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FUEL RESEARCH INSTITUTE
OF SOUTH AFRICA.

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SUBJECT:
ONDERWERP: A PRELIMINARY STUDY OF THE TECHNICAL AND ECONOMIC ASPECTS OF WASHING A CERTAIN WITBANK DUFF IN A CYCLONE IN ORDER TO RECOVER THE COKING FRACTION.

DIVISION:
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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

REPORT NO. 2 OF 1952.

A PRELIMINARY STUDY OF THE TECHNICAL AND ECONOMIC ASPECTS OF WASHING A CERTAIN WITBANK DUFF IN A CYCLONE IN ORDER TO RECOVER THE COKING FRACTION.

INTRODUCTION:

A float and sink survey of the smaller sizes of coal produced as natural arisings in the Witbank area indicated that many of these coals contained a reasonably high proportion of coking coal and that this coking fraction was concentrated in the material floating at about 1.35 specific gravity. The next step was then to investigate the problem of recovering the coking coal on a commercial scale. A detailed study was consequently made of the various fine coal cleaning processes and it was finally concluded that the cyclone washer was the only known process which showed promise of solving this formidable washing problem. The application of this washer to Witbank fine coal for the purpose of recovering the coking fraction was then carefully studied on semi-pilot plant scale. This work indicated that from the technical point of view it should be quite feasible to effect the desired separation in practice.

The question now arises whether it will pay to recover the coking coal as suggested. Since this is the most important question of all as far as the producers of coal are concerned, it warrants the closest study. In the present paper some aspects of this problem are examined.

Since circumstances vary from colliery to colliery, it is virtually impossible to generalise and it was decided to focus attention on a specific hypothetical problem which could possibly be encountered in practice.

THE PROBLEM:/........

THE PROBLEM:

Assume a certain colliery in Witbank is washing 8 inches to zero coal in a Baum jig and that the duff ($-\frac{1}{4}$" + 0) is washed at 1.6 specific gravity, 100 tons of washed duff being produced per hour. Assume further that all the washed duff can be sold at 5/- per ton at pithead. It is required to investigate whether it would be an economic proposition to rewash the duff at 1.35 specific gravity in order to produce a coking fraction. It may be assumed that the middlings fraction (i.e. 1.35 - 1.6 S.G.) can also be sold for 5/- per ton provided that it is of satisfactory quality.

The investigation may broadly be divided into three phases.

(A) A study of the composition of the coal, selection of the plant and estimation of the quality of the products likely to be obtained in practice.

(B) Estimation of the capital and operating cost of the plant.

(C) A study of the economic potentialities of the procedure outlined above.

(A) (1) Composition of the Raw Duff:

In order that the investigation should have some practical basis, a fresh sample of a typical raw duff coal was procured from a colliery in the Witbank area and this was then regarded as the raw material being treated by the Baum jig.

After screening out and discarding all $+\frac{1}{4}$" material, the remaining duff was screened into three size fractions (viz. $-\frac{1}{4}$" + 20 mesh Tyler, -20 + 48 mesh Tyler and -48 mesh Tyler) and two samples were prepared from each size fraction. The one set of samples thus obtained was subjected to float and sink analysis at 1.35 and 1.6 specific gravity while the other set of samples

was floated/........

was floated at a large number of intermediate specific gravities, in order to study the composition of the raw material in greater detail. Ash content, swelling number, calorific value and volatile matter content values were determined for those specific gravity fractions which were considered to be of special interest.

The results of the screen analysis are reported in Table 1, taking minus ¼" material as 100%, and the results of the float and sink and other analyses are reported in Tables 2 and 3.

TABLE 1.

SCREEN ANALYSIS OF THE RAW DUFF (-¼" + 0 taken as 100%.)

Fraction.	%.
-¼" + 20 mesh	71.3
-20 + 48 mesh	15.9
-48 mesh + 0	12.8
Total	100.0

TABLE 2/.........

TABLE 2.

RESULTS OF FLOAT AND SINK ANALYSIS AT 1.35 AND 1.6 SPECIFIC GRAVITIES.

Specific Gravity Fraction.	Screen Fraction.														
	$-\frac{1}{4}$" + 20 mesh.					-20mesh + 48 mesh					-48mesh + 0				
	Yield %.	Ash %.	Sw. No.	Cal. Val.	Vol. %.	Yield %.	Ash %.	Sw. No.	Cal. Val.	Vol. %.	Yield %.	Ash %.	Sw. No.	Cal. Val.	Volatile %.
<1.35	34.6	4.5	5	14.45	34.2	36.9	3.7	6	14.34	35.2	27.9	4.4	5	-	34.0
1.35 - 1.6	54.5	13.3	1Ag	12.54	24.3	49.5	11.3	1Ag	12.75	24.3	56.7	11.0	1Ag	-	-
>1.6	10.9	45.6	-	-	-	13.6	47.7	-	-	-	15.4	45.2	-	-	-
Total	100.0	-	-	-	-	100.0	-	-	-	-	100.0	-	-	-	-

TABLE 3/............

TABLE 3.

RESULTS OF DETAILED FLOAT AND SINK ANALYSIS.

