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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

TECHNICAL MEMORANDUM NO. 5/1958.

EFFECTS OF CONTROLLED CRUSHING AND SCREENING ON THE ANALYSIS AND PETROGRAPHIC COMPOSITION OF BLESBOK COAL.

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ABSTRACT:

By applying the Bürstlein principle of controlled crushing and screening to coal from Blesbok Colliery it is possible to obtain a product of lower ash and higher swelling number but it is probably preferable to effect these improvements in the washer if they are desired.

Non-coking constituents tend to be constant in all size fractions obtained, hence the impracticability of eliminating them, or, in other words, of concentrating the coking and semi-coking constituents. It does not follow that coke improvement cannot be achieved by methods of selective crushing and screening.

The investigation should be extended to coal from the Durban Navigation Collieries.

Introduction.

Judged by overseas' standards, South African coking coals presently used, and the cokes they yield, can certainly not be regarded as first class products. Commercially, the position in this country is that coke producers are largely limited in the coals available to them. There is thus

relatively little/.........2.

relatively little possibility of effecting improvements in coke quality by widening the scope of blending with other coals, so that efforts to improve coke must be directed largely towards improvement of the coals or blends as used at present.

A possible avenue for improving coke quality is the application of the so-called Bürstlein process of petrographic preparation[x] to the coking blend or its components. The fundamental principle of this process is that overcrushing of the bright, more friable, fusible constituents must be avoided, while the duller, relatively inert constituents - which, incidentally, are also more resistant to pulverisation - should be crushed to a reasonably fine size before being remixed with the brighter fraction prior to charging to the coke oven. This, therefore, constitutes a reversal of the natural course of events in an ordinary crushing process where the softer constituents in the material are, on the average, crushed finer than the harder constituents.

To achieve this aim it is necessary to crush the coal in stages and to screen out the fines produced (in which the bright coal is concentrated) after every crushing stage. Once the desired degree of separation has been achieved the coarser inert concentrate can be crushed to any desired degree of fineness in a single stage before remixing with the concentrate of bright constituents which may not require any further crushing.

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[x] Anon. The Petrographic Preparation of Coals for Coking. Coke & Gas, Vol.18, July, 1956, p.246; Aug. 1956, p.288.

Samples obtained and their Treatment.

From a preliminary investigation of the enrichment of the fusible constituents of a few selected South African coking coals by a procedure of selective crushing and screening* it was concluded that a certain degree of concentration of petrographic constituents in these coals by this procedure was possible and the desirability of pursuing the investigations became apparent. It was consequently decided that the study should be extended in the first instance to some of the blend coking coals, and Blesbok Colliery (No. 5 Seam) was selected for the first study.

A certain amount of obvious shale and other dirt is loaded into separate tubs underground at Blesbok Colliery and sent direct to the dump. The rest of the run-of-mine coal passes via a conveyor belt to a 1½" screen (round holes) in the preparation plant. Some handsorting is done on + 1½" material before this is crushed in the flex-tooth crusher to -1½" prior to being remixed with the naturally arisen -1½" size fraction before passing into the washer.

Two bulk samples of Blesbok coal - both unwashed and representing a day's production - were obtained simultaneously in August 1957 for the proposed investigation. The one sample (No.57/541 B) represented the recombined -1½" products

described above/.......4.

* Fuel Research Institute Technical Memorandum No. 14/1957.

described above. It weighed 1,140 lb. The other sample (No. 57/541 C^1) represented the uncrushed and unscreened run-of-mine coal. (The procedure which had to be followed with the collection of this sample was not entirely satisfactory. The ideal method would have been to stop the conveyor belt regularly and to clear a certain length of the belt to yield an increment. Such a procedure could, however, not be followed as frequent stoppages of the belt would have interfered unduly with production. Increments therefore had to be taken in the only other way possible viz. from the moving belt, relying on judgement to have the various sizes included in their proper ratio. It is nevertheless considered that the sample obtained represented the run-of-mine coal reasonably well).

Sample C^1 weighed nearly 7 tons and it was therefore taken to the Institute's coal preparation pilot plant for preliminary treatment. The raw coal track hopper at this plant has a grid with 6" x 6" openings. All lumps larger than this size were broken by hand to pass through the openings together with the material already smaller than 6". This yielded sample C.

Sample C was screened into 6" x 3" and -3" size fractions at the grizzly bars of the pilot plant. The yields of these two products were 54.3% (Sample D^1) and 45.7% (Sample E), respectively.

Sample D^1 was crushed to -1½" to yield sample D in the single roll Jeffrey crusher at the pilot plant. (It had been the intention to crush the coal to a top size of about 3" but due to an error in the adjustment of the crusher 97% of the sample was below 1½" - round holes - in size after passing through the crusher)/..5.

through the crusher).

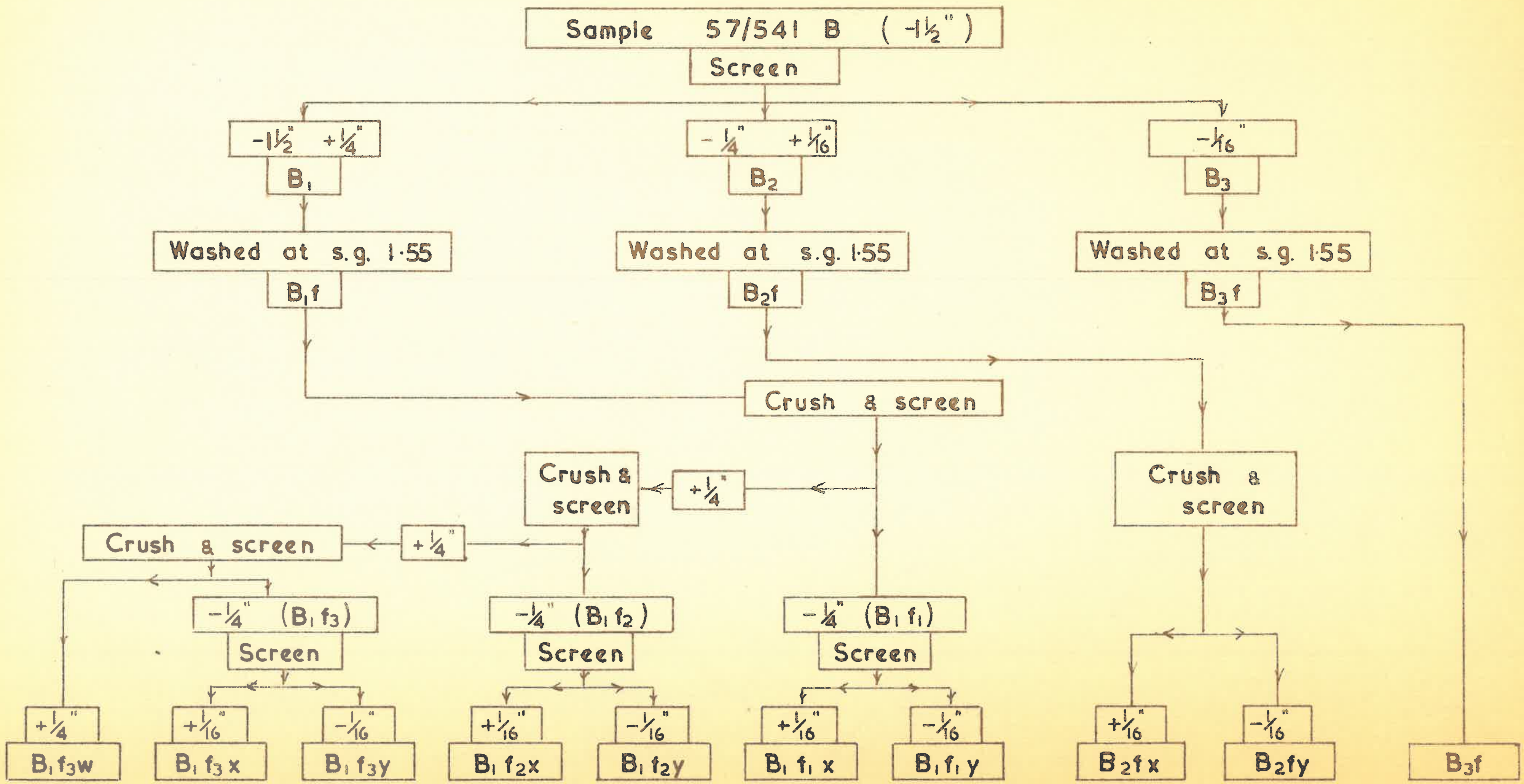
The subsequent treatment of samples B, D and E (or rather representative portions of them) is shown schematically in Diagrams 1,2,3 and 4, which also indicate the numbering adopted in order to identify sub-samples obtained in the investigation. The screens used had round holes except the 1/16" screen which was of woven wire construction.

