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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA

TECHNICAL MEMORANDUM NO. 14/1957.

A PRELIMINARY INVESTIGATION OF THE ENRICHMENT OF THE FUSIBLE CONSTITUENTS IN SOUTH AFRICAN COKING COALS BY A PROCEDURE OF CRUSHING AND SCREENING.

BY

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A PRELIMINARY INVESTIGATION OF THE ENRICHMENT OF THE FUSIBLE CONSTITUENTS IN SOUTH AFRICAN COKING COALS BY A PROCEDURE OF CRUSHING AND SCREENING.

SUMMARY:

Samples of coal from Durban Navigation (D.N.C.), Navigation S.A.C.E. and Blesbok Collieries were investigated. It was found that by crushing the coal to approximately -1½" top size (present practice at the collieries) enrichment of the fusible constituents (i.e. the vitrite and clarite) in the -¼" fraction was considerable for D.N.C. and Blesbok coals. The effect on Navigation coal was only slight. By crushing the coal to -3/16" and screening at ⅛" and 22 mesh it was found that considerable enrichment took place in the case of Navigation in the -⅛"+ 22 mesh coal.

It appears that in order to enrich the fusible constituents by selective crushing and screening, it is not necessary to pass the coal through many crushing cycles and that efficient screening is probably more important.

The results also indicate that the coarser coal from a particular crushing operation will invariably contain less vitrite than the finer coal derived from the same crushing operation.

INTRODUCTION:

The process of petrographic coal preparation as popularised by Mr. Bürstlein, has been devised to enrich the coking constituents in coals which ordinarily contain a low ratio of active to inert petrographic constituents.

Coal preparation plants applying this process are to be found in the Saar and Lorraine. In the Ruhr the process has been modified to suit the coal and their particular problems.

In Oran, North Africa, a plant similar to that in Lorraine is operated for enriching the gas coal for their gasworks.

The Bürstlein Process.

In this process two factors play a major rôle; firstly, the separation of the coal into its petrographic entities or rather concentrates of these and secondly, the close control of the grain sizes.

The separation of coal into its petrographic entities.

The microlithotypes constituting a coal differ in strengths. It has been established that durite is approximately ten times harder than vitrite. Clarite has a hardness falling between that of vitrite and durite. Carbonaceous shale has been found to be considerably harder than durite. Fusain has practically no resistance to mechanical disintegration. It is thus clear that if a hammer-mill is employed to break the coal the vitrite and fusite (and to a degree the clarite), being much softer than the durite and carbonaceous shale, would be pulverised to a greater extent than the other constituents.

In order to/........3.

In order to avoid this the run of mine coal is passed over a screen having apertures of the order of 3 m.m. Most of the fusite particles as well as the vitrite and clarite of less than 3 m.m. diameter pass through without further breaking. The oversize material consisting of durite, carbonaceous shale and the larger lumps of coal pass over the screen to a special type of breaker. This breaker is designed in such a way that the lumps of coal are given a mild impact only. The coal is then recycled over the screen where the -3m.m. size coal again passes through, thus escaping further breakage.

It has been found that the coking constituents lose some of their binding power through weathering rather rapidly when they are too fine. The active constituents must therefor be reasonably coarse. On the other hand the inerts must be in a given narrow size range. If they are too fine they would cause excessive absorption of bituminous binder, thus causing the coke to lack cohesion. If they are too coarse, the infusible material would form centres of weakness in the coke.

The purpose of the whole process is to bring each petrographic constituent to the optimum size for the production of a strong coke.

The Possibilities of Applying the "Bürstlein Process" to S.A. Coking Coals.

It has already been stated that the Bürstlein process is being applied in the Saar and Lorraine.

The coals occurring in these provinces are mainly high volatile coking coals fairly similar to that presently mined at D.N.C. However, the ash content is considerably lower than that of South African coals. It is also known that the durite in some of the Saar coals exhibits swelling properties. It is

doubtful/.......4.

doubtful whether any of the durites found in South Africa would reveal such properties.

Generally speaking South African coals are inferior to these coals, notwithstanding the fact that there are certain similarities.

In the Ruhr where the process is also applied, the fusible constituents i.e. the vitrite and clarite form between 60 and 70 per cent of the bulk, while their transition materials generally still carry a high amount of exinite. This is rarely the case in South Africa. Some of our best coking coals notably D.N.C., Enyati, Blesbok, Navigation and Hlobane carry less than 35 per cent of fusible constituents. These coals also carry a large proportion of vitrinertite, (consisting of a mixture of vitrinite and inertinite,) the behaviour of which in the coking process is still very obscure. The fusite very seldom exceeds 10% and is generally of the order of 5 - 7%. The carbonaceous shale varies considerably but tends to be on the high side, namely from 5 to 10% and in certain cases, notably that of Navigation, of the order of 15%.

In general South African coals are also considerably harder than European coals.

From the above it is clear that South African coals differ appreciably from the coals to which the process is currently applied.

In order to find out whether the behaviour of South African coking coals will be similar to that of European coals and whether an enrichment of vitrite is possible, a series of experiments were devised.

These experiments were merely exploratory and in further work or in practice considerable modifications may have to be introduced.

Crushing of the Samples.

The coals investigated were subjected to three stages of crushing.

The first stage of crushing was carried out at the colliery where the run-of-mine coal was passed through a roll-crusher, which gave a product of approximately 1½ inch top size.

The other two stages of crushing were carried out at the Institute.