Specific Gravity Fraction.	Screen Fraction.						Specific Gravity Fraction.	Screen Fraction.		
	$-\frac{1}{4}$" + 20#			-20# + 48#				-48# + 0		
	Yield %.	Ash %.	Sw. No.	Yield %.	Ash %.	Sw. No.		Yield %.	Ash %.	Swelling No.
<1.30	12.9	3.1	5	19.2	2.9	5	<1.3	15.1	2.4	$3\frac{1}{2}$
1.30-1.32	8.6	4.9	$5\frac{1}{2}$	9.5	4.4	$4\frac{1}{2}$	1.3-1.35	12.6	4.8	3
1.32-1.34	7.1	5.9	$3\frac{1}{2}$	5.1	5.7	2	1.35-1.4	15.5	6.5	1Ag
1.34-1.36	10.2	6.7	1Ag	6.9	6.3	1Ag	1.4-1.45	18.3	10.4	
1.36-1.38	7.9	8.1	1Ag	5.1	7.1		1.45-1.5	13.1	11.3	
1.38-1.40	7.7	9.2		5.9	8.1		1.5-1.6	9.5	19.2	
1.40-1.42	7.4	10.6		9.7	9.1		>1.6	15.9	46.4	
1.42-1.45	8.8	12.5		8.0	11.6					
1.45-1.5	13.3	19.1		8.0	14.5					
1.5-1.6	5.2	24.2		9.1	20.9					
>1.6	10.9	44.2		13.5	46.4					
Total	100.0	-	-	100.0	-	-	Total	100.0	-	-

If the values in Table 2 are compared with those in Table 3 for the appropriate specific gravities and suitable calculations are made it will be found that the agreement as regards yield is very close in all cases. It will be noted, however, that the values of the swelling number are lower in Table 3 than in Table 2, the difference being quite appreciable in the case of the finest fraction. Now carbon tetrachloride-benzole mixtures were used for float and sink analysis and it is concluded from the difference in the swelling numbers that repeated immersion in carbon tetrochloride with intermediate drying of the fractions adversely affects the swelling properties of the coal, particularly in the case of fine material which has a greater exposed surface than coarse coal per unit of weight.

From this/..........

From this it may be inferred that the true swelling indices of the specific gravity fractions are actually somewhat higher than those shown in Table 3. However, this fact is of little consequence for the purpose of the present investigation, except that some allowance has been made for it in estimating the quality of the products expected in practice.

It will be clear from Table 2 that it should be possible, theoretically, to recover a substantial quantity of high quality coking coal from the raw duff by effecting a separation in the region of 1.35 specific gravity. In addition, the middlings fraction (1.35-1.6) should be quite acceptable as a boiler fuel.

The results in Table 3 are most interesting and have an important bearing on the possibilities of recovering the coking fraction on a commercial scale. Thus it will be seen that the swelling constituents of the raw -¼" + 20 and -20 + 48 mesh fractions is confined to material floating at about 1.34 or 1.35 specific gravity. If the separation were effected at, say, 1.4 specific gravity the coking fraction would merely be diluted with non-swelling material, and since the swelling index of the coking constituents is not unduly high, the mixture may lose much of its value as a coking coal. In other words, in order to obtain the best coking coal, the theoretical separation to be aimed at should be at the specific gravity representing the boundry between swelling and non-swelling coal i.e. about 1.35 specific gravity. In practice, however, the separation will not be perfect and there is bound to be misplaced material i.e. some of the coking constituent will be lost and inert material will be recovered in the coking product. The less efficient the process the greater will be the relative proportions of the misplaced material and the lower will be the swelling index of the coking product. If the process is not very efficient it may be

possible/.........

possible to produce a coking product of satisfactory quality by reducing the specific gravity of separation (i.e. there will then be coking coal on both sides of the cutpoint and the effect of misplaced material will not be quite so great) but this will naturally result in loss of yield. Clearly, therefore, only by using the most efficient process possible can one hope to obtain the maximum possible yield of coking coal of acceptable quality. The cyclone washer using heavy medium is the most efficient fine coal cleaning process known at present and its application must, therefore, be considered. In fact, the author is of the opinion that it is the only process which could be considered for this separation despite claims to the contrary by certain renowned authorities.

The cyclone washer employing heavy medium has already been used in practice for treating iron ore etc. and has been used for some time on large pilot plant scale (35 tons per hour) for the beneficiation of fine coal and the so-called technical difficulties have apparently been overcome to such an extent that several large plants for treating coal have already been ordered in Europe and are at present in the course of erection. The cyclone washer has thus passed the laboratory stage and must be regarded as being in the picture for commercial application.

(2) The Application of the Cyclone Washer :

The cyclone may be used in 2 ways in order to effect a separation according to specific gravity viz.

(a) Using a heavy medium suspension.

(b) Using water alone.

The latter is clearly the cheaper installation and therefore, the more attractive if cost only is considered. However, when using the cyclone with heavy medium the separation is extremely sharp and the products closely approach those obtained by float and sink analysis while the separation with water alone is relatively poor. Without going into details, the author is of the opinion/.........

the opinion that the use of the cyclone with water alone is out of the question for the desired separation, at least in the case of the larger sizes. Its possible application to the slurry will be considered in due course. Further analysis will thus be based on the assumption that heavy medium will be used.

While there are many potential media for use in a cyclone, the general concensus of opinion seems to be that magnetite (or other magnetic media) is the most suitable and for the present the discussion will be confined to this material. However, in practice other media will also have to be carefully considered before final action is taken.

When washing fine coal in a heavy medium suspension, the separation of the washed products from the medium becomes a major problem. As a first step, the products can be rinsed on vibrating screens. However, $\frac{1}{2}$ mm. aperture screen cloth is about the finest which could be used in practice, with the result that $-\frac{1}{2}$ mm. coal and dirt will pass through with the medium and some other method must be used to recover these small particles. By using magnetite, magnetic separation, a very exact method, may be employed to effect this separation. If it is desired to keep the fine coal and fine dirt (or middlings in this case) separate, a twin magnetic circuit will have to be provided which, in effect, implies duplication of equipment. In addition, the greater the amount of fines present the greater the capacity of the magnetic separators to be installed. Magnetic separators are relatively costly pieces of equipment and if it is desired to clean the coal down to zero size the capital cost of the plant is liable to be substantially higher than would be the case if the bottom size is limited to say $\frac{1}{2}$ mm. The cost is naturally influenced by the percentage of fines in the coal. In Europe, the coal is often friable and the percentage of fines is high and the general policy is to remove as much as possible of the minus $\frac{1}{2}$ mm. material prior to washing.

