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on Environmental Improvement*

*COAL WASHERY DESIGN-II  
THE COMPUTATION OF  
RECIRCULATING LOADS*

JACQUELINE L. PICARD

METALS REDUCTION AND ENERGY CENTRE

DECEMBER, 1971

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COAL WASHERY DESIGN - II  
THE COMPUTATION OF RECIRCULATING LOADS

by

Jacqueline L. Picard\*

SUMMARY

This bulletin, part II of a series, deals with the EMR<sup>1)</sup> process for the beneficiation of coal. Several considerations have contributed to its publication. Firstly, one of the elements of process design is, that two-stage operation with recirculation of intermediate products, properly applied, may enhance the separation efficiency and the financial returns of a processing plant. Secondly, the prevention of pollution at the source enforces effective control of water clarification and slimes removal. For these reasons alone, closed-circuit operation of processing plants deservedly receives more attention to-day than it has in the past.

Effective control of slimes and recirculating middlings requires detailed information on the separating efficiency of the equipment units and involves the calculation of individual solids' flowrates under steady-state conditions. The processing of this data poses a problem in that the volume of work, if done manually or on a calculator, requires too much time.

Detailed instructions are given for calculating closed-circuit flow diagrams, using a small digital computer. Derivations of circuit equations are presented in an appendix. A "decision flowchart", applicable to any combination of separators (to a maximum of five units), is presented for calculating the "recirculation coefficient"  $\lambda$  of individual size-fractions and gravity-fractions of the raw feed as it passes through the plant. Applications of the method of calculation are illustrated for a number of unit combinations encountered in coal washeries.

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1) Abbreviation for: Energy, Mines and Resources.

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par

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Résumé

Ce bulletin, la deuxième partie d'une série, traite d'un procédé du ministère de l'Energie, des Mines et des Ressources pour l'enrichissement du charbon. Plusieurs considérations ont favorisé sa publication. D'abord, un des éléments du calcul fondamental d'une installation est que si l'opération à deux étages avec la recirculation des produits intermédiaires est utilisée correctement, l'efficacité de séparation et les profits d'une installation de traitement pourront augmenter. Ensuite, l'empêchement de pollution à la source assure un contrôle efficace pour la purification de l'eau et pour l'enlèvement des boues. Pour ces seules raisons, on doit porter plus d'attention aujourd'hui qu'auparavant à l'opération en circuit fermé des installations de traitement.

Le contrôle efficace des boues et de la recirculation des mixtes nécessite les renseignements détaillés sur l'efficacité de séparation des unités de l'équipement et implique le calcul des "débits particuliers des solides" sous régime stable. Le traitement de ces données pose un problème de sorte que si le volume de travail se fait manuellement ou par une machine à calculer, il nécessite trop de temps.

On donne des instructions détaillées pour le calcul en circuit fermé des schémas de fonctionnement, en utilisant un calculateur numérique. Les dérivations des équations de circuit se trouvent à l'appendice. On présente un "diagramme déterminant de débits", applicable à n'importe quelle combinaison de séparateurs (à un maximum de cinq unités) pour le calcul du "coefficient de recirculation" des fractions particulières de taille et de gravité de l'alimentation brute pendant qu'elle parcourt l'installation. On illustre l'application de la méthode de calcul pour un nombre de combinaisons d'unités rencontré dans les lavoirs de charbon.

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## INTRODUCTION

The design of a coal washery is generally based on the size consist of the raw feed and on the float-sink data of one or more size fractions. From this information the expected overall yield of clean coal containing the required ash content can be derived for any array of coal cleaning equipment whose separating characteristics are known. Evidently, the performance of any single separator in such an array depends on its separation efficiency (as expressed by the error curve) as well as on the conditions under which it is operated, especially the rate of feed and the feed composition. Factors such as maintenance and quality of the equipment are of no less importance but these are outside the scope of this publication.

It is considered normal procedure to designate the feed rate and composition of a separator, say a dewatering screen, by calculating the amount and composition of the coal fed to it from a coal cleaning device, e.g. a jig, by applying the error curve of the jig to its own raw feed and allowing for a certain amount of slimes known from previous experience with similar installations operating elsewhere. Allowance for variations in feed rate and feed composition is made, using tolerance limits that permit reasonable flexibility without affecting the equipment cost too drastically. The same principle is followed for all other equipment units of the proposed washery; and the equipment manufacturers who are invited to submit quotations, base their estimates and their guarantees on the aforementioned information, as obtained from the main contractor for the project. When the plant is commissioned and problems arise during the start-up period, the disputes commonly center on variations from the expected feed rate and composition. The coal dewatering screens are overloaded because the jig carries far more fines than anticipated; and as a result the centrifuges do not dewater the load-out product to the desired moisture content so that coal freezes in the cars etc.

These problems will be aggravated if slimes and middlings are recirculated in the plant, unless the resulting build-up is properly accounted for in advance. Controlled recirculation of slimes and middlings does not interfere with efficient separation and may notably improve it. It offers advantages of simplicity and low cost in washeries where flaky, friable coals are cleaned in bulk, especially where large and variable amounts of fines are in evidence.

The degree to which slimes and middlings can be recirculated depends mainly on the type of separators used; for instance, in one washery a 24-in. compound water cyclone (cap. 95-142 tph) was found to operate satisfactorily on a new feed of 125 tph with a recirculating load of 250 tph, total 375 tph.

The introductory remarks that follow briefly present the principle of controlled recirculation and the procedures described in the body of this report.

The principle of recycling plant water with respect to alleviating stream pollution by coal washeries suggests the consequent recirculation of a certain amount of relatively fine solids (slimes) along with this water. As well, coarser products such as middlings, underproducts of dewatering screens, overproducts of classifier cyclones, etc. may be included in the recirculating plant water.

In a closed-circuit wash plant the feed (F') to the initial processing unit thus consists of the "raw" coal feed (F) plus a certain quantity of solids that recirculate and, to some extent, build up in the system concurrent with the continuous removal of various finished products. The magnitude of build-up can be readily calculated, as will be shown, given the separating characteristics or capabilities of the various devices used in the plant. The maximum build-up attained is referred to as the steady-state, i.e., the equilibrium condition wherein the sum of the washery products equals the washery feed. The degree of build-up is expressed by a recirculation coefficient ( $\lambda$ ), also called recirculation



factor or ratio,

$$\lambda = \frac{F'}{F}$$

To give wider scope to the discussion that follows, the terms "plant" or "system" will be used interchangeably and will be defined as being "any portion of a washery that contains equipment which, from any feed material, produces a product that will be recirculated to the initial treatment stage of that portion of the washery". In effect, and by definition, a system or plant may comprise an entire washery, or a washery may consist of a number of systems or plants.

The coal washery can be a complex operation designed to produce an optimum clean coal product and reject (two-product separation), with or without some secondary products (3-, 4-product separation). This is accomplished by means of sorting and sizing procedures, initially acting upon the raw feed and followed by retreatment, in stages, of the resulting intermediate products. Design of a washery requires a particular solution for a particular coal and is based on working within a specified and usually pre-determined framework of capital cost, operating cost, etc. in relation to capacity, feed coal characteristics, and quality specifications of finished products. Hence, as a first step before proceeding to design calculations, it is necessary to establish the basic equipment requirements and from prior considerations, to decide which products might need to be recirculated. Refinements and modifications can be made later upon reviewing the results of the preliminary design. As a result, the design process might require several runs, after feedback of this information and following adjustment, before an optimum solution can be obtained.