As a petrographic disintegrator was not available the crushing operations indicated in Diagrams 1 - 4 were carried out in a Jeffrey Junior (8" x 15") Swing Hammer Pulveriser with the screen bars removed in order to limit the amount of size reduction obtained with each pass of a sample through the pulveriser. A further control on the severity of crushing was possible by altering the speed of the engine driving the pulveriser. Generally, pulveriser rotor speeds varying between 1000 and 2000 r.p.m. were used, depending on the extent of crushing desired.

The bulk samples obtained consisted of unwashed coal, but in order to eliminate as far as possible disturbing effects of impurities on the results obtained it was decided to wash samples resulting from preliminary screening at a specific gravity of 1.55 as indicated in the diagrams.

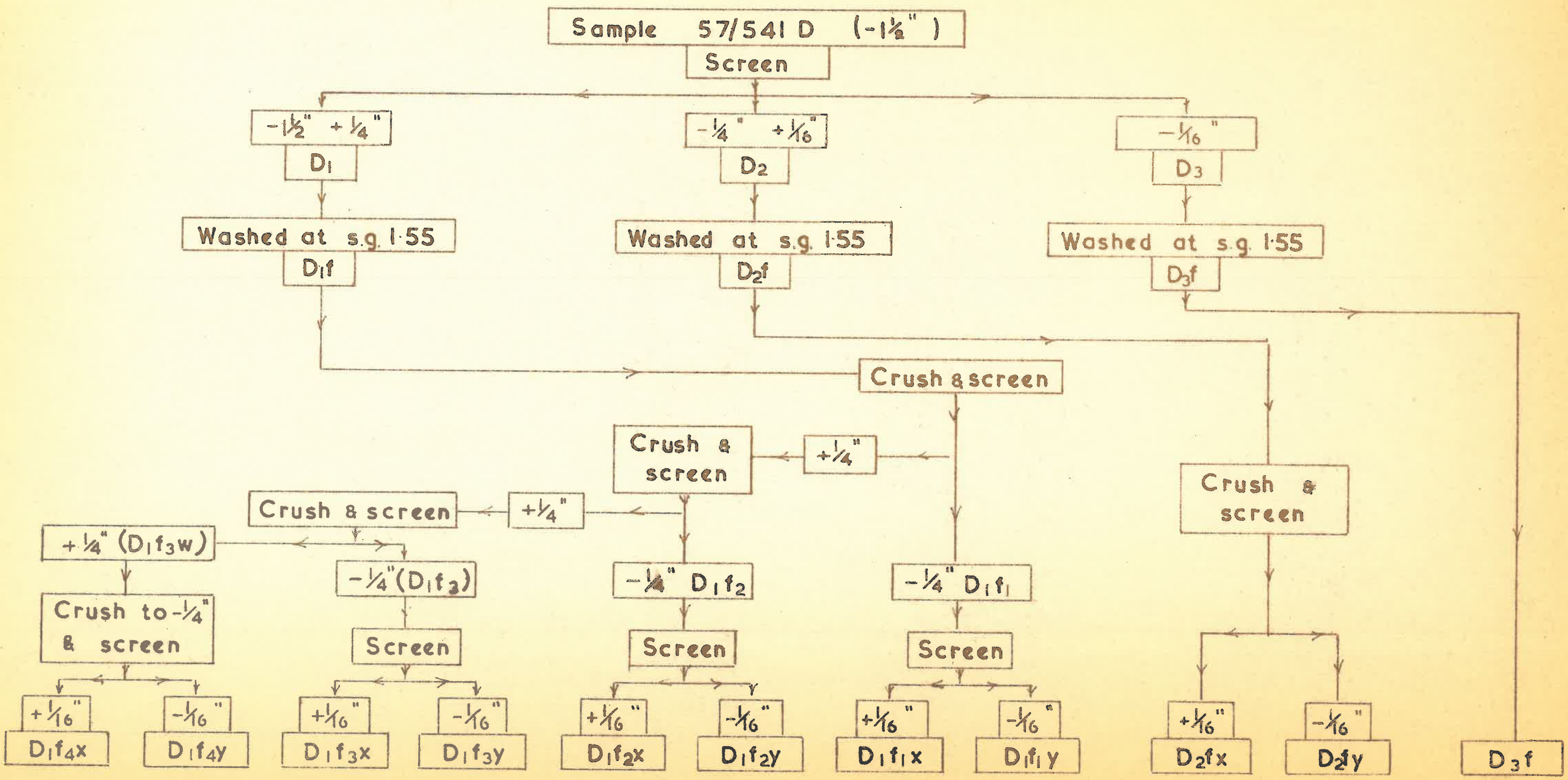
Generally speaking, the crushing and screening operations were designed to isolate in stages the more friable constituents of the coal. To achieve this any material passing a ¼" screen each time after an unavoidable or deliberate disintegration had been effected was removed from the oversize and rescreened using a 1/16" screen in order to compare the characteristics of the two smaller size fractions thus obtained. By doing this it was also possible to obtain

DIAGRAM I.



