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1 OVERVIEW OF RESULTS

In this work four models were entered into the Microsim unit library. The Whiten crushing model was modified for the crushing of haematite and a new model was developed for the gyradisc crushing of haematite. The Karra screen model was enhanced to include the use of 'poly' decks and non-square screen apertures. The Rose efficiency model was developed for simulation where screening efficiency is known from data or experiments.

These crushing and screening models have been found to be accurate for the simulation of the sub-plants, and are in good agreement individually with experimental data.

A study of gyradisc product size distributions revealed that there were two breakage mechanisms occuring in the crushing chamber. These mechanisms were interparticle comminution by compression and by abrasion, each yielding a distinctive Rosin-Rammler product size distribution. The parameters describing these Rosin-Rammler distributions vary with ore type. Therefore the gyradisc model is limited in its applicability to the specific type of iron ore processed in the plant. The Whiten model is similarly limited to the crushing of haematite, as model parameters will vary for different ores.

Crushing applications can be modelled with reasonable accuracy by considering only crusher settings and ore breakage characteristics. Only if operating conditions differ markedly from normal, must operating conditions be taken into account. Feed rates should remain within manufacturers' specifications for accurate simulation, although the gyradisc model can be used over the entire range of feed rates tested.

The screening models developed in this work follow two approaches. Both the Rose and the enhanced Karra models are transferable to other screening applications. The Rose efficiency model can be extended to screening of different materials by using screenability characteristics tests.

The Rose model is more accurate than the enhanced Karra model, but relies on data obtained from screening operations on similar

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machines. It is the responsibility of the user to ensure that efficiencies input to the simulator correspond with recorded flow rates. If necessary, efficiencies should be modified, preferably using experimental data for the efficiency at the simulated flow rate. This is particularly important when the optimisation facility is used.

Simulation studies on the quaternary plant showed that Microsim was capable of simulating accurately the product from this sub-plant, both when there were two products (lumpy and fine ore) and when there were three products (lumpy, fine and direct reduction ore). The overall production ratios predicted were within two percent of those observed on plant.

A sensitivity analysis of variables on the quaternary plant revealed that the ratio of ore produced was most sensitive to changes in the values of the closed side settings of the fresh feed and recirculating feed crushers and less sensitive to changes in screen apertures. Changes in screen apertures could cause a significant proportion of the products to be beyond specification.

The optimisation facility of Microsim was then used for improving the ratio of lumpy to fine ore in the quaternary plant. The target ratio was taken as 25:75, the overall plant target. The optimisation variables were taken to be the closed side settings of the fresh feed crusher and the recirculating feed crusher. This optimisation study revealed that only a slight improvement of this ratio could be achieved in the quaternary plant, indicating that this plant is operating close to its optimum. Physical considerations were used to constrain the values of the optimisation variables.

In order to improve the ratio of lumpy to fine ore beyond the abovementioned optimum, modifications would have to be made in the preliminary comminution section of the plant (sub-plant 1).

Simulation of this preliminary comminution sub-plant was however not accurate. This could be ascribed to the fact that this sub-plant is fed by tip-trucks and therefore does not operate in steady state conditions. Microsim is a steady state simulator, hence its use in simulating this sub-plant (or any other application where steady-state conditions do not prevail) should be avoided. The accuracy of

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the Nordberg gyratory crushing model was not established, and could be a source of error.

The washing and screening plant (sub-plant 2) was accurately simulated using the new models in Microsim.

Accurate simulation of crushing and screening applications depends on the careful choice of size classes. The maximum number of size classes should be used. If necessary this maximum (set at 20 in the standard version of Microsim) may be increased by editing and recompiling the Microsim program. Size classes should preferably be chosen to coincide with screen apertures in simulation studies. It is not possible to do this when using the optimisation routine with screen apertures as optimisation variables. The user should be aware that this may affect the accuracy of the optimisation. It is also wise to perform several optimisation runs, varying step changes of the optimisation variables, in order to detect premature termination of the optimisation routine.

Microsim is a useful tool for simulation and optimisation of ore dressing flowsheets. The process engineer can use Microsim to assess inexpensively the effect of changes to the plant. New units can also be designed using the optimisation facility. Good quality input and careful evaluation of results are, however, essential to successful application of Microsim.

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2 INTRODUCTION

2.1 Introduction to ore dressing simulation

With the advent of high speed digital computation, computer simulation has become a valuable tool to understand and analyze industrial processes.

Ore dressing has lagged behind the chemical process industries in the field of simulation because of the difficulty of handling a material particle size distribution in calculation procedures. Nevertheless, ore dressing simulators have developed in the last decade to be of great value in all stages of plant development.

In initial stages of plant design, the process and economic feasibility of various alternative flowsheets and unit sizes can be evaluated using models not dependent on empirically derived data. Thereafter, simulators can be used with more reliable data and/or models in pilot plant scale operation. Hence optimum operation of full scale plants can be determined by repeated simulation. Likewise, design and parameter estimation can be done by repeated simulation, using simple models for convergence and complex models for the final design. Some simulators have the capability to do repeated simulation using an optimisation algorithm.