The second stage consisted of reducing the coal to -3/16" in a Sturtevant rotary crusher, while in the third stage of crushing the reduction of the -3/16" coal to -22 mesh was carried out in a Hush pulverizer.

The Hush pulverizer is of simple design. It consists of two adjustable parallel plates. One plate is stationary and the other revolves at high speed while the coal is fed axially through the stationary plate. By feeding the coal slowly to this mill the formation of excessive fines could be prevented.

At the start of the crushing operations in the Hush pulverizer, the plates are set at a distance of somewhat less than 3/16 of an inch. The crushed product is then screened over a 22 mesh screen. The oversize is again crushed after a slight reduction of the distance between the 2 plates, In this manner the operation is repeated several times. Finally the mill is set to allow the remainder of the oversize material (which is usually only a few grammes) to be crushed to -22 mesh.

By following this/........6.

By following this procedure the petrographic disintegrator is simulated and the production of very fine coal is kept to a minimum.

For the final crushing of the Navigation coal, the procedure was slightly modified. Instead of passing the coal through the Hush a manually operated steel roll was employed. The coal was spread evenly on a flat steel plate and the roller slowly passed over it several times without exerting extra pressure. The product was screened, the oversize retreated, etc. until the whole sample was -22 mesh.

The Scope of the Investigation.

Work was carried out on the three coals currently used to prepare a coking blend at the coke ovens of the South African Iron & Steel Industrial Corporation.

Each coal was sampled at the coke ovens and represents the washed product (after handling) as received from the colliery. The amount of size reduction by handling must be regarded as being normal for each coal.

After storage under water for some time (these samples were also taken for other purposes) the coals were recovered from the water and screened after drying.

The screen sizes used and the fractions obtained were as follows:-

Screen fraction.	Designation of Sample.
+ 1"	C1
1 x $\frac{1}{2}$"	C2
$\frac{1}{2}$"x $\frac{1}{4}$"	C3
$\frac{1}{4}$"x $\frac{1}{8}$"	C4
$\frac{1}{8}$"x 22 mesh	C5
- 22 mesh	C6 C7.

Each of the/..........7.

Each of the coarser size fractions i.e. those from C1 to C4 was crushed to -3/16". The crushed product was then screened into the following fractions:-

Screen Fraction.	Designation.			
3/16" x $\frac{1}{8}$"	C14,	C24,	C34,	C44.
$\frac{1}{8}$" x 22 mesh	C15,	C25,	C35,	C45.
22 x 100 mesh	C16,	C26,	C36,	C46.
-100 mesh	C17,	C27,	C37,	C47.

Samples C14, C15, C24, C25, C35, C44 and C45 were crushed to -22 mesh and divided into 22 x 100 mesh and -100 mesh fractions as the following table indicates.

Screen Fraction.	Designation.
22 x 100 mesh	C146, C246, C256, C346, C356, C446, C456.
- 100 mesh	C147, C247, C257, C347, C357, C447, C457.

It will be noted that only the original fractions C1, C2, C3 and C4 were crushed to -3/16". Fractions C5, C6 C7 consisted of smaller coal. A diagramatic sampling and crushing scheme is attached at the end of this report.

No attempt was made to separate the -22 mesh coal of sample C6C7 into 22 x 100 mesh and -100 mesh fractions. During storage the coals were kept in bags under water and the subsequent handling of the bags resulted in the loss of some of the fines.

Samples for petrographic analyses were obtained from all the screen fractions. In addition swelling numbers and ash determinations were done on all the samples.

The Purpose of the Investigation.

Assuming that South African coking coals possess characteristics which would make the application of the Bürstlein

process/.........8.

process feasible, it is clear that an attempt had to be made to (a) establish as accurately as possible at what limits of grain size these characteristics would disappear or would be accentuated thus enabling their best utilization and (b) evaluate the amount of enrichment.

Presentation of Results:-

All the results obtained on the three coal samples are contained in Tables 1 - 3.

These tables are rather comprehensive and the information is somewhat scattered. For the sake of simplification the data have been sorted and presented in a series of further tables. A complete list of the tables are given below:-

Table.	Data relating to:-
1.	Results obtained on Durban Navigation coal Sample 56/397C.
2.	" " " Navigation Coal " 56/398C.
3.	" " " Blesbok Coal " 56/399C.
4.	Petrographical analyses of the original screen fractions.
5.	" " " " +$\frac{1}{8}$" coal.
6.	" " " " -$\frac{1}{8}$" + 22 mesh coal..
7.	" " " " -22 + 100 mesh coal.
8.	" " " " -100 mesh coal
9.	The enrichment of the fusible constituents in the Durban Navigation coal.
10.	The enrichment of the fusible constituents in the Navigation (S.A.C.E.) coal.
11.	The enrichment of the fusible constituents in the Blesbok coal.

Discussion of Results/......10.

Discussion of Results.

A. The coals as received.

These coals had been crushed at the colliery to a top size of 1½ inches. A screen analysis gave the following results:-

Sample.	Screen Size.	Per Cent.		
		D.N.C.	Navigation	Blesbok
C1	+ 1"	7.6	12.9	10.6
C2	-1" + ½"	25.1	32.8	25.0
C3	-½" + ¼"	23.0	20.8	26.3
C4	-¼" + ⅛"	19.7	14.9	17.4
C5	-⅛" + 22 mesh	20.0	12.5	15.4
C6C7	-22 mesh	4.6	6.1	5.3

The D.N.C. coal contained slightly more -¼" material than Navigation and Blesbok coals. In general the Natal coals are somewhat more friable than the coals from Transvaal and this may or may not explain the difference.