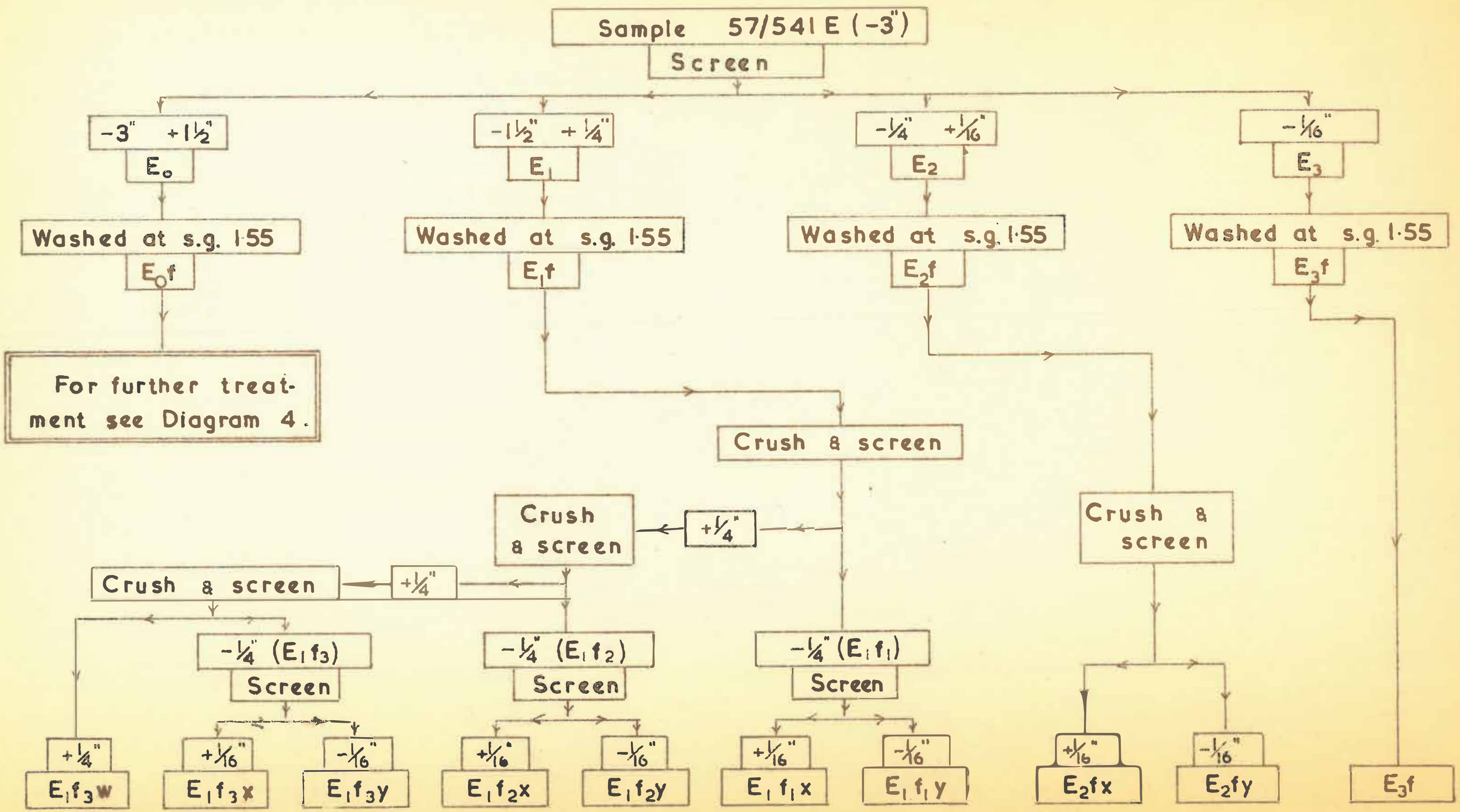
Sample 57/541 B (-1½")
Screen
-1½" +¼"
B₁
- ¼" +1/16"
B₂
-1/16"
B₃
Washed at s.g. 1·55
B₁f
Washed at s.g. 1·55
B₂f
Washed at s.g. 1·55
B₃f
Crush & screen
Crush & screen
+¼"
Crush & screen
+¼"
Crush & screen
-¼" (B₁f₃)
Screen
-¼" (B₁f₂)
Screen
-¼" (B₁f₁)
Screen
+¼"
B₁f₃w
+1/16"
B₁f₃x
-1/16"
B₁f₃y
+1/16"
B₁f₂x
-1/16"
B₁f₂y
+1/16"
B₁f₁x
-1/16"
B₁f₁y
+1/16"
B₂fx
-1/16"
B₂fy
B₃f

DIAGRAM 2



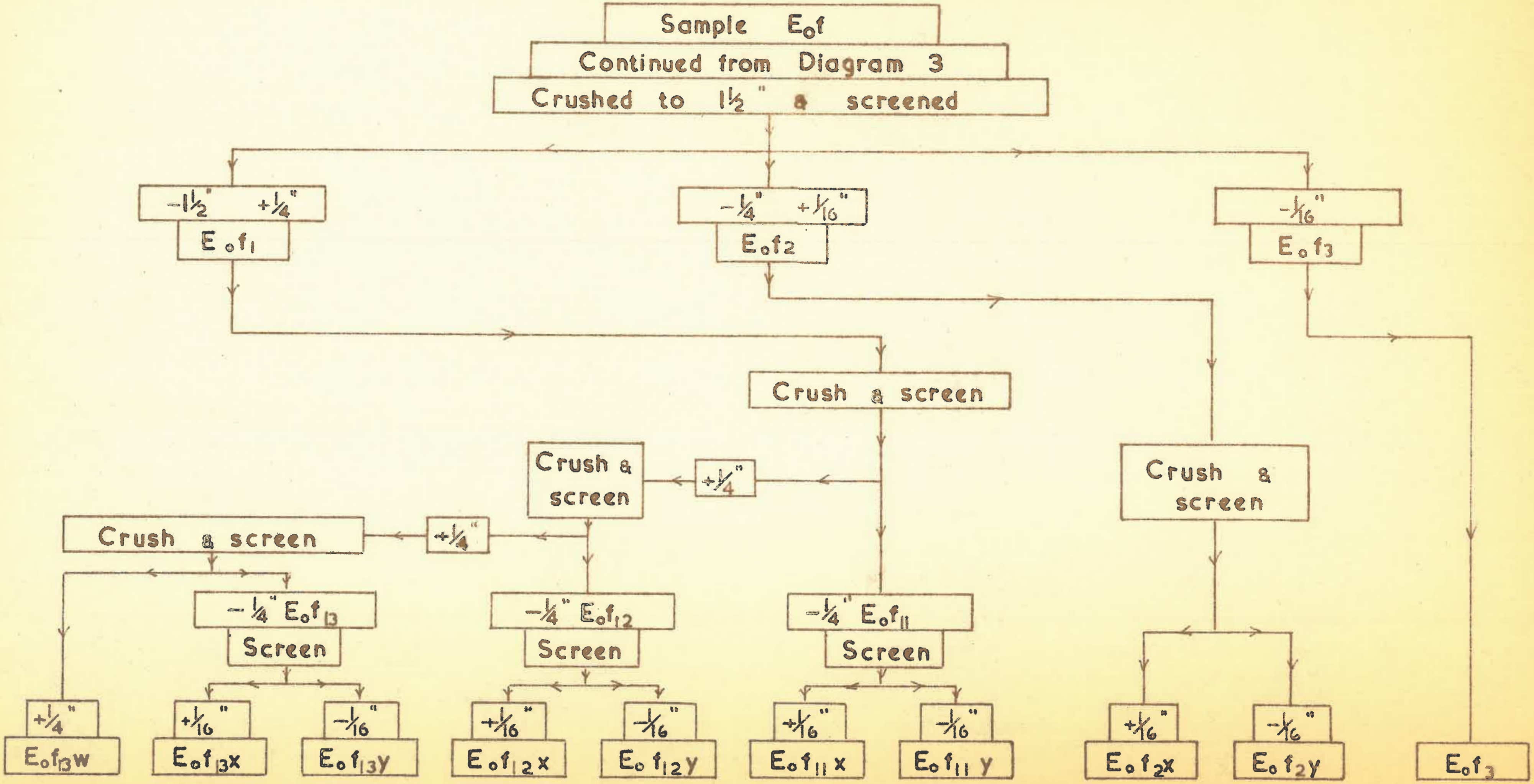
Sample 57/541 D (-1½")
Screen
-1½" +¼"
D1
-¼" +1/16"
D2
-1/16"
D3
Washed at s.g. 1·55
D1f
Washed at s.g. 1·55
D2f
Washed at s.g. 1·55
D3f
Crush & screen
+¼"
Crush & screen
Crush & screen
+¼"
Crush & screen
+¼" (D1f3w)
-¼" (D1f3)
-¼" D1f2
-¼" D1f1
Crush to -¼" & screen
Screen
Screen
Screen
+1/16"
D1f4x
-1/16"
D1f4y
+1/16"
D1f3x
-1/16"
D1f3y
+1/16"
D1f2x
-1/16"
D1f2y
+1/16"
D1f1x
-1/16"
D1f1y
+1/16"
D2fx
-1/16"
D2fy
D3f

DIAGRAM 3



Sample 57/541 E (-3")
Screen
-3" +1½"
E₀
Washed at s.g. 1·55
E₀f
For further treatment see Diagram 4.
-1½" +¼"
E₁
Washed at s.g. 1·55
E₁f
-¼" +1/16"
E₂
Washed at s.g. 1·55
E₂f
-1/16"
E₃
Washed at s.g. 1·55
E₃f
Crush & screen
+¼"
Crush & screen
+¼"
Crush & screen
-¼" (E₁f₃)
Screen
-¼" (E₁f₂)
Screen
-¼" (E₁f₁)
Screen
Crush & screen
+¼"
E₁f₃w
+1/16"
E₁f₃x
-1/16"
E₁f₃y
+1/16"
E₁f₂x
-1/16"
E₁f₂y
+1/16"
E₁f₁x
-1/16"
E₁f₁y
+1/16"
E₂fx
-1/16"
E₂fy
E₃f

DIAGRAM 4.


