Section 1 – Ore Dressing Investigations

TR6_99-160

R. 361, R. 364, R. 365, R. 366 & R. 368

CLAY – SOUTH MOUNT CAMERON

by W. St. C. Manson, J. Liddy and P. L. James.

(1) This investigation deals with the treatment of several samples of weathered granite from South Mount Cameron district in north-east Tasmania from leases held by D. Brown and partners for the production of clay suitable for use in the manufacture of paper.

The work consisted of removal of impurities such as coarse quartz and fine grit from the clay by agitation after dispersion with sodium silicate, classification, screening and removal of finest sand by treatment in small diameter hydrocyclones.

Where necessary, bleaching with sodium hypochlorite or chlorine has been tested to increase brightness of the clay. Degritted clay pulps have been flocculated with aluminium sulphate, and then submitted to filtration to remove surplus water in preparation of final drying of the refined clay. Samples of degritted and dispersed clay have been centrifuged to assess the effect on economics for subsequent flocculation and drying, and also to determine the nature of the clays that can be produced by this means. From results of evaluation of bores and yields of refined clay in experimental work, the yield of clay would range from 30 to 40%, and a yield of 33⅓% for assessment of economics appears to be reasonable.

(2) Associated Pulp and Paper Mills Ltd., Burnie, are users of considerable quantities of filler clay in paper manufacture, and a specification has been provided by them as a guide to cover clay suitable for their specific uses. This specification is as follows:—

Brightness

(A.S.T.M. Directional Reflectance Method designation E97-55) originally 80 and later reduced to 77.

Grit (Quartz)

Chemical Method, less than 3%.

Sizing

Plus 200 mesh-Nil. Plus 30 microns less than 2%.

The quantity of one micron clay generally ranges from 25 to 40%, and the clay as naturally produced experimentally has been stated to be satisfactory for one micron clay content.

Ignition Loss

Not specific. but of the order of 12%.

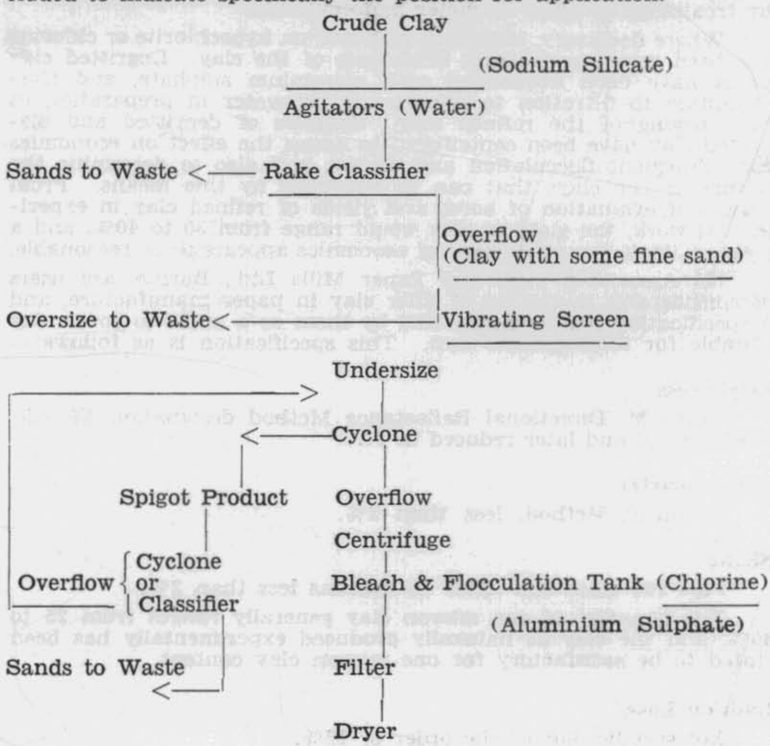
Redispersibility

The dried product to be redispersible. Samples of dried clays were submitted to A.P.P.M. Ltd., and were reported by them to be redispersible.

The method used for determination of grit by chemical means is shown in Appendix II.

(3) The treatments given to the bulk samples of clay have resulted in the production of paper clay of a quality which complies with the specification referred to above. Some samples are not bleachable to the desired brightness with hypochlorite which indicated that selective mining is necessary to maintain the high standard of brightness required for the industry. Iron stained clay can be bleached by reduction with zinc hyposulphite, but the previous test work by A.P.P.M. Ltd., reports regression of brightness and the process is not favoured.

(4) The following flowsheet shows the treatment process which has resulted in production of high quality filler clays. Some attention has been given to additional recovery of clay from the primary cyclone spigot, and a possible application is shown in the flowsheet. The bleach process is shown, but this would not be consistently necessary to give the desired brightness. A centrifuge is also included to indicate specifically the position for application.



(5) The results of each treatment process are briefly summarised below.

(a) Agitation and Dispersion

High densities for economic treatment and to provide a scrubbing action to clean the clay from quartz was satisfactory with dispersed pulps containing 50 to 60% of solids. Sodium silicate at the rate of 10 lbs. per ton of crude material resulted in acceptable dispersion. No tests were made on "as mined" material to determine the requisite agitation period. However, air-dried material readily broken to half-inch size was effectively slacked in less than five minutes.

(b) Classification and Screening

Removal of coarse sand to about 60 mesh was effective in a six-inch Akins classifier with a crude clay overflow of over 30% solids. The discarded coarse sand contained about 2% clay, and this represents an overall loss of about 3% of the clay. An electric vibrating screen was effective for removal of root, bark and tramp oversize &c. and plus 72 mesh sand.

(c) Cyclone

Tests have been conducted with three-inch and 30 mm cyclones at various high pulp densities to remove the finest quartz, &c., to 30 micron size, and to produce a clay with a maximum content of 2% plus 30 micron material.

The clay is naturally flocculated, and in this condition the pulp is appreciably more viscous than in the dispersed condition, consequently at high densities cycloning results in a more effective separation in the dispersed condition.

The desired sizing separation is readily obtainable in a 30 mm cyclone with feed densities of the order of 32% solids at 40 p.s.i. A three-inch cyclone at pressures up to 75 p.s.i. produced too coarse an overflow at the above high density, and research indicated that the solids content of the feed would have to be reduced to about 20% before a primary overflow of 98% minus 30 microns was produced. Further work may be desirable to determine the most economic cyclone set up for this separation.

(d) Centrifuge

Application of separation by this means has two features of usefulness.

(1) Separation of the coarser clay as a pulp of about 50% solids, and an effluent of low solid content containing the finest clay. Subsequent flocculation and filtration of the effluent only can result in an economy as compared with the addition of flocculant to the total clay pulp. Details of tests are given which show that any preference for use of the centrifuge is dependent upon the relative quantities of clay separated, and the overall effect of filtration capacity and cost.

(2) Use of the effluent as a separate product for marketing as a coating clay.

(e) Bleach

The use of chlorine gas is effective for increase of brightness of clays stained with organic matter, and is appreciably more economic than the solution of sodium hypochlorite. Excess chlorine may be a disability on completion of the bleach process, and although this can be destroyed with sodium bi-sulphate, tests have shown some reduction of brightness caused by the use of this reagent. It has been suggested that application of bleach as a batch process could have the advantage of mixing bleached clay pulps with clay pulps which do not require bleaching as a means of the destruction of residual chlorine. Investigations have not included this method of operation. Application of bleach to the total clay would be made after de-gritting the dispersed pulp.

(f) Filtration

Numerous leaf tests were undertaken to test variables for efficient and economic filtration. Generally, filter capacity is related to the volume of pulp filtered, and thus it is of special significance that all treatment processes should be performed at highest practical densities to ensure low cost treatment, particularly for filtration. The results of leaf tests were used for selected tests with a 1′ x 3′ FEinc rotary vacuum filter fitted for string discharge. This unit was made available on loan from the Chemical Plant and Engineering Co. Ltd., Ashley Street, Footscray.

Flocculation was satisfactory with aluminium sulphate in amounts ranging from 15 to 45 lbs. per ton of refined clay. Filtration rates were recorded under varying conditions, and these will vary with the nature of the clay, per cent solids and temperature of the pulp, and other conditions affecting flocculation.

Typical results were as follows:—

Temperature°C.	Cake Thickness	Filtration Rate Lbs of Clay/Sq. Ft./Hour
11	9-12/64 inch	3-5
58	9-13/64 inch	6-12

Discharge of filter cakes of the above thickness takes place by flexure as the cake passes over the roller. Increase in speed produces thinner cakes, and when sufficiently thin, discharge takes place mainly on the alignment comb and filtration rates are doubled by this means. This method of cake removal could be of economic interest, and consideration could be given to this method of operation.

(g) Drying

Drying of the clay has not been included in the investigation with the exception of the effects of heating to various temperatures. This work shows the necessity for temperature control in the drying process. Overheating results in reduction of brightness.

Chemical requirements for treatment will vary considerably with variations in the nature of the clay. To indicate the general cost of chemicals used in the test work typical quantities and costs of chemicals are shown.

Reagent	Refined Clay Lbs./Ton of Rate	Cost Ton at South Mt Cameron	Cost per Ton of Clay
		£	£
Sodium Silicate	30	30	0,4
Aluminium Sulphate	30	40	0.6
Tetra Sodium Pyrophosphate	5	140	0.32

The above chemicals were used for dispersion and flocculation of the clay, and redispersion before drying.

Other chemicals and supplies of interest have been costed and are listed below.

Chlorine—£122 per ton at South Mt Cameron.
Sodium Bisulphite—£88 per ton at South Mt Cameron.
Sodium Hypochlorite—Seven shillings and sixpence per gallon at South Mt Cameron containing 12% chlorine.
Calcium Chloride— £42 6s. per ton at South Mt Cameron.
Sodium Thiosulphate—£75 per ton at South Mt Cameron.
Oil Fuel, light and heavy—£26 5 s. and £18 per ton at South Mt Cameron.
Coal—£6 per ton at South Mt Cameron.
Power—Estimated by Mr. H. K. Turner 1.34 pence K.W.H. from costs at Dorset Dredge.

Chemicals for bleach using 6.7 lbs. of chlorine per ton of clay, and sodium bisulphite to destroy excess chlorine show a cost of 10s. per ton of clay.

Our thanks are recorded for assistance given to us in these investigations by the Chief Chemist, Mr. McKercher and staff of A.P.P.M. Ltd., Burnie, and Mr. G. J. Robertson, Chief Chemist of the Ballarat Clay Co.

The Crude Clay Samples

A total of six crude clay samples were obtained from the South Mt Cameron deposit. These were as follows:—

Sample No.	Weight of Sample	Location of Sample
R. 361	2 Tons	Near Bore Hole No. 3, North block
R. 364	1 Cwt.	Bore Hole No. 7, to 16 feet
R. 365A	1 Cwt.	Bore Hole No. 8
R. 365B	1 Cwt.	Bore Hole No. 8
R. 366	1 Cwt.	Bore Hole No. 16, to 22 feet.
R. 368	1 Ton	Near Bore Holes Nos. 1 & 2, North block

Samples R. 361 and R. 368 were obtained as bulk samples of average quality crude clay for pilot plant tests, involving beneficiation by degritting and sizing in classifiers and cyclones, and dewatering by filtration.

Samples R. 364, R. 365 and R. 366 were obtained specifically as sources of organically stained crude clay for bleaching tests.

A sizing of R. 361 is more or less typical of the crude clays tested.

