Energy, Mines and Resources Canada
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CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

SPOC
Simulated Processing of Ore and Coal

Chapter 1 Summary

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The SPOC Manual

Chapter 1 Summary

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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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*Simulated Processing of Ore and Coal

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 first chapter of the SPOC Manual is intended as a general introduction to all the other chapters in which the mineral process evaluation and optimization methodology is presented. This chapter also provides a brief description of available software for mainframe and microcomputers and provides information on its distribution by the Technology Information Division, CANMET.

RÉSUMÉ

Ce premier chapitre du manuel SPOC est un guide général qui présente les autres chapitres où l'on traite de la méthodologie d'évaluation et d'optimisation des procédés minéralurgiques. Le lecteur y trouvera aussi une description sommaire des programmes de calcul développés pour ordinateurs centraux et pour micro-ordinateurs, ainsi que la façon de les obtenir de la Division de l'information technologique du CANMET.

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 is 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.

Special credits are due to Frederic Flament, Ralph Pilgrim, Jean Leung and Wayne Cameron as in-house contributors to the manuals and software; to Louis Sirois for his constant support of the project since its conception; and to Joan Stewart for her intensive contribution to the word processing of the manuals.

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1. INTRODUCTION

Computer simulation of mineral processes has slowly emerged as an established branch of activity in R&D centres and in several teaching institutions after decades of slow progress. Substantial efforts to develop application software based on years of research on process modelling are being pursued in many countries (1,2,3,4,5). The late 80's should see a flurry of success stories about significant leaps of productivity achieved in several plants through systematic process evaluation and computer simulation studies.

In Canada, the SPOC project (Simulated Processing of Ore and Coal) was initiated at CANMET in 1980 with the objective of developing and transferring to the mineral industry a computer-based methodology for process evaluation and optimization. The project deliverables include:

- an engineering manual covering most aspects of off-line computer simulation;
- a bank of FORTRAN software accessible through data communication lines for user familiarization and distributed at a nominal cost in source form by CANMET.

The yearly progress reports of the project contain detailed information on the project elements since 1980 (6). The context of SPOC can be summed up by quoting Gordon Agar's 1975 statement during a workshop on research needs in the mineral industry: "What is needed is a joint effort between the academic community and one or more enlightened industrial concerns. The effort will have to be an iterative one, with data collection followed by testing the model, modification of the model(s), more testing, prediction, modification, data collection and so on" (7). A few parallel initiatives had been reported in papers or research contract reports (8,9) but there was an obvious need for CANMET to bridge the gap between the R&D and the production sectors by undertaking a project that would document past applications, and induce a new generation of initiatives through the consolidation and transfer of suitable manuals and software. The effort took shape as the CANMET SPOC project, in which **methodology transfer** was to play a key role (10).

The resources allocated to meet the project objectives are summarized in Figure 1. A total of $600 000 was spent for 21 contracts, of which $160 000 was assumed by industrial contractors. The CANMET contribution in personnel ranged from three to four persons each year, of which only one full-time position was maintained during the entire project. The yearly project undertakings were accepted on a case-to-case basis within the constraints of the Research Program Office of CANMET. The project benefited from regular contributions by consultants from the EMR Computer Science Centre. All administrative and word-processing tasks were fitted into the stream of on-going CANMET activities. A steering committee composed of seven representatives of the mineral and coal industry was consulted seven times to review the project elements in an industrial perspective. This chapter introduces the methodology discussed in the various chapters of the SPOC Manual and can be used as a reference document for readers unfamiliar with the SPOC Manual and software distributed by CANMET.

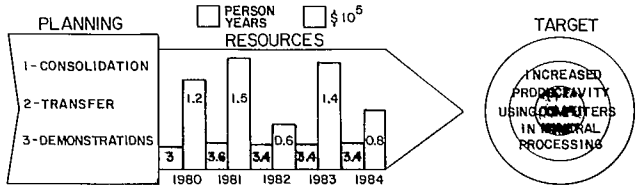

Fig. 1 — The SPOC project objective, structure and resources

2. THE SPOC METHODOLOGY, STEP BY STEP

The methodology for process evaluation and optimization advocated in the SPOC Manual follows a step-by-step approach as illustrated in Figure 2. Considering that models used to describe mineral processes are always either empirical or phenomenological (11), the collection of data for model development or model validation is a key step that determines the accuracy of subsequent data-processing steps. The more accurate the sampling, the more accurate the models and simulation results. The **sampling** of particulate material, however, is by no means a trivial exercise as can be seen by perusing the manuals of the world's experts, J. Merks and P. Gy (12,13). Based largely on statistical models, the theory of sampling still remains too often divorced from a very lax practice where collecting "enough" material takes prominence over sample representativity and error minimization. Chapters 2, 2.1 and 2.2 discuss sampling methodology under several aspects: tools, sample size, techniques for sampling, error propagation.