During normal operation of the full scale plant, simulators are used to optimise plant performance, to determine the influence of variable or parameter changes and to determine the parameter changes required for new products, without doing any on-plant trials or making use of cumbersome hand calculations. Such usage is an important aim of the ore beneficiation plant.

The simulator can be used to estimate parameters of a particular material, unit operation from plant data and to develop alternative models of unit operations. The development of primarily crushing and screening models will be dealt with in this work.

The implementation of control strategies is facilitated through the use of a simulator, particularly if a dynamic simulator is used or a model developed from first principles, since plant behaviour is then known and plant response can be predicted.

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Simulators are used for the training of plant personnel to run the plant proficiently as well as to prevent costly errors occurring. This serves as a vehicle for technology transfer from a research environment to the plant.

Since supervisory control of the plant is envisaged, simulation studies would be significant in the development of control strategies.

To use a general purpose simulator efficiently on a given plant, it is necessary to enhance it using a combination of theoretical and empirical modelling and historical data. In this work, a general purpose simulator, Microsim (8,34,50,51), is upgraded for application as a cheap and effective means of simulating the plant for a variety of purposes.

Simulation of entire plants is usually restricted to simulation of steady state operation only in order to reduce the complexity of the problem. The scope of this work is therefore limited to steady state simulation only.

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2.2 Introduction to the ore beneficiation plant and simulation thereof

The ore beneficiation plant produces two (or sometimes three) products of concentrated iron ore from run-of-mine viz. lumpy, fine and, if required, direct reduction ore. The ore sizes for the three products are as follows:

Ore	Size (mm)
Lumpy	25/8
Fine	5/2
Direct Reduction	11/5

The production percentages and tonnages will vary according to market demand.

If direct reduction ore is not required, this material is crushed to fine ore and plant parameters are changed to maintain a better ratio of fine to lumpy ore. Ideally, the ratio of fine to lumpy ore should be 1:3, but to date the best ratio achieved has been 2:3.

A method is required to quantify plant performance, and hence to provide a means of plant optimisation according to the production percentages and tonnages required.

The metallurgical optimisation and maintenance of standards is the primary aim of simulation of the plant. However, minimization of waste (and hence lowered cost of land rehabilitation) is a secondary aim.

The plant can be considered as four separate sub-plants:

(1)Preliminary comminution of run-of-mine (SP1)
(2)Washing and screening (SP2)
(3)Beneficiation of four size fractions for ore
(CDP, MDP, CCP, FCP)
(4)Crushing and screening of ore to products (SP4).

These sub-plants are shown schematically in figures 1 to 7, as Microsim flow diagrams detailing only the metallurgical flow and representing parallel units as one. All ancillary equipment is not

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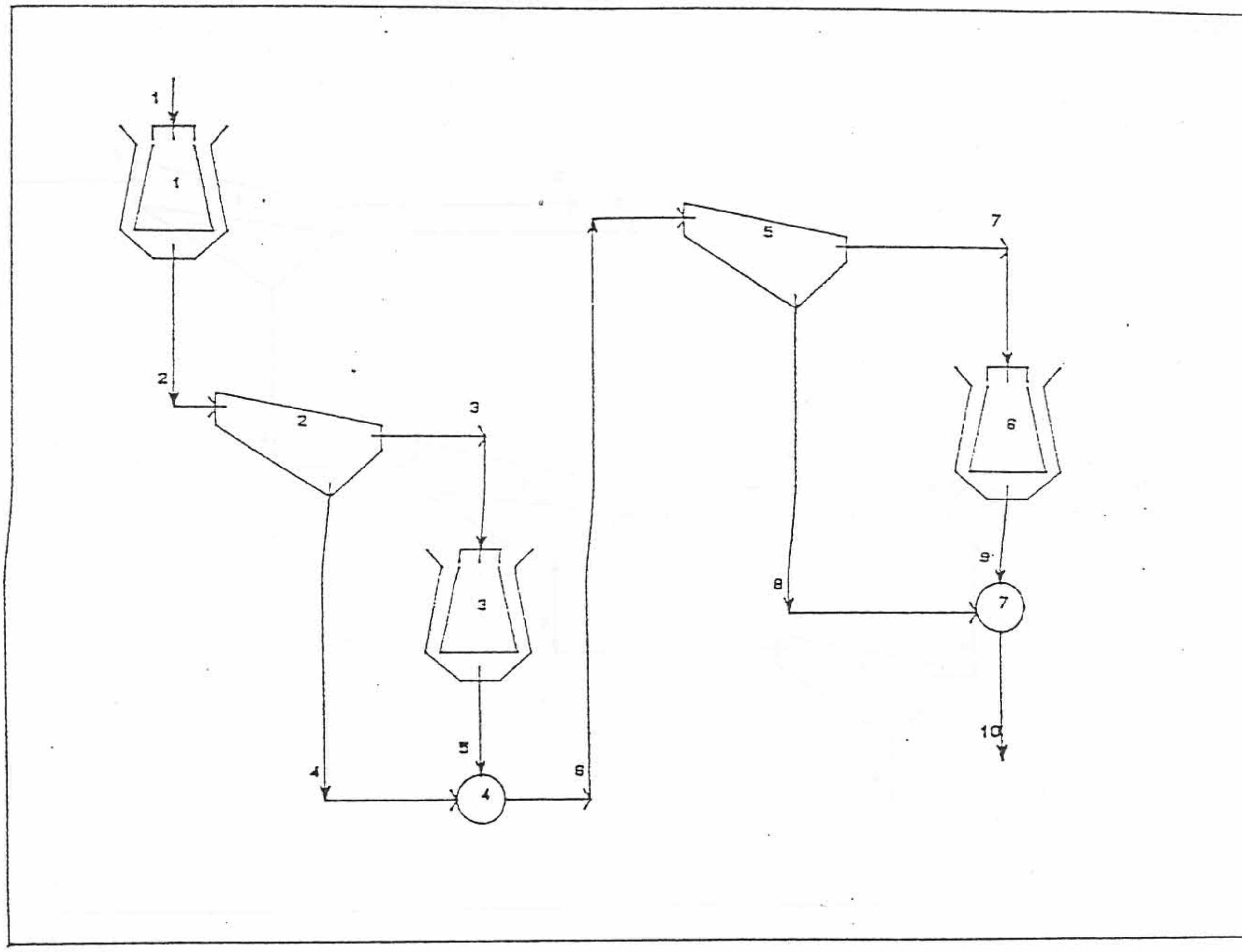

