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The Use of Simulation Tromp Partition Curves in Developing the Flowsheet of Plant Extensions at Grootegeluk Coal Mine

T. DE LANGE and P.E. VENTER

Grootegeluk Coal Mine, Iscor Ltd, South Africa

Extensions to the beneficiation plant at the Grootegeluk Coal Mine are currently being planned in order to provide power station coal for Escom's Matimba Power Station, presently under construction. A simulation model was developed on the Olivetti M-24 microcomputer to facilitate the development of the envisaged flowsheet. The computer program simulates the heavy-medium separation and screening unit operations. The model is based on the construction of the Tromp partition curve described by an arctangent function, allowing ideal and non-ideal separations.

The paper discusses the determination of the parameters required by the arctangent curve from standard process parameters such as Epm, Wolf cutpoint, Tromp cutpoint and screening efficiency. The accuracy and shortcomings of the model are discussed, while an overview of the application of the model to evaluate borehole and bulk sample analyses is also given. It is concluded that the model is an invaluable aid to general flowsheet development.

Introduction

The Grootegeluk Coal Mine, situated in the Waterberg coal-field 20 km west of Ellisras, is Iscor's major source of coking coal. The beneficiation plant treats some 3 000 t/h of raw coal from the Upper and Middle Ecca, yielding approximately 12% coking coal and 24% of a middlings fraction.

Extensive plant expansion became necessary when the contract to supply 12 x 10^6 tons per annum of middlings coal to Escom's Matimba Power Station, currently under construction, was awarded to Iscor. A computer model was developed as part of the flowsheet design to facilitate detailed evaluation of borehole and bulk sampling data.

This paper describes the simulation model involved, the accuracy of the model for both heavy-medium separation circuits and screening operations, and illustrates the application of the model during the flowsheet development phase.

System demands

Borehole and bulk sampling campaigns were launched as the first steps in the development of the envisaged flowsheet. The analyses specified on these samples included, among others, fractional ash, heat value and sink/float analyses.

Conventionally, these sets of data would have been manipulated by hand to yield fractional densimetric curves and Mayer curves. Ideal cutpoints would then be utilized to calculate graphically the

expected yields at specified heat values or ash values.

However, this conventional method had the following disadvantages:

a) The method was tedious and time consuming;
b) the data could not be analyzed into satisfactory depth, due to time limitations; and
c) only ideal separations could be induced, while the extrapolation to practical expected organic and screening efficiencies proved to be complicated and time consuming.

The need therefore existed to utilize a computer simulation model in order to eliminate the disadvantages of the hand method. The model had to be able to

a) accept the raw data in the format available, calculate the information required to draw washability curves and present results in a summarized format;
b) simulate the heavy-medium and size separation unit processes by calculating partition factors, using a history of standard process parameters accumulated on the Grootegeluk coking coal beneficiation plant;
c) allow a choice of Epm values, organic efficiencies and other parameters in order to simulate, *non-ideally*, the specific heavy-media separation process required at each point in the flowline. Simulation of the non-ideal screening process had to be facilitated by the choice of screening efficiencies;
d) compute the total sink/float and screen analyses of both products of each separation step, in order to permit a step-by-step development of a logical flowline.

The model therefore had to be able to compute full partition curves for either a density or a screening operation. The computation of separation product characteristics could then be facilitated.

To evaluate borehole data (in addition to the above) this model had to be able to

a) compute blended washability data for different boreholes; and
b) compute expected yields at specified ash, heat value or density cutpoints.

By using this model it is clear that the supplied data from borehole and bulk samples could be manipulated extensively, maximising the usage of given data, thus permitting the development of a more accurate and practically orientated plant flowsheet than would have been possible otherwise.

Overview of existing models

The specific requirements as discussed above, together with the given time constraints, virtually excluded the use of an existing simulator package. Although Iscor was negotiating the purchase of MODSIM from Prof. R.P. King[1] of the University of the Witwatersrand, the package was not available at that stage, as it was still being prepared for distribution.

The use of other simulation packages was excluded owing to

a) inability to cater for the format of the raw data;
b) equipment information required by such packages, which was unavailable at that stage of the design; and
c) the time constraints involved, i.e. purchasing and commissioning.

The decision was therefore taken to use an available APPLE II+ microcomputer and develop a model in-house. The APPLE was later replaced by an Olivetti M-24.

Modelling

Heavy-medium separation

Iscor Grootegeluk had been using a coal washer performance program for weekly metallurgical audits for some time already. This program is similar to the one described by Wizzard[2]. An extensive database, including Tromp curve cutpoints, probable errors and Wolf curve cutpoints was therefore available for incorporation into the model.

Performance curve fitting

In order to determine the metallurgical performance of a coal washer, samples of the feed, product and tailings are taken and applied to a sink-float analysis. Discrete Tromp partition factors are then calculated in the conventional way[3]. (This is referred to as the observed partition factors).

The performance evaluation program fits an arctangent curve to the observed partition factors according to the following equation [4,5]:

$$t = \frac{100(P_1 - \mathrm{Arctan}(P_2(d - P_3)))}{P_1 - P_4} \qquad [1]$$

where

t = fitted Tromp partition factor (ie. the probability that a coal particle of a given density, *d*, will report to the overflow) (%)

d = density (g/cm³)

$P_1 - P_4$ = parameters describing the shape of the specific separation curve.

The general shape of this curve (referred to as the fitted curve) is given in Figures 1 and 4.

