (4). The state of a node is a binary number consisting of as many digits as there are cycles in the node. A zero digit in position i (from the right) means that cycle i is not open. A one means it is open. For example, in a three cycle complex node, a binary state of 101 (i.e., $2^0 + 2^2 = 5$) indicates in a single number that two cycles are cut. These are cycles 1 and 3. The minimum state would therefore be 0 (no open cycle) and the maximum state 7 (all cycles open). The tear stream algorithm aims at finding the lowest cost path to the maximum state of a complex node.

Search of the Lowest Cost Tear-Set

1. Initial state of the node is zero.
2. The next stream in the node is cut (starting by the first).
3. The cycle(s) to which this stream belongs is (are) identified.
4. The state and cost are computed.
5. By means of a binary number similar to the node state, i.e., in a four-stream cycle (1,2,3,4), a record is kept of which stream is cut in each cycle. If 1 and 3 of this four-stream cycle are cut, the binary representation of the state is 1010, the decimal value of which is 10.
6. Each state is immediately compared to previous states. If a previous state exists and the two costs are compared, only the state with the lower cost path is retained.
7. Steps 2 through 6 are repeated until each stream has been cut and a list of states with minimum cost has been obtained.
8. Each of the non-maximal states obtained in g contains uncut cycles which are considered in turn for cutting, starting from the lowest cycle (right-most in the binary state representation). To avoid redundant computations of equivalent permutations of the same tear sets, a stream is cut only if its number is larger than stream numbers already in the set (i.e., tear sets are built with ascending stream numbers).

9. After each cut, a state is computed with its cost and retained if it represents an improvement over the existing tear set leading to the same state.
10. Steps 8 and 9 are repeated until only one set of torn streams leading to the maximal state at the lowest cost remains.

Ordering of Computations in a Torn Complex Node

To solve a complex node by iteration, the sequence, in which the unit modules are to be accessed, must be arranged. This is done by modifying the SCM of the node to reflect the temporary division of the torn streams into two segments. The output segments (e.g., 3 in Figure 1) are added to the SCM with a termination unit number of zero. The SCM rows corresponding to the torn streams before this addition are also modified to set their origin unit numbers to zero to represent the input segments (e.g., 3′ in Figure 1). This new SCM of the complex node is acyclic, and its rows can be arranged to ensure a feed-forward of material. This is done by moving all streams with a given destination unit before those originating from that unit. The sequence of computation is given by the originating unit list where repeats and zeroes are ignored.

Remark on Stream Numbers

All stream numbers used in the original flowsheet are arbitrary. The only requirement is that they be unique. As sequential searches in the various algorithms would be very slow and costly when the order of the SCM rows is arbitrary, the overall computations of STEP 1 and STEP 2 algorithms are performed on the index number of the rows, as if the streams had been entered in increasing numbers starting from one. At display time, indexing restores and prints the results with the original stream numbers entered in the SCM.

2.2.3 The Predictive Material Balance Computation Technique: MATFLO Program

The MATFLO program reads a data file created by the FLOWAN program that contains the stream connection matrix, the feed information, the unit information, the node connection matrix, the calculation order as determined by the FLOWAN algorithm, the tear-set corresponding to each complex node, and the calculation order inside a complex node. An example of this file is given with the sample run.

MATFLO uses the node connection matrix and calculation order to compute the flow rate through each node.

If the node is simple, then the appropriate unit model, determined by counting the number of input and output streams, is called for the flow rate calculation, and the program proceeds to the next node in the calculation order.

If the node is complex, the node decomposition information, containing its own stream connection matrix, unit calculation order, and tear set are read from the data file created by FLOWAN. There is an option of initializing the tear streams if they are known but they are usually left at the default value of zero. The relative accuracy required, the number of iterations until the next check point, and the number of iterations per report serve as controls to prevent an undesirable runaway iteration.

The iteration is initially by the direct substitution method to set up the conditions required for applying the Aitkins Delta Squared (ADS) method explained in detail in SPLITX Section 2.2.4. The iterations continue until the ADS method produces a final solution within the given tolerance, as determined by the modified Cauchy criterion described in SPLITX Section 2.2.4.2.

2.2.4 Detailed Description of Aitkins Delta Squared Method Applied to Material Balance Calculations in Torn Recycle Loops

2.2.4.1 Introduction

The Aitkins Delta Squared method permits rapid convergence when the separators can be described by linear split-coefficient models. The computational instability observed when some split-coefficients approach values of 0.9 is discussed here in relation to the interaction of recycle loops in a complex flowsheet. Also shown are the conditions under which the algorithm can be initiated safely to produce convergence. A formula is also given for computing the number of direct substitution iterations required to achieve the same convergence values. This may be of practical use when lock-cycle tests are being planned and their duration has to be assessed from limited split-coefficient determinations in batch experiments (11).

2.2.4.2 Aitkins Delta Squared method of convergence acceleration (12)

The material flow rate (or any other calculated process variable) for class j at iteration i can be expressed as:

$$x_j^i = f(x_j^{i-1}) = a_j x_j^{i-1} + b_j \qquad \text{Eq 1}$$

$$x_j^{i+1} - x_j^i = a_j\,(x_j^i - x_j^{i-1}) \qquad \text{Eq 2}$$

and

$$a = \frac{x^{i+1} - x^i}{x^i - x^{i-1}} \qquad \text{Eq 3}$$

(the j subscripts have been dropped for clarity).

Given iteration numbers m and i such that $m = i + p$, for $p > 0$, then:

$$x^m - x^i = x^{i+p} - x^i = (x^{i+1} - x^i)$$

$$+ (x^{i+2} - x^{i+1}) + .. + (x^{i+p} - x^{i+p-1}) \quad \text{Eq 4}$$

Repeated application of Equation 1 yields $x^i = a^k x^{i-k}$ or $x^{k+1} = a^k x^i$ (k is an exponent in a^k) and the following relation holds:

$$x^{k+1} - x^{k+i-1} = a^k(x^i - x^{i-1}) \quad \text{Eq 5}$$

Substituting Equation 5 in Equation 4 and letting k vary from 1 to p:

$$x^m - x^i = a(1 + a + a^2 + ... + a^{p-1})(x^i - x^{i-1}) \quad \text{Eq 6}$$

For $0 < a < 1$, this equation converges as

$$\sum_{k=0}^{\infty} a^k = \frac{1}{1 - a} \quad \text{Eq 7}$$

and $x^m > x^i$ for $m > i$. The fixed point or convergence value is obtained when $m \rightarrow \infty$:

$$x = x^i + \frac{a'}{1 - a}(x^i - x^{i-1}) \quad \text{Eq 8}$$

Therefore, from Equation 3 and Equation 8, assuming that "a" is constant, the fixed point can be calculated directly from three consecutive values of x. This is known as the Aitkins Delta Squared method (12). For the recycle loop shown in Figure 2, the value of "a" is equivalent to a global split factor of the recycle loop or the derivative of the process variable on the recycle stream as, from Equation 1 and Equation 2:

$$a = \frac{f(x^i) - f(x^{i-1})}{x^i - x^{i-1}} \quad \text{Eq 9}$$

This is also known as the asymptotic convergence factor (12). The Wegstein method of convergence acceleration (13) uses Equation 3 to approximate "a", and the bounded Wegstein method constrains the value of the ratio $a/(1 - a)$ to the interval [0,5] or [0,10]. It will be shown later that the constraint arises from frequent instability of the computation when "a" approaches a value of 1 in multiloop flowsheets.

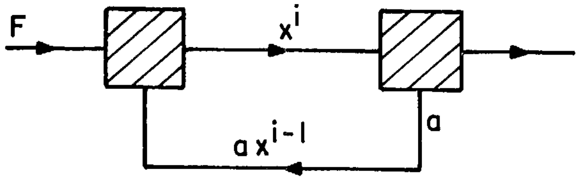


Fig. 2 — Elementary recycle loop

The use of iterative methods requires a criterion for determining whether the computed answer is sufficiently close to the solution. The Cauchy criterion (14) could be used, but it has to be the relative Cauchy criterion to avoid obtaining the error in absolute terms, i.e.,

$$\frac{x - x^m}{x} < \frac{x - x^m}{x^m} < \epsilon, \; x^m < x \quad \text{Eq 10}$$

For successive iterations Equation 10 leads to:

$$\frac{x^{m+1} - x^m}{x^{m+1} + x^m} < \epsilon \quad \text{Eq 11}$$

2.2.4.3 Estimating the number of direct substitutions to meet a given convergence criterion

In planning actual experiments such as lock-cycle tests, it is of interest to be able to discriminate, before starting, those tests that converge in a reasonable (i.e., economically acceptable) number of cycles from those that will not converge fast enough to be justified. Agar et al. (11) reported using direct substitution simulation to predict the number of iterations in locked-cycle flotation tests from batch experiments. The required number of iterations can be computed, without actually performing the simulation, by a formula derived from Equations 6, 8, and 10. By straight algebraic manipulation, the relationship

$$\frac{x^i + \frac{a}{1 - a}(x^i - x^{i-1}) - x^i - a(x^i - x^{i-1}) \sum_{k=0}^{m-i-1} a^k}{x} < \epsilon$$

using $x^i > x^{i-1}$, which is true for a constant feed to the plant, and $\frac{1}{1 - a} = \sum_{k=0}^{\infty} a^k$, gives:

$$a^{m-i+1} < \frac{\epsilon(x^i - ax^{i-1})}{x^i - x^{i-1}}$$

The logarithm yields:

$$m > \frac{\log \frac{\epsilon(x^i - ax^{i-1})}{x^i - x^{i-1}}}{\log a} + i - 1 \quad \text{Eq 12}$$

As "a" approaches a value of 1, the value of m approaches infinity, and Equation 12 can be approximated by:

$$m > \frac{\log \epsilon}{\log a} \text{ for } i = 1$$

Table 2 lists the values of m corresponding to $\epsilon = 10^{-6}$. Convergence seems to be very slow as "a" becomes greater than 0.9. Note that this is also precisely when $a/(1 - a)$ becomes greater than 9, i.e., when the limiting conditions of the bounded Wegstein method are met.

Table 2 — Values of m with $\epsilon = 10^{-6}$

Split factor a	Number of iterations m
0.85	85
0.9	132
0.99	1375
0.999	13809
0.9999	138149
0.99999	1381566

2.2.4.4 Mapping a complex flowsheet into an equivalent single loop

Figure 3 shows how a multi-loop flowsheet can be reduced to an equivalent single-loop circuit and how the tear sets are visible on the reduced representation. If [3] is chosen as the tear-stream, the following recursive relationship is true:

$$x_3^i = x_i + x_3^{i-1}(S_3 + (1 - S_3)S_4)$$

$$A = S_3 + (1 - S_3)S_4$$

$$x_3^0 = x_1;\ x_3^1 = x_1 + x_1A;\ x_3^2 = x_1(1 + A + A^2)$$

and

$$x_3^{\infty} = x_1\frac{1}{1 - A}$$

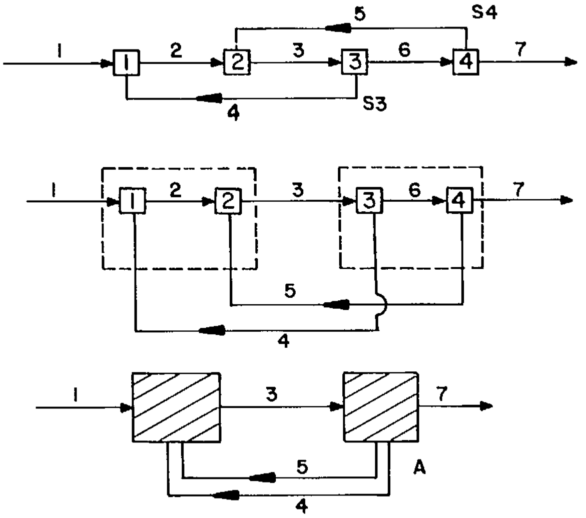


Fig. 3 — Simple step-by-step mapping of a flowsheet into a simple loop

A is the equivalent simple-loop split coefficient of the complex flowsheet. If A can be calculated from the individual unit split coefficients S_3 and S_4, the ADS convergence acceleration can be applied to the simulation of this flowsheet after three iterations.

In Figure 3, x_3^i and x_5^i are all related by combinations of constants S_3 and S_4. Because A is the derivative of a tear stream variable (Equation 9), the values of A obtained along any tear stream are identical. This is not the case in the flowsheet represented in Figure 4 with its equivalent single loop showing two tear-sets, (2,4) and (3,5,6,7). The equivalent split coefficient obtained along stream 2 is different from that obtained along streams during the first few iterations. The two values eventually converge quite rapidly to a common equivalent split coefficient, depending on the split coefficients. This is because of iterative delay between the tear streams so that they do not necessarily converge at the same rate at the beginning of the computation. Only after several iterations (typically 10 to 20) do the rates of convergence become similar, and a uniform convergence acceleration can be applied.

No method was found of determining whether there are starting values for the tear stream variables that compensate for these delays. It was observed that non-zero guesses for the initial values of the tear-streams are often worse for convergence purpose than zero values.

The convergence acceleration algorithm is best initiated when the value of the median equivalent split coefficient of a tear set is smaller than one. The geometric median value defined as:

$$a^i_{med} = \frac{a^{i-1}_{max} + a^{i-1}_{min}}{2}$$

was found to converge faster to "a" than the average value. Convergence to a given accuracy is achieved

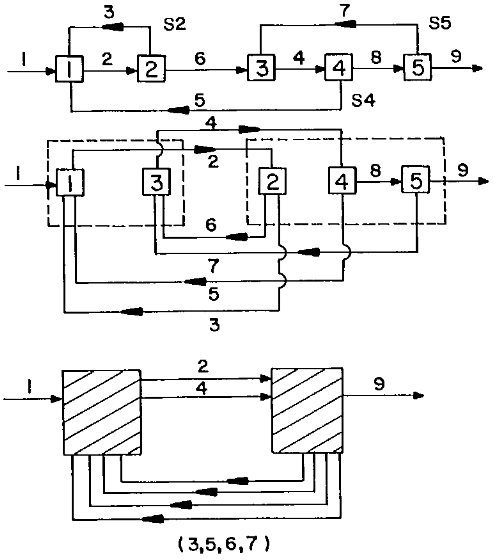


Fig. 4 — Mapping a complex flowsheet into a simple loop

when the relative Cauchy criterion (Equation 11) is satisfied by the predicted final values.

2.2.4.5 Simulating a complex flowsheet

All the above observations and algorithms can be illustrated by simulating a complex flowsheet as shown in Figure 5a. The units are either mixers or separators described by a known split coefficient. The flowsheet has been designed to be nontrivial for tear-set selection, and to give rise to multiple interactions in the convergence because of long-range cycle loops such as streams 8 and 16.

Decomposition into cycles and complex nodes

The stream connection matrix for the flowsheet was read by the COD program (15) to compute a tear-set of lower weight (i.e., minimum number of streams when all streams carry equal weight) and a complex node. The results showed two possible sets: set (5,11) or set (6,9,10,14,16,18). Set (5,11) is the set with the lower weight. Figures 5b and 5c show a simple-loop representation of the same flowsheet.

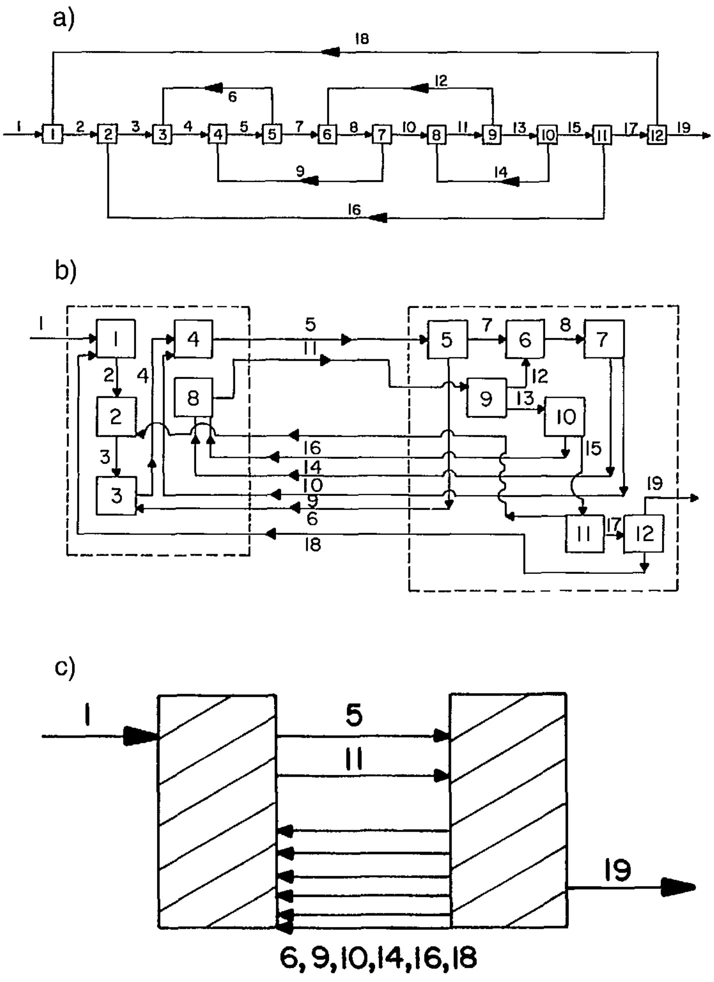


Fig. 5 — Flowsheet used to illustrate the application of the ADS method of convergence acceleration

Monitoring the convergence behaviour

The simulation of this flowsheet was performed, starting with zero values for the two tear streams 5 and 11, and the convergence behaviour was studied for different values of the individual split coefficients of the separators. These coefficients were varied from 0.1 to 0.9 by increments of 0.1, for all separators, and four observations were recorded:

1. The material flow rates were calculated by the direct substitution method.
2. The prediction number of direct substitution iterations required to reach a convergence criterion of 10^{-6}, according to Equation 12, was computed as soon as the median equivalent split coefficient dropped below a value of 1 and for each successive iteration.
3. The equivalent split coefficient of the circuit was recorded for both tear streams 5 and 11.
4. The ADS acceleration was activated as soon as the median equivalent split coefficient for both tear streams became smaller than 1 and the predicted fixed point was recorded.

These results are illustrated in Tables 3a, 3b, and 3c.

The first observation from Table 3c is that direct substitution methods would be prohibitively expensive. Even when all separators have a modest split coefficient of 0.5, 639 iterations are required. When all separators have a split coefficient of 0.9, then 11 466 847 iterations are required for an accuracy of 10^{-6}.

The second observation is that, because of iteration delays involving material flow between recycle loops caused by the introduction of tears, the equivalent simple-loop split factors are initially different across tear streams 5 and 11 (Table 3b). These split factors can be seen to converge quite rapidly to a common value. The predicted flow rates are computed by the ADS method (Equation 8) using the median equivalent split factor of the last iteration when it becomes smaller than 1. The program continues iterating until the relative errors for each tear (Equation 11) meet the convergence criterion.

Finally, the estimated number of direct substitution iterations stabilizes relatively early, as shown in Table 3c. In practice this can be used to decide whether to perform actual tests, as discussed in the following section. Of interest is that the number of estimated direct substitution iterations is 637 for tear streams 5 and 639 for tear stream 11. This results from flow delays caused by the location of the tears in the computation sequence. The accuracy of the number of estimated direct substitution iterations was verified in the example by computing the solution by direct substitution, when practical, and by ADS convergence acceleration. Both answers match closely.

Table 3a — Material flow rate computed using the Aitkins Delta Square method for various split coefficients and flowsheet of Figure 4

Stream No.	Split coefficients								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
13	1.3717	1.9531	2.9155	4.6296	8.0000	15.6250	37.0370	125.0000	999.9996
15	1.2346	1.5625	2.0408	2.7778	4.0000	6.2500	11.1111	25.0000	100.0000
17	1.1111	1.2500	1.4286	1.6667	2.0000	2.5000	3.3333	5.0000	10.0000
19	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
18	.1111	.2500	.4286	.6667	1.0000	1.5000	2.3333	4.0000	9.0000
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
16	.1235	.3125	.6122	1.1111	2.0000	3.7500	7.7778	20.0000	90.0000
2	1.1111	1.2500	1.4286	1.6667	2.0000	2.5000	3.3333	5.0000	10.0000
3	1.2346	1.5625	2.0408	2.7778	4.0000	6.2500	11.1111	25.0000	100.0000
6	.1543	.5188	1.4790	4.4582	16.0000	76.1719	556.9274	8500.0010	737999.6959
7	1.3887	2.0752	3.4509	6.6872	16.0000	50.7813	238.6832	2125.0003	81999.9662
12	.1524	.4883	1.2495	3.0864	8.0000	23.4375	86.4198	500.0001	8999.9963
8	1.5411	2.5635	4.7004	9.7737	24.0000	74.2188	325.1029	2625.0003	90999.9625
9	.1541	.5127	1.4101	3.9095	12.0000	44.5313	227.5721	2100.0002	81899.9662
4	1.3889	2.0813	3.5198	7.2359	20.0000	82.4219	568.0385	8525.0010	738099.6958
5	1.5430	2.5940	4.9299	11.1454	32.0000	126.9532	795.6106	10625.0013	819999.6621
14	.1372	.3906	.8746	1.8519	4.0000	9.3750	25.9259	100.0000	899.9996
10	1.3870	2.0508	3.2903	5.8642	12.0000	29.6875	97.5309	525.0001	9099.9962
11	1.5242	2.4414	4.1649	7.7160	16.0000	39.0625	123.4568	625.0001	9999.9959

Table 3b — Results when all split coefficients are equal to 0.5

Iterate	Direct subst. flow rate Tear 5	Equivalent split factor Tear 5	Direct subst. flow rate Tear 11	Equivalent split factor Tear 11	Median equivalent split factor Tear 5 & 11	Predicted flow rate ADS method Tear 5	Relative error predicted Tear 5	Predicted flow rate ADS method Tear 11	Relative error predicted Tear 11	No. of direct substitution iterations	
										Tear 5	Tear 11
1	1.0000	—	0.0000	—	—	—	—	—	—	—	—
2	1.7500	0.75	0.2500	—	0.75	—	—	—	—	—	—
3	2.4219	0.895833333	0.5625	1.25	1.072916667	—	—	—	—	—	—
4	3.0625	0.953488372	0.8867	1.0375	0.995494186	—	—	—	—	—	—
5	3.6848	0.971417683	1.2090	0.993975904	0.982696793	—	—	—	—	—	—
6	4.2925	0.976559435	1.5257	0.982765152	0.979662293	38.8070	0.56877046	19.5126	0.57545060	791	793
7	4.8869	0.977999146	1.8360	0.979716708	0.978857927	33.5169	0.07314494	16.7825	0.07522115	672	674
8	5.4684	0.978399558	2.1397	0.978875707	0.978637633	32.3922	0.01706516	16.2023	0.0175898	646	648
9	6.0374	0.978510711	2.4370	0.978642770	0.978576741	32.1051	0.00445131	16.0542	0.00459059	640	642
10	6.5942	0.978541551	2.7278	0.978578182	0.978559866	32.0284	0.00119508	16.0147	0.00123264	638	640
11	7.1391	0.978550106	3.0125	0.978560267	0.978555187	32.0077	0.00032341	16.0040	0.00033358	637	639
12	7.6723	0.978552480	3.2910	0.978555298	0.978553889	32.0021	0.00008771	16.0011	0.00009047	637	639
13	8.1940	0.978553138	3.5636	0.978553920	0.978553529	32.0006	0.00002380	16.0003	0.00002455	637	639
14	8.7046	0.978553320	3.8303	0.978553537	0.978553429	32.0002	0.00000646	16.0001	0.00000666	637	639
15	9.2042	0.978553371	4.0913	0.978553431	0.978553401	32.0000	0.00000175	16.0000	0.00000181	637	639
16	9.6931	0.978553385	4.3467	0.978553402	0.978553394	32.0000	0.00000048	16.0000	0.00000049	637	639

Table 3c — Estimated number of direct substitution iterations for an accuracy of 10^{-6} on tear stream 11, when all separators have the following split coefficients

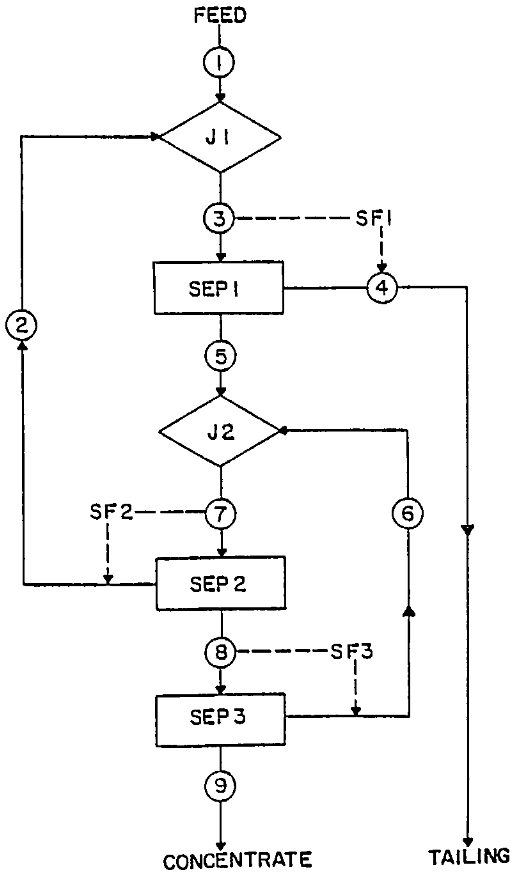
Iteration	Split Coefficients								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1									
2									
3									
4	31	52	113	1349					
5	25	51	106	264	—				
6	24			242	793				
7				239	674	—			
8					648	2260			
9					642	2383	—		
10					640	2305	14303	—	
11	24	51	106		639	2280	13170	181639	—
12						2272	12833	161953	11949026
13						2269	12725	157182	11546058
14						2269	12689	155895	11480238
15						2268	12678	155539	11469128
16							12674	155439	11467236
17							12672	155411	11466917
18								155403	11466863
19								155401	11466853
20				239	639	2268		155401	11466854
21								155400	11466857
22							12672	155400	11466847

2.2.4.6 Predicting locked cycle flotation test results from batch data

To demonstrate the program, the complete single run of a flotation circuit simulation as published by Agar (11) is reproduced below. The flowsheet and corresponding data are shown in Figure 6. Tables 4 and 5 summarize the results and show that both the direct substitution and the Aitkins Delta Squared methods produce equivalent results. Furthermore, the number of direct substitution iterations predicted by Equation 12 agrees with the actual number of iterations found by Agar. The sample run is given in Section 4.

2.2.4.7 Conclusion

A FORTRAN program featuring automatic flowsheet decomposition, tear stream algorithm, and convergence acceleration by the Aitkins Delta Squared method has been presented. The prediction material balance of any complex flowsheet in which the unit models can be described by a linear split coefficient can be easily obtained, even when direct substitution would require thousands of iterations. Its applicability for predicting material balance flow rates has been demonstrated on hypothetical and real examples.



STREAM CONNECTION MATRIX

STREAM	ORIGINATING UNIT	DESTINATION UNIT	WEIGHT
1	0	1	1.0
2	4	1	1.0
3	1	2	1.0
4	2	0	1.0
5	2	3	1.0
6	5	3	1.0
7	3	4	1.0
8	4	5	1.0
9	5	0	1.0

SPLIT COEFFICIENTS

UNIT	WEIGHT	CU	NI	FE
SEP 1	0.7966	0.0783	0.1313	0.6157
SEP 2	0.6088	0.0700	0.1369	0.2930
SEP 3	0.3543	0.0513	0.2970	0.2150

FEED FLOW RATES

STREAM	WEIGHT	CU	NI	FE
1	100.0	0.17	0.41	11.88

Fig. 6 — Flowsheet, stream connection matrix split coefficients, and feed flow rates for Agar example

Table 4 — Results of simulation of Agar example comparing the ADS method and the direct substitution method

a) Calculated stream flow by ads method

Stream 11	Weight	Cu	Ni	Fe
1	100.0000	.1700	.4100	11.8800
2	16.7890	.0124	.0780	1.8190
3	116.7890	.1824	.4880	13.6990
4	93.0341	.0143	.0641	8.4345
8	10.7882	.1641	.4921	4.3892
9	6.9659	.1557	.3459	3.4455
6	3.8222	.0084	.1461	.9437
5	23.7549	.1681	.4240	5.2645
7	27.5771	.1765	.5701	6.2082

b) Calculated assay using ads method

Stream 11	Weight	Cu	Ni	Fe
1	100.0000	.1700	.4100	11.8800
2	16.7890	.0736	.4649	10.8345
3	116.7890	.1561	.4179	11.7297
4	93.0341	.0153	.0689	9.0660
8	10.7882	1.5215	4.5611	40.6853
9	6.9659	2.2354	4.9659	49.4626
6	3.8222	.2203	3.8235	24.6891
5	23.7549	.7075	1.7848	22.1619
7	27.5771	.6400	2.0673	22.5122

c) Calculated stream flow by direct substitution

Stream 11	Weight	Cu	Ni	Fe
1	100.0000	.1700	.4100	11.8800
2	16.7875	.0124	.0780	1.8188
3	116.7875	.1824	.4880	13.6988
4	93.0329	.0143	.0641	8.4344
8	10.7872	.1641	.4915	4.3888
9	6.9653	.1557	.3456	3.4452
6	3.8219	.0084	.1460	.9436
5	23.7546	.1681	.4239	5.2645
7	27.5765	.1765	.5699	6.2081

d) Calculated assay by direct substitution

Stream 11	Weight	Cu	Ni	Fe
1	100.0000	.1700	.4100	11.8800
2	16.7875	.0736	.4644	10.8345
3	116.7875	.1561	.4178	11.7297
4	93.0329	.0153	.0689	9.0660
8	10.7872	1.5216	4.5567	40.6851
9	6.9653	2.2356	4.9611	49.4623
6	3.8219	.2203	3.8198	24.6890
5	23.7546	.7076	1.7845	22.1619
7	27.5765	.6400	2.0666	22.5121

Table 5 — Comparison of the estimated number of direct substitution iterations from Agar example and computed using ADS method

Method	Required relative accuracy	Estimated direct substitution iterations			
		Weight	Cu	Ni	Fe
Agar	0.001	6	5	8	6
ADS	0.001	6	4	8	6
ADS	0.0005	6	4	8	6
ADS	0.0001	7	5	10	7
ADS	0.00005	8	5	11	8

3. SYSTEM DOCUMENTATION

3.1 COMPUTER EQUIPMENT

SPLITX was developed and runs on a CYBER 730 computer with a maximum of 70K words (octal) of core memory available for time-sharing jobs. SPLITX has been converted to run on an IBM-PC.

3.2 PERIPHERAL EQUIPMENT

SPLITX is normally run interactively and can save input data on disk files. A session record which can be routed to a line printer is kept.

3.3 SOURCE PROGRAM

Figure 5a shows the SPLITX simulation system processing order and how the flow of data is transmitted between components.

The external file input and saving of data in ENTRY are optional. All information may be created in ENTRY or retrieved from a file. Program FLOWAN must be executed before MATFLO and after any change in the flowsheet via ENTRY. FLOWAN does not alter feed or unit data.

3.4 PROGRAM CAPABILITIES

Limitations on problem size are strictly dependent on array dimensions within the three programs. The default sizes are listed in Sections 3.4.1 and 3.4.2 which follow.

3.4.1 ENTRY — Data Entry Program

Number of streams	100
Number of units	25
Number of parameters per unit	100
Number of feed streams	10
Number of characteristics per feed	40

All dimensions in this program are set in labelled common, and maximum dimension overruns are controlled by constants in a data statement in the main line. Conversion to different problem sizes means that all common blocks must be found and changed.

3.4.2 FLOWAN — Flowsheet Analysis Program

Number of streams	100
Number of units	100
Number of streams belonging to cycles	300
Number of streams in stack for path searching	300
Number of streams in nets	300
Number of streams in largest node, including tear segments	100
Number of units in node calculation order	100
Number of tear streams per node	100
Number of simultaneous states in tearing algorithm	100
Number of streams in node stream connection matrix	100
Number of nodes in node calculation order	100

All arrays in this program are controlled with dimension statements in a short main line. Dimension sizes are set by two constants in a data statement. All arrays and dimensions are passed to subroutines as arguments. Therefore, only the main line has to be modified if a larger problem size is desired.

3.4.3 MATFLO — Material Balance Program

Number of streams	100
Number of units	100
Number of streams in largest node, including tear segments	100
Number of units in node calculation order	100
Number of streams in node stream connection matrix	100
Number of nodes in node calculation order	100
Number of parameters for all units	500
Number of units with parameters	100
Number of characteristics, including water for material balance calculations	15

All arrays in this program are controlled with dimension statements and data statements in a short main line. All arrays and sizes are passed as arguments to subroutines. Thus, only the main line has to be modified to increase the capacity.

3.5 DATA INPUT, PROGRAM OPTIONS, OUTPUT

All data inputs are prompted by the interactive program and entered in free format, i.e., in sequence, using either blanks or commas as separators. Input data may be read to disk storage for re-entry if a problem will be subjected to extensive analysis over more than one session at the terminal.

3.6 PROGRAM STRUCTURE OF THE SPLITX SYSTEM

Program ENTRY consists of a main line and all subroutines and functions compiled into one load module.

Program FLOWAN consists of a stand-alone main line. All called subroutines reside in a binary program library. The CDC EDITLIB facility is used to create the binary subroutine library. This structure allows the absolute dimension sizes in FLOWAN to be altered to suit the problem size without recompiling the program, because all required dimension sizes are declared in the main line and passed to the subroutines as arguments.

Program MATFLO consists of a stand-alone main line and subroutine FINPRT, the final output print routine. All other subroutines are in the same binary program library. The reason for this structure has been discussed above. FINPRT is with the main line, because it allows easy changing of the final output format.

3.7 PROGRAM AND SUBROUTINE DESCRIPTIONS

3.7.1 ENTRY — Program and Subroutine Description

ENTRY:	displays the main menu and processes the chosen option.
INUNI:	inputs and/or updates unit information interactively.
INCHAR:	inputs and/or updates the flowsheet stream connection matrix.
INFEED:	inputs and/or updates the feeds to the plant.
RDFILE:	reads the existing data on file nine.
VERIFY:	checks the flowsheet for inconsistencies and produces a report.
ADDUNI:	adds new units and their parameters interactively.
DELIST:	produces an index list in decreasing order for the delete options.
SAVEDA:	saves the data that have been entered by the user (or retrieved from old input file) on file 9.
HAVEAL:	checks to ensure that all flowsheet, unit, and feed information exists.
ISEARC:	searches for a unit number in an array.
IACCEP:	checks if an interactively entered integer is between two given limits.

3.7.2 FLOWAN — Program and Subroutine Description

FLOWAN:	dimensions all necessary arrays for passing as arguments to the control subroutine FLOSHT.
FLOSHT:	performs the flowsheet analysis and node decomposition control subroutine.
RDSTRM:	reads the stream connection matrix from file 7.
RDUNFL:	reads the unit information from file 7.
CYCLE:	finds all the cycles as sequence of streams in the plant.
MAXNET:	groups all cycles found by subroutine cycle into maximal nets.
NODES:	forms the simple and complex nodes using the maximal nets. A node stream connection matrix and the node calculation order is determined.
TEAR:	finds the best tear set in each complex node such that the cost (weight) is a minimum.
TEAROR:	determines the unit calculation order within a node given a set of tear streams.
PATH:	finds all paths between the tear streams of a complex node.
RANK:	determines the unit calculation order from a stream connection matrix.
BITOFF:	determines if the n'th bit of a variable is a zero or a one. n is counted from the right side of the variable.

3.7.3 MATFLO — Program and Subroutine Description

MATFLO:	dimensions all necessary arrays for passing as arguments to the control subroutine FLOCAL.
FLOCAL:	controls the flowrate computation through each node (simple or complex) as determined by program FLOWAN.
RDNSGC:	reads the number of size intervals NS, the number of density intervals NG, and the number of stream characteristics NC from file 7.
RDSTRM:	reads the stream connection matrix from file 7.
RDUNMA:	reads the unit information from file 7.

RDFEED: reads the plant feed information from file 7.

COMPLX: solves the flowrates for a complex node by applying Aitkins Delta Squared method.

SIMPLE: computes the flowrate through a simple node (unit) by analyzing the number of input and output streams and calling the appropriate linear unit model.

FINPRT: prints the final output report of flowrates in each stream of the plant.

STACK: rearranges the flowrate array so that the flowrates of the requested stream are the last entry.

INITR: inputs initial tear stream flowrates interactively.

INCRIT: inputs interactively the relative convergence criterion, the number of iterations to be performed, and the frequency of printout.

TRANSF: calls the appropriate transformer unit subroutine.

BMMOD: allows the flowsheet to have units with one input and one output.

ADDER: simulates a linear mixing unit of two or three input streams.

SPLIT: calls the appropriate separator unit subroutine.

SEPR: simulates a linear split coefficient separator with either two or three output streams.

4. SAMPLE RUN

As shown in Section 2.2.4.6, the SPLITX simulator is demonstrated by using the Agar data (11). In this example, NS = 1, NG = 1, NC = 4, where NC = no. of characteristics (weight, copper, nickel, and iron). The five parameters required for the separator units are the split coefficients for the form characteristics followed by the water flow split factor (= 0). All data are entered in free format.

The following notes explain various features of the sample run.

Note 1: The flowsheet and data from Figure 6 are to be entered into program ENTRY.

Note 2: The program continues to prompt for stream information until a 0 terminates input.

Note 3: Deliberate errors are introduced in streams 5, 6, 8, and 10 to illustrate the modification features later.

Note 4: The unit data from Figure 6 are to be entered into program ENTRY.

Note 5: Junction units require no parameters.

Note 6: Deliberate error introduced.

Note 7: The fifth parameter or split coefficient is the water flow split factor.

Note 8: The feed data from Figure 6 are to be entered into program ENTRY.

Note 9: A deliberate feed stream error is introduced.

Note 10: The VERIFY option of ENTRY gives a report of flowsheet errors that must be corrected. Note that unit parameters and feed flow rates cannot be checked for errors and the analyst is responsible for their integrity.

Note 11: The analyst decides to save the data entered even though there are errors present.

Note 12: The analyst is prompted for a title that will be displayed on all subsequent printouts by all the programs in the system.

Note 13: The analyst decides to quit the program for now and is prompted to ensure that the data have been saved.

Note 14: The data file created during the session is listed.

Note 15: The analyst decides to correct the data entered previously and calls program ENTRY again.

Note 16: The analyst retrieves the data previously stored. The operator is prompted again to prevent accidental destruction of interactively entered data.

Note 17: Stream 10, (index 9) is recognized as an error and is deleted. The analyst should be aware that every set of deletions alters the index structure of the SCM.

Note 18: Streams 5, 6 and 8 are modified. Modification does not alter the SCM index structure.

Note 19: The SCM is now correct.

Note 20: The unit data are being corrected. Unit 6 is not necessary and is deleted. The analyst must be aware that each set of deletions alters the index structure.

Note 21: Unit 2 is being corrected. The modify option consists of the delete option followed by the add option. The analyst should be aware of the change in index structure when the units are listed. Unit 2 moved from index 2 to index 5.

Note 22: The only way to modify feed information is to delete it and then re-enter it.

Note 23: The feed is added as a new stream. The stream number is corrected.

Note 24: The analyst decides to inspect the separators in the unit data.

Note 25: The flowsheet appears to be consistent.

Note 26: The operator saves the data without changing the title.

Note 27: The corrected printout of file 9 is shown.

Note 28: The flowsheet analysis is performed by program FLOWAN.

Note 29: The analyst chooses the detailed printout of the flowsheet analysis.

Note 30: This plant contains two cycles. The streams comprising each cycle are listed.

Note 31: This plant comprises only one node. The streams that comprise this node (#1) are listed.

Note 32: A stream connection matrix of the nodes in the plant is shown. To differentiate between simple and complex nodes, complex nodes are designated with negative numbers and simple nodes retain their original unit numbers. In this example, there are no independent simple nodes. Stream 1 is a feed to the node, and streams 4 and 9 are the outputs.

Note 33: The order in which the flow rate in the nodes are calculated is given.

Note 34: Each node is decomposed in turn following the calculation order. The set of minimum cost tear streams is stream 7. The flow rate unit calculation order is also determined.

Note 35: All paths that exist between the tear streams are listed.

Note 36: The printout of file 7 is presented.

Note 37: This file is the same as file 9 except that the node SCM, the node calculation order, the SCM within each node, the tear set of each node, and the unit calculation within each node is added.

Note 38: The material flow program MATFLO is executed.

Note 39: The analyst chooses the detailed printout format.

Note 40: The analyst chooses to leave the tear streams at the default stacking values of zero.

Note 41: The analyst chooses a relative accuracy of .001 and wants to iterate five times receiving an iteration report at each iteration.

Note 42: The first iteration can only show the direct substitution result. Calculation of the equivalent medium split factors starts on the second iteration.

Note 43: Most of the calculations are working. The predicted flow rates for water are not functioning because it has a split factor of zero. The program detects this condition later and stops checking for acceleration conditions. For relative error, information about three previous iterations is needed. This is still unavailable.

Note 44: The information required for estimating the number of direct substitution iterations is now available and shown. In general each tear may have slightly different values here as illustrated in Table 1c.

Note 45: The zero split factor in the water recycle loops is detected and the input value of 35.00 is shown. The relative error for water is set to zero and is dropped out of the iteration.

Note 46: The relative error for all characteristics is less than 0.001 and the Cauchy criterion is fulfilled.