This operation/.......

This operation is naturally not 100% efficient and in Europe it is not unusual for the deslimed product to contain anything up to 10 or 15% of coal smaller than ½ mm. Having deslimed the coal, the practice is to recover the products at ½ mm. on screens and the underflow is sent to a common magnetic circuit where all non-magnetic slimes (i.e. coal and dirt) are rejected together. It is absolutely necessary to remove these slimes in order to control the viscosity of the suspension. In effect, coal under ½ mm. in size present in the feed is not washed (except for that portion of it which adheres to the coarser products.) In South Africa the percentage of fines is relatively low (see Table 1) and it is doubtful whether preliminary dedusting or desliming would be necessary as a general rule, but the economic aspects will have to be studied carefully before it can be decided whether it will pay to recover the fine coal and dirt separately as explained above. Fortunately, in the present case this difficulty does not arise. The raw duff is first washed at 1.6 specific gravity in a Baum jig together with other sizes and only the washed duff is to be rewashed in the cyclone at 1.35 specific gravity. During washing in the Baum, the extreme fines will automatically be lost to the jig slurry system and the washed duff can thus be regarded as being deslimed. For the purpose of the present investigation it will be assumed that all minus 48 mesh material in the raw duff goes to the jig slurry circuit.

A detailed screen analysis of the -20 + 48 mesh fraction is shown in Table 4.

TABLE 4.

SCREEN ANALYSIS OF THE -20 + 48 MESH FRACTION.

Screen Size (Tyler)	Percentage of the Raw Duff.
-20 + 24	3.4
-24 + 32	5.8
-32 + 35	2.1
-35 + 48	4.6
Total:	15.9

Now/.......

Now a 32 mesh Tyler screen has $\frac{1}{2}$ mm. aperture, and it follows that if "deslimed" duff is treated in the cyclone washer, a maximum of about 7% of the raw duff will be lost through the cyclone rinsing screens. It hardly appears worth while to go to the added expense of recovering this material separately. It would be simpler to use a single magnetic circuit and to allow the non-magnetic rejects to join the jig slurry system.

The above considerations lead to the conclusion that $-\frac{1}{4}$" + $\frac{1}{2}$ mm. material should be washed in the cyclone with medium. The $-\frac{1}{2}$ mm. material will be available as a slurry and its recovery will be considered later.

THE TREATMENT OF $-\frac{1}{4}$" + $\frac{1}{2}$ MM. MATERIAL:

When treating a wide size range in a cyclone with medium, the specific gravity of separation is not constant for all sizes but increases with decreasing particle size. Thus if the mean specific gravity of separation for the $-\frac{1}{4}$" + 20 mesh fraction is 1.35, the mean specific gravity of separation for the -20 + 48 mesh fraction is likely to be about 1.38 and that of the -48 mesh + 0 fraction (assuming all the coal is washed in medium) is likely to be of the order of 1.45. For the purpose of the present investigation, it will be assumed that the washability characteristics of the -20 + $\frac{1}{2}$ mm. fraction is similar to that of the -20 + 48 mesh fraction for which data is available. By applying known cyclone partition curves to the washability curves of the $-\frac{1}{4}$" + 20 mesh and -20 + 48 mesh fractions (the latter to represent -20 + $\frac{1}{2}$ mm. fraction) at 1.35 and 1.38 specific gravities respectively, it was estimated that the values shown in Table 5 would represent the results likely to be obtained in practice. In order to obtain the swelling numbers and other data, the various specific gravity fractions (Table 3) were actually mixed in the appropriate proportions to obtain a

practical/........

"practical" product, which was analysed.

TABLE 5.

ESTIMATED RESULTS LIKELY TO BE OBTAINED IN PRACTICE WHEN WASHING -¼" + ½ MM. COAL IN A CYCLONE.

Screen Fraction.	S. G. of Separation.	Yield of Coking Coal as % of Fraction.	Sw. No.	Ash %.	Cal. Val. lb/lb.	Yield of Coking Coal as % of Raw Duff.
-¼" + 20 mesh	1.35	35.0	4½	5	14.19	25.0
-20 mesh + ½mm.	1.38	44.6	4	5	14.11	4.1
Total -¼" +½ mm.	-	-	4-4½	5	14.18	29.1

Thus by treating only the -¼" + ½ mm. fraction, it appears possible to recover about 29% of the raw duff as coking coal having about 5% ash, 4 to 4½ swelling number, 7 to 8% moisture, and probably 34% volatile matter, a product which should be most acceptable particularly to the steel industry. On the basis of coal actually sent to the cyclone (i.e. duff washed at 1.6 specific gravity in the Baum and deslimed at, say, 48 mesh) the yield of coking fraction would be of the order of 37.5 per cent, allowing for the -½ mm. + 48 mesh material not treated in the cyclone. About 55% of the remainder of the cyclone feed will be recovered as middlings and 7½% will be lost as slurry. It was also estimated that the final middlings fraction would have roughly the following properties:-

13.5% ash, 12.5 lb/lb calorific value, 24% volatile matter and 7 to 8% moisture. In arriving at these figures allowance was also made for the fact that the Baum jig will not make a perfect separation at 1.6 specific gravity. From the above values it appears that the middlings should be quite satisfactory for steam raising purposes.

The Treatment of -½ mm. Material:

The plus ½ mm. material in the raw duff has now been taken care of and only the -½ mm. + 0 fraction remains to be considered. It will be noted in Tables 1 and 4 that this fraction amounts to some 19.5% of the raw duff and can not, therefore, be disregarded. Due to size degradation in the plant as a whole, the actual amount of slurry produced may be substantia lly greater but this can not be considered at present.

For the purpose of the present investigation it will be assumed that the slurry from the existing washery is run to waste as is the usual practice in South Africa. Thus, in both the present set up and the proposed cyclone arrangement, the slurry represents waste material and the cyclone plant would only be penalised to the extent of the additional slurry produced. Utilisation of the slurry must, therefore, be regarded as an entirely separate problem.