The use of the arctangent function dif-

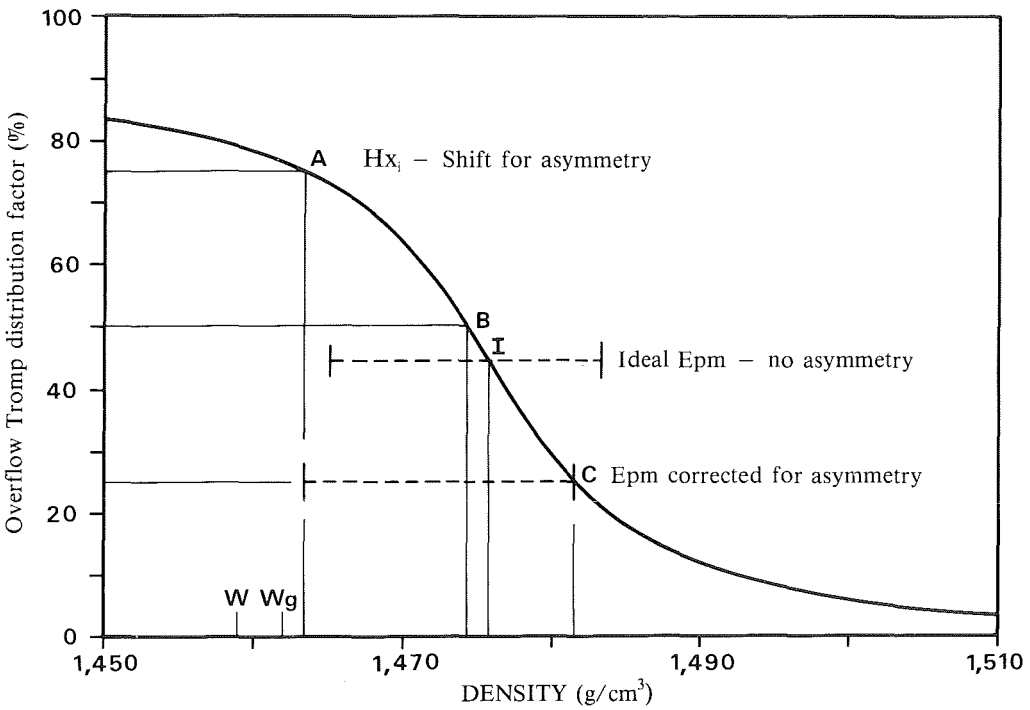

FIGURE 1. Plot of the overflow Tromp distribution factor against density showing the development of the HMS simulation model

Points A = ($d_{75,75}$)
B = ($d_{50,50}$) Tromp cutpoint
C = ($d_{25,25}$)
I = (d_i, t_i) Arctan inflection point
W = True mass based Wolf cutpoint
Wg = Two-dimensional Wolf cutpoint based on graphic integration

fers from the method followed by Wizzard, who made use of a Weibull distribution. The arctangent approach is preferred, since it culminates in a two- dimensional search, instead of four, thus reducing the number of iterations required from +/- 1000 to +/- 120, whilst still obtaining correlation coefficients of 0,995 and higher.

The objective of the simulation model was simple: to *reverse the process of performance evaluation*. This meant that starting with calculated results available, one had to work backwards until the product and tailings streams have been found.

This was approached as follows:

a) Determine which information is required to solve the four parameters P_1 to P_4;
b) Solve the parameters and obtain a *simulated* Tromp partition curve;
c) Transform the continuous partition curve into discrete intervals, by means of integration;
d) apply the discrete partition factors to the feed stream washability data;
e) calculate the simulated product and tailings streams;
f) compare the simulated streams to those observed and refine the model;
g) replace the historical performance data with those desired on the new plant.

Parameter solving

The influence of each of the parameters P_1 to P_4 is better understood by rearranging Equation [1] as follows:

$$t = a \operatorname{Arctan}[b (d - c)] + e \qquad [2]$$

where

t = overflow Tromp distribution factor, as before (%)
d = density (g/cm³)
a = overall efficiency parameter
b = parameter describing sharpness of separation
c = horizontal shift of the arctan inflection point (Under symmetrical conditions, parameter *e* would be equal to 50, in which case *c* would be equal to the Tromp cutpoint)
e = parameter describing the degree of asymmetry of the partition curve

Four points, distributed evenly on the partition curve, are required to solve the four parameters *a, b, c* and *e*. Finding the root of the Arctan equation, i.e. the inflection point, would solve parameter *c* immediately, thus making it a logical choice to find. The points (d_{25},25) and (d_{75},75) are distributed evenly enough around the inflection point in order to consider finding them as well. This leaves only one point not yet defined.

Ideally, one would endeavour to use the Tromp cutpoint in order to find the inflection point and the Ecart Probable Moyen (Epm) as a degree of sharpness to solve d_{25} and d_{75}, since these values have found widespread application in the coal processing industry.

Tromp cutpoint

At this stage it is not possible to substitute the Tromp cutpoint for the inflection point, because of the asymmetry involved. However, if the degree of asymmetry is known, it can be corrected for, by using the linear relationship assumed to apply in the centre region of the partition curve.

Wolf cutpoint

When integrating the top error area from the left of the curve and at the same time

integrating the bottom area from the right, one arrives at the point of equal error area intersection. Under symmetrical conditions, this intersection will coincide with the Tromp cutpoint at t = 50. However, the larger the extent of asymmetry, the larger will be the difference between these two cutpoints. Since integration from two sides is nothing else than a two-dimensional version of the Wolf cutpoint calculation, it followed that the the difference between the Tromp and Wolf cutpoints was a key in the search for the inflection point. Therefore, the relationship between the difference in the Tromp and Wolf cutpoints and the abscissa of the inflection point had to be established.

This relationship was determined by means of linear regression on 25 observations as

$$t_I = 50{,}25 - 377{,}2\ x \qquad [3]$$

where

t_I = Abscissa of inflection point

x = Tromp cutpoint - Wolf cutpoint

The relationship is considered significant with a coefficient of correlation of 0,91 as exemplified in Figure 2. Furthermore, if no asymmetry is present, one would expect that with $x = 0$, t_I would be equal to 50. The constant in Equation [3] is acceptably close to this theoretical value, at 50,25.

Sharpness of separation

In order to obtain the ordinate of the inflection point, parameter c, it is necessary to find the horizontal difference between this point and the Tromp cutpoint, defined as follows:

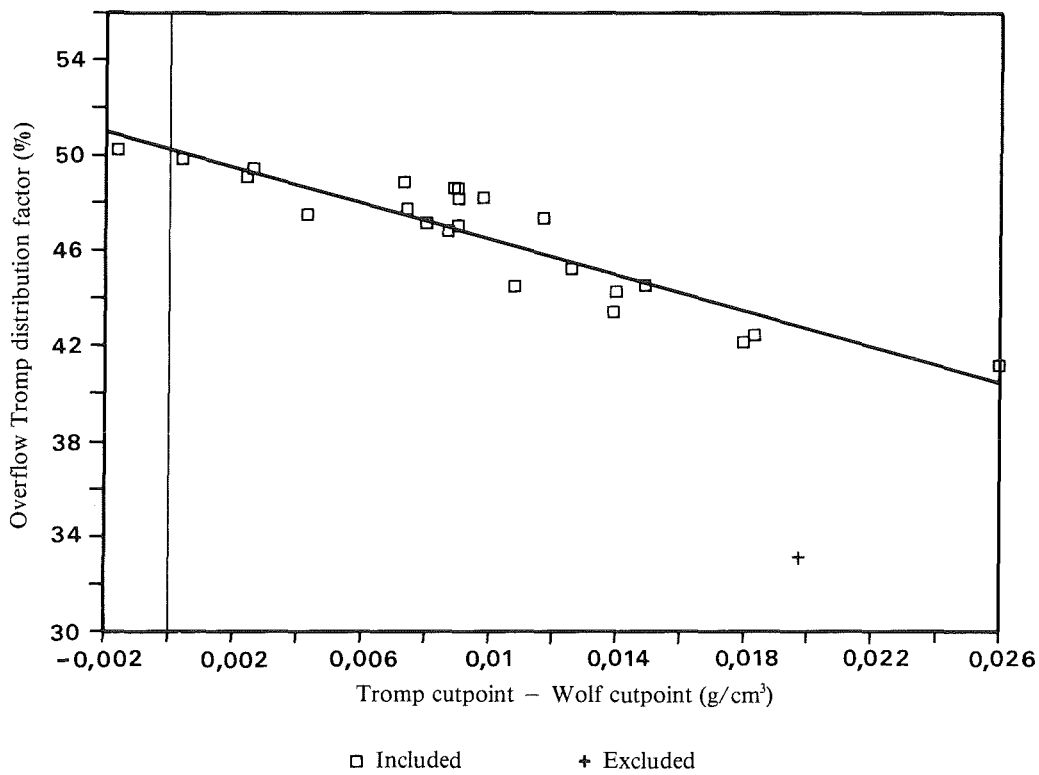

FIGURE 2. Plot of the difference between Tromp and Wolf cutpoints against the distribution factors of the Arctan inflection point.

Liner regression: $t_i = 50{,}25 - 377{,}2 \times$ (correlation coefficient = 0,91)

$$x_I = d_I - d_{50} \quad [4]$$

This can be done by determining the slope in the linear section of the partition curve and applying it to the vertical difference, which is already known (t_I - 50). Assuming that the linear relationship holds from d_{25} to d_{75}, the slope, *m*, is given as:

$$m = (75 - 25) / (d_{75} - d_{25}) \quad [5]$$

For coal processing, *m* is always negative.

Applying the definition of the Ecart Probable Moyen to coal beneficiation, we find:

$$Epm = (d_{25} - d_{75}) / 2 \quad \text{(positive)} \quad [6]$$

and substitution thereof into Equation [5], we find *m* in terms of Epm:

$$m = -25 / Epm \quad [7]$$

Solving for asymmetry

The horizontal difference between the Tromp cutpoint and the inflection point is therefore:

$$x_I = \frac{(t_I - 50)}{m} \quad [8]$$

The inflection point, d_I, may now be found in terms of the Tromp cutpoint, by rearranging [4]:

$$d_I = d_{50} + x_I \quad [9]$$

Solving d_{75} and d_{25}

The Ecart Probable is generally not distributed symmetrically around d_{50}. Our research has shown that the Epm tends to shift according to the extent of asymmetry present and that it is distributed symmetrically around an imaginary axis lying in an opposite direction from d_{50} than the inflection point, d_I, but with equal distance, x_I. Therefore, d_{75} and d_{25} may be found by compensating for this shift in asymmetry:

$$d_{75} = d_{50} - x_I - Epm \quad [10]$$

and

$$d_{25} = d_{50} - x_I + Epm \quad [11]$$

Solving arctan parameters

The parameters *a,b,c* and *e* may now be solved by assigning the following initial values:

$$a = 100 / \pi \quad [12]$$

$$c = d_I \quad [13]$$

$$e = t_I \quad [14]$$

leaving *b* to be solved by substitution in [2] with (d,t) = (d_{75},75).

Refinement of parameters

The above parameters must be refined, owing to the approximation made in Equation [3] and the assumption made in Equation [12]. Furthermore, an additional point on the Tromp curve is required since the points d_{25}, d_{50}, d_I and d_{75} lie in a narrow band on the curve. Since Equation [12] is based on an assumption, the additional point required must lie closely to the end points of the distribution curve in order to incorporate the effect of overall efficiency. The maximum observed distribution factor was chosen here, e.g. (1,24 ; 99), referred to as d_M and t_M.

An iterative procedure is then followed whereby the four calculated data pairs are substituted into Equation [2], according

to following four equations:

$$b = \frac{\mathrm{Tan}[(t_{75}-e)/a]}{d_{75}-c} \quad [15]$$

$$e = t_{25} - a\ \mathrm{Arctan}[b\ (d_{25}-c)] \quad [16]$$

$$a = \frac{t_M - e}{\mathrm{Arctan}[b\ (d_M - c)]} \quad [17]$$

and

$$c = d_{50} - \frac{\mathrm{Tan}[(t_{50} - e)/a]}{b} \quad [18]$$

applied in the order as shown.

It was found that the set of parameters converge within 5 iterations in those cases where the originally observed partition factors were fitted adequately by the arctan curve. However, divergence was found in the cases where the observed partition curve had exhibited a low efficiency tail in the lower density region. This tail can often be ascribed to analytical errors made in the laboratory. The situation was rectified by limiting the number of iterations to 2, thus achieving a meta-stable convergence.

Discrete partition factors

The arctan curve describes a continuous partition factor. In practice, discrete density intervals are used to obtain the partition factors. The partition factor thus calculated is associated with the midpoint of the density interval. It is therefore necessary to integrate the simulated Tromp curve across the density interval in order to obtain the simulated discrete partition factor for that particular interval.

If T represents the integral of the arctan curve, then

$$T = a\ (d-c)\ \mathrm{Arctan}[b(d-c)] + e(d-c) - \frac{a(\ln[1+b^2(d-c)^2])}{2b} \quad [19]$$

which results into

$$T_J = \frac{T(d_{J-1})-T(d_J)}{d_J - d_{J-1}} \quad [20]$$

where T_J is the discrete partition factor for the Jth interval.

Size separation

Apling (1985) describes a method to measure the performance of screens,[6] which is essentially the same as that followed in the coal washer performance program. In this method the natural logarithm of screen aperture is plotted on the ordinate axis instead of the density. (See Figures 3 and 5 for the general form of the distribution curve.)

Following the exemplary work of Apling it was decided to simulate non-ideal screening operations too by means of the Tromp partition curve and to follow a similar route to the one described above in generating the partition curve. A problem at hand was that very little plant history was available, since Apling's method of computing the screening performance curve had not been used at Grootegeluk at that stage. (It has since been implemented.) The only process parameters available were therefore (i) undersize screen efficiency and (ii) the nominal cutpoint.