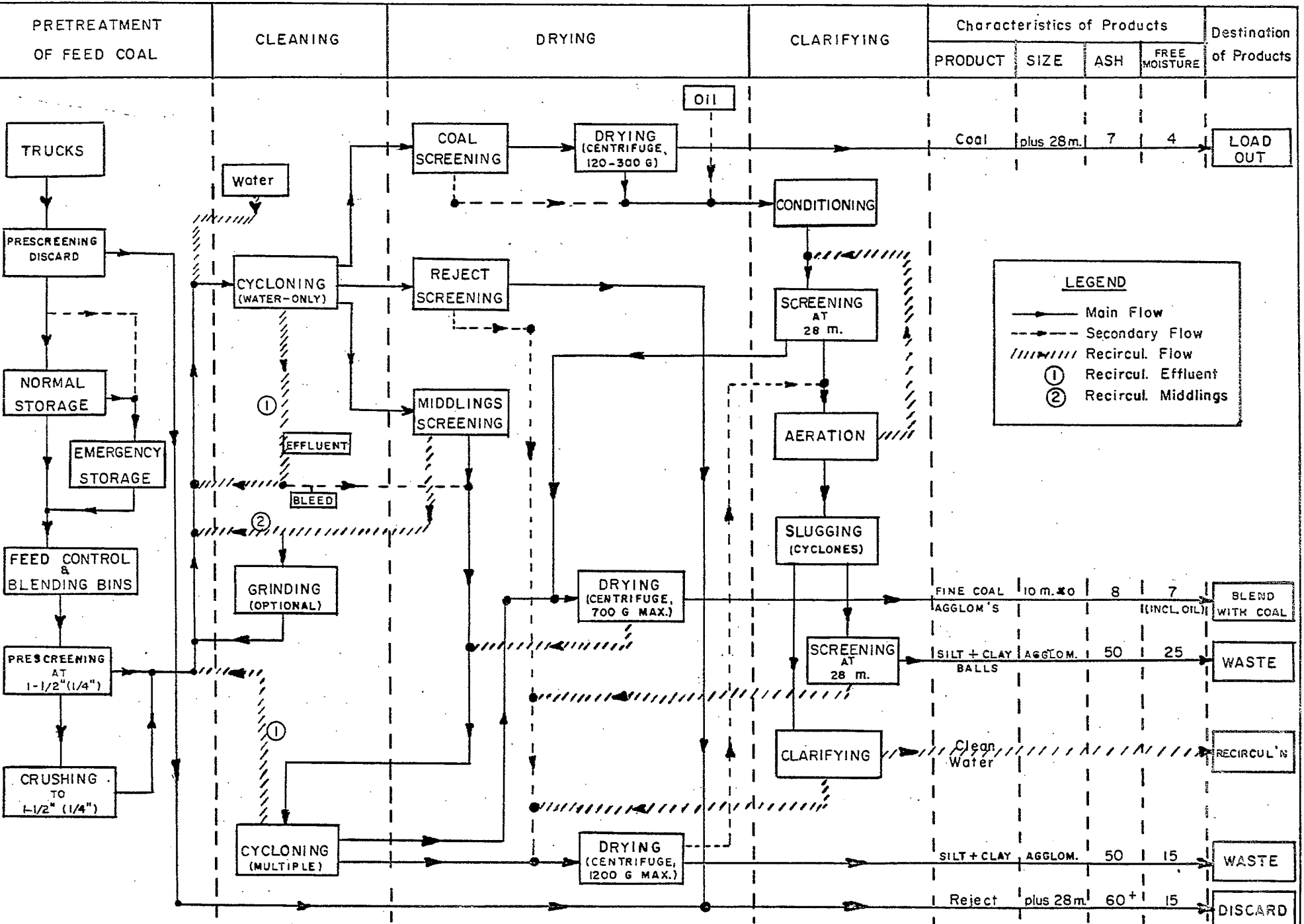
The computation of  $\lambda$ , which defines the steady-state feed condition, requires knowledge of the characteristic error curves<sup>1)</sup> of the separators being used in the plant. From these error curves it is possible to derive the ultimate fractional make-up of all products (finished and recirculating) which emanate from the various stages of the system.

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1) Used synonymously with partition curve, distribution curve, efficiency curve and recovery curve.



Fig. 1 - E.M.R. Process Flowsheet<sup>1)</sup>



**LEGEND**

- Main Flow
- - - Secondary Flow
- //// Recircul. Flow
- ① Recircul. Effluent
- ② Recircul. Middlings

1) Water-only Cyclones + Oil-dewatering process, Dept. of Energy, Mines and Resources, Canada.

The calculation of  $\lambda$  for a basic 5-unit plant has been programmed for the Olivetti-Underwood P101 computer. Specifications are given in the main text, permitting calculation by hand, if desired. Principles and derivation of the program are covered in detail in the appendix. A hand calculation is strongly recommended as a good exercise to initiate an operator and to promote a clear understanding of the procedure.

Calculations for plants with more than 5 units require either a computer with a larger memory bank or a combination of the calculations to be discussed in the next section of this report.

## THE WASHERY FLOW PATTERN

Flowsheets of most washeries indicate the existence of recirculating products; some are of minor importance, others may represent a considerable volume of solids relative to the feedrate of raw coal to the plant. On the general flowsheet of Fig. 1, for example, there are eight recirculating flows, but only two of these (1), (2), tend to affect the overall solids flowrate materially. Both streams originate from the main cleaning section. Effluent (1), representing the overproduct of the classifier cyclone either before or after further beneficiation by multiple 2-in. cyclones, returns to the prepared new feed. It may represent 1/2 to 3/4 of the wash plant's water flow, depending on the system's capacity for absorbing the build-up of slimes present in the feed.

The second recirculating product (No. 2 on Fig. 1) is the dewatered middlings returning to the new feed. Recirculation of this product can be profitable provided the resulting build-up in the cleaning section can be absorbed without the need for a substantial increase in throughput capacity.

When the amount of middlings is relatively large, grinding may well be considered as a means of increasing the washery's yield of clean coal. The ground middlings returning to the new feed do not constitute a true recirculating product, but rather the product of a selective grinding operation on the intergrown coal fraction contained in the plant feed.

When the amount of middlings is smaller than indicated above, and recirculation without grinding becomes more attractive from an economic point of view, the uncrushed material recirculates to the new feed entering the cleaning section and builds up to a level that depends on the cleaning efficiency of the separators involved, sorters<sup>1)</sup> as well as

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1) Densimetric separators.

sizers. Because the type and the arrangement of these basic units vary considerably from one washery to the next, the method presented below was developed so as to permit the calculation of build-up for any arrangement of sorters and sizers. The effect of each individual separator on the overall build-up of slimes and middlings is determined by its error curves for sorting and/or sizing. One deliberate restriction was introduced in order to accommodate the user who has access to only a small, engineering, desk computer: arrangements of two to five separators, at the maximum, can be handled with the design presented in this report. Larger configurations can be split into smaller groups of two to five units, as is demonstrated by an example given in the appendix.

#### Notation and Symbols

The two products of any separator are here designated as o v e r p r o d u c t and u n d e r p r o d u c t. For the primary separator of a system the symbol for the overproduct is O; for the underproduct, U. For a secondary separator receiving product O the overproduct is designated as OO, its underproduct OU. Another secondary separator receiving U produces an overproduct designated UO and an underproduct UU, etc. The origin and main characteristics of each product can thus be recognized at a glance.

A clear distinction between p r o d u c t c o m p o n e n t s must furthermore be made because virtually all sorters are also sizers, whilst sizers - in the context of this report, are sizers only. Because slimes particles tend to "stay with the water" and, in all gravitational sorters, discharge with the light fraction, the term overproduct (O) in this report always represents the light and/or fine product<sup>1)</sup> of the separator (sorter or sizer); and the underproduct (U) always represents a

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1) This excludes froth cells, where water reports substantially to the heavy fraction. The difference in this case is immaterial as all the particles are classed as slimes.



heavy or/and coarse product. For jigs, tables, cyclones, dense-medium baths and the like, these notations correspond with the physical overproducts and underproducts. For s c r e e n s the notation is consequently the reverse of what one would normally associate with the overproduct, in the physical sense. It appears illogical from the physical point of view for the conventional screen, e.g. vibrators, sieve bend, but not for the vertical basket drier. Thus, with one notable exception, the above notations conform with physical reality.

Each product consists of a plurality of gravity and/or size fractions that are identified by means of the e r r o r c u r v e s that apply to the separator involved. Where it concerns a sizing effect or operation, the p a r t i t i o n n u m b e r (PN) of each size fraction of the product, i.e. its fractional weight in terms of the weight of the corresponding size fraction in the feed to the separator, is designated ( $R_i$ ) where it concerns the coarse product; and ( $1 - R_i$ ) for the fine product.

Where it concerns a sorting operation the partition number or y i e l d of each densimetric fraction of the product - i.e., its fractional weight in terms of the weight of the corresponding fraction in the feed to the sorter - is designated ( $Y_i$ ) where it concerns the light product; and ( $1 - Y_i$ ) for the heavy product.

In sorters where the densimetric separation and a sizing effect occur simultaneously, both symbols (R and Y) are employed. In sizers, only (R) applies.

#### Calculation of $\lambda$

The calculations required for finding the overall recirculation coefficient  $\lambda$  are condensed in Table 1, a standard form that accommodates combinations of maximum five separators. The procedure is summarized below, in eight successive steps.

1. A basic flow diagram of the circuit is sketched in the blank space provided for that purpose in the top part of Table 1 (p.11).
2. The headings marked "unit" (jig, cyclone etc.) and "process" (sizing or sorting) are then filled out in accordance with the flow diagram.

3. In column 1 a series of size fractions are designated for which individual values of R and Y are to be found.
4. In the last column of Table 1, enter the size consist of the new feed to the circuit.
5. If a portion (b) of a recirculating product is bled off, enter the fractional weight of solids in terms of the total recirculating product in the top row of table.
6. To find R and Y values for columns 2 to 8, use the decision flowchart shown on Fig. 2. This flowchart provides for a Unit 1 (see the legend) that may either precede the primary separator 2 (as in an EMR-process flowchart) or be absent. If absent, the  $R_1$  values on Table 1 are shown to equal 1. If, on the other hand, a Unit 1 does exist in the configuration shown, the partition numbers  $R_1$  are filled out for each size fraction, as indicated by its size error curve. It is noted that Units 1 and 4 represent sizers only, whereas Units 2, 3 and 5 may be sizers or sorters.