Fig 1 Flow diagram for sub-plant 1: Preliminary comminution

Unit 1: Primary gyratory crusher, OSS = 225mm
Unit 2: Grizzly, Aperture = 120 x 120mm
Unit 3: Secondary Symons cone crusher, CSS = 90mm
Unit 5: Grizzly, Aperture = 80 x 80mm
Unit 6: Tertiary Symons cone crusher, CSS = 50mm
Units 4 and 7: Mixers

Stream 10 corresponds to stream 1 of SP2

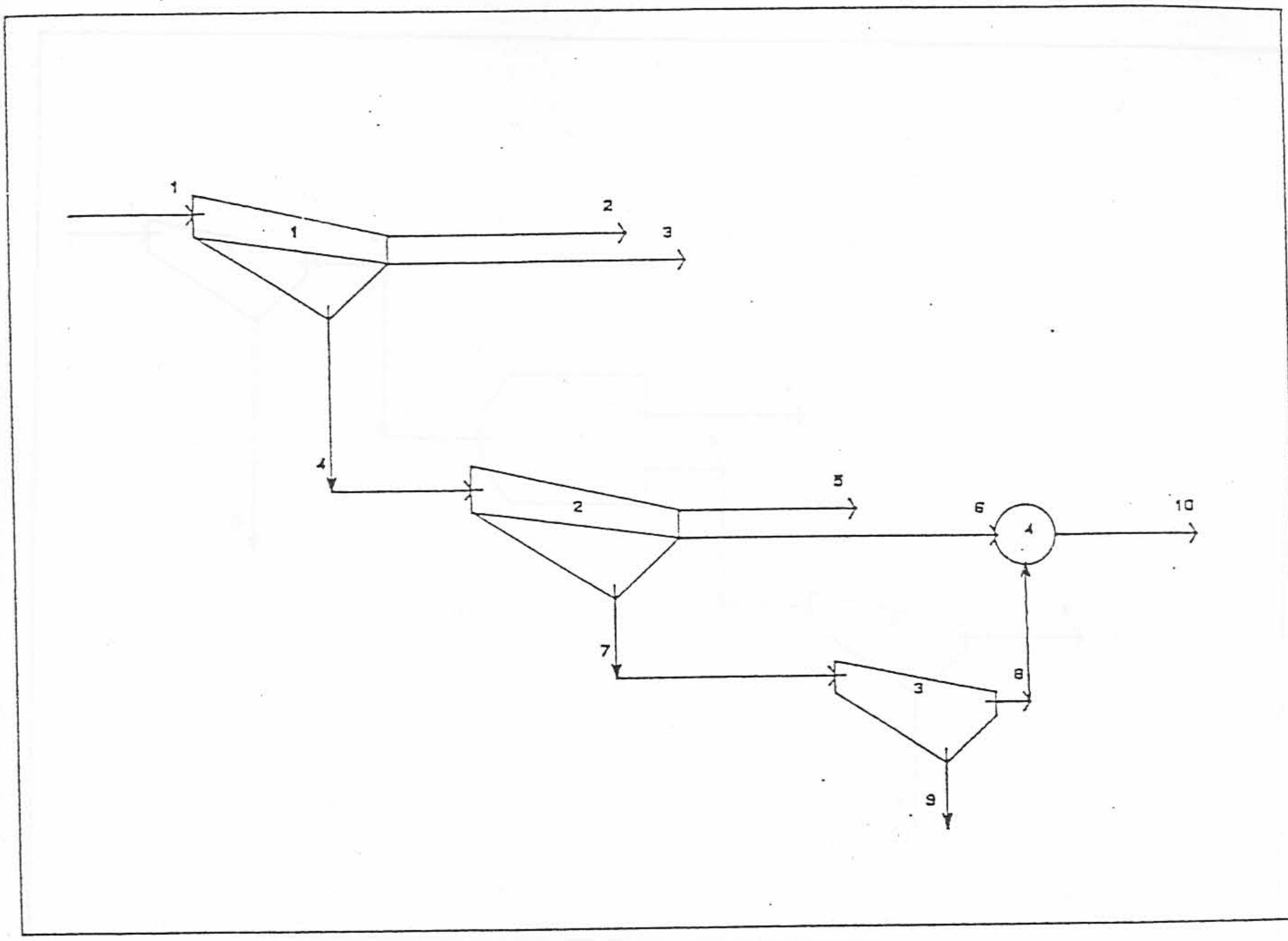

Fig 2 Flow diagram for sub-plant 2: Washing and screening

Unit 1: Primary screen, Top deck aperture = 26,2 x 26,2mm