Model assumptions

As less information was available than required to describe the partition curve accurately, the following assumptions had to be made (see Figure 3):

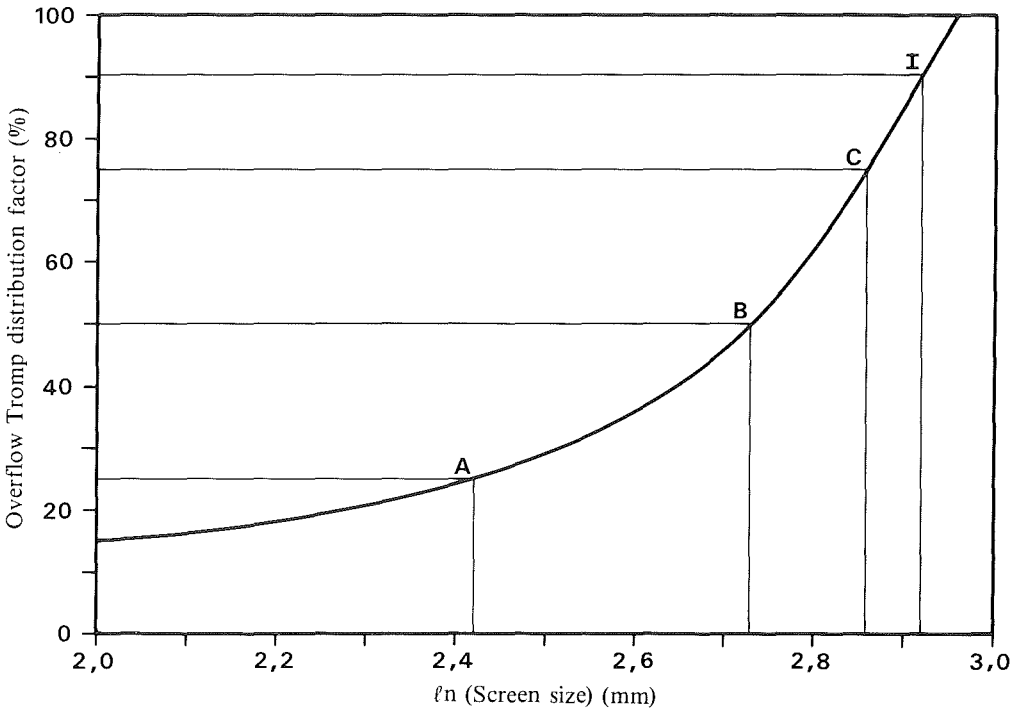

FIGURE 3. Plot of the overflow Tromp distribution factor against the natural logarithm of screen size showing the development of the screening simulation model.

Points A = $(d_{25,25})$
B = $(d_{50,50})$ Tromp cutpoint (15,3 mm)
C = $(d_{75,75})$
I = (d_i, t_i) Arctan inflection point (18,5 mm)

(1) The nominal cut size of the screen is equivalent to the size where material has a 90% probability of reporting to the overflow, i.e. d_{90}.

(2) The vertical range of the undersize distribution is between 0 and 90% .

(3) The inflection point of the Tromp curve coincides with d_{90}.

(4) The oversize distribution ranges between 90 and 100% .

(5) The lower size limit, d_L, is taken as the smallest size fraction divided by 2. (Zero cannot be used since the logarithm of 0 is not defined.)

Based on the little historical data available all these assumptions are largely valid. As further work was done it was found that the ordinate of the inflection point does not always coincide with the nominal size but differs within a ratio between 1,0 and 1,25. Futhermore, the abscissa of the inflection point tend to vary between 75 and 92% instead of the 90% assumed initially.

Parameter solving

Based on assumption (2) parameter *a* is defined as

$$a = 180 / \pi \qquad [21]$$

and according to assumptions (1) and (3) parameter *c* is defined as

$$c = \ln (d_{90}) \qquad [22]$$

and

$$e = 90 \qquad [23]$$

This leaves only *b* yet to be determined.

Tromp undersize efficiency

By defining *f* as

$$f = \ln(d_{90}) - \ln(d_L) \qquad [24]$$

and substituting into [19], the error area of true undersize separation, E_U, may be calculated as follows:

$$E_U = af \operatorname{Arctan}(-bf) + ef + \frac{a \ln(1 + b^2 f^2)}{2b} \quad [25]$$

Furthermore, by defining the total undersize area as the rectangular block 100f, the Tromp undersize efficiency, Eff_{UT}, may be defined as

$$Eff_{UT} = \frac{100f - E_U}{f} \quad [26]$$

By entering a required undersize efficiency Eff_{UR}, *b* can be solved by iteration until $Eff_{UR} = Eff_{UT}$. Since *b* can vary between 0,1 and 2000 a geometric interval halving routine was used until $Eff_{UT} - Eff_{UR}$ is less than a preselected tolerance.

Discrete partition factors

The discrete partition factors may once again be calculated as discussed previously. Once obtained, these are applied to the size intervals of the feed stream in order to generate the overflow (product) and underflow (tailings) streams.

Model accuracy

Heavy-medium separation model

A typical simulated partition curve is shown in Figure 4, with the observed partition factors and the fitted curve calculated by the performance evaluation program. It can be seen that both the

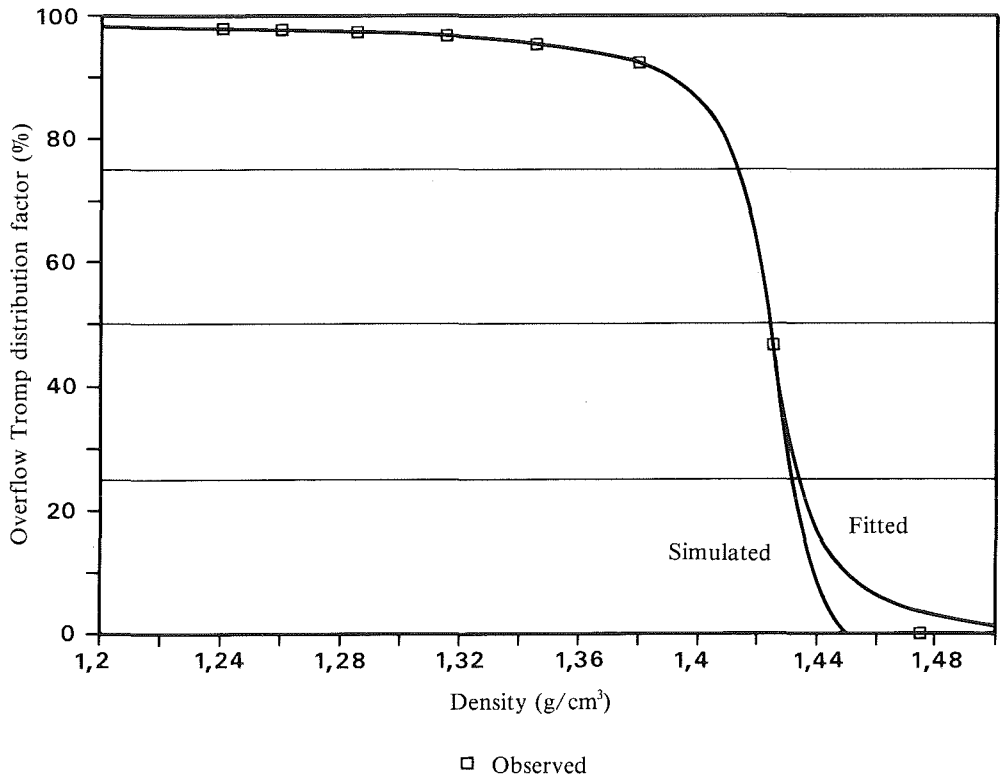

FIGURE 4. Plot of overflow Tromp distribution factor against density showing the accuracy of the HMS model

Observed Determined from sampling.
Fitted Curve generated by the performance evaluation program.
Simulated Curve generated by the HMS simulation model.

simulated and fitted curve deviate from the observed points only in the high density region, by more or less equal amounts.

