

R.654. Methods to reduce the density of washery circulating slurry, Fingal.

Investigation R.651 revealed that the excessively large amounts of fine solids retained in the washery circulating water were seriously reducing jig performance in the fine sizes with consequent high ash contents in the fine washed coal.

Environmental conditions limit the amount of solids which can be continuously discharged from the plant in slurry form, as the settling dams and ponds do not have the capacity to retain solids and return clean water to the plant circuit at the rate required to keep densities down to acceptable levels.

This investigation deals with the examination of washery products connected with the settling cone and tailing dams with the object of establishing a method of preventing the present harmful build up of fine solids in the circulating water.

TEST WORK

The work involved settling tests on the settling pond overflow, water sink-float and froth flotation tests on the cone discharge and 0.5 mm slurry screen oversize, and froth flotation tests on the main sump overflow and centrifuge effluent. The latter two products go directly and continuously to the settling dams.

Some products from the froth flotation tests were examined for settling and filtration characteristics.

The test samples used in this investigation were the same as used in Investigation R.651 and some of the results reported in that report are repeated here for comparison.

TEST RESULTS

The results of tests outlined are given below:

*Settling pond overflow (Plant water supplement)**Constitution*

Density	1020 kg/m ³
Solids	3%
Solids made up of:	24% coal
	76% shale

Settling test

Settling column height	40.5 cm
H ₂ SO ₄ addition	0.2 ml/l
pH	3.5
Solids	3%

Result

Time (hr)	Clear liquid (cm)	Settled to solids (%)
16	7.7	3.7
24	10.1	4.0
40	12.82	4.5

Time (hr)	Clear liquid (cm)	Settled to solids (%)
112	20.3	5.9
160	23.0	7.3

A control test without the additive showed no sign of settlement over the period of the test.

Cone discharge

Flotation test (Reported in Investigation R.651)

Product	% Wt	% Ash
F3C	84.2	28.4
F3T	1.9	44.0
F2T	5.7	40.5
F1T	8.2	76.4
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Head	100.0	33.3

Coal concentrate

Filtration rate (Buchner funnel) was 400 ml/minute
 $\equiv 22 \text{ l/m}^2/\text{minute}$

Moisture in cake $\equiv 36\%$

Cake thickness $\equiv 5 \text{ cm}$

Flotation tailing

Settling time 1 hour
 Settled to 22% solids (F1T)
 22% solids (F2T)
 28% solids (F3T)

Sink-float test at a density of 1600 kg/m³

Product	% Wt	% Ash
F 1600	72.3	20.9
S/K 1600	27.7	55.9
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Head	100.0	30.6

Centrifuge effluent (12.8% solids as produced)

Flotation test (Reported in Investigation R.651)

Product	% Wt	% Ash
F3C	59.8	16.6
F3T	1.6	69.3
F2T	3.2	72.9
F1T	35.4	47.8
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Head	100.0	30.3

Coal concentrate

Filtration rate (Buchner funnel) was 350 ml/minute
≡ 19 l/m²/minute
Moisture in cake ≡ 35%
Cake thickness ≡ 1.2 cm

Flotation tailing

Settling time 1 hour
Settled to 26% solids (F1T)
6% solids (F2T)
5% solids (F3T)

Main sump overflow (11.8% solids as produced)

Flotation test

Product	% Wt	% Ash
FC	63.6	21.2
FT	36.4	65.2
Head	100.0	37.2

Coal concentrate filtration

Quantitative data was not taken but the filtration rate was rapid and comparable to previous tests.

Flotation tailing

Settling test 48.2 cm column
Initial settling rate 2.5 cm/minute
Settled to 14% solids in 16 hours

Fines (0.5 mm slurry screen oversize)

Froth flotation test (Reported in Investigation R.651)

Product	% Wt	% Ash
F2C	70.2	21.9
F2T	16.7	35.1
F1C	86.9	24.4
F1T	13.1	51.7
Head	100.0	28.0

Filtration and settling

No quantitative data was obtained but the results were similar in all respects to other samples tested.

Sink float test at a density of 1600 kg/m³ (Reported in Investigation R.651)

Product	% Wt	% Ash
F 1600	83.3	22.8
S/K 1600	16.7	58.7
Head	100.0	29.8

Composite fines

A composite was made up of the five products above in the proportions shown in the material balance in Investigation R.651. This composite then represents all the minus one millimetre material produced by the washery. The slurry screen oversize is included because the coal is of indifferent quality and no sample of individual slurry screen feed or undersize was available.