Material balance calculations in mineral processing can refer to two different applications. In the context of SPOC, the expression Material Balance computation refers to the calculation of coherent flow rates for various species analyzed in the process streams.

The objective of such a calculation is usually to keep track of the process inventories in the various concentrate stockpiles. In other cases it is performed to assess the efficiency of process units, to determine circulating loads, etc. Several authors, however, use the expression material balance to describe process simulation which of course must produce results that satisfy material balance constraints.

Although the two applications are very related, the term material balance is restricted in the SPOC Manual, to the computation of coherent flow rates and assays from experimental data collected in a real circuit. This topic is discussed in Chapters 3, 3.1, and 3.2 of the SPOC Manual. Sampling and material balance are obviously very related subjects since the sampling error model directly affects the material balance results.

Process Modelling in the context of SPOC is the development of mathematical models relating product variables to feed variables and operating conditions. Model selection is the first step at which a choice must be made between different types of models: empirical, phenomenological, simple, complex, etc. For instance, if the model is to be used in real-time simulation, it is essential that the computation time be sufficiently short. The amount and precision of the data used to validate the model is also critical, the range of variations for any given variable and the number of data points stored in the database will determine whether the variable can be explicit in the model equations. Experimental design is therefore essential when collecting data for modelling. It is discussed in Chapters 4, 4.1 and 8 which cover modelling in general and in the particular case of ball mills.

Model calibration is the fine adjustment of a particular model to describe a given set of feed, product, and operating variables. The simplest case of model calibration is the linear regression of two variables. Complex models on the other hand may involve several variables and non-linear relationships. The topic of model calibration is discussed in Chapters 7, 7.1, 7.2 and 7.3.

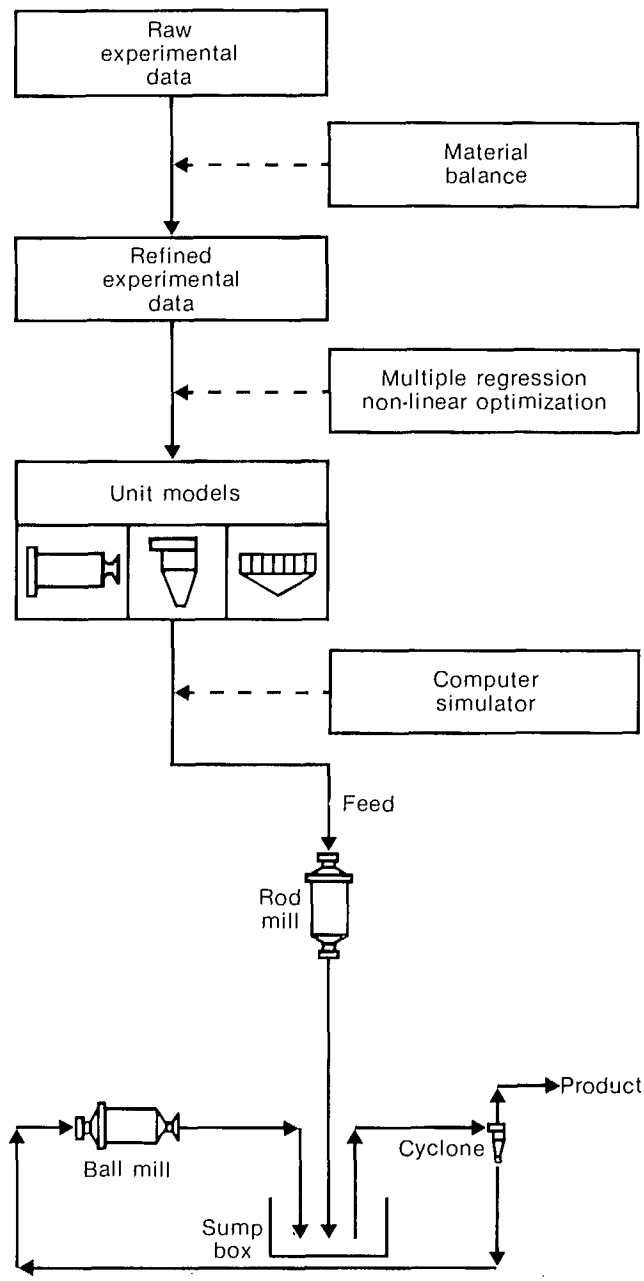

Fig. 2 — The SPOC project methodology

Numerous process models have been published in the scientific literature and in most cases provide a useful starting point for modelling studies. Chapters 5, 5.1 and 5.2 present a narrative as well as an engineering description of several models of process units used for crushing, grinding, classification, flotation, and other operations.

Process simulation is the last step shown in Figure 2. The process information collected by sampling, and represented by the model equations, can be used to predict the product of any combination of feed and operation variables within the range for which the model is valid. The most common application of process simulation is the optimization of existing flowsheets by searching the most adapted process variables achieving a desired result.