The decision chart provides the rest of the instructions required for filling out the remaining columns, including those for  $Y_2$  and  $Y_3$ , viz., the yields of clean coal for individual size fractions. In many cases an average yield figure for the entire size range is sufficient.

7. Fill out values of the recirculation ratio for each individual size fraction, using the following equations:

$$\lambda = 1/F \text{ ----- 1}$$

$$F = AM + (1 - A) K \text{ ----- 2}$$

$$A = R_1 (R_2 Y_2 - R_2 + 1) \text{ ----- 3}$$

$$M = R_4 + b (1 - R_4) \text{ ----- 4}$$

$$K = (1 - Y_3) R_3 + (1 - R_3 + R_3 Y_3) R_5 \text{ ----- 5}$$

These equations can conveniently be combined in a single program (55 steps) for a small engineering computer.

8. Finally, the overall recirculation coefficient  $\lambda$  is found from:

$$\lambda = \sum q_i \lambda_i / 100 \text{ ----- } 6$$

where  $q$  = weight of size fraction, % (last column, Table 1).

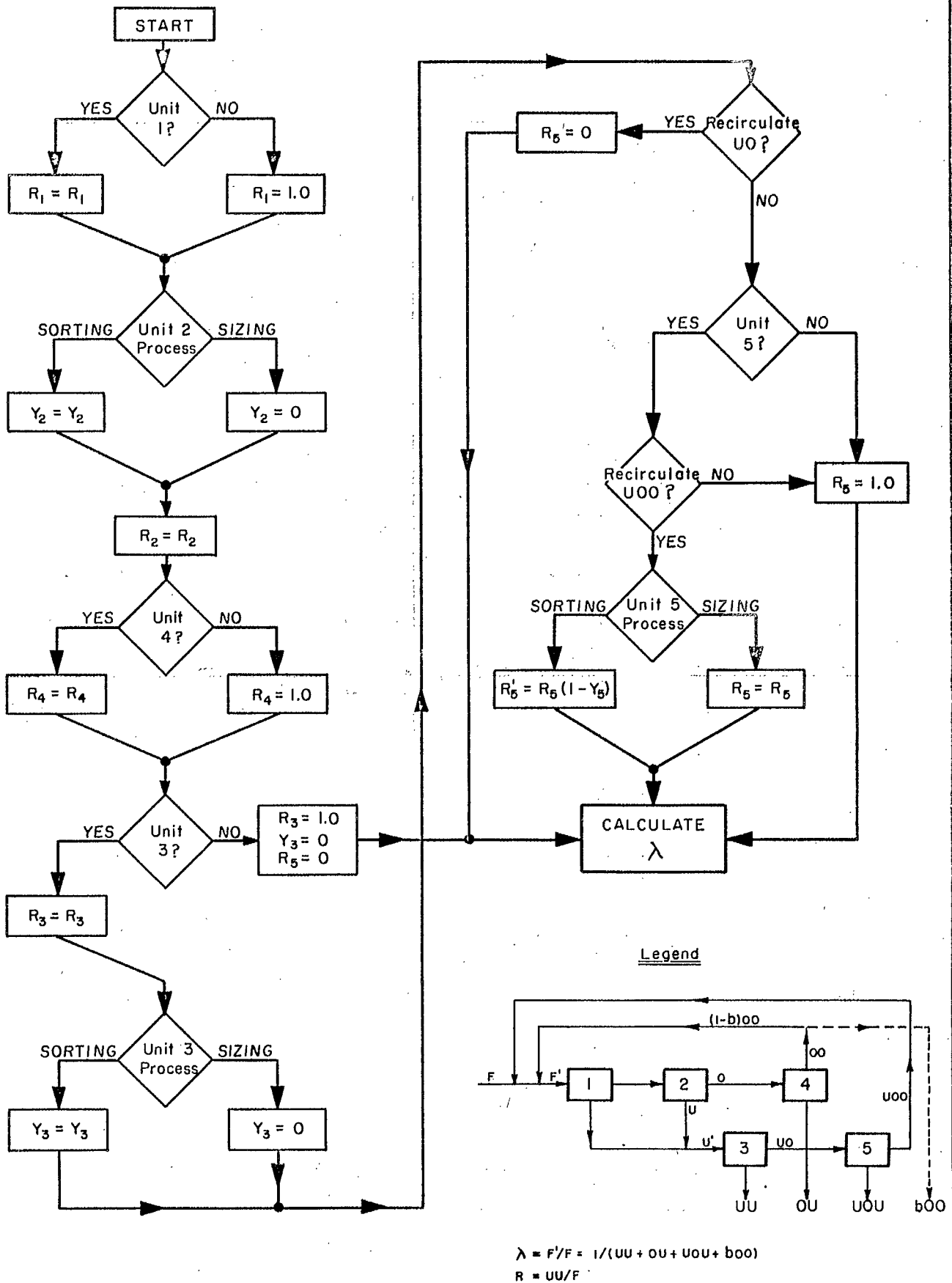
Error curves with reference to both specific gravity and size separations for various types of units may be determined from actual test work, they may be taken from results of tests reported in the literature, and even from a manufacturer's bulletin. A compendium of such curves and related information is a basic requirement and a very desirable possession for the design engineer because a great variety of separators may be considered from one case to the next.

For present purposes of calculating recirculating loads, the primary area of concern is with the separation of material according to size because the slimes' fractions are generally the main contributors to the recirculation of solids within the plant. As stated earlier, however, material of an essentially coarser non-slimes nature such as middlings resulting from a specific gravity separation may in some instances make up part or virtually all of the recirculating load. Though these calculations apply generally to any system where products recirculate, the cleaning of coal by the E M R process, shown on Fig. 1, is of special interest as a prime example of a two-stage system with recirculation of intermediate products. This basic cleaning circuit will be discussed in more detail in the next section.





Fig. 2-Decision Flowchart for Calculation of Recirculation Factor,  $\lambda$  and Overall Partition Number,  $R$ .



## FIVE-UNIT CLEANING CIRCUIT (EMR)

The basic equipment and its products are presented diagrammatically on Fig. 3.

Unit 1. Pulp Divider

The pulp divider is not a processing device in the usual sense. Its purpose, as the name implies, is to split the water of the feed stream in a given ratio between the primary-stage compound water cyclone (CWC) and the secondary-stage CWC by size classification, thus providing "injection water", at a controlled pressure, for diluting the feed material entering the second-stage CWC from the primary-stage CWC. The partition number is given by  $R_1$  which denotes the fractional weight of a given particle size fraction in the feed to the pulp divider that reports to the coarse product, i.e., the feed to CWC-1. The remaining portion of that size fraction goes with the injection water and therefore equals  $(1-R_1)$ . The partition numbers of the pulp divider are found from its size error curve on Fig. 4.

Unit 2. Primary Compound Water Cyclones (CWC-1)

The CWC is a sorting device, its mode of separation being one essentially according to the specific gravity of a given particle: light particles go to the overflow, and heavy ones to the underflow. It is normally found, however, that a classification (sizing) effect overrides the sorting process on the finest sizes. Taking the simplified view, the separation by a sorting device may be looked upon as being the sum of effects of the sorting and sizing processes superimposed one upon the other.

With regard to the sizing effect which takes place independently of the sorting as if the CWC were a classifier cyclone, the coarse product of this unit is given by  $R_2$  and the fine overflow product by  $(1-R_2)$  in the same manner as described above for the pulp divider. Since the feed partition number is  $R_1$ , the resultant fractional values with respect to size will be  $R_1R_2$  and  $R_1(1-R_2)$  for the CWC-1 coarse and fine products respectively.