Size Fraction B.S. Screen	Percent Weight
+ 44 mesh	39
— 44 + 60 mesh	5
— 60 + 100 mesh	3
— 100 + 200 mesh	3
— 200 + 350 mesh	3
— 350 + 30 microns	5
— 30 + 20 microns	5
— 20 microns	37
	100

In all of the crude clays handled only a very small amount of the quartz is coarser than ⅜-inch size.

The clay contents of each of the six bulk samples in terms of minus 30 micron material were:—

	%
R. 361	42
R. 364	41
R. 365A	44
R. 365B	34
R. 366	48
R. 368	50

Bouyoucos hydrometer sizings of the clays prepared by the "minus 30 micron separation" method (see appendix for details) were:—

Size Fraction	Clay					
	R.361	R.364	R.365A	R.365B	R.366	R.368
+ 10 micron	14	14	17	18	7	12
— 10 + 5 micron	17	21	16	17	12	23
— 5 + 2 micron	24	24	29	28	25	31
— 2 + 1 micron	23	21	13	14	16	12
— 1 micron	22	20	25	23	40	22

Clays obtained by the minus 20 micron "Evaluation of Weathered Granite" method (see appendix for details) had brightnesses as follows:—

	Clay					
	R.361	R.364	R.365A	R.365B	R.366	R.368
Unbleached brightness	76	71	74	60	69½	79
Maximum brightness attained with excess Chlorine	77	83½	81	76½	82½	84

Dispersion of the Crude Clay

Sodium silicate was used throughout the laboratory and pilot plant work to disperse the crude clay prior to de-gritting. Sodium silicate gave satisfactory dispersion, and the dispersed clay was later readily flocculated with aluminium sulphate and other flocculants.

Other dispersants were not tested.

Quantity of Sodium Silicate required for dispersion

There is no absolute laboratory method of measuring the degree of dispersion of a clay pulp. It is thus difficult to determine the quantity of sodium silicate required to disperse crude clay.

Laboratory bench scale tests showed that clays prepared by either of the standard decantation methods (see appendix for details) produced clays meeting the tentative specifications of A.P.P.M. Ltd. when the crude clay was dispersed with 9-10 pounds per ton of sodium silicate. These tentative specifications are discussed later.

Approximately 10 lbs. of sodium silicate per ton of crude clay was used throughout pilot plant test work. This usage agrees closely with 11 pounds per ton of crude clay used by Ballarat Clay Co. Pty. Ltd., Ballarat.

Grades of Sodium Silicate

Several grades of sodium silicate are available from manufacturers. We have no data relating to the relative economic effectiveness of these different grades in dispersing crude clay. Rubanit Roofing and Paper Products Pty. Ltd. have suggested either N84 or A140 grades for clay dispersion.

Silicate and Dolomite Sales (N.S.W.) Pty. Ltd. have suggested N84 grade.

Ballarat Clay Co. Pty. Ltd., and A.P.P.M. Ltd. both use N84 for dispersing clay.

Several grades of sodium silicate were used during test work and were all effective in dispersing the crude clay.

Cost of Sodium Silicate for Dispersion of Crude Clay

Rubanit Roofing and Paper Products Pty. Ltd. have quoted N84 Sodium Silicate at £18 5s. per ton F.O.B. Melbourne, in minimum lots of 10 x 44 gallons. Price includes non-returnable drums.

Cost at South Mt Cameron has been estimated at £30 per ton.

At 10 lbs. per ton of crude clay, cost of sodium silicate will be £0.13 per ton of crude clay.

Assuming an average yield of 33% of paper clay from the crude clay the cost of sodium silicate will be £0.39 per ton of paper clay.

Summary: Dispersion

(1) Crude clay can be satisfactorily dispersed with approximately 10 lb./ton of sodium silicate.

(2) Several grades of sodium silicate are available, but N84 grade seems to be favoured for clay dispersion generally.

(3) Cost of sodium silicate for dispersion is estimated at £0.39 per ton of paper clay.

Agitation for Dispersion of Crude Clay

Dispersion of the crude clay with sodium silicate at high pulp densities requires some agitation. It is difficult to translate laboratory and pilot plant scale agitation on air-dried clays to commercial practice using large lumps of wet clay.

Test work involved comparatively dry clay with maximum sizes of about ¼-inch for laboratory work, and air-dried clays up to about 1-inch size for pilot plant work. Under these conditions, experience has shown that agitation of a few minutes only is required. We have no data relating to agitation required to disperse large lumps of wet clay, say 1-2 feet diameter.

The pilot plant agitators used were No. 1 Denver conditioner-super agitators. Dispersed mobile pulps up to 70% solids could be obtained, but it was impracticable to operate at this high pulp density. Good operation was experienced at pulp densities of 50-60% solids, and pilot plant dispersion was carried out in this range.

Agitation times of approximately five minutes were adequate to wash the quartz clean and to disperse the clay. It is possible that, in practice, no particularly prolonged agitation of the crude clay pulp will be required, and that normal plant handling will be sufficient.

There is some evidence that excessive agitation degrades the clay subsequently removed, possibly by breaking up the quartz. In one test (detailed later) the following results were obtained from duplicate samples.

Time of agitation	Yield on decantation	Brightness of Clay
Minutes	%	%
1	41.5	73.0
1	41.5	72.8
30	44.9	71.8
30	44.2	72.2

This table indicates that the increased agitation increased the yield by about 3%, and degraded the brightness of the clay by almost one unit.

Summary: Agitation

(1) The air-dried clays were readily dispersed with little agitation in pilot plant work.

(2) Excessive agitation appears to increase the yield of clay, but the clay is degraded in quality.

Removal of Quartz Gravel and Sand from Dispersed Crude Clay

Pilot Plant Operation

The minus 1-inch air-dried crude clay was fed to a No. 1 Denver conditioner-super agitator by means of a vibrating feeder. Regulated quantities of make-up water and sodium silicate were added continuously.

Addition of sodium silicate—10 pounds per ton of crude clay.

Retention time in agitator— Five minutes (average).

Pulp density in agitator—50-60% solids.

The dispersed pulp was fed to a 6-inch Akins spiral classifier to remove gravel and coarse sand. Entrained clay was washed out of the classifier sands by spray water.

Classifier overflow was pumped to a Hummer electric vibrating screen, fitted with a 72 mesh stainless steel cloth. The screen scalped out the small quantity of wood and fibrous vegetable material present in the crude clay, plus a small quantity of tramp oversize in the classifier overflow. Screen oversize returned to the classifier. The screen undersize gravitated to a second Denver agitator for storage prior to cycloning.

Notes on Pilot Plant Operation

(1) Densities of Pulps

For later filtration the density of the pulp should be maintained as high as possible. Cyclone tests (detailed later) indicate that clay of acceptable quality can be obtained by treating pulps in a 30 mm cyclone at 34-35% solids to give cyclone overflow pulp densities of about 30% solids. With more dense pulps the clay in cyclone overflow fails to meet the specifications for grit and sizing. This factor then limits the density of the screen undersize to 34-35% solids.

The scalping screen removes very little solids, and the density of the feed to the screen, i.e., classifier overflow is thus limited to about 35-36% solids.

The primary agitation and dispersion can be carried out at densities up to 60% solids. Removal of the classifier sands from a feed of this density leaves a pulp of up to about 40% solids. The density of this pulp as classifier overflow is reduced to the required 35-36% solids by the application of spray water to the classifier sands to give maximum recovery of entrained clay. A small quantity of spray water is also applied to the scalping screen.

(2) Loss of Entrained Clay in Classifier Sands

Dispersion at high densities allows maximum use of spray water to recover clay from the classifier sands. Tests showed less than 2% of minus 30 micron material in the classifier sands. This loss of clay in the classifier sands amounts to about 2 or 3% of the recoverable clay in the original crude clay.

(3) Use of Scalping Screen

The crude clay contains a small quantity of wood and fibrous vegetable matter. This, together with a small amount of tramp oversize, was scalped out by a 72 mesh screen. Without this scalping screen ahead of the cyclone, considerable difficulty was encountered with blockages of the very small underflow orifice of the 30 mm cyclone.

As the clay in the pulp is dispersed when fed to the scalping screen, the fine clay and water readily pass through the screen. The quantity of tramp oversize is small (apart from the particles of vegetable matter), but would quickly block the underflow orifice if not removed prior to cycloning.

(4) Storage in Second Denver Agitator

Production rate of the cyclone feed pulp was less than the capacity of the cyclone-pump combination. Use was made of this agitator to store the pulp and to ensure a uniform feed to the cyclone.

Summary: Pilot Plant Operation

(1) A dispersed clay pulp (suitable as feed to a 30 mm cyclone for final degritting) was prepared in the pilot plant involving:—

- (*a*) Agitation and dispersion with sodium silicate in a No. 1 Denver conditioner-super agitator.
- (*b*) Removal of coarse gravel and sands in an Akins 6-inch spiral classifier.
- (*c*) Removal of vegetable trash and some tramp oversizes by a 72 mesh Hummer screen.

(2) Initial agitation and dispersion of the crude clay should be at high densities, to allow maximum use of wash water to remove entrained clay in the classifier sands.

(3) Loss of clay in the classifier sands amounts to about 2 to 3% of the recoverable clay in the crude feed.

(4) A scalping screen ahead of the 30 mm cyclone is essential to minimize blockages of the cyclone orifice.

Production of Paper Clay in a 30 mm Cyclone

The 30 mm Cyclone and Pump

Production of paper clay was obtained by treating the classifier overflow in a 30 mm hydrocyclone, supplied by Liquid-Solid Separations, London.

The cyclone is rubber lined, and has a fixed vortex finder ⅜-inch outside diameter and ¼-inch inside diameter. The diameter of the orifice can be varied by removing or adding rubber spacers containing graded orifices.

Consideration of the problem of sizing the clay in a 30 mm cyclone indicated an operating pressure of not less than 40 p.s.i., and as the desired results were obtained at this pressure from pulps of up to 35% solids, tests were not conducted at lower pressures.

The cyclone was fed by a ¾"/1" Kelly and Lewis water pump. The pump-cyclone unit handled approximately three gallons per minute of feed at a pressure of 40 p.s.i.

The cyclone was mounted over the conical pump sump. Flexible lines taking both cyclone overflow and underflow allowed the products to be returned to the pump sump, or to be removed as desired.

Specifications Relating to Grit and Sizing

A tentative specification, drawn up by A.P.P.M. for our guidance, includes the following specifications:—

> "Material coarser than 200 mesh B.S.S. nil, coarser than 30 microns not more than 2%."
>
> "Grit by the sulphuric acid digestion method, reference Analytical Chemistry, Treadwell and Hall, ninth English edition, volume 2, page 422, not to exceed 3%."

Cyclone Tests

The object of treatment in the 30 mm cyclone was to produce a clay containing not more than 2% of plus 30 micron material. A typical sizing of cyclone feed is shown below.

Fraction	Percent Weight
— 60 + 100 mesh	5.0
— 100 + 200 mesh	5.2
— 200 + 350 mesh	5.6
— 350 mesh + 30 micron	8.9
— 30 micron + 20 micron	9.0
— 20 micron	66.3

The clay was produced by cycloning the dispersed pulp. The finest sized fractions in the samples tested are clay, and are free of quartz and mica. The quartz from the weathered granite is comparatively coarse, and the bulk of this quartz is removed by classification. Almost all of the plus 30 micron material in the feed to the cyclone is removed in the cyclone underflow.

With the clays tested, R.361 and R.368, and operation of the cyclone to give a product to meet the specification of not more than 2% coarser than 30 microns, the clays readily meet the specification relating to grit.