Flotation test

Product	% Wt	% Ash
F2C	68.6	24.2
F2T	9.9	41.2
FlT	21.5	50.4
Head	100.0	31.5

Coal concentrate

Filtration rate (Buchner funnel) was 207 ml/minute
 = 11.2 l/m²/minute
 Cake thickness = 5 cm

Flotation tailings

Settling test 48.2 cm
 Initial settling rate 1.2 cm/minute
 Settled to 20% solids in 3 hours

Settling tests on 'as produced' material

Main sump overflow

11.8% solids, H₂SO₄ to pH 4.8
 40.5 cm column
 Initial settling rate 0.25 cm/minute
 Settled to 13% solids in 3 hours

Centrifuge effluent

12.8% solids, H₂SO₄ to pH 5.0
 40.5 cm column
 Initial settling rate 0.03 cm/minute
 Settled to 30% solids in 3 hours

Note: (1) All flocculated pulps observed showed a definite demarcation between clear liquid and thickened product. Without flocculent no such demarcation was observed, the very fine coal and shale particles remaining in suspension indefinitely.

(2) The flotation conditions for all tests reported were similar, that is:

H₂SO₄ to pH 5.0
Fuel oil 0.9 kg/t
MIBC 9 g/t

The amounts of fuel oil and MIBC do not represent the optimum dosage and no attempt has been made to determine this.

The use of sulphuric acid has a dual purpose, to depress silica and silicates during flotation and to ensure that flotation tailings are sufficiently acid to promote effective flocculation. A pH of 5.0 appears adequate for the latter.

(3) The filtration tests were done on a 6 inch vacuum funnel using a No. 1 Whatman filter paper. Filtration rates should be regarded as indicative only.

(4) All ash determinations are reported on a moisture free basis.

Comments on test results

The tests have shown that it is possible to clarify by flocculation and settlement the washery products carrying coal and shale slimes. The size of particle involved and the dilution of the pulp are factors affecting both the degree of settlement which can be achieved and the ultimate bulk density of the settled pulp. This is clearly shown by comparing the settling test results of the 'as produced' pond overflow (ultra fine material), main sump overflow (high proportion of ultra-fines) and centrifuge effluent (relatively low ultra-fine content).

The collected data from tests on the three products are as follows:

Washery product	% Solids			
	'as is'	Thickened Time (hr)	Sizing	
			% -75 μ m	-20 μ m
Pond overflow	3	7/160	100	100
Main sump overflow	11.8	13/3	83	70
Centrifuge effluent	12.8	30/3	49	40

The products making up the fine effluent from the washery contain an average of approximately 70% of relatively good quality coal, which can be recovered by froth flotation.

Filtration tests show that the coal flotation concentrate has a rapid filtration rate. Further tests would be necessary to determine optimum cake thickness and moisture content in commercial filtration.

Flotation tailings are flocculated at pH 5.0 and settle rapidly to give a clear separation between clean liquid and thickened pulp. As in the untreated effluents, there is a relationship between particle size and the final bulk density of the thickened product, the very fine material settling to about 14% solids and the coarser material to about 25% solids. Quantitative filtration tests were not undertaken on the thickened tailings but observation of a qualitative test (not reported) indicate that the rate would be much less than that of the coal concentrate.

GENERAL DISCUSSION

The main objective of this investigation was to find a method of overcoming the problem of the high proportion of slimes in the washery circulating water causing high ash content in washed slack coal.

To significantly reduce the density of the circulating slurry, it is necessary to considerably increase the continuous slurry discharge over present levels.

The simplest way of containing the increased rate of solids discharge would be to enlarge the capacity of the settling dams and provide an overflow, for return to the plant, at least comparable in solids content to that currently being returned. The increase in settling area required would be in proportion to the increase in the rate of slurry bleed from the plant. This rate could be only determined by prolonged testing, but an increase of three to four times could be envisaged. The Company's property on which the washery is situated is not large enough to allow an increase in dam capacity to this extent.

A possible alternative to increased settling area is to induce more rapid settling of fine solids by flocculation. This should allow more solids to be released continuously and at the same time provide clean settling pond overflows for return to the plant. Acidification to pH 5.0 with sulphuric acid is an economic and adequate means of achieving the desired flocculation.

This method may be a temporary measure only, as an increased amount of flocculated thickened pulp will fill the dams at least as quickly as is presently being achieved. The prospect of slower drying out of solids in dams should not be overlooked.

The relative advantages and disadvantages of such a method could only be properly assessed by plant testing.

A more permanent solution to the problem could be the incorporation of a froth flotation system for the removal of fine coal from the circulating slurry. The plant material balance calculated and reported in Investigation R.651 indicates that about 94 t of fine solids from the washery are entering the dams in slurry form every 8 hour shift.

The products involved are:

- (1) Settling cone discharge (daily pre-shift dumping).
- (2) Centrifuge effluent (continuous discharge).
- (3) Main sump overflow (continuous discharge).