With sizing now concluded, the process of sorting takes over, operating on the coarse product only: each size or range of sizes in the coarse

Fig.3-Flowsheet of Basic 5-Unit System (General Case)

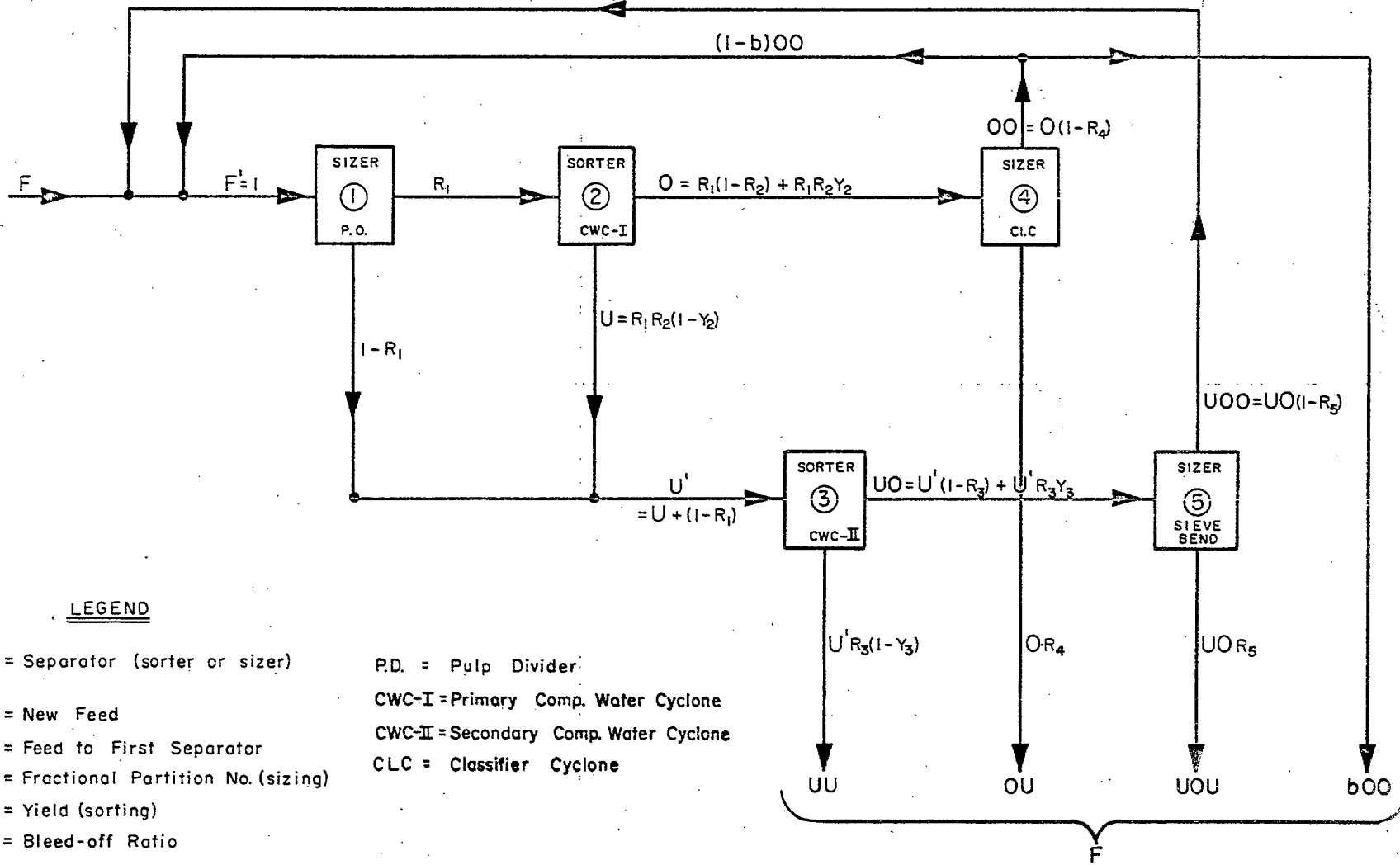
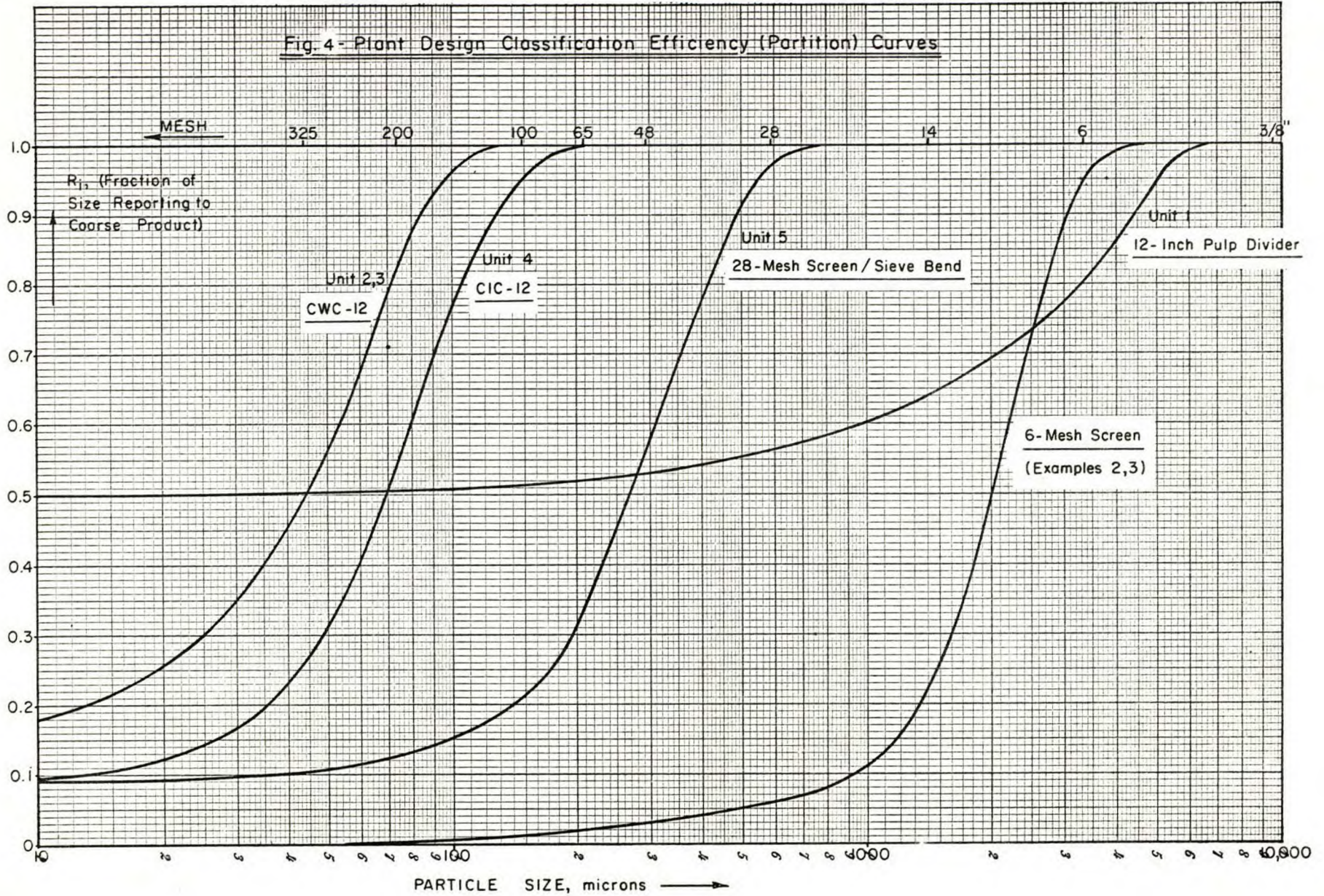




Fig. 4 - Plant Design Classification Efficiency (Partition) Curves





product is now separated into the portion  $Y_2$  which denotes the "yield" of light material going to the overflow product and its complement  $(1-Y_2)$  which represents the quantity of heavy product that will remain in the underflow. The resultant fractional values for both separations combined will therefore be  $R_1R_2(1-Y_2)$  for coarse-heavy (high-ash) and  $R_1(1-R_2) + R_1R_2Y_2$  for fine-light (low-ash) products, (U) and (O) respectively.

At this stage, the feed stream has been separated effectively into two streams: the overproduct (O) with corresponding equation  $O = R_1(1-R_2) + R_1R_2Y_2$ , and the underproduct (U). The latter constitutes the bulk of the feed to CWC-II. The corresponding equation  $U' = R_1R_2(1-Y_2) + (1-R_1)$  represents the sum of (U) and the pulp divider solids for each size fraction individually.

#### Unit 3. CWC-II (Secondary Compound Water Cyclones)

Operation of this unit is identical to CWC-I except that it is adjusted to separate at a higher cutpoint. It is a sorting device and treats the feed product  $U'$  described above. The coarse-heavy product (UU) is determined by  $UU = U'R_3(1-Y_3)$ , and the fine-light product (UO) by  $UO = U'(1-R_3) + U'R_3Y_3$ . The UO product is commonly referred to as Middlings.

#### Unit 4. CLC (Classifier Cyclones)

This unit treats product (O) and, by a sizing procedure, produces the partially dewatered clean coal product (OU) and an effluent product (OO) which may be either wholly recirculated or partly bled off as (bOO), where  $b$  = fractional weight (in terms of O) of solids bled off. These products are given by  $OR_4$  and  $O(1-R_4)$  respectively. The fraction of effluent bleed-off denoted by the factor ( $b$ ) may be given by any value between 0 and 1. Equation for the recirculating effluent thus becomes  $(1-b) OO = (1-b)(1-R_4)$ .

#### Unit 5. Sieve Bend

This is a "sizer" that treats the middlings UO to produce, in this case, a final, dewatered, coarse-sized product UOU; and a relatively dilute effluent or undersize UOO that recirculates entirely to the feed point. Partition numbers for the sieve bend are shown jointly with those of the preceding separators on Fig. 4.