Other clays in the deposit could contain more very fine quartz, and separated clays from such may not meet the grit specification, although passing the sizing specification.

Evaluation of the cyclone overflows with reference to the 30 micron sizing was by the A.P.P.M. method " Evaluation of paper clays for 30 micron separation " (see appendix).

More detailed sizings of some typical products were made with a Bouyoucos type soil hydrometer, No. 152 H, following the A.S.T.M. tentative standard-designation D 422-54 T for grain size analysis of soils.

30 mm Cyclone Operation

Effect of Pulp Density

For best economic filtration, the density of the pulp should be maintained as high as possible. Little difficulty was experienced in producing clays to meet the 30 micron sizing specification by cycloning pulps at low densities. Test work was directed towards obtaining a high yield of acceptable quality clay in an overflow of relatively high pulp density.

The following series of tests show the inter-relation between grit and sizing of the cyclone overflow with pulp density on clay R.361.

Test No.	Cyclone Feed Pulp Density % Solids	Primary Cyclone Overflow				Cyclone U/flow Pulp Density % Solids
		Yield from Crude Clay	Pulp Density % Solids	Grit %	Plus 30 Microns %	
7	32	28.0	27	1.7	1.3	46
6	34	29.0	30	2.0	1.9	45
5	37	29.0	34	2.4	3.9	46
4	41	29.0	37	2.9	4.9	46

This series of tests indicates:—

(1) Yield of clay in the cyclone overflow is reasonably constant, and seems independant of pulp density of the feed.

(2) The grit content of the overflow increases with increase in pulp density, but with the highest pulp density tested (41% solids in feed: 37% solids in overflow) the grit content of the overflow on the samples tested still meets the tentative specification.

(3) The plus 30 micron content of the overflow increases with increase in pulp density. Overflows with pulp densities of 31% and 34% solids met the tentative specification. Overflows with pulp densities of 37% and 41% solids did not meet the specification.

(4) Pulp density of the underflow is reasonably constant, and is independent of pulp density of the feed in the range tested.

Clays R.361 and R.368 were produced by cycloning for other test work, such as filtration and centrifuging. These clays were generally evaluated for grit and for plus 30 micron content. Yield in terms of crude clay was determined in some cases.

Typical 30 mm Cyclone Test Results

Test No.	Clay	Cyclone Feed Pulp Density % Solids	Primary Cyclone Overflow: Primary Yield from Crude Clay %	Primary Cyclone Overflow: Cyclone Pulp density % Solids	Primary Cyclone Overflow: Grit %	Primary Cyclone Overflow: Plus 30 Microns %	Cyclone U/flow Pulp Density % Solids	Cyclone U/flow % —30 Micron Material
1	R.361	26	32	23	2.0	1.0	44	69
2	R.361	25	34	24	2.1	1.4	47	69
10	R.361	33	....	29	2.2	1.0	44	....
13	R.368	34	39	30	1.0	1.4	45	52
14	R.368	35	37	31	1.2	1.5	46	53

These tests indicate that clay produced by cycloning samples R.361 and R.368 at feed densities of up to 33-35% solids will give clay overflows of up to 30% solids which meet the tentative specifications relating to plus 30 micron sizing and grit.

Further recovery of clay is possible by retreatment of the primary cyclone underflow by further cycloning, or by classification, as shown in the following example.

Thus in test R.361/1 results of primary cycloning were:—

Product	Weight % of Crude Clay	Pulp Density % Solids	Grit %	Plus 30 Microns %
Primary Overflow	32	23	2.0	1.0
Primary Underflow	12	44	....	31.0
Feed to Cyclone	44	26	....	....

The primary cyclone underflow was then diluted with water and again cycloned.

Product	Weight % of Crude Clay	Pulp Density % Solids	Grit %	Plus 30 Microns %
Secondary Overflow	4	5	....	1.0
Secondary Underflow	8	46	....	44.0
Primary Underflow	12	....	....	31.0

This method allows the clay yield to be increased, but the clay pulp is more dilute. Normally such dilute pulp should not be added to the primary cyclone overflow, but could readily be circulated back to the original dispersing agitator without decreasing the plant pulp density, or alternatively join the feed to the primary cyclone.

Retreatment of cyclone underflow for recovery of additional clay has also been tested by classification by decantation. The results obtained by both methods are shown below, and indicate a high quality product by classification.

	Feed % Solids Weight	% of Crude Clay	Overflow % + 30 Microns	Overflow % Grit
Classification	20	2.6	0.7	1.6
Recyclone	15	2.5	2.8	3.5

A series of tests was carried out on clay R.361 in the naturally flocculated state. The object of these tests was to examine indicated costs of degritting and subsequent flocculation with clay dispersed with sodium silicate.

The cyclone feed pulp was obtained by agitating the crude clay with water only, and screening on a 72 mesh screen.

Test No.	Cyclone Feed Pulp Density % Solids	Cyclone Overflow: Yield from Crude Clay %	Cyclone Overflow: Pulp Density % Solids	Cyclone Overflow: Plus 30 Microns %	Cyclone Overflow: Grit %
11a	31	27	27	5.7	3.2
11b	23	24	20	4.2	2.3
11c	18	21	12	1.0	1.5
11d	12	21	10	1.0	1.3

The results show that acceptable quality clay can be obtained only at comparatively low pulp densities, and that overall clay yield is much less than that obtained from dispersed pulps.

As a result of the unfavourable comparison, flocculation and filtration tests were not proceeded with.

Tentative A.P.P.M. Specification: 200 Mesh

The specification requires "material coarser than 200 mesh nil". Unless a 200 mesh screen is incorporated in the circuit, it is unlikely that this specification will be met. The proportion of plus 200 mesh material in various products is listed below.

Product	Sizing: % + 200 Mesh
Cyclone Overflow R.361, Test 4	0.23
Cyclone Overflow R.361, Test 10	0.20
Cyclone Overflow R.361, FEinc Filter Feed	0.12
Test 13, R.368	Trace
Ballarat Clay, ex A.P.P.M.	0.10
English Clay, ex A.P.P.M.	0.05

Sizing of Cyclone Overflows

Cyclone overflows from clay R.361 were sized by the Bouyoucos hydrometer method with the following results.

Size Product	% Weight Sample "A"	% Weight Sample "B"
+ 30 Microns	3.5	2.0
— 30 + 20 Microns	2.0	1.5
— 20 + 10 Microns	8.0	8.5
— 10 + 5 Microns	19.5	18.0
— 5 + 1 Micron	42.0	44.0
— 1 Micron	25.0	26.0

Sample "A" was produced in a pulp of 33% solids.

Sample "B" was produced in a pulp of 21% solids.

A sample of R.361 cyclone overflow was sized by sedimentation, and the grit content of each fraction was determined.

Size Fraction	% Weight	% Grit	% Distribution of Grit
— 30 + 18 Microns	6.2	12.0	37
— 18 + 8 Microns	12.8	4.5	28
— 8 Microns	81.0	0.9	35
Composite Clay	100.0	2.0	100

The sizing shows clearly the predominance of grit in the coarser sizes.

Preparation of Paper Clay in a 3-inch Cyclone

A series of tests was carried out on clay R.361 to determine the possibility of using a 3-inch cyclone in place of the 30 mm cyclone previously used in paper clay production. The 30 mm cyclone has a very small orifice, an unless considerable care is taken in preparation of the cyclone feed, this orifice is easily blocked. A 3-inch cyclone has a much larger orifice, and hence is much more attractive from the aspect of orifice blockage.

The cyclone used was a 3-inch rubber lined unit made by Warman Equipment (W.A.) Pty. Ltd. The cyclone was fed by a Warman split case pump, driven by a variable speed motor. Portion of the pump discharge could be by passed back to the pump sump.

The pulp was prepared by the normal pilot plant procedure.

Variables tested in the series included cyclone inlet pressure, density of feed pulp, and underflow orifice diameter.

In general, at similar pulp densities, the 3-inch cyclone gave more plus 30 micron material in the overflow than the 30 mm cyclone under similar conditions. Progressive dilution of the feed decreased the quantity of plus 30 micron material in the overflow. An overflow product meeting A.P.P.M.'s tentative specification of not more than 2% plus 30 microns was obtained with a feed of 21% solids and an inlet pressure of 75 p.s.i. giving a cyclone overflow density of 19% solids. Other variables tested had little effect upon results. Volume of cyclone feed ranged from 9-12 g.p.m.

Test Results—3-inch Cyclone

Test	Pressure p.s.i.	Cyclone Feed: Pulp Density % Solids	Cyclone Overflow		
			Pulp Density % Solids	% + 30 Microns	% Grit
A.	40	33	32	6.3	....
D.	60	33	30	5.1	....
F.	70	30	27	4.2	....
G.	75	28	24	2.9	....
H.	75	21	19	1.9	2.0

The trend towards better quality clay with dilution of feed pulp is clearly indicated in the above table of test results.

Bleaching with Sodium Hypochlorite

Clays from the Gladstone area are usually coloured to some extent with organic matter. It is possible to improve the colour (brightness) of many of these clays by bleaching with chlorine. Initial bleaching tests were carried out using sodium hypochlorite, supplied from Launceston manufactured stock by Imperial Chemical Industries of Australia and New Zealand Limited. The sodium hypochlorite solution, as supplied, contains 12.5-12.8 grams of available chlorine per 100 ml. of solution.

Some obvious factors influencing bleaching are:—

1. Quantity of available chlorine used.
2. Time of contacts with the chlorine.
3. Temperature.
4. Removal of bleach liquors and washing the clay free from liquors.

Work was not carried out to determine the effect of temperature on bleaching. It was considered that bleaching would probably be carried out in unheated pulps.

Work was not carried out to determine the effect of washing the clay free of bleach liquor after bleaching. It would be unpracticable to do this and still retain the comparatively high pulp densities desired during filtration.

Initial bleach work was attempted on the bulk sample R.361. The separated clay from R.361 had a brightness of about 76, and it proved impossible to increase the brightness of this clay by more than one unit. Four additional bulk samples of clay were then obtained from areas known to give clays of low brightness to determine the effect of bleaching—these were samples R.364, R365A, R.365B and R.366. Later, bulk sample R.368 was also used in bleach test work.

Bleaching Tests

Various clays were prepared by decantation after normal dispersion with sodium silicate. The prepared clay pulp was then divided into a number of similar samples in sealed plastic bottles. Varying quantities of sodium hypochlorate were added to the plastic bottles which were agitated at irregular intervals. Portion of the pulp in each bottle was removed at predetermined intervals, flocculated with aluminium sulphate, filtered, dried, and the brightness of the clay determined.