It is also used for the design or modification of a flowsheet configuration by design engineers. Unit simulators are discussed in Chapters 5, 5.1 and 5.2 while circuit simulators are documented in Chapter 6.

Finally, Chapter 8 contains user's guides for several ancillary programs that may be useful in the mineral processing laboratory or that were developed too late to be included in the other chapters.

The software generated by the SPOC project is generally consistent in language, style and documentation. The programming language is FORTRAN 4. Most programs have been initially tested on a CDC CYBER mainframe computer operating under NOS/BE or INTERCOM (14,15,16). Special care has been taken to avoid machine-dependent features in order to facilitate conversion to other mainframes.

A measure of success in this aspect of the programs is that they were all converted to IBM-PC microcomputers in less than three months by a programmer without previous access to, or training in, these programs. Specific programs of fairly large size such as MATBAL have been implemented by outside users in less than 48 hours on different mainframes. Both the CDC mainframe and the IBM-PC microcomputer versions can be acquired from CANMET as described in Section 3.2. The various chapters and computer programs are described in the following sections.

2.1 SAMPLING

2.1.1 Documents

The following chapters in the SPOC series contain information related to sampling.

2.1.1.1 Chapter 2 — Sampling Methodology

This treatise on sampling first examines the sources of error in sampling, relying on the theory of GY (1979) to develop practical relationships. It then describes the equipment and techniques for sampling various parts of a solid processing circuit. The need for proper planning of a sampling campaign is emphasized and details of such planning and preparation are given. The final section deals with the choice of data from the sampling campaign which will provide the least sensitive estimates of flow rates by the node imbalance minimization method. This involves sensitivity analysis on the measured data, using singular value matrix decomposition theory. The method is illustrated by numerical examples.

2.1.1.2 Chapter 2.1 — SAMBA computer program

SAMBA is a conversational implementation of the method of flowsheet sensitivity analysis described in Chapter 2 of the SPOC Manual. For a given flowsheet and sampling data set the user can compare the flow rates obtained for different sampling designs and select a solution of least sensitivity to experimental errors.

2.1.1.3 Chapter 2.2 — Grinding circuit sampling

This chapter of the SPOC Manual presents a case study of sampling experiments conducted at the Brenda Mines grinding circuit for modelling purposes. The notions of flowsheet analysis, experimental design, sampling campaign planning and execution, and even computing of circuit steady-state material balance, are covered in a practical context that provides a most useful supplement to other chapters in which each topic is expanded.

2.1.2 Software

The following programs are related to sampling (numbers between parentheses refer to chapters where the program is described).

2.1.2.1 SAMBA (2.1)

SAMBA determines the sensitivity of a sample material balance method to the design of the sampling experiments including sample location, nature and precision. It can be used to assess hypothetical sampling schemes or to process real sampling data in the least error sensitive fashion.

2.1.2.2 GYFORM (8)

GYFORM computes GY's simplified formula for the variance of the relative sampling fundamental error.

$$\sigma^2_{FE} = C\,\ell\,f\,g\,d^3\left[\frac{1}{M_S} - \frac{1}{M_L}\right]$$

where:

σ^2_{FE} = variance of the relative sampling fundamental error

M_S = sample mass (g)

M_L = lot mass (g)

C = composition factor (g/cm^3)

ℓ = liberation factor (0 or 1)

f = particle shape factor (0.5)

g = size distribution factor

d = maximum particle size (cm).

C, the most variable coefficient, is given by:

$$C = \frac{1 - X_L}{X_L}\left[(1 - X_L)\rho_c + X_L\rho_g\right]$$

where:

X_L = critical concentration

ρ_c = specific gravity of critical component

ρ_g = specific gravity of non-critical component (g/cm^3).

2.1.2.3 TIMESR (8)

TIMESR performs time series analysis. It calculates mean, variance, and variogram for time or space dependent data entered by the user.

2.1.2.4 STATPD (8)

STATPD calculates statistics of paired data. It computes from a pair of data x's and y's the mean, the variance, the standard deviation, the coefficients of variation, the difference and the absolute difference.

2.1.2.5 ANOVA (8)

ANOVA performs a one- and two-way analysis of variance for an experiment with more than two treatments.

2.1.2.6 URANDT (8)

URANDT simulates samples drawn from a normal population, and illustrates the concepts of a sampling error model and its application to simulation studies.

2.1.2.7 FADESN (8)

FADESN analyzes the results of factorial experiments. It calculates the sum of squares, regression coefficients, the experimental error (either from replicate measurements or from interaction effects that are insignificant and negligible) and finally performs the F-test to determine the significance of each effect.

2.2 MATERIAL BALANCE

2.2.1 Documents

The following chapters contain information on material balance computation.

