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FUEL RESEARCH INSTITUTE

OF SOUTH AFRICA

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TECHNICAL MEMORANDUM NO. 15 OF 1973

REPORT ON A COMPOUND WATER CYCLONE INVESTIGATION ON VAN DYKS DRIFT FINES

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INTRODUCTION

Following upon investigations with a 100 mm compound water cyclone, and a literature survey, the Fuel Research Institute decided to acquire a bigger unit with a diameter of 200 mm. This cyclone is capable of cleaning coal to a top size of 3 mm, and its capacity of 2-5 tons of dry feed per hour is considerably higher than the 0,6 tons per hour of the smaller unit.

The new compound water cyclone was installed in the middle of 1972. It replaced the previous unit on the test rig, which required only minor alterations. A cross-section of the cyclone and an overall view of the test rig are shown in Diagrams 1 and 2. The main operating data of this cyclone are as follows:

Top size of coal	3 mm
Dry feed	2-5 t/h
Flow rate of pulp	29 m^3/h
Inlet pressure (min.)	0,56 kg/cm^2
Max. % solids in feed	8-15 %

/After ......

After a few preliminary tests with various coals the work was concentrated on Van Dyks Drift fines. As this coal is relatively easy to clean, it was decided not to perform full analyses of products in all tests. Later, preference was given to Landau minus 0,5 mm coal. This investigation will be covered in a separate report.

THE COAL

The Van Dyks Drift coal was delivered to the Institute as a filter cake with a moisture content varying between 15 and 20%. The washability characteristics of the plus 75 micron fraction are shown in Table 1 and Figure 1 and its size consist in Table 2.

The washability data of the deslimed material indicate a fairly easy to clean coal. To produce 7% ash coal, it should be separated at a specific gravity of 1,54 with a theoretical yield of 81%. The ± 0,1 near gravity material at this point amounts to 23%.

TEST PROCEDURE

The design of the test rig at this stage does not enable continuous operation. Thus the method employed in all these tests was batch operation in a closed circuit. Both overflow and underflow from the cyclone were recycled back to the batch for some 10 minutes in order to reach a steady state in the system and to build up the hindered-settling bed in the tricone of the cyclone. The auxiliary pump was recycling the pulp, providing turbulence in the batch and reducing the settlement of the coal.

/After ......

After this period of stabilising conditions in the system, both flows, product and discard, were simultaneously sampled for about 10 seconds, the time being recorded. The samples were weighed as pulp, and after draining and drying as dry products, providing all necessary data for direct determination of yield, solids percentages, flow rate, etc.

A new batch, consisting of 250 litres of water and a corresponding amount of wet coal, was used for every separate test.

CYCLONE SETTINGS

The settings of the cyclone operating variables were found from an abridged Factorial test. Of the six variables, i.e.

Type of tricone,
Percentage of solids in feed,
Vortex finder diameter,
Vortex finder clearance,
Apex orifice diameter,
Inlet pressure,

the first is a fixed property of the cyclone. The second was eliminated from the Factorial test because of its lesser influence on the cyclone performance. The remaining four were included, partly or fully, in the test.

The solids content in the feed pulp, which was fixed at 10% in all tests, shows some deviations from this value. This is due partly to sedimentation in the batch and partly to the uneven distribution of the moisture in the bulk of the coal.

In the first stage of the Factorial test the wide vortex finder (100 mm) was used. Despite the fact that the other variables were chosen to give the lowest yield, i.e. fully open apex orifice (50 mm) and the biggest possible vortex finder clearance (130 mm), the yield was as high as 85-90%. Even reduction of the feed pressure from the minimum value of 0,56 to 0,42 kg/cm^2 produced only slightly lower yields.

According to the washability characteristics and size consist of the coal, and the cyclone efficiency, the yield should be some 20-30% lower to produce 7% ash in a deslimed product. It was clear that the work with the 100 mm vortex finder could not meet this requirement and these tests were abandoned.

The work was continued, using a narrow (67 mm) vortex finder. The other three variables were set in all combinations of the following values:

	low	medium	high
Vortex finder clearance (mm)	10	50	90
Apex diameter (mm)	30	40	50
Inlet pressure (kg/cm^2)	0,56		0,70

The results of these tests are reported in Table 3.

TESTS WITH OPTIMUM CYCLONE SETTINGS

Results of the Factorial test indicate that the best compromise between the highest yield and lowest ash are tests Nos.17 and 18, applying a wide vortex finder clearance and small apex orifice diameter. These tests were

/successfully ......

successfully repeated (tests 23-25), and the last one was subjected to a more detailed analysis.

Both clean coal and discard of test No. 25 were screened and all size fractions above 75 microns were subjected to "float and sink" analysis. These results are reported in Tables 4 and 5.

The difference between the overall yield (68,5%) and the yield after desliming (65,02%) is due to a high cut point of the minus 75 micron fraction, of which 93% went to the clean coal. There is also a discrepancy between the directly determined ash in deslimed clean coal (7,0%) and that calculated from float and sink data of all size fractions (7,4%); the latter was calculated from 28 increments.