CLAY R.364

Quantity of Chlorine Added: % of Clay	Brightness		
	After Five Hours Contact	After 24 Hours Contact	After 48 Hours Contact
Nil	70.6	71.8	71.0
0.09	75.0	75.8	75.0
0.19	77.4	78.0	78.6
0.94	81.6	81.8	82.0
1.89	82.4	82.6	83.0
2.83	83.2	83.0	83.4
3.77	83.0	83.2	83.0
4.72	83.6	83.0	83.0

CLAY R.365B

Quantity of Chlorine Added: % of Clay	Brightness		
	After Five Hours Contact	After eight Hours Contact	After 72 Hours Contact
Nil	60.0	60.4	60.4
0.17	62.6	63.2	63.6
0.35	67.4	67.2	67.4
0.87	71.8	72.0	73.8
1.74	75.0	74.4	75.4
3.47	76.4	75.8	76.4

CLAY R.365A

Quantity of Chlorine Added: % of Clay	Brightness After 28 Hours Contact
Nil	74.2
0.11	77.0
0.22	78.6
0.55	80.2
1.10	81.0
1.64	81.0
2.19	81.2

CLAY R.366

Quantity of Chlorine Added: % of Clay	Brightness After 26 Hours Contact
Nil	69.4
0.14	73.8
0.27	77.2
0.68	79.4
1.36	82.0
2.04	82.8
2.71	82.6

CLAY R.368

Quantity of Chlorine Added: % of Clay	Brightness After 18 Hours Contact
Nil (triplicate)	78.8, 78.6, 79.2
0.45 (duplicate)	83.4, 84.0
0.46	83.8
0.93	84.2

The tests on clays R.364 and R.365B above indicate that there is little, if any, gain in brightness due to contact times in excess of five hours. Differences obtained in these series appear to be due to random experimental error. Minimum contact times for bleaching were not determined.

The above tests show that the brightness increases with chlorine additions up to about 2% chlorine, but the maximum gain in brightness is obtained from the initial 0.1-0.5% chlorine addition.

From the attached graph an approximation can be obtained of the gain in brightness due to successive additions of 0.1% chlorine.

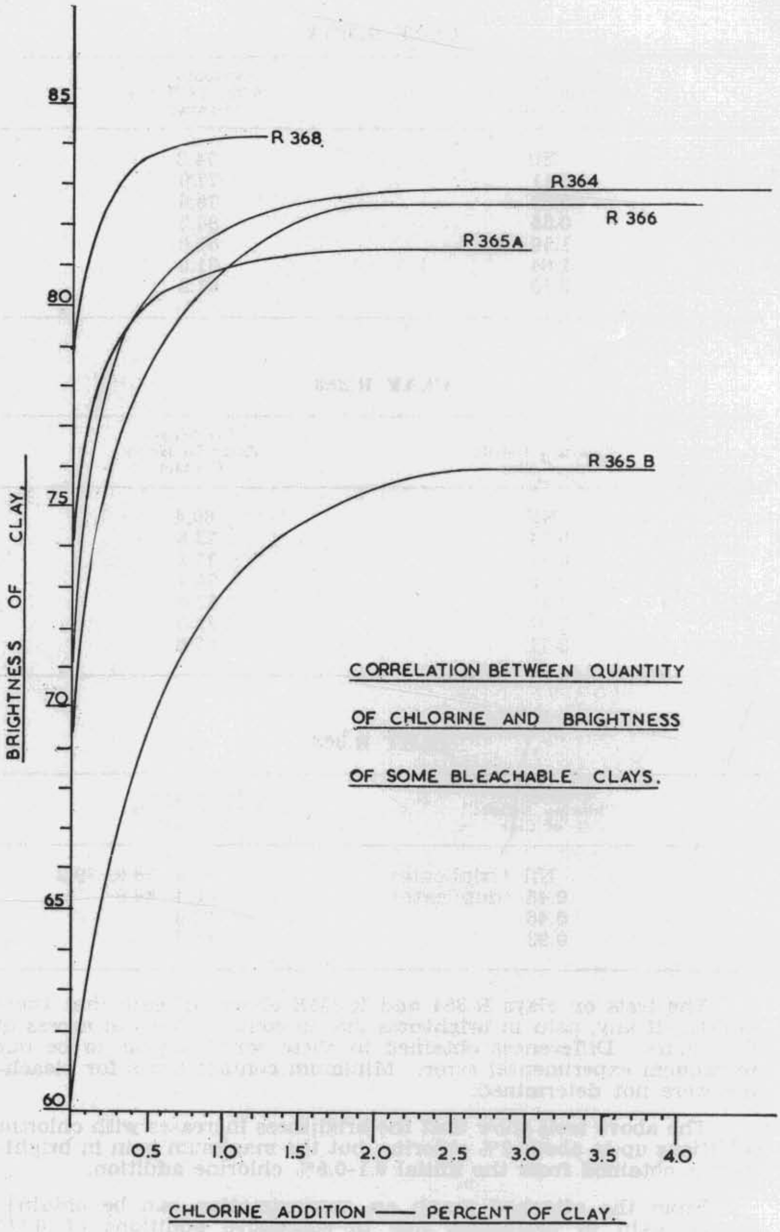


FIGURE 20.

5 cm

Addition of 0.1% Chlorine in Range	Gain in Brightness Units			
	R.364	R.365A	R.365B	R.366
Nil-0.1	3.9	2.8	2.3	3.0
0.1-0.2	3.0	1.6	2.2	3.0
0.2-0.3	1.2	0.8	1.6	2.1
0.3-0.4	0.7	0.3	1.4	0.5
0.4-0.5	0.5	0.4	0.9	0.6
0.5-0.6	0.4	0.2	0.9	0.4
0.6-0.7	0.4	0.2	0.7	0.4
0.7-0.8	0.3	0.2	0.7	0.5
0.8-0.9	0.2	0.1	0.7	0.6
0.9-1.0	0.2	0.1	0.5	0.4

The above table clearly shows how the initial addition of 0.1% chlorine gives a substantial increase in brightness of the clays. Subsequent additions give further increases, but the grain per unit chlorine addition rapidly decreases. In commercial practice, it is probable that maximum economic gain in brightness would be obtained with an addition of 0.2 or 0.3% chlorine, taking into account the fact that some of the clays do not require bleaching to meet the brightness standard.

Bleaching tests, quoted above, on samples R.364-R.366 may give the impression that the brightness of all clays from the area are bleachable with chlorine. This is not so. Some clays of low colour are stained with iron minerals or chlorite, and are virtually unbleachable with chlorine. The following series of clays were prepared by decantation. Half of the separated clay was bleached with 1.4% chlorine (as hypochlorate) with 18 hours contact.

Sample No.	Brightness of original clay	Brightness of bleached clay	Increase in brightness due to bleaching
1219	71½	78½	7
1220	71	79	8
1221	80	80½	½
1222	70½	83	12½
1223	71½	79½	8
1224	74	80½	6½
1225	73	79	6
1226	71½	72	½
1227	61	70	9
1228	61½	66	4½
1229	71	79	8
1230	71	77	6
1231	69½	76½	7
1233	76	80½	4½
1234	75	79½	4½
1255	74½	77	2½

In this series the increase in brightness due to bleaching varied from a ½ unit to 12½ units, with 12 of the 16 clays showing increases of between 4½ and 9 units. The two samples showing a gain of only ½ unit can be regarded as unbleachable. Although it must be remembered that one of these samples had a high initial brightness, and it is perhaps unreasonable to expect any increase.

Cost of Bleaching, using Launceston Manufactured Sodium Hypochlorite

Cost of sodium hypochlorite has been quoted by I.C.I.A.N.Z. as 6s. 6d. per gallon F.O.R. Launceston Freight and handling to South Mt Cameron, plus return to Launceston of the empty container, substantially increases the cost of hypochlorite at South Mt Cameron.

The cost of bleaching (using hypochlorite) at South Mt Cameron has been estimated (for chemicals only) per ton of clay, as:—

£1 3s. using 0.2% available chlorine;
£2 using 0.3% available chlorine; and
£3 3s. using 0.5% available chlorine.

Cost of Bleaching using South Mount Cameron Manufactured Sodium Hypochlorite

An estimate can be made of the cost of manufacture of sodium hypochlorite at South Mt Cameron. However, the proposed industry is not likely to employ more than one or two technical officers, and it may be a burden for a small industry to manufacture its own sodium hypochlorite.

I.C.I.A.N.Z. have quoted as follows:—

Solid Caustic Soda: 868 lb. drums. £68 per ton ex wharf, Launceston.

Chlorine

Chlorine has been priced at £88 15s. per ton, F.O.B., Melbourne, and with freight and handling charges, including return empties to Melbourne, the cost at South Mt Cameron amounted to £122 per ton.

Without taking into consideration capital cost of the hypochlorite plant, or labour and power &c. required, the cost of bleaching has been estimated for chemicals only per ton of clay as:—

£0.4, using 0.2% available chlorine;
£0.6, using 0.3% available chlorine; and
£1.0, using 0.5% available chlorine.

Bleaching with Sodium Hypochlorite, Summary

(1) Sodium hypochlorite is an effective bleach for some coloured clays from South Mt Cameron area. Other coloured clays are not bleached by chlorine.

(2) There is no advantage in using bleach contact times in excess of five hours. Minimum contact times were not investigated.

(3) There is gradual increase in the brightness of bleachable coloured clays with chlorine additions up to about 2%.

(4) Maximum gain in brightness per unit of chlorine occurs with the initial addition. Subsequent additions give further increases in brightness, but the gain per unit chlorine addition rapidly decreases.

(5) Cost of sodium hypochlorite has been estimated per ton of clay as:—

Usage of Chlorine	Launceston Manufactured	South Mt Cameron Manufactured
0.2%	£1.3	£0.4
0.3%	£1.9	£0.6
0.5%	£3.2	£1.0

Destroying Excess Hypochlorite after Bleaching

Presence of excess available chlorine in the pulp after bleaching could result in severe corrosion of the equipment used in later dewatering and drying operations.

Sodium bisulphite, or sodium thiosulphate can be used to destroy excess chlorine.

After addition of excess sodium hypochlorite to a clay pulp, with irregular agitation and overnight contact, the odor of chlorine is noted in the pulp. We have no data concerning the ability of different clays to consume chlorine. It is reasonable to assume that this ability will vary widely, and it may depend upon the organic content of the clay.

Residual Chlorine Related to Initial Chlorine Addition

A series of filtration tests carried out on clay R.361 to determine the effect of sodium hypochlorite as a flocculant proved abortive. The filtrates gave some interesting data relating to chlorine consumption after overnight contact.

Quantity of Chlorine Added: % of Clay	Available Chlorine in Filtrate		pH Value of Filtrate
	As % of Clay in Original Pulp	As % of Initial Addition	
Nil	Nil	....	6.8
0.07	0.01	14	..
0.14	0.07	50	7.9
0.28	0.18	64	8.0
0.43	0.29	67	8.0
0.57	0.40	70	8.2
0.85	0.61	72	8.5
1.14	0.95	83	8.7

It will be noted that the quantity of residual chlorine in the filtrate increases rapidly with increased initial hypochlorite addition.

Some data are also available from pilot plant filtration work on bleached pulps. Full details of this work are given later. The following extract relates to the residual chlorine content of the filtrate.

(1) Filtration test on clay R.368, first run. Chlorine added to pulp 0.50% of clay. Available chlorine in solution after overnight contact and filtration, 38% of initial addition.

(2) Filtration test on clay R.368, second run. Chlorine added to pulp 0.50% of clay. Available chlorine in solution after overnight contact and filtration, 38% of initial addition.

Consumption of chlorine in these two pilot plant tests is much higher than that obtained in laboratory tests. This difference may be due to use of commercial equipment in the pilot plant as against glass and plastic equipment used in the laboratory tests.

Cost of Destroying Excess Chlorine

I.C.I.A.N.Z have quoted sodium bisulphite at £76 per ton ex wharf, Bell Bay, and sodium thiosulphate at £70 per ton ex wharf, Bell Bay.

On the basis of these costs, sodium bisulphite will destroy excess chlorine at about one-quarter of the cost of an equivalent quantity of sodium thiosulphate.

The cost of destroying each 0.1% available chlorine with sodium bisulphite at South Mt Cameron has been estimated at £0.13 per ton of clay.