Sample E_0f
Continued from Diagram 3
Crushed to 1½" & screened
−1½" +¼"
E_0f_1
−¼" +1/16"
E_0f_2
−1/16"
E_0f_3
Crush & screen
Crush & screen
+¼"
Crush & screen
Crush & screen
+¼"
−¼" E_0f_{13}
Screen
−¼" E_0f_{12}
Screen
−¼" E_0f_{11}
Screen
+¼"
$E_0f_{13}w$
+1/16"
$E_0f_{13}x$
−1/16"
$E_0f_{13}y$
+1/16"
$E_0f_{12}x$
−1/16"
$E_0f_{12}y$
+1/16"
$E_0f_{11}x$
−1/16"
$E_0f_{11}y$
+1/16"
E_0f_2x
−1/16"
E_0f_2y
E_0f_3

some indication of the desirability of continuing or stopping the procedure after a certain stage had been reached.

The percentage yields of products obtained by washing, crushing and screening are shown in Tables 1,2 and 3.

Analyses of Products.

Analytical details of the samples obtained in the investigation appear in Tables 4, 5 and 6.

A comparison of sample B with sample C is possible by considering the calculated data for combined sizes shown in the last two lines of Table 4. These results were as follows:-

Sample	Floats at s.g. 1.55.			
	Yield %	Ash %	Volatiles %	Sw. No.
B	89.5	9.1	33.2	3
C	91.1	10.0	32.9	2½ - 3

The appreciable difference in ash contents of the two washed products is probably explained by the fact that Sample C was in an appreciably coarser state when washed than Sample B so that release of dirt from coal was more complete in the case of Sample B. It is not considered that the difference is connected to any appreciable extent with the hand sorting carried out in the case of Sample B on the larger lumps before crushing at the Colliery.

Considering/...............7.

TABLE 1.

Yields of Products resulting from Screening, Washing, or Crushing and Screening, Sample 57/541 B.

Sample No.	Yield %	Calculated on	Sample No.	Yield %	Calculated on	Sample No.	Yield %	Calculated on
B1	63.0	B	B2	18.9	B	B3	18.1	B
B1f	88.5 55.8	B1 B	B2f	90.7 17.2	B2 B	B3f	91.0 16.5	B3 B
B2fx	46.5 42.2 8.0	B2f B2 B	B2fy	53.5 48.5 9.2	B2f B2 B			
B1f3	15.6 13.8 8.7	B1f B1 B	B1f2	26.5 23.5 14.8	B1f B1 B	B1f1	35.8 31.7 20.0	B1f B1 B
B1f3x	71.7 11.2 9.9 6.2	B1f3 B1f B1 B	B1f2x	69.4 18.4 16.3 10.3	B1f2 B1f B1 B	B1f1x	64.1 22.9 20.3 12.8	B1f1 B1f B1 B
B1f3y	28.3 4.4 3.9 2.5	B1f3 B1f B1 B	B1f2y	30.6 8.1 7.2 4.5	B1f2 B1f B1 B	B1f1y	35.9 12.9 11.4 7.2	B1f1 B1f B1 B
B1f3w	22.1 19.6 12.3	B1f B1 B	B1f 123x) + B1f3w)	74.6 66.1 41.6	B1f B1 B	B1f 123y)	25.4 22.5 14.2	B1f B1 B

............../8.

TABLE 2.

Yields of Products resulting from Screening, Washing, or Crushing and Screening, Sample 57/541 D.

Sample No.	Yield %	Calculated on	Sample No	Yield %	Calculated on	Sample No	Yield %	Calculated on.
D1	84.7	D	D2	9.6	D	D3	5.7	D
D1f	93.6 79.3	D1 D	D2f	93.5 9.0	D2 D	D3f	85.5 4.9	D3 D
D1f1	37.1 34.7 29.4	D1f D1 D	D2fx	47.9 44.8 4.3	D2f D2 D	D2fy	52.1 48.7 4.7	D2f D2 D
D1f1x	65.4 24.3 22.7 19.2	D1f1 D1f D1 D	D1f1y	34.6 12.8 11.9 10.1	D1f1 D1f D1 D			
D1f3w	23.6 22.1 18.7	D1f D1 D	D1f3	14.1 13.2 11.2	D1f D1 D	D1f2	25.2 23.6 20.0	D1f D1 D
D1f4x	48.9 11.5 10.8 9.1	D1f3w D1f D1 D	D1f3x	68.8 9.7 9.1 7.7	D1f3 D1f D1 D	D1f2x	67.7 17.1 16.0 13.6	D1f2 D1f D1 D
D1f4y	51.1 12.1 11.3 9.6	D1f3w D1f D1 D	D1f3y	31.2 4.4 4.1 3.5	D1f3 D1f D1 D	D1f2y	32.3 8.1 7.6 6.4	D1f2 D1f D1 D
D1f1-4x	62.6 58.6 49.6	D1f D1 D	D1f1-4y	37.4 35.0 29.7	D1f D1 D			

................/9.

T A B L E 3.

Yields of Products resulting from Screening, Washing, or Crushing and Screening Sample 57/541 E.

Sample No.	Yield %	Calculated on	Sample No.	Yield %	Calculated on	Sample No	Yield %	Calculated on
E1	48.8	E	E2	10.2	E	E3	8.1	E
E1f	88.3 42.9	E1 E	E2f	89.1 9.1	E2 E	E3f	83.7 6.8	E3 E
E1f3	13.8 12.2 6.0	E1f E1 E	E1f2	25.4 22.4 10.9	E1f E1 E	E1f1	41.9 37.0 18.1	E1f E1 E
E1f3w	18.9 16.7 8.1	E1f E1 E	E2fx	39.5 35.2 3.6	E2f E2 E	E2fy	60.5 53.9 5.5	E2f E2 E
E1f3x	68.3 9.4 8.2 4.1	E1f3 E1f E1 E	E1f2x	68.0 17.3 15.3 7.5	E1f2 E1f E1 E	E1f1x	64.9 27.2 24.0 11.7	E1f1 E1f E1 E
E1f3y	31.7 4.4 3.9 1.9	E1f3 E1f E1 E	E1f2y	32.0 8.1 7.1 3.4	E1f2 E1f E1 E	E1f1y	35.1 14.7 13.0 6.3	E1f1 E1f E1 E
E1f123x) + E1F3) w)	72.8 64.2 31.4	E1f E1 E	E1f123y	27.2 24.0 11.6	E1f E1 E			

Eo : (contd. on next page)

T A B L E 3 (Continued)

Sample No.	Yield %	Calcul- ated on	Sample No	Yield %	Calcul- ated on	Sample No.	Yield %	Calcul- ated on.
Eo	32.9	E	Eof	90.9 29.9	Eo E			
Eof1	68.2 62.0 20.4	Eof Eo E	Eof2	16.8 15.3 5.0	Eof Eo E	Eof3	15.0 13.6 4.5	Eof Eo E
Eof13w	31.7 21.7 19.7 6.5	Eof1 Eof Eo E	Eof2x	55.0 9.2 8.4 2.8	Eof2 Eof Eo E	Eof2y	45.0 7.6 6.9 2.3	Eof2 Eof Eo E
Eof13	15.7 10.7 9.7 3.2	Eof1 Eof Eo E	Eof12	16.7 11.4 10.4 3.4	Eof1 Eof Eo E	Eof11	35.9 24.5 22.3 7.3	Eof1 Eof Eo E
Eof13x	69.2 10.9 7.4 6.7 2.2	Eof13 Eof1 Eof Eo E	Eof12x	68.4 11.4 7.8 7.1 2.3	Eof12 Eof1 Eof Eo E	Eof11x	62.6 22.5 15.3 13.9 4.6	Eof11 Eof1 Eof Eo E
Eof13y	30.8 4.8 3.3 3.0 1.0	Eof13 Eof1 Eof Eo E	Eof12y	31.6 5.3 3.6 3.3 1.1	Eof12 Eof1 Eof Eo E	Eof11y	37.4 13.4 9.1 8.3 2.7	Eof11 Eof1 Eof Eo E
Eof 1/123y) +Eof) 13w)	76.5 52.2 47.4 15.6	Eof1 Eof Eo E	Eof 1/123y	23.5 16.0 14.6 4.8				

................/11.