The specific gravity distribution cuves are plotted in Figure 2 and the size distribution curves in Figure 3. When plotting the size distribution curves, the size of 800 microns was used as an approximate mean value for fractions over 500 microns, since 96% thereof lies in the range between 500 and 1000 microns, and for the 4% over 1 mm a mean value of 2 mm was chosen.

All these curves were plotted according to the last sub-table of Table 5, which requires some explanation. The figures read by columns are the points of the specific gravity distribution curves of indicated size fraction. The first four figures in the horizontal lines represent the size distribution curves of corresponding specific gravity fractions; the bottom line figures belong to the size distribution curve of the whole coal and at the same time they express the yields of individual size fractions.

/COMMENTS ......

COMMENTS ON PERFORMANCE

A comparison of specific gravity and size distribution curves reveals the combined separating and classifying effects of the cyclone. Considering these curves theoretically, the "ideal" s.g. distribution curve should be vertical and the size distribution curve horizontal, but both of them show a considerable slope over the whole abscissa ranges.

The s.g. distribution curves differ considerably and, in the case of finer fractions, they do not cut the 25% or even 50% line. To enable a linear extrapolation, some effort was made to straighten them, using probability scale on ordinate and linear s.g., log (s.g.) and log (s.g.-1) on the abscissa, but without much success. Therefore, from the float and sink analysis only the following data can be obtained:

Size µm	% in deslimed feed	Yield %	C.P.	E.P.
All over 500	28,0	50,2	1,415	0,088*
All over 250	67,9	58,6	1,48	0,20
All over 150	86,4	62,1	1,54	0,25
All over 75	100,0	65,0	1,575	0,31*

* extrapolated

As can be seen from Table 5, the distribution factors of two coarser fractions show a certain anomaly at minus 1,3 specific gravity, i.e. lighter fractions are separated with lower yields than the heavier. This is illustrated by reversed size distribution curves in Figure 3. Such a

/phenomenon ......

phenomenon would require a more detailed study and probably could be explained by a shape effect of the particles. By visual examination of coarser fractions, numerous lamella-shaped particles were observed. Thus it appears that the cyclone not only separates and classifies the coal, but also, to some extent, sorts it according to the particle shape.

CONCLUSION

This work has proved that the compound water cyclone is able to produce low-ash coal from Van Dyks Drift fines in a single-stage operation. A maximum yield, calculated on the basis of deslimed (+75 micron) material, of about 65% is to be expected. Such a yield of 7% ash coal corresponds to an organic efficiency of about 80%.

To achieve this, a narrow vortex finder (67 mm), narrow apex orifice (30 mm), and wide vortex finder clearance (90 mm), must be employed. The capacity of the cyclone under these conditions is between 2,0 and 2,5 tons of dry feed per hour and can be somewhat increased by using a more concentrated feed.

The classifying effect has a deteriorating influence on its overall separating efficiency. Due to this effect, the cut point of individual size fractions are spread over a wide range of specific gravity, as shown below:

/8 ......

Size µm	Yield %	C.P.
Over 500	50,2	1,415
500 x 250	64,5	1,59
250 x 150	74,9	over 2,0
150 x 75	83,7	over 2,0
below 75	93,0	not analysed
Total over 75	65,0	1,575

It is practically impossible to adjust the cyclone operating variables to match all size fractions of a given coal. One end of the size range always suffers in order to accommodate the other. There are two ways in which to solve, or at least alleviate, this problem and improve the overall performance of this kind of separator:

(a) To use a classified feed.
(b) To employ two-stage operation, preferably with recirculation of middlings, one cyclone being set to low and another to high cut point.

As classifying operations on the feed would increase the overall cost of cleaning, two-stage operation seems to be a possible answer to the problem. Nevertheless, easy to clean coals such as Van Dyks Drift can be successfully treated by the 200 mm compound water cyclone without the above-mentioned arrangements.

(SIGNED) A. Saler

SENIOR RESEARCH OFFICER

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12/3/1973.
AS/KW

TABLE 1

WASHABILITY DATA OF VAN DYKS DRIFT FILTER CAKE

Specific Gravity	Fractional		Cumulative floats		Cumulative sinks		Charac-teristic
	Yield %	Ash %	Yield %	Ash %	Yield %	Ash %	
F1,3	6,21	2,4	6,21	2,40	93,79	14,81	3,10
1,3 - 1,4	40,44	4,8	46,65	4,48	53,35	22,41	26,43
1,4 - 1,5	29,97	9,8	76,62	6,56	23,38	38,56	61,63
1,5 - 1,6	7,56	17,0	84,18	7,50	15,82	48,87	80,40
1,6 - 1,7	4,86	22,6	89,04	8,32	10,94	60,63	86,61
1,7 - 1,8	1,27	33,2	90,31	8,67	9,69	64,10	89,67
S1,8	9,69	64,1	-	-	-	-	95,15
Whole coal	100,00	-	100,00	14,04	-	-	-

TABLE 2

SCREEN ANALYSIS OF VAN DYKS DRIFT FILTER CAKE

Size Fraction	% Yield	% Ash
Over 1000 μm	1,2	11,0
1000 x 500 "	19,9	11,7
500 x 250 "	31,4	13,0
250 x 150 "	18,3	14,6
150 x 75 "	12,6	15,4
75 x 0 "	16,6	21,9

/TABLE 3 ......