The petrographic analyses in table 4 indicate that in the case of Durban Navigation coal there has been a sharp increase in the vitrite content from the +¼" to -¼" fraction. This increase is also evident, but to a lesser degree, for the Blesbok coal. For the Navigation coal the increase in vitrite content has been so gradual that practically only the -22 mesh fraction can be regarded as having been appreciably enriched.

The +⅛" Coal/..........11.

The +⅛" Coal Fractions After the Second Crushing.

The screen fractions (with the exception of C5 and C6C7) were crushed to -3/16" and screened.

The hardest constituents will naturally be found in the coarsest size fractions. This being the case it can be expected that the petrographic analyses would reveal a low vitrite and high durite content. That this is actually the case can be observed from the results recorded in table 5. The fractions C14 and C24 (table 5) contain considerably less vitrite than fractions C34 and C44. With the durite contents, on the other hand, the position is reversed. This tendency is very clear for D.N.C. and Blesbok coals. The sudden transition is not so evident for Navigation coal.

This behaviour is an indication that at a certain screen size after the first crushing, somewhere between ½" and ¼", a petrographic separation has started to take place in the D.N.C. and Blesbok coals, and that the physical constitution of the Navigation coal is somewhat different. Apparently this coal must be crushed to a size smaller than ¼" to obtain appreciable liberation of petrographic constituents.

The -⅛" + 22 mesh Coal fractions after the Second Crushing.

The samples in question are C15, C25, C35 and C45. They consisted of the -⅛" +22 mesh fractions obtained after crushing to -3/16" and screening.

Taking the behaviour of the $+\frac{1}{8}$" coal fractions into account two things can be expected. Firstly, the coal fractions derived from screen fractions C1 and C2 would yield less vitrite and appreciably more durite in comparison with the samples derived from fractions C3 and C4. Secondly, a petrographic separation may occur in the Navigation coal.

From the values recorded in table 6, it can be seen that this is the case for D.N.C. and Navigation coals. It can also be noted that a petrographic separation has taken place in the Navigation coal.

The vitrite figures for Blesbok coal, on the other hand, remain more or less constant which may be an indication that the critical grain size necessary for a petrographic separation had already been attained or passed.

The -22 + 100 mesh coal fractions resulting from all the crushings.

It has been clear that the coarser, i.e. harder coal (or conversely that having the highest durite content) yields less vitrite than the finer (or softer) coal.

A study of the petrographic characteristics of the -22 + 100 mesh material, should therefore also reflect this position. This study has the advantage that there are at least 36 samples under consideration, which enables one to draw more definite conclusions.

Samples C146,/..............13.

Average Petrographic Analyses of the -22 + 100 mesh Coal Fractions

(Calculated from the results recorded in Table 7)

Colliery and Sample No.	Size after 2nd Crushing.	No. of Crushings.	Petrographic Analyses.					
			% Vi	(%) Cl.	(%) V.I.	(%) Du.	(%) Fu.	(%) C.S.
D.N.C. 56/397								
C146 - 446	+ $\frac{1}{8}$"	3	18.0	8.3	23.9	39.1	6.7	4.0
C156 - 456	- $\frac{1}{8}$") + 22 mesh)	3	23.5	9.3	20.1	35.9	7.0	4.0
C16 - 46	- 22 mesh	2	34.5	7.4	23.7	25.0	7.0	2.4
Navig. 56/398								
C146 - 446	+ $\frac{1}{8}$"	3	15.5	13.6	26.3	31.3	4.9	8.4
C156 - 456	-$\frac{1}{8}$") +22 mesh)	3	21.6	15.9	24.8	29.1	4.6	4.0
C16 - 46	- 22 mesh	2	27.4	12.5	25.6	20.5	3.5	10.5
Blesbok 56/399								
C146 - 446	+ $\frac{1}{8}$"	3	15.3	17.2	16.6	31.6	7.5	11.8
C156 - 456	- $\frac{1}{8}$") + 22 mesh)	3	23.3	14.9	14.2	34.0	4.9	8.7
C16 - 46	- 22 mesh	2	35.0	12.3	15.5	24.0	5.7	7.5

From these average petrographic analyses it is apparent that there is a step-wise increase in vitrite with decreasing size after the second crushing.

It appears that in order to enrich the fusible constituents by selective crushing and screening it is not necessary to pass the coal through many crushing cycles and that the screening is probably more important.

The results also indicate that the coarser coal from a particular crushing operation will invariably contain less vitrite than the finer coal derived from the same crushing operation.

The - 100 mesh coal fractions resulting from the second and third crushings.