The accuracy of the heavy-medium separation model is further exemplified in Figures 6 to 8, representing the errors between simulated and actual values at various confidence levels, the latter being determined by the performance evaluation program. These results, and others, are further summarized in Table 1.

There is no doubt that other simulators might achieve better accuracies, but these were considered accurate enough for the particular application, with the advantage that only *process* paramaters are utilized. The accuracy in predicting the Wolf cutpoint may be enhanced by compensating for the difference between the graphical cutpoint and mass based cutpoint. This value is more or less fixed for the application at Grootegeluk at 0,003 g/cm³. (See Figure 1 - points W and W_g).

The prediction of organic efficiency may also be enhanced by utilizing more accurate forms of interpolation than the linear form that was used. Recent investigations at Grootegeluk showed that a logarithmic interpolation is by far more accurate, while interpolation by using Lagrange polynomials yields unpredictable results.

TABLE 1. Accuracy of HMS model

Parameter	Absolute errors		
Confidence level*	50%	80%	95%
Concentrate ash, %	0,24	0,48	1,00
Misplaced material,%	0,6	1,0	2,0
Wolf cutpoint, g/cm³	0,002	0,004	0,006
Epm (Ecart)	0,001	0,002	0,004
Organic efficiency,%	1,6	3,0	9,0
Clean coal yield, %	0,5	0,9	1,4

(*) To read as follows: in 50% of the cases the simulated concentrate ash differed less than 0,24% absolute from the actual.

Size separation model

Acceptable accuracies were obtained only in those cases where it was known from experience that the assumptions made in the screen model were valid. Further work showed that in other cases acceptable accuracies could be obtained when the nominal cutpoint was replaced with the cutpoint of inflection, and the true partition factor of inflection was used instead of 90% . In other words, (d_I, t_I) had to be known. This is of course a limiting factor since usage of the co-ordinates of the inflection point is a novel concept introduced in this paper. More research will therefore be necessary to establish the relationship between more widely used parameters, such as the nominal size, Epm values etc. and those mentioned above.

Furthermore, there is no reason not to follow the same route as had been used in the HMS model, apart from a lack of a database where the relevant parameters have been established. This had only become available after the implementation of the performance evaluation program for screening operations.

A typical plot of the fitted and simulated partition curves are shown in Figure 5, whilst Table 2 summarizes the relative RMS errors (root mean squared) of some typical parameters. Relative errors are given since a logarithmic transformation was used to normalize the size ranges.

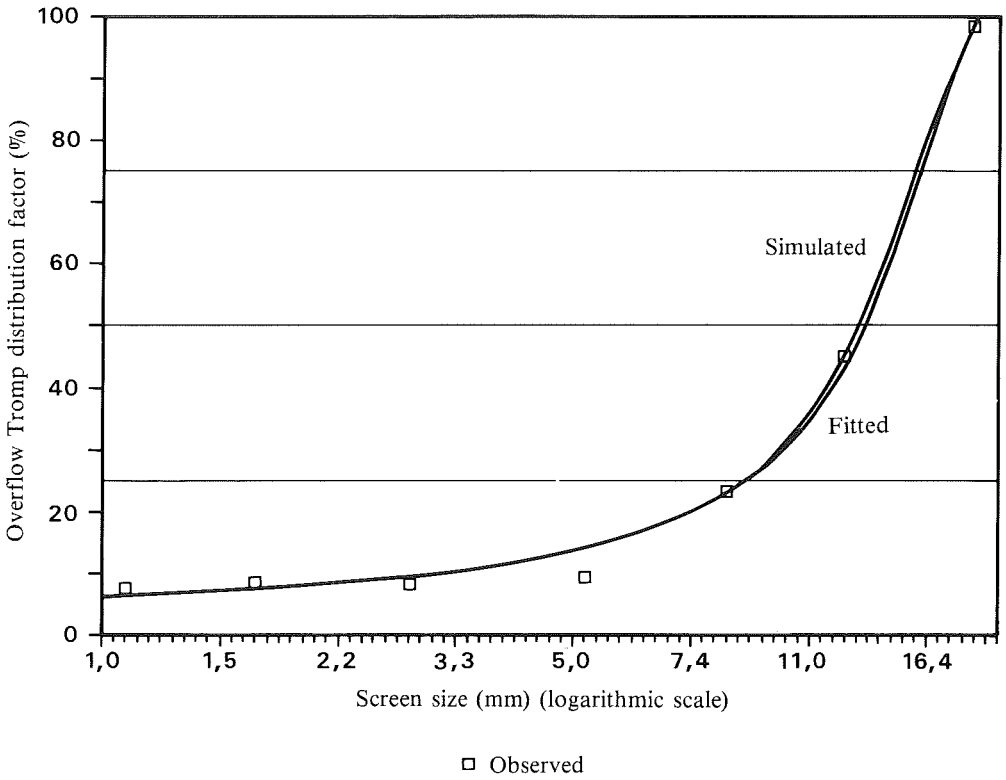

FIGURE 5. Plot of overflow Tromp distribution factor against screen size showing the accuracy of the screening model

Observed Determined from sampling.
Fitted Curve generated by the performance evaluation program.
Simulated Curve generated by the screening simulation model.

TABLE 2. Accuracy of Screening Model

Parameter	RMS errors
Tromp cutpoint, mm	2,1%
Wolf cutpoint, mm	3,5%
Epm (Ecart)	11,9%
Tromp U/f efficiency, %	1,5% Abs
O/f yield, %	0,8% Abs
Misplaced material, %	1,3% Abs

Application of the model

Geology and mining

The Waterberg coal field can be divided into the Upper and Middle Ecca series, while the Lower Ecca is not developed. The stratigraphic series consists of 11 coal zones with interbedded shale layers with each zone subdivided into *samples*. The Upper Ecca contains bright and dull coal, suitable for the production of coking coal. For mining operations, 4 benches have been developed, with bench 1 as overburden. The transition zone, bench 5, exhibits too high a phosphorus content to be rendered suitable for the production of coking coal. The Middle Ecca contains no bright coal and is only suitable for the production of power station coal. This section is divided into mining benches 6 to 14, of which bench 14 will not be mined as the overlying sandstone layer, bench 13, is too thick.