T A B L E 4.

Analytical Details Pertaining to Sample No. 57/541 B.

Size	+ 1/16"				- 1/16"					Combined Sizes (Calculated)				
Sample No.	% of B	Ash %	Vols.%	Sw.No.	Sample No.	% of B	Ash %	Vols %	Sw.No.	Sample no.	% of B	Ash %	Vols.%	Sw.No.
B3f	-	-	-	-	B3f	16.5	8.2	33.1	4	B3f	16.5	8.2	33.1	4
B2fx	8.0	9.1	32.9	3	B2fy	9.2	7.3	33.4	3½-4	B2f	17.2	8.1	33.2	3½
B1f1x B1f2x B1f3x B1f3w	12.8 10.3 6.2 12.3	8.7 9.7 10.5 11.8	33.8 33.6 33.4 32.4	3½ 2½-3 2 1½	B1f1y B1f2y B1f3y -	7.2 4.5 2.5 -	7.5 8.3 9.2 -	33.6 33.2 33.1 -	3½-4 3-3½ 3 -	B1f1 B1f2 B1f3xy B1f3w	20.0 14.8 8.7 12.3	8.3 9.3 10.1 11.8	33.7 33.5 33.3 32.4	3½-4 3 2-2½ 1½
Weighted Average: B1f	41.6	10.1	33.3	2½		14.2	8.1	33.4	3½	B1f	55.8	9.6	33.3	2½-3
Weighted Average: B123f	49.6	10.0	33.2	2½		39.9	7.9	33.3	3½-4	Bf	89.5	9.1	33.2	3
Weighted Average for Cf (i.e. Df + Ef)*	53.7	10.7	32.8	2-2½		37.5	9.0	33.1	3-3½	Cf	91.1	10.0	32.9	2½-3

* From Tables 5 and 6, for comparing sample B with sample C. Yields are expressed as percentages of (0.543 D + 0.457 E).

T A B L E 5.

Analytical Details pertaining to Sample No. 57/541 D.

Size.	+ 1/16"				- 1/16"					Combined Sizes (Calculated)				
Sample No.	% of D.	Ash %	Vols.%	Sw.No.	Sample No	% of D	Ash %	Vols.%	Sw.No.	Sample No	% of D	Ash %	Vols.%	Sw.No.
D3f	-	-	-	-	D3f	4.9	7.7	33.6	3-3½	D3f	4.9	7.7	33.6	3-3½
D2fx	4.3	9.9	32.8	2½-3	D2fy	4.7	8.0	33.6	3	D2f	9.0	8.9	33.2	3
D1f1x D1f2x D1f3x D1f4x	19.2 13.6 7.7 9.1	9.9 10.9 11.2 13.6	33.3 32.5 32.6 32.7	3 2 1½ 1	D1f1y D1f2y D1f3y D1f4y	10.1 6.4 3.5 9.6	8.6 9.6 10.3 11.8	33.1 32.8 32.8 32.4	3 2½ 2 2	D1f1 D1f2 D1f3* D1f4	29.3 20.0 11.2 18.7	9.5 10.5 10.9 12.7	33.2 32.6 32.7 32.5	3 2-2½ 1½ 1½
Weighted) Average:) D1f)	49.6	11.1	32.9	2		29.6	10.1	32.8	2½		79.2	10.7	32.8	2-2½
Weighted) Average:) D 123 f**)	53.9	11.0	32.8	2		39.2	9.6	33.0	2½-3	Df	93.1	10.4	32.9	2½

* Or : D1f3w ; ** Or : Df.

Considering sample B (Table 4) it is clear that the -1/16" coal obtained at each stage in the stepwise procedures followed contained a concentration of low-ash material which also revealed a relatively high swelling number. As the stepwise procedure (for example in the case of Sample B1f) was repeated, however, the possibilities of exploiting such effects diminished. Thus, the final -1/16" fraction obtained (Sample B1f3y) had a higher ash content (9.2%) and a lower swelling number (3) than the first + 1/16" fraction obtained (sample B1f1x) which had 8.7% ash and a swelling number of 3½, and the limiting stage in the desired separation had therefore already been passed in this particular case. Remarkably enough, there appears to be no tendency for volatile contents to be affected in a similar way by the type of treatment applied.

If all the washed -1/16" size fractions obtained are combined they amount to 39.9% of the original sample and have an ash content of 7.9% and a swelling number of 3½-4. The complement of this material, i.e. the combined +1/16" size fractions, amounts to 49.6% of the original sample; it has an ash content of 10.0% and a swelling number of 2½.

The two sub-samples of sample C, viz. D and E (Tables 5 and 6) show the same general trend, but that of D is less obvious. For example, the ash contents of the final -1/16" and + 1/16" products obtained (Table 5) were 9.6 and 11.0 respectively, and the swelling numbers 2½-3 and 2. This sample, it will be recalled, was originally a coarse fraction (6" x 3"). Either its characteristics were somewhat different from those of the other samples subjected to stepwise crushing and screening, or the degree of crushing in one pass to $-1\frac{1}{2}$" in the single roll crusher at the pilot plant was too drastic with the result that the possibilities of subsequent separation of harder and softer constituents were impaired to some extent. The fact that washed size fractions of D had higher ash contents and lower swelling numbers than corresponding washed size fractions of E (see Table 7) indicates that the characteristics of the two samples were, in fact, different and that this difference no doubt arose in the natural (and selective) breakage processes originally occurring during the winning of the coal.

TABLE 7.

Comparison of corresponding Washed Size Fractions of Samples D and E.

Size of Coal when washed (in)	Sample No.	Ash %	Sw. No.	Sample No.	Ash %	Sw. No.
$-\frac{1}{16}$	D3f	7.7	$3-3\frac{1}{2}$	E3f	7.1	$4-4\frac{1}{2}$
$\frac{1}{4}$ x $\frac{1}{16}$	D2f	8.9	3	E2f	7.8	4
$1\frac{1}{2}$ x $\frac{1}{4}$	D1f	10.7	$2-2\frac{1}{2}$	E1f	9.3	3
3 x $1\frac{1}{2}$	-	-	-	Eof	10.8	$2-2\frac{1}{2}$
All sizes	Df	10.4	$2\frac{1}{2}$	Ef	9.5	3

Referring to sample E (Table 6) the difference in behaviour between the size fractions 3" x $1\frac{1}{2}$" (sample Eo) and $1\frac{1}{2}$" x $\frac{1}{4}$" (sample E1) generally resembles that just described in respect of samples D and E.

In all cases where $+\frac{1}{4}$" size fractions (w - samples) were left after repeated crushing and screening, these had relatively high ash contents (11.8 to 13.5%) and in no case a swelling number exceeding $1\frac{1}{2}$. Such material would thus probably not be very desirable in the type of blend in which

Blesbok coal is normally used.

Reverting to sample B, it will be seen from Table 4 that during the washing of this sample, the yield of washed coal was 89.5% and the calculated ash and swelling number thereof 9.1% and 3, respectively.

From the results in Table 4 it can be estimated that, by applying the crushing and screening procedure adopted in these tests, the optimum ash reduction would be achieved by discarding a further 29%. The yield would then be about 60.5% (calculated on unwashed coal) and the material would have an ash content and swelling number of 8.3% and 3½-4, respectively.

By merely discarding the 10.5% sinks obtained during washing and the 12.3% material represented by sample B1f3w the yield would be 77.2% and the ash and swelling number 8.7% and 3-3½, respectively.