TABLE 4

SCREEN ANALYSIS OF WASHERY PRODUCTS FROM TEST 25

Size fraction µm	Clean Coal (68,5%)		Discard (31,5%)		Raw Coal (Reconstituted)	
	% Yield	% Ash	% Yield	% Ash	% Yield	% Ash
+1000	0,74	) 6,2	3,56	) 17,9	1,63	) 12,0
1000 x 500	17,23	)	35,20	)	22,89	)
500 x 250	32,94	7,1	39,43	23,6	34,98	13,0
250 x 150	17,74	8,0	12,92	34,8	16,22	14,8
150 x 75	14,50	8,7	6,15	48,4	11,87	15,2
-75	16,85	20,5	2,74	49,4	12,41	22,5
Total	100,00	9,6	100,00	25,1	100,00	14,5

/TABLE 5 ......

TABLE 5

FLOAT AND SINK DATA ON +75 MICRON WASHERY PRODUCTS FROM TEST NO. 25

CLEAN COAL (65,02%)

Specific Gravity	+500 µm		500x250 µm		250x150 µm		150x75 µm		All Sizes	
	% Yield	% Ash	% Yield	% Ash	% Yield	% Ash	% Yield	% Ash	% Yield	% Ash
F1,3	0,67	1,8	2,12	1,7	1,15	2,0	0,89	2,1	4,83	1,9
1,3-1,4	15,03	4,5	22,79	4,2	11,29	4,0	8,97	3,8	58,08	4,2
1,4-1,5	5,19	9,1	10,95	8,7	6,19	8,7	5,00	8,0	27,33	8,6
1,5-1,6	0,51	18,7	2,36	18,0	1,45	17,7	1,17	15,9	5,49	17,5
1,6-1,8	0,15	29,8	1,02	28,1	0,69	28,4	0,42	22,5	2,28	27,3
1,8-2,0	0,02	40,1	0,17	38,3	0,22	35,2	0,23	34,0	0,64	35,7
S2,0	0,04	56,2	0,21	49,1	0,34	50,9	0,76	52,7	1,35	51,8
Total	21,61	6,2	39,62	7,1	21,33	8,0	17,44	8,7	100,00	7,4

DISCARD (34,98%)

Specific Gravity	+500 µm		500x250 µm		250x150 µm		150x75 µm		All Sizes	
	% Yield	% Ash	% Yield	% Ash	% Yield	% Ash	% Yield	% Ash	% Yield	% Ash
F1,3	0,82	2,3	1,48	2,0	0,29	2,6	0,06	2,5	2,65	2,2
1,3-1,4	12,07	4,9	12,78	5,7	2,91	5,2	0,80	4,8	28,56	5,3
1,4-1,5	15,14	10,3	10,57	9,5	2,82	10,2	1,13	9,6	29,66	10,0
1,5-1,6	4,06	20,0	3,27	19,2	0,95	19,2	0,45	19,5	8,73	19,6
1,6-1,8	2,34	31,3	3,00	31,5	0,89	30,9	0,28	29,2	6,51	31,2
1,8-2,0	1,15	45,3	1,03	48,1	0,38	47,7	0,22	44,5	2,78	46,6
S2,0	4,27	67,9	8,41	68,2	5,05	70,1	3,38	78,2	21,11	70,2
Total	39,85	17,9	40,54	23,6	13,29	34,8	6,32	48,4	100,00	24,4

/TABLE 5 (Contd.) .....

TABLE 5 (Contd.)

RECONSTITUTED FEED

Specific Gravity	+500 µm		500x250 µm		250x150 µm		150x75 µm		All Sizes	
	% Yield	% Ash	% Yield	% Ash	% Yield	% Ash	% Yield	% Ash	% Yield	% Ash
F1,3	0,72	2,0	1,89	1,8	0,85	2,1	0,60	2,1	4,06	1,9
1,3-1,4	14,00	4,6	19,29	4,5	8,36	4,2	6,11	3,9	47,76	4,4
1,4-1,5	8,67	9,8	10,82	9,0	5,01	9,0	3,65	8,2	28,15	9,1
1,5-1,6	1,75	19,8	2,68	18,5	1,27	18,1	0,92	16,5	6,62	18,5
1,6-1,8	0,91	31,1	1,71	30,2	0,76	29,4	0,37	24,3	3,75	29,7
1,8-2,0	0,42	45,1	0,47	45,8	0,28	41,2	0,23	37,6	1,40	43,4
S2,0	1,52	67,7	3,08	67,4	1,99	68,0	1,67	70,7	8,26	68,3
Total	27,99	12,0	39,94	13,0	18,52	14,8	13,55	15,2	100,00	13,3