2.2.1.1 Chapter 3 — Material balance

This chapter of the SPOC Manual has been developed for the participants to a workshop on material balance computation. The various methods of material balance calculation are reviewed in order of increasing complexity. The two packages BILMAT and MATBAL are largely documented in Chapters 3.1 and 3.2 to which the reader is referred. The justification of methods requiring computers is presented on the basis of a search for best estimators, i.e., estimators that take into consideration as much experimental information as possible in order to provide "well informed" estimates. Each family of methods is illustrated by numerical exercises.

2.2.1.2 Chapter 3.1 — BILMAT computer program

Material balance computations for complex ore and coal flowsheets are based on large experimental data sets and require a computer. The BILMAT program has been developed to solve such complex problems and compute a sensitivity analysis of the estimated process variables.

This user's guide has been written for two main types of users: the process engineer who wants to access it as a black box to compute his material balances and the research engineer interested in the method and the program itself. The FORTRAN routines are fully documented and two sample runs are presented.

2.2.1.3 Chapter 3.2 — MATBAL computer program

MATBAL is a FORTRAN program to calculate data adjustments required in order to satisfy mass conservation equations valid for a mineral process flowsheet. The calculation is done by minimizing the sum of squares of assay and flow rate adjustments weighted by their reciprocal variance. The available data and the mass conservation equations are coded in a suitable form and the derivatives of a Lagrangian function are internally calculated and cancelled to obtain the adjustments and flow rates which are a solution to the problem. The precision of calculated flow rates can also be obtained.

Writing a program to perform such calculations is only part of the overall task if the method is to be transferred to the end user in the mineral industry. Program documentation has traditionally been the weak point which jeopardizes and often cancels all efforts made to develop a program. This user's manual is an attempt to avoid such a dead-end by fully explaining both the method and the program so that the program can be installed in different computers or translated if FORTRAN is not supported by a given machine. The documentation follows the standards of the A.S.C.E.*

2.2.2 Software

The following programs have been selected for material balance computation.

2.2.2.1 MATBAL (3.2)

MATBAL computes the coherent material balance from sampling data by a least-square method that simultaneously calculates flow rates and adjusts assays according to a given normal error distribution. It can process complex flowsheets and redundant data. Error estimates for the calculated flow rates are also available.

2.2.2.2 BILMAT (3.1)

BILMAT solves the same type of problems as MATBAL but was developed to process a larger variety of experimental data including assays of particle size fractions.

2.2.2.3 NPRD (8)

NPRD implements the N-product formula. Given a unit or a circuit with $N+1$ branches on which $N-1$ assays have been measured, the flow distribution is calculated and a computation of the precision of the results is also performed if the sampling error is known.

2.3 MODEL CALIBRATION

2.3.1 Documents

The following chapters in the SPOC series contain information on model calibration.

2.3.1.1 Chapter 4 — Modelling and simulation

This chapter introduces the concepts of modelling and simulation of mineral processes in practical terms. The general terminology applying this discipline is defined, and several case stories of industrial applications are briefly reviewed. The sequence of steps leading to a circuit simulator are described in the case of simple models for ball mills and hydrocyclones with an introduction to experimental design. Finally, the appendices present several useful techniques of statistical data analysis and regressions as well as a complete data set obtained during the analysis of the Gibraltar grinding circuit.

2.3.1.2 Chapter 4.1 — Industrial ball mill modelling

A simple kinetic ball mill model proved adequate after testing with 100 sets of industrial grinding data. The essential components of the model are (a) a breakage function determined from laboratory tests; (b) a mixers-in-series residence time distribution; and (c) a selection function derived from industrial data. Results show that the absolute selection function (S_iH) is statistically invariant with changes in feedrate, feedsize distribution and pulp density over the normal operating range. All the experiments and calculational procedures used in the calibration of the model are fully documented. This includes an examination of model residuals and a discussion of model reliability.

2.3.1.3 Chapter 7 — Model calibration

Phenomenological or empirical models used to describe most mineral and coal process units require extensive calibrations at the development stage as well as for any subsequent update. The range of techniques required for such calibrations goes from simple linear regression to computation-intensive, multivariable non-linear model calibrations.

The SPOC software library contains programs to address these model calibration requirements which are reviewed through selected sample runs. References are given to the appropriate software.

2.3.1.4 Chapter 7.1 — STAMP computer program

The STAMP program is a conversational package dedicated to experimental data analysis. STAMP features data entry and data file maintenance, various regression methods (including simple linear regression, multiple linear regression, stepwise linear regression, polynomial regression) and three non-linear optimization algorithms (Powell, Simplex and Rosenbrock). Options selection is menu driven.

This chapter is a user's guide to the program and includes a detailed sample run.

The version of the program described here (STAMP84) was written in FORTRAN for a Cyber 730 computer. It easily runs in a 70 K words memory in CDC terminology (29 K words decimal), but uses file structure and FORTRAN routines specific to Cyber. A version is also available for an IBM-PC environment.