Bottom deck aperture = 10 x 10mm
Unit 2: Secondary screen, Top deck aperture = 6,3 x 6,3mm
Bottom deck aperture = 1,75 x 12mm
Unit 3: Dewatering screen
Unit 4: Mixer

Stream 2 corresponds to stream 1 of CDP
Stream 3 corresponds to stream 1 of MDP
Stream 5 corresponds to stream 1 of CCP
Stream 10 corresponds to stream 1 of FCP

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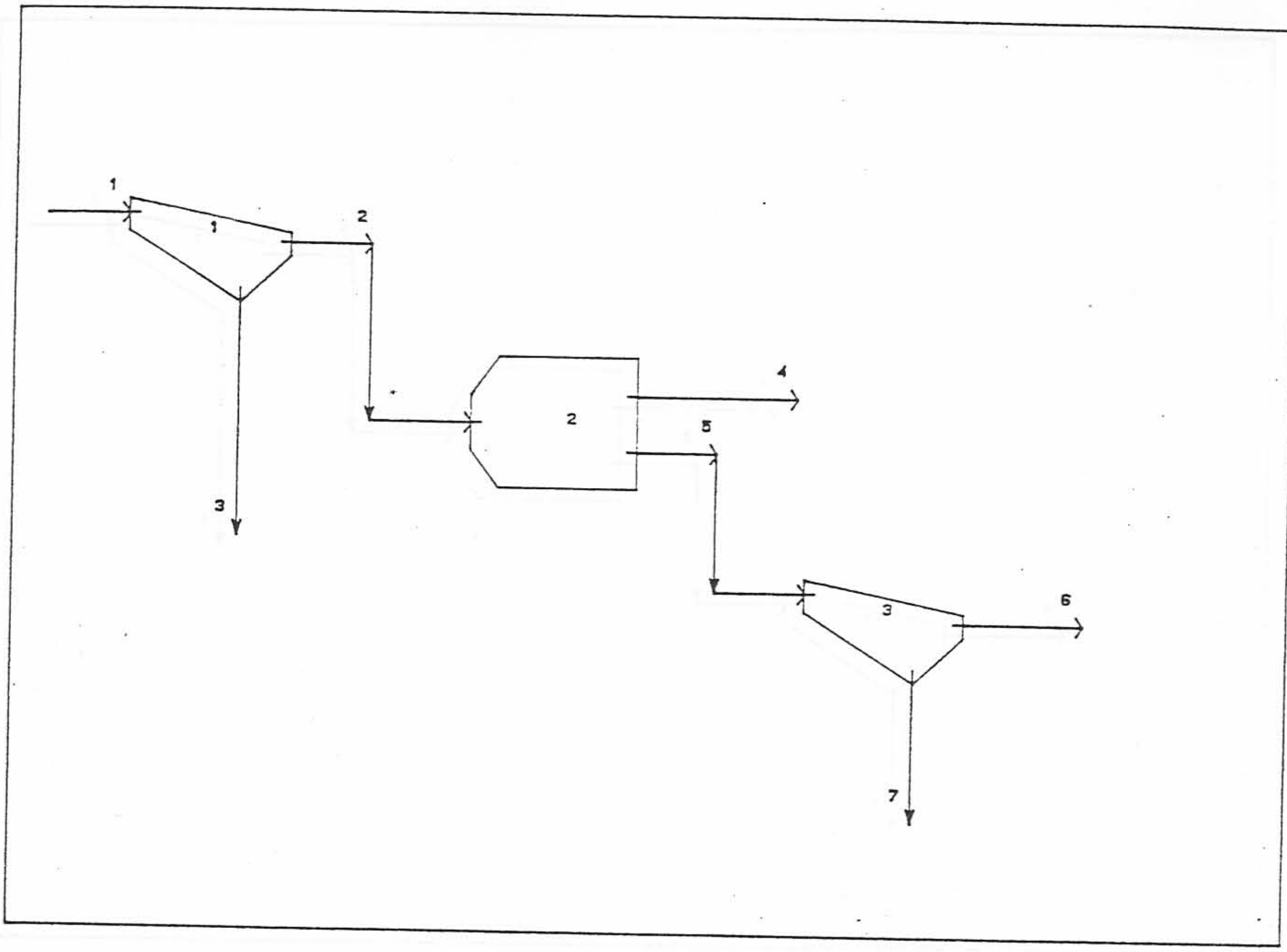

Fig 3 Flow diagram for the coarse drum beneficiation plant.