Note 47: The analyst's five iterations are completed and prompts begin again. Five more iterations are selected (see Note 41).

Note 48: The program applies Aitkins Delta Squared acceleration.

Note 49: The final solution is shown for all streams.

Note 50: The analyst chooses to execute MATFLO again.

Note 51: A shorter, less detailed printout is selected.

Note 52: The analyst chooses to initialize the tear streams. Entry of a negative number will initialize all characteristics.

Note 53: The analyst chooses the relative accuracy, and 10 iterations, receiving an iteration report every second iteration.

Note 54: The maximum estimated direct substitution iterations are different from the previous number because of the initialization of tear streams.

Note 55: This is an example of the less detailed report.

Note 56: The final report shows the same solution as before.

```
                    MAIN MENU
                    =========

         0. QUIT
         1. ENTER OR MODIFY FLOWSHEET INFORMATION
         2. ENTER OR MODIFY UNIT INFORMATION
         3. ENTER OR MODIFY FEED DATA
         4. RETRIEVE DATA FROM PREVIOUS FILE
         5. DATA CONSISTENCY CHECK
         6. SAVE DATA ENTERED


   CHOOSE OPTION (0 TO 6)
 ==>        1                                                    $$$NOTE 1

 THERE ARE    0 STREAMS IN THE PLANT


          FLOWSHEET INFORMATION MENU
          ==========================

           0. RETURN TO MAIN MENU
           1. LIST STREAMS
           2. ADD NEW STREAM(S)
           3. MODIFY STREAMS
           4. DELETE STREAM
           5. SAVE DATA ENTERED

        ENTER OPTION (0 TO 5)
 ==>        2
 ENTER NEW RECORD(S) (4 VALUES PER RECORD)                       $$$NOTE 2

     - STREAM NUMBER
     - ORIGINATING UNIT
     - DESTINATION UNIT
     - WEIGHT
SEPARATE EACH FIELD BY A COMMA OR A BLANK
ENTER '0' FOR END OF INPUT
 ?         1         0         1      1.000
 ?         2         4         1      1.000
 ?         3         1         2      1.000
 ?         4         2         0      1.000
 ?         5         5         3      1.000                      $$$NOTE 3
 ?         6         2         3      1.000
 ?         7         3         4      1.000
```

```
?           8          4          2       1.000
?          10          4          5       1.000
?           9          5          0       1.000
?           0

THERE ARE   10 STREAMS IN THE PLANT

                            4 VALUES PER RECORD
            ****************************************
INDEX       STREAM     ORIG.UNIT    DEST.UNIT    WEIGHT
   1           1          0            1         1.00
   2           2          4            1         1.00
   3           3          1            2         1.00
   4           4          2            0         1.00
   5           5          5            3         1.00
   6           6          2            3         1.00
   7           7          3            4         1.00
   8           8          4            2         1.00
   9          10          4            5         1.00
  10           9          5            0         1.00


         FLOWSHEET INFORMATION MENU
         ==========================

          0. RETURN TO MAIN MENU
          1. LIST STREAMS
          2. ADD NEW STREAM(S)
          3. MODIFY STREAMS
          4. DELETE STREAM
          5. SAVE DATA ENTERED

       ENTER OPTION (0 TO 5)
==>         0



                   MAIN MENU
                   =========

      0. QUIT
      1. ENTER OR MODIFY FLOWSHEET INFORMATION
      2. ENTER OR MODIFY UNIT INFORMATION
      3. ENTER OR MODIFY FEED DATA
      4. RETRIEVE DATA FROM PREVIOUS FILE
      5. DATA CONSISTENCY CHECK
      6. SAVE DATA ENTERED


  CHOOSE OPTION (0 TO 6)
==>         2
```

$$$NOTE 4

```
THERE ARE    0 UNITS IN THIS PLANT


           UNIT INFORMATION MENU
           =====================

        0. RETURN TO THE MAIN MENU
        1. LIST SPECIFIC UNIT INFO. (PARAMS, OPTION)
        2. ADD NEW UNIT(S)
        3. MODIFY UNIT
        4. DELETE UNIT
        5. SAVE DATA ENTERED

      ENTER OPTION (0 TO 5)
==>         2

ENTER FLOW SHEET NUMBER OF THE UNIT TO BE ADDED
   ( 0 TO TERMINATE INPUT SEQUENCE) ==>         1

ENTER NAME OF UNIT (UP TO 6 CHARACTERS)==>J1

ENTER         - NUMBER OF INPUT
              - NUMBER OF OUTPUT
              - NUMBER OF PARAMETERS
     SEPARATE EACH BY A COMMA OR A BLANK
==>         2         1         0                                          $$$NOTE 5

ENTER THE 10 OPTIONS FOR THIS UNIT
             1     2     3     4     5     6     7     8     9    10
OPTION ==>   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0

ENTER FLOW SHEET NUMBER OF THE UNIT TO BE ADDED
   ( 0 TO TERMINATE INPUT SEQUENCE) ==>         2

ENTER NAME OF UNIT (UP TO 6 CHARACTERS)==>SEP1

ENTER         - NUMBER OF INPUT
              - NUMBER OF OUTPUT
              - NUMBER OF PARAMETERS
     SEPARATE EACH BY A COMMA OR A BLANK
==>         1         2         0                                          $$$NOTE 6

ENTER THE 10 OPTIONS FOR THIS UNIT
             1     2     3     4     5     6     7     8     9    10
OPTION ==>   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0

ENTER FLOW SHEET NUMBER OF THE UNIT TO BE ADDED
   ( 0 TO TERMINATE INPUT SEQUENCE) ==>         3

ENTER NAME OF UNIT (UP TO 6 CHARACTERS)==>J2

ENTER         - NUMBER OF INPUT
              - NUMBER OF OUTPUT
              - NUMBER OF PARAMETERS
     SEPARATE EACH BY A COMMA OR A BLANK
==>         2         1         0

ENTER THE 10 OPTIONS FOR THIS UNIT
             1     2     3     4     5     6     7     8     9    10
OPTION ==>   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
```

```
ENTER FLOW SHEET NUMBER OF THE UNIT TO BE ADDED
   ( 0 TO TERMINATE INPUT SEQUENCE) ==>          4

ENTER NAME OF UNIT (UP TO 6 CHARACTERS)==>SEP2

ENTER           - NUMBER OF INPUT
                - NUMBER OF OUTPUT
                - NUMBER OF PARAMETERS
     SEPARATE EACH BY A COMMA OR A BLANK
==>          1          2         5

ENTER THE 10 OPTIONS FOR THIS UNIT
             1      2      3      4      5      6      7      8      9     10
OPTION ==>  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0

ENTER THE    5 PARAMETERS FOR THIS UNIT
10 BY 10 AS QUERIED BY THE PROGRAM
SEPARATE EACH OF THEM BY A COMMA OR A BLANK

PARMS                 1      2      3      4      5      6      7      8      9     10

  1 TO   5==>  .6088 .0700 .1369 .2930 0.0                                          $$$NOTE 7

ENTER FLOW SHEET NUMBER OF THE UNIT TO BE ADDED
   ( 0 TO TERMINATE INPUT SEQUENCE) ==>          5

ENTER NAME OF UNIT (UP TO 6 CHARACTERS)==>SEP3

ENTER           - NUMBER OF INPUT
                - NUMBER OF OUTPUT
                - NUMBER OF PARAMETERS
     SEPARATE EACH BY A COMMA OR A BLANK
==>          1          2         5

ENTER THE 10 OPTIONS FOR THIS UNIT
             1      2      3      4      5      6      7      8      9     10
OPTION ==>  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0

ENTER THE    5 PARAMETERS FOR THIS UNIT
10 BY 10 AS QUERIED BY THE PROGRAM
SEPARATE EACH OF THEM BY A COMMA OR A BLANK

PARMS                 1      2      3      4      5      6      7      8      9     10

  1 TO   5==>  .3543 .0513 .2970 .2150 0.0

ENTER FLOW SHEET NUMBER OF THE UNIT TO BE ADDED
   ( 0 TO TERMINATE INPUT SEQUENCE) ==>          6

ENTER NAME OF UNIT (UP TO 6 CHARACTERS)==>J3

ENTER           - NUMBER OF INPUT
                - NUMBER OF OUTPUT
                - NUMBER OF PARAMETERS
     SEPARATE EACH BY A COMMA OR A BLANK
==>          2          2         0

ENTER THE 10 OPTIONS FOR THIS UNIT
             1      2      3      4      5      6      7      8      9     10
OPTION ==>  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0

ENTER FLOW SHEET NUMBER OF THE UNIT TO BE ADDED
   ( 0 TO TERMINATE INPUT SEQUENCE) ==>          0
```

```
 THERE ARE    6 UNITS IN THIS PLANT

                         UNIT LIST
          ********************************************
           UNIT                 NB OF     NB OF     NB OF
INDEX     NUMBER     NAME       INPUT     OUTPUT    PARAMS

  1          1     J1             2         1         0
  2          2     SEP1           1         2         0
  3          3     J2             2         1         0
  4          4     SEP2           1         2         5
  5          5     SEP3           1         2         5
  6          6     J3             2         2         0


              UNIT INFORMATION MENU
              =====================

           0. RETURN TO THE MAIN MENU
           1. LIST SPECIFIC UNIT INFO. (PARAMS, OPTION)
           2. ADD NEW UNIT(S)
           3. MODIFY UNIT
           4. DELETE UNIT
           5. SAVE DATA ENTERED

         ENTER OPTION (0 TO 5)
 ==>           0



                       MAIN MENU
                       =========

         0. QUIT
         1. ENTER OR MODIFY FLOWSHEET INFORMATION
         2. ENTER OR MODIFY UNIT INFORMATION
         3. ENTER OR MODIFY FEED DATA
         4. RETRIEVE DATA FROM PREVIOUS FILE
         5. DATA CONSISTENCY CHECK
         6. SAVE DATA ENTERED


    CHOOSE OPTION (0 TO 6)
 ==>           3                                                  $$$NOTE 8

 THERE ARE    0 FEEDS IN THIS PLANT


              FEED INFORMATION MENU
              =====================

                0. RETURN TO THE MAIN MENU
                1. LIST FEED FLOW RATES
                2. ADD NEW FEED(S)
                3. DELETE FEED(S)
                4. SAVE DATA ENTERED
```

```
         ENTER OPTION (0 TO 4)
==>          2
```

$$$NOTE 9

```
ENTER          - FEED STREAM INDEX
               - NUMBER OF SIZE INTERVALS, PAN INCLUDED (NS)
               - NUMBER OF DENSITY INTERVALS (NG)
               - NUMBER OF STREAM CHARACTERISTICS (NC)
    SEPARATE EACH BY A COMMA OR A BLANK
    ENTER '0' TO END
==>     2     1     1     4

ENTER FEED FLOW RATES:

WATER==>     35.00

CHARACTERISTIC #  1
          DENSITY INTERVALS (NG)
             1
NS=  1==>100.00

CHARACTERISTIC #  2
          DENSITY INTERVALS (NG)
             1
NS=  1==>   .17

CHARACTERISTIC #  3
          DENSITY INTERVALS (NG)
             1
NS=  1==>   .41

CHARACTERISTIC #  4
          DENSITY INTERVALS (NG)
             1
NS=  1==> 11.88

ENTER          - FEED STREAM INDEX
               - NUMBER OF SIZE INTERVALS, PAN INCLUDED (NS)
               - NUMBER OF DENSITY INTERVALS (NG)
               - NUMBER OF STREAM CHARACTERISTICS (NC)
    SEPARATE EACH BY A COMMA OR A BLANK
    ENTER '0' TO END
==>     0

THERE ARE    1 FEEDS IN THIS PLANT

                              FEED FLOW RATE
          ***********************************************
INDEX     FEED STREAM     NS     NG     NC     WATER

  1            2           1      1      4   35.000
```

```
           FEED INFORMATION MENU
           =====================

            0. RETURN TO THE MAIN MENU
            1. LIST FEED FLOW RATES
            2. ADD NEW FEED(S)
            3. DELETE FEED(S)
            4. SAVE DATA ENTERED

        ENTER OPTION (0 TO 4)
==>         0

                   MAIN MENU
                   =========

      0. QUIT
      1. ENTER OR MODIFY FLOWSHEET INFORMATION
      2. ENTER OR MODIFY UNIT INFORMATION
      3. ENTER OR MODIFY FEED DATA
      4. RETRIEVE DATA FROM PREVIOUS FILE
      5. DATA CONSISTENCY CHECK
      6. SAVE DATA ENTERED


  CHOOSE OPTION (0 TO 6)
==>         5                                                         $$$NOTE 10

FEED NOT DEFINED ON STREAM #     1
NUMBER OF INPUT  MISMATCH FOR UNIT #    2
NUMBER OF OUTPUT MISMATCH FOR UNIT #    4
NUMBER OF OUTPUT MISMATCH FOR UNIT #    6
NUMBER OF INPUT  MISMATCH FOR UNIT #    6
THERE'S NO FEED IN THIS FLOWCHART
NO PATH TO UNIT #     1 FROM FEED
NO PATH TO UNIT #     2 FROM FEED
NO PATH TO UNIT #     3 FROM FEED
NO PATH TO UNIT #     4 FROM FEED
NO PATH TO UNIT #     5 FROM FEED
NO PATH TO UNIT #     6 FROM FEED

NO CONTINUOUS PATH BETWEEN FEED AND PRODUCTS STREAM



                   MAIN MENU
                   =========

      0. QUIT
      1. ENTER OR MODIFY FLOWSHEET INFORMATION
      2. ENTER OR MODIFY UNIT INFORMATION
      3. ENTER OR MODIFY FEED DATA
      4. RETRIEVE DATA FROM PREVIOUS FILE
      5. DATA CONSISTENCY CHECK
      6. SAVE DATA ENTERED
```

```
      CHOOSE OPTION (0 TO 6)
    ==>          6                                                      $$$NOTE 11

 DO YOU WISH A NEW TITLE? ANSWER (Y/N) ? Y
ENTER NEW TITLE, MAXIMUM 80 CHARACTERS.                                 $$$NOTE 12
AGAR PAPER COMPARISON RUN

    *** DATA SAVED ON UNIT #9 ***

AGAR PAPER COMPARISON RUN


                       MAIN MENU
                       =========

          0. QUIT
          1. ENTER OR MODIFY FLOWSHEET INFORMATION
          2. ENTER OR MODIFY UNIT INFORMATION
          3. ENTER OR MODIFY FEED DATA
          4. RETRIEVE DATA FROM PREVIOUS FILE
          5. DATA CONSISTENCY CHECK
          6. SAVE DATA ENTERED


      CHOOSE OPTION (0 TO 6)
    ==>          0                                                      $$$NOTE 13


                  QUIT OPTION
                  ===========

PLEASE ENSURE THAT THE ENTERED DATA HAS BEEN SAVED USING
THE 'SAVE' OPTION! FAILURE TO DO SO WILL RESULT IN LOSS
OF ENTERED DATA.
    DO YOU REALLY WANT TO QUIT (Y/N) ?Y
 DO YOU WISH A NEW TITLE? ANSWER (Y/N) ? Y
ENTER NEW TITLE, MAXIMUM 80 CHARACTERS.
AGAR PAPER COMPARISON RUN

    *** DATA SAVED ON UNIT #9 ***
```

$$$NOTE 14

```
AGAR PAPER COMPARISON RUN
-9                                          *** S C M    S E C T I O N ***
    1    0    1      1.00
    2    4    1      1.00
    3    1    2      1.00
    4    2    0      1.00
    5    5    3      1.00
    6    2    3      1.00
    7    3    4      1.00
    8    4    2      1.00
   10    4    5      1.00
    9    5    0      1.00
-99                                         *** F E E D    S E C T I O N ***
     2     1     1     4   35.0000
                100.0000     .1700     .4100   11.8800
-999                                        *** U N I T     S E C T I O N ***
     1  J1         2     1     0
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000
     2  SEP1       1     2     0
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000
     3  J2         2     1     0
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000
     4  SEP2       1     2     5
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                   .6088     .0700     .1369     .2930    0.0000
     5  SEP3       1     2     5
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                   .3543     .0513     .2970     .2150    0.0000
     6  J3         2     2     0
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000
-99999                            *** E N D   O F   I N F O R M A T I O N ***
```

$$$NOTE 15

```
                       MAIN MENU
                       =========

          0. QUIT
          1. ENTER OR MODIFY FLOWSHEET INFORMATION
          2. ENTER OR MODIFY UNIT INFORMATION
          3. ENTER OR MODIFY FEED DATA
          4. RETRIEVE DATA FROM PREVIOUS FILE
          5. DATA CONSISTENCY CHECK
          6. SAVE DATA ENTERED


      CHOOSE OPTION (0 TO 6)
    ==>         4
```

$$$NOTE 16

```
        RETRIEVE DATA FROM FILE
        =======================
    WHEN THIS OPTION IS USED, ALL DATA ENTERED INTERACTIVELY UNTIL NOW
    IS LOST AND REPLACED BY DATA FROM FILE
    DO YOU WISH TO CONTINUE THE PROCESS OF THIS OPTION (Y/N) ? Y

AGAR PAPER COMPARISON RUN



                       MAIN MENU
                       =========

          0. QUIT
          1. ENTER OR MODIFY FLOWSHEET INFORMATION
          2. ENTER OR MODIFY UNIT INFORMATION
          3. ENTER OR MODIFY FEED DATA
          4. RETRIEVE DATA FROM PREVIOUS FILE
          5. DATA CONSISTENCY CHECK
          6. SAVE DATA ENTERED


      CHOOSE OPTION (0 TO 6)
    ==>         1

    THERE ARE   10 STREAMS IN THE PLANT

                          4 VALUES PER RECORD
                ******************************************
    INDEX       STREAM    ORIG.UNIT   DEST.UNIT    WEIGHT
       1           1          0            1       1.00
       2           2          4            1       1.00
       3           3          1            2       1.00
       4           4          2            0       1.00
       5           5          5            3       1.00
       6           6          2            3       1.00
       7           7          3            4       1.00
       8           8          4            2       1.00
       9          10          4            5       1.00
      10           9          5            0       1.00


             FLOWSHEET INFORMATION MENU
             ==========================

              0. RETURN TO MAIN MENU
              1. LIST STREAMS
              2. ADD NEW STREAM(S)
              3. MODIFY STREAMS
              4. DELETE STREAM
              5. SAVE DATA ENTERED
```

```
              ENTER OPTION (0 TO 5)
       ==>           4

       ENTER THE INDICES TO BE DELETED,ZERO TO STOP


   ==>       9                                                               $$$NOTE 17

   ==>       0

       *** RECORD #  9 DELETED ***

       THERE ARE    9 STREAMS IN THE PLANT

                               4 VALUES PER RECORD
                   ****************************************
       INDEX        STREAM     ORIG.UNIT    DEST.UNIT    WEIGHT
          1            1           0            1        1.00
          2            2           4            1        1.00
          3            3           1            2        1.00
          4            4           2            0        1.00
          5            5           5            3        1.00
          6            6           2            3        1.00
          7            7           3            4        1.00
          8            8           4            2        1.00
          9            9           5            0        1.00


                FLOWSHEET INFORMATION MENU
                ==========================

                 0. RETURN TO MAIN MENU
                 1. LIST STREAMS
                 2. ADD NEW STREAM(S)
                 3. MODIFY STREAMS
                 4. DELETE STREAM
                 5. SAVE DATA ENTERED

              ENTER OPTION (0 TO 5)
       ==>           3
       ENTER INDEX OF RECORD TO CHANGE (1 TO   9)
       ENTER '0' TO RETURN TO THE MENU
       ==>           5                                                       $$$NOTE 18

       ENTER NEW RECORD #   5
       STREAM, ORIG.UNIT, DEST.UNIT, WEIGHT
       SEPARATE EACH BY A COMMA OR A BLANK
       ==>           5         2         3     1.000
       RECORD #   5 REPLACED
       ENTER INDEX OF RECORD TO CHANGE (1 TO   9)
       ENTER '0' TO RETURN TO THE MENU
       ==>           6
```

```
ENTER NEW RECORD #   6
STREAM, ORIG.UNIT, DEST.UNIT, WEIGHT
SEPARATE EACH BY A COMMA OR A BLANK
==>         6         5         3     1.000
RECORD #   6 REPLACED
ENTER INDEX OF RECORD TO CHANGE (1 TO   9)
ENTER '0' TO RETURN TO THE MENU
==>         8

ENTER NEW RECORD #   8
STREAM, ORIG.UNIT, DEST.UNIT, WEIGHT
SEPARATE EACH BY A COMMA OR A BLANK
==>         8         4         5     1.000
RECORD #   8 REPLACED
ENTER INDEX OF RECORD TO CHANGE (1 TO   9)
ENTER '0' TO RETURN TO THE MENU
==>         0

THERE ARE    9 STREAMS IN THE PLANT

                      4 VALUES PER RECORD
            *****************************************
INDEX       STREAM    ORIG.UNIT   DEST.UNIT   WEIGHT
   1           1         0            1       1.00                  $$$NOTE 19
   2           2         4            1       1.00
   3           3         1            2       1.00
   4           4         2            0       1.00
   5           5         2            3       1.00
   6           6         5            3       1.00
   7           7         3            4       1.00
   8           8         4            5       1.00
   9           9         5            0       1.00


         FLOWSHEET INFORMATION MENU
         ==========================

          0. RETURN TO MAIN MENU
          1. LIST STREAMS
          2. ADD NEW STREAM(S)
          3. MODIFY STREAMS
          4. DELETE STREAM
          5. SAVE DATA ENTERED

       ENTER OPTION (0 TO 5)
==>         0
```

```
AGAR PAPER COMPARISON RUN


                      MAIN MENU
                      =========

             0. QUIT
             1. ENTER OR MODIFY FLOWSHEET INFORMATION
             2. ENTER OR MODIFY UNIT INFORMATION
             3. ENTER OR MODIFY FEED DATA
             4. RETRIEVE DATA FROM PREVIOUS FILE
             5. DATA CONSISTENCY CHECK
             6. SAVE DATA ENTERED


         CHOOSE OPTION (0 TO 6)
     ==>         2

     THERE ARE    6 UNITS IN THIS PLANT

                        UNIT LIST
             ***********************************************
             UNIT                 NB OF     NB OF     NB OF
    INDEX   NUMBER      NAME      INPUT     OUTPUT    PARAMS

      1         1     J1            2         1         0
      2         2     SEP1          1         2         0
      3         3     J2            2         1         0
      4         4     SEP2          1         2         5
      5         5     SEP3          1         2         5
      6         6     J3            2         2         0


                UNIT INFORMATION MENU
                =====================

               0. RETURN TO THE MAIN MENU
               1. LIST SPECIFIC UNIT INFO. (PARAMS, OPTION)
               2. ADD NEW UNIT(S)
               3. MODIFY UNIT
               4. DELETE UNIT
               5. SAVE DATA ENTERED

             ENTER OPTION (0 TO 5)
     ==>         4

     ENTER THE INDICES TO BE DELETED,ZERO TO STOP


 ==>     6                                                     $$$NOTE 20


 ==>     0

      *** RECORD #   6 DELETED ***
```

```
    THERE ARE    5 UNITS IN THIS PLANT

                          UNIT LIST
           **********************************************
            UNIT               NB OF     NB OF     NB OF
   INDEX   NUMBER     NAME     INPUT     OUTPUT    PARAMS

     1         1    J1          2          1         0
     2         2    SEP1        1          2         0
     3         3    J2          2          1         0
     4         4    SEP2        1          2         5
     5         5    SEP3        1          2         5


               UNIT INFORMATION MENU
               =====================

            0. RETURN TO THE MAIN MENU
            1. LIST SPECIFIC UNIT INFO. (PARAMS, OPTION)
            2. ADD NEW UNIT(S)
            3. MODIFY UNIT
            4. DELETE UNIT
            5. SAVE DATA ENTERED

          ENTER OPTION (0 TO 5)
    ==>         3


         TO MODIFY UNIT INFORMATION:
     - FIRST DELETE THE UNIT (OPTION 4)
     - THEN RE-ENTER THE UNIT (OPTION 2)

    ENTER THE INDICES TO BE DELETED,ZERO TO STOP


==>     2


==>     0

     *** RECORD #   2 DELETED ***

    ENTER FLOW SHEET NUMBER OF THE UNIT TO BE ADDED
       ( 0 TO TERMINATE INPUT SEQUENCE) ==>         2

    ENTER NAME OF UNIT (UP TO 6 CHARACTERS)==>SEP1

    ENTER         - NUMBER OF INPUT
                  - NUMBER OF OUTPUT
                  - NUMBER OF PARAMETERS
         SEPARATE EACH BY A COMMA OR A BLANK
    ==>         1         2         5

    ENTER THE 10 OPTIONS FOR THIS UNIT
                 1     2     3     4     5     6     7     8     9    10
    OPTION ==>   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
```

$$$NOTE 21

```
    ENTER THE    5 PARAMETERS FOR THIS UNIT
    10 BY 10 AS QUERIED BY THE PROGRAM
    SEPARATE EACH OF THEM BY A COMMA OR A BLANK

    PARMS                 1     2     3     4     5     6     7     8     9    10

      1 TO    5==>  .7966 .0783 .1313 .6157 0.0

    ENTER FLOW SHEET NUMBER OF THE UNIT TO BE ADDED
       ( 0 TO TERMINATE INPUT SEQUENCE) ==>         0

    THERE ARE    5 UNITS IN THIS PLANT

                          UNIT LIST
           ***********************************************
            UNIT                NB OF     NB OF     NB OF
   INDEX   NUMBER      NAME     INPUT     OUTPUT    PARAMS

     1         1    J1           2          1         0
     2         3    J2           2          1         0
     3         4    SEP2         1          2         5
     4         5    SEP3         1          2         5
     5         2    SEP1         1          2         5


               UNIT INFORMATION MENU
               =====================

            0. RETURN TO THE MAIN MENU
            1. LIST SPECIFIC UNIT INFO. (PARAMS, OPTION)
            2. ADD NEW UNIT(S)
            3. MODIFY UNIT
            4. DELETE UNIT
            5. SAVE DATA ENTERED

          ENTER OPTION (0 TO 5)
    ==>         0

AGAR PAPER COMPARISON RUN


                       MAIN MENU
                       =========

          0. QUIT
          1. ENTER OR MODIFY FLOWSHEET INFORMATION
          2. ENTER OR MODIFY UNIT INFORMATION
          3. ENTER OR MODIFY FEED DATA
          4. RETRIEVE DATA FROM PREVIOUS FILE
          5. DATA CONSISTENCY CHECK
          6. SAVE DATA ENTERED
```

```
      CHOOSE OPTION (0 TO 6)
    ==>         3

    THERE ARE    1 FEEDS IN THIS PLANT

                                FEED FLOW RATE
              ***********************************************
    INDEX     FEED STREAM     NS    NG    NC    WATER

      1           2           1     1     4   35.000



               FEED INFORMATION MENU
               =====================

                0. RETURN TO THE MAIN MENU
                1. LIST FEED FLOW RATES
                2. ADD NEW FEED(S)
                3. DELETE FEED(S)
                4. SAVE DATA ENTERED

            ENTER OPTION (0 TO 4)
    ==>         3

    ENTER THE INDICES TO BE DELETED,ZERO TO STOP


==>     1                                                                   $$$NOTE 22


==>     0


    *** RECORD #  1 DELETED ***

    THERE ARE    0 FEEDS IN THIS PLANT


               FEED INFORMATION MENU
               =====================

                0. RETURN TO THE MAIN MENU
                1. LIST FEED FLOW RATES
                2. ADD NEW FEED(S)
                3. DELETE FEED(S)
                4. SAVE DATA ENTERED

            ENTER OPTION (0 TO 4)
    ==>         2                                                           $$$NOTE 23
```

```
ENTER         - FEED STREAM INDEX
              - NUMBER OF SIZE INTERVALS, PAN INCLUDED (NS)
              - NUMBER OF DENSITY INTERVALS (NG)
              - NUMBER OF STREAM CHARACTERISTICS (NC)
    SEPARATE EACH BY A COMMA OR A BLANK
    ENTER 'O' TO END
==>     1     1     1     4

ENTER FEED FLOW RATES:

WATER==>     35.00

CHARACTERISTIC #  1
          DENSITY INTERVALS (NG)
             1
NS=  1==>100.00

CHARACTERISTIC #  2
          DENSITY INTERVALS (NG)
             1
NS=  1==>   .17

CHARACTERISTIC #  3
          DENSITY INTERVALS (NG)
             1
NS=  1==>   .41

CHARACTERISTIC #  4
          DENSITY INTERVALS (NG)
             1
NS=  1==> 11.88

ENTER         - FEED STREAM INDEX
              - NUMBER OF SIZE INTERVALS, PAN INCLUDED (NS)
              - NUMBER OF DENSITY INTERVALS (NG)
              - NUMBER OF STREAM CHARACTERISTICS (NC)
    SEPARATE EACH BY A COMMA OR A BLANK
    ENTER 'O' TO END
==>     0

THERE ARE     1 FEEDS IN THIS PLANT

                            FEED FLOW RATE
          ***********************************************
INDEX     FEED STREAM     NS    NG    NC    WATER

  1           1           1     1     4   35.000


           FEED INFORMATION MENU
           =====================

            0. RETURN TO THE MAIN MENU
            1. LIST FEED FLOW RATES
            2. ADD NEW FEED(S)
            3. DELETE FEED(S)
            4. SAVE DATA ENTERED
```

```
          ENTER OPTION (0 TO 4)
   ==>          0

AGAR PAPER COMPARISON RUN



                        MAIN MENU
                        =========

          0. QUIT
          1. ENTER OR MODIFY FLOWSHEET INFORMATION
          2. ENTER OR MODIFY UNIT INFORMATION
          3. ENTER OR MODIFY FEED DATA
          4. RETRIEVE DATA FROM PREVIOUS FILE
          5. DATA CONSISTENCY CHECK
          6. SAVE DATA ENTERED


      CHOOSE OPTION (0 TO 6)
   ==>          2

   THERE ARE    5 UNITS IN THIS PLANT

                           UNIT LIST
          *********************************************
           UNIT               NB OF    NB OF    NB OF
  INDEX   NUMBER     NAME     INPUT    OUTPUT   PARAMS

    1        1     J1          2        1        0                     $$$NOTE 24
    2        3     J2          2        1        0
    3        4     SEP2        1        2        5
    4        5     SEP3        1        2        5
    5        2     SEP1        1        2        5


               UNIT INFORMATION MENU
               =====================

            0. RETURN TO THE MAIN MENU
            1. LIST SPECIFIC UNIT INFO. (PARAMS, OPTION)
            2. ADD NEW UNIT(S)
            3. MODIFY UNIT
            4. DELETE UNIT
            5. SAVE DATA ENTERED

          ENTER OPTION (0 TO 5)
   ==>          1

    ENTER UNIT INDEX (1 -  5) , 0 TO QUIT

   ==>          3
```

```
  UNIT REFERENCE NUMBER             4
  NAME OF UNIT                SEP2
  NUMBER OF INPUT STREAM            1
  NUMBER OF OUTPUT STREAM           2
  NUMBER OF PARAMETERS              5

  OPTIONS :         0.000     0.000     0.000     0.000     0.000
                    0.000     0.000     0.000     0.000     0.000

  PARAMETERS :     .60880    .07000    .13690    .29300   0.00000


  ENTER UNIT INDEX (1 -  5) , 0 TO QUIT

 ==>         4

  UNIT REFERENCE NUMBER             5
  NAME OF UNIT                SEP3
  NUMBER OF INPUT STREAM            1
  NUMBER OF OUTPUT STREAM           2
  NUMBER OF PARAMETERS              5

  OPTIONS :         0.000     0.000     0.000     0.000     0.000
                    0.000     0.000     0.000     0.000     0.000

  PARAMETERS :     .35430    .05130    .29700    .21500   0.00000


  ENTER UNIT INDEX (1 -  5) , 0 TO QUIT

 ==>         5

  UNIT REFERENCE NUMBER             2
  NAME OF UNIT                SEP1
  NUMBER OF INPUT STREAM            1
  NUMBER OF OUTPUT STREAM           2
  NUMBER OF PARAMETERS              5

  OPTIONS :         0.000     0.000     0.000     0.000     0.000
                    0.000     0.000     0.000     0.000     0.000

  PARAMETERS :     .79660    .07830    .13130    .61570   0.00000


  ENTER UNIT INDEX (1 -  5) , 0 TO QUIT

 ==>         0

 THERE ARE    5 UNITS IN THIS PLANT

                       UNIT LIST
        **********************************************
         UNIT               NB OF     NB OF     NB OF
INDEX   NUMBER     NAME     INPUT     OUTPUT    PARAMS

  1         1    J1          2          1         0
  2         3    J2          2          1         0
  3         4    SEP2        1          2         5
  4         5    SEP3        1          2         5
  5         2    SEP1        1          2         5
```

```
              UNIT INFORMATION MENU
              =====================

           0. RETURN TO THE MAIN MENU
           1. LIST SPECIFIC UNIT INFO. (PARAMS, OPTION)
           2. ADD NEW UNIT(S)
           3. MODIFY UNIT
           4. DELETE UNIT
           5. SAVE DATA ENTERED

         ENTER OPTION (0 TO 5)
    ==>        0

AGAR PAPER COMPARISON RUN


                      MAIN MENU
                      =========

         0. QUIT
         1. ENTER OR MODIFY FLOWSHEET INFORMATION
         2. ENTER OR MODIFY UNIT INFORMATION
         3. ENTER OR MODIFY FEED DATA
         4. RETRIEVE DATA FROM PREVIOUS FILE
         5. DATA CONSISTENCY CHECK
         6. SAVE DATA ENTERED


       CHOOSE OPTION (0 TO 6)
    ==>        5
   *** DATA APPEARS TO BE CONSISTENT ***

AGAR PAPER COMPARISON RUN


                      MAIN MENU
                      =========

         0. QUIT
         1. ENTER OR MODIFY FLOWSHEET INFORMATION
         2. ENTER OR MODIFY UNIT INFORMATION
         3. ENTER OR MODIFY FEED DATA
         4. RETRIEVE DATA FROM PREVIOUS FILE
         5. DATA CONSISTENCY CHECK
         6. SAVE DATA ENTERED


       CHOOSE OPTION (0 TO 6)
    ==>        6
 DO YOU WISH A NEW TITLE? ANSWER (Y/N) ? N
```

$$$NOTE 25

$$$NOTE 26

```
    *** DATA SAVED ON UNIT #9 ***


AGAR PAPER COMPARISON RUN


                       MAIN MENU
                       =========

             0. QUIT
             1. ENTER OR MODIFY FLOWSHEET INFORMATION
             2. ENTER OR MODIFY UNIT INFORMATION
             3. ENTER OR MODIFY FEED DATA
             4. RETRIEVE DATA FROM PREVIOUS FILE
             5. DATA CONSISTENCY CHECK
             6. SAVE DATA ENTERED


      CHOOSE OPTION (0 TO 6)
    ==>         0


                  QUIT OPTION
                  ===========

PLEASE ENSURE THAT THE ENTERED DATA HAS BEEN SAVED USING
THE 'SAVE' OPTION! FAILURE TO DO SO WILL RESULT IN LOSS
OF ENTERED DATA.
    DO YOU REALLY WANT TO QUIT (Y/N) ?Y

AGAR PAPER COMPARISON RUN
-9                                       *** S C M    S E C T I O N ***  $$$NOTE 27
    1    0    1      1.00
    2    4    1      1.00
    3    1    2      1.00
    4    2    0      1.00
    5    2    3      1.00
    6    5    3      1.00
    7    3    4      1.00
    8    4    5      1.00
    9    5    0      1.00
-99                                      *** F E E D    S E C T I O N ***
     1     1     1     4   10.0000
                  100.0000     .1700     .4100   11.8800
-999                                     *** U N I T     S E C T I O N ***
     1  J1         2      1      0
                    0.0000    0.0000    0.0000    0.0000    0.0000
                    0.0000    0.0000    0.0000    0.0000    0.0000
                    0.0000
```

```
     3  J1          2     1     0
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000
     4  SEP 2       1     2     4
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                   .6088     .0700     .1369     .2930
     2  SEP1        1     2     4
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                   .7966     .7830     .1313     .6157
     5  SEP3        1     2     4
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                   .3543     .0513     .2970     .2150
-99999                            *** E N D   O F   I N F O R M A T I O N ***

AGAR PAPER COMPARISON RUN                                                      $$$NOTE 28


DO YOU WANT A DETAILED PRINTOUT OF THE FLOW SHEET ANALYSIS (Y/N) ?  Y          $$$NOTE 29


          NUMBER OF CYCLES =    2                                              $$$NOTE 30
          ******************************

CYCLE #    !   STREAMS COMPOSING CYCLE
CYCLE   1 !        7      2      3      5
CYCLE   2 !        8      6      7

          NUMBER OF COMPLEX NODES =      1                                     $$$NOTE 31
          ******************************

NODE  #    !   STREAMS COMPOSING COMPLEX NODE
NODE    1 !      7     2     3     5     8     6
```

```
                          NODE SCM                                            $$$NOTE 32
          *******************************
                   *         *         *

                   1         0        -1
                   4        -1         0
                   9        -1         0
NODE CALCULATION ORDER (NEGATIVE VALUES INDICATE A COMPLEX NODE)


 -1                                                                           $$$NOTE 33



*** COMPLEX NODE NUMBER    1 DECOMPOSITION
*** MINIMUM COST IS        1.00
*** FOR SET OF TEAR STREAMS
       7                                                                      $$$NOTE 34
*** UNIT CALCULATION ORDER IS
   4   1   2   5   3
*** PATHS BETWEEN TEAR STREAMS ARE:
PATH   1 !     7   8   6   7                                                  $$$NOTE 35
PATH   2 !     7   2   3   5   7

END OF FLOW SHEET ANALYSIS

AGAR PAPER COMPARISON RUN                                                     $$$NOTE 36
-9                                           *** S C M   S E C T I O N ***
     1    0    1      1.00
     2    4    1      1.00
     3    1    2      1.00
     4    2    0      1.00
     5    2    3      1.00
     6    5    3      1.00
     7    3    4      1.00
     8    4    5      1.00
     9    5    0      1.00
-99                                          *** F E E D   S E C T I O N ***
     1     1     1     4   10.0000
                100.0000     .1700     .4100   11.8800
-999                                         *** U N I T   S E C T I O N ***
     1  J1           2     1     0
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000
     3  J1           2     1     0
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000
     4  SEP 2        1     2     4
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                   .6088     .0700     .1369     .2930
```

```
     2  SEP1       1     2     4
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                   .7966     .7830     .1313     .6157
     5  SEP3       1     2     4
                  0.0000    0.0000    0.0000    0.0000    0.0000
                  0.0000    0.0000    0.0000    0.0000    0.0000
                   .3543     .0513     .2970     .2150                  $$$NOTE 37
-99999                             *** E N D   O F   I N F O R M A T I O N ***
NSCM          3
    1    0   -1    1

    4   -1    0    4

    9   -1    0    9

NCORD         1
   -1

CNSCM        -1   10
    7    0    4    7

    2    4    1    2

    1    0    1    1

    3    1    2    3

    5    2    3    5

    8    4    5    8

    6    5    3    6

    4    2    0    4

    9    5    0    9

    7    3    0    7

NODE         -1    6    1    5
TEAR    -1    7    7

NCALC   -1    4

NCALC   -1    1

NCALC   -1    2

NCALC   -1    5

NCALC   -1    3



AGAR PAPER COMPARISON RUN                                                  $$$NOTE 38



DO YOU WANT A DETAILED PRINTOUT OF THE FLOW RATE CALCULATION (Y/N) ? Y     $$$NOTE 39
```

```
FLOW RATE ITERATION FOR COMPLEX NODE     1


DO YOU WISH TO INITIALIZE TEAR STREAMS (Y/N) ?
N                                                                          $$$NOTE 40
ENTER THE FOLLOWING 3 VALUES
IN ORDER TO CONTINUE THE ITERATION ( 0 TO STOP )
1)- CONVERGENCE CRITERION(RELATIVE ACCURACY)
2)- NUMBER OF ITERATIONS TO NEXT CHECKPOINT
3)- NUMBER OF ITERATIONS PER REPORT
  .001   5   1                                                             $$$NOTE 41

ITERATION NUMBER        1                        COMPLEX NODE        1



TEAR STREAM        7

FLOW RATES BY DIRECT SUBSTITUTION                                          $$$NOTE 42
        20.3400           .1567           .3562          4.5655          35.0000

PREDICTED FLOW RATES USING AITKINS D2 ACCELERATION
********************************************************************************

RELATIVE ERROR IN PREDICTED FLOW RATE
.1000000000+100 .1000000000+100 .1000000000+100 .1000000000+100 .1000000000+100



EQUIVALENT MEDIAN SPLIT FACTORS FOR COMPLEX NODE ARE
0.0000000000000 0.0000000000000 0.0000000000000 0.0000000000000 0.0000000000000


ITERATION NUMBER        2                        COMPLEX NODE        1



TEAR STREAM        7

FLOW RATES BY DIRECT SUBSTITUTION
         25.6779           .1743           .4898          5.7735          35.0000

PREDICTED FLOW RATES USING AITKINS D2 ACCELERATION
********************************************************************************
```

```
RELATIVE ERROR IN PREDICTED FLOW RATE
 .1000000000+100 .1000000000+100 .1000000000+100 .1000000000+100 .1000000000+100


EQUIVALENT MEDIAN SPLIT FACTORS FOR COMPLEX NODE ARE
  .2624320800000  .1122280000000  .3752657300000  .2646049000000 0.0000000000000


ITERATION NUMBER        3                         COMPLEX NODE        1


TEAR STREAM        7                                                        $$$NOTE 43

FLOW RATES BY DIRECT SUBSTITUTION
         27.0787           .1762           .5400           6.0932          35.0000

PREDICTED FLOW RATES USING AITKINS D2 ACCELERATION
         27.5771           .1765           .5701           6.2082****************

RELATIVE ERROR IN PREDICTED FLOW RATE
 .1000000000+100 .1000000000+100 .1000000000+100 .1000000000+100 .1000000000+100


EQUIVALENT MEDIAN SPLIT FACTORS FOR COMPLEX NODE ARE
  .2624320800000  .1122280000000  .3752657300000  .2646049000000 0.0000000000000


ITERATION NUMBER        4                         COMPLEX NODE        1


TEAR STREAM        7

FLOW RATES BY DIRECT SUBSTITUTION
         27.4463           .1765           .5588           6.1778          35.0000

PREDICTED FLOW RATES USING AITKINS D2 ACCELERATION
         27.5771           .1765           .5701           6.2082****************

RELATIVE ERROR IN PREDICTED FLOW RATE
 .6183758439E-14 .2516130462E-14 .3115816438E-14 .2289043818E-14 .1000000000+100

ESTIMATED DIRECT SUBSTITUTION ITERATIONS ARE                                $$$NOTE 44
               6               4               8               6               0
```

```
EQUIVALENT MEDIAN SPLIT FACTORS FOR COMPLEX NODE ARE
  .2624320800002  .1122279999998  .3752657300000  .2646049000000 0.0000000000000

MAXIMUM ESTIMATED DIRECT SUBSTITUTION ITERATIONS ARE:
               6               4               8               6               0


ITERATION NUMBER        5                        COMPLEX NODE        1



TEAR STREAM        7

FLOW RATES BY DIRECT SUBSTITUTION
         27.5428           .1765           .5659          6.2002         35.0000

PREDICTED FLOW RATES USING AITKINS D2 ACCELERATION                        $$$NOTE 45
         27.5771           .1765           .5701          6.2082         35.0000

RELATIVE ERROR IN PREDICTED FLOW RATE
 .1030626406E-13 .2516130462E-140.               .2289043818E-140.        $$$NOTE 46

ESTIMATED DIRECT SUBSTITUTION ITERATIONS ARE
               6               4               8               6               0


EQUIVALENT MEDIAN SPLIT FACTORS FOR COMPLEX NODE ARE
  .2624320799987  .1122279999977  .3752657300000  .2646048999998 0.0000000000000

MAXIMUM ESTIMATED DIRECT SUBSTITUTION ITERATIONS ARE:
               6               4               8               6               0

ENTER THE FOLLOWING 3 VALUES
IN ORDER TO CONTINUE THE ITERATION ( 0 TO STOP )
1)- CONVERGENCE CRITERION(RELATIVE ACCURACY)
2)- NUMBER OF ITERATIONS TO NEXT CHECKPOINT
3)- NUMBER OF ITERATIONS PER REPORT
  .001   5   1                                                            $$$NOTE 47

ITERATION NUMBER        6                        COMPLEX NODE        1


TEAR STREAM        7
```