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* *Engineering Computer Program Documentation Standards;* ***Journal of the Soil Mechanics and Foundations Division SM3,*** March/Mars 1973, pp. 249-266.

2.3.1.5 Chapter 7.2 — FINDBS computer program

This manual describes the various procedures involved in the development of a ball-mill simulator. The major task is the estimation of the breakage rate and distribution parameters which are central to the model. That is why the bulk of this volume is devoted to describing the methods, mathematics and computer programs used to calculate model parameters. Section 1 outlines the general structure of the kinetic ball-mill model. Section 2 focuses on the laboratory tests and computation techniques required to estimate the breakage distribution and rate parameters. Finally, Section 3 illustrates the methods using data from an operating industrial mill.

The computer programs are interactive and fully documented and can therefore be used without a detailed knowledge of the principles. However, it must be emphasized that a correct interpretation of the results depends on a thorough understanding of the kinetic model. For that reason, program users should at least read Section 1 describing the basis of the method. Further explanations and analysis appear in the remaining sections; the mathematics have been detailed in the appendices. The program structure should allow easy modifications.

2.3.1.6 Chapter 7.3 — RTD and MIXERS computer programs

The transport properties of material through various ore and coal processing units are important factors which control the performance of those units. This manual describes the basic tools for determining the flow pattern for a piece of equipment. The residence time distribution is defined, as well as three approaches to represent it. Then, several experimental methods based on tracers are presented and compared. The FORTRAN programs used to process the tracer data are fully documented, as are the mathematics on which they are based. All the methods and programs are illustrated with actual data from industrial grinding and flotation circuits.

This manual is directed to plant process engineers. All the necessary definitions are given, and only limited mathematical ability is required to apply the methods and use the programs. For those more familiar with process modelling, extended appendices give details of the mathematics. This should allow ongoing improvements and modifications to the packages as well as independent programming of the methods for users who want to have their own program in a language other than FORTRAN.

2.3.2 Software

The following programs are related to model calibration.

2.3.2.1 STAMP (7.1)

STAMP is a conversational regression package for easy entry and manipulation of experimental data, basic statistical calculations, study of correlations and calculation of coefficients by various types of regressions including non-linear optimization by direct-search.

2.3.2.2 FINDBS (7.2)

FINDBS is an interactive program to calculate the breakage and selection function coefficients of the kinetic model of ball mills. Ore characteristic breakage functions can be computed from batch mill experiments and used in conjunction with industrial data to determine the machine-dependent selection functions that will allow accurate simulations within the range of observed variables.

2.3.2.3 RTD and MIXERS (7.3)

RTD is a conversational program to calculate the residence time distribution that best describes the material transport through the mill, from tracer experiments. This program is most useful when recycled tracer overlaps the primary signal in the experimental data. MIXERS uses a discretized residence time distribution to calibrate a tank-in-series model of the distribution.

2.3.2.4 HCAL (7)

HCAL is proposed for the calibration of hydrocyclone efficiency curves. Two kinds of models are available, the equation developed by Plitt and used in the simulation module HCONE or the model proposed by Lynch.

2.4 PROCESS SIMULATION

2.4.1 Documents

The following chapters contain information on process simulation.

2.4.1.1 Chapter 5 — Unit models: part A

Specific mathematical models of comminution and flotation equipment are described and the need for quantifying equipment constraints is discussed along with the limitations of each model.

The mathematical description of a primary gyratory crusher, a primary jaw crusher, a secondary cone crusher, a tertiary cone crusher, a crushing rolls, an autogenous grinding mill and a flotation cell have been converted to FORTRAN programs for subsequent use as subroutines in an executive steady state simulator.

Documentation should permit potential users to install subroutines in different computers or to translate them into language other than FORTRAN.

2.4.1.2 Chapter 5.1— Unit models: part B

Specific mathematical models of classification and coal-processing equipment are described. Constraints and limitations are discussed for the following mod-

els: rotary beaker, a general coal crusher model, four screen models (Karra, Whiten, Valliant and a sieve bend model), a hydrocyclone model, a gravity classifier model and a specific gravity separator model. For each FORTRAN program, a small driver and test data are provided.

2.4.1.3 Chapter 5.2 — Unit models: part C

Mathematical models of the following units are described: rod mill, ball mill, balling drum, rotary vacuum filter, Mogensen sizer. For each model, a brief engineering discussion as well as test data are provided.

2.4.1.4 Chapter 6 — Flowsheet simulators

This crushing plant simulator is based on industrial data and can be used for the optimization of existing plants or the design of new plants. It allows fast computations at a lower cost and reduces the chances of error. For a meaningful use of the program and a good interpretation of the results, the user must be familiar with crushing plant practice.

2.4.2 Software for Process Unit Simulation

The following programs are related to process simulation.

2.4.2.1 PGCRUS (5)

PGCRUS (Primary gyratory crusher model). This model was proposed and developed by Mular and uses the concept of selection/breakage/classification. The only design variable included in the model is the open side set.