DISTRIBUTION FACTORS

Specific Gravity	+500 µm	500x250 µm	250x150 µm	150x75 µm	All Sizes	+150 µm	+250 µm
F1,3	60,3	72,7	88,1	96,5	77,2	73,9	69,3
1,3-1,4	69,8	76,8	87,8	95,4	79,1	76,7	73,9
1,4-1,5	38,9	65,8	80,3	89,2	63,1	59,3	53,9
1,5-1,6	18,9	57,3	74,0	82,9	53,9	49,2	42,1
1,6-1,8	10,5	38,7	59,1	73,6	39,4	35,7	28,9
1,8-2,0	3,1	23,6	51,8	66,1	30,0	22,9	14,0
S2,0	1,7	4,4	11,1	29,5	10,6	5,8	3,5
Total	50,2	64,5	74,9	83,7	65,0	62,1	58,6

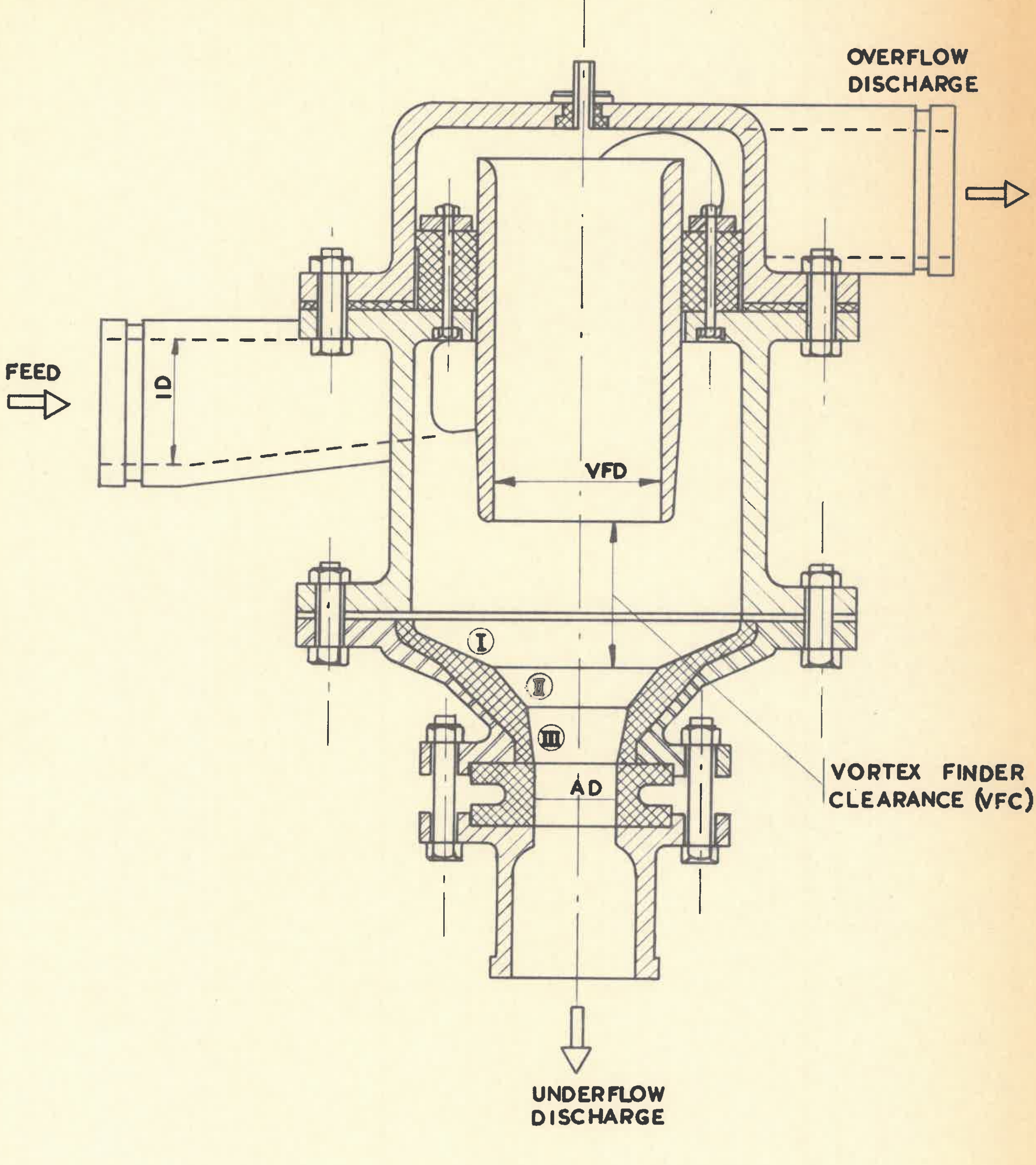

DIAGRAM I CROSS-SECTION C.W.C.-8

DIAGRAM 2

SCHEME OF THE CYCLONE AND TEST RIG.