Unit 1: Feed preparation screen, aperture = 4,5 x 35mm
Unit 2: Wemco drum separator, specific gravity = 3,8
Unit 3: Sinks screen, aperture = 2,7 x 33mm

Stream 6 corresponds to stream 1 of SP4

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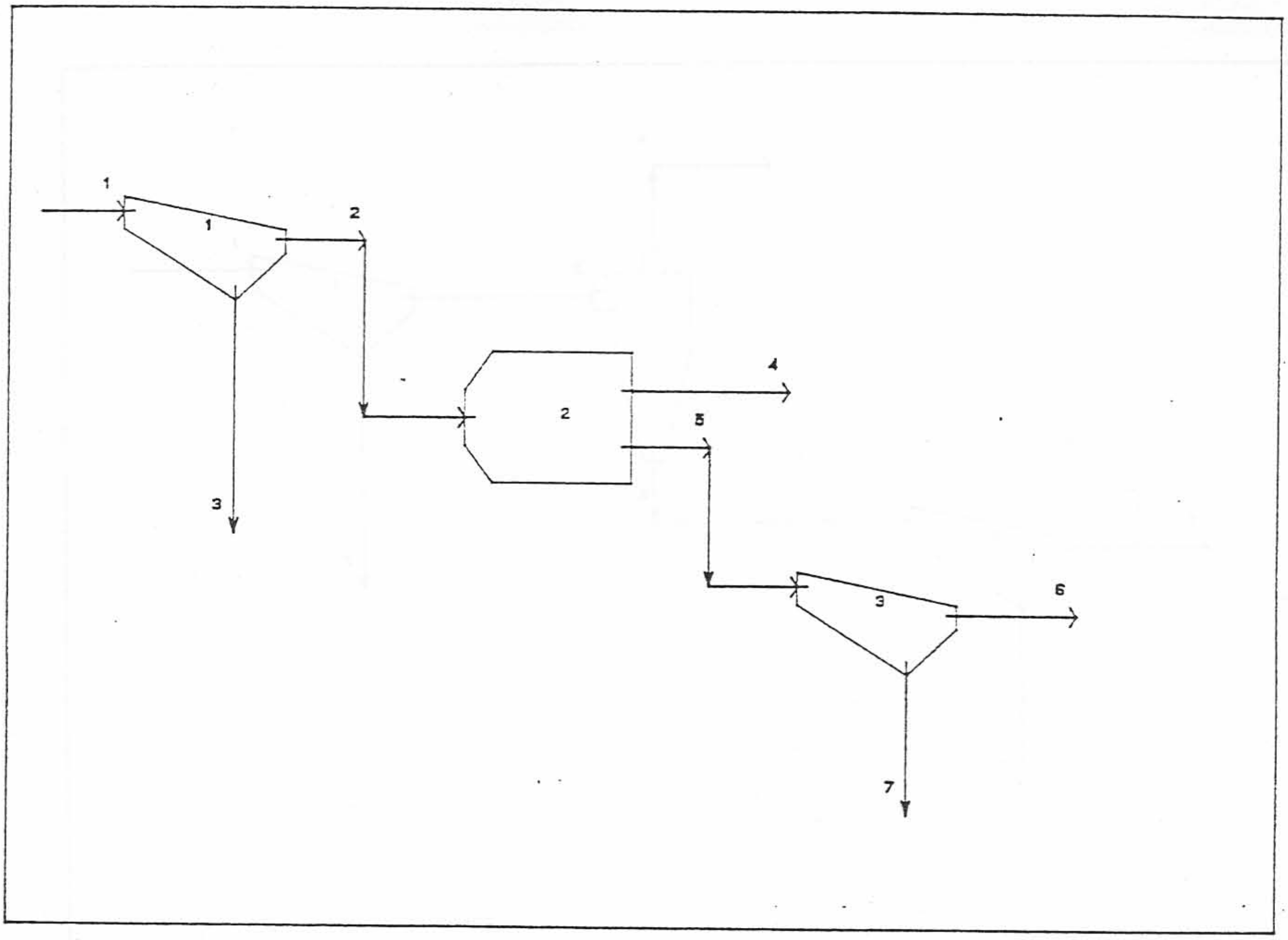

Fig 4 Flow diagram for the medium drum beneficiation plant

Unit 1: Feed preparation screen, aperture = 10 x 10mm
Unit 2: Wemco drum separator, specific gravity = 3,7
Unit 3: Sinks screen, aperture = 5 x 5mm