$$$NOTE 48

```
AITKINS D2 ACCELERATION NOW APPLIED TO TEAR STREAM    7 ITERATION #         6
PREDICTED FLOW RATES USING AITKINS D2 ACCELERATION
         27.5771           .1765           .5701          6.2082         35.0000

RELATIVE ERROR IN PREDICTED FLOW RATE
 .1030626406E-13 .2516130462E-140.               .4578087635E-140.

ESTIMATED DIRECT SUBSTITUTION ITERATIONS ARE
               6               4               8               6               0


EQUIVALENT MEDIAN SPLIT FACTORS FOR COMPLEX NODE ARE
  .2624320800057  .1122279999977  .3752657300000  .2646049000014 0.0000000000000

MAXIMUM ESTIMATED DIRECT SUBSTITUTION ITERATIONS ARE:
               6               4               8               6               0

INDEX STREAM        STREAM FLOW RATES

CHARACTERISTIC        1             2             3             4             5
```

$$$NOTE 49

```
   1    1      100.0000         .1700         .4100       11.8800       35.0000

   2    2       16.7890         .0124         .0780        1.8190        0.0000

   3    3      116.7890         .1824         .4880       13.6990       35.0000

   4    4       93.0341         .0143         .0641        8.4345        0.0000

   5    8       10.7882         .1641         .4921        4.3892       35.0000

   6    9        6.9659         .1557         .3459        3.4455       35.0000

   7    6        3.8222         .0084         .1461         .9437        0.0000

   8    5       23.7549         .1681         .4240        5.2645       35.0000

   9    7       27.5771         .1765         .5701        6.2082       35.0000

END OF FLOW RATE SIMULATION

AGAR PAPER COMPARISON RUN
```

$$$NOTE 50

```
DO YOU WANT A DETAILED PRINTOUT OF THE FLOW RATE CALCULATION (Y/N) ? N      $$$NOTE 51


FLOW RATE ITERATION FOR COMPLEX NODE     1



DO YOU WISH TO INITIALIZE TEAR STREAMS (Y/N) ?
Y                                                                           $$$NOTE 52
     FOR TEAR STREAM     7
ENTER            -ESTIMATED FLOW RATES: (NEGATIVE FOR ALL ZEROES)

     WATER==>      0.00

    CHARACTERISTIC #  1
              DENSITY INTERVALS (NG)
                  1
    NS=  1==> 20.00

    CHARACTERISTIC #  2
              DENSITY INTERVALS (NG)
                  1
    NS=  1==>  1.00

    CHARACTERISTIC #  3
              DENSITY INTERVALS (NG)
                  1
    NS=  1==>   .50

    CHARACTERISTIC #  4
              DENSITY INTERVALS (NG)
                  1
    NS=  1==>  8.00
ENTER THE FOLLOWING 3 VALUES
IN ORDER TO CONTINUE THE ITERATION ( 0 TO STOP )
1)- CONVERGENCE CRITERION(RELATIVE ACCURACY)
2)- NUMBER OF ITERATIONS TO NEXT CHECKPOINT
3)- NUMBER OF ITERATIONS PER REPORT
  .001  10  2                                                               $$$NOTE 53

ITERATION NUMBER        2                           COMPLEX NODE        1



TEAR STREAM        7

PREDICTED FLOW RATES USING AITKINS D2 ACCELERATION
********************************************************************************

RELATIVE ERROR IN PREDICTED FLOW RATE
 .1000000000+100 .1000000000+100 .1000000000+100 .1000000000+100 .1000000000+100
```

```
ITERATION NUMBER        4                              COMPLEX NODE        1


TEAR STREAM         7

PREDICTED FLOW RATES USING AITKINS D2 ACCELERATION
         27.5771           .1765            .5701            6.2082****************

RELATIVE ERROR IN PREDICTED FLOW RATE                                        $$$NOTE 54
0.                .2516130462E-140.                .2289043818E-14 .1000000000+100

MAXIMUM ESTIMATED DIRECT SUBSTITUTION ITERATIONS ARE:
               5                4                5                5                0


ITERATION NUMBER        6                              COMPLEX NODE        1


TEAR STREAM         7                                                        $$$NOTE 55

AITKINS D2 ACCELERATION NOW APPLIED TO TEAR STREAM     7 ITERATION #         6
PREDICTED FLOW RATES USING AITKINS D2 ACCELERATION
         27.5771           .1765            .5701            6.2082           0.0000

RELATIVE ERROR IN PREDICTED FLOW RATE
 .4122505626E-14 .2516130462E-140.                .2289043818E-140.

MAXIMUM ESTIMATED DIRECT SUBSTITUTION ITERATIONS ARE:
               5                4                5                5                0


INDEX STREAM         STREAM FLOW RATES

CHARACTERISTIC          1             2             3             4             5

                                                                             $$$NOTE 56

   1    1       100.0000          .1700         .4100       11.8800        0.0000

   2    2        16.7890          .0124         .0780        1.8190        0.0000

   3    3       116.7890          .1824         .4880       13.6990        0.0000

   4    4        93.0341          .0143         .0641        8.4345        0.0000
```

```
     5    8     10.7882        .1642        .4921       4.3892       0.0000

     6    9      6.9659        .1557        .3459       3.4455       0.0000

     7    6      3.8222        .0084        .1461        .9437       0.0000

     8    5     23.7549        .1681        .4240       5.2645       0.0000

     9    7     27.5771        .1765        .5701       6.2082       0.0000

END OF FLOW RATE SIMULATION
```

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CRSHEX

CRUSHING PLANT SIMULATION EXECUTIVE

P. Chassat, C. Gauthier

CONTENTS

TABLES

FIGURE

1. PROGRAM IDENTIFICATION

Program Title: **CR**u**SH**ing Plant **EX**ecutive.

Program Code Name: CRSHEX.

Authors: P. Chassat, C. Gauthier.

Organization:
Les Industries
Piedmont Ltée
20 Blvd., Montague
Boucherville, Québec
J4B 5E7.

Date: May 1985.

Updates: This is the original version.

Source Language: Microsoft FORTRAN, Version 3.2 (1985).

Availability: Complete program listing is available from:
CANMET,
Energy, Mines and Resources,
Technology Information Division,
555 Booth Street
Ottawa, Ontario
K1A 0G1.

2. ENGINEERING DOCUMENTATION

2.1 NARRATIVE DESCRIPTION

2.1.1 Introduction

This simulation program can be used both for optimizing an existing plant and for designing new flowsheets.

It is used for the *optimization of an existing plant*:

- by matching product specification with the customer's request;
- by computing the size of the stock piles;
- by allowing the best flowsheet to meet special requests to be computed;
- by allowing the operation of individual units or their replacement by other units to be optimized;
- by reducing or increasing the throughput.

It is used for the *design of new flowsheets* by allowing any meaningful combination of available unit models to be simulated.

This simulator is based almost exclusively on industrial data.

2.1.2 Principles of Crushing

2.1.2.1 How a rock breaks

A rock can break in three different ways; by impact, by attrition, or by compression. The best results are usually produced by impact, or rapid compression. The resulting fragments are produced by breakage along the natural grain boundaries.

Table 6 shows the usual type of breakage that occurs in different types of crushers.

Table 6 – Type of breakage by crushers

Crusher type	Type of breakage
1. Hammer	Impact, attrition, shearing
2. Impactor	Impact
3. Cone	Impact, compression
4. Jaw	Impact, compression
5. Gyratory	Impact, compression
6. Rolls	Compression

2.1.2.2 Crushing stages

There is normally a maximum of four crushing stages to reduce the size of rocks from a quarry or a mine. The objectives of these stages are usually:

Primary:	To reduce the sizes of the bigger blocks to a size that can easily be carried on a conveyor belt toward the secondary crushers (approximately 203 mm).
Secondary:	To produce industrial minerals (gravel, concrete, asphalt) following precise specifications, or to produce tertiary crusher feed (approximately 51 mm).
Tertiary:	To produce material finer than 20 mm for concrete, gravel, and asphalt, or to feed a concentrator in a mine.
Quaternary:	This stage is only required for special products finer than 6 mm.

Table 7 shows the different types of crushers normally used during the different stages of crushing.

Hammer and impact crushers cannot be used for material containing more than 15 per cent silica, as this material would be too abrasive.

Table 7 — Types of crusher for different crushing stages

	Crushing stage			
Type of crusher	Primary	Secondary	Tertiary	Quaternary
1. Gyratory	x	x		
2. Impact	x	x	x	
3. Jaw	x			
4. Standard cone		x		
5. Shorthead cone		x	x	
6. Roll		x	x	x
7. Hammer	x	x	x	x

2.1.3 Principles of Screening

Two basic processes occur during screening: segregation and separation.

2.1.3.1 Segregation

Segregation is a process that can be described as follows: as the material is shaken and moves from one end of the screen to the other, the larger particles reach the top of the bed of material, and the smaller particles migrate through the coarser particles and accumulate at the bottom of the bed of material.

Segregation always occurs during screening, and permits fine particles to migrate through the coarse particle bed. The screen width has a strong influence on the thickness of the bed and therefore on the segregation. Segregation is also influenced by a combination of two factors: the *speed* which is a function of the specifications of the material, the type of screen, the thickness of the bed, the amplitude of its stroke, but principally the angle of inclination of the screen; and the *stroke* of the screen, which is a function of the amplitude, the direction of rotation, and principally its frequency.

If the bed of material on the screen is too thin, the bouncing of the fine particles reduces their probability of passing through the openings. On the other hand, if the bed is too thick, the migration of fine particles through the bed is hindered and the fine particles are carried on the overflow with the coarse particles. Therefore, there is always an optimum thickness of the bed of material for a given feed rate and a given screen.

2.1.3.2 Separation

Separation is the process for which the screens are designed. Particles that are smaller than the opening of the screen pass to the underflow according to a law of probability.

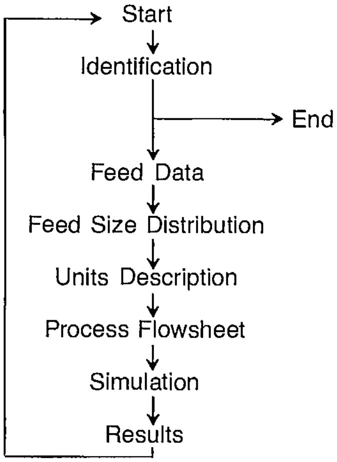
This stage of screening is strongly influenced by the shape of the particles. The smaller the particles, the higher the probability of their passing through the opening of the screen. The longer the screen, the higher the probability of the particles passing through the screen. Better efficiency can be obtained by inclining the screen and by using rectangular openings. Humidity or clay in the material produces agglomeration and reduces the efficiency of the screens.

2.2 METHOD OF SOLUTION

The crushing plant simulator is easy to use, flexible, and interactive, but it requires the user to have a knowledge of crushing practice.

2.2.1 Structure of the Simulator

2.2.1.1 Flowsheet



2.2.1.2 Identification

The user must enter the name of the client, a reference number, and the date of the simulation or the user must terminate the execution.

2.2.1.3 Feed data

This step requires the entry of data characterizing the material:

- type of material (limestone, granite, trap rock, ore, others)
- a comment on the condition of the material
- the specific gravity of the material in tonnes per cubic metre
- the Bond work index in kWh per tonne
- the percentage humidity in the feed
- the number of metric tonnes per hour to be processed.

Only the material condition does not intervene in the calculations.

2.2.1.4 Feed size distribution

In this step the user must enter the size distribution of the feed material. Two options are given:

1. The size distribution of the feed can be entered if available.

2. Typical size distribution after blasting can be selected from a file. The user can choose from:

   Limestone: 0-915 mm, 0-610 mm, 0-508 mm or 0-457 mm
   Granite: 0-915 mm, 0-610 mm, 0-508 mm or 0-457 mm
   Trap rock: 0-915 mm, 0-610 mm, 0-508 mm or 0-457 mm
   Gravel: 0-457 mm, 0-305 mm or 0-203 mm.

2.2.1.5 Description of units

Seven different processes are available in the crushing plant simulator: crushing, screening, splitting, mixing, storage in silo, stock piling, and feeding with feeder. The user must specify the type of process desired and then describe the type of unit to be selected. (The storage processes have different process units.)

Crushing:
- jaw crusher
- gyratory crusher
- standard cone crusher
- shorthead cone crusher
- impact crusher
- hammer mill
- roll crusher
- other crusher.

Screening:
- screen with one to four horizontal decks
- screen with one to four inclined decks.

Splitting:
- splitting of a stream into two, three or four substreams.

Mixing:
- mixing of two, three or four streams into one stream
- mixing can be in an open circuit or in a closed circuit.

Storage in silo:
- this allows the flow rate in a flowsheet to be regularized and several products to be mixed.

Stock piling:
- storage in a buffer pile to regularize the system
- storage in a final stock pile.

Feeding:
- feeder with grizzly
- feeder without grizzly.

2.2.1.6 Process flowsheet

At this step the user must indicate the stream connections for the process to be simulated. The user must specify the type of unit that is fed by the stream displayed on the screen. The streams are numbered sequentially according to a sequence determined by the program. There is also an internal verification of the consistency of the connections given by the user.

2.2.1.7 Simulation

At this step the simulation of the different units is performed according to the order established in the process flowsheet. The user cannot intervene during this step.

2.2.1.8 Results

This step allows the following results to be displayed for each unit:

- the size distribution
- the various unit parameters
- the unit efficiency.

The user can decide to modify selected variables such as:

- feed data
- feed size distribution
- unit operating variables
- list of units
- process flowsheet.

2.2.2 Crushing Units

To select the correct crushing unit, the user must consider the type of material being processed; hot or cold, dry or wet, soft or hard, brittle or abrasive. The feed size distribution, the throughput in tonnes per hour, and the required product size must also be considered.

2.2.2.1 Jaw crusher

The jaw crusher is the oldest type of crusher used for reducing rocks. Most jaw crushers are used as primary crushers, the size of the product being limited by the open side setting. The product of the jaw crusher is usually slabby. The open side setting in the simulator can be varied from 25.4 mm to 406.4 mm. All the curves representing the product of the jaw crusher are adjusted to 80 per cent passing the open side setting for limestone-type material with a density of 1.6 tonnes per cubic metre and a Bond work index (wi) of 10 kWh per tonne. For material other than limestone a correction is made. Table 8 gives the different types of material and the percentage passing the open side setting.

The setting that is equivalent to 80 per cent passing (Table 9) is calculated for the conditions under study.

When the equivalent open side setting is obtained, the actual crushing simulation is performed and the characteristic curves for a jaw crusher product are used.

Table 8 — Percentage passing the jaw crusher setting for different materials

wi	Characteristics	Scalped	Not-scalped
5-10	Soft	85%	90%
5-10	Soft (spongy)	82%	85%
10-13	Medium (limestone)	85%	88%
10-13	Medium (slabby)	80%	85%
13	Hard (brittle) (ore)	80%	85%
13	Hard (resistant) (granite)	75%	75%
13	Hard (slabby) (trap rock)	70%	75%

Note: Scalped: with previous screening.
Not-scalped: without previous screening.

Table 9 — Equations for calculating the setting equivalent to 80% passing

Per cent passing	Open side setting ≤101.6 mm	Open side setting >101.6 mm
70	(1.2012*CSS) – 0.4687	(1.1897*CSS) – 0.3793
75	(1.1045*CSS) – 0.4232	(1.0860*CSS) + 0.4484
80	(1. *CSS) 0	(1. *CSS)
82	(0.9818*CSS) – 0.7769	(0.9647*CSS) + 0.7429
85	(0.9409*CSS) – 1.6666	(0.9130*CSS) + 1.2108
88	(0.8981*CSS) – 2.4143	(0.8605*CSS) + 1.9027
90	(0.8614*CSS) – 2.5277	(0.8232*CSS) + 2.1970

Note: CSS = open-side setting given with the unit specifications. The program selects the correct equation for calculating the setting equivalent to 80% passing.

2.2.2.2 Gyratory crusher

This type of crusher is used mainly as a primary crusher and sometimes as a secondary crusher. Crushing with gyratory crusher does not involve any dead-time during which a block could occur in the crusher as can happen in a jaw crusher. The fragments emerging from this type of crusher are usually cubic. The possible settings of the gyratory crusher vary from 25.4 mm to 406.4 mm. Results are similar to those obtained with the jaw crusher, with the exception of the percentage passing versus the type of material, as shown in Table 10.

The subsequent steps are the same as for the jaw crusher.

2.2.2.3 Cone crusher

Two types of cone crushers are considered: the standard cone crusher, which is used mainly as secondary crusher; and the shorthead cone crusher, which is used as a tertiary crusher. These two types of crushers have a very good performance on abrasive and hard rocks, and both produce fragments with cubic shapes. Cone

Table 10 — Percentage passing the gyratory crusher setting for different materials

wi	Characteristics	Scalped	Not-scalped
5-10	Soft	85%	90%
5-10	Soft (spongy)	82%	85%
10-13	Medium (limestone)	85%	88%
10-13	Medium (slabby)	82%	85%
13	Hard (brittle) (ore)	82%	88%
13	Hard (resistant) (granite)	75%	80%
13	Hard (slabby) (trap rock)	75%	75%

Note: Scalped: with previous screening.
Not-scalped: without previous screening.

crushers tend to seize when fed with humid or sticky material that agglomerates. The possible open side settings of these crushers vary between 3.2 mm and 76.2 mm.

Parameters that can be varied by the user are the type of crusher (whether cone or shorthead), the type of chamber, the work index, and the opening. All the cone crusher curves are adjusted to 80 per cent passing the open side setting for limestone-type material with a specific gravity of 1.6 tonnes per cubic meter, and a Bond work index of 10 kWh per tonne. For different conditions, the correction that must be made is described in Table 11 which lists the percentage passing obtained on a standard cone crusher. For a shorthead cone crusher, the user must add 5 per cent to the result found in Table 11.

2.2.2.4 Impact crusher

This type of crusher gives a very high reduction ratio. It is normally used as primary crusher and very often replaces two stages of crushing. It cannot be used with a very hard and abrasive material. Impact crushing usually produces a high percentage of fines which can be a disadvantage in some cases. The possible settings of the impact crusher in the simulator are between 12.7 mm and 203.2 mm. The operating parameters that can be varied are the Bond work index, the opening, the rotation speed (rpm), and the type of crusher. Since all the efficiency curves for the impact crusher are based on limestone-type material, all readings are made at 80 per cent passing the opening of the crusher.

For other conditions, the following corrections are made:

- correction for the rotor length
- correction for the speed of rotation
- an adjustment of the percentage passing the opening of the crusher, which depends on the type of material:

if wi < 10 ppo = ppo + 5%
if wi ≥ 10 and < 13 ppo = ppo
if wi ≥ 13 ppo = ppo − 5%

where: ppo = percentage passing the opening

- the equivalent opening corresponding to 80 per cent passing curves is calculated
- the crusher product is then calculated for the given conditions.

2.2.2.5 Hammer mill

The hammer mill is similar to the impact crusher but usually produces particles finer than 100 mesh. It can be used in a very efficient manner to produce material with 100 per cent passing 6.35 mm.

The hammer mill can have a reduction ratio of over 40. It can also crush humid material but cannot be used for abrasive or hard material. As for any other type of crusher, all the size distribution curves of the products are based on limestone-type material in a product in which 80 per cent of the material is finer than the opening of the crusher.

The opening of the crusher can be adjusted between 4.76 mm and 38.1 mm. For other conditions the following corrections are made:

- The system verifies whether the crusher has a grate.

Table 11 — Percentage passing on a standard cone crusher

Type of chamber	Soft material			Medium material			Hard material		
	A	B	C	A	B	C	A	B	C
Extra fine	85	81	75	81	77	71	77	73	67
Fine	83	79	73	79	75	69	75	71	65
Medium	80	76	71	76	72	67	72	68	63
Coarse	75	71	67	71	67	63	67	63	59
Extra coarse	70	66	63	66	62	59	62	58	55

Note: Numerics are per cent passing.
A: setting, 12.7 mm
B: setting, 12.7 mm and 25.4 mm
C: setting, 25.4 mm
Soft material: wi < 10
Medium material: wi ≥ 10 and wi < 13
Hard material: wi ≥ 13

- The size distribution corresponding to the given operating conditions is selected.
- If necessary, an interpolation is performed to calculate the product size distribution.

2.2.2.6 Roll crushers or other types

For this type of crusher, the size distribution of the product is provided by the user.

2.2.3 Screening Units

2.2.3.1 Screens

This part of the simulator uses the model by Karra which is described in Chapter 5.1 of the SPOC manual.

This model has been modified to add the option of dividing a deck into two sections with different openings. The model first calculates the product size distribution of each section and recombines them to obtain the overall size distribution of the screen overflow and underflow.

2.2.3.2 Feeder with grizzly

This model is essentially the same as the Karra model except for the correction factor CAP, which depends on the ratio of the opening of the grizzly to the sum of the opening and the grizzly bar width.

$$\mathrm{CAP} = \mathrm{Opening}/(\mathrm{opening} + \mathrm{bar\ width})$$

This correction factor affects the d50 calculated in the Karra model, and therefore reduces the experimentally observed efficiency of the grizzly.

2.3 PROGRAM CAPABILITIES

In its present version, the simulator can handle up to 35 units and 45 streams. These numbers can be increased. The system has been verified up to 1000 tph. Although the simulator is thought to be robust, a successful simulation depends largely on the expertise of the user.

2.4 INPUT DATA

The system performs a verification on each data entry. The most frequent errors are logical errors made during the description of the process flowsheet. This type of error will be discussed in CRSHEX Section 4.1. It is always possible to back-track to correct a data entry.

2.5 FLOWSHEET AND DATA OUTPUT

The subroutines can be easily understood, even by a non-FORTRAN programmer, because the FORTRAN code is structured and annotated with comments. The program outputs are illustrated in the sample run presented in CRSHEX Section 5.

3. SYSTEM DOCUMENTATION

3.1 EQUIPMENT

The hardware required for using the simulator is as follows:

- micro-computer IBM-PC 256K
- two soft-disk drives
- an operating system MS-DOS 3.0 (or more recent)
- a microsoft FORTRAN compiler version 3.2 (or more recent).

3.2 MAIN PROGRAM AND SUBROUTINES

The reader is referred to the program source code in which numerous comments allow the various calculation steps to be easily understood.

4. OPERATING DOCUMENTATION

4.1 USER-CONTROLLED ERROR MESSAGES

The simulator features a system of data verification that produces error messages at the lower part of the screen. The user must correct the data immediately before proceeding with data entry.

4.2 NON-USER-CONTROLLED ERROR MESSAGES

Four types of errors that require a cancellation of the execution may occur during use of the simulator:

- during the simulation when the throughput is higher than 1500 tph
- when the screen opening is equal to zero
- when the lower deck of screen has an opening that is wider than the deck above
- when the process does not end with a stock-piling step.

5. SAMPLE RUN

5.1 GENERAL DATA

The user wants to crush 400 tph with the following equipment:

- one grizzly feeder type LPE-9 length 4877 mm, width 1219 mm length of the grizzly 1829 mm;
- one jaw crusher model J-3048;
- one inclined screen M-13, 6096 mm by 1524 mm with three decks;
- one inclined screen M-16, 7315 mm by 2134 mm with three decks;
- one cone crusher, standard type, 51 in. (ST-51);
- one cone crusher, shorthead, 51 in. (SH-51).

The flowsheet has already been established and is shown in Figure 7. The objective is to obtain the maximum throughput of products A and B that meets the following specifications:

A — 19 mm product	100% passing 25 mm 0-10% passing 12.7 mm
B — 13 mm product	100% passing 19 mm 0-10% passing 4 mesh 0-2% passing 8 mesh

5.2 TYPE OF MATERIAL

The following are the characteristics of the material:

- the material is limestone;
- the size distribution is standard after blasting, size range 0-609 mm (0-24 in.);
- the Bond work index is 10 kWh/t;
- the specific gravity is 1.6 t/m^3;
- the per cent humidity is 0%.

5.3 DATA INPUT

The program is essentially designed to converse with the user. The relevant information for solving this example is requested by prompts.

After obtaining the results corresponding to the initial specifications of the unit variables, the user then modifies the input data until the expected results are produced.

5.4 SAMPLE RUN 1

5.4.1 Comments

Screens 1 to 23 give all the information needed to execute the program the first time, following the flowchart shown in Figure 7.

5.4.2 Results

The different results obtained in sample run 1 are shown in screens 24 to 40. These are presented in two parts. The first part is a description of the unit and its operating conditions; the second gives a size analysis in per cent passing, as well as the number of tonnes of material treated, the number of tonnes of water, and the maximum dimension of the material.

Screen 33 shows a 51-in. standard cone crusher (unit 7), with a capacity of 339 tph and an open side set of 22 mm capable of accepting blocks of 252 mm. This is impossible since a crusher of this type was originally defined in screen 13, having a setting of 22 mm and a *coarse* cavity capable of treating 245 tph. Also, the maximum size of blocks to the crusher is 241 mm. Some corrections are necessary.

It may be observed also, in screens 35 and 36, that modifications to the 3-deck inclined screen (unit 10) are needed since the efficiency of decks 1 and 2 is not acceptable. Also, in screen 38, streams 18 (product A) and 20 (product B) do not meet the specifications given in CRSHEX Section 5.1.

In screen 39, it can be seen that the 51-in. short head cone crusher (unit 11) needs a capacity of 382 tph for a setting of 12 mm. This is impossible because a crusher of this type, under conditions as cited in Figure 7, has a capacity of only 200 tph. A modification is needed here.

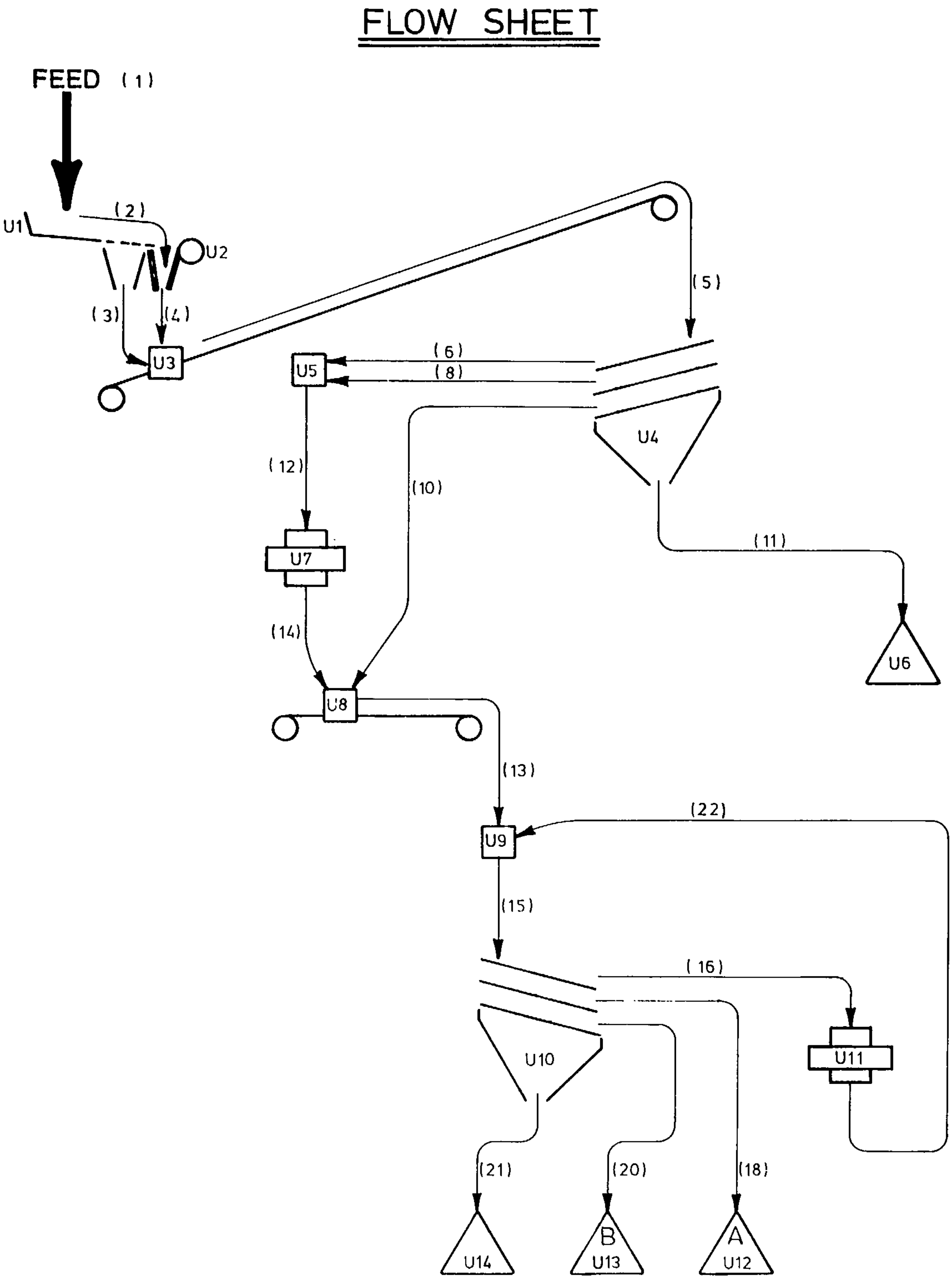
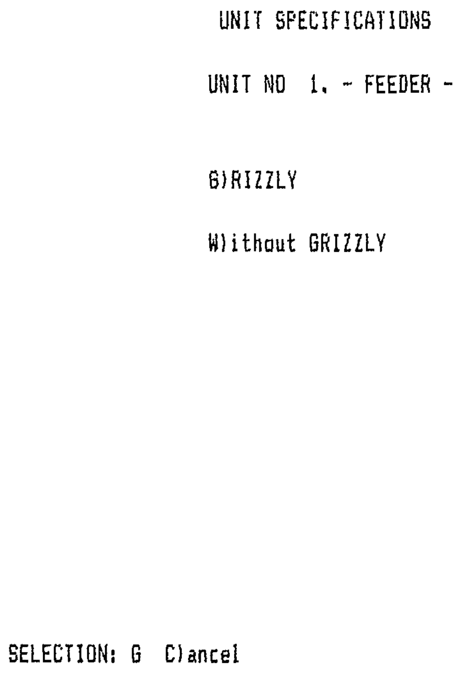


Fig. 7 — Proposed flowsheet for producing products A and B

```
                                                  22/11/85

                    CRUSHER SIMULATION PACKAGE



                     USER IDENTIFICATION

                    1. Name:  test # 1                              1

                    2. Reference number:   1234

                    3. Date:  22/11/85




           SELECTION:   <ret>continue  - (#)correction - E)nd simulation


                     IHHHHHHHHHHHHHHHHHHHHHHH;
                     :       Feed data       :
                     HHHHHHHHHHHHHHHHHHHHHHHH<

         1. Type of Material     : Limestone

         2. Condition of Material: normal

         3. Density of Material  :    1.600   tonnes/cubic meter    2

         4. Bond Index (WI)  :       10.000  Kwh / tonne

         5. % of Humidity (H2O)       .0 %


         6. Tph (metric) to process :   400  tonnes / hour



             SELECTION: [ ]  <ret>continue  - (#)correction
```

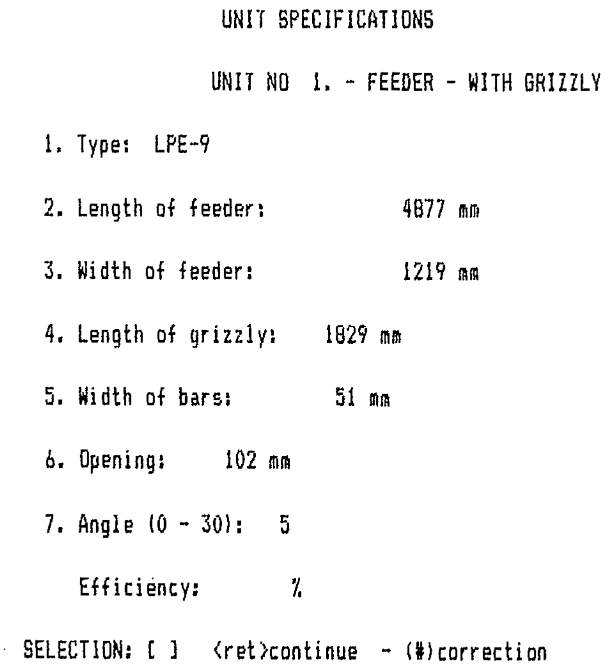
```
            IHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH;
            :    FEED SIZE DISTRIBUTION    :
            HHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH<

      Please enter the FEED size distribution


1. Granite     0-36 in             9. Trap Rock   0-36 in
2.  "  "       0-24 in            10.   "   "     0-24 in
3.  "  "       0-20 in            11.   "   "     0-20 in              3
4.  "  "       0-18 in            12.   "   "     0-18 in
5. Limestone   0-36 in            13. Gravel      0-12 in
6.   "   "     0-24 in            14.  "  "       0-8  in
7.   "   "     0-20 in
8.   "   "     0-18 in            15. Other




            SELECTION [6 ]
```

```
                  UNIT SPECIFICATIONS

                 UNIT NO  1.


    1. Crusher                           5. Silo

    2. Screen                            6. Stock Pile               4

    3. Separation                        7. Feed

    4. Recombination




SELECTION: 7  <ret>continue  - (#)unit type
              E)nd (stop)
```



```
                UNIT SPECIFICATIONS

               UNIT NO  1. - FEEDER -


               G)RIZZLY

               W)ithout GRIZZLY









SELECTION: G  C)ancel
```

5



```
                UNIT SPECIFICATIONS

               UNIT NO  1. - FEEDER - WITH GRIZZLY

   1. Type:  LPE-9

   2. Length of feeder:           4877 mm

   3. Width of feeder:            1219 mm

   4. Length of grizzly:    1829 mm

   5. Width of bars:         51 mm

   6. Opening:      102 mm

   7. Angle (0 - 30):   5

      Efficiency:        %

 SELECTION: [ ]   <ret>continue  - (#)correction
```

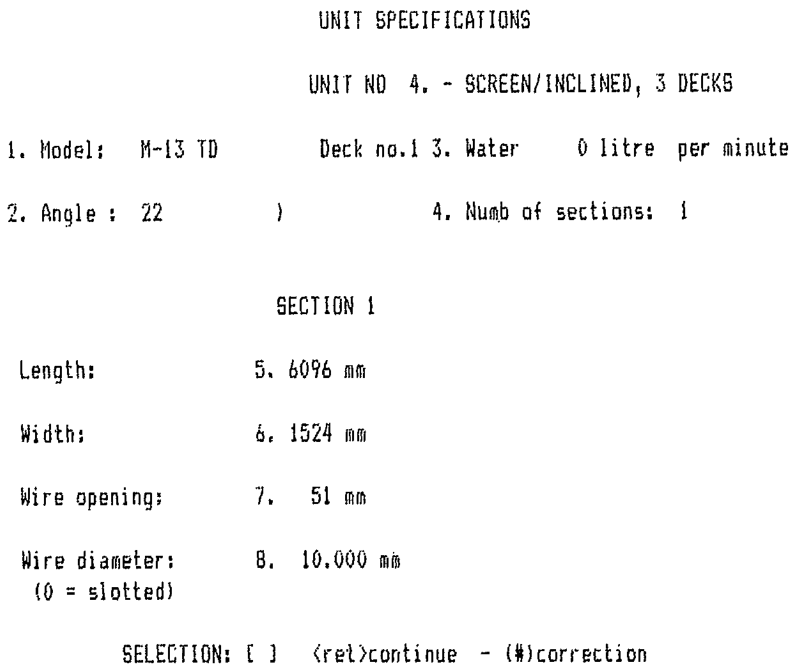
6

```
                    UNIT SPECIFICATIONS

                  UNIT NO  2. - CRUSHER    JAW


1. Model:   J-3048

2. Capacity:    311  tonnes

3. Maximum opening:       762 mm

4. Setting:   152 mm





 SELECTION: [ ]   <ret>continue  - (#)correction
```

7

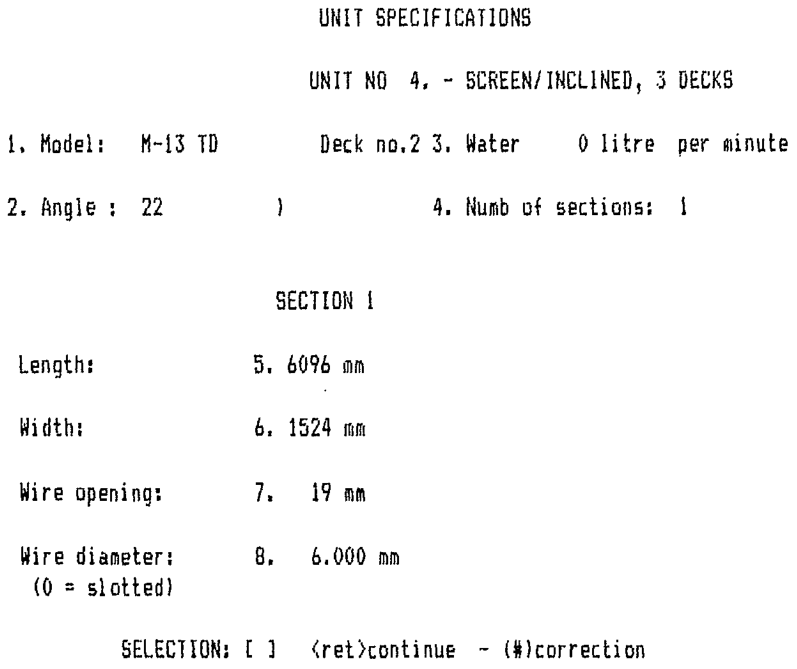
```
                    UNIT SPECIFICATIONS

                  UNIT NO  3.  - RECOMBINATION -


                  N)ormal




Number of streams: [2]   ( 2, 3 or 4 )
```

8



```
                              UNIT SPECIFICATIONS

                             UNIT NO  4. - SCREEN/INCLINED, 3 DECKS

1. Model:   M-13 TD          Deck no.1 3. Water     0 litre  per minute

2. Angle :  22           )              4. Numb of sections:  1


                        SECTION 1

 Length:             5. 6096 mm

 Width:              6. 1524 mm

 Wire opening:       7.   51 mm

 Wire diameter:      8.  10.000 mm
  (0 = slotted)

           SELECTION: [ ]   <ret>continue  - (#)correction
```