In summary, by a combination of sizing and sorting processes, the 5-unit plant produces four final products that are continuously removed from the system (UU, OU, UOU, and b00); and two products (U00) and (1-b)00 that recirculate and combine with the new feed (F) to produce the feed F' to unit 1.

Changes in the plant just described, as well as variations in the error curves, can be effected in relation to the P101 program by arithmetically "eliminating" or "modifying" one or another of the separators that are included in this general model, using the decision flowchart (Fig. 2) discussed in the previous section. It provides, for example, for the possibility that UO may or may not be recirculated or retreated; and, if it is retreated, the effluent product U00 may or may not be recirculated. The decisions made here will determine the values to be assigned to the various input data ( $R_i$ ) in Table 1.

It may not be so obvious from reading the decision flowchart that those units defined as sizers can also be changed over to sorters and that products other than those specified may in part or wholly be recirculated. Situations not covered by the program would, however, require preliminary calculations, in the manner shown on Table 2, before entering the data in the input (Table 1).

TABLE 2.

Fractional Solids Flowrates for a Five-Unit System

Process Step	Separator types		Feed		Separator Products			
	Example	Type of Separation			For sorters: the light fraction		For sorters: the heavy fraction	
			Symbol	Solids, per size fr.	Symbol	Solids, per size fr.	Symbol	Solids, per size fr.
1	Pulp Divider	Sizing	F'	$\lambda F$	-	$R_1 F'$	-	$(1-R_1) F'$
2	CWC I	Sorting	-	$R_1 F'$	0	$R_1 (R_2 Y_2 - R_2 + 1) F'$	U	$R_1 F' - 0$
3	CWC II	Sorting	U'	$\frac{[R_1 (R_2 - R_2 Y_2 - 1) + 1] F'}{= F' - 0}$	UO	$U' (R_3 Y_3 - R_3 + 1)$	UU	$U' R_3 (1 - Y_3)$
4	Cl.C	Sizing	0	$R_1 (R_2 Y_2 - R_2 + 1) F'$	00	$\begin{cases} 0(1-R_4) (1-b) \\ 0(1-R_4) b \end{cases}$	OU	$OR_4$
5	Sieve bend	Sizing	UO	$U' (R_3 Y_3 - R_3 + 1)$	UOO	$U' (1-R_5) (R_3 Y_3 - R_3 + 1)$	UOU	$U' R_5 (R_3 Y_3 - R_3 + 1)$

Notes: (F) stands for new feed to plant, equals sum of end products leaving plant;  
 (F') is feed to first separator; includes F and recirculating products;  
 (R) stands for  $R_i$ , the fractional residue of each size fraction (i) of the feed that reports to the coarse product of a sizer. (R) is called the (fractional) partition number of a separator. (R) likewise represents the residue of a size fraction (i) for combination of separators (see Appendix).  
 The above definition applies alike to cyclones, screens, jigs, pulp divider, flotation machines or any other type of mineral separator.  
 (Y) stands for  $(Y_i)$ , the fractional yield of light product for each size fraction (i) of the sized feed. Yield refers exclusively to sorting operations. Therefore, for sizing operations the yield  $Y = 0$ .

## NUMERICAL EXAMPLES

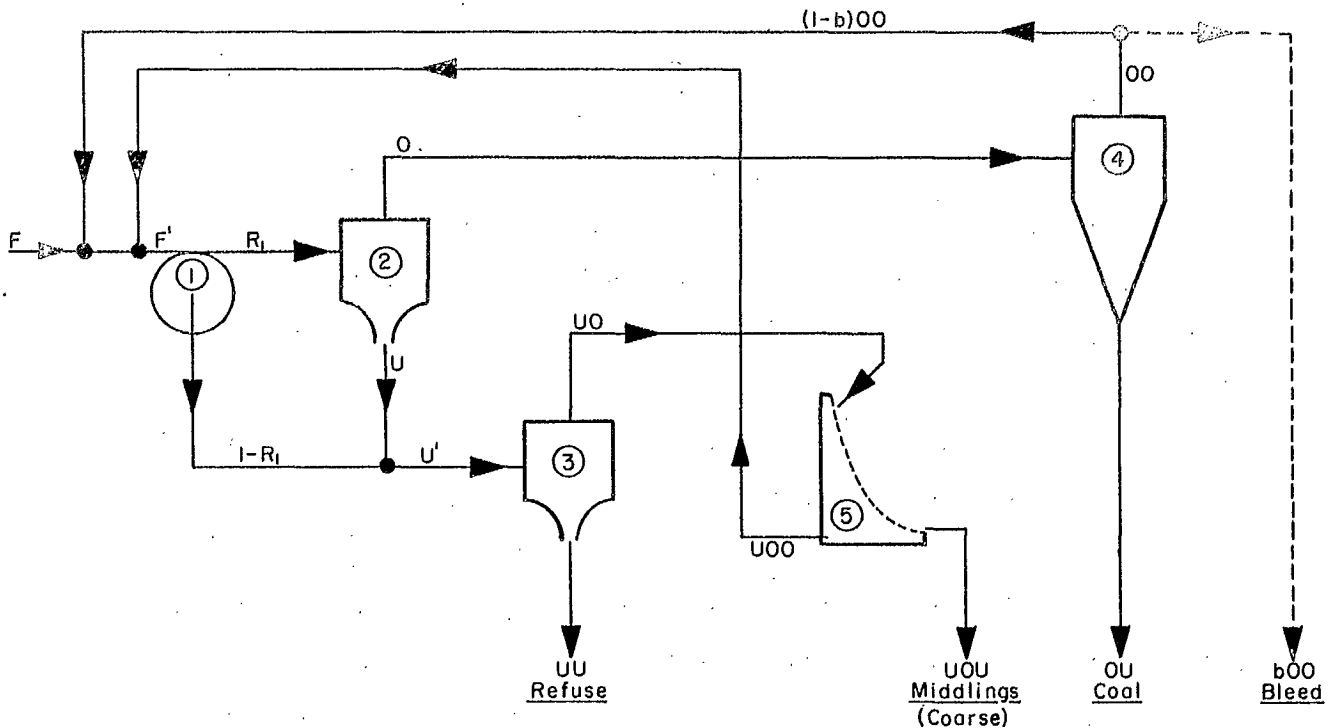
The best way to illustrate the calculation of  $\lambda$  is to refer to the examples (1 to 5) that follow. These examples represent work sheets according to the model shown on Table 1. The numbering (1 to 5) of the units corresponds with the indices of  $R_1$ ,  $R_2$ , etc. shown in the columns of Table 1.

Symbols used on the worksheets are explained in the text of section on the washery flow pattern.

With this information, the five examples that follow are now self-explanatory. The error curve of the 6-mesh dewatering screen used in examples 2 and 3 is presented on Fig. 4.

A graph showing the values of  $\lambda$  for individual size fractions is presented on Fig. 5. The overall value of  $\lambda$  can be calculated in the manner explained above (instructions for calculating  $\lambda$ , Step 8).