There are several possible uses for this slurry; e.g.:

(1) In the existing plant, a portion or all of the slurry could be blended with the washed duff either with or without preliminary cleaning.

(2) If a cyclone is used to treat the washed duff, a portion or all of the slurry could be blended with the middlings fraction.

(3) The coking fraction could be recovered from the slurry for blending with that obtained from the cyclone plant.

It is beyond the scope of the present paper to discuss all these possibilities fully and only the preparation of a coking fraction from the slurry will be considered. There is bound to be a market for fine coking coal, while it may be more difficult to dispose of slurry in South Africa for steam raising purposes even when mixed with a coarser fraction.

For purposes of discussion it will be assumed that the composition of the -48 mesh + 0 fraction is representative of the entire slurry.

Clearly a cyclone plant using medium to treat slurry would be a very costly one, as previously explained, and can probably be ruled out without detailed investigation. However, a cyclone with water may be a possible solution and will now be considered from a theoretical point of view. Actual tests in a cyclone with water will have to be conducted before the final decision is made.

By applying a partition curve of a cyclone with water to the washability data of the -48 mesh + 0 fraction it was estimated that about 35% of the slurry (6.8% of the raw duff) could be recovered and that this product would have about 9% ash content and a swelling number of about 2. Assuming a vacuum filter is used to dewater the product a moisture content of about 20 - 22% could be expected. Now, the ratio of coking fraction recovered from -¼" + ½ mm. coal to coking fraction recovered from slurry is likely to be of the order of 3.5 or 4 to 1. A blend of the two should yield a product having a swelling number of 3½ to 4, an ash content of 6% and a moisture content of 10 to 11% and it will represent about 36% of the raw duff. This material should be quite acceptable as a blend coking coal for metallurgical purposes. The remainder of the slurry could either be run to waste using the existing arrangements for this purpose or a proportion of it could be blended with the middlings with or without further cleaning at a higher gravity. These alternatives will not, however, be considered at this stage.

Froth flotation has not been mentioned as a possible method of recovering the coking fraction from the slurry because the operating cost is high (of the order of 5/- per ton input including interest and depreciation). Moreover it has not yet been possible to demonstrate in South Africa that bright coking coal can be separated from shale and dull coal by means of froth flotation.

It is/........

It is now necessary to investigate the economic possibilities of rewashing the $-\frac{1}{4}$" + $\frac{1}{2}$ mm. washed duff in a cyclone with medium and of treating the slurry in a cyclone with water.

(B) (1) Capital Cost of the Plant:

(a) Cyclone with Medium:

Since the duff has been washed in a jig, it can be assumed that it will have been deslimed, probably at about 48 mesh, as previously stated, and hence no provision need be made for desliming the coal. In addition, any coal slurry from the cyclone plant could join the existing slurry circuit of the jig, assuming that this circuit is large enough to handle the small additional quantity. Since Witbank duff is reasonably hard, it could be pumped with the suspension and thus eliminate a costly elevator which would be required if a gravity head feed were used. The nature of the feed conveyor to the cyclone plant depends on the jig plant layout and can only be provided for by allowing a nominal sum. Similarly, a nominal sum will have to be taken for the conveyors to dispose of the coking fraction and middlings. It will also be assumed that washed duff bunkers have been provided in the existing washery and that it will be possible to allow the cyclone products to drain in these. Deslimed duff drains readily so that large bunkers are not required and, in addition, more than enough time should be available during railway transportation for the material to have not more than 7 or 8% of moisture on arrival at the consumer, hence centrifugal drying need not even be considered.

It will be assumed that magnetite will be used as medium and, as stated previously, in order to eliminate a duplicate magnetic circuit it will be assumed that only plus $\frac{1}{2}$ mm. material will be recovered separately. As a first approximation, it will be assumed that ready milled magnetite will be purchased, hence a

ball mill/.......

ball mill will not be included. Actually, it should be cheaper and probably preferable to mill the magnetite on site but this need not be considered in the present analysis.

On the above basis, the main flow sheet will roughly follow the basic lines indicated in Figure 1 (the flow sheet is only intended to show the major new components for estimating purposes and is relatively incomplete.)

The cost of the installation may now be considered. The whole plant is actually extremely small and the components can largely be arranged as convenient hence the plant can frequently be fitted into an existing Baum washery of reasonably roomy design. However, for safety a nominal sum will be included to cover possible additions to the building. It will be appreciated that it is extremely difficult to estimate the total cost of an additional plant unless all details relating to the layout etc. of the existing plant are known. Without these details one can only hope to arrive at a figure representing the order of magnitude (preferably too high for a first approximation) and this must be borne in mind when studying the present paper.

The major components of the plant together with their estimated cost in South Africa are listed in Table 6.

TABLE 6./........

TABLE 6.

MAJOR COMPONENTS OF 100 TONS PER HOUR CYCLONE PLANT.

Component.	Remarks.	Estimated Cost in South Africa.
(1) Feed Conveyor	Nominal sum.	£1000
(2) Mixing tank.		£400 (2)
(3) Medium pump with motor and starter.	1200 gals./min. capacity.	£1200 (1)
(4) 5 Cyclones.	4 in use, 1 standby.	£400
(5) Medium rinsing screens for coking coal and middlings.	2,10'x4' vibrating screens for coal. 2,10'x4' vibrating screens for middling.	£5000 (1)
(6) Coking coal conveyor.	Nominal sum.	£1000
(7) Middlings conveyor.	Nominal sum.	£1000
(8) Magnetic separators.	2, 48" wide Dings separators ($8,000 each in U.S.A.)	£8000
(9) Medium Thickeners.	2, each 21' diameter.	£1500 (2)
(10) Water pump with motor and starter.	1800 gals/min. capacity.	£1500 (1)
(11) Sundry pumps, sumps, instruments etc.		£4000
(Total component cost)		£25,000

(1) Quotation by local firm.