Purging Excess Chlorine with Air or Vacuum

An attempt was made to purge the excess chlorine from a pulp bleached with sodium hypochlorite, by blowing air through the pulp for 16 hours. Negligible drop in the available chlorine content of the pulp was obtained. Similar tests with pulp maintained under vacuum for some 18 hours showed negligible drop in available chlorine content.

Destruction of Excess Chlorine with Unbleached Clays

Laboratory work has indicated that some of the clays at South Mt Cameron do not require bleaching. It may be possible to destroy a slight excess of chlorine by blending bleached pulps with pulp not requiring bleaching. No work was carried out along these lines.

Effect on Brightness when Destroying Excess Chlorine

A sample of R.368 clay was prepared by decantation and divided into a number of similar samples. Identical quantities of sodium hypochlorite were added to two pairs of samples. After irregular agitation, and overnight contact, one set of samples was flocculated with aluminium sulphate and filtered. The chlorine content of the filtrate was then determined, and the equivalent quantity of sodium thiosulphate to reduce the excess chlorine was calculated. An excess of sodium thiosulphate was then added to destroy the excess chlorine in the duplicate samples. The brightness of each filter cake was determined after drying, &c.

Quantity of Cl added as % of clay	Cl in filtrate as % of clay	$Na_2S_2O_3$ (Calc.) to destroy excess Cl as % of clay	Actual $Na_2S_2O_3$ added to destroy Cl as % of clay	Cl in filtrate solution	Brightness of clay	Decrease in brightness due to $Na_2S_2O_3$ (units)
Nil	Nil	....	....	....	79.2	....
0.46	0.32	....	....	....	83.8	....
0.46	....	2.2	2.8	Nil	82.0	1.8
0.93	0.67	....	....	....	84.2	....
0.93	....	4.8	5.6	Nil	82.8	1.4

The decrease in brightness due to the destruction of the excess chlorine by thiosulphate is about 1½ units. It is not known whether this degradation in brightness can be expected with other clays under similar conditions.

The proportion of residual chlorine in this test is of the same order as that obtained during earlier laboratory tests from similar initial additions of hypochlorite.

If the proposed industry expects to use chlorine bleach and later destroy excess chlorine chemically, more work on the above lines should be carried out.

Destroying Excess Chlorine, Summary

(1) After bleaching with hypochlorite there remains some residual available chlorine in the pulp solution.

(2)) The quantity and proportion of residual chlorine in the pulp solution increases with increase in initial hypochlorite addition.

(3) Residual chlorine from pilot plant scale tests was considerably less than that obtained from laboratory tests using similar initial hypochlorite addition.

(4) 0.1% of excess chlorine per ton of clay can be destroyed with sodium bisulphite for £0.13.

(5) Chemical destruction of excess chlorine may cause some degradation in brightness. Further consideration of this aspect is warranted if the proposed industry expects to use chlorine for bleaching.

(6) It may be possible to destroy excess chlorine by blending bleached and unbleached clays.

Bleaching with Chlorine Gas

Bleaching with gaseous chlorine, as opposed to bleaching with sodium hypochlorite, offers some obvious advantages in cost of chemicals. It is to be expected that use of gaseous chlorine will be more difficult technically.

Several series of tests were carried out to determine the relative merits of the two methods of bleaching.

Samples of clays R.365A, R.365B and R.366 were prepared by decantation after agitation with sodium silicate. The prepared clays were divided into a number of similar samples in sealed plastic bottles. Various pre-determined quantities of sodium hypochlorite solution or chlorine gas were then added to each sample as required. The samples were agitated at irregular intervals and allowed to stand overnight. The samples were then filtered, &c., and the brightness of each sample determined.

In the tables following, the quantity of chlorine added refers to the actual addition. No account was taken of residual chlorine.

CLAY R.365A

Chlorine Added: % of Clay	Brightness of Clay: Chlorine Gas	Hypochlorite
Nil	74½	74½
0.11	77	78½
0.22	79	78
0.32	78½	79½
0.43	80	78½
0.54	80	79
0.65	80½	79½
0.75	81	79
0.86	80½	80
0.98	81	....

CLAY R.365B

Chlorine Added: % of Clay	Brightness of Clay: Chlorine Gas	Hypochlorite
Nil	60	60
0.11	62½	63
0.22	64½	64½
0.34	68	65½
0.45	69	65
0.56	71	63½
0.67	71½	67½
0.78	72½	69
0.89	73½	69

CLAY R.366

Chlorine Added: % of Clay	Brightness of Clay: Chlorine Gas	Hypochlorite
Nil	68	68
0.10	73	72
0.20	75½	75
0.30	76½	78
0.40	76½	75
0.50	77½	77
0.60	76½	79
0.70	77½	79
0.80	77½	80
0 90	78	....

On the basis of these tests, it seems that gaseous chlorine is as effective as chlorine from sodium hypochlorite in bleaching the South Mt Cameron clays.

The actual addition of gaseous chlorine to the clay pulp may present handling and corrosion problems. I.C.I.A.N.Z. have indicated that they will offer technical advice on the handling of chlorine gas for bleaching.

Cost of Bleaching with Gaseous Chlorine

As previously stated the total cost of chlorine at South Mt Cameron is approximately £122 per ton of chlorine.

Cost of bleaching (chemicals only) per ton of clay is thus:—

£0.24 using 0.2% chlorine;
£0.37 using 0.3% chlorine;
£0.61 using 0.5% chlorine.

This cost is considerably less than that derived using sodium hypochlorite.

Flocculation by Gaseous Chlorine

Addition of gaseous chlorine will flocculate clay dispersed with sodium silicate. The degree of flocculation increases (within limits) with increase in chlorine added. The flocculation is accompanied by a decrease in pH value.

Similar samples of clay R.366 were obtained by decantation after dispersion with sodium silicate.

Varying quantities of chlorine were then bubbled through the pulp in measuring cylinders. A high proportion of the chlorine passed through the pulp and was not absorbed.

Chlorine Added to Pulp % of Clay	pH Value of Pulp
Nil	7.3
0.76	4.6
1.40	3.1
2.16	2.8
4.32	2.4

Bleaching with Chlorine Gas, Summary

(1) Chlorine gas is as effective as sodium hypochlorite for bleaching stained clays.

(2) Chlorine gas readily flocculates clay dispersed with sodium silicate.

(3) Cost of bleaching by gaseous chlorine is appreciably less than bleaching with sodium hypochlorite, considering chemicals only. The following table shows the comparative chemical cost of chlorine gas and sodium hypochlorite manufactured at Launceston and South Mt Cameron.

Usage of Chlorine % of Clay	Gaseous Chlorine	Launceston Manufactured	Sth Mt Cameron Manufactured
0.2	£0.24	£1.3	£0.40
0.3	£0.37	£1.9	£0.6
0.5	£0.61	£3.2	£1.0

Flocculation and Filtration

The naturally occuring clay has a pH value of about four and is in a flocculated condition, but was dispersed with sodium silicate to allow best conditions for degritting in dense pulps. The clay, dispersed with 10 lb./ton of sodium silicate, will on standing gradually re-flocculate. In addition, many other chemicals will readily flocculate the clay, but insufficiently to allow good subsequent filtration rates. These chemicals include sulphuric acid, sodium hypochlorite and chlorine. Of various flocculants tested to date, aluminium sulphate has been found the most satisfactory.

The high molecular weight water soluble synthetic polymers are extremely effective flocculants. However, as the filter cake must be readily redispersible, the use of these reagents appears unlikely.

Filtration Tests

Considerable preliminary work on filtration was carried out with Buchner funnel filtration tests. This work gave much information which was incorporated in later filter leaf tests and pilot plant scale filtration tests. In view of the data obtained from pilot plant scale filtration tests, it is proposed to merely summarize filter leaf tests, and to mention only such Buchner funnel tests as are relevant.

Laboratory Test Leaf Procedure

A laboratory test leaf filter was supplied by Chemical Plant & Engineering Co. Pty. Ltd., Melbourne. The laboratory test leaf filter has an effective filter area of 6" x 4". The filter is fitted with interchangeable cloths, strings for cake discharge, &c. A tabulation, supplied with the filter, quotes times for filtration and dewatering corresponding to various filter speeds at different drum submergences. As the pilot plant filter had a drum submergence of 37½%, all laboratory test leaf filtration tests corresponded to 37½% submergence.

When discussing laboratory leaf test results, the time cycle of the test is summarized as " filter speed, r.p.m.", and the time cycles employed correspond to this speed, in r.p.m., at 37½% submergence.

A vacuum of 15-16 inches of mercury was used throughout filter leaf tests.

Pilot Plant Filter

The pilot plant was a three feet diameter by one foot face width, FEinc string discharge rotary vacuum filter. The filter was made available by Chemical Plant & Engineering Co. Pty. Ltd. of Melbourne.

The filter bath has two overflow ports, corresponding to 25 and 37½% submergence. All tests were carried out at 37½% submergence. With the tank supplied, the submergence could not be increased above 37½%.

Filter cloth used for the bulk of the tests was No. 416 Terylene cloth, obtained through Australian Titan Products Pty. Ltd., Tasmania. String used was " Emu " Brand No. 5, Bricklayers Macrame.

The filter was fitted with provision for rollers, but these were not used during plant tests. Vacuum used on both filtration and dewatering cycles was 15-16 inches of mercury, with a little fluctuation due to the cyclic nature of the valves, &c.

Filter speed is variable, and is controlled by a variable pitch Reeves pulley. Motors of 960 and 1440 r.p.m. were used, and filter speeds in the range of one revolution in 20 minutes to one revolution in 2¾ minutes were possible.

Probably due to the lack of elevation between the filtrate receivers and the position of the filtrate pump, the filtrate pump was not effective. No filtrate pump was used during the tests as the filtrate receivers proved more than adequate to store the filtrate during the period of the tests. No problems were encountered during filtration test runs.

Quantity of Aluminium Sulphate for Flocculation

Buchner funnel tests showed that an increase in the quantity of aluminium sulphate increased the filtration rate of the clay within limits. The requirements of various clays varied somewhat, but generally it was found that additions of between 15 and 45 pounds of aluminium sulphate per ton of clay gave reasonable filtration rates. Beyond a certain point additional aluminium sulphate gives no further benefit, and may result in slightly decreased filtration rates. In general, a series of Buchner funnel tests was carried out to obtain an approximation of the optimum addition of aluminium sulphate before filter leaf tests.

Cost of Aluminium Sulphate for Flocculation

On the basis of Launceston prices, the cost of aluminium sulphate at South Mount Cameron has been estimated at £45 per ton.

The consumption of aluminium sulphate appears to vary from clay to clay, and we have used between 15 and 45 pounds per ton, with a general average of about 25 or 30 pounds per ton.

Usage pounds per ton	Cost of Aluminium Sulphate per ton of clay
15	£0.3
30	£0.6
45	£0.9

Filter Leaf Tests

Filter leaf tests were carried out on the bulk samples R.361, R.364, R.365A, R.365B, R.366 and R.368. A number of variables were investigated, including filter speed, increase in temperature and effect of rolling on moisture content of the filter cake.

1. *Preparation of Clay Pulps.*

The clays were prepared by decantation after ½ hour agitation with 14 pounds of sodium silicate per ton of crude clay. Sodium hypochlorite was added to give the equivalent of 0.5% available chlorine. Aluminium sulphate was added at a quantity predetermined by Buchner funnel tests. The quantities used are given below.

All pulps had a specific gravity of 1.180-1.190, equivalent to 25-26% solids, except clay R.361, which had a specific gravity of 1.24, equivalent to 31% solids. Temperatures of the pulps are stated below.