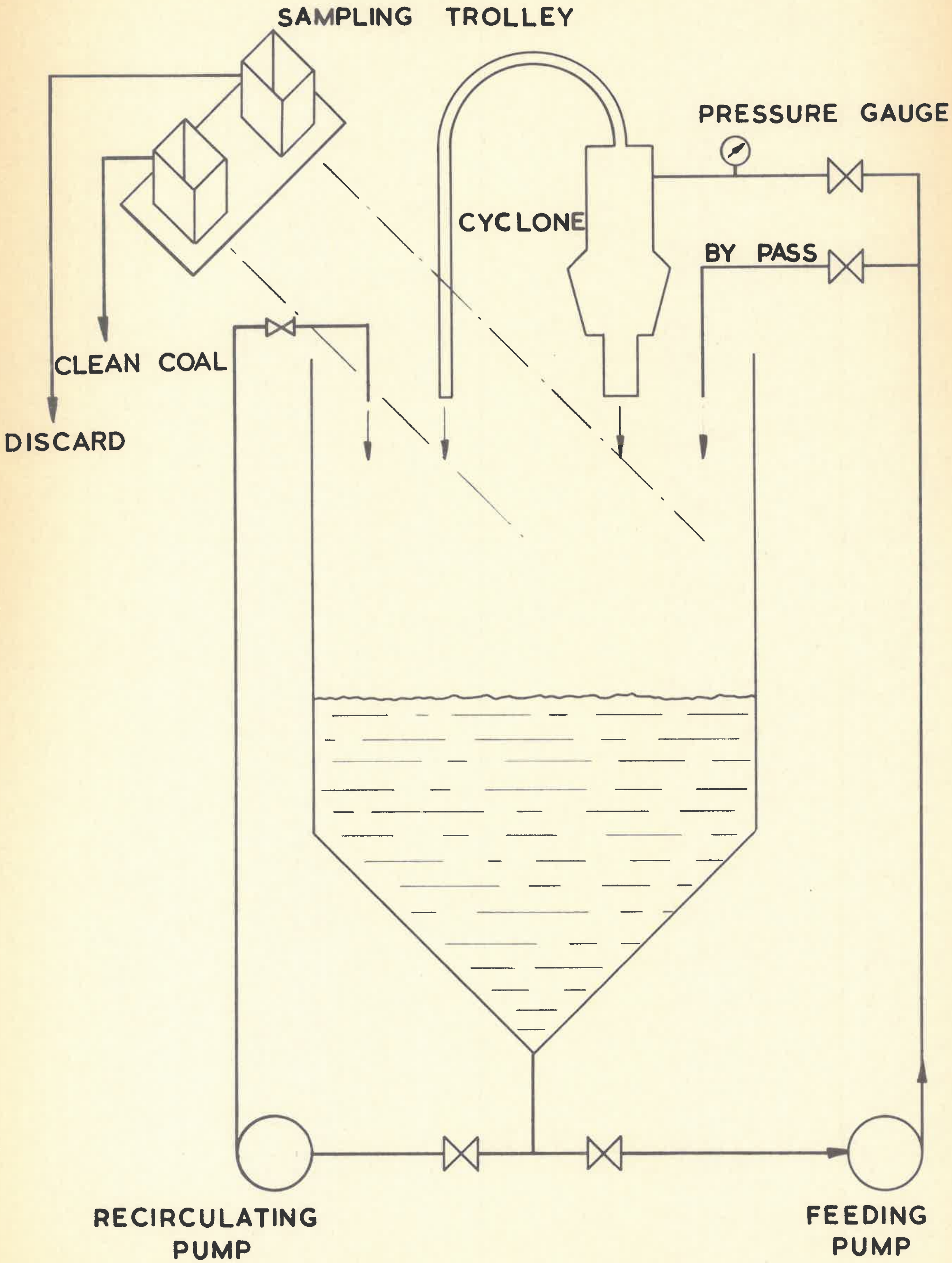

FIG. 1

WASHABILITY CHARACTERISTICS OF THE VAN DYKS DRIFT FINES.