Judged by results obtained during a washability investigation carried out some time ago on Blesbok coal* it would appear that the extra beneficiation obtained in the present investigation by controlled crushing and screening, and indicated above, could also readily (and probably more economically) have been obtained by more drastic washing. The washing procedure would, therefore, probably be preferred unless there are other decided advantages to be gained from a controlled crushing and screening procedure. This aspect is considered in the following sections.

/...............17.

* J. Chem. Met. Min Soc. S.Afr., Nov.1952, 53, 111.

The Petrographic behaviour of the Coal under various conditions of Crushing and Screening.

The samples analysed for ash, volatiles and swelling numbers in the first part of this report were also analysed petrographically. The results of these analyses are recorded in Tables 8, 9 and 10.

The microlithotypes constituting the coal have been combined in entities on a practical basis as the following schedule indicates:-

Entity	Microlithotype.
A. Coking Constituents	Vitrite (Vi) Clarite (Cl)
B. Semi-coking Constituents	Durite) Intermediate Duro-clarite) Material Claro-durite) (I.M.)
C. Non-coking Constituents.	Vitrinertite (V.I.) Fusite and other (Fu) Carbinites Shaly coal and carbonaceous shale (C.S.)

Summary of position/.......18.

Summary of position as disclosed by petrographic study:-

From a study of the petrographical results recorded in Tables 8, 9 and 10, the following facts emerge:-*

(i) The coarser coal fractions contain less coking constituents than the finer coal fractions.

(ii) The non-coking constituents remain reasonably constant in all the coal fractions. This being so, it follows that by the process of stepwise crushing and screening employed in this investigation a separation of the non-coking constituents from the rest cannot be made.

(iii) There exists a close relationship between the coking constituents and the semi-coking constituents. As the former decrease the latter increase and the sum of the two remain practically constant.

(iv) The results indicate that the enrichment of the coking constituents will be of doubtful practical value since the yields are too low.

(v) As an alternative, attention should be given to the control of grain size of the coal which may improve the physical properties of the coke.

The influence of mild crushing and subsequent screening on the Petrographic Constituents.

Previous work** indicated that the finer coal fractions invariably contained more coking constituents than the coarser fractions.

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* These will be discussed in more detail presently.

** F.R.I. Technical Memo No. 14/1957.

That this is also the case in the present investigation can be seen from the following results obtained on relatively mildly crushed samples:-

Sample No.		Size Fraction (in)	Petrographic Analyses.		
			Coking constituents %	Semi-coking constituents %	Non-coking constituents %
B	B3f	$-{}^{1}/16$	50.9	23.7	25.4
	B2f	$-\frac{1}{4} + {}^{1}/16$	40.6	32.3	27.1
	B1f	$-1\frac{1}{2} + \frac{1}{4}$	35.2	37.2	27.6
D	D3f	$-{}^{1}/16$	42.2	33.8	24.4
	D2f	$-\frac{1}{4} + {}^{1}/16$	44.1	34.2	21.7
	D1f	$-1\frac{1}{2} + \frac{1}{4}$	33.7	41.2	25.1
E	E3f	$-{}^{1}/16$	61.1	23.7	15.1
	E2f	$-\frac{1}{4} + {}^{1}/16$	40.7	37.6	21.7
	E1f	$-1\frac{1}{2} + \frac{1}{4}$	41.5	33.3	25.2
	Eof	$-3 + 1\frac{1}{2}$	29.7	42.2	27.9

In sample B there is a stepwise increase in coking constituents as the size of the coal decreases.
Samples D3f and D2f contain nearly the same amounts of coking constituents but these are about 10% more than those contained in sample D1f i.e. the coarsest coal.
Sample E3f, (i.e. the fine coal in sample E) contains approximately 30% more coking constituents than the coarsest fraction (Sample Eof).
There is very little difference in petrographic constitution between samples E2f and E1f.
Some petrographic enrichment has taken place in the $-\frac{1}{4}" + {}^{1}/16"$

and $-^1/16$" coal fractions of sample B. This is also the case with sample D, although the beneficiation of coking constituents in the $-^1/16$" coal in contrast to that in the $-\frac{1}{4}$" + $^1/16$" fraction is low. On the other hand, the petrographic separation in the case of sample E already occurred in the $-1\frac{1}{2}$" + $\frac{1}{4}$" fraction, which is rather surprising in the light of previous experience with Blesbok coal. Normally, it occurs in the $-\frac{1}{4}$" coal fraction. In this respect, the behaviour of sample B, and to a lesser extent that of sample D, can be regarded as normal and that of sample E as abnormal.

The behaviour of the non-coking constituents under various conditions of crushing and screening.

From Tables 8 - 10 it appears that the non-coking constituents (i.e. the sum of the vitrinertite, carbinite and carbonaceous shale) remain practically constant in all the coal fractions. The tendency for the concentration of the non-coking constituents to decrease in the finer coal fractions or to increase in the coarser (or harder) coal fractions is only slight.
There are a few exceptions, and even then the divergence is not great.

The following are the average percentages of the non-coking constituents in each of the main samples:-

Sample	Average Non-coking constituents (%)
Bf	27.1
Df	24.7
Ef	25.0
Eof	27.9

From the results/....23.

From the results recorded it can be concluded that the method of crushing and screening employed in this investigation did not cause the non-coking constituents to concentrate appreciably in any specific crushing or screening operation and they cannot therefore be removed from the coking constituents by this means.

<u>The behaviour of the semi-coking constituents under various conditions of crushing and screening</u>.

The semi-coking constituents comprise the micro-lithotypes, durite, claro-durite and duro-clarite. Since South African coals contain very little durite, the bulk of the semi-coking constituents is composed of claro- durite and duro-clarite. It therefore contains the macerals vitrinite, exinite and inertinite (or carbinite), intimately mixed in various proportions.

Inspection of the results indicates that there is a very close relationship between the semi-coking constituents and the coking constituents.

Some of the results illustrating this, are as follows:-

/................24.

	Sample No.	Coking const.%	Semi-Coking const. %	Sum of Coking and semi-coking const. %
Finer coal fractions	B3f	50.9	23.7	74.6
	D3f	42.2	33.8	76.0
	E3f	61.1	23.7	84.8
	Eof3	35.1	40.6	75.7
Coarser coal fractions	Blfy	52.8	26.5	79.3
	Blfx	43.9	32.3	76.2
	Dlfly	49.7	25.3	75.0
	Dlflx	40.0	35.8	75.8
	Elflx	40.6	32.3	72.9
	Elfly	53.9	21.1	75.0
Coarsest coal fractions	Blf3x	26.4	42.1	68.5
	Blf3w	21.0	42.2	63.2
	Dlf3y	28.6	46.5	74.7
	Dlf3x	22.2	53.0	75.2
	Dlf4y	23.6	54.0	77.6
	Dlf4x	11.6	63.1	74.7
	Eofl3x	19.7	59.0	78.7
	Eofl3w	21.4	50.3	71.7

It is clear that the contents of the coking constituents in the finer and coarser coal fractions are high and those of the semi-coking constituents are low. (exception: sample Eof3). In the coarsest coal fractions the position is reversed. In all cases the sum of the coking and semi-coking constituents remains practically constant.

This relationship/........25

This relationship was also found in a previous investigation[*] of Blesbok and two other coals. For the purpose of that investigation the comminution of the sub-samples was very severe and the relationship was then not so surprising.

This behaviour also explains the peculiarity mentioned earlier, namely that the volatile matter content remains constant in spite of the crushing and screening operations. The semi-coking constituents, although higher in ash, carry enough volatile-rich exinites to compensate for the loss of volatile matter in those fractions where the coking constituents are low (c.f. samples D1f4y, Eof13w etc. in Tables 5, 6, 9 and 10).

Further consideration of Enrichment of Petrographic constituents.