2.4.2.2 PJCRUS (5)

PJCRUS (Primary jaw crusher model). This model treats the Primary jaw crusher as a special case of the Primary gyratory crusher model using scalped (screened) feed. The only design variable included in the model is the open side set.

2.4.2.3 SCCRUS (5)

SCCRUS (Secondary cone crusher model) is the Whiten cone crusher model modified by Hatch and Mular.

2.4.2.4 TCCRUS (5)

TCCRUS (Tertiary cone crusher model) is similar to the modified Whiten model for the secondary cone crusher. It was developed for a 7-foot short head cone crusher equipped with a 300 hp motor at 4.16 kv.

2.4.2.5 CRSHRO (5)

CRSHRO (Crushing rolls model). The concept used is that breakage leads to material smaller than the particular size range of interest. Material remaining within the size range after passing through the rolls is considered material that is unbroken (by-passed).

2.4.2.6 ATMILL (5)

ATMILL (Autogenous mill model). The basic model is after Gault and Lynch.

2.4.2.7 FLTCLS (5)

FLTCLS (Flotation cell model). This is based on the model of a flotation cell and bank of cells by Mular and Bull. An interactive method using linear interpolation is used to determine estimates of tailing volume, convergence being judged by the difference between successive estimates.

2.4.2.8 ROTARY (5.1)

ROTARY (Rotary breaker model). This is Valliant's model which supposes that coal is processed serially in a number of tumbling events. Each event consists of coal breakage followed by screening.

2.4.2.9 VACRSH (5.1)

VACRSH (Valliant model of crusher). This is Valliant's model which identifies three crushing zones in coal breakage. This model is said to be capable of simulating gyratory/jaw, single roll, multiple roll or cage mill crushers, either in primary or secondary mode.

2.4.2.10 KSCRN (5.1)

KSCRN (Screening model by Karra). This model incorporates all the parameters which are deemed significant in evaluating a screen's performance. The model relationships were established from data obtained from 20 dry screening tests.

2.4.2.11 WSCRN (5.1)

WSCRN (Whiten screen model). This model has been used in the simulation of coarse screens in mineral crushing plants. The model computes the mean probability that particles within a narrow size interval will report to the screen oversize product.

2.4.2.12 VSCRN (5.1)

VSCRN (Valliant screen model). This is a relatively simple model for coarse screening requiring a minimum of user inputs. It is capable of simulating both wet and dry screening for both top and bottom decks and for projected throughfall apertures from 18 to 0.01 in.

2.4.2.13 BEND (5.1)

BEND (Sieve bend model). This model consists of a series of empirical equations which relate the partition curve parameters in terms of the feed slurry per cent solid, the mass flow rate of water, and the slot width (width of opening between bars).

2.4.2.14 HCONE (5.1)

HCONE (Hydrocyclone model). The Plitt model is based on a large database of over 200 tests involving both laboratory and industrial scale cyclones. HCONE is available as three different models:

- HCONE1 calculates the partition curve parameters from cyclone dimensions and operating conditions.
- HCONE2 calculates the partition curve from values of the cyclone parameters D50C, EM and RF.
- HCONE3 uses a fixed partition (efficiency) curve.

2.4.2.15 GCLASS (5.1)

GCLASS (Gravity classifier model). The model is applicable to any type of gravity classifier where the settling area can be defined, e.g. Hydroseparators, spiral or rake classifiers, classifier cones.

2.4.2.16 SGSEP (5.1)

SGSEP (Specific gravity separator model). This model is the partition curve used in the coal industry for many years. The partition curve is, in general, considered to be characteristic of the unit used and independent of the feed density.

2.4.2.17 RMILL (5.2)

RMILL (Rod mill model). This is the classical Lynch-Callcott matrix model using breakage and selection functions.

2.4.2.18 BMILL (5.2)

BMILL (Ball mill model). This is the kinetic model of ball-milling based on concepts of breakage and selection functions, and tank-in-series residence time distribution.

2.4.2.19 MOGENS (5.2)

MOGENS (Mogensen sizer model). This routine simulates the operation of a linear, multi-deck, probability screening machine known as the Mogensen sizer. The probability screening machine sacrifices a degree of screening accuracy in favour of higher throughput and reduced blinding.

2.4.2.20 VACFIL (5.2)

VACFIL (Vacuum filter model). This model is based on the work of H. Rudolf. Using the operational parameters of a unit filter an estimate of the unit throughput and filter cake thickness and moisture is obtained.

2.4.2.21 BALDRM (5.2)

BALDRM (Balling drum model). This model is based on the work of M. Cross. The balling drum circuit output is described as a function of time. There are two growth mechanisms, with fresh feed and in the absence of fresh feed.

2.4.2.22 MIXER2, MIXER3 (5.2)

MIXER2 and MIXER3 simulate the mixing of two or three slurry streams, respectively.