9

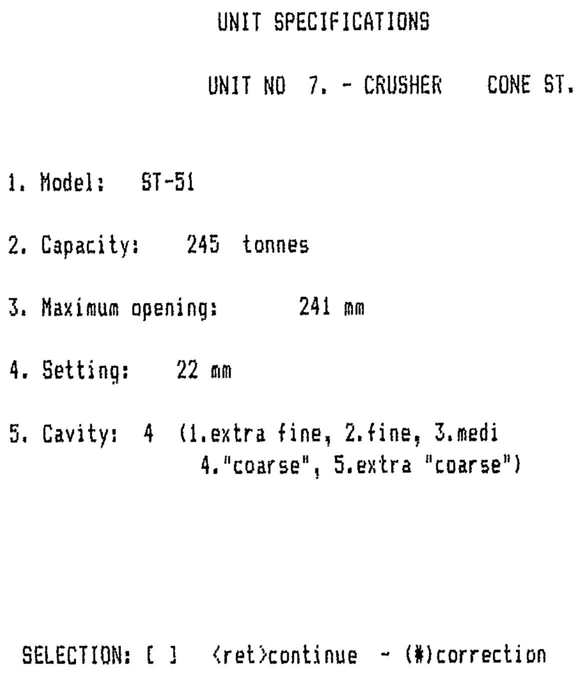


```
                              UNIT SPECIFICATIONS

                             UNIT NO  4. - SCREEN/INCLINED, 3 DECKS

1. Model:   M-13 TD          Deck no.2 3. Water     0 litre  per minute

2. Angle :  22           )              4. Numb of sections:  1


                        SECTION 1

 Length:             5. 6096 mm

 Width:              6. 1524 mm

 Wire opening:       7.   19 mm

 Wire diameter:      8.   6.000 mm
  (0 = slotted)

           SELECTION: [ ]   <ret>continue  - (#)correction
```

10

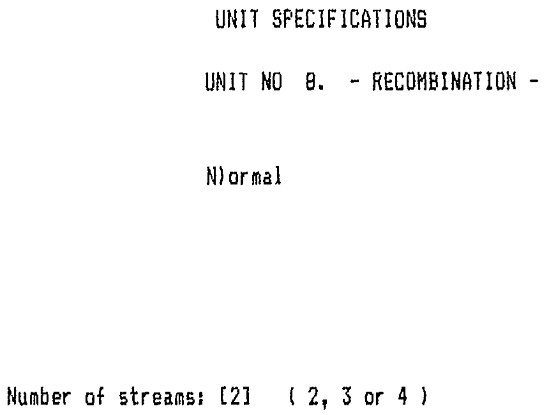
```
                     UNIT SPECIFICATIONS

                    UNIT NO  4. - SCREEN/INCLINED, 3 DECKS

1. Model:   M-13 TD        Deck no.3 3. Water     0 litre  per minute

2. Angle :  22          )             4. Numb of sections:  1

                 SECTION 1
                                                                      11
 Length:             5. 6096 mm

 Width:              6. 1524 mm

 Wire opening:       7.    6 mm

 Wire diameter:      8.   3.000 mm
  (0 = slotted)

          SELECTION: [ ]  <ret>continue  - (#)correction
```

```
                     UNIT SPECIFICATIONS

                    UNIT NO  5.  - RECOMBINATION -                    12


                    N)ormal




         Number of streams: [2]   ( 2, 3 or 4 )
```



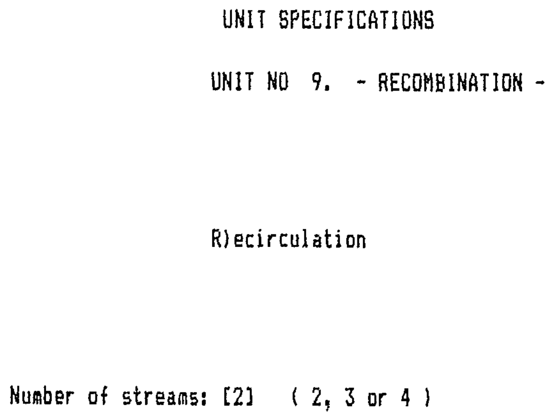
```
                UNIT SPECIFICATIONS

              UNIT NO  7. - CRUSHER    CONE ST.


1. Model:   ST-51

2. Capacity:    245  tonnes

3. Maximum opening:       241 mm

4. Setting:    22 mm

5. Cavity:  4  (1.extra fine, 2.fine, 3.medi
                4."coarse", 5.extra "coarse")




 SELECTION: [ ]   <ret>continue  - (*)correction
```

13



```
                UNIT SPECIFICATIONS

               UNIT NO  8.  - RECOMBINATION -


               N)ormal




Number of streams: [2]   ( 2, 3 or 4 )
```

14



```
                UNIT SPECIFICATIONS

               UNIT NO  9.  - RECOMBINATION -



               R)ecirculation




Number of streams: [2]   ( 2, 3 or 4 )
```

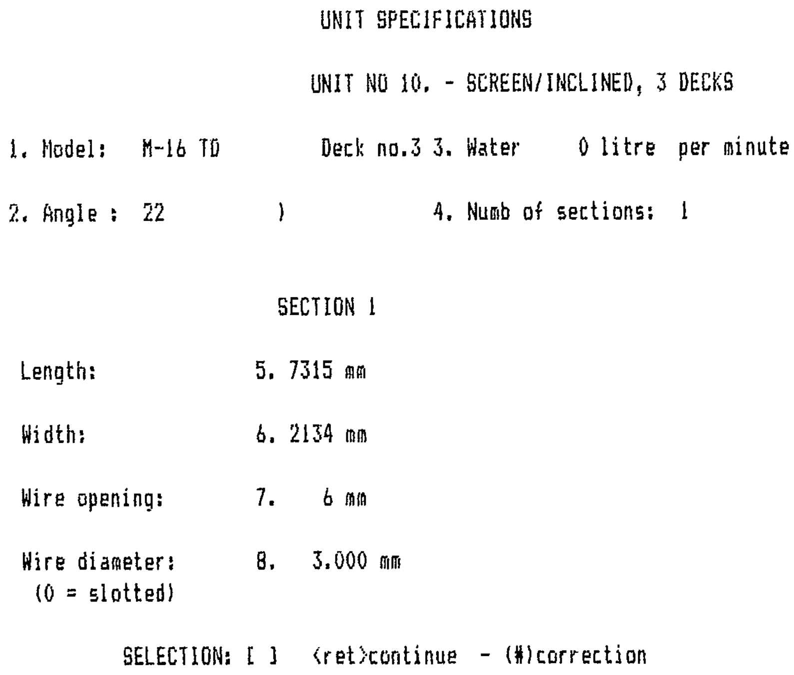
15

```
                    UNIT SPECIFICATIONS

                  UNIT NO 10. - SCREEN/INCLINED, 3 DECKS

1. Model:   M-16 TD        Deck no.1 3. Water     0 litre  per minute

2. Angle :  22          )            4. Numb of sections:  1


                SECTION 1

 Length:              5. 7315 mm

 Width:               6. 2134 mm

 Wire opening:        7.   19 mm

 Wire diameter:       8.   5.000 mm
  (0 = slotted)

         SELECTION: [ ]   <ret>continue  - (#)correction
```

16

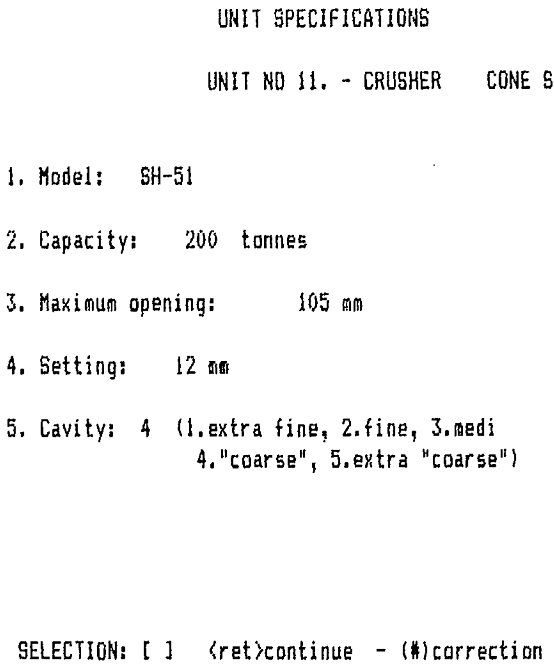
```
                    UNIT SPECIFICATIONS

                  UNIT NO 10. - SCREEN/INCLINED, 3 DECKS

1. Model:   M-16 TD        Deck no.2 3. Water     0 litre  per minute

2. Angle :  22          )            4. Numb of sections:  1


                SECTION 1

 Length:              5. 7315 mm

 Width:               6. 2134 mm

 Wire opening:        7.   13 mm

 Wire diameter:       8.   4.000 mm
  (0 = slotted)

         SELECTION: [ ]   <ret>continue  - (#)correction
```

17



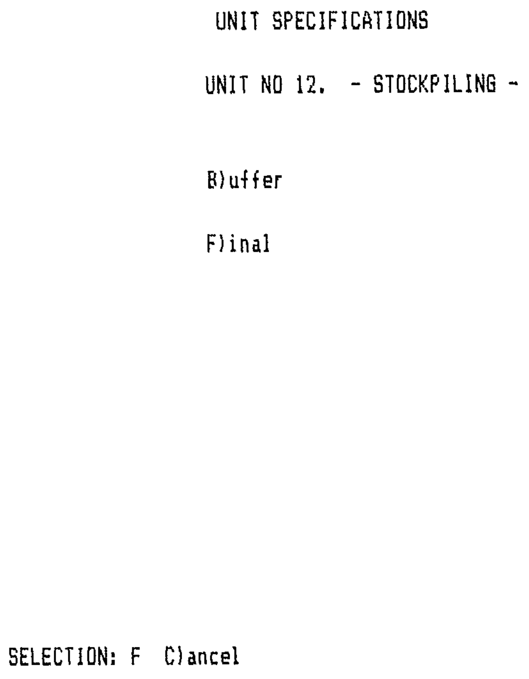
```
                    UNIT SPECIFICATIONS

                  UNIT NO 10. - SCREEN/INCLINED, 3 DECKS

1. Model:   M-16 TD        Deck no.3 3. Water     0 litre  per minute

2. Angle :  22          )             4. Numb of sections:  1


                  SECTION 1

 Length:              5. 7315 mm

 Width:               6. 2134 mm

 Wire opening:        7.    6 mm

 Wire diameter:       8.   3.000 mm
  (0 = slotted)

          SELECTION: [ ]  <ret>continue  - (#)correction
```

18



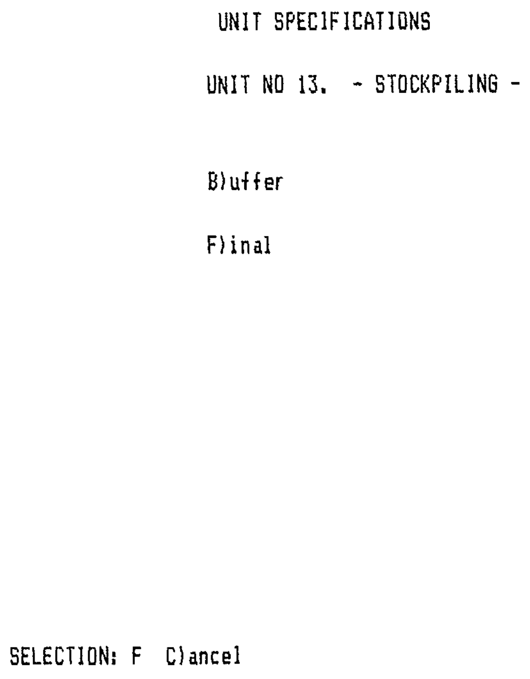
```
                    UNIT SPECIFICATIONS

                  UNIT NO 11. - CRUSHER    CONE SH.


      1. Model:   SH-51

      2. Capacity:    200  tonnes

      3. Maximum opening:       105 mm

      4. Setting:    12 mm

      5. Cavity:  4  (1.extra fine, 2.fine, 3.medi
                      4."coarse", 5.extra "coarse")



      SELECTION: [ ]  <ret>continue  - (#)correction
```

19



```
               UNIT SPECIFICATIONS

              UNIT NO 12.  - STOCKPILING -


              B)uffer

              F)inal





SELECTION: F  C)ancel
```

20



```
               UNIT SPECIFICATIONS

              UNIT NO 13.  - STOCKPILING -


              B)uffer

              F)inal





SELECTION: F  C)ancel
```

21

```
                    UNIT SPECIFICATIONS

                   UNIT NO 14.   - STOCKPILING -


                   B)uffer                                          22

                   F)inal





    SELECTION: F  C)ancel
```

```
                   UNIT SPECIFICATIONS

                  UNIT NO 15.


        1. Crusher                    5. Silo
                                                                    23
        2. Screen                     6. Stock Pile

        3. Separation                 7. Feed

        4. Recombination




    SELECTION:    <ret>continue   - (#)unit type
                  U)pdate         - E)nd          - L)ist
```

```
                    EXECUTION OF MODEL
                    ------------------

Do you wish to modify certain parameters of the model               24
simulation (Y/N)? n
```

```
                    DESCRIPTION of unit no.     1

                                  - FEEDER - WITH GRIZZLY

               1. Type: LPE-9

               2. Length of feeder:          4877 mm

               3. Width of feeder:           1219 mm

               4. Length of grizzly:    1829 mm                                25

               5. Width of bars:        51 mm

               6. Opening:     102 mm

               7. Angle (0 - 30):   5

                  Efficiency:   92.5 %


  G)ranulomytrie - <ret>continue  [G]


               str.  1        str.  2        str.  3
610    mm      100.0 %        100.0 %        100.0 %
305    mm       74.0 %         62.0 %        100.0 %
203    mm       56.0 %         35.7 %        100.0 %
152    mm       46.0 %         21.1 %        100.0 %
102    mm       34.0 %          5.0 %         96.9 %
 89    mm       31.0 %          2.6 %         92.7 %
 76    mm       28.0 %          1.3 %         86.1 %
 63    mm       23.0 %           .4 %         72.2 %
 51    mm       18.0 %           .1 %         57.0 %
 38    mm       13.0 %           .0 %         41.3 %                        26
 25    mm        8.0 %           .0 %         25.5 %
 19    mm        5.0 %           .0 %         16.0 %
 12.7 mm         3.0 %           .0 %          9.7 %
  9.5 mm         1.5 %           .0 %          4.9 %
  4 mesh          .5 %           .0 %          1.7 %
  8 mesh          .2 %           .0 %           .7 %
 16 mesh          .0 %           .0 %           .1 %
 30 mesh          .0 %           .0 %           .1 %
 50 mesh          .0 %           .0 %           .1 %
200 mesh          .0 %           .0 %           .1 %
 Tph            400  tonnes    274  tonnes    126  tonnes
 Water            0  tonne       0  tonne       0  tonne
Gr. max.        610 mm         610 mm         152 mm
 D)escription - <ret> continue :
```

```
            DESCRIPTION of unit no.      2

                              - CRUSHER    JAW


1. Model:   J-3048

2. Capacity:    311  tonnes                                          27

3. Maximum opening:       610 mm

4. Setting:   152 mm


   Efficiency :   88.1 %
   R/Reduction:    4.1
   Energy consumption:         41.2 kwh



    G)ranulomytrie - <ret>continue  [G]


                    str. 2          str. 4
  610    mm         100.0 %         100.0 %
  305    mm          62.0 %         100.0 %
  203    mm          35.7 %          96.8 %
  152    mm          21.1 %          85.4 %
  102    mm           5.0 %          61.8 %
   89    mm           2.6 %          55.2 %
   76    mm           1.3 %          48.3 %
   63    mm            .4 %          41.5 %
   51    mm            .1 %          34.7 %                            28
   38    mm            .0 %          27.8 %
   25    mm            .0 %          21.0 %
   19    mm            .0 %          17.6 %
   12.7 mm             .0 %          12.2 %
    9.5 mm             .0 %           9.5 %
    4 mesh             .0 %           5.9 %
    8 mesh             .0 %           3.6 %
   16 mesh             .0 %           2.0 %
   30 mesh             .0 %            .7 %
   50 mesh             .0 %            .0 %
  200 mesh             .0 %            .0 %
    Tph               274  tonnes     274  tonnes
    Water               0  tonne        0  tonne
  Gr. max.            610 mm          253 mm
   D)escription - <ret> continue :
```

```
                    DESCRIPTION of unit no.      4

                                   - SCREEN/INCLINED, 3 DECKS

1. Model:  M-13 TD         Deck no.1 3. Water:     0 litre  per minute

2. Angle :  22                       4. Numb of sections:  1


                    SECTION 1

 Length:             5. 6096 mm

 Width:              6. 1524 mm

 Wire opening:       7.   51 mm

 Wire diameter:      8.  10.000 mm
   (0 = slotted)

 Deck efficiency:    99.1 %
<ret> to continue
```

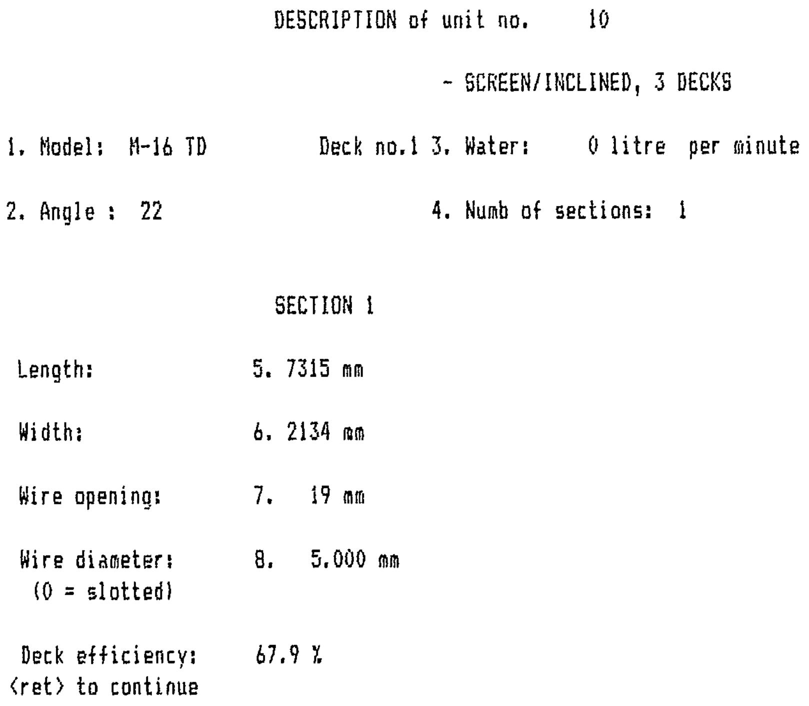
29

```
                    DESCRIPTION of unit no.      4

                                   - SCREEN/INCLINED, 3 DECKS

1. Model:  M-13 TD         Deck no.2 3. Water:     0 litre  per minute

2. Angle :  22                       4. Numb of sections:  1


                    SECTION 1

 Length:             5. 6096 mm

 Width:              6. 1524 mm

 Wire opening:       7.   19 mm

 Wire diameter:      8.   6.000 mm
   (0 = slotted)

 Deck efficiency:    98.6 %
<ret> to continue
```

30

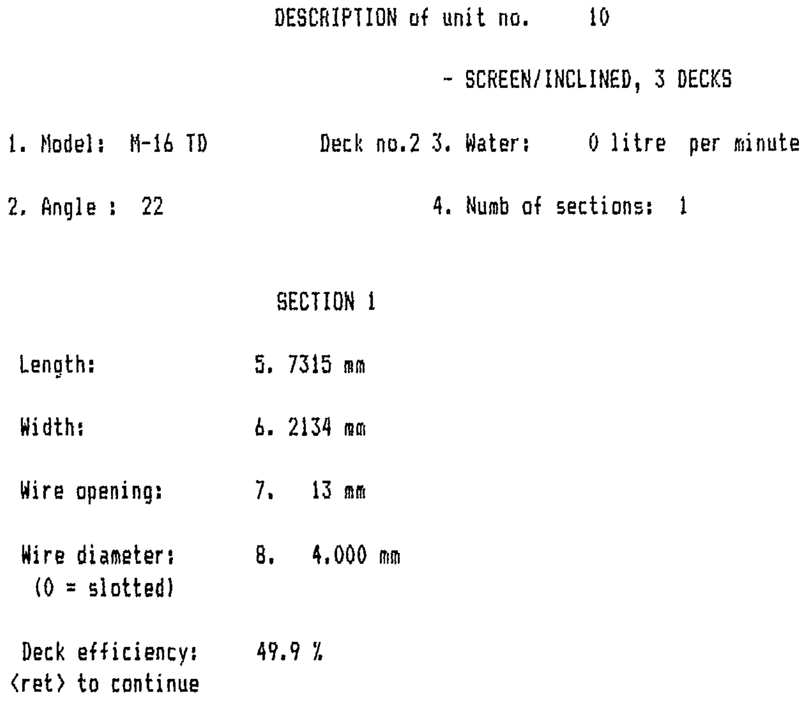
```
                    DESCRIPTION of unit no.      4

                                   - SCREEN/INCLINED, 3 DECKS

1. Model:  M-13 TD         Deck no.3 3. Water:     0 litre  per minute

2. Angle :  22                       4. Numb of sections:  1


                    SECTION 1
                                                                        31
 Length:             5. 6096 mm

 Width:              6. 1524 mm

 Wire opening:       7.    6 mm

 Wire diameter:      8.   3.000 mm
  (0 = slotted)

 Deck efficiency:   100.0 %
 G)ranulomytrie - <ret>continue  [ ]


          str.  5    str.  6    str.  8    str. 10    str. 11
610    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
305    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
203    mm  97.8 %    96.4 %   100.0 %   100.0 %   100.0 %
152    mm  90.0 %    83.8 %   100.0 %   100.0 %   100.0 %
102    mm  72.9 %    56.2 %   100.0 %   100.0 %   100.0 %
 89    mm  67.0 %    46.7 %   100.0 %   100.0 %   100.0 %
 76    mm  60.2 %    35.7 %   100.0 %   100.0 %   100.0 %
 63    mm  51.2 %    21.2 %   100.0 %   100.0 %   100.0 %
 51    mm  41.7 %     7.9 %    94.5 %   100.0 %   100.0 %
 38    mm  32.1 %     1.3 %    70.4 %   100.0 %   100.0 %           32
 25    mm  22.4 %      .2 %    31.2 %   100.0 %   100.0 %
 19    mm  17.1 %      .1 %    10.4 %    95.2 %   100.0 %
 12.7 mm   11.4 %      .0 %      .9 %    60.8 %   100.0 %
  9.5 mm    8.0 %      .0 %      .1 %    29.1 %   100.0 %
  4 mesh    4.6 %      .0 %      .0 %     2.1 %    87.5 %
  8 mesh    2.7 %      .0 %      .0 %      .1 %    53.9 %
 16 mesh    1.4 %      .0 %      .0 %      .0 %    28.3 %
 30 mesh     .5 %      .0 %      .0 %      .0 %    10.2 %
 50 mesh     .0 %      .0 %      .0 %      .0 %      .3 %
200 mesh     .0 %      .0 %      .0 %      .0 %      .3 %
  Tph       400       247        92        41        20  tonnes
  Water       0         0         0         0         0  tonne
Gr. max.    253 mm    253 mm     64 mm     25 mm     10 mm
 D)escription - <ret> continue :
```

```
                    DESCRIPTION of unit no.      7

                                   - CRUSHER    CONE ST.


          1. Model:   ST-51

          2. Capacity:    339  tonnes

          3. Maximum opening:       253 mm                          33

          4. Setting:    22 mm

          5. Cavity:  4  (1.extra fine, 2.fine, 3.medi
                           4."coarse", 5.extra "coarse")

             Efficiency :  100.0 %
             R/Reduction:    3.2
             Energy consumption:        77.6 kwh


   G)ranulomytrie - <ret>continue  [G]


                  str. 12          str. 14
 610   mm         100.0 %          100.0 %
 305   mm         100.0 %          100.0 %
 203   mm          97.4 %          100.0 %
 152   mm          88.2 %          100.0 %
 102   mm          68.1 %          100.0 %
  89   mm          61.1 %          100.0 %
  76   mm          53.1 %          100.0 %
  63   mm          42.5 %          100.0 %
  51   mm          31.3 %          100.0 %
  38   mm          20.0 %           98.7 %
  25   mm           8.6 %           79.5 %                          34
  19   mm           2.9 %           55.7 %
  12.7 mm            .2 %           31.4 %
   9.5 mm            .0 %           20.7 %
   4 mesh            .0 %           10.8 %
   8 mesh            .0 %            6.8 %
  16 mesh            .0 %            4.9 %
  30 mesh            .0 %            3.9 %
  50 mesh            .0 %            3.5 %
 200 mesh            .0 %            3.1 %
   Tph              339  tonnes      339  tonnes
   Water              0  tonne         0  tonne
 Gr. max.           253 mm            40 mm
  D)escription - <ret> continue :
```



```
                         DESCRIPTION of unit no.     10

                                        - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD          Deck no.1 3. Water:     0 litre  per minute

2. Angle :  22                        4. Numb of sections:  1


                         SECTION 1

 Length:               5. 7315 mm

 Width:                6. 2134 mm

 Wire opening:         7.   19 mm

 Wire diameter:        8.   5.000 mm
  (0 = slotted)

 Deck efficiency:      67.9 %
<ret> to continue
```

35



```
                         DESCRIPTION of unit no.     10

                                        - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD          Deck no.2 3. Water:     0 litre  per minute

2. Angle :  22                        4. Numb of sections:  1


                         SECTION 1

 Length:               5. 7315 mm

 Width:                6. 2134 mm

 Wire opening:         7.   13 mm

 Wire diameter:        8.   4.000 mm
  (0 = slotted)

 Deck efficiency:      49.9 %
<ret> to continue
```

36

```
                     DESCRIPTION of unit no.     10

                                   - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD         Deck no.3 3. Water:     0 litre  per minute

2. Angle :  22                       4. Numb of sections:  1


                     SECTION 1                                          37

 Length:              5. 7315 mm


 Width:               6. 2134 mm


 Wire opening:        7.    6 mm


 Wire diameter:       8.   3.000 mm
  (0 = slotted)


 Deck efficiency:     89.9 %
 G)ranulomytrie - <ret>continue  [G]


          str. 15   str. 16   str. 18   str. 20   str. 21
610    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
305    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
203    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
152    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
102    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 89    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 76    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 63    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 51    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 38    mm  99.4 %    98.8 %   100.0 %   100.0 %   100.0 %
 25    mm  90.9 %    81.9 %   100.0 %   100.0 %   100.0 %              38
 19    mm  79.6 %    59.4 %   100.0 %   100.0 %   100.0 %
 12.7 mm   57.6 %    19.2 %    93.4 %   100.0 %   100.0 %
  9.5 mm   39.3 %     3.4 %    55.5 %   100.0 %   100.0 %
  4 mesh   15.5 %      .0 %      .6 %    19.2 %    94.9 %
  8 mesh    8.6 %      .0 %      .0 %      .1 %    59.3 %
 16 mesh    5.6 %      .0 %      .0 %      .0 %    38.9 %
 30 mesh    4.2 %      .0 %      .0 %      .0 %    29.4 %
 50 mesh    3.6 %      .0 %      .0 %      .0 %    25.2 %
200 mesh    3.1 %      .0 %      .0 %      .0 %    21.8 %
  Tph        762       383       208        60       111  tonnes
  Water        0         0         0         0         0  tonne
Gr. max.     40 mm     40 mm     19 mm     10 mm     10 mm
 D)escription - <ret> continue :
```

```
                    DESCRIPTION of unit no.     11

                              - CRUSHER    CONE SH.


          1. Model:   SH-51

          2. Capacity:    383  tonnes
                                                                  39
          3. Maximum opening:       40 mm

          4. Setting:    12 mm

          5. Cavity:  4  (1.extra fine, 2.fine, 3.medi
                           4."coarse", 5.extra "coarse")

             Efficiency :   99.9 %
             R/Reduction:    2.0
             Energy consumption:       117.2 kwh


      G)ranulomytrie - <ret>continue  [G]


                     str. 16         str. 22
     610   mm        100.0 %         100.0 %
     305   mm        100.0 %         100.0 %
     203   mm        100.0 %         100.0 %
     152   mm        100.0 %         100.0 %
     102   mm        100.0 %         100.0 %
      89   mm        100.0 %         100.0 %
      76   mm        100.0 %         100.0 %
      63   mm        100.0 %         100.0 %
      51   mm        100.0 %         100.0 %
      38   mm         98.8 %         100.0 %                          40
      25   mm         81.9 %         100.0 %
      19   mm         59.4 %          99.1 %
      12.7 mm         19.2 %          80.5 %
       9.5 mm          3.4 %          56.9 %
       4 mesh           .0 %          21.0 %
       8 mesh           .0 %          11.0 %
      16 mesh           .0 %           6.8 %
      30 mesh           .0 %           4.9 %
      50 mesh           .0 %           4.0 %
     200 mesh           .0 %           3.3 %
      Tph              383  tonnes      383  tonnes
      Water              0  tonne         0  tonne
     Gr. max.           40 mm            20 mm
      D)escription - <ret> continue :
```

5.5 SAMPLE RUN 2

5.5.1 Comments

The second sample run comprises the following changes suggested by the results of the first sample run:

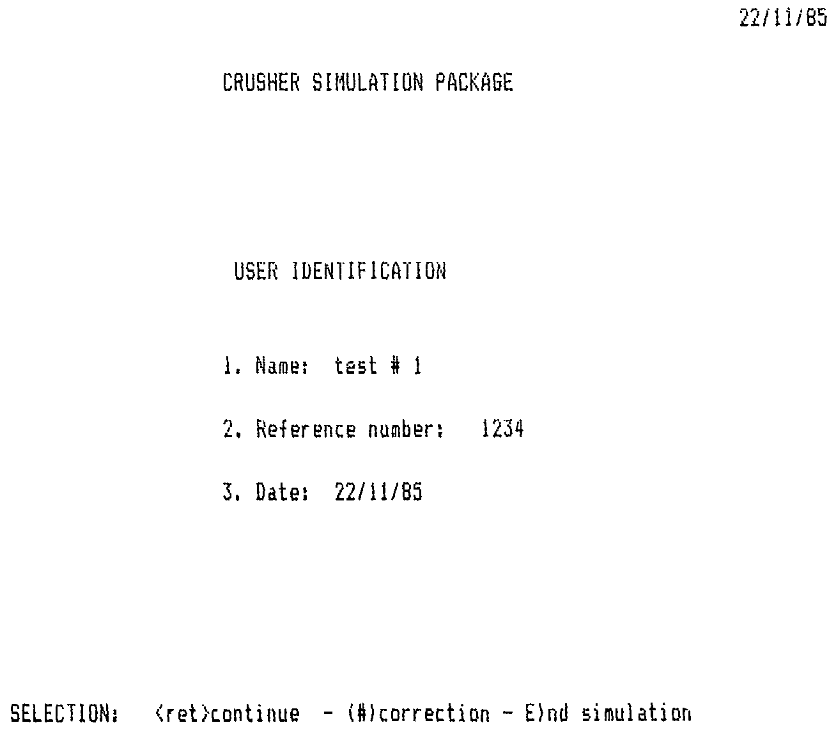
- — reduce the tonnage per hour treated in the system to 300 tph — screen 42;
- — reduce the open-side setting of the jaw crusher (U2) to reduce the maximum size of the blocks being fed to the standard cone crusher (U7) — screen 45;
- — change the opening of the second deck of the screen unit 4, to reduce the quantity of material to be broken by the standard cone crusher (U7) — screen 46;
- — increase the open-side setting of the standard cone crusher (U7) to enable it to admit larger blocks and thus have a larger capacity — screen 47;
- — change the opening of the three screen decks (U10) to improve the efficiency of the first and second decks. A fast method effecting this change is to divide each deck into two sections. The first section is given an opening larger than the second section, to enable it to discharge more quickly the first section of each deck — screens 48 and 49;
- — increase the open-side setting of the short head cone crusher (U11) so as to admit a larger quantity of material. Also, the type of cavity is changed to help in again producing a good quantity of fine particles — screen 50.

5.5.2 Results

The results obtained for this second sample run are given in screens 51 to 62. It may be observed that better results are obtained for most of the units.

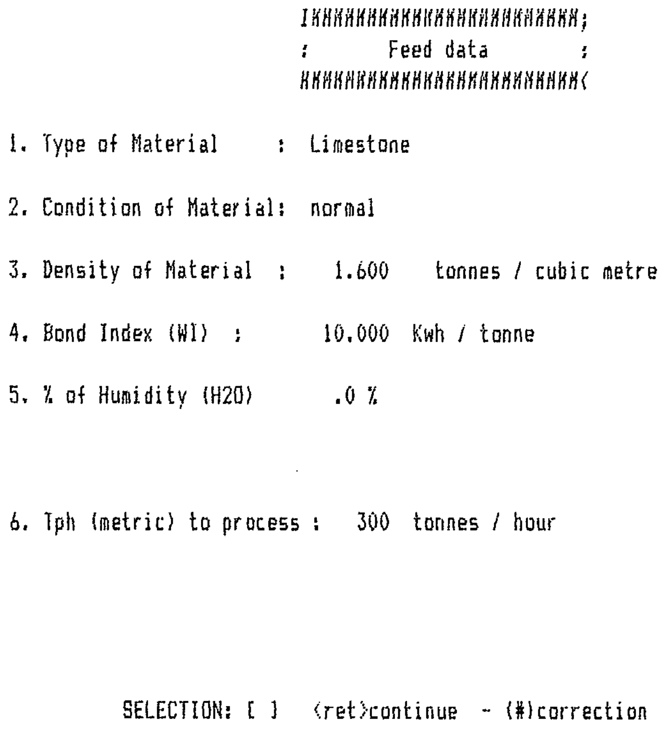
In screen 60, however, the efficiency obtained by the third deck of the three-deck inclined screen (U10) is too low to make a classified product. Screen 61 confirms that this deck (No. 3) does not permit the product B (stream 20) to meet the specifications given in CRSHEX Section 5.1.

Some changes are still required.



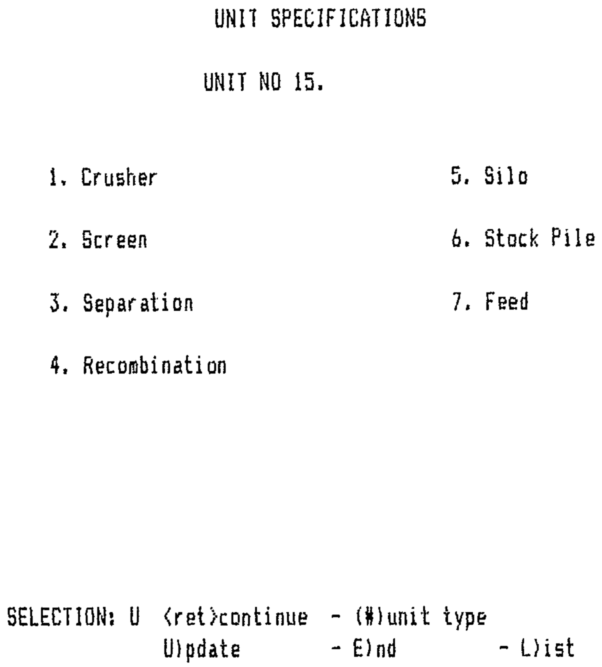
```
                                                22/11/85

                    CRUSHER SIMULATION PACKAGE



                     USER IDENTIFICATION


                    1. Name:  test # 1

                    2. Reference number:   1234

                    3. Date:  22/11/85




SELECTION:   <ret>continue  - (#)correction - E)nd simulation
```

41



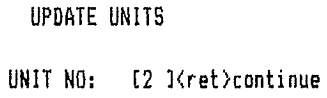
```
                  IHHHHHHHHHHHHHHHHHHHHHHHH;
                  :       Feed data        :
                  HHHHHHHHHHHHHHHHHHHHHHHHH(

1. Type of Material     :  Limestone

2. Condition of Material:  normal

3. Density of Material  :    1.600    tonnes / cubic metre

4. Bond Index (WI)  :       10.000  Kwh / tonne

5. % of Humidity (H2O)       .0 %


6. Tph (metric) to process :   300  tonnes / hour



         SELECTION: [ ]   <ret>continue  - (#)correction
```

42



```
                    UNIT SPECIFICATIONS

                  UNIT NO 15.

      1. Crusher                      5. Silo

      2. Screen                       6. Stock Pile

      3. Separation                   7. Feed

      4. Recombination



SELECTION: U  <ret>continue   - (#)unit type
              U)pdate         - E)nd          - L)ist
```

43



```
   UPDATE UNITS

UNIT NO:   [2 ]<ret>continue
```

44

```
                    UPDATE UNITS

                  UNIT NO:.  2 - CRUSHER    JAW


     1. Model:   J-3048

     2. Capacity:    274  tonnes

     3. Maximum opening:      762 mm

     4. Setting:   114 mm






      SELECTION: [ ]   <ret>continue  - (#)correction
```

45

```
                    UPDATE UNITS

                  UNIT NO:.  4 - SCREEN/INCLINED, 3 DECKS

1. Model:  M-13 TD          Deck no2 3. Water     0 litre  per minute

2. Angle :  22                        4. Numb of sections:  1


                 SECTION 1

 Length:             5. 6096 mm

 Width:              6. 1524 mm

 Wire opening:       7.   22 mm

 Wire diameter:      8.   6.000 mm
  (0 = slotted)

      SELECTION: [ ]   <ret>continue  - (#)correction
```

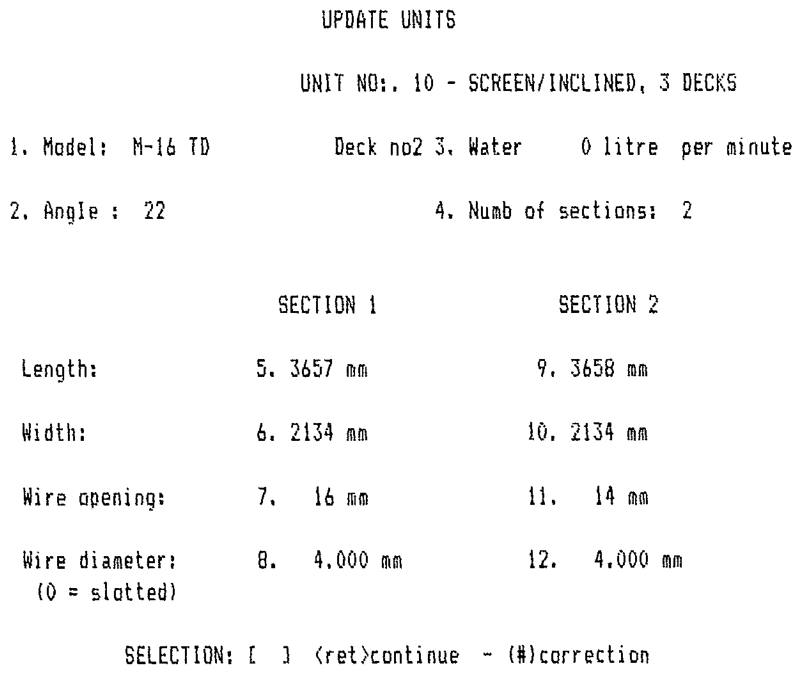
46

```
                    UPDATE UNITS

                  UNIT NO:.  7 - CRUSHER    CONE ST.


     1. Model:   ST-51

     2. Capacity:    275  tonnes

     3. Maximum opening:       241 mm

     4. Setting:    31 mm

     5. Cavity:  4  (1.extra fine, 2.fine, 3.medi
                      4."coarse", 5.extra "coarse")



      SELECTION: [ ]   <ret>continue  - (#)correction
```

47

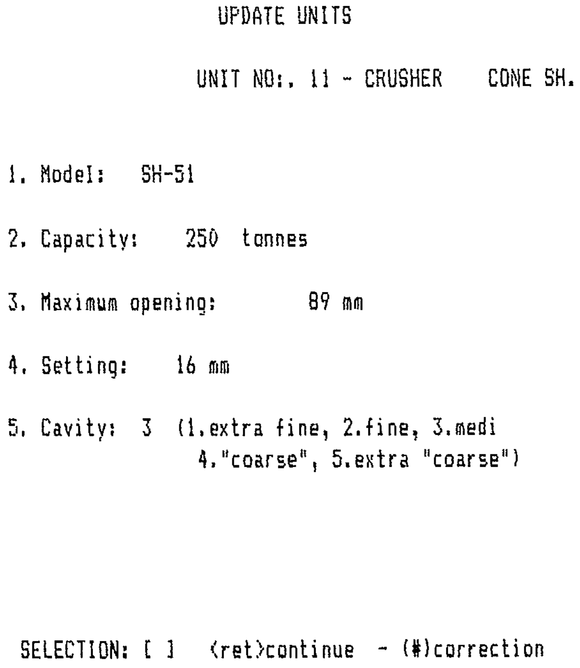
```
                    UPDATE UNITS

                  UNIT NO:. 10 - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD          Deck no1 3. Water     0 litre  per minute

2. Angle :  22                       4. Numb of sections:  2

                        SECTION 1            SECTION 2

 Length:              5. 3657 mm          9. 3658 mm

 Width:               6. 2134 mm         10. 2134 mm

 Wire opening:        7.   24 mm         11.   22 mm

 Wire diameter:       8.   5.000 mm      12.   5.000 mm
  (0 = slotted)

          SELECTION: [  ]  <ret>continue  - (#)correction
```