Stream 6 contains LUMPY ORE product

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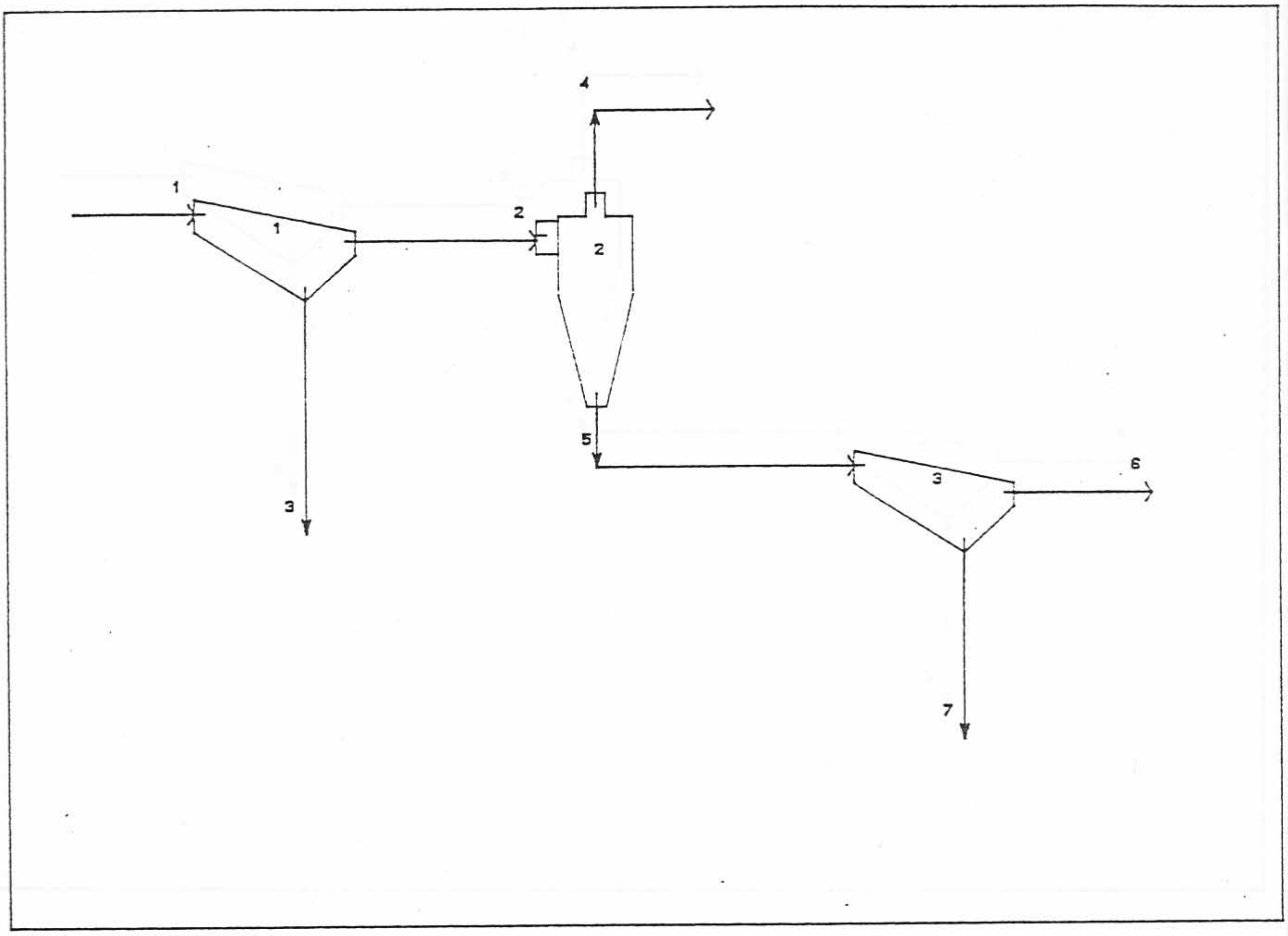

Fig 5 Flow diagram for the coarse cyclone beneficiation plant

Unit 1: Feed preparation screen, aperture = 3,15 x 3,15mm
Unit 2: Dense medium hydrocyclone, specific gravity = 3,1
Unit 3: Sinks screen, aperture =3,15 x 3,15mm