Filter cloth Terylene 416 was used on all the tests detailed below.

2. *Filtration Rates at Various Filter Speeds*

Clay R.368
Temperature: atmospheric = 9°C
Aluminium Sulphate: 45 lb./ton

Filter Speed r.p.m.	Filtration Rate: lb./sq.ft./hr. of dry clay	Moisture in Filter Cake %
1/16	3.7	41.7
1/14	4.2	42.0
1/12	4.2	43.0
1/10	4.7	42.3
1/8	5.3	43.1

Clay R.361
Temperature: atmospheric = 8° to 10°C.
Aluminium Sulphate: 25 or 26 lb./ton.

Filter Speed r.p.m.	lb./sq.ft./hr. of dry clay	Moisture Content of Filter Cake * %	Thickness of Filter Cake inches *
1/16	4.9	....	....
1/16	5.3	46.1	13-14/64
1/16	5.1	48.5	14-16/64
1/16	5.2	48.0	13-14/64
1/14	....	47.1	13/64
1/12	5.4	48.1	11-12/64
1/10	5.9	48.2	9-10/64
1/8	7.2	....	....
1/8	7.0	48.0	10/64

* Some cakes were rolled for reduction of moisture tests: other cakes were rolled over half the area. Figures quoted for moisture content and cake thickness refer to unrolled cakes.

The filtration rate increases significantly with increase in filter speed. The actual thickness of filter cake decreases with increase in filter speed—this aspect is discussed later.

3. *Filtration Rates at Elevated Temperatures*

Buchner filtration tests established that increased pulp temperature markedly increased filtration rates. The effect of temperature upon filtration rate when all other conditions remain constant is shown in the series below using clay R.368 and aluminium sulphate 45 lb./ton.

Temp. °C	Filter Speed r.p.m.	Filtration Rate lb./sq.ft./hr. of dry cake	Moisture Content of cake %
9	1/8	5.3	43.1
32	1/8	7.7	41.3
43	1/8	7.5	40.4
52	1/8	8.2	40.8
61	1/8	9.0	40.2

Because the filter speed has remained constant, and the filtration rate has increased, the thickness of filter cake has naturally increased considerably.

A better comparison of filtration rates should be possible when the cake thickness is the same in both cases. This is readily attained by using increased filter speeds at the elevated temperatures.

Clay	Temp. °C	Aluminium Sulphate lb./ton of clay	Filter Speed r.p.m.	Filtration Rate lb./sq.ft./hr. of dry cake	Moisture content of filter cake %	Filter Cake thickness (approx.) inches
R.361	8	26	1/16	5.3	46.1	13-14/16
	40	26	1/10	9.7	46.6	16-20/64
	57	26	1/8	9.5	46.9	18-19/64
R.364	11	44	1/16	4.0	47.2	12/64
	58	44	1/8	8.0	47.6	13/64
R.365A	11	28	1/16	5.2	46.8	12/64
	56	28	1/8	11.6	43.4	13/64
R.365B	9	46	1/16	3.9	44.0	10-11/64
	62	46	1/8	9.3	44.0	13-14/64
R.366	10	30	1/16	3.1	47.8	8-9/64
	59	30	1/8	6.5	47.2	9-10/64
R.368	9	45	1/16	3.7	41.7	....
	61	45	1/8	9.0	40.2	

The tabulation on the previous page shows clearly how the filtration rate is approximately doubled by heating the pulp from about 8-10°C to about 60°C.

Buchner funnel tests indicated further advantages by boiling or almost boiling the pulp. Reliable test leaf filtration data on boiling pulps was not obtained due to the difficulties in maintaining other conditions constant, and to experimental manipulation difficulties, with boiling viscous pulps.

Correlation between Moisture Content of Filter Cake and Fineness of Clay

The moisture content of the filter cakes of the various clays tested vary in the range 40-48% moisture, and is related to the fineness of the clay. This is illustrated in the following table, which compares the moisture contents of the filter cakes obtained from filter leaf tests at atmospheric temperatures and equivalent 1/16 r.p.m., with the quantity of minus two micron material in the minus 30 micron separated clays.

Clay	% Moisture in Filter Cake	% Minus 2 Micron Material in minus 30 Micron Clay
R.366	48	56
R.361	46	45
R.364	47	41
R.365A	47	38
R.365B	44	37
R.368	42	34

On the very fine clays, such as centrifuge overflows, containing between 60 and 70% minus one micron material, the moisture content of the filter cake is approximately 60%.

Effect of Pressure Rolling on Moisture Content of Filter Cake.

FEinc string discharge filters are equipped so that the filter cake can be pressure rolled to reduce the moisture content of the cake, if so desired. A series of leaf tests were carred out on clays R.361 and R.368 to determine the effect of rolling on the moisture content of the filter cakes. In some cases, half of the filter leaf was rolled, and half remained unrolled. In other cases the test was duplicated, and the whole cake rolled or not rolled respectively.

CLAY R.368

Temp. °C	Filter Speed r.p.m.	% Moisture In Unrolled Cake	% Moisture In Rolled Cake	Decreased in Moisture Content of Filter Cake %
9	1/16	46.6	41.7	4.9
9	1/14	46.0	42.0	4.0
9	1/12	46.7	43.0	3.7
9	1/10	46.5	42.3	4.2
9	1/8	47.0	43.1	3.9
32	1/8	46.6	41.3	5.3
43	1/8	45.7	40.4	5.3
52	1/8	44.9	40.8	4.1
61	1/8	46.0	40.2	5.8

Average decrease in moisture content of filter cakes due to rolling 4.6%.

CLAY R.361

Temperature: 8° to 10°c

Filter Speed r.p.m.	% Moisture In Unrolled Cake	In Rolled Cake	Decrease in Moisture Content of Filter Cake %
1/16	48.5	45.1	3.4
1/16	48.0	46.2	1.8
1/12	48.1	45.3	2.8
1/10	48.2	46.0	2.2
1/8	48.0	45.3	2.7

Average decrease in moisture content of filter cake due to rolling 2.6%.

Laboratory Filtration Tests, Summary

(1) Clay dispersed with sodium silicate can readily be flocculated by various chemicals. Aluminium sulphate was the best flocculant tested.

(2) Quantity of aluminium sulphate for optimum filtration rates varies with different clays, and usage was in the limits of 15 to 45 pounds per ton of clay.

(3) Cost of aluminium sulphate is:—

Usage: pounds per ton	Cost, per ton of clay
15	£0.30
30	£0.60
45	£0.90

(4) Moisture content of filter cakes varied with different clays in the range 40 to 48% per cent moisture, and depends upon the fineness of the clay.

(5) Increased filter speeds, resulting in thinner filter cakes, result in significantly increased filtration rates.

(6) Elevated pulp temperatures significantly increase filtration rates of the clays: an increase of about 50 centrigrade degrees approximately doubles filtration rates.

(7) Pressure rolling of filter cakes reduces the moisture content of the cake on an average of 4.6% for clay R.368, and 2.6% for clay R.361.

PILOT PLANT FILTRATION TESTS

1. Preparation of Pulps

Pulps for filtration were prepared in the pilot plant by cycloning in a 30 m.m. cyclone after dispersion with sodium silicate, as discussed earlier in the report.

The cyclone overflow was collected in 10 gallon storage drums. Sodium hypochlorite, equivalent to 0.50% of available chlorine, was added to the pulp, and after vigorous agitation for a few minutes the pulp was allowed to stand overnight.

The pulp was flocculated next morning with aluminium sulphate, which was added just prior to filtration. The addition of the aluminium sulphate resulted in a very viscous pulp, which made thorough mixing in of the last of the flocculant rather doubtful. The pulp was added to the filter tank as required.

The filter tank is provided with an agitator, and it is assumed that this agitator gave a uniform feed in the filter tank.

Quantities of aluminium sulphate added were predetermined by Buchner funnel tests.

CLAY R.361

Pulp density: 31% solids: specific gravity of pulp 1.24.

Temperature: atmospheric = 9°C.

Aluminium Sulphate: 23 pounds per ton.

Duration of Test: Minutes	Filter Speed r.p.m.	Filtration Rate lb./sq.ft./hr. of Dry Cake	Moisture Content of Cake %	Cake Thickness Inches
30	1/20	3.4	47.2	14/64
30	1/15	4.2	47.0	12/64
30	1/12	4.5	46.3	10-11/64
20	1/9½	5.0	46.3	9-10/64

CLAY R.368

First Run

Pulp density: 30% solids:: specific gravity of pulp 1.23.

Temperature: atmospheric = 8°C.

Aluminium Sulphate: 45 pounds per ton.

Duration of Test: Minutes	Filter Speed r.p.m.	Filtration Rate lb./sq.ft./hr. of Dry Cake	Moisture Content of Cake %
30	1/17	4.1	46.8
30	1/15	4.1	46.6
20	1/9½	5.2	46.0
15	1/6½	6.5	46.0
8	1/3¾	8.5	45.9

Quantity of available chlorine added for bleaching = 0.50% of clay.

Quantity of available chlorine in filtrate liquors after filtration = 0.19% of clay.

Consumption of chlorine was 62% of that added. This proportion is considerably higher than that obtained under laboratory tests (see earlier discussion).

CLAY R.368
Second Run

Pulp density: 27% solids.
Temperature: atmospheric = 9°C.
Aluminium Sulphate: 45 pounds per ton.

Duration of Test: Minutes	Filter Speed r.p.m.	Filtration Rate lb./sq.ft./hr. of Dry Cake	Moisture Content of Cake %
10	1/6⅓	5.7	46.6
10	1/3⅔	7.0	46.6
10	1/2$^{9}/_{10}$	8.3	46.5
10	1/2¾	9.1	45.6

Quantity of available chlorine added for bleaching = 0.50% of clay.

Quantity of available chlorine in filtrate liquors after filtration = 0.19% of clay.

Consumption of chlorine was 62% of initial addition. This consumption is identical with that obtained from the first run with clay R.368.

This second run on clay R.368 was carried out to determine the effect of comparatively high filter speeds on filtration. Most of the clay was discharged at the alignment comb, rather than from the discharge roll.

Thickness of Filter Cake

The FEinc string discharge filter is designed so that the filter cake is lifted from the drums by the series of strings provided. As the strings change direction over the discharge roll, the cake falls from the strings. As the strings return to the drum, they pass through the alignment comb. This comb quickly builds up with pieces of filter cake, and eventually the returning strings are wiped clean of adhering lumps of filter cake by the accumulation of clay.

With clay filter cakes thicker than about ⅛ inch, good discharge from the strings occurs at the discharge roll, but as mentioned above, any clay adhering to the strings is wiped off at the comb, and eventually there is a small but regular discharge of clay at this point.

With cakes less than about ⅛ inch, discharge from the roll decreases and most of the clay discharges from the alignment comb.

Carried still further, with very thin cakes such as produced with centrifuge effluents (see later) and relatively high filter speeds, no cake is discharged at the rolls, and all is discharged at the alignment comb.

We can see little objection to this type of discharge. The clay builds up on the comb irrespective of the cake thickness, and the strings are then pulled through an accumulation of clay on the comb. It does not seem to matter whether only a small part or whether the majority of the clay is discharged at the comb, as far as wear on the strings or comb is concerned. This argument applies only to very fine clay, with virtually no quartz or other abrasive material. It is suggested that this method of operation be referred to manufacturers for their opinion.

Increasing filter speed significantly increases the capacity of a filter. For example, the following figures are taken from the two runs with clay R.368.