2.4.3 Software for Process Flowsheet Simulation

2.4.3.1 CRSHEX (6)

CRSHEX (Crushing plant executive) has been developed for the interactive simulation of crushing plants on an IBM-PC type of microcomputer.

2.4.3.2 GRNDEX (6)

GRNDEX is used to simulate grinding plants involving rod mill, ball mills, hydrocyclones and mixers. The unit modules that can be used are: RMILL, BMILL, HCONE, and two or three stream mixers.

2.4.3.3 HCONEX (6)

HCONEX is used to simulate a multicycloning unit involving solids recycling and water addition. It uses two kinds of unit modules, HCONE unit module and the MIXER2 and MIXER3 unit modules.

2.4.3.4 FLOTEX (6)

FLOTEX is used to simulate a flotation plant involving solids recycling and water addition. It uses two kinds of unit modules, the FLTCLS module and the MIXER2 and MIXER3 modules.

2.4.3.5 SPLITX (6)

SPLITX is a general flowsheet 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.

2.5 MISCELLANEOUS COMPUTATIONS

2.5.1 Documents

During the course of the SPOC project, several computer programs have been developed or adapted to perform ancillary tasks or routine laboratory computations. They are documented in Chapter 8 of the manual. A brief description of these programs is given below.

2.5.2 Software

2.5.2.1 METCAL (8)

METCAL computes the species distribution and absolute content from assay values of several fractions of a feed material. The program offers options for ore and coal, combinations of fractions, table format.

2.5.2.2 PARTSZ (8)

PARTSZ manipulates particle size data in various representations (cumulative, non-cumulative, etc.).

2.5.2.3 BONDWI and SBOND (8)

BONDWI is a conversational implementation of the bond work index (WI) formula used to process results of laboratory tests.

SBOND calculates the simplified bond formula for work index determinations using a reference material of known WI.

2.5.2.4 UCONV

UCONV performs unit conversion from and to metric in conversational mode.

2.5.2.5 COMPLOT

COMPLOT is computer data plotting utility program. x-y graphs with optional axes and labels can be previewed, modified and sent to hard copy plotter. It requires a Textronix graphic terminal, and software libraries. Conversion to other machines may be more difficult.

3. METHODOLOGY TRANSFER

From the start, the SPOC project was aimed towards a methodology transfer between R&D centres and the mineral industry (17-21). The release of software and the distribution of the SPOC Manual by the Technology Information Division of CANMET provide a durable channel to achieve this transfer, but it is clear that the human factor plays a major role in drawing the full benefits from the SPOC methodology. In other words, what is needed is not only a series of soft disks and a collection of manuals, but also a new profile of mineral processing engineer for whom interaction with a computer terminal is as natural as reading the technical literature. This integration of the computer as an everyday tool is done routinely in the engineering schools of the mid-80's but requires special training for engineers from previous vintages. This has been the objective of the many seminars given between 1980 and 1985 (Fig. 3) and will remain a critical element of the post-project activities.

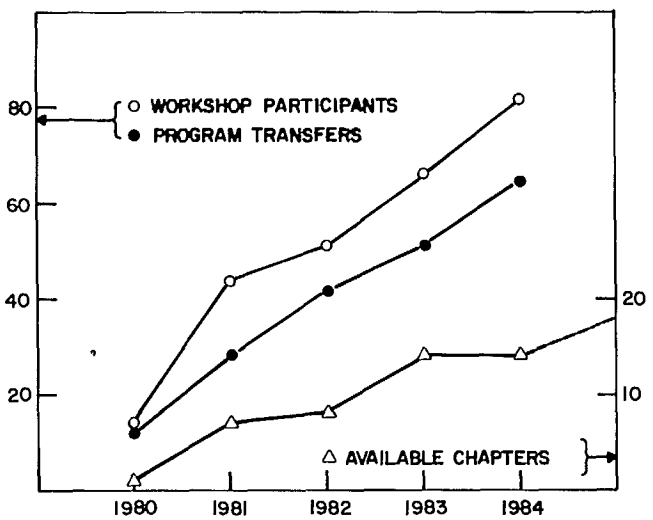

Fig. 3 — Methodology transfer during the SPOC project

3.1 SPOC MANUAL TRANSFER

The SPOC manual consists of 18 separate chapters as listed in Table 1. They can be acquired separately or as a set from:

CANMET,
Technology Information Division
555 Booth Street
Ottawa, Ontario
K1A 0G1

Table 1 — List of the SPOC chapters

Chapter	Title
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 & MIXERS Computer Program
8	Utility Programs

3.2 SPOC SOFTWARE TRANSFER

The FORTRAN programs generated by the SPOC project can be acquired in source form from the Technology Information Division of CANMET.