From the available results it has been possible to calculate the petrographic constitution of the bulk samples (after washing) which is as follows:-

Sample	Petrographic Constitution.		
	Coking const. %	Semi-coking const. %	Non-coking const. %
Bf	39.1	33.8	27.1
Df	35.2	40.1	24.7
Ef	38.9	36.1	25.0
Cf (i.e. Df & Ef combined)	36.8	38.4	24.8

* F.R.I. Technical Memo No.14/1957.

It can be noted/........ 26.

It can be noted that the percentage of coking constituents in sample Cf (i.e. Df and Ef combined in their proper ratio) is slightly lower than those insample Bf.

The reason for this can probably be found in the sampling method. Mention has been made that sample C^1 was taken from a moving belt. It appears that the full proportion of naturally arising fines may not have been included in the sample.

The washed -1/16" coal fraction of sample B (B3f) amounted to 16.5% of the original unwashed sample while those of sample D (D3f), sample E (E3f) and sample Eo (Eof3) were only 4.9, 6.8 and 4.5 per cent, respectively.

If sub-sample B3f of sample B is not taken into account at all, the rest of sample B (consisting of sub-samples B1f and B2f) gives a petrographical analysis very similar to that of sample C^1 (washed) which is calculated to be as follows:-

Sample.	Petrographic analyses		
	Coking Constituents %	Semi-coking Constituents %	Non-coking Constituents %
Bf (excluding B3f)	36.5	36.0	27.5
C1 (washed)	36.8	38.4	24.8

Generally speaking, the yields of the enriched coal are disappointingly low as can be seen from the following:-

..............27

Sample	Yield % on original unwashed coal.	Petrographic Analyses.		
		Coking Constituents %	Semi-coking Constituents %	Non-coking constituents %
B*	68.5	43.7	31.2	25.1
D**	42.9	43.4	32.8	23.8
E***	54.4	44.6	32.6	22.8

If these petrographic analyses are compared with those of the total washed samples (see table on page 23) it will be noted that the beneficiation of the coking constituents was really very small, namely 4.6, 8.2 and 5.7 per cent for samples B, D and E, respectively.

Conclusions and/...............28

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* Fractions considered: B3f + B2f + B1f1 + B1f2.

** " " : D3f + D2f + D1f1

*** " " : E3f + E2f + E1f1 + E1f2 + Eof3 + Eof2 petrographic enrichment to this component. This argument does not necessarily apply to other components of the blend, nor does it follow that coke beneficiation cannot be achieved by subjecting the blend or its components to special crushing (possibly combined with screening) procedures.

Of the three coals previously investigated*, that from Navigation Colliery (S.A.C.E) appeared to hold out the least promise regarding the possibilities of petrographic beneficiation. There would, therefore, be little purpose in extending the type of investigation described in the present report to this coal. On the other hand, the possibilities appeared better with D.N.C. than with Blesbok coal, and it is therefore proposed to extend the investigation to D.N.C. coal.

Finally, the effect on coke quality of removing the coarsest size fraction from Iscor's crushed blend, recrushing this fraction (or portion of it) and remixing with the rest before coking, should be investigated.

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TECHNICAL OFFICER
and C.C. la Grange.
PRINCIPAL TECHNICAL OFFICER.

PRETORIA.
21ST MARCH, 1958.

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* F.R.I. Technical Memo No. 14/1957.

T A B L

ANALYTICAL DETAILS PERTAI

Size	+ 1/16"				- 1	
Sample No.	% of E	Ash %	Vols. %	Sw. No.	Sample No.	% of E
E3f	-	-	-	-	E3f	6.8
E2fx	3.6	9.0	32.5	3½	E2fy	5.5
Elf1x Elf2x Elf3x Elf3w	11.7 7.5 4.1 8.1	8.3 9.4 10.5 11.8	33.2 33.0 32.8 31.8	3½-4 3-3½ 2 1½	Elf1y Elf2y Elf3y -	6.3 3.4 1.9 -
Eof3	-	-	-	-	Eof3	4.5
Eof2x	2.8	11.0	32.8	2½	Eof2y	2.3
Eofl1x Eofl2x Eofl3x Eofl3w	4.6 2.3 2.2 6.5	10.1 10.8 11.7 13.5	32.6 32.7 32.3 32.6	2½ 1½ 1½ 1	Eofl1y Eofl2y Eofl3y -	2.7 1.1 1.0 -
Weighted Average: Eofl1-13	15.6	11.8	32.6	1½		4.8
Weighted Average: Eof	18.4	11.7	32.6	1½		11.6
Weighted Average: Elf	31.4	9.8	32.7	2½-3		11.6
Weighted Average: E123f	35.0	9.7	32.7	2½-3		23.9
Weighted Average: Eol23f*	53.4	10.4	32.7	2½		35.4

* Or : Ef

E 6.

ING TO SAMPLE NO. 57/541.E

/16"			Combined Sizes (Calculated)				
Ash %	Vols. %	Sw. No.	Sample No.	% of E	Ash %	Vols. %	Sw. No.
7.1	33.6	4-4½	E3f	6.8	7.1	33.6	4-4½
7.0	33.9	4½	E2f	9.1	7.8	33.3	4
7.7	33.2	4	E1f1	18.1	8.1	33.2	3½-4
8.3	32.8	3-3½	E1f2	10.9	9.1	32.9	3-3½
9.3	32.7	2½-3	E1f3	6.0	10.1	32.8	2-2½
-	-	-	E1f3w	8.1	11.8	31.8	1½
9.6	32.7	3	Eof3	4.5	9.6	32.7	3
8.9	33.4	3-3½	Eof2	5.0	10.0	33.1	2½-3
9.5	32.7	3	Eof11	7.3	9.9	32.6	2½-3
9.9	32.7	2½	Eof12	3.4	10.5	32.7	1½-2
10.8	32.7	2½	Eof13	3.2	11.4	32.4	1½-2
-	-	-	Eof13w	6.5	13.5	32.6	1
9.8	32.7	2½-3		20.4	11.4	32.6	2
9.5	32.8	3		29.9	10.8	32.7	2-2½
8.1	33.0	3½-4		43.0	9.3	32.8	3
7.6	33.4	4-4½		58.9	8.8	33.0	3½
8.2	33.2	3½-4	Ef	88.8	9.5	32.9	3

T A

PETROGRAPHIC ANALYSES

Sample Number.	Original Size of Fraction (ins)	Number of Crushings.	Screened to (Ins)	Yield of Original %	Vi	Cl
B3f	- 1/16"	1	-1/16	16.5	37.3	13.6
B2f*	- ¼ + 1/16	1		17.2		
B2fx	- ¼ + 1/16	2	+1/16	8.0	24.8	12.6
B2fy	- ¼ + 1/16	2	-1/16	9.2	35.6	7.8
B1f*	-1½ + ¼	1		55.8		
B1f1*	-1½ + ¼	2	- ¼	20.0		
B1f1x	-1½ + ¼	2	+ 1/16	12.8	28.3	15.6
B1f1y	-1½ + ¼	2	- 1/16	7.2	38.8	14.0
B1f2*	-1½ + ¼	3	- ¼	14.8		
B1f2x	-1½ + ¼	3	+ 1/16	10.3	18.6	9.8
B1f2y	-1½ + ¼	3	- 1/16	4.5	38.0	11.0
B1f3*	-1½ + ¼	4	- ¼	8.7		
B1f3x	-1½ + ¼	4	+ 1/16	6.2	16.6	9.8
B1f3y	-1½ + ¼	4	- 1/16	2.5	24.8	9.4
B1f3w	-1½ + ¼	4	+ ¼	12.3	10.8	10.2

T A

PETROGRAPHIC ANALYS

D3f	- 1/16	1	- 1/16	4.9	30.6	11.6
D2f*	- ¼ + 1/16	1		9.0		
D2fx	- ¼ + 1/16	2	+ 1/16	4.3	19.4	19.3
D2fy	- ¼ + 1/16	2	- 1/16	4.7	35.6	13.4
D1f*	- 1½ + ¼	1		79.3		
D1f1*	- 1½ + ¼	2	- ¼	29.4		
D1f1x	- 1½ + ¼	2	+ 1/16	19.2	23.1	16.9
D1f1y	- 1½ + ¼	2	- 1/16	10.1	35.9	13.8
D1f2*	- 1½ + ¼	3	- ¼	20.0		
D1f2x	-1½ + ¼	3	+ 1/16	13.6	17.3	16.4
D1f2y	- 1½ + ¼	3	- 1/16	6.4	17.7	12.1
D1f3*	- 1½ + ¼	4	- ¼	11.2		
D1f3x	- 1½ + ¼	4	+ 1/16	7.7	9.4	12.8
D1f3y	- 1½ + ¼	4	- 1/16	3.5	17.7	10.9
D1f3w	- 1½ + ¼	4	+ ¼	18.7	11.3	7.5
D1f4x	- 1½ + ¼	5	+ 1/16	9.1	5.9	5.7
D1f4y	- 1½ + ¼	5	- 1/16	9.6	13.1	10.5

* Calculated Values.