(2) Estimated on the basis of £150 per ton of metal for ¼" plate.

The cost of erecting standard components can usually be taken as about 20% of the total component cost i.e. £5,000 However, an additional £5000 will be allowed for erection, including pipe work, making £10,000 in all. Provision must also be made for the royalty to be paid for using the plant and £5000 will be allowed for this purpose. If another £10,000 is allowed for contingencies, it appears that the total cost of the erected plant should be of the order of £50,000. To this must

be added/.......

be added the cost of alterations and additions to the washery building. Allowing a substantial sum for this, say, £20,000, it appears that the total capital outlay should not exceed about £70,000. The items constituting the total estimated cost of the plant are summarised in Table 7.

TABLE 7.

SUMMARY OF CAPITAL COST OF 100 TONS/HOUR CYCLONE PLANT.

Cost of components	£25,000
Erection cost	£10,000
Royalty	£ 5,000
Allowance for contingencies	£10,000
Total cost of unit erected	£50,000
Alterations and additions to building ...	£20,000
Total cost of plant	£70,000

In all further calculations, the capital cost of the plant will be taken as £70,000 which is considered to be a reasonable reflection of the maximum outlay in normal circumstances.

(b) Cyclone with Water for Slurry Treatment:

The ratio between the amount of Baum washed duff and the amount of slurry can be expected to be about 3.5 to 1. Thus if the main cyclone plant has a capacity of 100 tons per hour of feed, the slurry plant will have to be capable of treating about 30 tons per hour. It will be assumed that the discards from this plant will be run to waste in the existing slurry circuit, thus provision will only have to be made to recover the coking fraction (35%) on a vacuum filter. The vacuum filter will thus only be required to have a capacity of about 10 tons per hour, and only about 250 square feet of filter area will be required - quite a small unit. In addition to the filter drums (say 2, each of 125 square feet area) the following ancilliary equipment is required for the filtration plant.

2 vacuum/.........

2 Vacuum pumps, each pump having a capacity of 350 ft^3 of free air per minute and an installed horsepower of 15.

2 Blowers each delivering 250 ft^3 of free air per minute and an installed H.P. of 7½.

2 Extraction tanks each of 50 ft^3 capacity.

2 Extraction pumps each of 30 gallons per minute and installed H.P. of 7½.

The filtration plant will probably constitute the major item of cost and has therefore been specified in detail.

Baum plants are usually provided with some form of thickener for slurry (Spitz Kasten or the familiar "Tower") so it will be assumed that the slurry plant can be supplied with feed of suitable consistency without additional cost.

The flow sheet which will be required will probably follow the basic lines indicated in Figure 2 - only new items of equipment are shown.

Additional storage bunkers may be required but since the existing layout is not known these can not be taken into account.

Unfortunately, the operating characteristics of the cyclone with water are not known at present so that it is only possible to guess at the total volume of slurry to be handled and its distribution on the basis of experience with the cyclone using medium and hence the duty of the pump, thickener etc.

The major components are listed in Table 8 together with their estimated cost.

TABLE 8.

MAJOR COMPONENTS OF A 30 TONS PER HOUR CYCLONE SLURRY PLANT.

Component.	Remarks.	Estimated Cost.
(1) Pump sump		£200
(2) Pump with motor and starter.	800 gals/min.	£1000
(3) 3 Cyclones	2 in use, 1 standby	£250
(4) Thickener	30 ft. dia.	£1200
(5) Diaphragm pump and motor.		£550
(6) Filtration plant.	Price is guessed	£5000
(7) Conveyor		£400
(8) Paddle mixer		£400
(9) Unforseen		£1000
	Total Component Cost:	£10,000

Taking 20% of the component cost as erection cost and allowing a further £3,000 for royalty and contingencies it appears that the total cost of the plant should be of the order of £15,000. The thickener may be placed outside if necessary and the rest of the plant should occupy a very small space, thus it is not anticipated that additional building will be required.

OPERATING COST OF THE PLANT./......

OPERATING COST OF THE PLANT:

(a) 100 Tons/Hour Cyclone Plant Using Magnetite.

The following calculations are based on the Dutch State Mines experience with the 35 tons per hour pilot plant at Emma Colliery.

Labour.

One operator per shift is required at Emma and it is considered that one operator should be sufficient for a 100 tons per hour plant (in all probability the Baum operator could exercise the necessary supervision, but this possibility will be neglected for the present.) Assume a European operator receives a monthly wage of £80 and allow him one native assistant at a monthly wage of £10. Maintenance labour required at Emma is equivalent to ½ fitter per shift, thus a 100 tons per hour plant could be expected to require one fitter per shift, at a monthly wage of, say, £80. Assuming the fitter also has a native assistant, the monthly wage bill should be about £180 or about £2,200 per annum for single shift operation.

Assume the plant operates 5½, 8 hour shifts or 44 hours per week and 48 weeks per year. Hence total operation per annum is about 2,100 hours and assuming the plant is operating at full load all the time, 210,000 tons of raw coal can be treated. Hence labour cost per ton input =

$$\frac{£2,200}{210,000} = 2.5 \text{ pence.}$$

Assuming the average load for the year to be 90% full load, labour cost per ton input is approximately 2.8 pence.

Medium.

Medium consumption at Emma is approximately 1½ lb. magnetite per ton input. Assume that due to lack of experience it will be 2 lb. per ton. Assuming milled magnetite costs £8.10.0d. per ton on site, medium cost is approximately 2 pence per ton input.

Power./......

Power.

Power consumption at Emma is 4 H.P. per ton input. To allow for additional conveying etc. which may be necessary power consumption will be taken as 5 H.P. or roughly 4 K.W. hours per ton treated. Assuming power cost to be $\frac{1}{2}$ penny per kilowatt hour, power cost per ton input is 2 pence.