The results obtained on the -100 mesh coal fractions are recorded in table 8. The average values of these fractions are as follows:-

Average Petrographic analyses of the -100 mesh coal Fractions

(Calculated from Table 8)

Colliery and Sample No.	Size after 2nd crushing.	Number of Crushings.	Petrographic Analyses					
			Vi(%)	Cl(%)	V.I.(%)	Du(%)	Fu(%)	C.S.(%)
D.N.C.56/397								
C147 - 447	+ $\frac{1}{8}$"	3	36.6	5.4	19.6	19.4	16.6	2.4
C157 - 457	- $\frac{1}{8}$") + 22 mesh)	3	46.2	4.3	16.0	16.0	15.8	1.7
C17 - 57	- 22 mesh	2	49.3	3.4	14.8	11.8	17.6	3.1
Navig. 56/398								
C147 - 447	+ $\frac{1}{8}$"	3	31.5	6.1	18.1	19.3	20.4	4.6
C157 - 457	- $\frac{1}{8}$") + 22 mesh)	3	38.1	7.3	20.1	13.9	17.7	2.9
C 17 - 57	- 22 mesh	2	39.6	5.1	17.1	13.5	20.7	4.0
Blesbok 56/399								
C147 - 447	+ $\frac{1}{8}$"	3	42.6	6.4	15.4	17.2	13.8	4.6
C157 - 457	- $\frac{1}{8}$") + 22 mesh)	3	48.4	6.5	14.5	13.8	14.3	2.5
C 17 - 57	- 22 mesh	2	50.3	5.1	11.2	12.3	17.4	3.7

The values for the -100 mesh coal show the same stepwise increase in vitrite observed in the -22 + 100 mesh material. However, the increase is appreciably smaller in passing from the C157 - 457 to the C17 - 57 samples.

Coal in such a fine state as -100 mesh has certain disadvantages and is undesirable in the manufacture of coke. However, it is important to note that the study of these fine coal fractions seem to confirm the physical characteristics observed and commented on in the discussion of the -22 + 100 mesh coal fractions.

The General Behaviour of the microlithotypes under the experimental conditions.

Vitrite:-

The behaviour of the vitrite which is the most important microlithotype in this investigation has been discussed in detail, and will not be discussed again.

Clarite:-

In general, none of the coals contain an exceptionally high percentage of clarite, and it is doubtful whether its presence in such small quantities would influence the coking process much.

There is also a tendency for the clarite content to be at its lowest whenever the vitrite content is at its highest. Repeated comminution has obviously caused some of the vitrinite to part from the exinite, thus giving higher vitrite values and lower clarite values.

Since the main function of the spores in this microlithotype is to supply bitumen for the coking process, it may be desirable to add a predetermined amount of pitch in lieu thereof.

Vitrinertite:-

It appears that the vitrinertite content in the +22 mesh coal sizes is somewhat variable and does not show specific tendencies.

In the -22 mesh coal fractions, the values become practically constant for each coal. Those for Navigation and D.N.C. are of the same order (23 - 26%) but the Blesbok values are approximately 10% lower.

The values also/........19.

The values also remain fairly constant for the -100 mesh coal fractions.

It appears that this maceral is not amenable to petrographic separation (especially in the finer fractions). Its behaviour with reference to selective crushing and screening seems to be of a neutral character.

Durite:-

The durite values in this investigation follow a somewhat opposite course to that of the vitrite values. This is not by reason of any petrographical relationship but merely as a result of their different relative strengths. Since durite is about ten times harder than vitrite, it follows that it will tend to concentrate in the coarser coal fractions.

Fusite:-

The fusite values vary considerably in the screen fractions and remain relatively low.

A significant change occurs in passing to the -100 mesh coal fractions. The increase in fusite is sharp for all three coals and in some cases values higher than 20% have been recorded.

The presence of the fusite does not seem to have a profound influence on the swelling properties of the coal. The -100 mesh coal from D.N.C. had an average fusite content of 16.6% and a normal average swelling number of 6. In one particular case (Sample C57) the sample contained 18.2% fusite and gave a swelling number of 7. A sample of Navigation coal (Sample No. C37) containing 20.2% fusite gave a swelling number of 2.

It appears that the fusite is inert and its influence on the coking properties of a coal is probably only that of a diluent.

Carbonaceous Shale

The carbonaceous shale content varies considerably in the original fractions for Blesbok and Navigation coal. For D.N.C. coal it remains fairly constant. In the +⅛" fractions it becomes more constant for each coal. It again varies somewhat in the -⅛" + 22 mesh coal fractions. This variance may be due to the fact that the carbonaceous shale is to some extent being broken up in its original entities viz. vitrite, durite, semi-fusinite and the clay minerals (depending on the type of carbonaceous shale.) In the finer fractions i.e. the -22 + 100 mesh and -100 mesh fractions the carbonaceous shale remains constant for each coal, but shows in all cases slightly lower values in the -100 mesh fraction.

The decrease in carbonaceous shale content in the finest coal fraction with the sudden increase of the fusite leaves the impression that the carbonaceous shale could have broken up into its petrographic entities. The clay minerals have no reflective power to speak of and could thus easily be overlooked in the course of the petrographical analysis. This being the case, false values are to be expected. However, in some cases (which will be discussed later) it has been possible to verify the determined values by calculated values. From a comparison of these results it appears that the determined values for the carbonaceous shale are correct. This means that the carbonaceous shale did not break up into its petrographic entities.

Evaluation of the Enrichment of the Fusible Constituents.

In considering to what extent the fusible constituents were enriched by repeated crushing and screening, it must be clearly understood that the comminution of the coal samples has been very drastic. In this respect the investigation deviates somewhat from the Bürstlein process, where crushing is not carried out to such a limit. In the application of the Bürstlein process (or a variation thereof) such optimistic results cannot perhaps be expected.

The crushing of the coals proceeded in three stages.

Results obtained on the Coal from Durban Navigation Colliery

The details of the enrichment of fusibles caused by the three stages of crushing are contained in table 9 at the end of this report. Appreciable enrichment took place in the $-\frac{1}{4}$" coal after the first crushing operation as the following tabulation indicates.