48



```
                         UPDATE UNITS

                       UNIT NO:. 10 - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD          Deck no2 3. Water     0 litre  per minute

2. Angle :  22                       4. Numb of sections:  2


                      SECTION 1               SECTION 2

 Length:            5. 3657 mm              9. 3658 mm

 Width:             6. 2134 mm             10. 2134 mm

 Wire opening:      7.    16 mm            11.    14 mm

 Wire diameter:     8.    4.000 mm         12.    4.000 mm
  (0 = slotted)

          SELECTION: [   ]  <ret>continue  - (#)correction
```

49



```
                         UPDATE UNITS

                       UNIT NO:. 11 - CRUSHER    CONE SH.


          1. Model:   SH-51

          2. Capacity:    250  tonnes

          3. Maximum opening:        89 mm

          4. Setting:    16 mm

          5. Cavity:  3  (1.extra fine, 2.fine, 3.medi
                          4."coarse", 5.extra "coarse")




          SELECTION: [ ]  <ret>continue  - (#)correction
```

50

```
                    DESCRIPTION of unit no.      1

                                    - FEEDER - WITH GRIZZLY

            1. Type: LPE-9

            2. Length of feeder:            4877 mm

            3. Width of feeder:             1219 mm

            4. Length of grizzly:    1829 mm

            5. Width of bars:         51 mm

            6. Opening:      102 mm

            7. Angle (0 - 30):    5

               Efficiency:    95.4 %

   G)ranulomytrie - <ret>continue  [ ]
```

51

```
                    DESCRIPTION of unit no.      2

                                    - CRUSHER    JAW

          1. Model:    J-3048

          2. Capacity:    274  tonnes

          3. Maximum opening:       610 mm

          4. Setting:    114 mm

             Efficiency :    73.9 %
             R/Reduction:    3.1
             Energy consumption:        22.8 kwh

   G)ranulomytrie - <ret>continue  [ ]
```

52

```
                  DESCRIPTION of unit no.     4

                                   - SCREEN/INCLINED, 3 DECKS

1. Model:  M-13 TD          Deck no.1 3. Water:     0 litre  per minute

2. Angle :  22                        4. Numb of sections:  1


                  SECTION 1

 Length:              5. 6096 mm

 Width:               6. 1524 mm

 Wire opening:        7.   51 mm

 Wire diameter:       8.  10.000 mm
  (0 = slotted)

 Deck efficiency:     99.1 %
<ret> to continue
```

53

```
                  DESCRIPTION of unit no.     4

                                   - SCREEN/INCLINED, 3 DECKS

1. Model:  M-13 TD          Deck no.2 3. Water:     0 litre  per minute

2. Angle :  22                        4. Numb of sections:  1


                  SECTION 1

 Length:              5. 6096 mm

 Width:               6. 1524 mm

 Wire opening:        7.   22 mm

 Wire diameter:       8.   6.000 mm
  (0 = slotted)

 Deck efficiency:     98.7 %
<ret> to continue
```

54

```
                    DESCRIPTION of unit no.      4

                                  - SCREEN/INCLINED, 3 DECKS

1. Model:  M-13 TD         Deck no.3 3. Water:     0 litre  per minute

2. Angle :  22                       4. Numb of sections:  1


                     SECTION 1                                          55

 Length:             5. 6096 mm

 Width:              6. 1524 mm

 Wire opening:       7.    6 mm

 Wire diameter:      8.   3.000 mm
  (0 = slotted)

 Deck efficiency:    100.0 %
 G)ranulomytrie - <ret>continue  [G]


          str.  5   str.  6   str.  8   str. 10   str. 11
610    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
305    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
203    mm  99.9 %    99.8 %   100.0 %   100.0 %   100.0 %
152    mm  97.6 %    95.7 %   100.0 %   100.0 %   100.0 %
102    mm  84.2 %    71.9 %   100.0 %   100.0 %   100.0 %
 89    mm  77.2 %    59.5 %   100.0 %   100.0 %   100.0 %
 76    mm  69.1 %    45.1 %   100.0 %   100.0 %   100.0 %
 63    mm  58.6 %    26.4 %   100.0 %   100.0 %   100.0 %
 51    mm  47.8 %     9.7 %    93.8 %   100.0 %   100.0 %
 38    mm  36.9 %     1.5 %    66.9 %   100.0 %   100.0 %                 56
 25    mm  25.9 %      .1 %    23.7 %    99.0 %   100.0 %
 19    mm  19.9 %      .0 %     5.8 %    86.2 %   100.0 %
 12.7 mm   13.6 %      .0 %      .4 %    49.7 %   100.0 %
  9.5 mm   10.0 %      .0 %      .1 %    24.5 %   100.0 %
  4 mesh    6.1 %      .0 %      .0 %     1.7 %    89.0 %
  8 mesh    4.0 %      .0 %      .0 %      .1 %    60.8 %
 16 mesh    2.5 %      .0 %      .0 %      .0 %    38.2 %
 30 mesh    1.6 %      .0 %      .0 %      .0 %    24.2 %
 50 mesh     .8 %      .0 %      .0 %      .0 %    12.4 %
200 mesh     .0 %      .0 %      .0 %      .0 %      .6 %
  Tph       300       169        70        42        20  tonnes
  Water       0         0         0         0         0  tonne
Gr. max.    221 mm    221 mm     64 mm     38 mm     10 mm
 D)escription - <ret> continue :
```

```
                 DESCRIPTION of unit no.      7

                            - CRUSHER   CONE ST.


      1. Model:  ST-51

      2. Capacity:   275  tonnes

      3. Maximum opening:      221 mm

      4. Setting:   31 mm

      5. Cavity:  4  (1.extra fine, 2.fine, 3.medi
                      4."coarse", 5.extra "coarse")

        Efficiency :   86.7 %
        R/Reduction:    3.5
        Energy consumption:        69.4 kwh


G)ranulomytrie - <ret>continue  [ ]
```

57

```
                  DESCRIPTION of unit no.     10

                             - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD        Deck no.1 3. Water:    0 litre  per minute

2. Angle :  22                      4. Numb of sections:  2


                  SECTION 1             SECTION 2

 Length:         5. 3657 mm             9. 3658 mm

 Width:          6. 2134 mm            10. 2134 mm

 Wire opening:   7.   24 mm            11.   22 mm

 Wire diameter:  8.   5.000 mm         12.   5.000 mm
  (0 = slotted)

 Deck efficiency:  36.9 %
<ret> to continue
```

58

```
                    DESCRIPTION of unit no.     10

                              - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD         Deck no.2 3. Water:     0 litre  per minute

2. Angle :  22                        4. Numb of sections:  2


                    SECTION 1                SECTION 2

 Length:            5. 3657 mm               9. 3658 mm

 Width:             6. 2134 mm              10. 2134 mm

 Wire opening:      7.    16 mm             11.    14 mm

 Wire diameter:     8.    4.000 mm          12.    4.000 mm
  (0 = slotted)

 Deck efficiency:   35.6 %
<ret> to continue
```

59

```
                    DESCRIPTION of unit no.     10

                              - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD         Deck no.3 3. Water:     0 litre  per minute

2. Angle :  22                        4. Numb of sections:  1


                    SECTION 1

 Length:            5. 7315 mm

 Width:             6. 2134 mm

 Wire opening:      7.    6 mm

 Wire diameter:     8.    3.000 mm
  (0 = slotted)

 Deck efficiency:   53.6 %
 G)ranulomytrie - <ret>continue  [ ]
```

60

```
               str. 15    str. 16    str. 18    str. 20    str. 21
610      mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
305      mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
203      mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
152      mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
102      mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 89      mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 76      mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 63      mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 51      mm  98.0 %    94.7 %   100.0 %   100.0 %   100.0 %
 38      mm  90.6 %    75.2 %   100.0 %   100.0 %   100.0 %
 25      mm  75.0 %    34.2 %   100.0 %   100.0 %   100.0 %
 19      mm  61.7 %     7.7 %    84.9 %   100.0 %   100.0 %
  12.7 mm  38.4 %      .0 %     9.2 %    87.5 %   100.0 %
   9.5 mm  25.7 %      .0 %      .2 %    55.8 %   100.0 %
   4 mesh  10.9 %      .0 %      .1 %    12.2 %   100.0 %
   8 mesh   6.6 %      .0 %      .0 %     1.0 %    91.9 %
  16 mesh   4.7 %      .0 %      .0 %      .0 %    69.7 %
  30 mesh   3.7 %      .0 %      .0 %      .0 %    54.9 %
  50 mesh   3.2 %      .0 %      .0 %      .0 %    47.2 %
 200 mesh   2.9 %      .0 %      .0 %      .0 %    43.7 %
   Tph       502       191       107       170        35  tonnes
   Water       0         0         0         0         0  tonne
 Gr. max.     60 mm     60 mm     25 mm     19 mm      5 mm
  D)escription - <ret> continue :
```

61

```
                    DESCRIPTION of unit no.     11

                                   - CRUSHER    CONE SH.


          1. Model:   SH-51

          2. Capacity:    250  tonnes

          3. Maximum opening:        60 mm

          4. Setting:    16 mm

          5. Cavity:  3  (1.extra fine, 2.fine, 3.medi
                          4."coarse", 5.extra "coarse")

             Efficiency :   76.5 %
             R/Reduction:    3.3
             Energy consumption:        71.2 kwh


    G)ranulomytrie - <ret>continue  [ ]
```

62

5.6 SAMPLE RUN 3

5.6.1 Comments

As suggested by the results of sample run 2, the opening of the third deck of the screen (U10) was increased to 7 mm while keeping all other specifications the same.

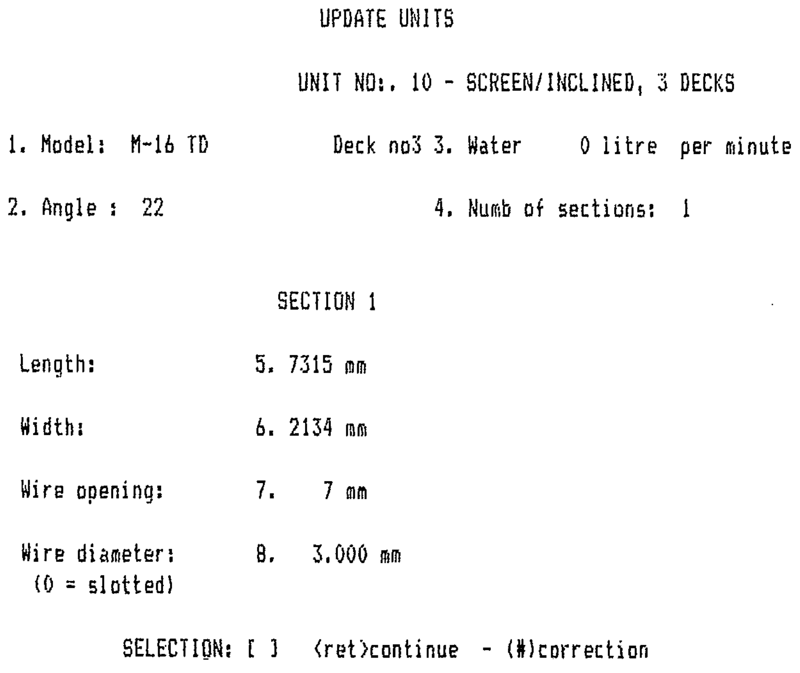
5.6.2 Results

Screens 63 to 67 show the results where changes have been made. It is clear that the efficiencies of the three decks of the inclined three-deck screens (U10) are now acceptable.

Also, the products obtained (A and B) meet the established specifications.

Therefore, this system can only treat 300 tph with the equipment specified in CRSHEX Section 5.1 and the flowsheet established in Figure 7. With this set up, the system can produce 107 tonnes per hour of product A (screen 67, stream 18) and 125 tonnes per hour of product B (screen 67, stream 20) within the specifications established in CRSHEX Section 5.1.

The remaining two products, units 6 and 14 (streams 11 and 21), may be mixed in a proportion which would permit the making of another saleable product with a size range from 0 to 9.5 mm, meeting a different specification. This would reduce the loss of non-saleable products.



```
                          UPDATE UNITS

                    UNIT NO:. 10 - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD          Deck no3 3. Water     0 litre  per minute

2. Angle :  22                         4. Numb of sections:  1

                         SECTION 1

 Length:              5. 7315 mm

 Width:               6. 2134 mm

 Wire opening:        7.    7 mm

 Wire diameter:       8.   3.000 mm
  (0 = slotted)

             SELECTION: [ ]  <ret>continue  - (#)correction
```

63

```
                    DESCRIPTION of unit no.     10

                                  - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD          Deck no.1 3. Water:     0 litre  per minute

2. Angle :  22                        4. Numb of sections:  2


                      SECTION 1              SECTION 2

 Length:            5. 3657 mm            9. 3658 mm

 Width:             6. 2134 mm           10. 2134 mm

 Wire opening:      7.   24 mm           11.   22 mm

 Wire diameter:     8.   5.000 mm        12.   5.000 mm
  (0 = slotted)

 Deck efficiency:   36.9 %
<ret> to continue
```

64

```
                    DESCRIPTION of unit no.     10

                                  - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD          Deck no.2 3. Water:     0 litre  per minute

2. Angle :  22                        4. Numb of sections:  2


                      SECTION 1              SECTION 2

 Length:            5. 3657 mm            9. 3658 mm

 Width:             6. 2134 mm           10. 2134 mm

 Wire opening:      7.   16 mm           11.   14 mm

 Wire diameter:     8.   4.000 mm        12.   4.000 mm
  (0 = slotted)

 Deck efficiency:   35.6 %
<ret> to continue
```

65

```
                    DESCRIPTION of unit no.     10

                                 - SCREEN/INCLINED, 3 DECKS

1. Model:  M-16 TD         Deck no.3 3. Water:     0 litre  per minute

2. Angle :  22                       4. Numb of sections:  1


                    SECTION 1
                                                                        66
 Length:             5. 7315 mm

 Width:              6. 2134 mm

 Wire opening:       7.    7 mm

 Wire diameter:      8.   3.000 mm
  (0 = slotted)

 Deck efficiency:    100.0 %
 G)ranulomytrie - <ret>continue  [G]


          str. 15   str. 16   str. 18   str. 20   str. 21
610    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
305    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
203    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
152    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
102    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 89    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 76    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 63    mm 100.0 %   100.0 %   100.0 %   100.0 %   100.0 %
 51    mm  98.0 %    94.7 %   100.0 %   100.0 %   100.0 %
 38    mm  90.6 %    75.2 %   100.0 %   100.0 %   100.0 %           67
 25    mm  75.0 %    34.2 %   100.0 %   100.0 %   100.0 %
 19    mm  61.7 %     7.7 %    84.9 %   100.0 %   100.0 %
 12.7 mm   38.4 %      .0 %     9.2 %    83.0 %   100.0 %
  9.5 mm   25.7 %      .0 %      .2 %    40.0 %   100.0 %
  4 mesh   10.9 %      .0 %      .1 %      .4 %    69.1 %
  8 mesh    6.6 %      .0 %      .0 %      .0 %    42.2 %
 16 mesh    4.7 %      .0 %      .0 %      .0 %    30.4 %
 30 mesh    3.7 %      .0 %      .0 %      .0 %    24.0 %
 50 mesh    3.2 %      .0 %      .0 %      .0 %    20.7 %
200 mesh    2.9 %      .0 %      .0 %      .0 %    19.2 %
  Tph        502       191       107       125        79  tonnes
  Water        0         0         0         0         0  tonne
Gr. max.     60 mm     60 mm     25 mm     19 mm     10 mm
 D)escription - <ret> continue :
```

GRNDEX

GRINDING PLANT SIMULATION EXECUTIVE

F. Flament, D. Laguitton

CONTENTS

TABLE

FIGURES

1. PROGRAM IDENTIFICATION

Program Title:	Flexible **GRiND**ing Circuit **EX**ecutive.
Program Code Names:	GRNDEX, GRNDNG, GRNDIT.
Author:	F. Flament.
Organization:	Energy, Mines and Resources, Canada Centre for Mineral and Energy Technology, Mineral Processing Laboratory.
Date:	July 1985.
Updates:	None.
Source Language:	CDC FORTRAN Extended 4.8 (American National Standard Institute FORTRAN X3.9 — 1966).
Availability:	Complete program listing is available from: CANMET, Energy, Mines and Resources Technology Information Division, 555 Booth Street Ottawa, Ontario K1A 0G1.

2. ENGINEERING DOCUMENTATION

2.1 NARRATIVE DESCRIPTION

This program is an interactive executive for the simulation of flexible grinding circuits. It is composed of three independent programs which are run successively. The first program, called GRNDEX, permits creation of the data file and writes a preprocessor, i.e., a main FORTRAN program, called GRNDNG. That main program, written specifically for the data set (i.e., flowsheet structure, unit model parameters, and feed characteristics), organizes the simulation of the grinding circuit using a bank of available subroutines. The third program, called GRNDIT, permits some modifications to the data file. The allowed modifications are those that do not require the preprocessor to be changed. This is to provide the user with an opportunity of performing several simulations of the same grinding plant under different operating conditions. The program is capable of accepting up to 29 units. On each stream, size distributions of up to 20 size intervals are accepted. The units are a rod mill, up to 5 ball mills, up to 10 hydrocyclones, up to 10 mixers, and up to 3 size distribution extrapolation modules. Other restrictions are imposed by the program's structure: only one feed stream to the plant is accepted, water addition streams are limited to 10, and extrapolation modules cannot be within a recycle loop.

2.2 METHOD OF SOLUTION

2.2.1 Preparation for Simulation

The grinding circuit must be analyzed in terms of a flowsheet composed of streams and units. Units must be rod mill, ball mills, hydrocyclones, and two- and three-stream mixers. Extrapolation modules can be added to the flowsheet. Each stream should be assigned a number and the feed stream to the plant must be given No. 1. Parameter values of each unit model and feed stream characteristics must be known. Finally, the data set must be given both a name and a title.

2.2.2 Flowsheet Analysis

The GRNDEX program requires a flowsheet description. The user must first enter the number of each type of unit and the total number of streams. Then for each unit, GRNDEX asks for the model type (if necessary), the feed stream(s), and the discharge stream(s) number(s).

From these entries, a stream connection matrix (called MSTR) is formed. The matrix is used by the subroutine COD to determine the order of simulation of the units and the tear streams that must be initialized before simulation can begin. The COD subroutine used in GRNDEX is a slightly modified version of that described in the section on the SPLITX program. From the stream connection matrix, the flowsheet is analyzed in terms of cycles and simple nodes (i.e., single units), computer nodes (i.e., units implied in a cycle), and tear streams within cycles. Subroutine CALLUN is then written. This consists of a series of FORTRAN statements to call the unit modules and their printout subroutines, and to perform convergence tests (IF statements). The COD subroutine is specific to GRNDEX in that it permits only calls to rod mill, ball mill, hydrocyclone, mixer, and extrapolation modules.

2.2.3 Unit Modules

The unit modules are those described in the SPOC Manual, Chapter 5.1 for the hydrocyclone units, and Chapter 5.2 for the rod mill, ball mill, mixer, and extrapolation units. The capabilities and limitations of the modules are also valid in GRNDEX.

2.3 PROGRAM CAPABILITIES

Limitations on problem size are dependent on dimensions, computer memory, and program structure. Modifying the limit values given here is not recommended:

Number of rod mill: 1
Number of ball mills: 5
Number of hydrocyclones: 10
Number of mixers: 10 (total number of 2- and 3-stream mixers)
Number of extrapolation modules: 3
Water addition streams: 10
Number of size intervals: 20

The feed should be stream 1.

An extrapolation module cannot be within a cycle. Size interval dimensions are defined from their number (pan included), ratio between them (usually $\sqrt{2}$), the 100 per cent passing sieve aperture, and the mean size of particles within the pan. After completing a simulation run, modifications to the data can be made and the simulation program run again.

2.4 DATA ENTRY, PROGRAM OPTIONS, OUTPUT

The GRNDEX and GRNDIT interactive programs have prompts for all data inputs. The data are entered in free format, i.e., in sequence, using either blanks or commas as separators. Input data may also be read by GRNDEX from a batch data file on disk storage created during a previous run or by a text edition. The basic steps of a simulation session are given in Figure 8. The program options are the unit module options described in Chapters 5.1 and 5.2 of the SPOC Manual.

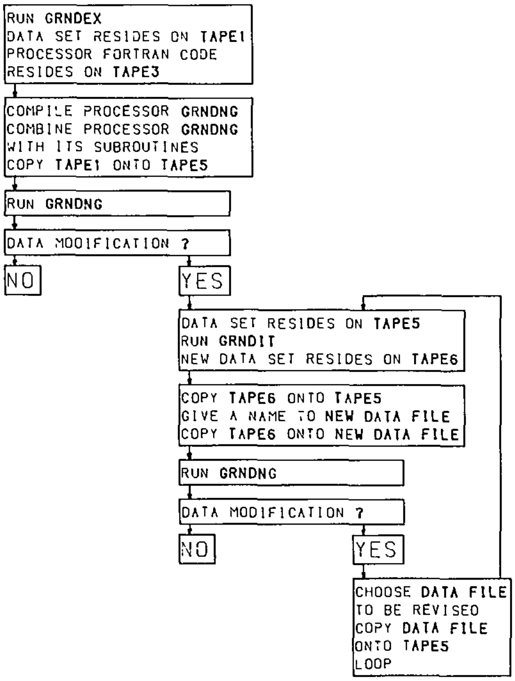


Fig. 8 — Linking GRNDEX, GRNDNG, GRNDIT and the data files

2.5 SAMPLE RUN

A sample is given to illustrate a grinding plant simulation session. The flowsheet used, reproduced in Figure 9, is a three-stage grinding circuit. Extrapolations have been introduced between stages to improve the description of the size distributions in the fine range and to avoid leading zeroes in the coarse range. Hypothetical, although realistic, data used in the sample run are reported in Table 12.

After completion of the simulation run, modification of the data was not attempted. In Section 2.5 of the description of the HCONEX program, details are given on the HCEDIT program which operates in a manner similar to that of GRNDIT.

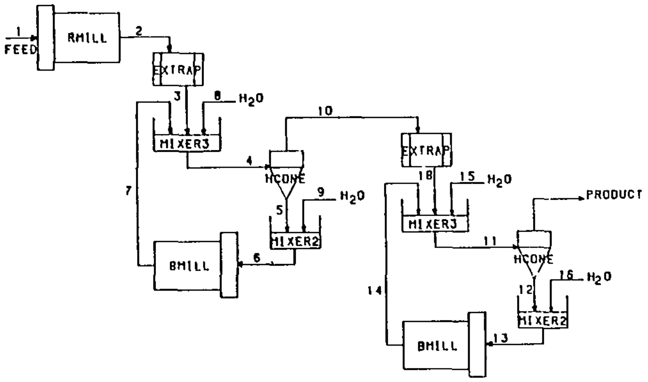


Fig. 9 — Flowsheet of GRNDEX sample run

Table 12 — GRNDEX sample run data

RMILL 1st stage: unit No. 1															
Constant 560															
B function	.075	.123	.177	.154	.141	.074	.081	.041	.044	.021	.019	.015	.01	.007	0.018
S function	1.	.9	.8	.6	.25	.2	.2	.2	.25	.4	.5	.5	.5	.5	0.
printing 1															
BMILL 2nd stage: unit No. 2															
B parameters	.3985	.9199	20.	.1374											
S parameters	253.	.6541	−.2261	−.1295											
Mixers R.T.	.5293	.1593	.0779												
Ref. size	11.480 mm														
BMILL 3rd stage: unit No. 3															
B parameters	.3985	.9199	20.	.1374											
S parameters	197.	.6541	−.2261	−.1295											
Mixers R.T.	.5293	.1593	.0779												
Ref. size	5.742 mm														
HCONE 2nd stage: unit No. 4															
Fixed D50C, EM and Rf															
8 cyclones; apex = 4.125 cm; roping factor = .56															
D50C = 720 μm; EM = 1.25; Rf = 35%															
HCONE 3rd stage: unit No. 5															
Fixed D50C, EM and Rf															
8 cyclones; apex = 3.175 cm; roping factor = .56															
D50C = 267 μm; EM = 1.78; Rf = 25.															
EXTRAP 1st stage: unit No. 6															
By 2 sieves															
New size intervals:	210	149	105												
EXTRAP 2nd stage: unit No. 7															
By 2 sieves															
New size intervals:	105	74	53												
Feed characteristics															
Solids = 125 t/h; water = 27 t/h															
100% passing sieve aperture: 26 900 μm; sieve ratio: $\sqrt{2}$															
Mean size within pass: 210 μm															
Solid specific gravity: 4.5															
Feed size distribution:	2.8	11.2	22.2	11.4	10.6	7.8	4.6	4.2	3.9	2.9	2.3	1.7	1.3	1.2	11.9
Water addition #8 = 70 t/h															
Water addition #9 = 20 t/h															
Water addition #15 = 100 t/h															
Water addition #16 = 6 t/h															

GRINDING CIRCUIT SIMULATION

PURPOSE : TO SIMULATE GRINDING PLANTS INVOLVING ROD MILL, BALL MILLS, HYDROCYLONES AND MIXERS

DESCRIPTION : GRNDEX IS A SIMULATOR EXECUTIVE WHICH ALLOWS THE SIMULATION OF GRINDING FLOWSHEETS. THE UNIT MODULES THAT CAN BE USED ARE: RMILL, BMILL, HCONE, MIXER2, MIXER3, AND EXTRAP.

GRNDEX IS MADE OF THREE INDEPENDENT PROGRAMS:

- THE DATA FILE EDITOR AND PRE-PROCESSOR WRITER
- THE EXECUTIVE
- THE DATA FILE MODIFIER

THEY ARE LINKED ALL TOGETHER BY PROCEDURES.

LIMITATIONS :

NUMBER OF ROD MILLS	1
NUMBER OF BALL MILLS	5
NUMBER OF HYDROCYCLONES	10
NUMBER OF MIXERS	10
NUMBER OF EXTRAPOLATION MODULES	3
NUMBER OF WATER ADDITION STREAMS	10
NUMBER OF SIZE INTERVALS	20
NUMBER OF SPECIFIC GRAVITIES	1
NUMBER OF CHARACTERISTICS	1

VARIABLES : GRNDEX USES ALL THE UNIT MODULES VARIABLES PLUS THE FOLLOWING ONES:

NRM = NUMBER OF RMILLS
NBM = NUMBER OF BMILLS
NCY = NUMBER OF HCONES
NMX = NUMBER OF MIXERS
NEX = NUMBER OF EXTRAPS
NSTR = NUMBER OF STREAMS
MSTR = STREAM CONNECTION MATRIX
PARAM = AN ARRAY WHICH CONTAINS ALL MODEL PARAMETERS REQUIRED BY THE UNIT MODULES
FLOW = AN ARRAY WHICH CONTAINS THE CHARACTERISTICS OF ALL THE STREAM FLOWS: SOLID AND WATER FLOW RATES, SIZE DISTRIBUTION IN % BY WEIGHT
OPT = AN ARRAY WHICH CONTAINS FOR EACH UNIT THE MODEL OPTION

```
    SAMPLE RUN1 :
    -----------                      --
         ------              -------!  !
        !EXTRAP!            ! RMILL !  !
        !      !<-----------!       !  !<-------FEED
         ------              -------!  !
          !    ----H O                 --
          !   !     2          ------                   PRODUCT
          !   !              -!EXTRAP!-     --H O       ------->
          !   !             ! !      ! !   !   2       !
          !   !             !  ------  !   !           !
          V   V             !          V   V           !
        ---------         -----     ---------        -----
       !  MIXER  !        \   /    !  MIXER  !       \   /
       !         !-------> \ /     !         !------> \ /

        ---------         HCONE     ---------        HCONE
         ^                  !        ^                 !
         !        -         V        !        -        V
         !  -----! !      -----      !  -----! !     -----
          -!BMILL! !     !MIXER!      -!BMILL! !    !MIXER!
           !     ! !<----!     !<--    !     ! !<---!     !<--
            -----! !      -----    !    -----! !     -----    !
                  -               H O         -              H O
                                   2                          2


            SIMULATION OF A GRINDING PLANT


   ENTER A RUN IDENTIFICATION
     (40 CHARACTERS MAXIMUM)
3-stage grinding circuit simulation


   DESCRIPTION OF THE FLOWSHEET
 ENTER NO. OF ROD MILL (0 OR 1), NO. OF BALL MILLS (0 TO 5)
 NO. OF CYCLONES (0 TO 10) AND NO. OF MIXERS (0 TO 10) :
1 2 2 4
```

```
 ENTER NO. OF EXTRAPOLATION MODULES (0 TO 3)
 AND NO. OF STREAMS : 2 18
  UNIT #1, ENTER FEED AND DISCHARGE
 STREAM NUMBERS OF THE ROD MILL : 1 2
 FOR EACH BALL MILL ENTER FEED AND DISCHARGE
 STREAM NUMBERS
 FOR UNIT #  2 : 6 7
    FOR UNIT #  3 : 13 14
 FOR EACH CYCLONE, ENTER MODEL TYPE AND
 FEED, UNDERFLOW AND OVERFLOW STREAM NUMBERS
 FOR UNIT #  4 : 2 4 5 10
 FOR UNIT #  5 : 2 11 12 17
 FOR EACH EXTRAPOLATION MODULE, ENTER FEED AND
 DISCHARGE STREAM NUMBERS
 FOR UNIT #  6 : 2 3
 FOR UNIT #  7 : 10 18
 FOR EACH MIXER, ENTER NUMBER OF FEED STREAMS AND
 ENTER FEEDS AND DISCHARGE STREAM NUMBERS
 FOR UNIT #  8 : 3 3 7 8 4
 FOR UNIT #  9 : 2 5 9 6
 FOR UNIT # 10 : 3 18 14 15 11
 FOR UNIT # 11 : 2 12 16 13


 ENTER NUMBER OF SIZE INTERVALS (MAX. 20) : 15


   DESCRIPTION OF THE ROD MILL
 ENTER ROD MILL CONSTANT : 560.
 ENTER BREAKAGE FUNCTION (15 VALUES)  :
.075 .123 .177 .154 .141 .074 .081 .041 .044 .021 .019 .015 .01 .007 .018
 ENTER SELECTION FUNCTION (15 VALUES) :
1. .9 .8 .6 .25 .2 .2 .2 .25 .4 .5 .5 .5 .5 0.
 ENTER ROD MILL PRINTING OPTION (1=SHORT,2=FULL) :1
```

```
  DESCRIPTION OF THE BALL MILLS

  FOR BALL MILL UNIT #  2
ENTER NO. OF B PARAMETERS, NO. OF S PARAMETERS AND
NO. OF PERFECT MIXERS : 4 4 3
ENTER THE  4 B  PARAMETERS : .3984 .9199 20. .1374

ENTER THE  4 S  PARAMETERS : 253. .6541 -.2261 -.1295

ENTER THE FRACTIONS OF TOTAL MEAN RESIDENCE TIME
FOR THE  3 PERFECT MIXERS : .5293 .1593 .0779

ENTER THE TOP SIEVE REFERENCE DIMENSION
USED IN FINDBS RUN : 11.480
  FOR BALL MILL UNIT #  3
ENTER NO. OF B PARAMETERS, NO. OF S PARAMETERS AND
NO. OF PERFECT MIXERS : 4 4 3
ENTER THE  4 B  PARAMETERS : .3984 .9199 20. .1374

ENTER THE  4 S  PARAMETERS :197. .6541 -.2261 -.1295

ENTER THE FRACTIONS OF TOTAL MEAN RESIDENCE TIME
FOR THE  3 PERFECT MIXERS : .5293 .1593 .0779

ENTER THE TOP SIEVE REFERENCE DIMENSION
USED IN FINDBS RUN : 5.7420


  DESCRIPTION OF THE CYCLONES

  FOR CYCLONE UNIT # 4, FIXED D50C, EM, RF VALUES
ENTER NUMBER OF CYCLONES IN PACK, THEIR APEX
DIMENSION AND THE ROPING FACTOR : 8. 4.125 .5600
ENTER THE D50C, EM AND RF(%) VALUES : 720. 1.25 35.
  FOR CYCLONE UNIT # 5, FIXED D50C, EM, RF VALUES
ENTER NUMBER OF CYCLONES IN PACK, THEIR APEX
DIMENSION AND THE ROPING FACTOR : 8. 3.175 .5600
ENTER THE D50C, EM AND RF(%) VALUES : 267. 1.78 25.
```

```
   DESCRIPTION OF THE EXTRAPOLATION MODULES

 FOR MODULE UNIT # 6, ENTER NO. OF FINE SIEVES
 TO BE ADDED : 2
 ENTER THE PASSING SIEVE APERTURES OF THE  3
 FINEST SIEVES OF THE RESULTING SIEVE DISTRIBUTION :
210. 149. 105.
 FOR MODULE UNIT # 7, ENTER NO. OF FINE SIEVES
 TO BE ADDED : 2
 ENTER THE PASSING SIEVE APERTURES OF THE  3
 FINEST SIEVES OF THE RESULTING SIEVE DISTRIBUTION :
105. 74. 53.


   DESCRIPTION OF THE FEED STREAM
 ENTER SOLID AND WATER FLOW RATES : 125. 27.
 ENTER THE 100% PASSING SIEVE APERTURE, THE SIEVES RATIO AND
 THE MEAN SIZE OF THE PARTICLES RETAINED WITH THE PAN :
26900. 1.414 210.
 ENTER SPECIFIC GRAVITY OF THE SOLIDS : 4.
 ENTER THE 15 VALUES OF THE SIZE DISTRIBUTION
 (WEIGHT % RETAINED) :
2.8 11.2 22.2 11.4 10.6 7.8 4.6 4.6 4.2 3.9 2.9 2.3 1.7 1.3 1.2 11.9
 ENTER WATER ADDITION STREAM # 8 FLOW RATE : 70.
 ENTER WATER ADDITION STREAM # 9 FLOW RATE : 20.
 ENTER WATER ADDITION STREAM #15 FLOW RATE : 100.
 ENTER WATER ADDITION STREAM #16 FLOW RATE : 6.

END OF SEARCH FOR COMPUTATION PATH WITH CODE          0
```

```
        3-STAGE GRINDING CIRCUIT SIMULATION


   UNIT #  1



                             ____
                            !    !___________________
                            !    !                   !
                            !    !     ROD MILL      !
        SFR=  125.00      --!    !                   !--  SFR=  125.00
        WFR=   27.00        !    !                   !    WFR=   27.00
         %S=   82.24      --!    !    2.7 STAGES     !--   %S=   82.24
                            !    !                   !
                            !    !___________________!
                            !____!
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                                 ROD MILL UNIT

        SCREENS                 FEED                PRODUCT
                           %CUM      %RET      %CUM      %RET

     26900.-19024.   100.000     2.800   100.000     0.000
     19024.-13454.    97.200    11.200   100.000     0.000
     13454.- 9515.    86.000    22.200   100.000      .441
      9515.- 6729.    63.800    11.400    99.559     1.654
      6729.- 4759.    52.400    10.600    97.905     4.635
      4759.- 3366.    41.800     7.800    93.270     9.185
      3366.- 2380.    34.000     4.600    84.084    11.716
      2380.- 1683.    29.400     4.200    72.368    11.056
      1683.- 1190.    25.200     3.900    61.312     9.837
      1190.-  842.    21.300     2.900    51.475     7.494
       842.-  595.    18.400     2.300    43.982     5.660
       595.-  421.    16.100     1.700    38.322     4.171
       421.-  298.    14.400     1.300    34.151     3.440
       298.-  210.    13.100     1.200    30.712     3.095
       210.-    0.    11.900    11.900    27.617    27.617

      SOLID FLOW RATE :    125.000
      WATER FLOW RATE :     27.000
      NO. OF STAGES   :      2.72
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
 26900. !                                                                    P
 19024. !                                                                  F P
 13454. !                                                          F         P
  9515. !                                           F                        P
  6729. !                                   F                              P !
  4759. !                           F                                   P    !
  3366. !                      F                                  P          !
  2380. !                   F                             P                  !
  1683. !                F                        P                          !
  1190. !             F                    P                                 !
   842. !           F                 P                                      !
   595. !         F               P                                          !
   421. !        F             P                                             !
   298. !       F           P                                                !
   210. !      F          P                                                  !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

   UNIT #  6

          EXTRAPOLATION OF SIZE DISTRIBUTION

          XMU          BEFORE         AFTER

        26900.  !      0.000  !
        19024.  !      0.000  !
      ----------!-------------!--------------!
        13454.  !       .441  !        .441  !
         9515.  !      1.654  !       1.654  !
         6729.  !      4.635  !       4.635  !
         4759.  !      9.185  !       9.185  !
         3366.  !     11.716  !      11.716  !
         2380.  !     11.056  !      11.056  !
         1683.  !      9.837  !       9.837  !
         1190.  !      7.494  !       7.494  !
          842.  !      5.660  !       5.660  !
          595.  !      4.171  !       4.171  !
          421.  !      3.440  !       3.440  !
          298.  !      3.095  !       3.095  !
          210.  !     27.617  !       2.938  !
          149.  !                     2.481  !
          105.  !                    22.198  !
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
   UNIT #  8
    SFR=  125.00
    WFR=   27.00-----------------------------------------
     %S=   82.24                                       !
                                                       !
              SFR=  304.05                             !
              WFR=   83.00-------------------------    !
               %S=   78.56                        !    !
                                                  !    !
                        SFR=    0.00              !    !
                        WFR=   70.00----------    !    !
                         %S=    0.00         !    !    !
                                         !   !    !    !   !
                                         !   V    V    V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  428.78
                                                  !---------->WFR=  180.00
                                                               %S=   70.43
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                           MIXER UNIT

        SCREENS            PRODUCT
                       %CUM      %RET

     13454.- 9515.   100.000      .863
      9515.- 6729.    99.137     1.892
      6729.- 4759.    97.244     3.683
      4759.- 3366.    93.561     6.235
      3366.- 2380.    87.326     8.285
      2380.- 1683.    79.040     9.397
      1683.- 1190.    69.644    10.314
      1190.-  842.    59.330    10.306
       842.-  595.    49.024     9.451
       595.-  421.    39.573     7.742
       421.-  298.    31.831     5.949
       298.-  210.    25.882     4.517
       210.-  149.    21.365     3.523
       149.-  105.    17.842     2.684
       105.-    0.    15.158    15.158
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
   UNIT #  4
                       ALL MASS FLOWRATES IN TONNES/HOUR

                                              SOLIDS  124.7
                                 --> OVERFLOW WATER   117.0
                                !             SLURRY  241.7
                         -------!-------
        SOLIDS  428.8    ! HYDROCYCLONE!
   FEED WATER   180.0 -->!             !
        SLURRY  608.8    !  D50C= 720.0!               NO. OF UNITS  8
                         !     M= 1.250!
                         !    RF= 35.0%!               DU=   4.13 CM
                         \             /
                          \           /
                           \         /
                            \       /
                             \     /
                              \   /
                               \ /
                                !           SOLIDS  304.1
                                V UNDERFLOW WATER    63.0
                                            SLURRY  367.1

   TO CONTINUE, ENTER ANY DIGIT AND <CR>1
..........................................................
          PARTICLE SIZE ANALYSES OF FLOWSTREAMS
          -------------------------------------
         PARTICLE SIZE           WEIGHT  PERCENT
            MICRONS        FEED     UNDERFLOW   OVERFLOW
         -------------      ----     ---------   --------
        13454 -    9514        .86       1.22       0.00
         9514 -    6729       1.89       2.67       0.00
         6729 -    4758       3.68       5.19        .00
         4758 -    3365       6.24       8.78        .03
         3365 -    2380       8.29      11.53        .37
         2380 -    1683       9.40      12.57       1.66
         1683 -    1190      10.31      12.72       4.45
         1190 -     841      10.31      11.25       8.01
          841 -     595       9.45       8.97      10.62
          595 -     421       7.74       6.39      11.05
          421 -     297       5.95       4.31       9.94
          297 -     210       4.52       2.94       8.36
          210 -     149       3.52       2.11       6.97
          149 -     105       2.68       1.51       5.54
          105 -       0      15.16       7.84      32.99
                           ------     ------     ------
                           100.00     100.00     100.00

         NO. OF SG FRACTIONS = 1
         SOLIDS SG RANGED FROM  4.50 TO  4.50
..........................................................
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
 13454. !                                                                    O
  9515. !                                                                   UO
  6729. !                                                                 UF O
  4759. !                                                              UF    O
  3366. !                                                       U   F        O
  2380. !                                               U     F              O
  1683. !                                       U       F                   O!
  1190. !                              U        F                       O    !
   842. !                      U         F                         O         !
   595. !                U         F                       O                 !
   421. !           U        F                      O                        !
   298. !        U       F                   O                               !
   210. !      U      F                O                                     !
   149. !    U     F              O                                          !
   105. !   U     F           O                                              !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

   UNIT #  9
    SFR=  304.05
    WFR=   63.00----------------------------------------
     %S=   82.84                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=    0.00                   !
                        WFR=   20.00----------         !
                         %S=    0.00         !         !
                                         !   !         !   !
                                         !   V         V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  304.05
                                                  !---------->WFR=   83.00
                                                               %S=   78.56

TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
                    MIXER UNIT

         SCREENS             PRODUCT
                        %CUM        %RET

      13454.- 9515.   100.000       1.217
       9515.- 6729.    98.783       2.669
       6729.- 4759.    96.114       5.194
       4759.- 3366.    90.920       8.780
       3366.- 2380.    82.140      11.532
       2380.- 1683.    70.608      12.568
       1683.- 1190.    58.040      12.718
       1190.-  842.    45.322      11.247
        842.-  595.    34.075       8.972
        595.-  421.    25.103       6.386
        421.-  298.    18.717       4.313
        298.-  210.    14.404       2.940
        210.-  149.    11.464       2.110
        149.-  105.     9.354       1.512
        105.-    0.     7.842       7.842
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

   UNIT #  2



                                 _____
                                !     !___________________
                                !     !                   !
                                !     !     BALL MILL     !
         SFR=  304.05         --!     !                   !--   SFR=  304.05
         WFR=   83.00           !     !                   !     WFR=   83.00
          %S=   78.56         --!     !     3 MIXERS      !--    %S=   78.56
                                !     !                   !
                                !     !___________________!
                                !_____!
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                          BALL MILL UNIT

         SCREENS            FEED                    PRODUCT
                       %CUM        %RET        %CUM        %RET

      13454.- 9515.   100.000      1.217     100.000       1.039
       9515.- 6729.    98.783      2.669      98.961       1.992
       6729.- 4759.    96.114      5.194      96.969       3.294
       4759.- 3366.    90.920      8.780      93.675       5.025
       3366.- 2380.    82.140     11.532      88.651       6.877
       2380.- 1683.    70.608     12.568      81.773       8.718
       1683.- 1190.    58.040     12.718      73.055      10.514
       1190.-  842.    45.322     11.247      62.541      11.466
        842.-  595.    34.075      8.972      51.075      11.011
        595.-  421.    25.103      6.386      40.063       9.210
        421.-  298.    18.717      4.313      30.853       6.979
        298.-  210.    14.404      2.940      23.874       5.098
        210.-  149.    11.464      2.110      18.776       3.761
        149.-  105.     9.354      1.512      15.015       2.766
        105.-    0.     7.842      7.842      12.249      12.249
```

```
     3 MIXERS INCLUDING PLUG FLOW OF :  .23
   MIXERS RT'S ARE :  .5293  .1593  .0779
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
 13454. !                                                                    P
  9515. !                                                                   P!
  6729. !                                                                 FP !
  4759. !                                                              F P   !
  3366. !                                                       F    P       !
  2380. !                                               F       P            !
  1683. !                                       F         P                  !
  1190. !                              F           P                         !
   842. !                      F           P                                 !
   595. !                F         P                                         !
   421. !           F        P                                               !
   298. !        F      P                                                    !
   210. !      F    P                                                        !
   149. !    F   P                                                           !
   105. !   F   P                                                            !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

   UNIT #  7


          EXTRAPOLATION OF SIZE DISTRIBUTION

          XMU          BEFORE         AFTER

        13454.  !      0.000  !
         9515.  !      0.000  !
      ----------!-------------!--------------!
         6729.  !       .001  !        .001  !
         4759.  !       .034  !        .034  !
         3366.  !       .372  !        .372  !
         2380.  !      1.664  !       1.664  !
         1683.  !      4.453  !       4.453  !
         1190.  !      8.013  !       8.013  !
          842.  !     10.617  !      10.617  !
          595.  !     11.048  !      11.048  !
          421.  !      9.939  !       9.939  !
          298.  !      8.360  !       8.360  !
          210.  !      6.968  !       6.968  !
          149.  !      5.541  !       5.541  !
          105.  !     32.992  !       5.025  !
           74.  !                     4.228  !
           53.  !                    23.739  !
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
   UNIT # 10
    SFR=  124.73
    WFR=  117.00-----------------------------------------
     %S=   51.60                                        !
                                                        !
              SFR=  289.65                              !
              WFR=   80.33--------------------------    !
               %S=   78.29                         !    !
                                                   !    !
                        SFR=     0.00              !    !
                        WFR=  100.00-----------    !    !
                         %S=     0.00          !    !    !
                                          !   !    !    !   !
                                          !   V    V    V   !
                                          !_________________!
                                          !                 !
                                          !     MIXER       !
                                          !_________________!
                                                   !
                                                   !           SFR=  414.12
                                                   !---------->WFR=  297.33
                                                                %S=   58.21
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                           MIXER UNIT

        SCREENS            PRODUCT
                       %CUM      %RET

      6729.- 4759.   100.000       .001
      4759.- 3366.    99.999       .021
      3366.- 2380.    99.978       .211
      2380.- 1683.    99.767       .991
      1683.- 1190.    98.776      3.066
      1190.-  842.    95.710      7.081
       842.-  595.    88.629     13.066
       595.-  421.    75.563     17.980
       421.-  298.    57.583     16.432
       298.-  210.    41.151     11.035
       210.-  149.    30.116      6.873
       149.-  105.    23.243      4.495
       105.-   74.    18.748      3.409
        74.-   53.    15.339      2.587
        53.-    0.    12.752     12.752
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
   UNIT #  5
                       ALL MASS FLOWRATES IN TONNES/HOUR

                                              SOLIDS  124.5
                                 --> OVERFLOW WATER   223.0
                                !             SLURRY  347.5
                         -------!-------
        SOLIDS  414.1    ! HYDROCYCLONE!
   FEED WATER   297.3 -->!             !
        SLURRY  711.5    !  D50C= 267.0!              NO. OF UNITS  8
                         !     M= 1.780!
                         !    RF= 25.0%!              DU=   3.18 CM
                         \             /
                          \           /
                           \         /
                            \       /
                             \     /
                              \   /
                               \ /
                                !           SOLIDS  289.7
                                V UNDERFLOW WATER    74.3
                                            SLURRY  364.0

   TO CONTINUE, ENTER ANY DIGIT AND <CR>1
...........................................................
          PARTICLE SIZE ANALYSES OF FLOWSTREAMS
          -------------------------------------

         PARTICLE SIZE          WEIGHT  PERCENT
            MICRONS        FEED     UNDERFLOW    OVERFLOW
         -------------     ----     ---------    --------
         6729 -   4758      .00         .00        0.00
         4758 -   3365      .02         .03        0.00
         3365 -   2380      .21         .30        0.00
         2380 -   1683      .99        1.42         .00
         1683 -   1190     3.07        4.38         .00
         1190 -    841     7.08       10.12         .01
          841 -    595    13.07       18.43         .57
          595 -    421    17.98       23.53        5.07
          421 -    297    16.43       17.95       12.89
          297 -    210    11.04        9.48       14.65
          210 -    149     6.87        4.59       12.18
          149 -    105     4.49        2.42        9.33
          105 -     74     3.41        1.56        7.70
           74 -     53     2.59        1.07        6.12
           53 -      0    12.75        4.71       31.46
                         ------      ------      ------
                         100.00      100.00      100.00

         NO. OF SG FRACTIONS = 1
         SOLIDS SG RANGED FROM  4.50 TO  4.50
...........................................................
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
  6729. !                                                                    O
  4759. !                                                                    O
  3366. !                                                                    O
  2380. !                                                                    O
  1683. !                                                                   UO
  1190. !                                                                UF  O
   842. !                                                         U  F       O
   595. !                                            U      F                O
   421. !                           U          F                         O   !
   298. !               U           F                           O            !
   210. !        U          F                         O                      !
   149. !     U        F                     O                               !
   105. !   U       F                  O                                     !
    74. !  U      F              O                                           !
    53. ! U     F            O                                               !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

   UNIT # 11
    SFR=  289.65
    WFR=   74.33----------------------------------------
     %S=   79.58                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=    0.00                   !
                        WFR=    6.00----------         !
                         %S=    0.00         !         !
                                         !   !         !   !
                                         !   V         V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  289.65
                                                  !---------->WFR=   80.33
                                                               %S=   78.29
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
                           MIXER UNIT

        SCREENS                PRODUCT
                           %CUM      %RET

      6729.- 4759.  100.000      .001
      4759.- 3366.   99.999      .030
      3366.- 2380.   99.969      .302
      2380.- 1683.   99.667     1.417
      1683.- 1190.   98.250     4.384
      1190.-  842.   93.866    10.120
       842.-  595.   83.747    18.433
       595.-  421.   65.313    23.526
       421.-  298.   41.787    17.952
       298.-  210.   23.836     9.480
       210.-  149.   14.355     4.591
       149.-  105.    9.765     2.419
       105.-   74.    7.345     1.563
        74.-   53.    5.782     1.070
        53.-    0.    4.712     4.712
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

   UNIT #  3



                             ____
                            !    !___________________
                            !    !                   !
                            !    !     BALL MILL     !
        SFR=  289.65      --!    !                   !-- SFR=  289.65
        WFR=   80.33        !    !                   !   WFR=   80.33
         %S=   78.29      --!    !      3 MIXERS     !--  %S=   78.29
                            !    !                   !
                            !    !___________________!
                            !____!
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                                 BALL MILL UNIT

        SCREENS                 FEED                PRODUCT
                           %CUM      %RET      %CUM      %RET

      6729.- 4759.  100.000      .001    100.000      .001
      4759.- 3366.   99.999      .030     99.999      .015
      3366.- 2380.   99.969      .302     99.984      .142
      2380.- 1683.   99.667     1.417     99.842      .701
      1683.- 1190.   98.250     4.384     99.142     2.468
      1190.-  842.   93.866    10.120     96.674     6.679
       842.-  595.   83.747    18.433     89.995    14.120
       595.-  421.   65.313    23.526     75.875    20.975
       421.-  298.   41.787    17.952     54.900    19.241
       298.-  210.   23.836     9.480     35.659    12.190
       210.-  149.   14.355     4.591     23.469     6.830
       149.-  105.    9.765     2.419     16.639     4.041
       105.-   74.    7.345     1.563     12.598     2.710
        74.-   53.    5.782     1.070      9.887     1.879
        53.-    0.    4.712     4.712      8.009     8.009
```

```
     3 MIXERS INCLUDING PLUG FLOW OF :   .23
   MIXERS RT'S ARE :   .5293   .1593   .0779
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
  6729. !                                                                    P
  4759. !                                                                    P
  3366. !                                                                    P
  2380. !                                                                    P
  1683. !                                                                   P!
  1190. !                                                                F P !
   842. !                                                         F   P      !
   595. !                                            F      P                !
   421. !                           F        P                               !
   298. !               F       P                                            !
   210. !        F     P                                                     !
   149. !     F    P                                                         !
   105. !   F   P                                                            !
    74. !  F  P                                                              !
    53. ! F  P                                                               !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

DO YOU WISH TO MODIFY YOUR DATA FILE?
TYPE YES OR NO - no
```