Filter Speed r.p.m.	Filter Capacity lb./sq.ft./hr. of Dry Cake
1/17	4.1
1/15	4.1
1/9½	5.2
1/6½	6.5
1/3¾	8.5

It appears from these, and similar, figures that if thin filter cakes, i.e. comb discharge, can be accepted, then a significant increase in filtrate rate can be obtained. From the above table, it appears that the filtration rate can be doubled by increasing the filter speed four times.

Now, previously, it was found that increasing the temperature of the pulp prior to filtration to about 60°C roughly doubled the filtration rate.

If comb discharge can be combined with filtration of heated pulp, it appears that filtration rates four times greater than those obtained at atmospheric temperatures may be attained. As previously mentioned all tests with the pilot plant filter were at atmospheric temperature.

Pilot Plant Filtration, Summary

(1) Pilot plant filtration work confirmed previous filter leaf test results, regarding filtration rates, moisture content of cakes, and increase in filtration rates with increase in filter speeds, resulting in the formation of thinner filter cake.

(2) A marked increase in filtration rates is possible if thin cakes can be discharged at the alignment comb. Manufacturers' advice regarding this proposal should be sought.

SOME ECONOMIC CONSIDERATIONS REGARDING FILTRATION

Filter Area Required

At atmospheric temperatures, the following filtration rates were obtained by leaf and pilot plant tests on the various clays.

Nature of Test	Clay	Filter Speed r.p.m.	Filtration Rate lb./sq.ft./hr. of Dry Clay
Pilot Plant	R.361	1/15	4.2
Filter Leaf	R.364	1/16	4.0
Filter Leaf	R.365A	1/16	5.2
Filter Leaf	R.365B	1/16	3.9
Filter Leaf	R.366	1/16	3.1
Pilot Plant	R.368	1/15	4.1

Average of the six clays is 4.1 lb./sq.ft./hour.

Assuming—

(1) an annual rate of production of 10,000 tons per year of 50 weeks,

(2) a five day week, 24 hour operation,

(3) filter working time: 85% of possible, then filter area required = 1100 sq. ft.

On the same basis, but assuming a seven day week, and working time of 85% of possible, the filter area required is 770 sq. ft.

Heating the filter feed pulp to about 60°C reduces these areas to about 560 sq. ft. on a five day basis, and 390 sq. ft. on a seven day basis.

Cost of Heating Pulp Prior to Filtration

Two fuels can be considered—

(a) furnace oil at £17.9 per ton at South Mount Cameron, calorific value 18,500 B.Th.U./lb.

(b) Tasmanian coal at £6 per ton at South Mount Cameron, calorific value 10,000 B.Th.U./lb.

Assuming a clay pulp at 30% solids, the heat required to raise the temperature 90 Fahrenheit degrees (i.e. 140°F) per 100 tons of pulp is 15,500,000 B.Th.Units.

Assuming an overall efficiency of 70% then the quantity of coal required would be one ton. At the cost of £6 per ton for coal, the cost per ton of clay would be £0.2.

On the same basis, the cost of furnace oil to heat the pulp would be £0.32 per ton of clay.

On the basis of fuel cost only, Tasmanian coal is considerably cheaper as a source of fuel.

Economics of Heating Prior to Filtration

The relative economic advantage of heating pulps will depend upon a number of inter-related factors.

(1) The increase in filtration rate, listed above, due to heating can be summarized:—

Clay	Atmospheric Temp. °C	Atmospheric Filtration Rate lb./sq.ft./hr.	Atmospheric Filter Speed r.p.m.	Elevated Temp. °C	Elevated Filtration Rate lb./sq.ft./hr.	Elevated Filter Speed r.p.m.	Increase in Filtration Rate %	Increase in Pulp Temp. °C
R.361	8	5.3	1/16	57	9.5	1/8	79	49
R.364	11	4.0	1/16	58	8.0	1/8	100	47
R.365A	11	5.2	1/16	56	11.6	1/8	123	45
R.365B	9	3.9	1/16	62	9.3	1/8	138	53
R.366	10	3.1	1/16	59	6.5	1/8	110	49
R.368	9	3.7	1/16	61	9.0	1/8	143	52
				AVERAGE OF SIX CLAYS			115	49

On the above clays, an increase in temperature of about 50 centrigrade degrees will roughly double the filtration rate.

(2) Cost of fuel to heat the pulp through 50 centrigrade degrees was shown to be £0.20.

(3) The cost of a drum filter 9 ft. x 10 ft., with a filter area of 250 sq. ft., covered against corrosion, has been estimated at between £8000 and £9000.

(4) For present purposes we can assume that the annual cost of filtration due to capital charges, amortization and maintenance is 30% of the capital cost of the filter.

(5) Filter area required under varying conditions was previously assessed as—

Pulp Temperature	Filter Area Required: 5 Day Week	Filter Area Required: 7 Day Week
Atmospheric	1100	770
Heated to 60°C	560	390

(6) On the basis of £8500 per 250 sq. ft. of filter area, and assuming pro rata capital cost, then capital cost of filters will be—

Pulp Temperature	Estimated Capital Cost: 5 Day Week	Estimated Capital Cost: 7 Day Week
Atmospheric	£37,400	£26,200
Heated to 60°C	£19,000	£13,300

(7) Thirty per cent of capital charges, over 10,000 tons per year will be —

Pulp Temperature	Estimated Cost/Ton Clay: 5 Day Week	Estimated Cost/Ton Clay: 7 Day Week
Atmospheric	£1.12	£0.79
Heated to 60°C	£0.57	£0.40

(8) Labour to operate the filters is assumed to be one man per shift, irrespective of the number of filters involved. Weekly wage of £15 per week of five eight hour shifts is assumed. Cost of labour, based on 10,000 tons of clay per year is—

£0.23 per ton of clay on a five day week.
£0.32 per ton of clay on a seven day week.

A summary of the various factors follows.

Operating Conditions / Temperature of Pulp	Operating Week	Fuel Cost per ton of Clay	Capital Charges per ton of Clay	Labour	Total Cost
Atmospheric	5 day	....	£1.12	£0.23	£1.35
Atmospheric	7 day	....	£0.79	£0.32	£1.11
Heated to 60°C	5 day	£0.20	£0.57	£0.23	£1.00
Heated to 60°C	7 day	£0.20	£0.40	£0.32	£0.92

Economic Conditions, Summary

These preliminary estimates indicate that there is an economic advantage in heating the pulp prior to filtration. They also indicate that operation on a seven day week is more economic than five day operation.

Drying

No experimental work has been carried out to determine the relative advantages or economics of various methods of drying the finished clay.

Effect of Increased Temperatures on Brightness of Various Clays

Some methods of drying involve contact of the clay with gas inlet temperatures of the order of 1000°F. In such cases there could be a short period of overheating. To determine the possible effect of excessive heat on various clays, a series of tests was carried out on natural and bleached clays. The clays tested all had a low initial brightness due to organic staining. The clays were maintained at the temperatures stated for half an hour.

(*a*) Tests on Bleached Clays

Brightness after Heat Treatment

Clay	Heated to 105°C	Heated to 122°C	Heated to 190°C	Heated to 250°C	Heated to 350°C	Heated to 450°C
R.364	83	82½	82	76½	74½	73
R.365A	80½	80½	79	73½	70½	68
R.365B	74½	74½	71½	66½	65	64½
R.366	81½	81½	79	77	71½	69½

The brightness of the clays is unchanged at 122°C, and has dropped only slightly at 190°c. At temperatures of 250°C and higher, there is appreciable degradation in brightness.

Brightness after Heat Treatment

(*b*) Tests on Unbleached Clays

Clay	Heated to 105°C	Heated to 122°C	Heated to 190°C	Heated to 250°C	Heated to 350°C	Heated to 450°C
R.364	71	71	66	62½	68	69
R.365A	74	74½	71½	66½	65	64½
R.365B	60	59½	56	51	59½	62
R.366	69½	69	65	66	69	69

The brightness of these unbleached clays gradually decreased with increase in temperature to 250°C. At higher temperatures the brightness increased again, and at 450°C, the brightness of three of the four clays approximated the initial brightness.

Cost of Drying

The moisture content of the filter cake varies somewhat with the different clays.

Clay	Average Moisture Content from Filter Tests
R.361	46½%
R.364	47½%
R.365A	46½%
R.365B	44 %
R.366	47½%
R.368	46½%
Average six clays	46½%

Pressure rolling may reduce this moisture by 2-4%, and redispersion with phosphates (see later) may increase it by a similar amount. These possibilities are neglected for present purposes.

Assuming—

(i) a weekly production of 200 tons of clay

(ii) initial temperature of filter cake 10°C

(iii) use of Tasmanian coal of 10,000 B.T.U./lb.

(iv) cost of coal at South Mout Cameron £6 per ton

then the quantity of coal required, and the cost per ton of clay will depend on the overall thermal efficiency (of fuel combustion and heat transfer) as follows.

Overall Thermal Efficiency	Tons of Coal Per Week	Cost of Coal per ton of Clay
25	80	£2.4
30	66	£2.0
40	50	£1.5
50	40	£1.2

These calculations assume the final moisture content of the finished product to be reduced to zero. In practice, it is possible that the moisture content of the clay would be reduced to somewhere between 3 and 10%, dependent upon the method of drying. Costs above relate merely to the cost of the fuel, and does not allow for capital costs, operation maintenance or depreciation, &c.

Redispersion of Filter Cake

The filter cake, flocculated with aluminium sulphate and containing about 47% moisture, can be liquified and the clay redispersed by the addition of small quantities of tetra sodium pyro phosphate.

No quantitative tests have been carried out to determine the minimum quantity of pyro phosphate required for redispersion. Several qualitive tests indicated that clay R.368 was readily liquified by agitation with about 9 lb. of pyro phosphate per ton of clay.

Under similar conditions Ballarat Clay Company Pty. Ltd. redisperse filter cake with 5 lb. per ton of tetra sodium pyro phosphate, and there seems little reason why this quantity would not suffice on South Mount Cameron clays.

A.P.P.M. carried out tests on a sample of clay R.361 prepared in the pilot plant in the usual manner. The sample was divided into two parts.

Part "A" was evaporated to dryness in an air oven in the dispersed state.

Part "B" was flocculated with 30 lb. per ton of aluminium sulphate and then dried.

In a letter dated 22nd August, 1960, A.P.P.M. made the following comment regarding these samples.

The Mines Department sample "A" was readily dispersible with a small quantity of sodium silicate, ¼% N84 grade. Sample "B" was also dispersible with silicate but the requirement was higher around 1½%. However, filtration before drying may reduce the demand. The A.P.P.M. bleached sample was dispersible with 1¼% silicate. As a point of interest sodium hypochlorite was added to sample "A" dispersed with 1% silicate and flocculation did not occur until 3% of available chlorine had been added.

The following methods were used to measure the degree of dispersion:—

(1) Time for a given volume to pass through an orifice as a measure of viscosity.

(2) Viscosity as measured with a wire type torsion viscometer.

(3) Sensitivity of a hydrometer placed in the slurry.

(4) Visual appearance.

Viscosities of the Mines Department samples slurried with:—

(*a*) No dispersant addition,

(*b*) 1% Calgon,

(*c*) 1½% N84 grade sodium silicate,

were compared with viscosities of slurries of E.T.M., Ballarat, English, Rodda and Huber clays.