Sample No.	Size.	% of Whole.	Vitrite (%)	Clarite (%)
C6C7	-22 mesh	4.6	47.9	7.5
C5	$-\frac{1}{8}$"+22 mesh	20.0	41.2	7.4
C4	$-\frac{1}{4}$"$+\frac{1}{8}$"	19.7	30.0	10.3
C3	$-\frac{1}{2}$"$+\frac{1}{4}$"	23.0	22.2	8.0
C2	-1"$+\frac{1}{2}$"	25.1	21.0	11.7
C1	+1"	7.6	19.1	13.8
Original coal (calculated)		100	28.2	9.7

Samples C6 C7 and C5 are definitely enriched. Since there is only a slight difference in the vitrite content of sample C4 and the original coal, the effect of further crushing on sample C4 must also be studied.

A summary/...........22.

A summary of the results appearing in table 9 are as follows:-

		Yield (%)	Vi (%)	Cl. (%)	Total (%)
(a)	Enrichment caused by the second crushing:	30.2	33.6	7.4	41.0
	Enrichment caused by the third crushing :	14.4	44.3	4.3	48.6
	Total enrichment:	69.0	39.0	6.8	45.8
(b)	Enrichment caused by the second crushing (excluding sample C4)	13.7	35.2	6.6	41.8
	Enrichment caused by the third crushing (Excluding Sample C4)	10.5	43.0	4.4	47.4
	Total enrichment:	68.5	37.5	7.6	45.1

It is obvious that there is no material advantage in the further crushing of Sample C4 i.e. -¼" +⅛" material.

It is also significant to note that the enrichment took place in the fine coal fractions. (Refer Table 9).

Results obtained on the coal from Navigation (S.A.C.E.) Colliery.

The details of the enrichment are to be found in Table 10. The enrichment that took place as a result of the first stage of crushing is negligible as the following table indicates:-

Sample No.	Size.	% of Whole	Vi (%)	Cl (%)
C6C7	-22 mesh	6.1	29.0	8.8
C5	-⅛"+22 mesh	12.5	25.0	11.4
C4	-¼"+⅛"	14.9	23.8	11.5
C3	-½"+¼"	20.8	22.6	11.6
C2	-1"+½"	32.8	20.3	12.0
C1	+ 1"	12.9	15.9	8.0
Original coal (calculated)		100	21.9	11.1

Only 6.1 /....................23.

Only 6.1 per cent of the whole showed a vitrite increase from 21.9 per cent to 29.0 per cent. By crushing two further stages the position becomes much more favourable as the following indicates:-

	Yield (%)	Vi (%)	Cl (%)	Total (%)
Enrichment caused by 2nd Crushing:	50.0	31.6	11.3	42.9
Enrichment caused by 3rd Crushing:	14.6	37.1	7.1	44.2
Total enrichment	70.7	32.5	10.2	42.7

Enrichment again took place in the fine coal fractions.

<u>Results obtained on the Coal from Blesbok Colliery</u>.

Although the results obtained by the first stage of crushing is somewhat better than in the case of the Navigation coal, it is still insignificant, as the following table indicates:-

Sample No.	Size.	% of Whole.	Vi(%)	Cl(%)
C6 C7	- 22 mesh	5.3	39.1	6.8
C5	-⅛"+ 22 mesh	15.4	35.6	10.7
C4	-¼"+ ⅛"	17.4	28.4	17.4
C3	-½" + ¼"	26.3	25.6	10.6
C2	-1" + %"	25.0	29.0	18.1
C1	+ 1"	10.6	22.8	13.8
Original Coal (calculated)		100	28.9	13.9

Enrichment took place in the -⅛" coal only. The results obtained by further crushing are contained in the following:-

Enrichment caused/..........24.

	Yield (%)	Vi (%)	Cl (%)	Total (%)
Enrichment caused by 2nd crushing :	17.6	38.4	11.4	49.8
Enrichment caused by 3rd crushing :	24.5	41.9	9.5	51.4
Total enrichment	62.8	39.1	10.1	49.2

Compared with Durban Navigation and Navigation coals, the Blesbok coal exhibits even a greater tendency to become enriched in the fine coal.

GENERAL:

Dilatometer Tests:-

Tests carried out on some of the coal fractions reveal that the average deformation temperature of the coal from Durban Navigation Colliery is 384°C while those of Navigation and Blesbok amount to 400°C and 404°C, respectively.

The average contraction of the coal for D.N.C. and Navigation amount to 23.4 per cent and 22.5 per cent respectively, while Blesbok coal gave an average figure of only 14.9 per cent.

The coal from Durban Navigation Colliery also gave an average expansion of 39.8 per cent. None of the samples examined from Navigation and Blesbok Collieries revealed any expansion properties whatsoever.

(No clear relationship between the fusite and carbonaceous shale content on the one hand and B.S. Swelling number and ash content on the otherhand has been found. It appears however, that there may be some relationship between the vitrite content and swelling number. This is to be expected.)

The Accuracy of the Petrographic Analyses.

From tables 1, 2 and 3 it will be noted that in many cases a coal yielding two fractions, (Sample C14 yielding C146 and C147 - see table 1 - is a good example of this) has a petrographic analysis which is not compatible with that of the two fractions obtained from it since in the case of vitrite the value obtained for sample C14 (13.1 per cent) should lie between the values obtained for the vitrite in samples C146 (15.7 per cent) and C147 (34.6 per cent). The value for sample C14,

calculated from/.......26.

calculated from the values for samples C146 and C147, is 19.9 per cent.