Ten boreholes, spaced over the planned mining operations for the next 40 years, were drilled and analysed, in order to determine the quality and expected yield of the raw coal to be treated in the envisaged beneficiation plant.

Borehole evaluation

The borehole cores were crushed to -25 mm and the -0,5 mm fraction removed. Evaluation of the borehole analyses was done by using the model to reconstitute the various zones from the *sample* analytical data, and subsequently the benches. A modified version of the computer model was then used to calculate, for each bench, the

(a) in-situ characteristics;
(b) mass yields at a density of 2,0 g/cm³, ideally and non-ideally separated;
(c) yields at other densities ranging between 1,8 and 2,0 ;
(d) yields at such density where a product with a 20 MJ/kg heat value is obtained; and
(e) sensitivity analysis on the yields at other heat values (ranging from 12 to 22 MJ/kg).

The -0,5 mm fractions were assumed to be beneficiated by spirals to yield a product of 20 MJ/kg and a discard of 4 MJ/kg; the results were incorporated into the above calculations.

From the in-situ characteristics it was possible to determine which benches could be mined without any beneficiation apart from size reduction. From the sensitivity and constant heat value analyses (items d and e above) it was determined which benches could be beneficiated together and which had to be beneficiated in separate plant modules.

Production constraints

The constraints introduced by the simultaneous adherence to product quality control and pit development were also elicited, by planning production, blending options and available clean coal stocks for the next 40 years. This showed that production peaks from the upper benches must occur, during initial production stages, if the pit is to be developed properly. This implied that certain plant modules had to be designed for dual purposes in order to eliminate unusable excess capacity once these production peaks had been passed.

Bulk sample evaluation

Bulk samples were collected bench by bench and crushed by the primary Bradford breakers in the existing plant. Analytical results were fed into the computer and extensive simulations performed at the following cutpoints:

(a) primary screens: 35, 25 and 15 mm, at 88% U/f efficiency;
(b) degradation screens: 30, 20 and 10 mm, at 92% U/f efficiency;
(c) feed preparation screens: 5, 3 and 1 mm, at 75% U/f efficiency;
(d) static bath HMS: 1,7 ; 1,8 ; 1,9 and 2,0 g/cm³ at 0,025 Epm and 90% organic efficiency;
(e) cyclone HMS: 1,7; 1,8; 1,9 and 2,0 g/cm³ at 0,017 Epm and 90% organic efficiency.

From the above simulations the optimized cutpoints were chosen and correlated with the minimum and maximum expected yields obtained from the borehole evaluations. Thus the average, minimum and maximum mass flowrates could be established for each stream, the flowline designed in detail and the reticulation balance completed.

Simulation results

Figure 9 shows a typical simulation study performed on bulk sample results from bench 2, which contains 13% coking coal in situ. It shows that with pulp densities of 1,8 g/cm³ in the cylcone plant and 1,9 g/cm³ in the static bath plant, (the maximum densities achievable with con-

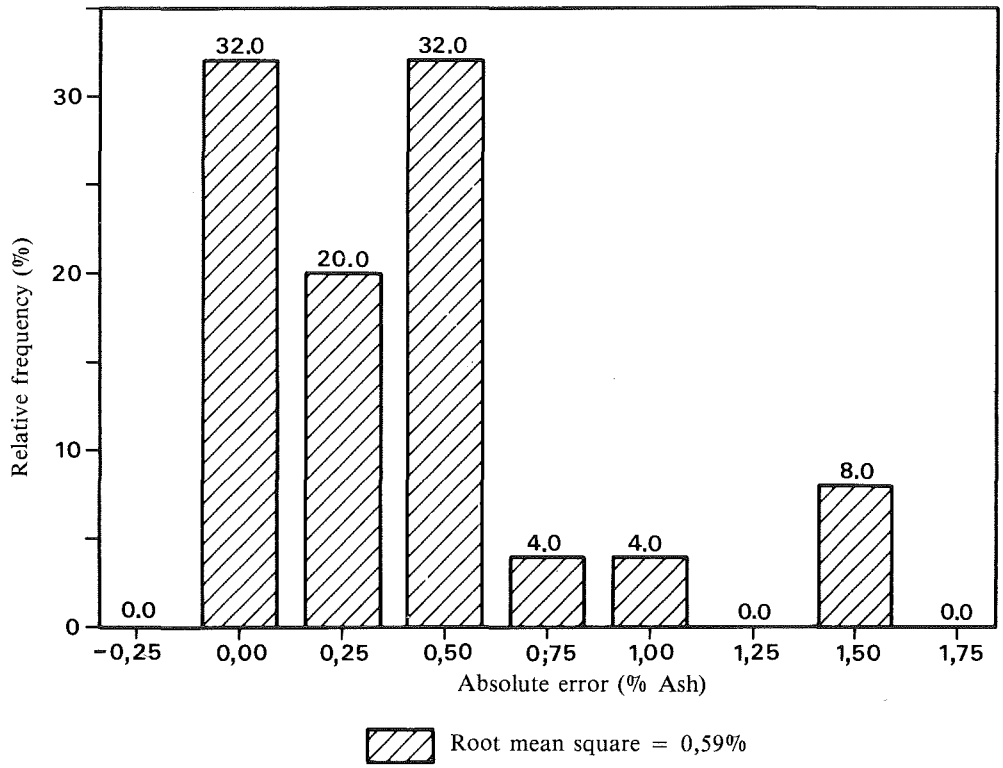

FIGURE 6. Histogram showing the relative frequency distribution of absolute error in concentrate ash values – HMS simulation model