Example 1 - General Case

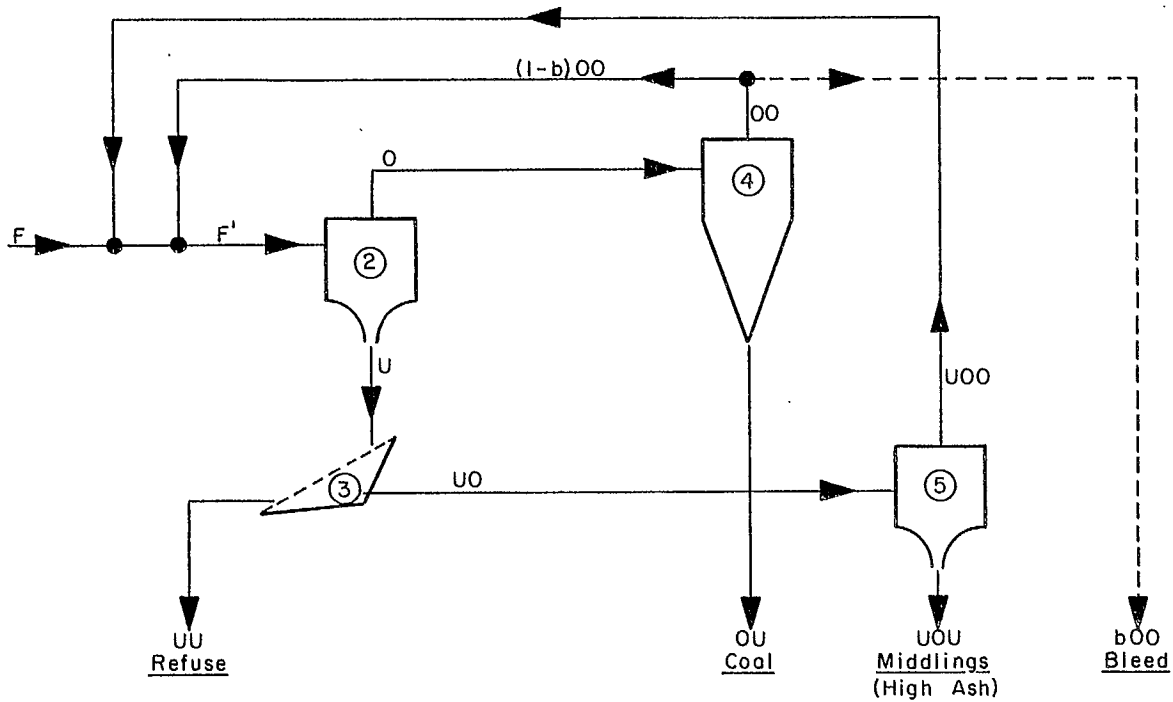


$b = 0$

UNIT	Pulp Divider	CWC-12	CWC-12	Cl.C-12	28 m. Sieve Bend	Yield <sup>1)</sup> Unit 2	Yield <sup>1)</sup> Unit 3	Recircul <sup>2)</sup> Factor	Size Consist of Feed, F wt, %
PROCESS	Sizing	Sorting	Sorting	Sizing	Sizing				
Size Fraction	$R_1$	$R_2$	$R_3$	$R_4$	$R_5$	$Y_2$	$Y_3$	$\lambda$	
>4000 $\mu$	0.95	1.0	1.0	1.0	1.0	0.25	0.15	1.0	
4000-2000	0.78	1.0	1.0	1.0	1.0			1.0	
2000-1000	0.65	1.0	1.0	1.0	1.0			1.0	
1000-500	0.58	1.0	1.0	1.0	1.0			1.0	
500-250	0.54	1.0	1.0	1.0	0.75			1.03	
250-150	0.52	1.0	1.0	1.0	0.30			1.10	
150-100	0.51	1.0	1.0	0.90	0.18			1.14	
100-80	0.50	0.94	0.94	0.71	0.14			1.23	
80-60	0.50	0.78	0.78	0.50	0.12			1.51	
60-40	0.50	0.56	0.56	0.30	0.11			2.15	
<40	0.50	0.26	0.26	0.11	0.10	0.25	0.15	4.49	
Mean						0.25	0.15		100.0

NOTES: 1) THE VALUES FOR  $Y_2$  AND  $Y_3$  ARE HERE SHOWN AS CONSTANT OVER THE ENTIRE RANGE OF SIZES. IN PRACTICE, DIFFERENT VALUES MAY BE EXPECTED. THESE WILL AFFECT  $\lambda$ ; IF THE DIFFERENCES FROM THE AVERAGE ARE LARGE.  
 2) THE MEAN VALUE OF  $\lambda$  IS OBTAINED BY WEIGHTING THE INDIVIDUAL VALUES IN PROPORTION TO THE SIZE CONSIST VALUES FOR EACH FRACTION (LAST COLUMN).

Example 2

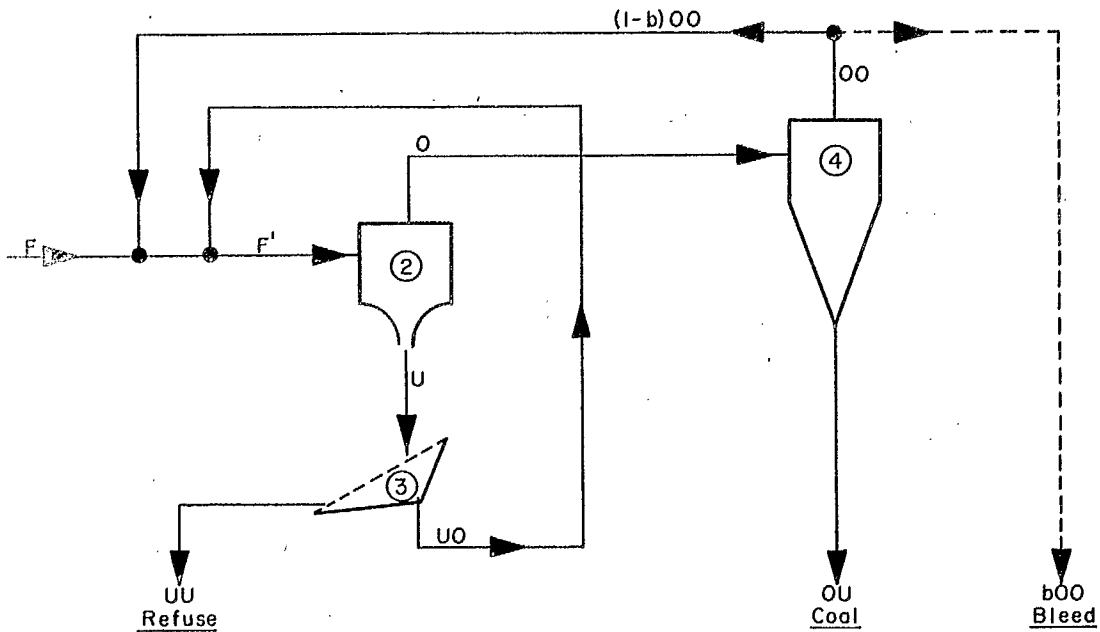


$b = 0$

UNIT		CWC-12	6 mm screen	Cl.C-12	CWC-12	Yield Unit 2	Yield Unit 3	Recircul'n Factor	Size Consist of Feed, F wt, %
PROCESS	—	Sorting	Sizing	Sizing	Sorting				
Size Fraction	P.N. $R_1$	$R_2$	$R_3$	$R_4$	$R_5^*$	$Y_2$	$Y_3$	$\lambda$	
>4000 $\mu$	1.0	1.0	1.0	1.0	0.85	0.25	0.0	1.0	
4000-2000		1.0	0.90	1.0	0.85			1.01	
2000-1000		1.0	0.25	1.0	0.85			1.09	
1000-500		1.0	0.075	1.0	0.85			1.12	
500-250		1.0	0.038	1.0	0.85			1.12	
250-150		1.0	0.018	1.0	0.85			1.12	
150-100		1.0	0.009	0.90	0.85			1.16	
100-80		0.94	0.006	0.71	0.80			1.29	
80-60		0.78	0.004	0.50	0.66			1.68	
60-40		0.56	0.003	0.30	0.48			2.66	
<40	1.0	0.26	0.001	0.11	0.22	0.25	0.0	7.60	
Mean						0.25	-		100.0

\* N.B. - With a sorting process at this stage, the values given for  $R_5^*$  are  $R_5(1-Y_5)$  with  $Y_5 = 0.15$ .

Example 3

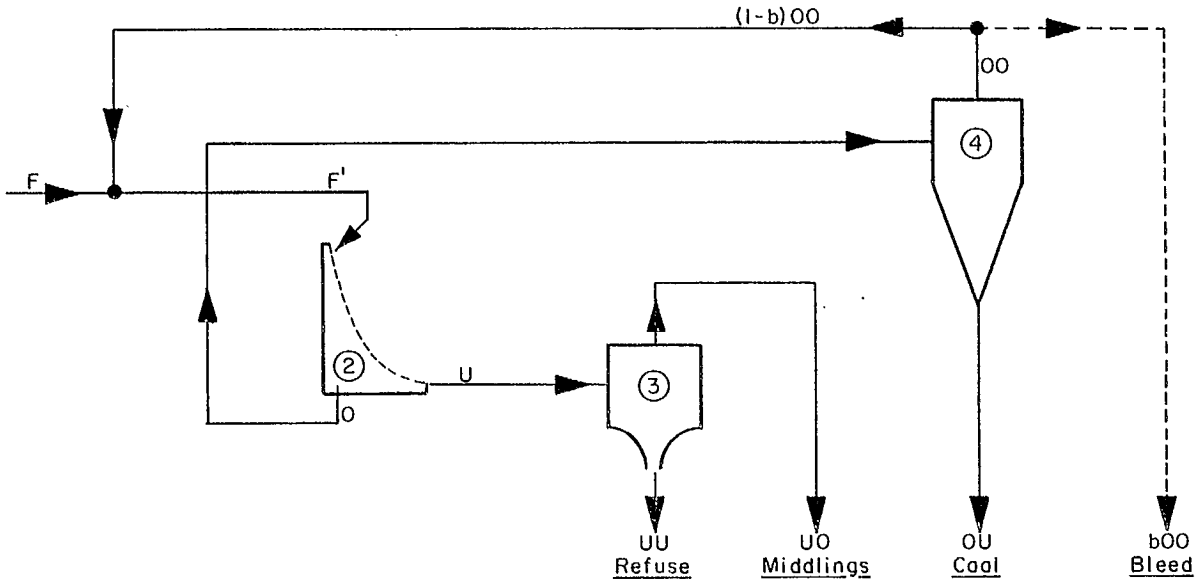


$b = 0$

UNIT		CWC-12	6 m. Screen	Cl.G-12		Yield Unit 2	Yield Unit 3	Recircul'n Factor	Size Consist of Feed, F wt, %
PROCESS	-	Sorting	Sizing	Sizing	-				
Size Fraction	P.N. $R_1$	$R_2$	$R_3$	$R_4$	$R_5$	$Y_2$	$Y_3$	$\lambda$	
>4000 $\mu$	1.0	1.0	1.0	1.0	0.0	0.25	0.0	1.0	
4000-2000		1.0	0.90	1.0				1.08	
2000-1000		1.0	0.25	1.0				2.28	
1000-500		1.0	0.075	1.0				3.26	
500-250		1.0	0.038	1.0				3.59	
250-150		1.0	0.018	1.0				3.80	
150-100		1.0	0.009	0.90				4.31	
100-80		0.94	0.006	0.71				4.68	
80-60		0.78	0.004	0.50				4.76	
60-40		0.56	0.003	0.30				5.71	
<40	1.0	0.26	0.001	0.11	0.0	0.25	0.0	11.27	
Mean						0.25	-		100.0