Wherever possible, all the values were calculated and it was found that in the case of the vitrite the average of the calculated values was 4.7 per cent higher than the average of the determined values. This phenomenon is difficult to explain since vitrite is by far the easiest microlithotype to identify.

The average difference between the determined and calculated values for the clarite amounted to 2.4 per cent which is less than the permissible error of 3%.

For the vitrinertite this difference amounted to 3.9 per cent.

In the case of the durite values the average difference amounted to no less than 6 per cent, and with a few exceptions only, the determined value was higher than the calculated value. An explanation for this discrepancy could perhaps be found in the definition of the durite as applied in South Africa. The durites in South Africa are composed of a mixture of black and grey durites. Black durite, forming a small proportion of the durites, consists of inertinite and exinite, while the grey durites, which constitute the bulk of the durites, consist of varying proportions of inertinite, exinite, vitrinite and in many cases clay minerals.

The average difference for the fusite values amounts to 2.3 per cent which is less than the permissible error. The calculated values tended to be somewhat higher than the determined values.

For the carbonaceous/.........27.

For the carbonaceous shale it was found that the average difference amounted to 2.4 per cent, again less than the permissible error. Since carbonaceous shale consists of a mixture of between 20 and 60 per cent clay minerals (by volume) and any or all of the other macerals, it appears probable that by repeated comminution the entities would separate to some extent with the consequent enrichment of the vitrite, clarite, vitrinertite, durite and fusite. A certain degree of enrichment of these microlithotypes is bound to take place but is probably small since the determined and calculated values for carbonaceous shale agree fairly closely in practically all the cases.

In order to establish whether the errors were caused by the second and/or third stage crushing and subsequent division of the samples, or during the stages of mixing the coal grains prior to, and during the moulding of the blocks, a series of tests were carried out which consisted of the following:-

After having finished a petrographical analysis, the plane of the polished surface was ground down by ca. 1 m.m. The block was then repolished and another analysis was done. By repeating this process it is possible to carry out a series of determinations until the block is so thin that it can no longer be handled. By following this procedure 6 or 7 surfaces can be obtained. Observations were carried out on six different blocks of which the particle distribution varied from 96 grains to 194 grains per cm^2. The maximum deviation from the average value in the case of the sample containing the lowest number of grains per cm^2 amounted to 3.2 per cent for the vitrite and 2.8 per cent for the durite. The

maximum deviation from/.........28.

The maximum deviation from the average values in the sample containing the highest number of grains per cm^2 amounted to 2.6 per cent for the vitrite and 3.5 per cent for the durite.

From these figures it appears that the coal grains were fairly well mixed with the Schneiderhöhn wax prior to pouring the mixture in the mould and that specific gravity separation while still in the semi-fluid state is negligible. It is more probable that the errors accurred during the crushing and dividing of the samples.

* * *

CONCLUSIONS:

Selective crushing and screening of the three coals studied has a marked influence on the enrichment of the fusible constituents.

Natural breakage during mining operations and the crushing of + 1½ inch run-of-mine coal to -1½ inch size prior to washing may serve to enrich the fusible constituents in the -¼" fraction. This was very clear in the case of the D.N.C. coal but somewhat less clear for Blesbok coal. It had virtually no influence on Navigation coal.

Navigation coal should be crushed to a relatively smaller maximum size before an appreciable enrichment of the fusible constituents will take place.

Each coal should be investigated separately to determine the relation between preparation (especially cleaning) in general and enrichment in particular.

By crushing the coal a second and third time enrichment took place only in the fine sizes which are not ordinarily of practical value.

The high percentage of fusite in the fine coal does not seem to have any deleterious effect on the coking properties of the coal.

RECOMMENDATIONS:-

In view of the fact that this investigation had certain shortcomings, it is felt that further work should be carried out but on a more practical basis.

The two main possibilities are to carry out work on either the run-of-mine coal or on the washed product. Since washing is essential and has more or less been standardized, it is more feasible to initiate investigations on the washed coal.

Assuming that the washed product shows little change in the petrographic analyses in all coal larger than $\frac{1}{4}$", separate investigations of these sizes do not seem worthwhile. The large coal should be subjected to stagewise impact degradation with the removal of the fines for investigation. The sizes of the broken coal for investigation must cover a range of 4 - 0 m.m.

Method to be followed in Comminution.

The material should be passed through the disintegrator and the -4 or -3 m.m. material removed after each pass. The process should be continued until 25 per cent has been removed. A petrographic analysis should be done on the different sizes of the fines.

This process should be repeated to get three further fines products of 25 per cent each which are then analysed

The -¼" + ⅛" portion of the -¼" coal could be subjected to similar treatment.

In case the raw coal is investigated the -1½" coal should be screened at ¼". The over and undersize should be separated at various specific gravities, say from 1.40 to 1.55. The specific gravities for treating the fines should perhaps be over a rather wider range than in the case of coarse material. A petrographic analysis should be done on each fraction.

TABLE 4.

PETROGRAPHIC ANALYSIS OF THE ORIGINAL SCREEN FRACTIONS AFTER ONE CRUSHING.