3. SYSTEM DOCUMENTATION

3.1 COMPUTER EQUIPMENT

GRNDEX is run on a CDC CYBER 730 computer with a maximum 70K words (octal) of core memory available for time-sharing jobs. GRNDEX can also be run on other computers with very minor modifications. It has been converted to run on IBM-PC microcomputers.

3.2 PERIPHERAL EQUIPMENT

A time-sharing terminal is the normal way of running this conversational program. Data can be stored on disk files.

3.3 SOURCE PROGRAM

Complete listing of the program can be obtained from:

CANMET,
Energy, Mines and Resources,
Technology Information Division,
555 Booth Street
Ottawa, Ontario
K1A 0G1.

3.4 VARIABLES AND SUBROUTINES

3.4.1 Variables

A list of variables is given in the prologues of each program and subroutines. Most variables are transmitted as arguments of subroutines. A labelled COMMON area of 1K words is reserved for internal storage of local variables.

Three variables, PARAM, FLOW, and OPT, used in the GRNDNG program must be understood before any modification to the code is made.

Array PARAM, which contains the unit parameter values, is partitioned in sectors of variable length. The structure of each sector depends on the model and unit type, and the user is referred to the module subroutine prologues for a detailed description. Forty-one components are allocated to the rod mill (RMILL), and 430 components to each ball mill (BMILL). The sectors of 34 components received for each hydrocyclone unit (HCONE1, HCONE2, and HCONE3) are next. The last sectors, of five components each, are dedicated to the extrapolation modules (EXTRAP).

Array FLOW contains data describing the streams: a sector of 5 + NS components is reserved for each stream. Each stream is partitioned as follows: components one to three are not used, components four and five are the solids and water flow rates, and the remaining NS components are the size distribution in wt %.

Array OPT has one component for each unit.

3.4.2 Main Programs and Associated Subroutines

The package is composed of three main programs. The list of subroutines associated with each is given below.

3.4.2.1 GRNDEX

GRNDEX:	(main program) to create the data file and write the GRNDNG main program, and the code for the subroutine CALLUN.
GRNDIN:	to prompt for data entry.
DATAP:	to write data file from user's entries.
WRTUN:	to write a FORTRAN CALL statement to a particular unit module subroutine.
DEFIN:	to define arrays ORIG and DEST as required by subroutine COD.
WRTEX:	to write the GRNDNG main FORTRAN program, the subroutine CALLUN statement, and its DIMENSION statements.
COD:	to search for computation path from the stream connection matrix and to organize the writing of subroutine CALLUN body. COD is a slightly modified version of FLOWAN described with the SPLITX package.
CYCLE:	to find all cycles in the flowsheet.
MAXNET:	to group all the cycles into maximal nets.
NODES:	to form simple and complex nodes using the maximal nets.
RANK:	to determine unit computation order.
BITOFF:	to determine if the nth bit of integer IN is 0 or 1.
TEAR:	to determine torn stream numbers.
TEAROR:	to determine the order for calculating units within a node, given the torn stream numbers.
PATH:	to find all the paths between torn streams within a complex node.
CODEX:	to provide an interface between GRNDEX and COD.
WRTOUT:	to write a FORTRAN CALL statement for a particular unit display subroutine.

3.4.2.2 GRNDNG

GRNDNG: (main program) to perform the simulation and print out results (written by GRNDEX subroutines).

CALLUN: to organize the computation path and print out results (written by GRNDEX subroutines).

RMILL: to simulate the rod mill.

RMOUT: to print out rod mill unit results.

CUMP: to transform a size distribution from non-cumulative to cumulative passing weight fractions.

NCUMP: to transform a size distribution from cumulative passing to non-cumulative weight fractions.

CUMR: to transform a size distribution from non-cumulative to cumulative retained weight fractions.

HCONE1: to simulate the hydrocyclone using the complete Plitt model.

HCONE2: to simulate the hydrocyclone using the Plitt model with fixed D50C, EM and Rf parameters.

HCONE3: to simulate the hydrocyclone using the fixed efficiency curve.

CYCOUT: to print out HCONE module results.

PART: to carry out a solid-solid separation using a ROSIN-RAMLER expression for a size-based partition curve including fines bypass.

INIT: to initialize array FLOW.

MIXER2: to simulate a 2-stream mixer.

MIXER3: to simulate a 3-stream mixer.

MX2OUT: to print out MIXER2 module results.

MX3OUT: to print out MIXER3 module results.

EXTRAP: to extrapolate a size distribution.

EXTOUT: to print out EXTRAP module results.

BMILL: to simulate a ball mill.

BMOUT: to print out BMILL unit results.

GRIND: to prompt product size distribution using the grinding matrix G.

MAKEZ: to compute matrix Z and its inverse from breakage and selection functions.

MAKEG: to compute matrix G from matrices V, Z, and Z inverse.

BREAK: to compute the breakage function from the breakage parameters.

SELECT: to compute the selection function from the selection parameters.

MAKEV: to compute the mixer's V function.

SETPAR: to organize the part of array PARAM reserved for ball mill parameters.

PLOTSZ: to display a scattergram of cumulative size distributions versus size intervals.

INITGR: to initialize a plotting array used by PLOTSZ.

READAT: to read the input data file.

3.4.2.3 GRNDIT

GRNDIT: (main program) to permit modifications to the data file.

NETW: to read the stream connection matrix and search for water addition stream numbers.

HC1ALT: to permit modification of HCONE1 parameter values.

HC2ALT: to permit modification of HCONE2 parameter values.

HC3ALT: to permit modification of HCONE3 parameter values.

FEDALT: to permit modification of the feed stream characteristics.

WATALT: to permit modification of the water addition stream flow rates.

RMALT: to permit modification of the rod mill parameter values.

BMALT: to permit modification of the ball mill parameter values.

EXTALT: to permit modification of the extrapolation module parameter values.

3.5 DATA STRUCTURE

GRNDEX main program reads data in free-field format from the input file, which can be declared as the key board or as a disk file. When data entry has been completed, data are written on unit 1. The main program GRNDNG and subroutine CALLUN are written in FORTRAN on unit 3. Prompts are written to the output file.

The GRNDNG main program reads data in free-field format from unit 5 and writes results on unit 6, declared as the output file. Answers to the prompts are read from the input file.

The GRNDIT main program reads data in free-field format from unit 5 and writes corrected data on unit 6. Corrections are read from the input file and prompts written to the output file.

3.6 STORAGE REQUIREMENTS

Storage requirements depend on the size of the data set: number of units, number of streams, and number of size intervals. Typically, it is less than 70K words on a CDC mainframe, or less than 380K on an IBM-PC.

3.7 MAINTENANCE AND UPDATES

CANMET does not provide any formal maintenance of the programs. Several updates are expected to evolve from the source programs distributed to users. CANMET would appreciate receiving comments on modifications that could improve substantially the overall program performance. An expected improvement is automatic data-checking.

4. OPERATING DOCUMENTATION

4.1 OPERATOR INSTRUCTIONS

GRNDEX has been developed on a CYBER 730 computer using NOS/BE batch-operating system and INTERCOM time-sharing system, and converted to an IBM-PC using MS.DOS.

4.2 OPERATING MESSAGES

Special messages, other than NOS/BE and INTERCOM messages, may be issued by subroutine COD, if abnormal conditions occur during the search for the computation path (see the SPLITX program description in this chapter of the SPOC manual).

4.3 CONTROL CARDS

To run the three programs, GRNDEX, GRNDNG, and GRNDIT together, job control cards are necessary. A sample control card deck is given in Figure 10. The Cyber Control Language (CCL) is used in the four procedures that manage data files and programs according to the sequence of steps given in Figure 8.

The main procedure is GRNDEX. It attaches all required files, including compiled programs and other procedures. Then GRNDEX calls the procedure GRNECT. Procedure GRNECT runs the GRNDEX program, compiles the GRNDNG program, combines GRNDNG with all its subroutines and runs it. Then GRNECT returns control to the GRNDEX procedure.

At this stage, procedure GRNDEX initiates a loop on both procedure GRNDIT, which runs GRNDIT program, and procedure GRANAME, which runs GRNDNG program using the modified data file.

4.4 ERROR RECOVERY

The program must be restarted after a fatal error. Most mistakes in data entry can be corrected by using the GRNDIT program.

4.5 RUN TIME

Run time depends on the size of the problem and on the number of times GRNDIT is used to correct data. Typical times are a few seconds on a mainframe computer and a few minutes on an IBM-PC.

```
.PROC,GRNDEX*I,DATA=(*N=INPUT,*F).
RETURN,B1,B2,BIN,LGO,GRNECT,GRNDIT,GRNAME,TAPE1,TAPE3.
IUSE,FINDMOI,FFLIPF,SPOC.
IGET,LGO=GRNDEX.BIN,B2=GRNDNG.BIN,BIN=GRNDIT.BIN,GRNECT.CCL,GRNDIT.CCL.
IGET,GRNAME.CCL.
DAYFILE,OFF.
GRNECT,DATA.
IFNO,END.ODO YOU WISH TO MODIFY YOUR #DATA FILE?
DAYFILE,ON.
REVERT,ABORT.
ENDIF,END.
SET,R1=0.
REWIND,TAPE1.
GRNDIT,TAPE1.
WHILE,R1.LT.10,LOOP.
SET,R1=R1+1.
GRNAME.
ENDW,LOOP.
REMARK.  #DATA SET QUOTA EXCEEDED
REMARK.  END
DAYFILE,ON.
REVERT.
EXIT,U.
COPDF,XX.
REWIND,XX.
COPY,XX.
RETURN,XX.
DAYFILE,ON.
REVERT.

.PROC,GRNDIT*I,NAME"OF DATA SET TO BE REVIEWED :"=(*F).
BIN,,,NAME.
REWIND,TAPE6,NAME.
REVERT.

.PROC,GRNAME*I,A"NAME FOR YOUR NEW DATA SET :"=(*F).
RETURN,A.
COPY,TAPE6,A.
RETURN,TAPE6.
REWIND,A.
LGO,,,A.
EXIT,U.
REWIND,A.
IFNO,END.ODO YOU WISH TO MODIFY YOUR DATA FILE?
REVERT,ABORT.
ENDIF,END.
GRNDIT.
REVERT.

.PROC,GRNECT,FFL1.
LGO,FFL1.
REWIND,TAPE3,TAPE1,FFL1.
FTN,I=TAPE3,B=B1,L=0,PMD.
REWIND,B1.
RETURN,LGO,TAPE3.
COPYBF,B1,LGO.
BKSP,LGO.
COPYBF,B2,LGO.
REWIND,LGO.
LGO,,,TAPE1.
REWIND,TAPE1.
REVERT.
```

Fig. 10 — Control card decks for GRNDEX

HCONEX

MULTIPLE HYDROCYCLONE CLASSIFICATION SIMULATION EXECUTIVE

F. Flament, D. Laguitton

CONTENTS

TABLE

FIGURES

1. PROGRAM IDENTIFICATION

Program Title:	Flexible **H**ydro**C**ycl**ON**e Circuit **EX**ecutive.
Program Code Names:	HCONEX, HCONE, HCEDIT.
Author:	F. Flament.
Organization:	Energy, Mines and Resources Canada Centre for Mineral and Energy Technology, Mineral Processing Laboratory.
Date:	May 1985.
Updates:	July 1985.
Source Language:	CDC FORTRAN Extended 4.8 (American National Standard Institute FORTRAN X3.9 — 1966).
Availability:	Complete program listing is available from: CANMET, Energy, Mines and Resources Technology Information Division, 555 Booth Street Ottawa, Ontario K1A 0G1.

2. ENGINEERING DOCUMENTATION

2.1 NARRATIVE DESCRIPTION

This program is an interactive executive for simulating multicyclone flowsheets. It is composed of three independent programs which are run successively. The first program, called HCONEX, permits data file creation and writes a preprocessor, i.e., a main FORTRAN program, called HCONE. That main program, written specifically for the data set (i.e., flowsheet structure, unit model parameters, feed characteristics) organizes the simulation of the circuit using a bank of available subroutines. The third program, called HCEDIT, permits some modifications to the data file. The allowed modifications are those that do not require the preprocessor to be changed. This is to provide the user with a chance to perform several simulations of the same multicycloning circuit under different operating conditions. The program is capable of accepting up to 15 units. On each stream a maximum of 20 size intervals and 10 specific gravity intervals are possible. The units may be HCONE1 (complete Plitt model of hydrocyclones), HCONE2 (Plitt model of hydrocyclones with fixed D50C, EM, and Rf values), HCONE3 (fixed efficiency curve), MIXER2 (2-stream mixer) or MIXER3 (3-stream mixer). Only one feed stream to the plant is tolerated. Up to 10 water addition streams are accepted.

2.2 METHOD OF SOLUTION

2.2.1 Preparation for Simulation

The multicycloning circuit should be analyzed in terms of a flowsheet composed of streams and units. Units should be hydrocyclones (HCONE1, HCONE2, and HCONE3 can simulate several parallel hydrocyclones) and/or mixers (if the stream mixer has more than three streams it should be simulated by 2- or 3-stream mixers). Each stream should be assigned a number starting with No. 1 for the feed stream to the plant. Hydrocyclone model types and the corresponding parameter values should be known. The feed stream characteristics should also be known. Finally, the data set should be given a name and a title.

2.2.2 Flowsheet Analysis

The HCONEX program organizes the flowsheet description. It first asks for the number of hydrocyclones, the number of mixers, and the total number of streams. Then, for each hydrocyclone, the user is prompted to enter the model type, the feed stream number, the underflow stream number, and the overflow stream number. Then for each mixer (if any), the user is prompted to enter the number of feed streams (two or three), the feed stream numbers, and the discharge stream number. From these entries, a stream convection matrix is formed and used by the subroutine COD to determine the order of simulation of the units and the tear streams that need to be initialized before simulation can start. The COD subroutine of HCONEX is similar to the COD subroutine of GRNDEX (see Section 2.2.2 in the description of GRNDEX in this chapter), which is a slightly modified version of the FLOWAN program described with the SPLITX executive in this chapter. The COD subroutine of HCONEX only permits calls to hydrocyclone and mixer models.

2.2.3 Unit Modules

The unit modules are described in Chapter 5.1 of the SPOC manual for the hydrocyclone modules, and in Chapter 5.2 for the mixer modules. The capabilities and limitations of the modules are also valid in HCONEX.

2.3 PROGRAM CAPABILITIES

Limitations on problem size are dependent on array dimensions, computer memory, and program structure. A modification to the limit values given here is not recommended:

Total number of units: 15
Water addition streams: 10
The feed stream should be given number 1
Number of size intervals: 20
Number of specific gravity intervals: 10
Size interval dimensions are defined from the 100 per cent passing sieve aperture (microns of each sieve) and the mean size of particles within the pan.

After completion of a simulation run, modifications to the data can be made, and the simulation program can be executed again.

2.4 DATA ENTRY, PROGRAM OPTIONS, OUTPUT

The HCONEX and HCEDIT interactive programs prompt for all data inputs. Data are entered in free format, i.e., in sequence, using either blanks or commas as separators. Input data may also be read by HCONEX from a batch data file on disk storage created during a previous run or by a text editor.

The basic steps of a simulation session are given in Figure 11. The program options are the unit module options as described in Chapters 5.1 and 5.2 of the SPOC Manual.

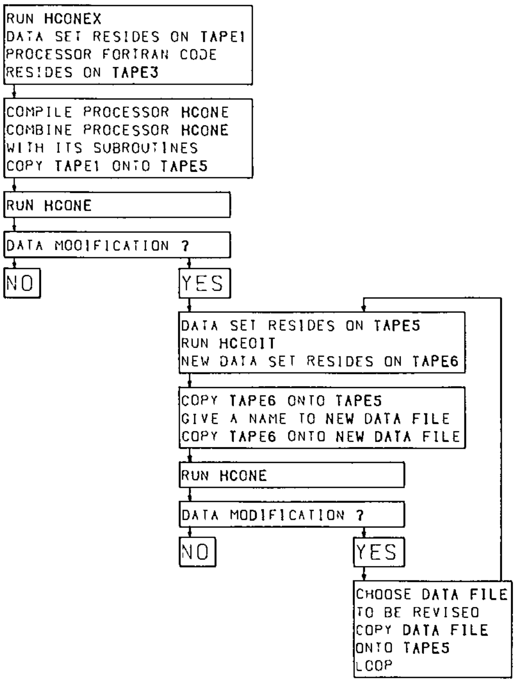


Fig. 11 — Linking HCONEX, HCONE, HCEDIT, and the data files

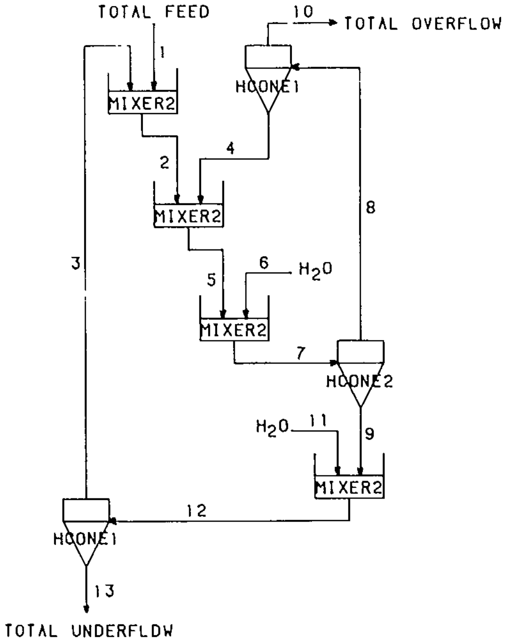


Fig. 12 — Flowsheet of HCONEX sample run

2.5 SAMPLE RUN

A sample run is reproduced here to illustrate a multi-cycloning plant simulation session. The flowsheet used is given in Figure 12. Particles are classified using three hydrocyclones. Hypothetical, though realistic, data used in the sample run are reported in Table 13.

After completion of the simulation run, modification of the data set is attempted to improve overall classification and demonstrate the use of HCEDIT. Modifiable data are classified in blocks. A block of data consists of a unit module parameter set, the feed characteristics, or the water addition stream flow rates. Each block of data is displayed or printed, record by record. Then the user is prompted to enter the record number to be modified, or one of the three following options:

D which stands for Display the block of data again;

N which stands for No more modifications in the block;

E which stands for Exit and terminates the modification mode.

When the user enters a record number, the complete corrected record should be reentered after the prompt has been issued.

Note that the program starts by asking for an eventual modification of the data set title. In the sample run, the user is also prompted to enter a new data set name. This prompt is not issued by HCEDIT but by the job control statements.

Table 13 — HCONEX sample run data

HCONE2: unit No. 1

Fixed D50C, EM and Rf
8 cyclones; apex = 3.75 cm; roping factor = .4433
D50C = 120 µm; EM = 3.8; Rf = 20%

HCONE1: unit No. 2

Complete Plitt model
8 cyclones; apex = 3.75 cm; roping factor = .4433
DC = 25.4 cm; DO = 8.9 cm; DI = 10.2 cm
FD50 = 1; FSPLT = 2.761; FPRESS = .4493
FEM = .615; FVH = 78.7 cm

HCONE1: unit No. 3

Complete Plitt model
8 cyclones; apex = 4.25 cm; roping factor = .4433
DC = 25.4 cm; DO = 8.9 cm; DI = 10.2 cm
FD50 = 1.; FSPLT = 2.761; FPRESS = .4493
FEM = .615; FVH = 78.7 cm

Feed characteristics
Solids = 316.5 t/h; water = 799.37 t/h
Size intervals µm 297/212 212/150 150/106 106/75 75/53 53/45 -45
Specific gravity = 2.8
Feed size distribution = 4.9 11.7 14.1 13. 9.4 6.2 40.7
Water addition stream #6 = 10 t/h
Water addition stream #11 = 170 t/h

HYDROCYCLONE NETWORK SIMULATION

PURPOSE : TO SIMULATE A MULTICYCLONING UNIT INVOLVING SOLIDS RECYCLING AND WATER ADDITION

DESCRIPTION: HCONEX IS A SIMULATOR EXECUTIVE WHICH ALLOWS THE SIMULATION OF SEVERAL HYDROCYCLONES ARRANGED IN A NETWORK. IT USES TWO KINDS OF UNIT MODULES: THE HCONE UNIT MODULE AND ITS THREE DIFFERENT MODELS (REFER TO HCONE UNIT MODELS) AND THE MIXER2 AND MIXER3 UNIT MODULES WHICH PERFORM THE MIXING OF TWO AND THREE STREAMS RESPECTIVELY.

HCONEX IS COMPOSED OF THREE INDEPENDENT PROGRAMS:

- THE DATA FILE EDITOR AND PRE-PROCESSOR WRITER
- THE EXECUTIVE
- THE DATA FILE MODIFIER

THEY ARE LINKED ALL TOGETHER BY PROCEDURES.

LIMITATIONS:

NUMBER OF UNITS : 15
NUMBER OF WATER ADDITION STREAMS: 10
MUMBER OF SIZE INTERVALS : 20
NUMBER OF SPECIFIC GRAVITY : 10
NUMBER OF CHARACTERISTICS : 1

VARIABLES : SAME AS THOSE USED BY HCONE UNIT MODULE PLUS THE FOLLOWING ONES:

NCY = NUMBER OF HYDROCYCLONES
NMX = NUMBER OF MIXERS
NSTR = NUMBER OF STREAMS
MSTR = STREAM CONNECTION MATRIX
PARAM = AN ARRAY WHICH CONTAINS ALL MODEL PARAMETERS REQUIRED BY THE UNIT MODULES
FLOW = AN ARRAY WHICH CONTAINS THE CHARACTERISTICS OF ALL THE STREAM FLOWS: SOLID AND WATER FLOW RATES, SIZE DISTRIBUTION IN % BY WEIGHT
OPT = AN ARRAY WHICH CONTAINS FOR EACH UNIT THE MODEL OPTION (1,2 OR 3 FOR HCONE, 2 OR 3 FOR MIXERS)

```
    SAMPLE RUN1:
    -----------          10
                 -------------------------> OVERFLOW
                !
                !II
              -----
              \ 1 / <---------------------------
               \ /                              !
                !             6                 !
                !4            !                 !8
                !             V                 !
   1 ---    2  ---  5        --- 7            -----
--->(   )---->(   )-------->(   )------------> \ 2 / I
     ---       ---           ---                \ /
      A                                          !
      !                                          !9
       -------------                             !
                    !3                           !
                  -----            12           ---
                  \ 1 /<-----------------------(   )<-------11
                   \ /                          ---
                    ! 13
                     ----> UNDERFLOW
```

```
          HYDROCYCLONE NETWORK SIMULATION
        ENTER A RUN IDENTIFICATION
          (40 CHARACTERS MAXIMUM)
multicycloning circuit simulation
     DESCRIPTION OF THE FLOWSHEET
ENTER NO. OF CYCLONES, NO. OF MIXERS AND NO. OF STREAMS :
3 4 13
FOR EACH CYCLONE, ENTER MODEL TYPE AND
FEED, UNDERFLOW AND OVERFLOW STREAM NUMBERS :
UNIT # 1 : 2 7 9 8
UNIT # 2 : 1 8 4 10
UNIT # 3 : 1 12 13 3
FOR EACH MIXER, ENTER NUMBER OF FEED STREAMS AND
ENTER FEEDS AND DISCHARGE STREAM NUMBERS :
UNIT # 4 : 2 1 3 2
UNIT # 5 : 2 2 4 5
UNIT # 6 : 2 5 6 7
UNIT # 7 : 2 9 11 12
     DESCRIPTION OF THE CYCLONES
ENTER NO. OF SIZE INTERVALS (PAN INCLUDED),
NO. OF SPECIFIC GRAVITIES AND NO. OF CHARACTERISTICS :
7 1 1
UNIT # 1, FIXED D50C, EM AND RF VALUES
ENTER NO. OF CYCLONES IN PACK,
THEIR APEX DIMENSION AND THE ROPING FACTOR :8. 3.75 .4433
ENTER A D50C VALUE FOR EACH SPECIFIC GRAVITY: 120.

ENTER EM AND RF(%) VALUES : 3.8 20.
```

```
UNIT # 2, COMPLETE PLITT MODEL
ENTER NO. OF CYCLONES IN PACK,
THEIR APEX DIMENSION AND THE ROPING FACTOR : 8. 3.75 .4433
ENTER THEIR DC, DO AND DI VALUES : 25.4 8.9 10.2
ENTER THEIR FD50, FSPLIT AND FPRESS VALUES : 1. 2.761 .4493
ENTER THEIR FEM AND FVH VALUES : .615 78.7
UNIT # 3, COMPLETE PLITT MODEL
ENTER NO. OF CYCLONES IN PACK,
THEIR APEX DIMENSION AND THE ROPING FACTOR : 8. 4.25 .4433
ENTER THEIR DC, DO AND DI VALUES : 25.4 8.9 10.2
ENTER THEIR FD50, FSPLIT AND FPRESS VALUES : 1. 2.761 .4493
ENTER THEIR FEM AND FVH VALUES : .615 78.7
     DESCRIPTION OF THE FEED STREAM
ENTER SOLID AND WATER FLOW RATES : 316.5 799.37
ENTER PASSING SIEVE APERTURES (MICRONS) :
297. 212. 150. 106. 75. 53. 45.ENTER THE SPECIFIC GRAVITIES ( 1 VALUES)
2.8
FOR EACH SPECIFIC GRAVITY
ENTER  7 MASS PERCENTAGES
(I.E.  7 VALUES PER LINE, ONE LINE PER SP. G.) :
4.9 11.7 14.1 13. 9.4 6.2 40.7
ENTER WATER ADDITION # 6 FLOWRATE : 10.
ENTER WATER ADDITION #11 FLOWRATE : 170.

        MULTICYCLONING CIRCUIT SIMULATION



UNIT #  6
    SFR=  606.65
    WFR= 1243.92----------------------------------------
     %S=   32.78                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=    0.00                   !
                        WFR=   10.00----------         !
                         %S=    0.00         !         !
                                         !   !         !   !
                                         !   V         V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  606.21
                                                  !---------->WFR= 1254.02
                                                               %S=   32.59
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
                           MIXER UNIT

        SCREENS            PRODUCT
                       %CUM      %RET

       297.-  212.   100.000     2.666
       212.-  150.    97.334     7.224
       150.-  106.    90.110    13.477
       106.-   75.    76.633    19.579
        75.-   53.    57.054    13.811
        53.-   45.    43.243     7.765
        45.-    0.    35.478    35.478
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

UNIT #  1
                       ALL MASS FLOWRATES IN TONNES/HOUR

                                              SOLIDS  375.2
                                 --> OVERFLOW WATER  1003.2
                                !             SLURRY 1378.4
                         -------!-------
        SOLIDS  606.2    ! HYDROCYCLONE!
   FEED WATER  1254.0 -->!             !
        SLURRY 1860.2    !  D50C= 120.0!               NO. OF UNITS  8
                         !     M= 3.800!
                         !    RF= 20.0%!               DU=   3.18 CM
                         \             /
                          \           /
                           \         /
                            \       /
                             \     /
                              \   /
                               \ /
                                !           SOLIDS  231.0
                                V UNDERFLOW WATER   250.8
                                            SLURRY  481.8

   TO CONTINUE, ENTER ANY DIGIT AND <CR>1
............................................................
          PARTICLE SIZE ANALYSES OF FLOWSTREAMS
          --------------------------------------
         PARTICLE SIZE           WEIGHT  PERCENT
            MICRONS        FEED     UNDERFLOW   OVERFLOW
         -------------      ----     ---------   --------

          297 -    212       2.67       7.00        .00
          212 -    150       7.22      17.92        .64
          150 -    106      13.48      23.54       7.28
          106 -     75      19.58      19.35      19.72
           75 -     53      13.81       9.04      16.75
           53 -     45       7.76       4.45       9.81
           45 -      0      35.48      18.71      45.80
                           ------     ------     ------
                           100.00     100.00     100.00

         NO. OF SG FRACTIONS = 1
         SOLIDS SG RANGED FROM  2.80 TO  2.80
............................................................
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
   297. !                                                                    O
   212. !                                                               U  F O
   150. !                                                   U         F      O
   106. !                                  U                 F         O     !
    75. !                    U                 F          O                  !
    53. !              U             F        O                              !
    45. !           U           F      O                                     !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

UNIT #  2
                       ALL MASS FLOWRATES IN TONNES/HOUR

                                              SOLIDS  154.7
                                 --> OVERFLOW WATER   855.0
                                !             SLURRY 1009.7
                        --------!-------
        SOLIDS  375.2    ! HYDROCYCLONE!
   FEED WATER  1003.2 -->!             !
        SLURRY 1378.4    !  D50C=  44.6!               NO. OF UNITS  8
                         !     M= 1.378!
                         !    RF= 14.8%!               DU=   3.75 CM
                         \             /               DC=  25.40 CM
                          \           /                DO=   8.90 CM
                           \         /                 DI=  10.20 CM
            PREDICTED       \       /                 FVH=  78.70 CM
            PRESSURE         \     /
            DROP = 177.5 KPA  \   /
                               \ /
                                !           SOLIDS  220.5
                                V UNDERFLOW WATER   148.2
                                            SLURRY  368.7

   TO CONTINUE, ENTER ANY DIGIT AND <CR>1
...........................................................
          PARTICLE SIZE ANALYSES OF FLOWSTREAMS
          --------------------------------------
         PARTICLE SIZE         WEIGHT  PERCENT
            MICRONS         FEED     UNDERFLOW   OVERFLOW
         -------------      ----     ---------   --------
          297 -    212       .00        .00        .00
          212 -    150       .64       1.08        .01
          150 -    106      7.28      11.84        .78
          106 -     75     19.72      29.00       6.48
           75 -     53     16.75      20.63      11.22
           53 -     45      9.81      10.22       9.22
           45 -      0     45.80      27.22      72.29
                           ------     ------     ------
                           100.00     100.00     100.00

         NO. OF SG FRACTIONS = 1
         SOLIDS SG RANGED FROM  2.80 TO  2.80
...........................................................
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
   297. !                                                                    O
   212. !                                                                    O
   150. !                                                                   UO
   106. !                                                           U  F    O!
    75. !                                       U         F             O    !
    53. !                        U            F                 O            !
    45. !                 U            F                  O                  !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

UNIT #  7
    SFR=  231.00
    WFR=  250.80----------------------------------------
     %S=   47.95                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=    0.00                   !
                        WFR=  170.00----------         !
                         %S=    0.00         !         !
                                         !   !         !   !
                                         !   V         V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  231.00
                                                  !---------->WFR=  420.80
                                                               %S=   35.44
TO CONTINUE, ENTER ANY DIGIT AND <CR>1


                           MIXER UNIT

        SCREENS            PRODUCT
                       %CUM      %RET

       297.-  212.   100.000     6.996
       212.-  150.    93.004    17.918
       150.-  106.    75.085    23.541
       106.-   75.    51.544    19.352
        75.-   53.    32.192     9.035
        53.-   45.    23.156     4.447
        45.-    0.    18.710    18.710
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
UNIT #  3
                       ALL MASS FLOWRATES IN TONNES/HOUR

                                              SOLIDS   69.6
                                 --> OVERFLOW WATER   296.4
                                !             SLURRY  366.0
                         -------!-------
        SOLIDS  231.0    ! HYDROCYCLONE!
   FEED WATER   420.8 -->!             !
        SLURRY  651.8    !  D50C=  78.7!               NO. OF UNITS  8
                         !     M= 1.206!
                         !    RF= 29.6%!               DU=   4.25 CM
                         \             /               DC=  25.40 CM
                          \           /                DO=   8.90 CM
                           \         /                 DI=  10.20 CM
            PREDICTED       \       /                 FVH=  78.70 CM
            PRESSURE         \     /
            DROP =  41.1 KPA  \   /
                               \ /
                                !           SOLIDS  161.4
                                V UNDERFLOW WATER   124.4
                                            SLURRY  285.8

   TO CONTINUE, ENTER ANY DIGIT AND <CR>1
...........................................................
          PARTICLE SIZE ANALYSES OF FLOWSTREAMS
          --------------------------------------
         PARTICLE SIZE           WEIGHT  PERCENT
            MICRONS         FEED     UNDERFLOW   OVERFLOW
         -------------      ----     ---------   --------

          297 -    212       7.00       9.61        .94
          212 -    150      17.92      22.92       6.31
          150 -    106      23.54      26.87      15.83
          106 -     75      19.35      19.06      20.03
           75 -     53       9.04       7.61      12.33
           53 -     45       4.45       3.33       7.03
           45 -      0      18.71      10.60      37.52
                           ------     ------     ------
                           100.00     100.00     100.00

         NO. OF SG FRACTIONS = 1
         SOLIDS SG RANGED FROM  2.80 TO  2.80
...........................................................
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
   297. !                                                                    0
   212. !                                                             U F   0!
   150. !                                             U     F           0    !
   106. !                          U       F                 0               !
    75. !             U      F                 0                             !
    53. !        U     F              0                                      !
    45. !     U     F            0                                           !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
UNIT #  4
    SFR=  316.50
    WFR=  799.37----------------------------------------
     %S=   28.36                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=   69.60                   !
                        WFR=  296.39----------         !
                         %S=   19.02             !     !
                                             !   !     !   !
                                             !   V     V   !
                                             !_________________!
                                             !                 !
                                             !      MIXER      !
                                             !_________________!
                                                      !
                                                      !           SFR=   386.10
                                                      !----------->WFR= 1095.76
                                                                   %S=    26.06
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                           MIXER UNIT

        SCREENS            PRODUCT
                       %CUM        %RET

       297.-  212.  100.000     4.187
       212.-  150.   95.813    10.729
       150.-  106.   85.084    14.412
       106.-   75.   70.672    14.267
        75.-   53.   56.405     9.929
        53.-   45.   46.477     6.349
        45.-    0.   40.127    40.127
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

UNIT #  5
    SFR=  386.10
    WFR= 1095.76----------------------------------------
     %S=   26.06                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=  220.55                   !
                        WFR=  148.17----------         !
                         %S=   59.82             !     !
                                             !   !     !   !
                                             !   V     V   !
                                             !_________________!
                                             !                 !
                                             !      MIXER      !
                                             !_________________!
                                                      !
                                                      !           SFR=   606.65
                                                      !----------->WFR= 1243.92
                                                                   %S=    32.78
```

```
TO CONTINUE, ENTER ANY DIGIT AND <CR>1


                           MIXER UNIT

        SCREENS              PRODUCT
                        %CUM       %RET

       297.-  212.    100.000      2.665
       212.-  150.     97.335      7.222
       150.-  106.     90.114     13.478
       106.-   75.     76.636     19.624
        75.-   53.     57.012     13.819
        53.-   45.     43.193      7.756
        45.-    0.     35.436     35.436
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

DO YOU WISH TO MODIFY YOUR DATA FILE?
TYPE YES OR NO - yes

     DATA FILE MODIFICATION PROGRAM

   MULTICYCLONING CIRCUIT SIMULATION
ENTER NEW RUN IDENTIFICATION
(OR K TO KEEP THE SAME ONE)
k

POSSIBLE MODEL TYPES :
    1 = COMPLETE PLITT MODEL
    2 = FIXED D50C, RF AND EM VALUES
    3 = FIXED RF AND EFFICIENCY VALUES
UNIT #   MODEL TYPE
  1          2
  2          1
  3          1
UNIT # 1 PARAMETERS: HCONE2 MODULE
REC. #1, NUMBER OF CYC., APEX DIAM.(CM), ROPING FACTOR
8. 3.175 .4433
REC. #2, D50C VALUES, ONE PER SPECIFIC GRAVITY
120.
REC. #3, EM AND RF(%) VALUES
3.8 20.
ENTER A REC. # OR D(ISPLAY, N(ONE, E(XIT : 2

ENTER NEW REC. # 2
150

ENTER A REC. # OR D(ISPLAY, N(ONE, E(XIT : e
ENTER A NAME FOR YOUR NEW DATA SET
data2
```

```
        MULTICYCLONING CIRCUIT SIMULATION


UNIT #  6
    SFR=  632.79
    WFR= 1230.93-----------------------------------------
     %S=   33.95                                        !
                                                        !
                                                        !
                                                        !
                                                        !
                                                        !
                        SFR=    0.00                    !
                        WFR=   10.00-----------         !
                         %S=    0.00          !         !
                                          !   !         !   !
                                          !   V         V   !
                                          !_________________!
                                          !                 !
                                          !      MIXER      !
                                          !_________________!
                                                   !
                                                   !           SFR=  632.33
                                                   !---------->WFR= 1241.04
                                                                %S=   33.75
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                           MIXER UNIT

        SCREENS            PRODUCT
                       %CUM      %RET

       297.-  212.  100.000     2.543
       212.-  150.   97.457     8.132
       150.-  106.   89.324    17.132
       106.-   75.   72.193    20.200
        75.-   53.   51.993    12.351
        53.-   45.   39.642     6.893
        45.-    0.   32.749    32.749
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
UNIT #  1
                       ALL MASS FLOWRATES IN TONNES/HOUR

                                              SOLIDS  422.7
                                 --> OVERFLOW WATER   992.8
                                !             SLURRY 1415.5
                         -------!-------
        SOLIDS  632.3    ! HYDROCYCLONE!
   FEED WATER  1241.0 -->!             !
        SLURRY 1873.4    !  D50C= 150.0!               NO. OF UNITS  8
                         !      M= 3.800!
                         !     RF= 20.0%!               DU=   3.18 CM
                         \             /
                          \           /
                           \         /
                            \       /
                             \     /
                              \   /
                               \ /
                                !           SOLIDS  209.6
                                V UNDERFLOW WATER   248.2
                                            SLURRY  457.8

   TO CONTINUE, ENTER ANY DIGIT AND <CR>1
...........................................................
          PARTICLE SIZE ANALYSES OF FLOWSTREAMS
          --------------------------------------
         PARTICLE SIZE           WEIGHT  PERCENT
            MICRONS         FEED     UNDERFLOW   OVERFLOW
         -------------      ----     ---------   --------
          297 -    212       2.54       7.64        .02
          212 -    150       8.13      19.32       2.58
          150 -    106      17.13      23.78      13.84
          106 -     75      20.20      16.90      21.84
           75 -     53      12.35       8.25      14.38
           53 -     45       6.89       4.32       8.17
           45 -      0      32.75      19.80      39.17
                           ------     ------     ------
                           100.00     100.00     100.00

         NO. OF SG FRACTIONS = 1
         SOLIDS SG RANGED FROM  2.80 TO  2.80
...........................................................
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
   297. !                                                                    O
   212. !                                                               U  F O
   150. !                                                 U          F     O !
   106. !                                U               F       O           !
    75. !                     U            F      O                          !
    53. !               U          F    O                                    !
    45. !            U        F   O                                          !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
UNIT #  2
                       ALL MASS FLOWRATES IN TONNES/HOUR

                                              SOLIDS  165.5
                                 --> OVERFLOW WATER   854.9
                                !             SLURRY 1020.4
                         -------!-------
        SOLIDS  422.7    ! HYDROCYCLONE!
   FEED WATER   992.8 -->!             !
        SLURRY 1415.5    !  D50C=  48.6!               NO. OF UNITS  8
                         !     M= 1.374!
                         !    RF= 13.9%!               DU=   3.75 CM
                          \            /               DC=  25.40 CM
                           \          /                DO=   8.90 CM
                            \        /                 DI=  10.20 CM
            PREDICTED       \       /                 FVH=  78.70 CM
            PRESSURE         \     /
            DROP = 180.7 KPA  \   /
                               \ /
                                !           SOLIDS  257.2
                                V UNDERFLOW WATER   137.9
                                            SLURRY  395.1

   TO CONTINUE, ENTER ANY DIGIT AND <CR>1
...........................................................
          PARTICLE SIZE ANALYSES OF FLOWSTREAMS
          --------------------------------------

         PARTICLE SIZE           WEIGHT  PERCENT
            MICRONS         FEED     UNDERFLOW   OVERFLOW
         -------------      ----     ---------   --------
          297 -    212        .02        .03        .00
          212 -    150       2.58       4.19        .08
          150 -    106      13.84      21.32       2.21
          106 -     75      21.84      29.83       9.43
           75 -     53      14.38      16.16      11.62
           53 -     45       8.17       7.68       8.92
           45 -      0      39.17      20.79      67.74
                           ------     ------     ------
                           100.00     100.00     100.00

         NO. OF SG FRACTIONS = 1
         SOLIDS SG RANGED FROM  2.80 TO  2.80
...........................................................
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
   297. !                                                                    0
   212. !                                                                    0
   150. !                                                                 UF 0
   106. !                                                  U     F         0 !
    75. !                             U           F                  0       !
    53. !                  U            F                    0               !
    45. !             U           F                   0                      !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
UNIT #  7
    SFR=  209.64
    WFR=  248.21----------------------------------------
     %S=   45.79                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=    0.00                   !
                        WFR=  170.00----------         !
                         %S=    0.00         !         !
                                         !   !         !   !
                                         !   V         V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  209.64
                                                  !---------->WFR=  418.21
                                                               %S=   33.39
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                           MIXER UNIT

        SCREENS            PRODUCT
                       %CUM      %RET

       297.-  212.   100.000     7.636
       212.-  150.    92.364    19.322
       150.-  106.    73.041    23.776
       106.-   75.    49.266    16.895
        75.-   53.    32.370     8.252
        53.-   45.    24.119     4.322
        45.-    0.    19.797    19.797
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

UNIT #  3
                       ALL MASS FLOWRATES IN TONNES/HOUR

                                              SOLIDS   59.1
                                 --> OVERFLOW WATER   293.6
                                !             SLURRY  352.7
                         -------!-------
        SOLIDS  209.6    ! HYDROCYCLONE!
   FEED WATER   418.2 -->!             !
        SLURRY  627.8    !  D50C=   73.6!               NO. OF UNITS   8
                         !     M= 1.210!
                         !    RF= 29.8%!               DU=   4.25 CM
                         \             /               DC=  25.40 CM
                          \           /                DO=   8.90 CM
                           \         /                 DI=  10.20 CM
            PREDICTED       \       /                 FVH=  78.70 CM
            PRESSURE         \     /
            DROP =  39.4 KPA  \   /
                               \ /
                                !           SOLIDS  150.5
                                V UNDERFLOW WATER   124.6
                                            SLURRY  275.1
```

```
   TO CONTINUE, ENTER ANY DIGIT AND <CR>1
...........................................................
          PARTICLE SIZE ANALYSES OF FLOWSTREAMS
          --------------------------------------
         PARTICLE SIZE           WEIGHT  PERCENT
            MICRONS         FEED     UNDERFLOW   OVERFLOW
         -------------      ----     ---------   --------
          297 -    212       7.64      10.30        .85
          212 -    150      19.32      24.50       6.15
          150 -    106      23.78      27.11      15.30
          106 -     75      16.90      16.70      17.40
           75 -     53       8.25       6.99      11.47
           53 -     45       4.32       3.25       7.05
           45 -      0      19.80      11.16      41.79
                           ------     ------     ------
                           100.00     100.00     100.00

         NO. OF SG FRACTIONS = 1
         SOLIDS SG RANGED FROM  2.80 TO  2.80
...........................................................
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        -------+------+------+------+------+------+------+------+------+------+
   297. !                                                                     O
   212. !                                                              U F   O!
   150. !                                             U    F             O    !
   106. !                          U      F                   O               !
    75. !              U       F                  O                           !
    53. !         U      F                O                                   !
    45. !       U     F              O                                        !
        -------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
UNIT #  4
    SFR=  316.50
    WFR=  799.37-----------------------------------------
     %S=   28.36                                        !
                                                        !
                                                        !
                                                        !
                                                        !
                                                        !
                        SFR=   59.11                    !
                        WFR=  293.64-----------         !
                         %S=   16.76          !         !
                                          !   !         !   !
                                          !   V         V   !
                                          !_________________!
                                          !                 !
                                          !     MIXER       !
                                          !_________________!
                                                   !
                                                   !          SFR=  375.61
                                                   !--------->WFR= 1093.01
                                                               %S=   25.58
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
                           MIXER UNIT

        SCREENS            PRODUCT
                       %CUM       %RET

       297.-  212.   100.000     4.263
       212.-  150.    95.737    10.826
       150.-  106.    84.911    14.288
       106.-   75.    70.623    13.692
        75.-   53.    56.931     9.726
        53.-   45.    47.204     6.333
        45.-    0.    40.871    40.871
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

UNIT #  5
    SFR=  375.61
    WFR= 1093.01----------------------------------------
     %S=   25.58                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=  257.19                   !
                        WFR=  137.92----------         !
                         %S=   65.09         !         !
                                         !   !         !   !
                                         !   V         V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  632.79
                                                  !---------->WFR= 1230.93
                                                               %S=   33.95
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                           MIXER UNIT

        SCREENS            PRODUCT
                       %CUM       %RET

       297.-  212.   100.000     2.542
       212.-  150.    97.458     8.129
       150.-  106.    89.329    17.146
       106.-   75.    72.183    20.250
        75.-   53.    51.933    12.341
        53.-   45.    39.592     6.882
        45.-    0.    32.710    32.710
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

DO YOU WISH TO MODIFY YOUR DATA FILE?
TYPE YES OR NO - yes
ENTER NAME OF DATA SET TO BE REVIEWED
data2
```

```
      DATA FILE MODIFICATION PROGRAM

   MULTICYCLONING CIRCUIT SIMULATION
ENTER NEW RUN IDENTIFICATION
(OR K TO KEEP THE SAME ONE)
k

POSSIBLE MODEL TYPES :
    1 = COMPLETE PLITT MODEL
    2 = FIXED D50C, RF AND EM VALUES
    3 = FIXED RF AND EFFICIENCY VALUES
UNIT #   MODEL TYPE
  1           2
  2           1
  3           1
UNIT # 1 PARAMETERS: HCONE2 MODULE
REC. #1, NUMBER OF CYC., APEX DIAM.(CM), ROPING FACTOR
8. 3.175 .4433
REC. #2, D50C VALUES, ONE PER SPECIFIC GRAVITY
150.
REC. #3, EM AND RF(%) VALUES
3.8 20.
ENTER A REC. # OR D(ISPLAY, N(ONE, E(XIT : N

UNIT # 2 PARAMETERS: HCONE1 MODULE
REC. #1, NUMBER OF CYC., APEX DIAM.(CM), ROPING FACTOR
8. 3.75 .4433
REC. #2, CYC. DIAM., VORTEX DIAM., INLET DIAM. (CM)
25.4 8.9 10.2
REC. #3, FD50, FSPLIT, FPRESS VALUES
1. 2.761 .4493
REC. #4, FEM AND FVH VALUES
.615 78.7
ENTER A REC. # OR D(ISPLAY, N(ONE, E(XIT : n

UNIT # 3 PARAMETERS: HCONE1 MODULE
REC. #1, NUMBER OF CYC., APEX DIAM.(CM), ROPING FACTOR
8. 4.25 .4433
REC. #2, CYC. DIAM., VORTEX DIAM., INLET DIAM. (CM)
25.4 8.9 10.2
REC. #3, FD50, FSPLIT, FPRESS VALUES
1. 2.761 .4493
REC. #4, FEM AND FVH VALUES
.615 78.7
```

```
ENTER A REC. # OR D(ISPLAY, N(ONE, E(XIT : n

REC. #1, SOLID AND WATER FEED FLOWRATES
316.5 799.37
REC. #2, PASSING SIEVE APERTURES (MICRONS)
297. 212. 150. 106. 75. 53. 45.
REC. #3, SPECIFIC GRAVITIES
2.8
FEED SIZE DISTRIBUTIONS
REC. # 4 FOR SPECIFIC GRAVITY  1
4.9 11.7 14.1 13. 9.4 6.2 40.7
ENTER A REC. # OR D(ISPLAY, N(ONE, E(XIT : 1

ENTER NEW REC. # 1
316.5 650.37

ENTER A REC. # OR D(ISPLAY, N(ONE, E(XIT : e
ENTER A NAME FOR YOUR NEW DATA SET
data3

        MULTICYCLONING CIRCUIT SIMULATION



UNIT #  6
    SFR=  603.26
    WFR= 1042.37----------------------------------------
     %S=   36.66                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=    0.00                   !
                        WFR=   10.00----------         !
                         %S=    0.00         !         !
                                         !   !         !   !
                                         !   V         V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  602.81
                                                  !---------->WFR= 1052.46
                                                               %S=   36.42
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
                           MIXER UNIT

        SCREENS                PRODUCT
                       %CUM      %RET

       297.-  212.   100.000     2.700
       212.-  150.    97.300     8.681
       150.-  106.    88.620    17.574
       106.-   75.    71.045    19.188
        75.-   53.    51.857    11.698
        53.-   45.    40.159     6.663
        45.-    0.    33.496    33.496
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

UNIT #  1
                       ALL MASS FLOWRATES IN TONNES/HOUR

                                              SOLIDS  400.1
                                 --> OVERFLOW WATER   842.0
                                 !            SLURRY 1242.1
                         --------!-------
        SOLIDS  602.8    ! HYDROCYCLONE!
   FEED WATER  1052.5 -->!             !
        SLURRY 1655.3    !  D50C= 150.0!              NO. OF UNITS  8
                         !     M= 3.800!
                         !    RF= 20.0%!              DU=    3.18 CM
                                       /
                         \            /
                          \          /
                           \        /
                            \      /
                             \    /
                              \  /
                                !            SOLIDS  202.7
                                V UNDERFLOW WATER    210.5
                                             SLURRY  413.2

   TO CONTINUE, ENTER ANY DIGIT AND <CR>1
...........................................................
          PARTICLE SIZE ANALYSES OF FLOWSTREAMS
          --------------------------------------
         PARTICLE SIZE           WEIGHT  PERCENT
            MICRONS        FEED     UNDERFLOW   OVERFLOW
         -------------     ----     ---------   --------
          297  -    212     2.70        7.99         .02
          212  -    150     8.68       20.34        2.78
          150  -    106    17.57       24.05       14.29
          106  -     75    19.19       15.83       20.89
           75  -     53    11.70        7.71       13.72
           53  -     45     6.66        4.12        7.95
           45  -      0    33.50       19.97       40.35
                          ------      ------      ------
                          100.00      100.00      100.00

         NO. OF SG FRACTIONS = 1
         SOLIDS SG RANGED FROM  2.80 TO  2.80
...........................................................
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
   297. !                                                                    O
   212. !                                                              U   F O
   150. !                                                U           F     O !
   106. !                               U                F       O           !
    75. !                    U             F      O                          !
    53. !               U          F     O                                   !
    45. !            U        F    O                                         !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

UNIT #  2
                       ALL MASS FLOWRATES IN TONNES/HOUR

                                              SOLIDS  173.1
                                 --> OVERFLOW WATER   713.3
                                !             SLURRY  886.4
                         -------!-------
        SOLIDS  400.1    ! HYDROCYCLONE!
   FEED WATER   842.0 -->!             !
        SLURRY 1242.1    !  D50C=  56.5!               NO. OF UNITS  8
                         !     M= 1.379!
                         !    RF= 15.3%!              DU=    3.75 CM
                         \             /              DC=   25.40 CM
                          \           /               DO=    8.90 CM
                           \         /                DI=   10.20 CM
            PREDICTED       \       /                FVH=   78.70 CM
            PRESSURE         \     /
            DROP = 139.5 KPA  \   /
                               \ /
                                !           SOLIDS  227.0
                                V UNDERFLOW WATER   128.7
                                            SLURRY  355.7

   TO CONTINUE, ENTER ANY DIGIT AND <CR>1
............................................................
          PARTICLE SIZE ANALYSES OF FLOWSTREAMS
          --------------------------------------
         PARTICLE SIZE           WEIGHT  PERCENT
            MICRONS         FEED     UNDERFLOW   OVERFLOW
         -------------      ----     ---------   --------
         297 -    212        .02        .03         .00
         212 -    150       2.78       4.76         .17
         150 -    106      14.29      22.69        3.29
         106 -     75      20.89      28.55       10.84
          75 -     53      13.72      15.13       11.87
          53 -     45       7.95       7.30        8.81
          45 -      0      40.35      21.53       65.02
                           ------     ------      ------
                           100.00     100.00      100.00

         NO. OF SG FRACTIONS = 1
         SOLIDS SG RANGED FROM  2.80 TO  2.80
............................................................
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
   297. !                                                                    0
   212. !                                                                    0
   150. !                                                                 UF 0
   106. !                                                 U      F         0 !
    75. !                             U           F                0         !
    53. !                  U             F                 0                 !
    45. !             U            F                0                        !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

UNIT #  7
    SFR=  202.67
    WFR=  210.49----------------------------------------
     %S=   49.05                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=    0.00                   !
                        WFR=  170.00----------         !
                         %S=    0.00         !         !
                                         !   !         !   !
                                         !   V         V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  202.67
                                                  !---------->WFR=  380.49
                                                               %S=   34.75
TO CONTINUE, ENTER ANY DIGIT AND <CR>1


                           MIXER UNIT

        SCREENS            PRODUCT
                       %CUM      %RET

       297.-  212.   100.000     7.993
       212.-  150.    92.007    20.338
       150.-  106.    71.669    24.050
       106.-   75.    47.619    15.826
        75.-   53.    31.793     7.707
        53.-   45.    24.086     4.120
        45.-    0.    19.966    19.966
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
UNIT #  3
                       ALL MASS FLOWRATES IN TONNES/HOUR

                                              SOLIDS   59.7
                                 --> OVERFLOW WATER   263.3
                                !             SLURRY  323.0
                         -------!-------
        SOLIDS  202.7    ! HYDROCYCLONE!
   FEED WATER   380.5 -->!             !
        SLURRY  583.2    !  D50C=  80.4!               NO. OF UNITS  8
                         !     M= 1.206!
                         !    RF= 30.8%!               DU=   4.25 CM
                         \             /               DC=  25.40 CM
                          \           /                DO=   8.90 CM
                           \         /                 DI=  10.20 CM
            PREDICTED       \       /                 FVH=  78.70 CM
            PRESSURE         \     /
            DROP =  34.0 KPA  \   /
                               \ /
                                !           SOLIDS  142.9
                                V UNDERFLOW WATER   117.2
                                            SLURRY  260.1

   TO CONTINUE, ENTER ANY DIGIT AND <CR>1
...........................................................
          PARTICLE SIZE ANALYSES OF FLOWSTREAMS
          --------------------------------------

         PARTICLE SIZE           WEIGHT  PERCENT
            MICRONS         FEED     UNDERFLOW   OVERFLOW
         -------------      ----     ---------   --------

          297 -    212       7.99      10.85       1.16
          212 -    150      20.34      25.68       7.56
          150 -    106      24.05      27.09      16.77
          106 -     75      15.83      15.42      16.80
           75 -     53       7.71       6.45      10.71
           53 -     45       4.12       3.08       6.61
           45 -      0      19.97      11.43      40.39
                           ------     ------     ------
                           100.00     100.00     100.00

         NO. OF SG FRACTIONS = 1
         SOLIDS SG RANGED FROM  2.80 TO  2.80
...........................................................
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

          CUMULATIVE WEIGHT %  VS  PASSING SIEVE APERTURE
          -----------------------------------------------

              10     20     30     40     50     60     70     80     90    100
        ------+------+------+------+------+------+------+------+------+------+
   297. !                                                                    0
   212. !                                                            U F    0!
   150. !                                          U     F             0     !
   106. !                       U       F                  0                 !
    75. !             U      F                 0                             !
    53. !        U      F               0                                    !
    45. !      U     F             0                                         !
        ------+------+------+------+------+------+------+------+------+------+
              10     20     30     40     50     60     70     80     90    100
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
UNIT #  4
    SFR=  316.50
    WFR=  650.37----------------------------------------
     %S=   32.73                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=   59.73                   !
                        WFR=  263.30----------         !
                         %S=   18.49         !         !
                                         !   !         !   !
                                         !   V         V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  376.23
                                                  !---------->WFR=  913.67
                                                               %S=   29.17
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                           MIXER UNIT

        SCREENS            PRODUCT
                       %CUM      %RET

       297.-  212.   100.000     4.307
       212.-  150.    95.693    11.042
       150.-  106.    84.651    14.524
       106.-   75.    70.127    13.603
        75.-   53.    56.524     9.609
        53.-   45.    46.915     6.265
        45.-    0.    40.650    40.650
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
UNIT #  5
    SFR=  376.23
    WFR=  913.67----------------------------------------
     %S=   29.17                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=  227.03                   !
                        WFR=  128.70----------         !
                         %S=   63.82         !         !
                                         !   !         !   !
                                         !   V         V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  603.26
                                                  !---------->WFR= 1042.37
                                                               %S=   36.66
```

```
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                             MIXER UNIT

        SCREENS              PRODUCT
                         %CUM        %RET

       297.-  212.    100.000       2.698
       212.-  150.     97.302       8.679
       150.-  106.     88.623      17.596
       106.-   75.     71.027      19.230
        75.-   53.     51.797      11.688
        53.-   45.     40.109       6.653
        45.-    0.     33.456      33.456
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

DO YOU WISH TO MODIFY YOUR DATA FILE?
TYPE YES OR NO - no
```

3. SYSTEM DOCUMENTATION

3.1 COMPUTER EQUIPMENT

HCONEX runs on a CDC CYBER 730 computer with a maximum 70K words (octal) of core memory available for time-sharing jobs. HCONEX can also run on other computers with very minor modifications. A version of HCONEX has been implemented on an IBM-PC microcomputer.

3.2 PERIPHERAL EQUIPMENT

A time-sharing terminal is normally used to run this conversational program. Data can be stored on disk files.

3.3 SOURCE PROGRAM

A complete listing of the program can be obtained from:

CANMET,
Energy, Mines and Resources,
Technology Information Division,
555 Booth Street
Ottawa, Ontario
K1A 0G1.

3.4 VARIABLES AND SUBROUTINES

3.4.1 Variables

A list of variables is given in the prologues of each program and subroutine. Most variables are transmitted as arguments of subroutines. A labelled COMMON area of 1K words is reserved for internal storage of local variables.

Three variables, PARAM, FLOW, and OPT, used in the HCONE program should be understood before any modification to the code is made. Array PARAM contains the unit parameter values: a sector of 13 + NG × (NS + 1) components (NG is the number of specific gravity intervals and NS the number of size intervals) is reserved for each hydrocyclone unit. The structure of each sector depends on the model type and is given in the prologues of subroutines HCONE1, HCONE2, and HCONE3.

The array FLOW contains data about the streams: a sector of 5 + NS × NG components is reserved for each stream. Each sector is partitioned as follows: components one to three are never used; components four and five are the solids and water flow rates; the remaining NS components are the solids distribution in wt % which are within each specific gravity interval.

Array OPT is composed of one component per unit.

3.4.2 Main Programs and Associated Subroutines

The package is composed of three main programs, each of which has its own subroutines. These are as follows:

3.4.2.1 HCONEX

HCONEX:	(main program) to create the data file and write HCONE main program and CALLUN subroutine code.
HCONIN:	to prompt for data entry.
DATAP:	to write data file from user's entries.
WRTUN:	to write a FORTRAN CALL statement to a particular unit module subroutine.
DEFIN:	to define arrays ORIG and DEST as required by subroutine COD.
WRTEX:	to write the HCONE main program FORTRAN code, the subroutine CALLUN statement, and its DIMENSION statements.
COD:	to search for a computation path from the stream connection matrix and to organize the writing of subroutine CALLUN body. COD is a modified version of FLOWAN described with the SPLITX package.
CYCLE, MAXNET, NODES, RANK, BITOFF, TEAR, TEAROR and PATH:	same as GRNDEX Section 3.4.2.1.
CODEX:	to provide an interfacing subroutine between HCONEX and COD.
WRTOUT:	to write a FORTRAN CALL statement to a particular unit display subroutine.

3.4.2.2 HCONE

HCONE:	(main program) to perform the simulation and print out results (written by HCONEX subroutines).
CALLUN:	to organize the computation path and print out results (written by HCONEX subroutines).
HCONE1:	to simulate the hydrocyclone using the complete Plitt model.

HCONE2:	to simulate the hydrocyclone using the Plitt model with fixed D50C, EM, and Rf parameters.
HCONE3:	to simulate the hydrocyclone using a fixed efficiency curve.
CYCOUT:	to print out HCONE module results.
PART:	to carry out a solid-solid separation using a ROSIN-RAMLER expression for a size-based partition curve including fines bypass.
INIT:	to initialize array FLOW.
MIXER2:	to simulate a two-stream mixer.
MIXER3:	to simulate a three-stream mixer.
MX2OUT:	to print out MIXER2 module results.
MX3OUT:	to print out MIXER3 module results.
PLOTSZ:	to display a scattergram of cumulative size distributions versus size intervals.
INITGR:	to initialize a plotting array used by PLOTSZ.
READAT:	to read the data file.

3.4.2.3 HCEDIT

HCEDIT:	(main program) to permit modifications to the data file.
NETW:	to read the stream connection matrix and search for water addition stream numbers.
HC1ALT:	to permit modification of HCONE1 parameter values.
HC2ALT:	to permit modification of HCONE2 parameter values.
HC3ALT:	to permit modification of HCONE3 parameter values.
FEDALT:	to permit modification of the feed stream characteristics.
WATALT:	to permit modification of the water addition stream flow rates.

3.5 DATA STRUCTURE

HCONEX main program reads data in free-field format from the input file, which can be declared as either the keyboard or a disk file. When the data entry is complete, data are written on unit 1. HCONE main program and subroutine CALLUN FORTRAN code are written on unit 3. Prompts are written to the output file.

HCONE main program reads data in free-field format from unit 5 and writes results on unit 6 declared as output file of HCONE. Answers to the prompts are read from the input file declared as the keyboard.

HCEDIT main program reads data in free-field format from unit 5 and writes corrected data on unit 6. Corrections are read from the input file declared as the keyboard, and prompts are written to the output file.

3.6 STORAGE REQUIREMENTS

Storage requirements depend on the size of the data set: number of units, number of streams, number of size intervals, and number of specific gravity intervals. It is smaller than 77K words on a CDC CYBER.

3.7 MAINTENANCE AND UPDATES

CANMET does not provide any formal maintenance of the programs. Several updates are expected to evolve from the source programs distributed to users. CANMET would appreciate receiving comments on modifications that could improve substantially the overall program performance. An expected improvement is automatic data-checking.

4. OPERATING DOCUMENTATION

4.1 OPERATOR INSTRUCTIONS

HCONEX has been developed on a CYBER 730 computer using NOS/BE batch-operating system and INTERCOM time-sharing system, and has been converted to an IBM-PC operating under MS.DOS.

4.2 OPERATING MESSAGES

Special messages, other than NOS/BE and INTERCOM messages, may be issued by subroutine COD if abnormal conditions occur during the search for the computation path (see description of the FLOWAN program in the SPLITX section of this chapter of the SPOC manual).

4.3 CONTROL CARDS

To run the three programs, HCONEX, HCONE, and HCEDIT together, job control cards are necessary. A sample control card deck is given in Figure 13. The Cyber Control Language (CCL) was used to write the four procedures that manage data files and programs according to the sequence of steps given in Figure 11.

Procedure HCONEX is the main procedure. It attaches all required files, including compiled programs and other procedures. Then HCONEX calls procedure HCONECT.

Procedure HCONECT runs the HCONEX program, compiles the HCONE program, combines the HCONE program with all its subroutines, and runs it. Then HCONECT returns control to HCONEX procedure.

At this stage, procedure HCONEX, using the modified data file, initiates a loop on both procedure HCEDIT, which runs the HCEDIT program, and procedure HCNAME, which runs the HCONE program.

4.4 ERROR RECOVERY

The program must be restarted after a fatal error. Most errors in data entry can be corrected by using the HCEDIT program.

4.5 RUN TIME

Run time depends on the size of the problem and on the number of times GRNDIT is used to correct data.

```
.PROC,HCONEX*I,DATA=(*N=INPUT,*F).
RETURN,B1,B2,BIN,LGO,HCONECT,HCEDIT,HCNAME,TAPE1,TAPE3.
IUSE,FINDMOI,FFLIPF,SPOC.
IGET,LGO=HCONEX.BIN,B2=HCONE.BIN,BIN=HCEDIT.BIN,HCONECT.CCL,HCEDIT.CCL.
IGET,HCNAME.CCL.
DAYFILE,OFF.
HCONECT,DATA.
IFNO,END.ODO YOU WISH TO MODIFY YOUR #DATA FILE?
DAYFILE,ON.
REVERT,ABORT.
ENDIF,END.
SET,R1=0.
REWIND,TAPE1.
HCEDIT,TAPE1.
WHILE,R1.LT.10,LOOP.
SET,R1=R1+1.
HCNAME.
ENDW,LOOP.
REMARK.  #DATA SET QUOTA EXCEEDED
REMARK.  END
DAYFILE,ON.
REVERT.
EXIT,U.
COPDF,XX.
REWIND,XX.
COPY,XX.
RETURN,XX.
DAYFILE,ON.
REVERT.

.PROC,HCEDIT*I,NAME"OF DATA SET TO BE REVIEWED :"=(*F).
BIN,,,NAME.
REWIND,TAPE6,NAME.
REVERT.

.PROC,HCNAME*I,A"NAME FOR YOUR NEW DATA SET :"=(*F).
RETURN,A.
COPY,TAPE6,A.
RETURN,TAPE6.
REWIND,A.
LGO,,,A.
EXIT,U.
REWIND,A.
IFNO,END.ODO YOU WISH TO MODIFY YOUR DATA FILE?
REVERT,ABORT.
ENDIF,END.
HCEDIT.
REVERT.

.PROC,HCONECT,FFL1.
LGO,FFL1.
REWIND,TAPE3,TAPE1,FFL1.
FTN,I=TAPE3,B=B1,L=0,PMD.
REWIND,B1.
RETURN,LGO,TAPE3.
COPYBF,B1,LGO.
BKSP,LGO.
COPYBF,B2,LGO.
REWIND,LGO.
LGO,,,TAPE1.
REWIND,TAPE1.
REVERT.
```

Fig. 13 — Control card deck for HCONEX

FLOTEX

FLOTATION PLANT SIMULATION EXECUTIVE

F. Flament, D. Laguitton

CONTENTS

TABLE

FIGURES

1. PROGRAM IDENTIFICATION

Program Title:	Flexible **FLOT**ation Circuit **EX**ecutive.
Program Code Names:	FLOTEX, FLTCLS, FLTDIT.
Author:	F. Flament.
Organization:	Energy, Mines and Resources, Canada Centre for Mineral and Energy Technology, Mineral Processing Laboratory.
Date:	June 1985.
Updates:	None.
Source Language:	CDC FORTRAN Extended 4.8 (American National Standard Institute FORTRAN X3.9 — 1966).
Availability:	Complete program listing is available from: CANMET, Energy, Mines and Resources, Technology Information Division, 555 Booth Street Ottawa, Ontario K1A 0G1.

2. ENGINEERING DOCUMENTATION

2.1 NARRATIVE DESCRIPTION

This program is an interactive executive for the simulation of flexible flowsheets for a flotation plant. It is composed of three independent programs which are run successively. The first program, called FLOTEX, permits data file creation and writes a preprocessor, i.e., a main FORTRAN program, called FLTCLS. This main program, written specifically for the data set (i.e., flowsheet structure, unit model parameters, and feed characteristics), organizes the simulation of the flotation plant by using a bank of available subroutines. The third program, called FLTDIT, permits some modifications to the data file. The allowed modifications are those that do not require the preprocessor to be changed. This is to provide the user with a chance to perform several simulations of the same flotation plant under different operating conditions. The program is capable of accepting up to 15 units. On each stream, a maximum of 20 size intervals and 10 specific-gravity intervals are possible. The units may be BANK (model of a bank of flotation cells), MIXER2 (2-stream mixer) or MIXER3 (3-stream mixer). Only one feed stream to the plant and up to 10 water addition streams are accepted.

2.2 METHOD OF SOLUTION

2.2.1 Preparation for Simulation

The flotation flowsheet should be analyzed in terms of streams and units. Units should be flotation cell banks or mixers, or both. (If the stream mixer has more than three streams, it should be decomposed into 2- and 3-stream mixers.) Each stream should be assigned a number starting with No. 1 for the feed stream to the plant. The parameter values for each flotation bank should be known, as well as the feed stream characteristics and the water addition flow rates. Finally, the data set should be given both a name and a title.

2.2.2 Flowsheet Analysis

The FLOTEX program organizes the flowsheet description. It first asks for the number of each type of unit and the total number of streams. Then for each unit, FLOTEX asks for the feed stream number, and the froth and tails stream numbers, if the unit is a flotation bank; or the model type (2- or 3-stream type), the feed stream numbers, and the discharge stream number, if the unit is a mixer. From these entries, a stream connection matrix is formed. The matrix is used by the subroutine COD to determine the order of simulation of the units and the tear streams that need to be initialized before simulation can start. The COD subroutine of FLOTEX is similar to the COD subroutine of GRNDEX Section 2.2.2, which is a slightly modified version of the FLOWAN program described with the SPLITX program in this chapter. The COD subroutine of FLOTEX only permits calls to flotation banks and mixer models.

2.2.3 Unit Modules

The unit modules are those described in Chapter 5 of the SPOC manual for the flotation bank units and Chapter 5.2 for the mixer units. The capabilities and limitations of the modules are also valid in FLOTEX.

2.3 PROGRAM CAPABILITIES

Limitations on problem size are dependent on array dimensions, computer memory, and program structure. A modification of the limiting values given here is not recommended:

Total number of units: 15
Water addition streams: 10
The feed stream should be given number 1
Number of size intervals: 20
Number of specific-gravity intervals: 10

After completion of a simulation run, modifications to the data can be made and the simulation program run again.

2.4 DATA ENTRY, PROGRAM OPTIONS, OUTPUT

The FLOTEX, FLTCLS, and FLTDIT interactive programs prompt for all data inputs. Data are entered in free format, i.e., in sequence using either blanks or commas as separators. Input data may also be read by FLOTEX from a batch data file on disk storage created during a previous run or by text editor.

The basic steps of a simulation session are given in Figure 14. The program options are the unit module options.

2.5 SAMPLE RUN

A sample run is reproduced here to illustrate a simulation session. The flowsheet is shown in Figure 15. Minerals are classified using three flotation banks. Hypothetical, though realistic, data used in the sample run are given in Table 14. After completion of the simulation run, a recovery computation is made among the main three streams. Modification of the data set was not attempted. In Section 2.5 of the description of HCONEX program in this chapter, details are given on HCEDIT program, which operates in a similar way to FLTDIT.