Stores.

Only the main items requiring periodic replacement will be considered.

The life of the screen cloth on the rinsing and drainage screens can be taken as approximately 2,000 hours and at 90% full load this represents 180,000 tons of raw coal treated. The total screen area is 160 square feet and taking the cost of good quality stainless steel screening ($\frac{1}{2}$ mm. aperture) at 25/- per square foot, the total cost of replacement is £200. Hence cost per ton input $= \frac{£200}{180,000} = 0.267$ pence, say 0.3 pence

Roughly speaking a cyclone constructed of mild steel also has a life of 2000 hours. Assuming 4 cyclones in use costing £80 each and 90% full load, the cost per ton input is approximately 0.4 pence.

Pump impellors and wear plates also have a life of about 2000 hours. Taking the total replacement cost at £500 for all pumps (this should be adequate to allow for damage to shafts, glands etc.) and allowing a further £200 for replacement of pipes the total cost per ton input at 90% load is approximately 0.9 pence.

Since the major items only amount to about $1\frac{1}{2}$ pence per ton input, an additional 2 pence per ton should be more than adequate for unforseen stores including oil and grease.

Capital Redemption.

Assume the plant will be operated one shift per day and that it is to be written off in 14 years (this is an average figure and includes the building.) Residual value of the plant

and building/.....

and building and interest on the annual sum provided for capital redemption will not be taken into account. Thus $\frac{1}{14}$th of the capital cost must be recovered per annum i.e. £5,000. At 90% load, about 189,000 tons of raw coal would be treated per annum and the charge per ton input would be approximately 6.3 pence.

Interest on Capital.

Taking interest on capital investment at 5%, £3,500 must be recovered at the end of the first year. This sum will decrease annually and disappear at the end of 14 years, an average annual value being about £1,900 (2.7% on total investment) or 2.4 pence per ton input.

The estimated operating cost of the plant assuming the average load to be 90% of full load is summarised in Table 9.

TABLE 9.

ESTIMATED OPERATING COST OF 100 TONS/HOUR CYCLONE PLANT USING MAGNETITE.

	Pence per ton input.
Labour (including maintenance)	2.8
Power	2.0
Stores:-	
Magnetite	2.0
Screen cloth	0.3
Cyclones	0.4
Pump and pipe maintenance	0.9
Unforseen	2.0
Capital Redemption	6.3
Interest on capital	2.4
Total operating cost	19.1

It appears, therefore, that the operating cost of the plant could safely be taken as, say, 1/9 per ton input for the purpose of further calculations.

(b) 30 Tons per Hour Cyclone Slurry Plant.

Labour.

The plant is extremely simple and it can be assumed that any/...

any supervision necessary can be exercised by the Baum and/or main cyclone plant operators. No operating labour cost will, therefore, be charged. Maintenance required should not be excessive but to be generous the equivalent of ½ fitter and ½ native assistant per shift will be allowed. On the basis of the previous calculations the maintenance labour cost should amount to approximately £540 per annum. Assuming the average load to be 90% of full load and 2,100 hours operation per annum, approximately 57,000 tons of raw slurry are treated per annum and the cost per ton input is 2.3 pence.

Power.

The total installed H.P. is estimated as follows:

Cyclone feed pump	20 H.P.
Thickener	2 H.P.
Filtration plant	70 H.P.
Diaphragm pump	10 H.P.
Paddle mixer	10 H.P.
Total:	112 H.P.

Assuming 80% of the installed H.P. is actually dissipated and allowing additional power for conveyors etc., it is estimated that the power consumption will be of the order of 4 H.P per ton input or 3 K.W. hour per ton treated i.e. 1½ pence per ton input.

Stores.

The life of filter cloth etc. is not known but it can be assumed that it is of the same order as for fine screen cloth. For simplicity the figures previously estimated for the cyclone with medium will be taken as being applicable here, viz.:

	Pence per ton input.
Screen cloth	0.3
Pump stores and pipes	0.9
Cyclones	0.4
Unforseen (including floculant if required.)	2.0
Total	3.6

Capital Redemption./.....

Capital Redemption.

Assuming the plant is to be written off in 14 years as before, £1,070 must be put aside annually. At 90% load, 57,000 tons of slurry are treated annually and the cost per ton input is 4.5 pence.

Interest on Capital.

Taking the average interest over 14 years as 2.7% on initial investment, £405 must be recovered annually and the cost per ton input is 1.7 pence.

The estimated operating cost of the slurry plant assuming the average load to be 90% of full load is summarised in Table 10.

TABLE 10.

ESTIMATED OPERATING COST OF 30 TON/HOUR CYCLONE SLURRY PLANT.

	Pence per ton input.
Labour	2.3
Power	1.5
Stores:	
Filter cloth	0.3
Pump stores and pipes	0.9
Cyclones	0.4
Unforseen	2.0
Capital redemption	4.5
Interest on capital	1.7
Total operating cost	13.6

It appears, therefore, that the operating cost of the slurry plant could be taken as, say, 1/3 per ton input.

(C) ECONOMIC POTENTIALITIES OF THE PROPOSED SCHEME:

(1) 100 Tons per Hour Cyclone Plant alone.

The estimated performance of the main cyclone plant treating washed duff from the Baum is summarised below for convenience:

Type of Product.	Yield of Product %.	Quality of Product.
Coking Fraction	37.5	4 to 4½ swelling number, 5% ash, 7 to 8% moisture.
Middlings	55.0	12.5 lb/lb calorific value, 13.5% ash, 24% volatile, 7-8% H_2O.
Slurry	7.5	-

Without rewashing it in a cyclone, 1 ton of Baum washed duff (including the small amount of slurry present) represents 5/- revenue.