3 L E 8.

OF SAMPLE 57/541 B.

'etrographic Analyses.				Petrographic Analyses on practical Basis		
V.I.	I.M.	Fu	C.S.	Coking Constit-uents %	Semi-coking Constituents %	Non-coking Constituents %
7.1	23.7	6.4	11.9	50.9	23.7	25.4
				40.6	32.3	27.1
15.5	31.8	6.0	9.3	37.4	31.8	30.8
11.8	32.8	2.0	10.0	43.4	32.8	23.8
				35.2	37.2	27.6
				47.1	30.2	22.7
11.1	32.3	3.1	9.6	43.9	32.3	23.8
11.7	26.5	2.0	7.0	52.8	26.5	20.7
				34.7	39.5	25.8
13.0	41.8	5.0	11.8	28.4	41.8	29.8
10.5	34.3	1.9	4.3	49.0	34.3	16.7
				28.6	41.9	29.5
11.7	42.1	3.8	16.0	26.4	42.1	31.5
9.4	41.3	4.2	10.9	34.2	41.3	24.5
11.3	42.2	6.3	19.2	21.0	42.2	36.8

L E 9.

ES OF SAMPLE 57/541 D.

16.3	33.8	3.6	4.1	42.2	33.8	24.0
				44.1	34.2	21.7
15.5	41.1	3.5	1.2	38.7	41.1	20.2
11.8	27.8	2.5	8.9	49.0	27.8	23.2
				33.7	41.2	25.1
				43.3	32.3	24.4
16.1	35.8	3.8	4.3	40.0	35.8	24.2
16.5	25.3	6.5	2.0	49.7	25.3	25.0
				34.6	33.7	31.7
23.6	32.3	4.9	5.5	33.7	32.3	34.0
8.9	49.7	5.8	5.8	36.4	36.7	26.9
				24.1	51.0	24.9
8.4	53.1	3.1	13.3	22.2	53.0	24.8
12.5	46.5	4.1	8.3	28.6	46.5	24.9
6.6	41.1	3.3	30.2	17.8	58.7	23.5
4.2	63.1	7.0	14.1	11.6	63.1	25.3
15.4	54.5	2.6	3.9	23.6	54.5	21.9

T A

PETROGRAPHIC ANALY

Sample Number	Original Size of Fraction (ins)	Number of Crushings.	Screened to (Ins)	Yield % of Original.	Petrograp	
					Vi %	Cl %
E3f	- 1/16	1	- 1/16	6.8	46.8	14.3
E2f*	- ¼ + 1/16	1	- ¼	9.1		
E2fx	- ¼ + 1/16	2	+ 1/16	3.6	26.6	13.5
E2fy	- ¼ + 1/16	2	- 1/16	5.5	28.3	12.9
E1f*	- 1½ + ¼	1		42.9		
E1f1*	- 1½ + ¼	2	- ¼	18.1		
E1f1x	- 1½ + ¼	2	+ 1/16	11.7	27.1	13.5
E1f1y	- 1½ + ¼	2	- 1/16	5.5	40.4	13.5
E1f2*	-1½ + ¼	3	- ¼	10.9		
E1f2x	- 1½ + ¼	3	+ 1/16	7.5	22.3	21.5
E1f2y	-1½ + ¼	3	- 1/16	3.4	34.0	13.4
E1f3*	-1½ + ¼	4	- ¼	6.0		
E1f3x	-1½ + ¼	4	+ 1/16	4.1	15.8	19.4
E1f3y	-1½ + ¼	4	- 1/16	1.9	21.4	16.6
E1f3w	- 1½ + ¼	4	+ ¼	8.1	12.6	20.1
Eof*	- 3 + 1½	1	- 1½	29.9		
Eof3	- 3 + 1½	2	- 1/16	4.5	23.8	11.3
Eof2*	- 3 + 1½	2	- ¼	5.0		
Eof2x	- 3 + 1½	3	+ 1/16	2.8	15.5	13.1
Eof2y	- 3 + 1½	3	- 1/16	2.3	30.2	11.5
Eof1*	- 3 + 1½	2		20.4		
Eof11*	- 3 + 1½	3	- ¼	7.3		
Eof11x	- 3 + 1½	3	+ 1/16	4.6	17.4	13.6
Eof11y	- 3 + 1½	3	- 1/16	2.7	23.2	15.1
Eof12*	- 3 + 1½	4	- ¼	3.4		
Eof12x	- 3 + 1½	4	+ 1/16	2.3	15.4	12.4
Eof12y	- 3 + 1½	4	- 1/16	1.1	18.5	10.6
Eof13*	- 3 + 1½	5	- ¼	3.2		
Eof13x	- 3 + 1½	5	+ 1/16	2.2	7.8	11.9
Eof13y	- 3 + 1½	5	- 1/16	1.1	13.5	17.8
Eof13w	- 3 + 1½	5	+ ¼	6.5	12.7	8.7

* Calculated values.

L E 10.

S OF SAMPLE 57/541 E

c Analyses				Petrographical Analyses on Practical Basis.		
V.I. %	I.M. %	Fu %	C.S. %	Coking Constit-uents %	Semi-coking Constit-uents %	Non-coking Constituents %
9.5	23.7	2.0	3.7	61.1	23.7	15.2
				40.7	37.6	21.7
12.4	28.8	5.8	12.9	40.1	28.8	31.1
7.6	43.3	1.8	6.2	41.1	43.3	15.6
				41.5	33.3	25.2
				45.1	28.3	26.6
10.9	32.3	6.0	10.2	40.6	32.3	27.1
14.9	21.1	5.4	4.7	53.9	21.1	26.0
				45.0	36.8	18.2
10.9	37.1	3.6	4.6	43.8	37.1	19.1
9.3	36.3	4.1	2.9	47.4	36.3	16.3
				36.0	38.9	25.1
16.3	38.9	4.4	5.2	35.2	38.9	25.9
12.4	38.7	7.0	3.9	38.0	38.7	23.3
18.1	35.6	6.8	6.8	32.7	35.6	31.7
				29.7	42.4	27.9
13.4	40.6	6.1	4.8	35.1	40.6	24.3
				34.5	34.6	30.9
14.8	41.7	3.6	11.3	28.6	41.7	29.7
19.8	26.0	7.1	5.4	41.7	26.0	32.3
				27.3	44.8	27.9
				33.7	34.9	31.4
15.0	37.1	5.6	11.3	31.0	37.1	31.9
17.8	31.2	6.3	6.4	38.3	31.2	30.5
				27.8	47.2	25.0
11.4	48.4	3.9	8.5	27.8	48.4	23.8
16.2	17.4	6.9	20.4	27.6	44.6	27.8
				23.3	54.3	22.4
9.6	59.0	5.0	6.7	19.7	59.0	21.3
15.8	43.7	3.2	6.0	31.3	43.7	25.0
16.0	50.3	4.8	7.5	21.4	50.3	28.3