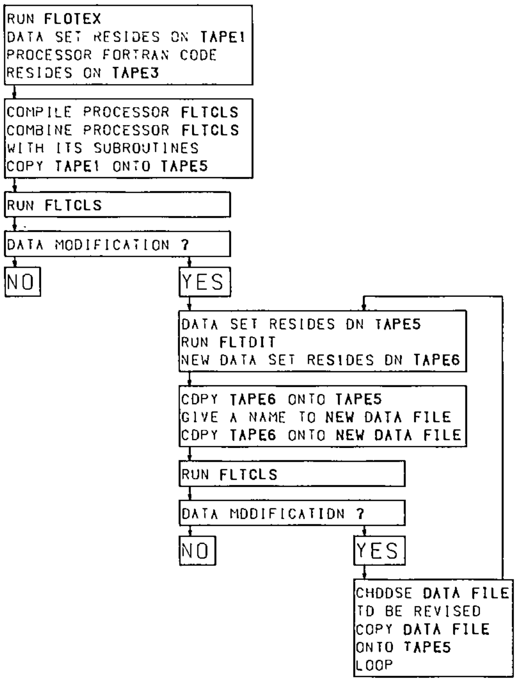


Fig. 14 — Linking FLOTEX, FLTCLS, FLTDIT, and the data files

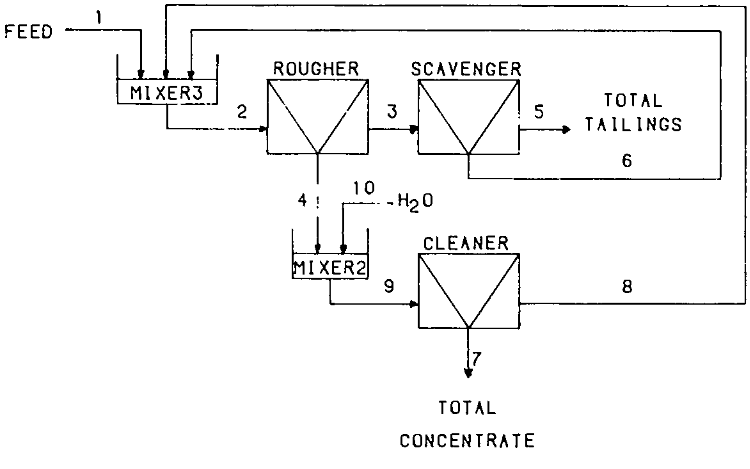


Fig. 15 — Flowsheet of FLOTEX sample run

Table 14 — FLOTEX sample run data

BANK: unit #1

ROUGHER
Water constant = 14.44; cell volume = 316.67 cu/ft; 7 cells
Flotation rate constants:

0.	0.	0.	0.
0.0017	0.0026	0.0001	0.0001
0.0668	0.1706	0.0013	0.0004
0.2123	0.4349	0.0034	0.0007
0.2660	0.5057	0.0029	0.0008
0.3187	0.3894	0.0033	0.0009
0.3132	0.4458	0.0034	0.0014
0.2665	0.3229	0.0023	0.0016
0.1920	0.1231	0.0018	0.0022

BANK: unit #2

SCAVENGER
Water constant = 18.14; cell volume = 316.67 cu/ft; 8 cells
Flotation rate constants:

0.	0.	0.	0.
0.0114	0.0966	0.0013	0.0010
0.0648	0.0742	0.0022	0.0016
0.0515	0.1055	0.0026	0.0026
0.0342	0.1113	0.0049	0.0052
0.0240	0.0899	0.0112	0.0099
0.0210	0.0557	0.0163	0.0159
0.0280	0.0338	0.0186	0.0204
0.2230	0.0852	0.0317	0.0313

BANK: unit #3

CLEANER
Water constant = 148.08; cell volume = 90 cu/ft; 8 cells.
Flotation rate constants:

0.	0.	0.	0.
0.0164	0.0283	0.0275	0.0031
0.0950	0.1782	0.0285	0.0189
0.2552	0.2996	0.0832	0.0327
0.2967	0.3164	0.0854	0.0253
0.3174	0.2889	0.0755	0.0119
0.3045	0.2337	0.0462	0.0050
0.2629	0.1993	0.0256	0.0039
0.1352	0.1386	0.0058	0.0042

Feed characteristics
Solids = 324 t/h; water = 335 t/h
Size intervals:

850/425	425/212.5	212.5/106.2	106.2/53.1
53.1/26.6	26.6/13.3	13.3/6.6	−4

Specific gravities of minerals:

4.2	4.675	5.018	2.581

Minerals: chalcopyrite; molybdenite; pyrite; gangue

Feed solids distribution:

0.0005	0.0001	0.0082	0.3016
0.0101	0.0002	0.1932	6.5484
0.0422	0.0056	0.5743	19.8843
0.0876	0.0115	0.7450	20.2085
0.0969	0.0108	0.8158	15.5575
0.0944	0.0090	0.6759	11.7539
0.0581	0.0057	0.5132	7.0319
0.0282	0.0031	0.3540	4.2388
0.0458	0.0086	0.8556	9.2215

Water addition #10: 40 t/h

FLOTATION SIMULATION CIRCUIT

PURPOSE : TO SIMULATE A FLOTATION PLANT INVOLVING SOLIDS RECYCLING AND WATER ADDITION

DESCRIPTION: FLOTEX ALLOWS THE SIMULATION OF A FLOTATION PLANT. IT USES 2 KINDS OF UNIT MODULES; THE FLTCLS MODULE WHICH INVOLVES THE OPERATION OF FLOTATION BANK (REFER TO FLTCLS UNIT MODULE FOR MORE DETAILS) AND THE MIXER2 AND MIXER3 MODULES WHICH INVOLVE THE MIXING OF 2 AND 3 STREAMS RESPECTIVELY.

FLOTEX IS COMPOSED OF THREE INDEPENDENT PROGRAMS:

- THE DATA FILE EDITOR AND PRE-PROCESSOR WRITER
- THE EXECUTIVE
- THE DATA FILE MODIFIER

THEY ARE LINKED TOGETHER BY PROCEDURES

LIMITATIONS:

NUMBER OF UNITS = 15
WATER ADDITION = 10
NUMBER OF SIZE INTERVALS = 20
NUMBER OF SPECIFIC GRAVITY= 10
NUMBER OF CHARACTERISTICS = 1

VARIABLES : SAME AS THOSE USED BY FLTCLS UNIT MODULE PLUS THE FOLLOWING ONES:

NFLOT = NUMBER OF FLOTATION BANKS
NMX = NUMBER OF MIXERS
NSTR = NUMBER OF STREAMS
MSTR = STREAM CONNECTION MATRIX
PARAM = AN ARRAY WHICH CONTAINS ALL MODEL PARAMETERS REQUIRED BY THE UNIT MODULES
FLOW = AN ARRAY WHICH CONTAINS THE CHARACTERISTICS OF ALL THE STREAM FLOWS; SOLID AND WATER FLOW RATES, SIZE DISTRIBUTION IN % BY WEIGHT
OPT = AN ARRAY WHICH CONTAINS FOR EACH UNIT THE MODEL OPTION

```
    SAMPLE RUN1:
    -----------
                  ----------------------------------------------
                 !                                              !
                 !                                              !
                 !                                              !
                 V          R         SC                        !
               -----      -----      -----                      !
       1      !     !2   !\   /!3   !\   /!                     !
   ---------->!     !--->! \ / !--->! \ / !----->5 TAILS        !
              !     !    !  V  !    !  V  !                     !
               -----      -----      -----                      !
                 ^          !          !                        !
                 !          !          !                        !
                 !          !          !                        !
                 !          !4         !            6           !
                8!          !           ------------------------
                 !   CL     V
                 !  ---     ---
                 ! !\ /! 9 !   !
                  -! V !<--!   !<------------10
                    ---     ---
                     !
                    7!
                     ! CONCENTRATE

          FLOTATION CELL NETWORK SIMULATION
        ENTER A RUN IDENTIFICATION
          (40 CHARACTERS MAXIMUM)
flotation plant simulation
        DESCRIPTION OF THE FLOWSHEET
   ENTER NO. OF FLOTATION BANKS, NO. OF MIXERS AND
   NO. OF STREAMS : 3 2 10
   FOR EACH BANK, ENTER THE FEED, FROTH
   AND TAILS STREAM NUMBERS :
   UNIT # 1 : 2 4 3
   UNIT # 2 : 3 6 5
   UNIT # 3 : 9 7 8
   FOR EACH MIXER, ENTER NO. OF FEED STREAMS
   THE FEED STREAM NUMBERS AND THE DISCHARGE STREAM NUMBER :
   UNIT # 4 : 3 1 6 8 2
   UNIT # 5 : 2 4 10 9
        DESCRIPTION OF THE FLOTATION BANKS
   ENTER NO. OF SIZE INTERVALS (PAN INCLUDED) AND
   NO. OF COMPONENTS (GANGUE INCLUDED) : 9 4
   UNIT # 1
   ENTER THE FLOTATION BANK TYPE
   (16 CHAR. MAX.) : rougher
   ENTER THE FROTH WATER CONSTANT, THE CELL
   VOLUME AND THE NO. OF CELLS : 14.44 316.67 7.
```

```
   ENTER THE FLOTATION RATE COEFFICIENTS

FOR SIZE INTERVAL # 1 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : 0. 0. 0. 0.
FOR SIZE INTERVAL # 2 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .0017 .0026 .0001 .0001
FOR SIZE INTERVAL # 3 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .0668 .1706 .0013 .0004
FOR SIZE INTERVAL # 4 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .2123 .4349 .0034 .0007
FOR SIZE INTERVAL # 5 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .266 .5057 .0029 .0008
FOR SIZE INTERVAL # 6 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .3187 .3894 .0033 .0009
FOR SIZE INTERVAL # 7 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .3132 .4458 .0034 .0014
FOR SIZE INTERVAL # 8 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .2665 .3229 .0023 .0016
FOR SIZE INTERVAL # 9 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .192 .1231 .0018 .0022
UNIT # 2
ENTER THE FLOTATION BANK TYPE
(16 CHAR. MAX.) : scavenger
ENTER THE FROTH WATER CONSTANT, THE CELL
VOLUME AND THE NO. OF CELLS : 18.14 316.67 8.
ENTER THE FLOTATION RATE COEFFICIENTS

FOR SIZE INTERVAL # 1 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : 0. 0. 0. 0.
FOR SIZE INTERVAL # 2 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .0114 .0966 .0013 .001
FOR SIZE INTERVAL # 3 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .0648 .0742 .0022 .0016
FOR SIZE INTERVAL # 4 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .0515 .1055 .0026 .0026
FOR SIZE INTERVAL # 5 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .0342 .1113 .0049 .0052
FOR SIZE INTERVAL # 6 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .024 .0899 .0112 .0099
FOR SIZE INTERVAL # 7 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .021 .0557 .0163 .0159
FOR SIZE INTERVAL # 8 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .028 .0338 .0186 .0204
FOR SIZE INTERVAL # 9 : ENTER 1 VALUE
PER SPECIFIC GRAVITY : .223 .0852 .0317 .0313
UNIT # 3
ENTER THE FLOTATION BANK TYPE
(16 CHAR. MAX.) : cleaner
ENTER THE FROTH WATER CONSTANT, THE CELL
VOLUME AND THE NO. OF CELLS : 148.08 90. 8.
```

```
   ENTER THE FLOTATION RATE COEFFICIENTS

   FOR SIZE INTERVAL # 1 : ENTER 1 VALUE
   PER SPECIFIC GRAVITY : 0. 0. 0. 0.
   FOR SIZE INTERVAL # 2 : ENTER 1 VALUE
   PER SPECIFIC GRAVITY : .0164 .0283 .0275 .0031
   FOR SIZE INTERVAL # 3 : ENTER 1 VALUE
   PER SPECIFIC GRAVITY : .095 .1782 .0285 .0189
   FOR SIZE INTERVAL # 4 : ENTER 1 VALUE
   PER SPECIFIC GRAVITY : .2552 .2996 .0832 .0327
   FOR SIZE INTERVAL # 5 : ENTER 1 VALUE
   PER SPECIFIC GRAVITY : .2967 .3164 .0854 .0253
   FOR SIZE INTERVAL # 6 : ENTER 1 VALUE
   PER SPECIFIC GRAVITY : .3174 .2889 .0755 .0119
   FOR SIZE INTERVAL # 7 : ENTER 1 VALUE
   PER SPECIFIC GRAVITY : .3045 .2337 .0462 .005
   FOR SIZE INTERVAL # 8 : ENTER 1 VALUE
   PER SPECIFIC GRAVITY : .2629 .1993 .0256 .0039
   FOR SIZE INTERVAL # 9 : ENTER 1 VALUE
   PER SPECIFIC GRAVITY : .1352 .1386 .0058 .0042
        DESCRIPTION OF THE FEED STREAM
   ENTER THE SOLID AND WATER FLOW RATES (STPH) : 324. 335.
   ENTER SIEVE APERTURES (MICRONS) :
850. 425. 212.5 106.2 53.1 26.6 13.3 6.6 4
   ENTER THE SPECIFIC GRAVITY VALUES
   OF THE  4 COMPONENTS : 4.2 4.675 5.018 2.581
   ENTER NAME OF EACH COMPONENT (16 CHAR. MAX.)
   FOR SP. GR. =  4.200  : chalcopyrite
   FOR SP. GR. =  4.675  : molybdenite
   FOR SP. GR. =  5.018  : pyrite
   FOR SP. GR. =  2.581  : gangue
   ENTER THE FEED PERCENT OF SPECIES BY WEIGHT

   FOR SIZE INTERVAL # 1 : ENTER 1 VALUE
   PER SP. GR. :.0005 .0001 .0082 .3016
   FOR SIZE INTERVAL # 2 : ENTER 1 VALUE
   PER SP. GR. : .0101 .0002 .1932 6.5484
   FOR SIZE INTERVAL # 3 : ENTER 1 VALUE
   PER SP. GR. : .0422 .0056 .5743 19.8843
   FOR SIZE INTERVAL # 4 : ENTER 1 VALUE
   PER SP. GR. : .0876 .0155 .745 20.2085
   FOR SIZE INTERVAL # 5 : ENTER 1 VALUE
   PER SP. GR. : .0969 .0108 .8158 15.5575
   FOR SIZE INTERVAL # 6 : ENTER 1 VALUE
   PER SP. GR. : .0944 .009 .6759 11.7539
   FOR SIZE INTERVAL # 7 : ENTER 1 VALUE
   PER SP. GR. : .0581 .0057 .5132 7.0319
   FOR SIZE INTERVAL # 8 : ENTER 1 VALUE
   PER SP. GR. : .0282 .0031 .354 4.2388
   FOR SIZE INTERVAL # 9 : ENTER 1 VALUE
   PER SP. GR. : .0458 .0086 .8556 9.2215

   ENTER WATER ADDITION #10 FLOWRATE : 40.
END OF SEARCH FOR COMPUTATION PATH WITH CODE          0
```

```
        FLOTATION PLANT SIMULATION


UNIT #  1
    ROUGHER

          OPERATING PARAMETERS


                NUMBER OF CELLS                      7
                NUMBER OF MINERALS                   4
                CELL VOLUME                        316.7    CU.FT.
                PERCENT SOLIDS IN PULP              39.6
                FEED RATE (SOLIDS)                 350.1    STPH OF SOLIDS
                FEED RATE (LIQUID)                 534.7    STPH OF WATER
                FROTH CONSTANT                      14.4

    IDENTIFICATION OF MINERALS         SPECIES NUMBER    SPECIES NAME

                                              1           CHALCOPYRITE
                                              2           MOLYBDENITE
                                              3           PYRITE
                                              4           GANGUE

                                   NOTE: FINAL SPECIES MUST BE GANGUE

                                       FEED FRACTIONS

                                       MINERAL SPECIES
                SIZE          1       2       3       4
                850.0       .0005   .0001   .0076   .2791
                425.0       .0104   .0004   .1808  6.1147
                212.5       .0558   .0063   .5433 18.6776
                106.2       .0906   .0113   .7060 19.1477
                 53.1       .0951   .0105   .7878 15.0780
                 26.6       .0903   .0089   .6880 11.8702
                 13.3       .0554   .0055   .5466  7.4946
                  6.6       .0274   .0030   .3851  4.6968
                  4.0       .0596   .0107  1.0410 11.2134

                SP.GR.     4.20    4.68    5.02    2.58


                                  FLOTATION RATE COEFFICIENTS

                850.0      0.0000  0.0000  0.0000  0.0000
                425.0       .0017   .0026   .0001   .0001
                212.5       .0668   .1706   .0013   .0004
                106.2       .2123   .4349   .0034   .0007
                 53.1       .2660   .5057   .0029   .0008
                 26.6       .3187   .3894   .0033   .0009
                 13.3       .3132   .4458   .0034   .0014
                  6.6       .2665   .3229   .0023   .0016
                  4.0       .1920   .1231   .0018   .0022
```

```
ROUGHER


                         INDIVIDUAL   CELL   OUTPUT
                         --------------------------


CELL      PERCENT       RETENTION      FROTH         FROTH        TAILS        TAILS
NUMBER    SOLIDS IN     TIME           SOLIDS        SOLIDS       SOLIDS       SOLIDS
          FEED          (MIN)          (TPH)         (%)          (TPH)        (%)

   1        39.572         .891          .640        36.608      349.498       39.578
   2        39.578         .892          .576        34.183      348.922       39.588
   3        39.588         .894          .525        32.123      348.398       39.602
   4        39.602         .896          .484        30.390      347.914       39.619
   5        39.619         .898          .452        28.943      347.462       39.638
   6        39.638         .899          .426        27.742      347.037       39.659
   7        39.659         .901          .405        26.750      346.632       39.681

                         FROTH MINERAL ASSAY   (%)

CELL     COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1         44.732         7.013         5.975        42.281
  2         40.505         5.806         6.639        47.050
  3         36.265         4.777         7.282        51.675
  4         32.135         3.912         7.889        56.063
  5         28.215         3.196         8.451        60.138
  6         24.577         2.608         8.961        63.854
  7         21.267         2.131         9.416        67.187


                         TAILS MINERAL ASSAY   (%)

CELL     COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1           .404          .044         4.884        94.668
  2           .338          .034         4.881        94.746
  3           .284          .027         4.878        94.811
  4           .239          .022         4.873        94.865
  5           .203          .018         4.869        94.910
  6           .173          .015         4.864        94.948
  7           .149          .012         4.859        94.981
```

```
                         MINERAL RECOVERY BASED ON FEED TO CELL

CELL      COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1          16.864        22.635          .224          .082
  2          16.519        21.784          .224          .082
  3          16.142        20.879          .224          .082
  4          15.734        19.937          .225          .082
  5          15.295        18.976          .225          .082
  6          14.824        18.015          .225          .082
  7          14.323        17.072          .226          .083

                         MINERAL RECOVERY BASED ON FEED TO BANK

CELL      COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1          16.864        22.635          .224          .082
  2          13.733        16.853          .223          .082
  3          11.203        12.634          .223          .082
  4           9.157         9.545          .223          .082
  5           7.501         7.274          .223          .082
  6           6.158         5.595          .223          .082
  7           5.068         4.347          .223          .082


ROUGHER

                                 CUMULATIVE   CELL   OUTPUT
                                 ---------------------------


CELL        RESIDENCE    FROTH          FROTH
NUMBER      TIME (MIN)   SOLIDS(TPH)    SOLIDS (%)


  1             .891          .640         36.608
  2            1.783         1.216         35.418
  3            2.677         1.741         34.356
  4            3.573         2.225         33.408
  5            4.471         2.677         32.560
  6            5.370         3.102         31.803
  7            6.271         3.507         31.124
```

```
                            FROTH MINERAL ASSAY  (%)

CELL      COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1            44.732         7.013         5.975        42.281
  2            42.730         6.441         6.289        44.539
  3            40.782         5.940         6.589        46.690
  4            38.901         5.499         6.872        48.729
  5            37.098         5.110         7.138        50.654
  6            35.380         4.767         7.388        52.465
  7            33.751         4.463         7.622        54.164

                    MINERAL RECOVERY BASED ON FEED TO BANK

CELL      COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1            16.864        22.635          .224          .082
  2            30.596        39.488          .447          .164
  3            41.800        52.123          .670          .245
  4            50.957        61.668          .894          .327
  5            58.458        68.942         1.117          .409
  6            64.616        74.537         1.340          .491
  7            69.684        78.884         1.562          .574

UNIT #  2
    SCAVENGER

          OPERATING PARAMETERS


                NUMBER OF CELLS                    8
                NUMBER OF MINERALS                 4
                CELL VOLUME                    316.7    CU.FT.
                PERCENT SOLIDS IN PULP          39.7
                FEED RATE (SOLIDS)             346.6    STPH OF SOLIDS
                FEED RATE (LIQUID)             526.9    STPH OF WATER
                FROTH CONSTANT                  18.1

    IDENTIFICATION OF MINERALS        SPECIES NUMBER    SPECIES NAME

                                              1           CHALCOPYRITE
                                              2           MOLYBDENITE
                                              3           PYRITE
                                              4           GANGUE

                                  NOTE: FINAL SPECIES MUST BE GANGUE
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                         FEED FRACTIONS

                         MINERAL SPECIES
          SIZE          1        2        3        4
          850.0      .0005    .0001    .0077    .2819
          425.0      .0103    .0004    .1825   6.1727
          212.5      .0375    .0023    .5443  18.8193
          106.2      .0270    .0011    .6981  19.2567
           53.1      .0215    .0008    .7814  15.1544
           26.6      .0157    .0011    .6808  11.9229
           13.3      .0099    .0005    .5405   7.5043
            6.6      .0062    .0005    .3835   4.6970
            4.0      .0198    .0052   1.0397  11.1718

          SP.GR.      4.20     4.68     5.02     2.58


                     FLOTATION RATE COEFFICIENTS

          850.0     0.0000   0.0000   0.0000   0.0000
          425.0      .0114    .0966    .0013    .0010
          212.5      .0648    .0742    .0022    .0016
          106.2      .0515    .1055    .0026    .0026
           53.1      .0342    .1113    .0049    .0052
           26.6      .0240    .0899    .0112    .0099
           13.3      .0210    .0557    .0163    .0159
            6.6      .0280    .0338    .0186    .0204
            4.0      .2230    .0852    .0317    .0313

SCAVENGER

                    INDIVIDUAL   CELL   OUTPUT
                    --------------------------

CELL     PERCENT      RETENTION     FROTH       FROTH       TAILS       TAILS
NUMBER   SOLIDS IN    TIME          SOLIDS      SOLIDS      SOLIDS      SOLIDS
         FEED         (MIN)         (TPH)       (%)         (TPH)       (%)

   1       39.681         .931       2.920      12.804     343.712      40.402
   2       40.402         .962       2.961      12.918     340.751      41.163
   3       41.163         .997       3.006      13.040     337.745      41.968
   4       41.968        1.034       3.055      13.170     334.690      42.823
   5       42.823        1.074       3.107      13.309     331.583      43.732
   6       43.732        1.117       3.164      13.457     328.419      44.701
   7       44.701        1.165       3.226      13.616     325.192      45.737
   8       45.737        1.217       3.294      13.786     321.898      46.848
```

```
                              FROTH MINERAL ASSAY  (%)

CELL      COMPONENT 1    COMPONENT 2    COMPONENT 3    COMPONENT 4    COMPONENT 5
NUMBER

  1             .978           .103          6.884         92.034
  2             .898           .097          6.872         92.133
  3             .826           .091          6.858         92.225
  4             .762           .085          6.843         92.309
  5             .705           .080          6.827         92.388
  6             .654           .074          6.809         92.462
  7             .608           .069          6.791         92.532
  8             .567           .064          6.770         92.599


                              TAILS MINERAL ASSAY  (%)

CELL      COMPONENT 1    COMPONENT 2    COMPONENT 3    COMPONENT 4    COMPONENT 5
NUMBER

  1             .141           .011          4.841         95.006
  2             .135           .011          4.824         95.031
  3             .129           .010          4.806         95.056
  4             .123           .009          4.787         95.081
  5             .118           .009          4.768         95.106
  6             .112           .008          4.748         95.132
  7             .107           .007          4.728         95.157
  8             .103           .007          4.707         95.184

                     MINERAL RECOVERY BASED ON FEED TO CELL

CELL      COMPONENT 1    COMPONENT 2    COMPONENT 3    COMPONENT 4    COMPONENT 5
NUMBER

  1            5.548          7.172          1.193           .816
  2            5.467          7.375          1.223           .835
  3            5.402          7.591          1.254           .856
  4            5.352          7.822          1.288           .878
  5            5.321          8.068          1.324           .902
  6            5.308          8.332          1.363           .928
  7            5.315          8.617          1.405           .956
  8            5.344          8.924          1.451           .986
```

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                         MINERAL RECOVERY BASED ON FEED TO BANK

CELL      COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1             5.548         7.172         1.193          .816
  2             5.164         6.846         1.208          .829
  3             4.823         6.527         1.224          .842
  4             4.521         6.215         1.241          .856
  5             4.254         5.909         1.260          .872
  6             4.017         5.610         1.279          .889
  7             3.809         5.318         1.301          .907
  8             3.627         5.033         1.324          .927

SCAVENGER

                                 CUMULATIVE   CELL   OUTPUT
                                 ---------------------------


CELL        RESIDENCE    FROTH          FROTH
NUMBER      TIME (MIN)   SOLIDS(TPH)    SOLIDS (%)


  1               .931         2.920        12.804
  2              1.893         5.881        12.861
  3              2.890         8.887        12.921
  4              3.924        11.941        12.984
  5              4.997        15.049        13.049
  6              6.115        18.213        13.118
  7              7.280        21.439        13.191
  8              8.497        24.734        13.267

                                 FROTH MINERAL ASSAY  (%)

CELL      COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1              .978          .103         6.884        92.034
  2              .938          .100         6.878        92.084
  3              .900          .097         6.871        92.132
  4              .865          .094         6.864        92.177
  5              .832          .091         6.856        92.221
  6              .801          .088         6.848        92.263
  7              .772          .085         6.840        92.303
  8              .745          .082         6.830        92.343
```

```
                    MINERAL RECOVERY BASED ON FEED TO BANK

CELL     COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1            5.548         7.172         1.193          .816
  2           10.712        14.019         2.402         1.645
  3           15.535        20.546         3.626         2.487
  4           20.056        26.760         4.867         3.343
  5           24.309        32.669         6.127         4.215
  6           28.327        38.280         7.406         5.104
  7           32.136        43.598         8.707         6.011
  8           35.763        48.631        10.031         6.937

UNIT #  5
    SFR=    3.51
    WFR=    7.76----------------------------------------
     %S=   31.12                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                                                       !
                        SFR=    0.00                   !
                        WFR=   40.00----------         !
                         %S=    0.00         !         !
                                         !   !         !   !
                                         !   V         V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=    3.51
                                                  !---------->WFR=   47.76
                                                               %S=    6.84
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

                             PRODUCT DISTRIBUTION

                             MINERAL SPECIES
         SIZE          1       2       3       4
         850.0      0.0000  0.0000  0.0000  0.0000
         425.0       .0110   .0006   .0113   .3828
         212.5      1.8541   .3960   .4403  4.6727
         106.2      6.3727  1.0166  1.4853  8.3741
          53.1      7.3715   .9684  1.4162  7.5338
          26.6      7.4650   .7807  1.4056  6.6704
          13.3      4.5564   .4965  1.1502  6.5406
           6.6      2.1291   .2506   .5504  4.6816
           4.0      3.9657   .5524  1.1662 15.3312

         SP.GR.     4.20    4.68    5.02    2.58
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

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UNIT #  3
    CLEANER

          OPERATING PARAMETERS


                NUMBER OF CELLS                           8
                NUMBER OF MINERALS                        4
                CELL VOLUME                            90.0    CU.FT.
                PERCENT SOLIDS IN PULP                  6.8
                FEED RATE (SOLIDS)                      3.5    STPH OF SOLIDS
                FEED RATE (LIQUID)                     47.8    STPH OF WATER
                FROTH CONSTANT                        148.1

    IDENTIFICATION OF MINERALS         SPECIES NUMBER    SPECIES NAME

                                             1            CHALCOPYRITE
                                             2            MOLYBDENITE
                                             3            PYRITE
                                             4            GANGUE

                                   NOTE: FINAL SPECIES MUST BE GANGUE

                                         FEED FRACTIONS

                                         MINERAL SPECIES
                SIZE           1       2       3       4
                850.0       0.0000  0.0000  0.0000  0.0000
                425.0        .0110   .0006   .0113   .3828
                212.5       1.8541   .3960   .4403  4.6727
                106.2       6.3727  1.0166  1.4853  8.3741
                 53.1       7.3715   .9684  1.4162  7.5338
                 26.6       7.4650   .7807  1.4056  6.6704
                 13.3       4.5564   .4965  1.1502  6.5406
                  6.6       2.1291   .2506   .5504  4.6816
                  4.0       3.9657   .5524  1.1662 15.3312

                SP.GR.      4.20    4.68    5.02    2.58


                                  FLOTATION RATE COEFFICIENTS

                850.0       0.0000  0.0000  0.0000  0.0000
                425.0        .0164   .0283   .0275   .0031
                212.5        .0950   .1782   .0285   .0189
                106.2        .2552   .2996   .0832   .0327
                 53.1        .2967   .3164   .0854   .0253
                 26.6        .3174   .2889   .0755   .0119
                 13.3        .3045   .2337   .0462   .0050
                  6.6        .2629   .1993   .0256   .0039
                  4.0        .1352   .1386   .0058   .0042
```

```
CLEANER


                          INDIVIDUAL   CELL   OUTPUT
                          -------------------------

CELL      PERCENT     RETENTION     FROTH      FROTH      TAILS      TAILS
NUMBER    SOLIDS IN   TIME          SOLIDS     SOLIDS     SOLIDS     SOLIDS
          FEED        (MIN)         (TPH)      (%)        (TPH)      (%)

   1         6.838       3.547        .761     39.440      2.745      5.563
   2         5.563       3.646        .447     27.440      2.297      4.816
   3         4.816       3.750        .280     18.959      2.017      4.364
   4         4.364       3.858        .190     13.527      1.828      4.077
   5         4.077       3.974        .139     10.191      1.688      3.885
   6         3.885       4.098        .110      8.134      1.578      3.748
   7         3.748       4.231        .092      6.815      1.486      3.646
   8         3.646       4.375        .081      5.919      1.405      3.567


                          FROTH MINERAL ASSAY  (%)

CELL     COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1         73.302         9.655         5.701        11.342
  2         65.029         8.670         7.933        18.368
  3         54.414         7.323        10.350        27.913
  4         42.537         5.745        12.486        39.232
  5         31.119         4.179        13.885        50.817
  6         21.602         2.846        14.365        61.186
  7         14.517         1.846        14.059        69.578
  8          9.623         1.159        13.244        75.975


                          TAILS MINERAL ASSAY  (%)

CELL     COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1         22.757         3.023         8.159        66.061
  2         14.528         1.923         8.203        75.346
  3          8.990         1.173         7.905        81.932
  4          5.508          .699         7.429        86.364
  5          3.394          .412         6.896        89.298
  6          2.122          .242         6.374        91.262
  7          1.351          .142         5.896        92.611
  8           .876          .083         5.474        93.567
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                    MINERAL RECOVERY BASED ON FEED TO CELL

CELL     COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1           47.164        46.956        16.224         4.542
  2           46.564        46.742        15.844         4.531
  3           45.666        46.425        15.384         4.517
  4           44.488        46.032        14.851         4.502
  5           43.088        45.594        14.254         4.488
  6           41.568        45.149        13.603         4.475
  7           40.062        44.736        12.913         4.464
  8           38.695        44.389        12.199         4.456

                    MINERAL RECOVERY BASED ON FEED TO BANK

CELL     COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1           47.164        46.956        16.224         4.542
  2           24.602        24.794        13.274         4.325
  3           12.893        13.115        10.846         4.116
  4            6.825         6.967         8.860         3.918
  5            3.669         3.724         7.240         3.729
  6            2.015         2.006         5.925         3.551
  7            1.135         1.090         4.859         3.384
  8             .657          .598         3.998         3.227

CLEANER

                            CUMULATIVE   CELL   OUTPUT
                            ---------------------------


CELL       RESIDENCE    FROTH          FROTH
NUMBER     TIME (MIN)   SOLIDS(TPH)    SOLIDS (%)


  1            3.547          .761        39.440
  2            7.193         1.208        33.944
  3           10.942         1.488        29.547
  4           14.801         1.678        26.058
  5           18.775         1.817        23.278
  6           22.873         1.927        21.038
  7           27.104         2.020        19.204
  8           31.479         2.100        17.680
```

```
                            FROTH MINERAL ASSAY  (%)

CELL     COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1           73.302         9.655         5.701        11.342
  2           70.238         9.290         6.528        13.944
  3           67.260         8.920         7.247        16.573
  4           64.465         8.561         7.839        19.135
  5           61.907         8.225         8.303        21.565
  6           59.601         7.917         8.650        23.832
  7           57.539         7.639         8.897        25.924
  8           55.698         7.390         9.064        27.847

                    MINERAL RECOVERY BASED ON FEED TO BANK

CELL     COMPONENT 1   COMPONENT 2   COMPONENT 3   COMPONENT 4   COMPONENT 5
NUMBER

  1           47.164        46.956        16.224         4.542
  2           71.767        71.750        29.498         8.867
  3           84.660        84.865        40.344        12.984
  4           91.484        91.832        49.204        16.901
  5           95.154        95.556        56.444        20.630
  6           97.168        97.562        62.369        24.182
  7           98.303        98.653        67.228        27.566
  8           98.959        99.251        71.226        30.793

UNIT #  4
    SFR=  324.00
    WFR=  335.00----------------------------------------
     %S=   49.17                                       !
                                                       !
              SFR=   24.73                             !
              WFR=  161.69-------------------------    !
               %S=   13.27                        !    !
                                                  !    !
                        SFR=   1.40               !    !
                        WFR=  37.98----------     !    !
                         %S=   3.57         !     !    !
                                         !   !    !    !   !
                                         !   V    V    V   !
                                         !_________________!
                                         !                 !
                                         !      MIXER      !
                                         !_________________!
                                                  !
                                                  !           SFR=  350.14
                                                  !---------->WFR=  534.67
                                                               %S=   39.57
TO CONTINUE, ENTER ANY DIGIT AND <CR>1
```

```
                             PRODUCT DISTRIBUTION

                             MINERAL SPECIES
         SIZE          1       2       3       4
         850.0       .0005   .0001   .0076   .2791
         425.0       .0104   .0004   .1808  6.1147
         212.5       .0558   .0063   .5433 18.6776
         106.2       .0906   .0113   .7060 19.1477
          53.1       .0951   .0105   .7878 15.0780
          26.6       .0903   .0089   .6880 11.8702
          13.3       .0554   .0055   .5466  7.4946
           6.6       .0274   .0030   .3851  4.6968
           4.0       .0596   .0107  1.0410 11.2134

         SP.GR.     4.20    4.68    5.02    2.58
TO CONTINUE, ENTER ANY DIGIT AND <CR>1

          PLANT MINERAL RECOVERY CALCULATIONS
RECOVERY
(ENTER 0 TO EXIT)
IN STREAM #5
BASED ON STREAM #1

IN STREAM #7
BASED ON STREAM #1

IN STREAM #0

  IN    BASED ON  COMPONENTS
                     1      2      3      4
STREAM   STREAM
   #        #
--------------------------------------------------------------------------------
   5        1      22.01  12.16  98.76  99.81
   7        1      77.85  87.75   1.24    .19
ANOTHER COMPUTATION (Y/N) ?n

DO YOU WISH TO MODIFY YOUR DATA FILE?
TYPE YES OR NO - no
```

3. SYSTEM DOCUMENTATION

3.1 COMPUTER EQUIPMENT

FLOTEX runs on a CDC CYBER 730 computer with a maximum 70K words (octal) of core memory available for time-sharing jobs. FLOTEX can also run on other computers with very minor modifications. An IBM-PC version of FLOTEX has also been developed.

3.2 PERIPHERAL EQUIPMENT

A time-sharing terminal is the normal way to run this conversational program. Data can be stored on disk files.

3.3 SOURCE PROGRAM

A complete listing of the program can be obtained from:

CANMET,
Energy, Mines and Resources,
Technology Information Division,
555 Booth Street
Ottawa, Ontario
K1A 0G1.

3.4 VARIABLES AND SUBROUTINES

3.4.1 Variables

A list of variables is given in the prologues of each program and the subroutines. Most variables are transmitted as arguments of subroutines. A labelled COMMON area of 1K word is reserved for internal storage of local variables.

Three variables, PARAM, FLOW, and OPT, used in FLTCLS program must be understood before any modification to the code is made.

Array PARAM contains the unit parameters values: a sector of 15 + NS × NG components (NG is the number of specific gravity intervals and NS the number of size intervals) is reserved for each flotation bank. The structure of each sector is given in the prologue of the subroutine BANK.

Array FLOW contains data about the streams: a sector of 5 + NS × NG components is reserved for each stream. Each sector is partitioned as follows: components one to three are never used; components four and five are the solids and water flow rates; the remaining components are the solids distribution in weight flow rates. Within each size interval these are the NG values of the specific gravity distribution.

Array OPT is composed of one component per unit.

3.4.2 Main Programs and Associated Subroutines

The FLOTEX package is composed of three main programs. The list of subroutines associated with each is given below:

3.4.2.1 FLOTEX

FLOTEX:	(main program) to create the data file and write FLTCLS main program and subroutine CALLUN code.
FLOTIN:	to prompt for data entry.
DATAP:	to write data file from user's entries.
WRTUN:	to write a FORTRAN CALL statement to a particular unit module subroutine.
DEFIN:	to define arrays ORIG and DEST as required by subroutine COD.
WRTEX:	to write the FLTCLS main FORTRAN program, the subroutine CALLUN statement, and its DIMENSION statements.
COD:	to search for the computation path from the stream connection matrix and to organize the writing of the subroutine CALLUN. COD is a modified version of program FLOWAN described with the SPLITX package.
CYCLE, MAXNET, NODES, RANK, BITOFF, TEAR, TEAROR, and PATH:	same as GRNDEX Section 3.4.2.1.
CODEX:	to provide an interface between FLOTEX and COD.
WRTOUT:	to write a FORTRAN CALL statement to a particular unit display subroutine.

3.4.2.2 FLTCLS

FLTCLS	(main program) to perform the simulation and print out the results (written by FLOTEX subroutines).
CALLUN:	to organize the computation path and print out results (written by FLOTEX subroutines).
BANK:	to simulate a bank of flotation cells.

FLOUT1: to print the characteristics of the feed stream to the bank and characteristics of the bank.

FLOUT2: to print the characteristics of the froth and tails streams of each cell and of the bank in individual and cumulative format, and print recoveries from the bank.

CELL: to compute floated solids flow rates from a cell.

INIT: to initialize array FLOW.

READAT: to read the data file.

MIXER2: to simulate a two-stream mixer.

MX2OUT: to print out MIXER2 module results.

MIXER3: to simulate a three-stream mixer.

MX3OUT: to print out MIXER3 module results.

RECOV: to permit interactive recovery computation.

3.4.2.3 FLTDIT

FLTDIT: (main program)
to permit modifications to the data file.

NETW: to read the stream connection matrix and search for water addition stream numbers.

FLTALT: to permit modifications of the values of the operating parameters of the flotation banks.

FEDALT: to permit modifications of the feed stream characteristics.

WATALT: to permit modifications of the water addition stream flow rates.

3.5 DATA STRUCTURE

FLOTEX main program reads data in free-field format from the input file which can be declared as either the keyboard or a disk file. When data entry is complete, data are written on unit 1. The FLTCLS main program and FORTRAN code for subroutine CALLUN are written on unit 3. Prompts are written on the output file.

FLTCLS main program reads data in free-field format from unit 5 and writes results on unit 6 declared as output file of FLTCLS. Answers to the prompts are read from the input file declared as the keyboard.

FLTDIT main program reads data in free-field format from unit 5 and writes corrected data to unit 6. Corrections are read from the input file declared as the keyboard, and prompts are written to the output file.

3.6 STORAGE REQUIREMENTS

Storage requirements depend on the data set size: number of units, number of streams, and number of size intervals.

3.7 MAINTENANCE AND UPDATES

CANMET does not provide any formal maintenance of the programs. Several updates are expected to evolve from the source programs distributed to users. CANMET would appreciate receiving comments on modifications that could substantially improve the overall program performance. Expected improvements are automatic data-checking and better flotation cell models.

4. OPERATING DOCUMENTATION

4.1 OPERATOR INSTRUCTIONS

FLOTEX has been developed on a CYBER 730 computer using NOS/BE batch-operating system and INTERCOM time-sharing system. An IBM-PC version using MS-DOS is also available.

4.2 OPERATING MESSAGES

Special messages, other than NOS/BE and INTERCOM messages, may be issued by subroutine COD if abnormal conditions occur during the search for the computation path (see the SPLITX program description in this chapter of the SPOC manual).

4.3 CONTROL CARDS

To run the three programs, FLOTEX, FLTCLS, and FLTDIT together, job control cards are necessary. A sample control card deck is shown in Figure 16. The Cyber Control Card Language (CCL) was used to write the four procedures that manage data files and to program according to the sequence of steps given in Figure 16.

Procedure FLOTEX is the main procedure. It attaches all required files, including compiled programs and other procedures. Then FLOTEX calls procedure FLTNECT.

Procedure FLTNECT runs FLOTEX program, compiles FLTCLS program, combines FLTCLS with all its subroutines, and runs it. Then FLTNECT returns control to FLOTEX procedure.

At this stage, procedure FLOTEX initiates a loop on procedure FLTDIT, which runs FLTDIT program, and procedure FLTNAME, which runs FLTCLS program, using the modified data file.

4.4 ERROR RECOVERY

Program must be restarted on fatal error. Most mistakes in the data entry program can be corrected using the FLTDIT program.

4.5 RUN TIME

Run time depends on the size of the problem and on the number of times FLTDIT is used to correct data.

```
.PROC,FLOTEX*I,DATA=(*N=INPUT,*F).
RETURN,B1,B2,BIN,LGO,FLTNECT,FLTDIT,FLTNAME,TAPE1,TAPE3.
IUSE,FINDMOI,FFLIPF,SPOC.
IGET,LGO=FLOTEX.BIN,B2=FLTCLS.BIN,BIN=FLTDIT.BIN,FLTNECT.CCL.
IGET,FLTNAME.CCL,FLTDIT.CCL.
DAYFILE,OFF.
FLTNECT,DATA.
SET,R1=0.
REWIND,TAPE1.
IFNO,END.ODO YOU WISH TO MODIFY YOUR #DATA FILE?
DAYFILE,ON.
REVERT,ABORT.
ENDIF,END.
FLTDIT,TAPE1.
WHILE,R1.LT.10,LOOP.
SET,R1=R1+1.
FLTNAME.
ENDW,LOOP.
REMARK.  #DATA SET QUOTA EXCEEDED
REMARK.  END
DAYFILE,ON.
REVERT.
EXIT,U.
COPDF,XX.
REWIND,XX.
COPY,XX.
RETURN,XX.
DAYFILE,ON.
REVERT.

.PROC,FLTDIT*I,NAME"OF DATA SET TO BE REVIEWED :"=(*F).
BIN,,,NAME.
REWIND,TAPE6,NAME.
REVERT.

.PROC,FLTNAME*I,A"NAME FOR YOUR NEW DATA SET :"=(*F).
RETURN,A.
COPY,TAPE6,A.
RETURN,TAPE6.
REWIND,A.
LGO,,,A.
EXIT,U.
REWIND,A.
IFNO,END.ODO YOU WISH TO MODIFY YOUR DATA FILE?
REVERT,ABORT.
ENDIF,END.
FLTDIT.
REVERT.

.PROC,FLTNECT,FFL1.
LGO,FFL1.
REWIND,TAPE3,TAPE1,FFL1.
FTN,I=TAPE3,B=B1,L=0,PMD.
REWIND,B1.
RETURN,LGO.
COPYBF,B1,LGO.
BKSP,LGO.
COPYBF,B2,LGO.
REWIND,LGO.
LGO,,,TAPE1.
EXIT,U.
REWIND,TAPE1.
REVERT.
```

Fig. 16 — Control card deck for FLOTEX

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