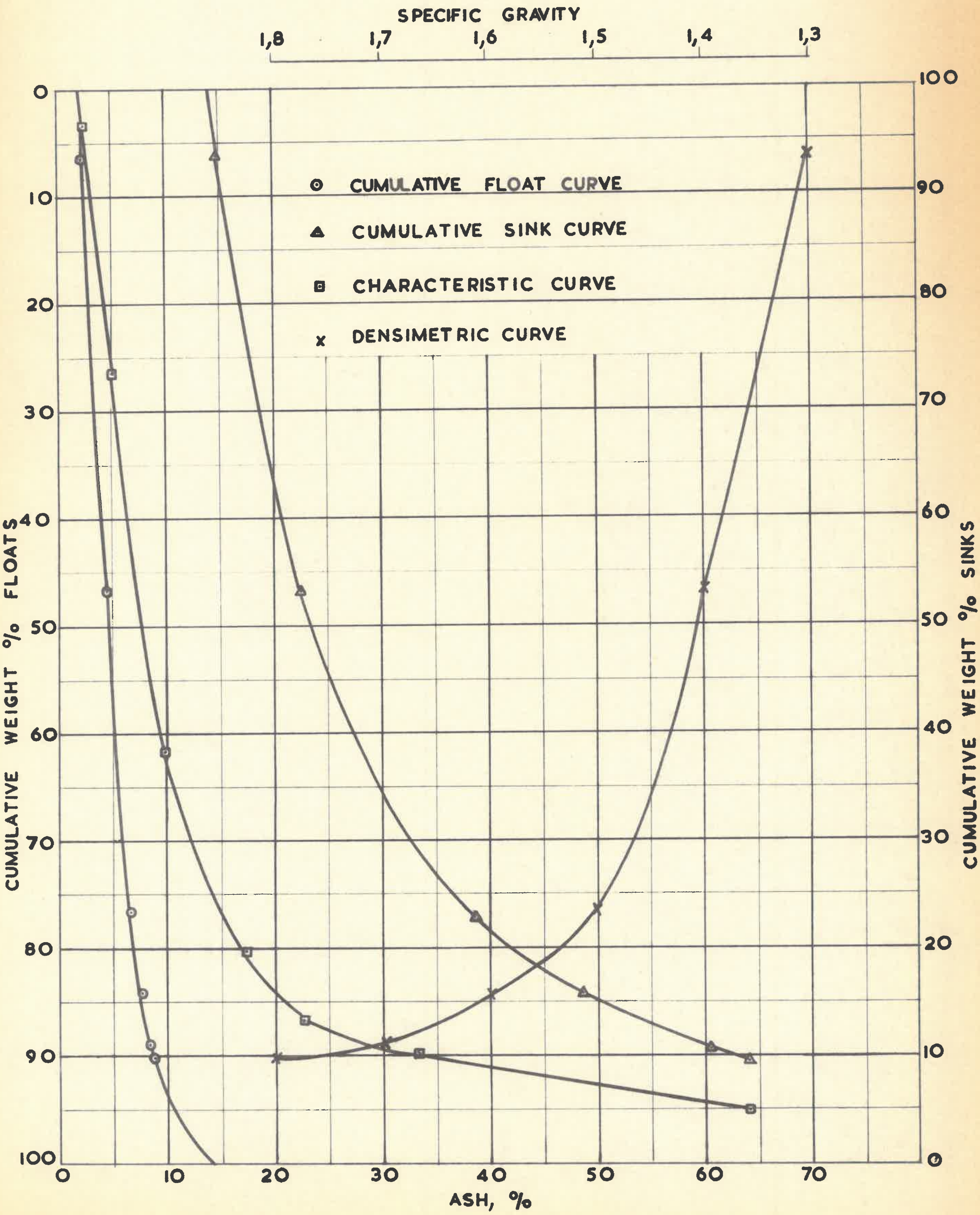

FIG. 2

S.G. DISTRIBUTION CURVES
TEST Nº 25.