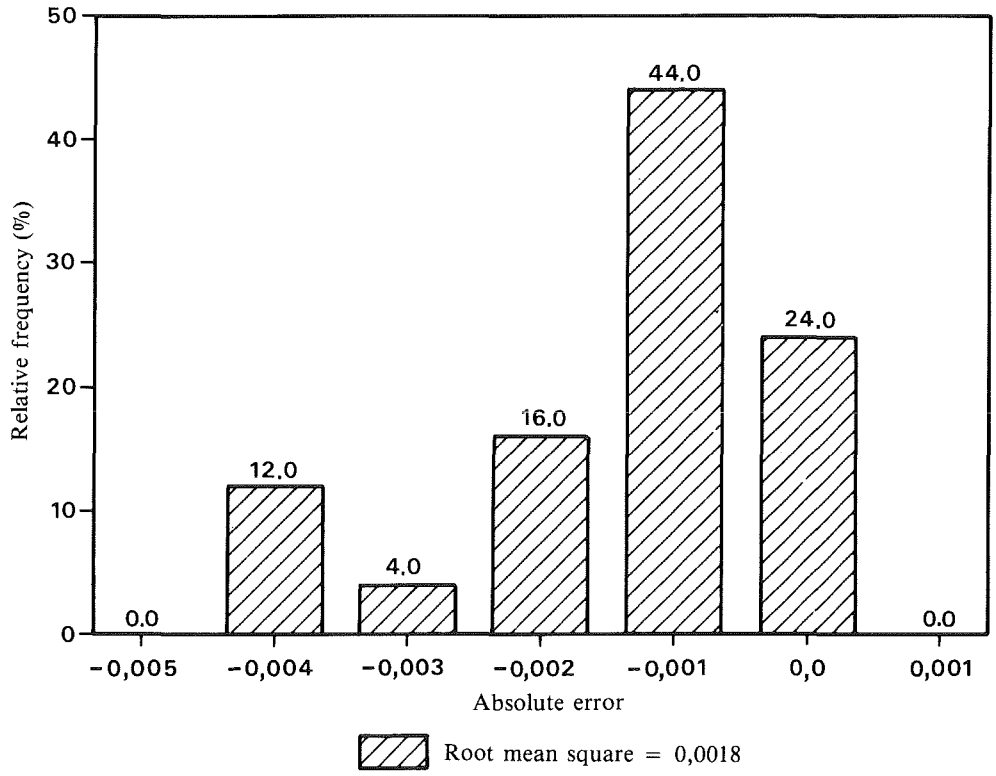

FIGURE 7. Histogram showing the frequency distribution of absolute error in Epm values – HMS simulation model

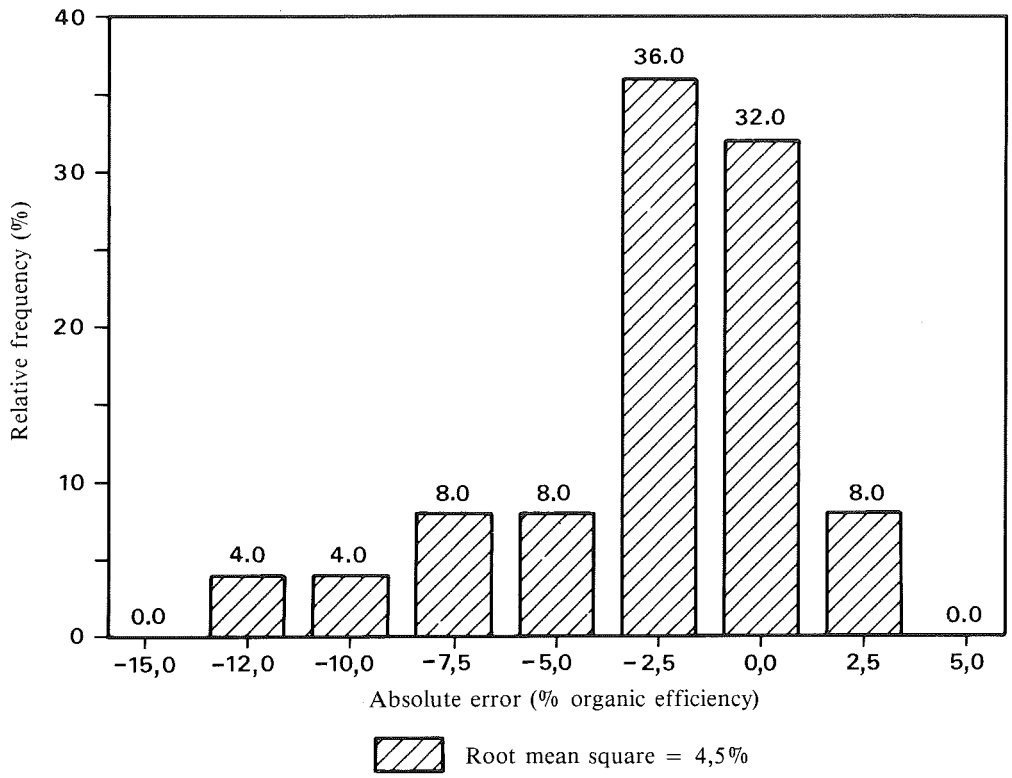

FIGURE 8. Histogram showing the frequency distribution of absolute error in organic efficiency – HMS simulation model

ventional equipment), the total expected yield was 44,6%, with a product ash content of 26,1% and a heat value of 23,5 MJ/kg. Since the contract specification is 35% ash and a heat value of 20 MJ/kg, it was clear that either higher operating pulp densities were required, or that a low ash coking coal stream had to be bled off in order not to discard valuable coal.

Figure 10 shows that with the same feed stream, a density of 2,28 g/cm³ was required in the cyclone plant and 2,05 g/cm³ in the static bath plant, in order to obtain the desired product quality. This would have resulted into a total yield of 55,8%, which was 11% more than in the previous situation. In this case the ash content would have been very acceptable at 84%, compared to 80% previously.

Over 180 separations were performed in the course of 6 days, thus producing 145 different flowsheets. This would have taken approximately 2 months if it had to be done by hand. The development of the simulation model and the programming thereof took approximately 2 weeks.

Conclusions

(a) The simulation model described here proved invaluable for general flowsheet development as far as the evaluation of borehole and bulk sample analytical results were concerned.

(b) The availability of such a model not only enabled the design engineers to meet their deadlines, but allowed the opportunity to exploit the available data into considerably more detail than would otherwise have been possible, thus arriving at a final flowsheet that should be much less prone to the development of bottlenecks and other design errors.