Assuming the middlings can be sold for 5/- per ton, the operating cost of the cyclone plant to be 1/9 per ton input and the slurry to represent waste material, it can be calculated that the coking fraction must be sold at 10/8d. per ton to break even.

Unfortunately the price of coking coal for metallurgical purposes is not known and it is not, therefore, possible to assess the potential profit accurately. However, from a study of "The Department of Mines Statistics for the Month of September 1951" it appears that the average selling price of all the coke produced in Natal was 29.7/- per ton F.O.R. (the ash content of the coke is not stated but is probably of the order of 15%) and the average yield of coke was about 50%. Allowing, say, 4/- per ton of coke produced for the operation of the coke ovens, it follows that one ton of coal was potentially worth 12/10d. As a first approximation, this figure will be taken as being the selling price of the coking fraction produced by the cyclone. On this basis, it follows that the profit would be about 2/2d. per ton of coking coal sold. Assuming 2,100 hours operation per annum at 90% full load, 189,000 tons of coal would be sent to the plant per annum and this should yield about 71,000 tons of coking coal. Thus the annual profit should be of the order of £7,700.

(2) 30 Tons/.......

(2) 30 Tons per Hour Cyclone Slurry Plant:

As previously explained, about 35% of the slurry could be recovered in a form which could be blended with the coking fraction obtained from the main cyclone plant. By itself it probably has very little value, if any, The potential profit will, therefor, be estimated on the assumption that the slurry is to be blended as indicated.

Now the operating cost of the slurry plant was estimated at 1/3d. per ton input and if the refuse from the slurry plant is to be run to waste, it follows that the "coking" fraction must bear the full cost of operation i.e. the coking slurry must be sold at not less than 3/7d. per ton to break even. If the blend can also be sold at 12/10d. per ton, it follows that the nett profit per ton of slurry is 9/3d. Assuming 57,000 tons of raw slurry (2,100 hours operation) are treated per annum, the yield of coking slurry should be about 20,000 tons and the annual profit should be of the order of £9,200. This figure was arrived at on the assumption that all the coking slurry was included in the blend, however, in order to satisfy market requirements as to quality, it may be necessary to add only a portion of the slurry and the profit will be decreased proportionately.

The economic possibilities of the schemes are briefly summarised in Table 11. The figures speak for themselves and require no further comment.

TABLE 11.

SUMMARY OF THE ECONOMIC POSSIBILITIES.

	Initial Capital Investment.	Nett Annual Profit.
(a) Duff only treated.	£70,000	£7,700
(b) Duff and slurry treated.	£85,000	£16,900

REMARKS./.......

Remarks.

The above analysis, although of a purely preliminary nature and based on many assumptions, appears to indicate that rewashing of the washed duff in order to produce a coking fraction has distinct economic possibilities. The next step is clearly for the interested party to reconsider the scheme, particularly from the capital investment point of view, in the light of more accurate data relating to the layout of existing Baum plant etc. If as a result of this study the picture is not altered unfavourably, it will be necessary to make tentative enquiries to find a market for the coking product. In this connection several possible customers may be approached, e.g.:

(1) The Steel Works.

(2) Companies producing foundry coke.

(3) Gas works in Johannesburg, Cape Town, Port Elizabeth etc.

Alternatively, the production of coke at the colliery may be considered. The price of good quality coke is often 35/- per ton and higher and the production of coke may thus be quite an attractive proposition. Since its ash content will be low the coke should be most valuable as foundry coke.

The low ash content of the coking fraction should have an important bearing on its selling price. In addition, if the coal is to be used in Transvaal, the railage cost will be substantially lower than in the case of coking coal from Natal and this should also influence the selling price favourably.

If there appears to be a market for the coking fraction at a suitable price, it would be desirable to carry out detailed cyclone washing tests (both with and without medium) in order to obtain reliable data relating to the yield and quality of the products before approaching the manufacturers of the equipment for tenders. It would also be an advantage to subject the products obtained from these washing tests to coking tests in order to have a firmer basis for further discussions with the prospective customer.

PRETORIA.
9th January, 1952.