Stream 6 corresponds to stream 3 of SP4

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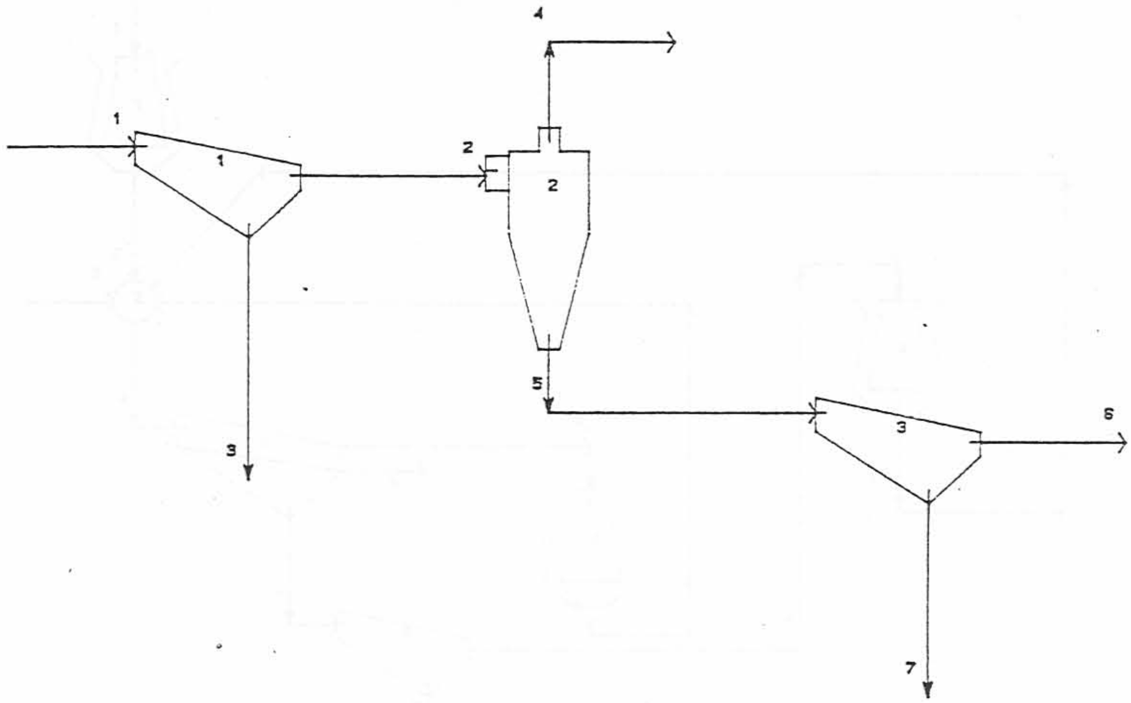

Fig 6 Flow diagram for fine cyclone beneficiation plant

Unit 1: Feed preparation screen, aperture = 0,63 x 12,5mm
Unit 2: Dense medium hydrocyclone, specific gravity = 3,1
Unit 3: Sinks screen, aperture = 0,63 x 12,5mm

Stream 6 contains FINE ORE product

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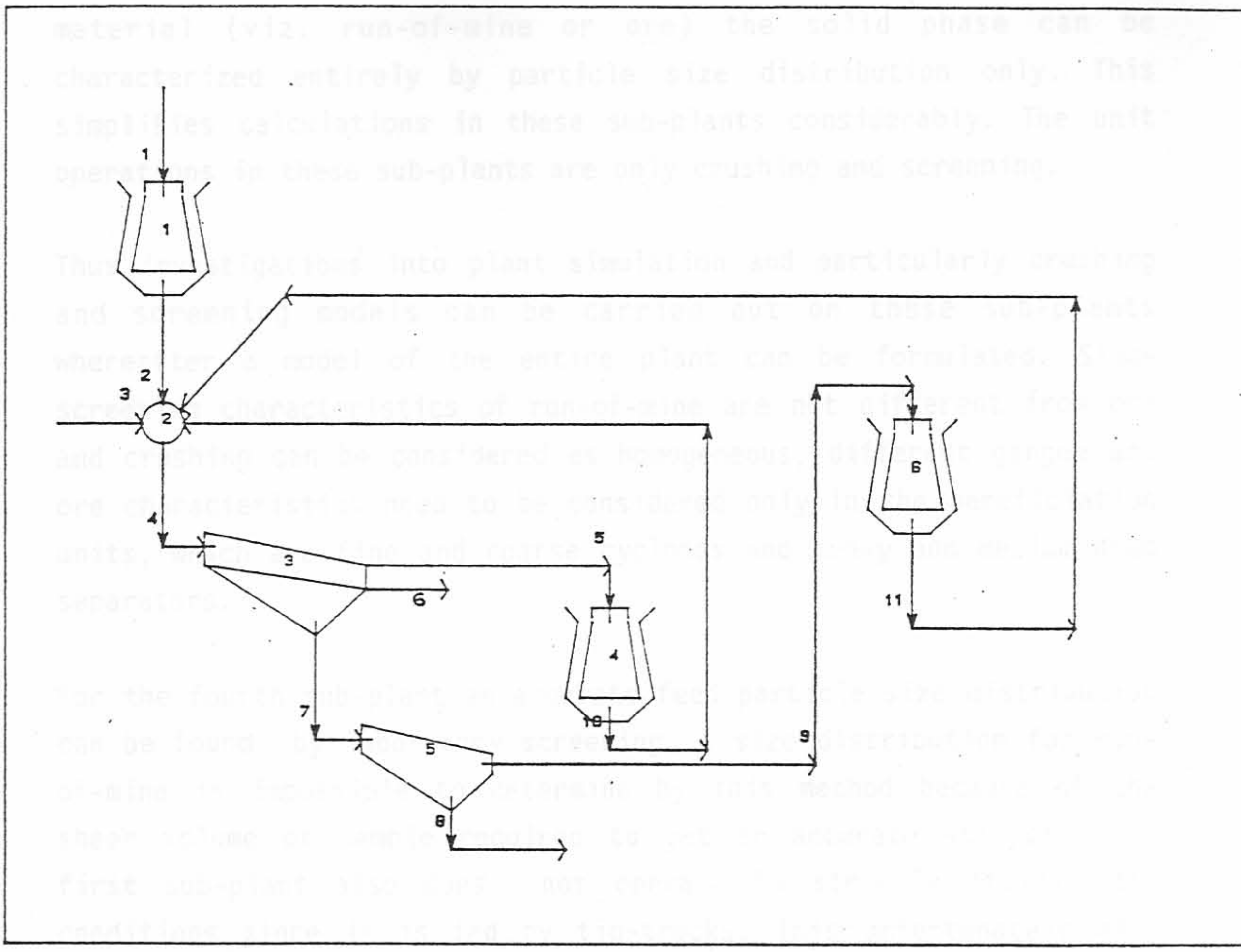