(c) The simulation accuracy achieved by

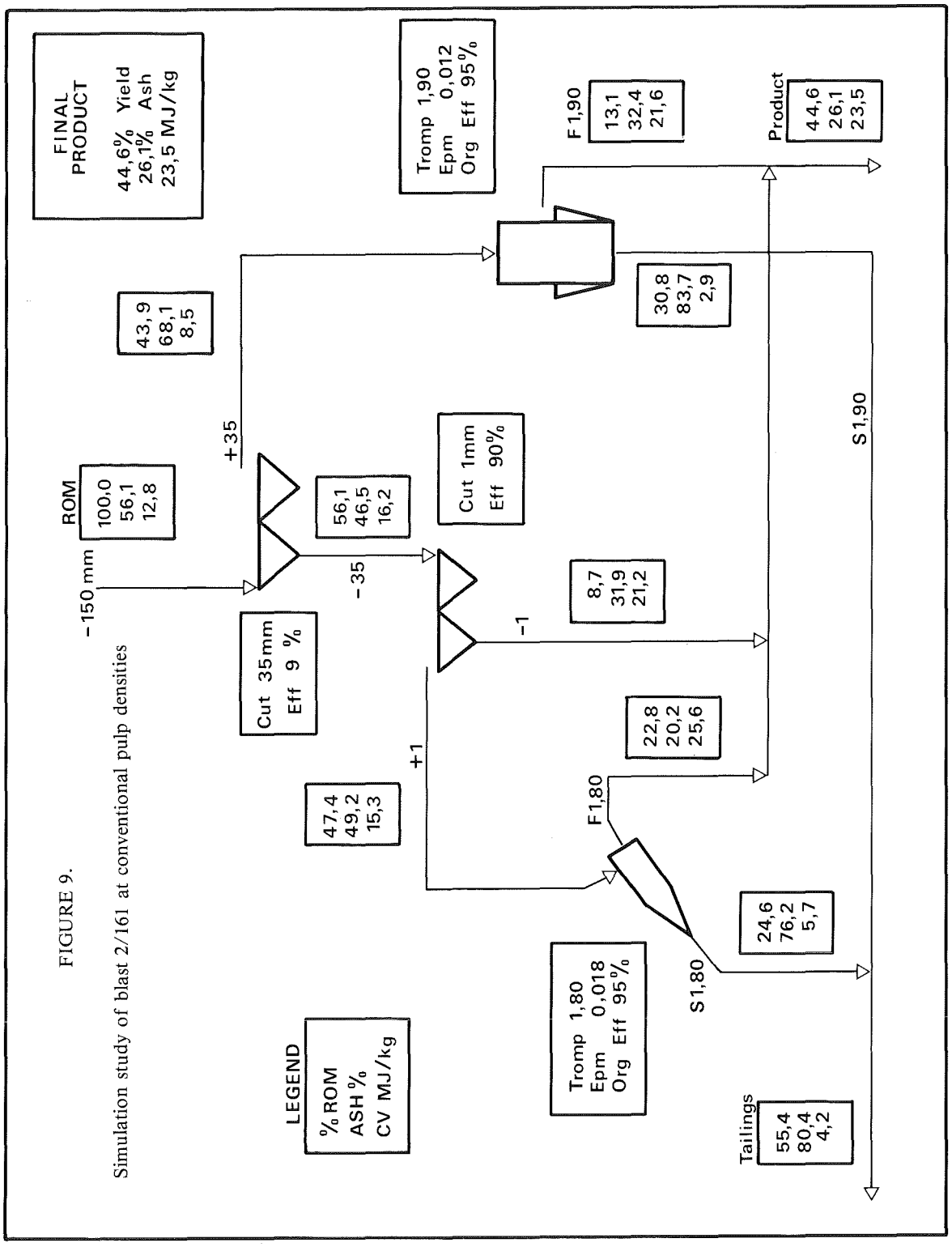

FIGURE 9.

Simulation study of blast 2/161 at conventional pulp densities

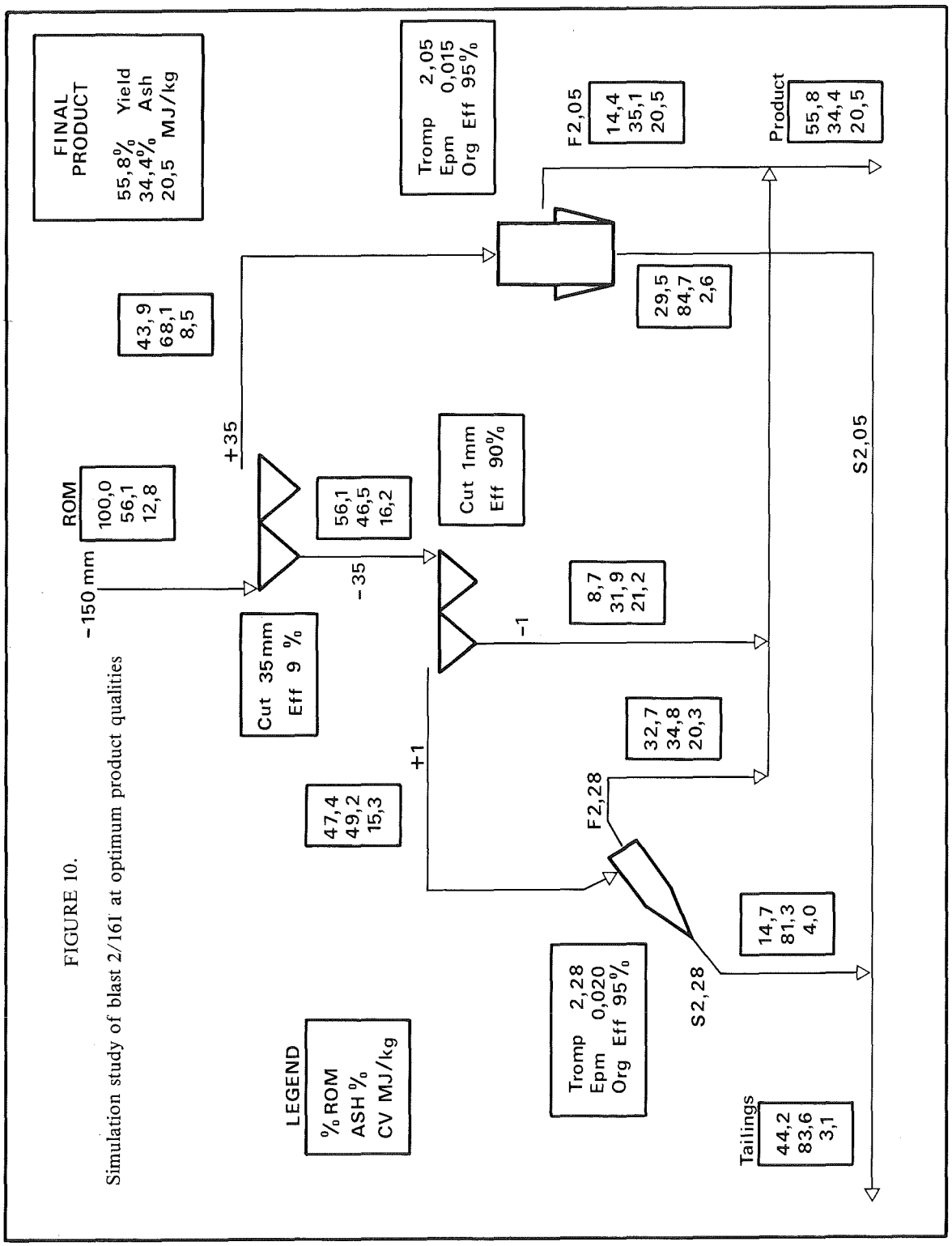

FIGURE 10.

Simulation study of blast 2/161 at optimum product qualities

the model was more than acceptable for the application in which it was used. Further refinement of the model to achieve higher accuracies and adaption for other applications is left to the research organizations, as computer modelling is not considered as the primary task of a production engineer based on a mine.

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