About 70% of this material is good quality fine coal and the continuous removal of this from the slurry by flotation is seen as a means of:

- (1) Allowing an increased rate of slurry bleed off from the plant.
- (2) Cleaning jig water and hence allowing greater washing efficiency.
- (3) Substantially increasing the overall coal recovery of the plant.
- (4) Alleviating the growing problem of fine tailing dispersal.
- (5) Avoiding the intermittent discharge of accumulated solids from the settling cone, hence removing the necessity for the 0.5 to one hour delay in plant start up.

Considerations (1) and (2) are closely inter-related. Clean jig water can only be maintained by an increased rate of removal of fines, and some

method of disposing of the fines at the required rate must be found. If 70% of the solids can be withdrawn from the slurry as good quality coal, acceptable to consumers, consideration (3) would also be achieved.

The dams would then receive per 8 hour shift 28-30 t of solids in flocculated slurry form, instead of the present 94 t, thus increasing their effective capacity by 200% and doing much towards the achievement of consideration (4).

The natural result of the operation would be to allow the settling cone to function as desired and hence remove the necessity for the long delays incurred in dumping accumulated solids resulting from the previous shift.

The technical and practical advantages of removing fine coal from the slurry are manifest from the above discussion and economic considerations will no doubt determine the overall feasibility of installing such a system at the washery. To assist in the assessment of this factor, the following exercise in predicting the alterations to washery production of slack coal has been undertaken. The exercise is based on the premises that all minus one millimetre material would be subjected to froth flotation for fine coal recovery; that commercial results would be similar to those obtained in the laboratory tests and that the quantities of material involved would be the same as those shown in the plant material balance estimated in Investigation R.651.

Products	t/day (8 hour)	% Ash	Ash Tonne units
Slack as presently produced	409	21.8	8916
'Fines' (-1 mm +0.5 mm) slurry screen oversize)	40	28.5	1140
Slack minus 'Fines'	369	21.1	7776
Cone discharge - coal concentrate	42	28.4	1190
Centrifuge effluent - coal concentrate	9	16.6	149
Main sump overflow - coal concentrate	19	21.2	400
'Fines' (-1 mm +0.5 mm) - coal concentrate	35	24.4	854
Total (-1 mm) coal flotation concentrate	106	24.7	18
Possible improved slack (+1 mm) due to improved jigging (from R.651 365 x 94)	346	19.6	6781
100			
Possible slack coal production with recovery of fine coal by flotation	452	20.8	9399
Change in moisture content			
Recent average moisture content of presently produced black coal			10%
Moisture content of flotation concentrate filter cake			35%
Probable moisture content of slack coal including flotation concentrate			15.8%*

*Note: This calculated moisture content is well above what could be expected in a commercial application, for the following reasons.

- (1) A suitably designed filter cycle would probably reduce the moisture of the flotation concentrate to less than 25%.
- (2) The wettest component of the presently produced slack coal, (the minus one millimetre material) would be removed, thus lowering the overall moisture content of the plus one millimetre slack coal.
- (3) The dewatering centrifuge would be able to operate more efficiently when clean water was to be removed, rather than the viscous slurry presently coating the feed.

A moisture content for the composite slack of 11.5-12.0% is probably realistic.

Change in sizing analysis - slack coal

Fraction	'As produced'	'Including fines recoverable
	(from R.651) % Wt	by flotation' % Wt
+½ inch	33.1	28.5
+¼	26.4	22.7
+⅛	16.6	14.3
+1 mm	12.9	11.1
+½ mm	11.9	7.8
-½ mm		15.6

In summary this means an increase in daily production of 43 t of washed slack coal, a 1% decrease in ash content of the slack, a 5.8% increase in its moisture content, and an increase of 11.5% in the minus one millimetre fraction, most of which would be in the -0.5 mm size range. The calculated increase in moisture content is considered to be liberal and in fact could be much less.

The application of flotation to the -0.5 mm material only should achieve a similar overall result, as the resultant decrease in jig water density would allow more efficient washing of the minus one millimetre +0.5 mm fraction of the raw coal feed.

Test No.	Time (Hours)	Consumption (kg/t)	Extraction
23	24	4.42	88
22	22	3.13	86
21	24	1.82	86

The material used was a composite made from samples 36082 and 36083 from Middle Arm dump, Bascofield. Sulphides and a little copper (not assayed) were contained in the head sample which assayed 2.7 g of gold per tonne. The following results were obtained from cyanidation tests:

Test No.	Time (Hours)	Consumption (kg/t)	Extraction
23	24	2.18	80.0
22	22	1.82	48.7
21	24	1.79	34.3

Each test was pulped (2 : 1 liquid : solid), stirred, filtered and washed.