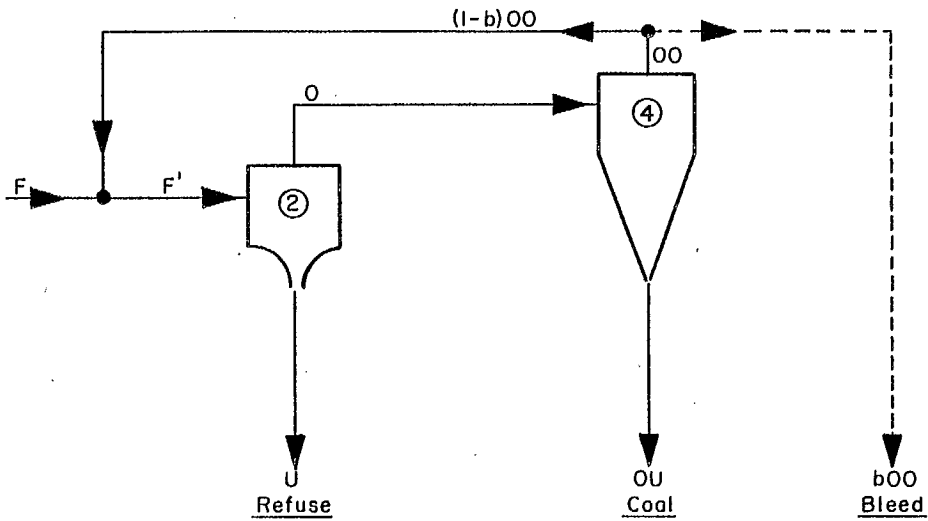
Example 4



$b = 0$

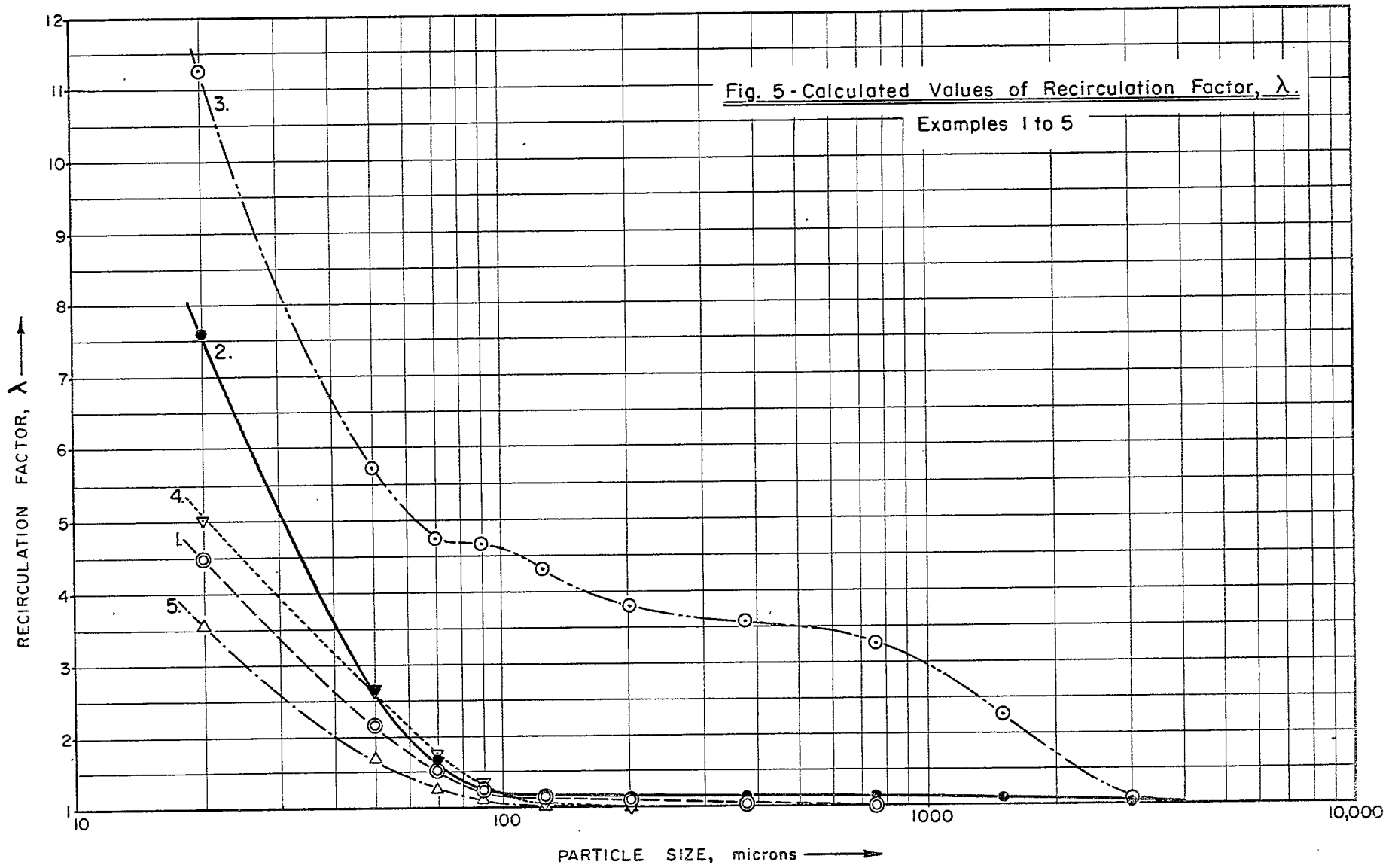
UNIT		28 m. SieveBend	CWC-12	Cl.C-12		Yield Unit 2	Yield Unit 3	Recircul'n Factor	Size Consist of Feed, F wt, %
PROCESS	-	Sizing	Sorting	Sizing	-	Yield Unit 2	Yield Unit 3	λ	
Size Fraction	P.N. R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	Y <sub>2</sub>	Y <sub>3</sub>		
>4000 μ	1.0	1.0	1.0	1.0	1.0	0.0	0.15	1.0	
4000-2000		1.0	1.0	1.0				1.0	
2000-1000		1.0	1.0	1.0				1.0	
1000-500		1.0	1.0	1.0				1.0	
500-250		0.75	1.0	1.0				1.0	
250-150		0.30	1.0	1.0				1.0	
150-100		0.18	1.0	0.90				1.09	
100-80		0.14	0.94	0.71				1.33	
80-60		0.12	0.78	0.50				1.78	
60-40		0.11	0.56	0.30				2.65	
< 40	1.0	0.10	0.26	0.11	1.0	0.0	0.15	5.02	
Mean						-	0.15		100.0

Example 5



$b = 0$

UNIT	CWC-12		Cl.C-12		Yield Unit 2	Yield Unit 3	Recircul'n Factor	Size Consist of Feed, F wt, %	
PROCESS	-	Sorting	-	Sizing	-	-	-	-	
Size Fraction \ P.N.	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	Y <sub>2</sub>	Y <sub>3</sub>	λ	
>4000 μ	1.0	1.0	1.0	1.0	0.0	0.25	0.0	1.0	
4000-2000		1.0		1.0				1.0	
2000-1000		1.0		1.0				1.0	
1000-500		1.0		1.0				1.0	
500-250		1.0		1.0				1.0	
250-150		1.0		1.0				1.0	
150-100		1.0		0.90				1.02	
100-80		0.94		0.71				1.09	
80-60		0.78		0.50				1.26	
60-40		0.56		0.30				1.68	
< 40	1.0	0.26	1.0	0.11	0.0	0.25	0.0	3.53	
Mean						0.25	-		100.0



### ANCILLARY CIRCUITS

The following is an illustration of the steps taken to reduce a system to the format required for calculation of  $\lambda$  using the computer program. The example is drawn from the water recovery section of the EMR process (Fig. 1) as applied to the Springhill washery.<sup>1)</sup> It consists of 2 elements, a clarifier and a centrifuge, with recirculation of centrifuge effluent to the clarifier feed and removal of fine solids occurring as centrifuge cake and as solids in the recovered plant water.