The source programs come in three categories for ordering purposes:

— CDC CYBER magnetic tape of all SPOC programs as operating on the CDC computer and in a version and style of FORTRAN (4.8) that makes transfer to other mainframes quite straightforward (see also Table 2);

— IBM-PC soft disks (5 1/4 in.) of individual programs or group of programs related by theme. The FORTRAN version is microsoft and the operating system is MS-DOS (see also Table 3);

— a magnetic tape containing a copy of all the IBM-PC source programs.

Table 2 — List of the mainframe computer programs

MAGNETIC TAPES, UNLABELLED, 9 TRACK, 1600 BPI*, ASCII or
EBCDIC, 80 CHARACTERS/RECORD, 50 RECORDS PER BLOCK (*OPTION)

SYSTEM USED:	CDC CYBER 730
OPERATING SYSTEM:	NOS/BE
FORTRAN COMPILER:	CDC FORTRAN EXTENDED 4.8
AVAILABLE AS:	TAPE No. 1: THE FORTRAN SOURCES TESTED ON A CDC CYBER TAPE No. 2: A COPY OF THE IBM-PC SPOC DISKETTES
PROGRAMS ON TAPE 1:	SAMBA, GYFORM, TIMESR, STATPD, ANOVA, URANDT, FADESN, MATBAL4, BILMAT, ADSTAMP, STAMP, FINDBS, RTD, MIXERS, HCAL, PGCRUS, PJCRUS, SCCRUS, FLTCLS, ROTARY, KSCRN, VSCRN, WSCRN, GCLASS, SGSEP TCCRUS, CRSHRO, ATMILL, VACRSH, BEND, HCONE, RMILL, BMILL, MOGENS, VACFIL, BALDRM GRNDEX, HCONEX, FLOTEX, SPLITX, METCAL, PARTSZ, BONDWI, SBOND, UCONV, NPRD, COMPLOT
PROGRAMS ON TAPE 2:	SEE LIST OF SPOC IBM-PC COMPUTER PROGRAMS (TABLE 3)

Table 3 — List of the IBM-PC computer programs

SOFT DISKS, 5 1/4 INCH, DOUBLE DENSITY		
SYSTEM USED:		IBM-PC XT (256K), 1 HARD DISK DRIVE AND ADAPTER (10MB), 1 SOFT DISK DRIVE AND ADAPTER (320K), 1 MATH COPROCESSOR 8087, PRINTER, KEYBOARD, COLOR/GRAPHICS MONITOR ADAPTOR (OPTIONAL), 1 SYSTEM MONITOR OR SYSTEM GRAPHICS MONITOR (OPTIONAL)
OPERATING SYSTEM:		MS-DOS VERSION 3.00
FORTRAN COMPILER:		MICROSOFT FORTRAN 77 VERSION 3-2 COMPILER FOR MS-DOS 8086 OBJECT LINKER VERSION 2.41
PACKAGE	NO. OF DISKETTES	PROGRAMS
1	1	SAMBA, GYFORM, TIMESR, STATPD, ANOVA, URANDT, FADESN
2	1	MATBAL4
3	1	BILMAT
4	2	STAMP
	1	STAMP (ADSTAMP)
5	1	FINDBS, RTD, MIXERS, HCAL
6	1	PGCRUS, PJCRUS, SCCRUS, FLTCLS, ROTARY, KSCRN, VSCRN, WSCRN, GCLASS, SGSEP, ATMILL, VACRSH, MOGENS
	2	TCCRUS, CRSHRO, BEND, HCONE, RMILL, BMILL, VACFIL, BALDRM
7	1	GRNDEX
	2	CRSHEX
8	1	HCONEX, FLOTEX
	2	SPLITX (1 of 2)
	3	SPLITX (2 of 2)
9	1	METCAL, PARTSZ, BONDWI, SBOND, UCONV, NPRD

3.3 REMOTE ACCESS TO DEMONSTRATIONS

Since late 1983, a system of demonstrations of the SPOC programs has been made available to the Canadian mineral processing industry to help users become familiar with the various programs of the SPOC libraries. Software development had limited the resources allocated to the exploitation of this training system which should experience a peak of activity during the post-project period. Request for temporary access to this remote training facility can also be routed to the Technology Information Division of CANMET.

3.4 DISCLAIMER AND CONDITIONS ON USE

The software and manuals distributed by CANMET are released under the following understanding:

- the charges do not cover any support and CANMET cannot undertake to provide assistance of any kind nor guarantee that the programs and documentation are free from errors. However, we will try to remain available for questions from users and we invite written suggestions to improve the programs;
- the programs or manuals may not be copied for use by persons or organizations other than the purchaser except with the written permission of CANMET;
- due acknowledgement is expected in the publications resulting from the use of programs or of modifications involving less than 50% of the executable statements;
- the use of the programs in commercial applications must be agreed in writing with CANMET.

The liaison officer can be contacted at the following address:

SPOC Liaison Officer
Technology Information Division
555 Booth Street
Ottawa, Ontario, Canada
K1A 0G1

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