(Sgd.) P. J. v.d. Walt

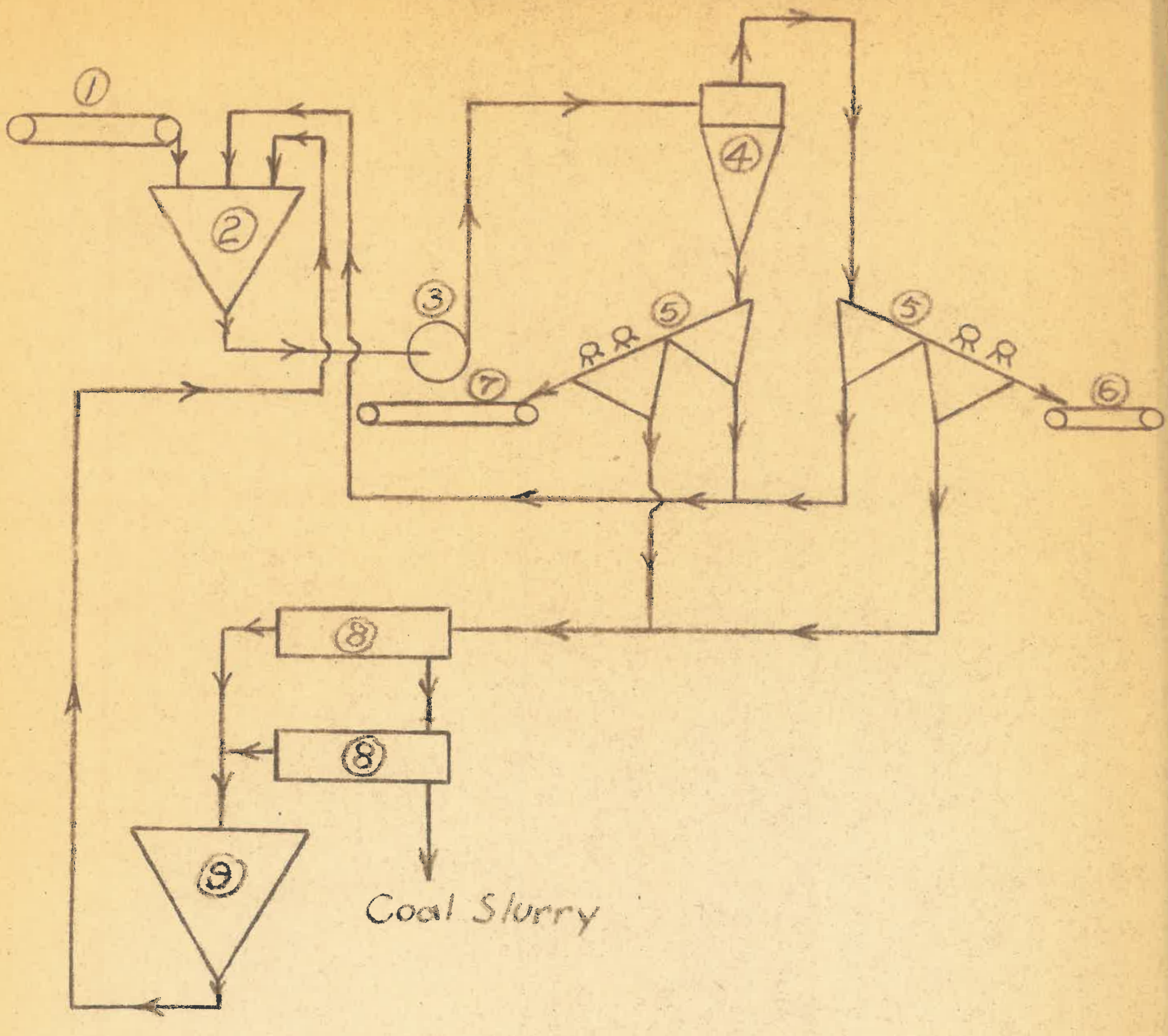

FIGURE 1

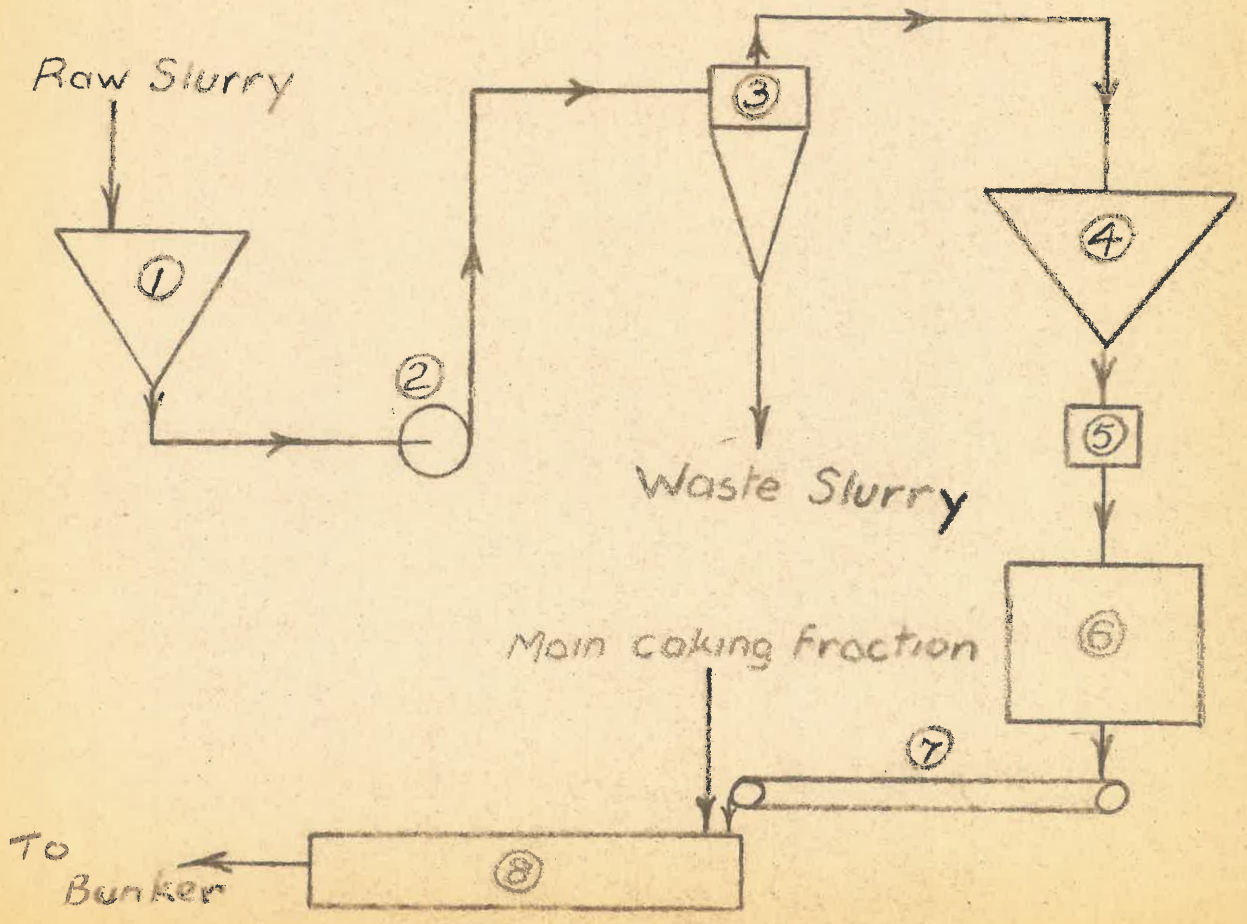

FIGURE 2