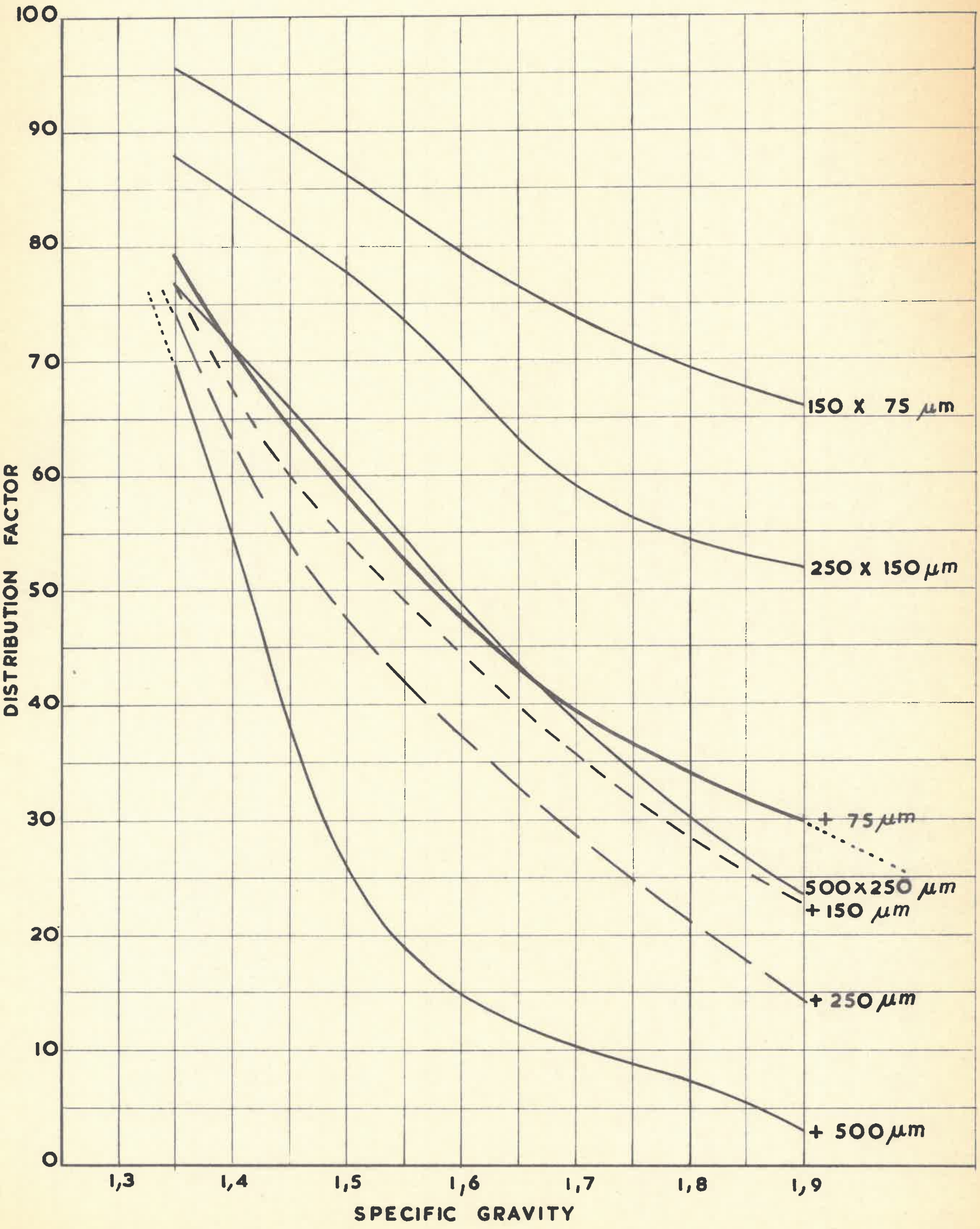

FIG. 3

SIZE DISTRIBUTION CURVES
TEST Nº 25

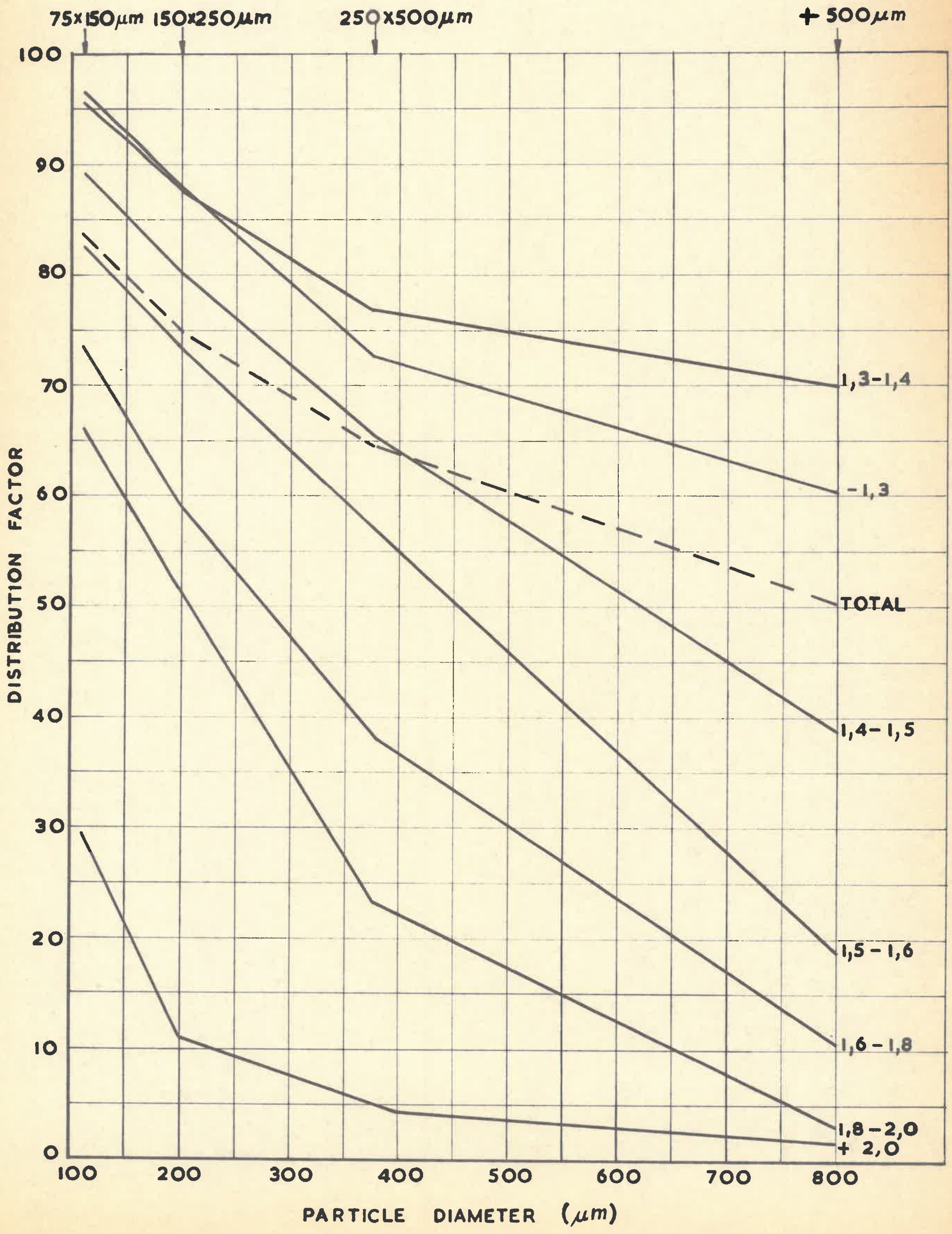

TABLE 3

RESULTS OF THE FACTORIAL TEST

Test No.	Cyclone Settings: VFD mm	VFC mm	AD mm	IP kg/cm^2	Solids in Feed* %	Solids In: Clean Coal %	Discard %	Flow Rate: Pulp t/h	Dry Coal t/h	Yield %	% Ash: Raw Coal*	Clean Coal	Discard	Clean Coal +75 µm: % Yield	% Ash	Clean Coal -75 µm: % Yield*	% Ash*
1	100	130	50	0,56	10,2	8,7	58,7	31,2	3,2	85,9	13,8	10,9	31,2	68,5	8,6	17,4	20,0
2	100	130	50	0,70	9,9	8,8	63,5	35,2	3,5	89,4	13,6	11,3	32,8	71,2	8,8	18,2	20,9
3	100	130	50	0,42	10,6	9,0	62,3	30,3	3,2	84,1	13,5	10,4	29,9	67,2	8,0	16,9	19,8
4	100	130	50	0,42	10,2	8,6	61,9	30,0	3,1	83,1	14,0	10,5	31,2	65,6	8,4	17,5	18,5
5	67	90	50	0,56	10,5	4,9	49,6	20,9	2,2	41,0	14,3	9,8	17,4	29,0	7,3	12,0	15,8
6	67	90	50	0,70	11,1	5,2	50,4	23,1	2,6	41,2	14,4	9,5	17,8	29,1	6,8	12,1	16,0
7	67	50	50	0,56	12,0	5,9	52,6	21,6	2,6	42,8	14,3	9,1	18,2	31,8	6,9	11,0	15,5
8	67	50	50	0,70	12,7	6,2	54,3	23,6	3,0	42,5	14,5	9,6	18,1	29,9	6,9	12,6	16,1
9	67	10	50	0,56	11,8	6,1	50,6	22,1	2,6	44,8	14,9	10,1	18,8	30,9	7,2	13,9	16,6
10	67	10	50	0,70	12,7	7,7	48,9	24,2	3,1	48,3	13,9	9,6	17,9	34,9	6,8	13,4	17,0
11	67	90	40	0,56	10,3	5,2	55,6	20,5	2,1	45,8	13,8	9,9	17,1	32,3	7,0	13,5	16,8