Sample Number.	Screen Size.	Petrographic Analysis. Vi %	Cl %	V.I. %	Du %	Fu %	C.S. %
56/397 C1	+1"	19.1	13.8	22.2	31.0	8.6	5.3
C2	-1"+½"	21.0	11.7	20.9	32.1	5.5	8.8
C3	-½"+¼"	22.2	8.0	20.0	34.5	8.5	6.8
(D.N.C) C4	-¼"+⅛"	30.0	10.3	20.9	29.0	2.8	7.0
C5	-⅛"+22m	41.2	7.4	18.9	20.4	5.9	6.2
C6C7	- 22m	47.9	7.5	16.9	14.9	6.4	6.4
56/398 C1	+1"	15.9	8.0	25.6	25.0	7.6	17.9
C2	-1"+½"	20.3	12.0	21.0	29.2	7.4	10.1
C3	-½"+¼"	22.6	11.6	23.9	18.5	9.2	14.2
(Navig) C4 *	-¼"+⅛"	23.8	11.5	22.3	18.9	8.9	14.6
C5	-⅛"+22m	25.0	11.4	20.6	19.3	8.6	15.1
C6C7	- 22 m	29.0	8.8	29.8	7.8	7.4	17.4
56/399 C1	+1"	22.8	13.8	10.8	36.0	9.3	7.3
C2	-1"+½"	29.0	18.1	7.3	32.2	4.8	8.6
C3	-½"+¼"	25.6	10.6	16.3	26.0	6.3	15.2
(Bles) C4	-¼"+⅛"	28.4	17.4	8.8	30.9	5.2	9.3
C5	-⅛"+22m	35.6	10.7	19.9	9.6	9.2	15.0
C6C7	- 22 m	39.1	6.8	12.3	26.9	7.5	8.3

* Estimated values.

TABLE 5.

PETROGRAPHIC ANALYSIS OF THE +$\frac{1}{8}$" COAL AFTER TWO CRUSHINGS.

Sample Number.	Originating from size fraction originally.	Petrographic Analysis.					
		Vi %	Cl %	V.I. %	Du %	Fu %	C.S. %
56/397 C14	+1"	13.1	2.1	31.5	42.6	9.0	1.7
C24 (D.N.C)	1" x $\frac{1}{2}$"	12.6	5.5	29.5	43.1	5.4	3.9
C34	$\frac{1}{2}$" x $\frac{1}{4}$"	23.5	5.6	25.0	33.7	8.9	3.3
C44	$\frac{1}{4}$" x $\frac{1}{8}$"	22.8	5.7	23.8	33.1	9.0	5.6
56/398 C14	+1"	11.9	8.7	21.8	38.5	11.6	7.5
C24 (Navig)	1 x $\frac{1}{2}$"	13.1	15.9	17.3	39.7	9.0	5.0
C34	$\frac{1}{2}$" x $\frac{1}{4}$"	15.9	17.6	21.0	32.7	7.0	5.8
C44	$\frac{1}{4}$" x $\frac{1}{8}$"	18.0	14.1	22.0	26.6	9.8	9.5
56/399 C14	+1"	15.4	8.6	11.8	45.2	7.1	11.9
C24 (Bles)	1 x $\frac{1}{2}$"	13.8	13.1	9.4	46.9	9.2	7.6
C34	$\frac{1}{2}$" x $\frac{1}{4}$"	20.4	12.5	16.0	36.5	5.8	8.9
C44	$\frac{1}{4}$" x $\frac{1}{8}$"	29.7	13.9	11.3	30.0	6.3	8.8

TABLE 6.

PETROGRAPHIC ANALYSIS OF THE -⅛" + 22 MESH COAL AFTER TWO CRUSHINGS.

Sample Number.	Originating from size fraction originally	Petrographic Analysis.					
		Vi %	Cl %	V.I. %	Du %	Fu %	C.S. %
56/397 C15	+1"	13.4	7.6	26.8	41.6	4.1	6.5
C25	-1" + ½"	15.2	10.6	22.1	43.3	6.6	2.2
(D.N.C) C35	-½" + ¼"	25.1	7.4	24.4	33.9	5.8	3.4
C45	-¼" + ⅛"	28.9	8.8	19.6	32.0	6.0	4.7
56/398 C15	+1"	22.0	11.7	14.9	33.4	9.8	8.2
C25	-1" + ½"	20.6	14.3	26.5	26.4	8.1	4.1
(Navig) C35	-½" + ¼"	30.1	15.2	18.8	17.7	13.9	4.3
C45	-¼" + ⅛"	30.1	9.4	27.1	20.7	7.5	5.5
56/399 C15	+1"	24.8	7.6	17.9	36.4	9.1	4.2
C25	-1" + ½"	20.4	9.5	13.5	41.2	9.2	6.2
(Cles) C35	-½" + ¼"	25.6	13.5	18.6	28.5	3.8	10.0
C45	-¼" + ⅛"	24.7	14.7	12.6	34.5	6.2	7.3

TABLE 7.

PETROGRAPHIC ANALYSIS OF THE -22+ 100 MESH COAL.