Fig 7 Flow diagram for sub-plant 4: Quaternary crushing and screening

Unit 1: Fresh feed shorthead crusher, CSS = 22mm
Unit 3: Primary screen, Top deck aperture = 25 x 25mm
Bottom deck aperture = 9 x 13mm
Unit 4: Recirculating feed shorthead crusher, CSS = 16mm
Unit 5: Secondary screen, Top deck aperture = 6,3 x 6,3mm
Unit 6: Gyradisc fines crusher, CSS = 9mm
Unit 2: Mixer

Stream 6 contains LUMPY ORE product
Stream 8 contains FINE ORE product

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included. Figure 7 shows the configuration for the production of fine and lumpy ore. The configuration for production of three ores is given later.

Since the first, second and fourth sub-plants have only one grade of material (viz. run-of-mine or ore) the solid phase can be characterized entirely by particle size distribution only. This simplifies calculations in these sub-plants considerably. The unit operations in these sub-plants are only crushing and screening.

Thus investigations into plant simulation and particularly crushing and screening models can be carried out on these sub-plants whereafter a model of the entire plant can be formulated. Since screening characteristics of run-of-mine are not different from ore and crushing can be considered as homogeneous, different gangue and ore characteristics need to be considered only in the beneficiation units, which are fine and coarse cyclones and heavy and medium drum separators.

For the fourth sub-plant an accurate feed particle size distribution can be found by laboratory screening. A size distribution for run-of-mine is impossible to determine by this method because of the sheer volume of sample required to get an accurate analysis. The first sub-plant also does not operate in strictly steady-state conditions since it is fed by tip-trucks. This unfortunately also limits the validity of steady state simulation of this sub-plant.

Screening is of critical importance at the plant, since this is the mechanism whereby the three products are separated and products beyond specification are financially penalized. Largely through changing screens will the product specifications be met for varying production percentages, thus making prediction of screening performance essential. Furthermore, screen replacement from wear provides the only real opportunity for modification of the plant without incurring additional cost or further delay. Since it is impossible to change the most important parameter of screening, namely the deck, except by shutting down the plant, the better the screen model, the more accurate the choice of screen. A model which will show the effect of new types of screens without direct plant tests will be of great economic value. The effects of using moulded plastic decks (called 'poly' decks, as used hereafter) and non-square

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(but still rectangular) screen apertures must be reflected in new models, as these decks are being used on the plant.

A very important consequence of plant modelling will be the application of the model in the envisaged control of the plant. Experience gained in modelling the plant can be usefully applied in the control project.

(Dynamic) Simulation studies of the plant will also enable optimisation of the use of tip-trucks by providing input to the computerized truck control system. This system currently only controls truck movement within the open-pit mine.

It is evident that a general purpose simulator for ore dressing operations is necessary. The simulator must be user-friendly and reliable, so that it can be used by plant personnel. Easy input of information to the simulator and documentation are essential.

If the simulator is modular it could be used for a great variety of flowsheets of other plants and be extended as new models are developed.

It must run on a computer system which is suitable for use in a mining environment and fairly inexpensive. Likewise the software should be easily expandable and inexpensive to maintain.

From experience with the Microsim users group, the following very important observations can be noted.

Plant engineers lose enthusiasm if the models they choose are unfamiliar and/or incorporate parameters with which they are unfamiliar (or are unmeasurable), even if these parameters are widely used in academic work. Likewise, design engineers prefer simple models with as few parameters as possible.

To overcome this, theoretical background of the models has to be supplied, together with estimates of parameters and/or detailed procedures of easy experiments to determine these parameters, using available equipment where necessary.

From the above it is obvious that models incorporated in the software

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should not require tuning by plant personnel. Although this is a common practice in research environments, it should be discouraged as models using exact plant parameters and ore characteristics are more easily accepted by plant personnel and are more meaningful.

Error handling by the simulator must prevent the program from hanging or terminating incorrectly and must guard against impossible solutions. All belief in a simulator can be lost through this.

In this work, crushing and screening models are investigated so that meaningful simulation studies can be done to meet the aims mentioned above. Other Corporate centres will benefit from these models and the experience gained from the simulations. The models developed and modified are thus ones that the plant and design engineer can understand, the parameters for which can be determined in a laboratory or plant and require no new test equipment.