12	67	90	40	0,70	10,0	5,2	56,1	22,8	2,3	47,0	14,1	9,6	18,0	33,0	6,7	14,0	16,5
13	67	50	40	0,56	11,0	5,6	53,5	20,2	2,2	45,1	14,0	10,0	17,3	30,4	6,6	14,7	17,0
14	67	50	40	0,70	10,5	5,2	54,2	22,8	2,4	44,4	14,2	9,8	17,8	31,2	7,1	13,2	16,2
15	67	10	40	0,56	13,1	6,8	59,5	20,7	2,7	45,9	15,3	9,6	20,2	33,0	7,4	12,9	15,5
16	67	10	40	0,70	12,0	6,8	52,8	23,8	2,9	50,1	14,0	9,0	19,0	36,1	6,4	14,0	15,7
17	67	90	30	0,56	11,1	7,8	58,3	21,6	2,4	65,5	15,1	9,8	25,1	50,9	7,2	14,6	18,9
18	67	90	30	0,70	10,9	8,2	53,9	24,1	2,6	70,5	13,8	9,7	23,5	55,0	7,0	15,5	19,3
19	67	50	30	0,56	10,3	7,8	55,0	20,6	2,1	68,9	13,6	9,7	22,2	52,9	7,4	16,0	17,3
20	67	50	30	0,70	10,7	7,8	59,1	23,6	2,5	68,2	14,4	9,8	24,2	51,1	7,1	17,1	18,0
21	67	10	30	0,56	10,5	8,2	51,2	21,0	2,2	74,7	14,1	10,2	25,5	56,8	7,4	17,9	19,1
22	67	10	30	0,70	10,1	7,9	53,1	22,9	2,3	74,5	14,4	10,6	25,3	56,0	7,7	18,5	19,4
23	67	90	30	0,56	11,1	8,0	54,4	21,1	2,3	67,2	14,0	9,5	23,3	51,5	6,8	15,7	18,3
24	67	90	30	0,70	11,4	8,7	56,1	23,8	2,7	71,9	13,8	9,6	24,6	55,8	7,1	16,1	18,3
25	67	90	30	0,56	10,5	8,1	53,7	20,9	2,2	68,5	14,5	9,5	25,3	55,2	7,0	13,3	19,9

Remarks: VFD - Vortex diameter
VFC - Vortex finder clearance
AD - Apex diameter
IP - Inlet pressure

* Calculated from the balance of products

All % yields based on total raw coal

/TABLE 4 ......