The system was redrawn from Fig. 1 in a more compact and understandable manner for our purposes here and is shown in Fig. 6. Upon analyzing this flowsheet, it is recognized that this is merely a variation of the general case, and that it can be made to fit the required program format very nicely.

Drawing this flowsheet again (Fig. 7) and taking only the total tonnage values, the necessary  $R_1$  values for total solids can be determined. With the assistance of the decision flowchart, the input data table can be then filled out and  $\lambda$  for the total solids' recirculation can be computed.

From Fig. 6 it can be seen that the slugging cyclone product (0.42 tph), centrifuge effluent (0.41 tph), and the minus 28 mesh product from 2 reject dewatering screens (18.96 tph) together constitute the feed (F'). Because only the first two products go directly to the clarifier (Unit 2) as shown in Fig. 6, it may be imagined that the first and last products together represent the products of a pulp divider and that their sum is the feed (F) to the system. The first column of the table will therefore contain the value (see Fig. 7):

$$R_1 = \frac{0.42 + 0.41}{0.42 + 0.41 + 18.96} = \frac{0.83}{19.79} = 0.0419$$

The clarifier performs a sizing operation only and the decision flowchart (Fig. 2) tells us to assign the value of 0 to the column for  $Y_2$ .

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1) A 200 tph plant for the recovery of saleable coal from a refuse dump.

The value of  $R_2$  will be  $0.82/0.83 = 0.9880$ . The clarifier overflow is removed directly from circulation and not retreated in a Unit 4. The value for  $R_4$  will therefore be 1.

Unit 3 is a sizing operation only; therefore  $Y_3 = 0$ , and effluent ( $U_0 =$  middlings) is recirculated. The value for  $R_3$  is thus  $19.37/19.78 = 0.9788$ , and  $R_5$  will be 0. The computed value of  $\lambda$  for total solids' recirculation is found to be 1.022.

Fig. 6- Water Recovery System - E.M.R. Process

(Values in brackets represent solids' flowrates, tph)

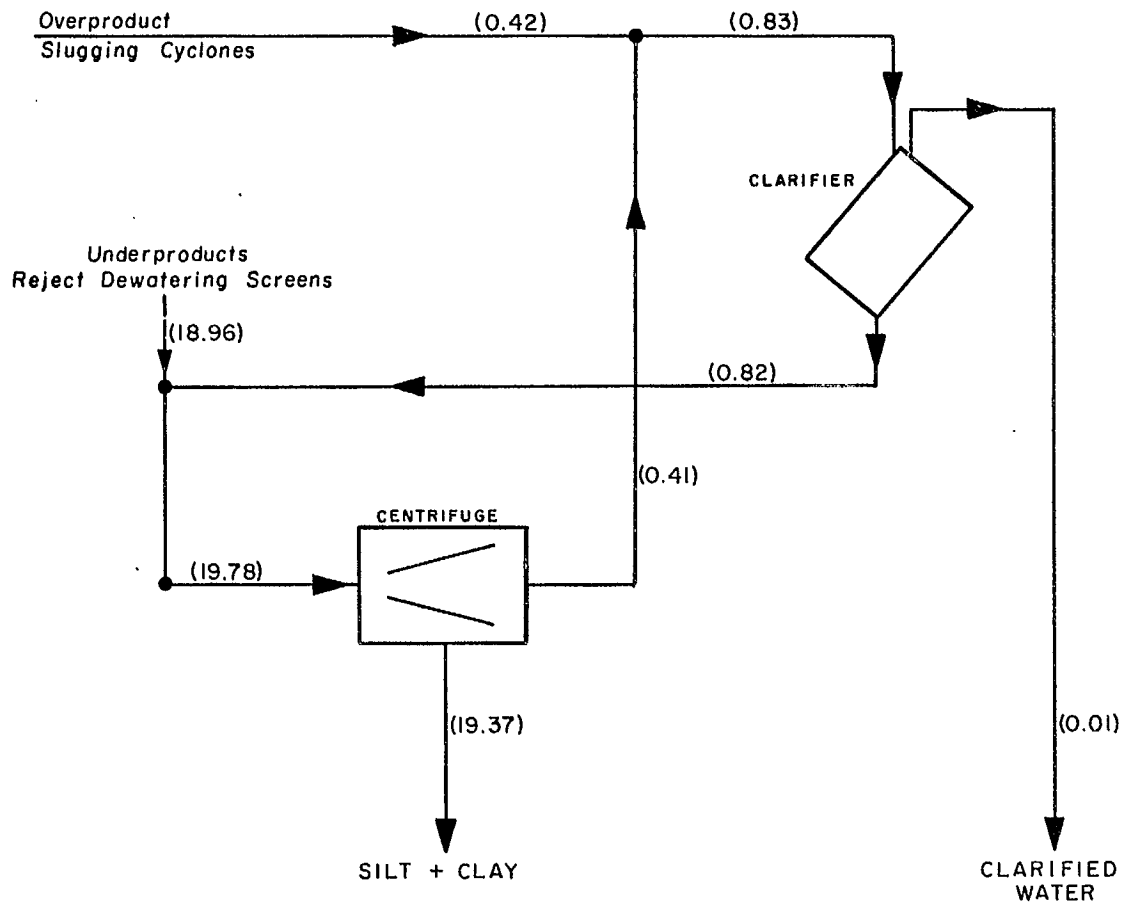
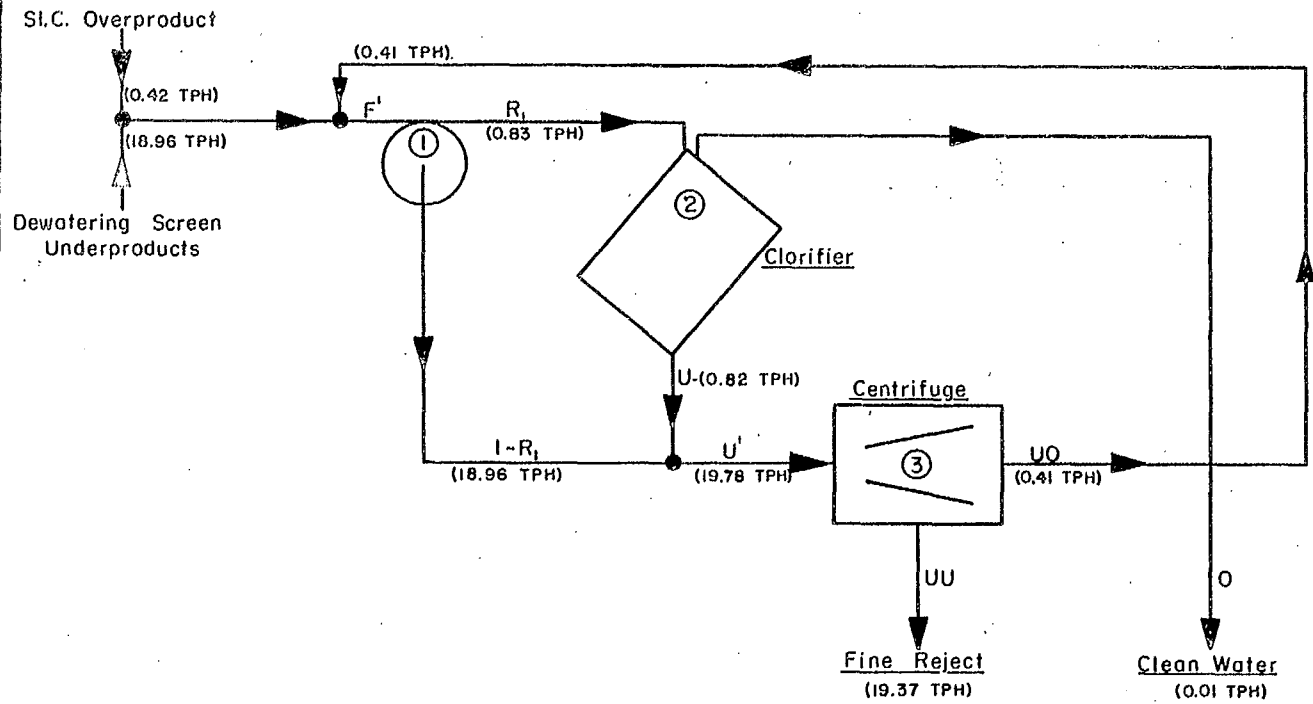


Fig. 7



$b = 0$

UNIT	"Pulp Divider"	Clarifier	Centrifuge			Yield Unit 2	Yield Unit 3	Recircul'n Factor	Size Consist of Feed, F wt, %
PROCESS	Sizing	Sizing	Sizing	-	-	Y <sub>2</sub>	Y <sub>3</sub>	λ	
Size Fraction \ P.N.	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>				
>4000 <sub>μ</sub>									
4000-2000									
2000-1000									
1000-500									
500-250	0.0419	0.9880	0.9788	1.0	0.0	0.0	0.0	1.022	
250-150									
150-100									
100-80									
80-60									
60-40									
<40									
Meon						-	-		100.0