Sample Number.	Number of Crushings.	Petrographic Analysis.					
		Vi %	Cl %	V.I. %	Du %	Fu %	C.S. %
56/397							
C146	3	(15.7	4.5	23.1	46.8	6.5	3.4
C246	3	(15.0	7.6	24.4	42.1	5.7	5.2
C346	3	(19.7	13.1	20.4	38.1	6.1	2.6
C446	3	(20.7	5.3	28.2	32.2	8.7	4.9
C156	3	14.3	9.9	19.8	43.7	4.6	7.7
D.N.C. C256	3	25.8	6.1	22.9	36.6	6.0	2.6
C356	3	23.0	8.2	19.0	35.7	7.9	6.1
C456	3	24.3	14.0	18.1	33.0	8.2	2.4
C 56	1	38.0	7.2	23.2	22.5	6.7	2.4
C16	2	21.4	4.2	28.4	38.0	4.0	4.0
C26	2	28.8	5.6	25.1	29.0	8.6	2.9
C36	2	31.9	10.6	24.2	26.3	6.0	1.0
C46	2	37.3	7.5	20.6	23.2	8.2	3.2
56/398							
C146	3	13.0	17.4	37.4	19.7	5.6	6.9
C246	3	16.4	12.2	19.2	40.2	6.5	5.5
C346	3	19.8	14.2	28.4	30.0	2.3	5.3
C446	3	10.5	12.3	27.9	25.9	4.3	19.1
Navig.							
C156	3						
C256	3	19.6	15.8	25.9	33.8	3.2	1.7
C356	3	23.3	16.0	23.5	29.8	5.1	2.3
C456	3	22.2	16.1	25.0	18.9	6.7	11.1
C 56	1	32.9	11.8	23.5	20.0	2.5	9.3
C 16	2	16.9	9.1	34.6	27.5	5.6	6.3
C 26	2	26.0	12.1	28.9	20.7	4.3	8.0
C 36	2	27.2	15.4	21.9	20.1	3.2	12.2
C 46	2	21.3	13.6	22.0	16.6	2.7	23.8
56/399							
C146	3	10.2	11.2	18.0	44.5	6.8	9.3
C246	3	17.0	19.4	16.2	22.5	10.2	14.7
C346	3	15.0	18.7	14.4	32.7	6.5	12.7
C446	3	15.9	15.1	19.6	36.9	5.0	7.5
Bles.							
C156	3	21.5	11.4	14.4	39.8	5.8	7.1
C256	3	21.0	13.4	15.4	36.1	5.5	8.6
C356	3	19.6	17.5	13.3	33.8	5.1	10.7
C456	3	32.0	15.8	13.4	28.1	3.5	7.2
C 56	1	38.0	12.5	18.1	19.8	6.1	5.5
C 16	2	29.8	11.3	13.4	36.4	2.6	6.5
C 26	2	25.5	9.9	10.5	38.2	5.4	10.5
C 36	2	36.5	12.4	18.2	17.7	6.6	8.6
C 46	2	40.3	16.0	9.1	20.2	4.8	9.6

TABLE 8.

PETROGRAPHIC ANALYSIS OF THE -100 MESH COAL.

Sample Number.	Number of Crushings	Petrographic Analysis.					
		Vi %	Cl %	V.I. %	Du %	Fu %	C.S. %
56/397							
C147	3	34.6	4.4	26.9	15.9	16.3	1.9
C247	3	34.9	4.2	22.6	17.6	18.4	2.3
C347	3	35.3	6.8	19.2	22.1	13.8	2.8
C447	3	42.4	5.3	11.6	19.4	18.9	2.4
C157	3	39.9	4.0	17.9	18.9	17.6	1.7
C257	3	43.0	4.5	17.4	20.3	13.0	1.8
C357	3	48.9	3.9	14.5	15.8	16.2	0.7
D.N.C. C457	3	48.8	4.6	15.3	10.5	18.1	2.7
C 17	2	43.4	4.1	21.5	12.2	18.3	0.5
C 27	2	45.8	3.6	17.9	13.8	17.2	1.7
C 37	2	48.8	3.2	14.3	14.6	17.0	2.1
C 47	2	53.4	2.9	13.8	11.0	16.8	2.1
C 57	2	51.0	3.4	12.8	9.7	18.2	4.9
56/398							
C147	3	25.3	6.1	20.2	22.7	19.7	6.0
C247	3	33.7	7.2	16.6	20.0	20.0	2.5
C347	3	28.6	8.3	21.9	17.6	17.8	5.8
C447	3	34.2	2.1	16.5	17.1	23.4	6.7
C157	3	27.9	7.1	19.8	22.2	19.3	3.7
C257	3	36.3	7.7	22.1	14.0	18.3	1.6
Navig. C357	3	43.9	8.3	19.5	11.8	14.7	1.8
C457	3	40.7	5.4	17.5	11.0	19.4	6.0
C 17	2	34.1	5.9	21.8	14.0	18.2	6.0
C 27	2	42.2	6.1	17.0	14.6	16.7	3.4
C 37	2	38.5	5.1	20.8	12.7	20.2	2.7
C 47	2	34.8	6.4	20.4	15.8	17.7	4.9
C 57	2	40.5	4.0	14.0	12.5	24.7	4.3
56/399							
C147	3	35.6	11.6	13.7	20.0	14.4	4.7
C247	3	35.7	6.1	12.9	20.1	14.9	10.3
C347	3	46.5	5.7	14.4	15.9	14.8	2.7
C447	3	45.8	6.4	20.2	15.3	10.8	1.5
Blesbok C157	3	46.1	6.4	11.2	17.4	14.1	4.8
C257	3	47.9	4.2	15.2	14.9	16.1	1.7
C357	3	46.9	7.4	16.4	14.2	12.9	2.2
C457	3	52.6	7.9	12.2	10.0	14.8	2.5
C 17	2	43.0	4.7	10.9	20.4	15.4	5.6
C 27	2	44.0	5.8	14.0	13.7	16.3	6.2
C 37	2	50.0	7.4	7.9	16.3	15.5	2.3
C 47	2	55.0	5.9	11.1	9.3	15.1	3.6
C 57	2	53.7	3.6	11.3	8.9	19.7	2.8