If viscosity can be taken as a reliable measure of dispersion, then the Gladstone clay can be satisfactorily dispersed at a concentration of 3lb. solids per gallon with sodium silicate. Of the clays listed above, Ballarat clay is the only one which disperses satisfactorily without addition of chemical. Indications are that calgon is no more effective a dispersent for the alum flocculated clay than silicate under the conditions of test. It may well be that at high solids concentration the silica gel may absorb so much water that viscosity is increased merely by lack of water and not by failure to disperse.

Dried lumps from samples "A" and "B" disintegrated or "slacked" readily in solutions of sodium silicate and indications are that our mixing plant could handle this material in either dispersed or flocculated form.

Ballarat clay is dried in a dispersed state, and this probably accounts for the ease of dispersion of the clay at A.P.P.M., as mentioned above.

If the South Mount Cameron clay is dried in the dispersed condition, it is assumed that it will behave in a similar manner to Ballarat clay.

If the South Mount Cameron clay is dried in the flocculated state, the tests carried out by A.P.P.M. indicate that it will be readily dispersible to A.P.P.M. requirements.

I.C.I.A.N.Z. have quoted Tetra sodium pyro phosphate at £135 per ton (in 56 lb. paper bags) at Launceston. Cost at South Mount Cameron has been estimated at £140. Cost of 5 lb. per ton of clay would be £0.32.

There are a number of different methods by which the clay filter cake can be dried. Unless it is necessary to liquify the cake before drying by such methods as drum driers (as at Ballarat) or spray driers, there is no point in redispersing the filter cake with tetra-sodium pyro phosphate.

We have no knowledge of the method of drying that will be used in the proposed commercial plant.

Use of Centrifuge for dewatering clay

There are two possible applications for a centrifuge in the preparation of the clay:—

(1) As a method of dewatering a large proportion of the clay prior to drying, leaving a relatively dilute pulp to be filtered.

(2) As a method of making coating grade clays by stripping portion of the finest sizes into a second product, to be filtered and dried separately.

This second application was not investigated by us and for this reason only a limited number of sizings were determined.

The Experimental Centrifuge

The Burton 7-inch centrifuge was hired from Roy Burton and Co. Pty. Ltd., Melbourne.

The unit is fitted with an agitated feed tank, gear pump for feed to the centrifuge, and a by pass valve to control the feed rate. Centrifuge speed can be varied by changing drive pulleys. All centrifuging tests were carried out at speeds of 2450 r.p.m., producing a centrifugal force of 600 times gravity.

Initial Tests

These tests were carried out at comparatively low densities and at variable feed rates. The pump installed in the unit did not allow the centrifuge to be fully loaded under conditions of test. These initial tests are of limited value as thickening tests as the feed rates were well below the capacity of the centrifuge, and the pulp densities are considerably less than likely to be used in practice. Tests were carried out on a sample of R.361, prepared by normal pilot plant procedure.

Test No.	Product	Pulp Density % Solids	Pulp Rate gals./hr.	Pulp Rate lbs./hr. of Solids	% Recovery of Solids
1	Discharge	53	1.0	7.9	76
	Effluent	4	5.8	2.5	24
	Feed	15	6.8	10.4	100
2	Discharge	53	2.0	16.2	60
	Effluent	7	14.3	10.8	40
	Feed	15	16.3	27.0	100
3	Discharge	52	1.4	10.4	77
	Effluent	7	4.8	3.1	23
	Feed	20	6.2	13.5	100
4	Discharge	54	3.1	24.8	63
	Effluent	9	14.1	14.6	37
	Feed	20	17.2	39.4	100
5	Discharge	54	2.6	20.6	72
	Effluent	11	6.8	8.0	28
	Feed	26	9.4	28.6	100
6	Discharge	55	4.0	33.3	61
	Effluent	14	13.4	20.7	39
	Feed	26	17.4	54.0	100

These tests show tthat when the centrifuge is handling feed rates well below its capacity:—

(1) The pulp density of the centrifuge underflow is relatively constant at 53-55% solids, irrespective of feed rates.

(2) An increase in the feed rate increases the proportion of solids reporting in the effluent.

(3) An increase in density, while maintaining the same feed rate in terms of pounds of solids per hour, increases the proportion of solids reporting in the discharge.

The centrifuge effluent from test No. 6 was sized and gave the following results.

Size Product	% Weight
+ 6 microns	0.2
— 6 + 1 microns	31.9
— 1 micron	67.9
	100.0

The discharge from test No. 6 was sized with a Bouyoucos hydrometer and gave the following results.

Size Product	% Weight
+ 30 microns	4.0
— 30 + 20 microns	1.5
— 20 + 10 microns	18.0
— 10 + 5 microns	23.0
— 5 + 1 microns	44.5
— 1 micron	9.0
	100.0

These sizings indicate that about 70% of the minus one micron material reported in the centrifuge effluent under the conditions of test.

Capacity of Centrifuge and Effect of Feed Rate

A series of tests was carried out on clay R.361 prepared by the standard pilot plant method to determine the capacity of the centrifuge. The pulp density was 31% solids. To carry out this series of tests, the pump supplied with the centrifuge unit was replaced by a larger gear pump.

One centrifuge test was also carried out on a sample of clay R.368 prepared by normal pilot plant methods.

Clay	Test No.	Product	Pulp Density % Solids	Pulp Rate, gals./hr.	Pulp Rate lb./hr. of solids	% Recovery of Solids
R.361	7	Discharge	54	4.6	37.1	45
		Effluent	20	19.8	45.2	55
		Feed	31	24.4	82.3	100
R.361	8	Discharge	54	7.3	60.0	38
		Effluent	22	37.5	98.3	62
		Feed	31	44.8	158.3	100
R.361	9	Discharge	55	8.0	66.8	39
		Effluent	22	39.9	104.3	61
		Feed	31	47.9	171.1	100
R.361	10	Discharge	55	9.8	82.5	28
		Effluent	25	70.2	207.8	72
		Feed	32	80.0	290.3	100
R.361	11	Discharge	55	9.9	82.5	24
		Effluent	27	81.1	263.2	76
		Feed	31	91.0	345.7	100
R.368	12	Discharge	55	7.5	62.7	75
		Effluent	13	14.8	21.0	25
		Feed	31	22.3	83.7	100

The tests on clay R.361 show:—

(1) The pulp density of the discharge is constant at 54-55% solids, confirming initial observations.

(2) The experimental centrifuge has a maximum discharge rate of about 9.8-9.9 gallons per hour under the conditions of the test. This occurs at feed rates of about 80 gallons per hour, under the conditions of the test.

(3) An increase in the feed rate increases the proportion of solids reporting in the effluent.

A comparison between test No. 7 with R. 361 and test No. 12 with R.368 is interesting. Under very similar conditions of feed rate and pulp density, there is a marked difference in the proportion of solids reporting in the respective products. Thus with clay R.361, 55% of the feed reports in the effluent. With clay R.368, only 25% of the clay reports in the effluent.

A tentative conclusion from these results was that clay R.368 contains considerably less very fine material (say minus one or minus two micron). This conclusion is supported to some extent by Bouyoucos hydrometer sizings on samples of clay prepared from clays R.361 and R.368 by decantation under similar conditions.

Size Product	Per Cent Weight R.361	R.368
+ 10 microns	14.0	11.5
— 10 + 5 microns	17.0	23.5
— 5 + 2 microns	24.0	30.5
— 2 microns	45.0	34.5

Thickening Dispersed Pulp by Settlement

The application of a centrifuge to thicken clay pulps has been detailed. Pulps can also be thickened by settlement and tests were undertaken to show this application. The process can also be applied to produce coating clays and is practised in various commercial plants.

A series of settlement tests were performed on dispersed clay R.361, prepared by normal pilot plant methods. The tests were carried out in glass measuring cylinders with a settlement column of 15 inches. The pulp density of the feed was 31% solids.

Test No.	Settlement Time Hours	Thickened Product % Solids	% Weight
1	1½	54	22
2	4	55	33
3	5	55	38
4	6	56	39
5	30	56	61
6	92	57	80

The density of the thickened pulp was 54-57% solids, which is very similar to that attained with the centrifuge. Increase in settlement time naturally increases the proportion of solids in the thickened product.

Similar results can be obtained with the centrifuge by varying the feed rate, and it appears probable that any thickening made by the centrifuge could be approximated by settlement over prolonged periods.

Filtration of Centrifuge Overflows

Use of the centrifuge will decrease the volume of clay pulp to be filtered, and will greatly decrease the solid content of the same pulp. This can reduce the cost of flocculant and redispersant. However the pulp to be filtered contains the finest fractions of the clay and this has a much lower filtration rate from dilute pulps than the normal clay.

Filtration of the whole clay was successful on No. 416 Terylene cloth. No. 416 cloth was unsuitable for filtration of the centrifuge overflow at atmospheric temperatures, as the bulk of the pulp passed through the filter cloth. Two multi-filament nylon cloths, No.'s 206 and 212, were received from Chemical Plant and Engineering Co. Pty. Ltd., Melbourne, for filtration of these fines. Although much more closely woven, these cloths still allow passage of some fines during filtration at atmospheric temperatures. At temperatures of 50-60°C, little or no clay passes through the cloths, due doubtless to better flocculation at these higher temperatures.

Clay R.361

Filter leaf tests were carried out on a sample of centrifuge overflow from test No. 6, outlined previously. Data from this test were:—

Test No.	Product	Pulp Density % Solids	Pulp Rate gals./hr.	Pulp Rate lb./hr. of Solids	% Recovery of Solids
6	Discharge	55	4.0	33.3	61
	Effluent	14	13.4	20.7	39
	Feed	26	17.4	54.0	100

Data relating to filtration tests on the effluent were:—

Pulp density 14% solids.

Bleaching with 0.69% chlorine as hypochlorite.

Aluminium sulphate 30 lb. per ton.
Temperature 8°C.

Filter cloth multi-filament nylon No. 212.

Submergence 37½%.

Vacuum 15 inches mercury.

Filter Speed r.p.m.	Filtration Rate lb./sq.ft./hr. of Dry Clay	Moisture Content of Filter Cake	Thickness of Filter Cake, Inches
1/16	2.3	57.7	7/64
1/12	2.6	58.6	6-7/64
⅛	3.2	59.5	5-6/64
1/6	3.7	62.7	4-5/64
average		59.6	

The filtrate contained a small quantity of very fine clay.

Filter cakes at the higher filter speeds were very thin, and although they lifted off the filter cloth freely, they did not fall away from the strings (see previous discussion on "Thickness of filter cake").

Various filter leaf tests at atmospheric temperatures concerning clays equivalent to the centrifuge feed have been detailed before. They can be briefly summarized as follows:—

Filter Speed r.p.m.	Filtration Rate lb./sq.ft./hr. of Dry Clay	Moisture Content of Filter Cake	Thickness of Filter Cake, inches	Aluminium Sulphate lb./ton
1/16	5.3	46.1	13-14/64	26
1/16	4.9	....	...	25
1/16	5.1	48.5	14-16/64	25
1/16	5.2	48.0	13-14/64	25
1/14	....	47.1	13/64	25
1/12	5.4	48.1	11-12/64	25
1/10	5.9	48.2	9-10/64	25
⅛	7.2	....		25
⅛	7.0	48.0	10/64	25
average		47.7		

Due to the inter relation of filter speed, cake thickness and filtration rates, it is difficult to directly compare filtration rates obtained for centrifuge feed and centrifuge overflow. The practicability or otherwise of comb discharge of filter cake is also most important.

An approximate comparison can be made from the available data, if it is assumed that average filtration rates are as follows:—

Filter Speed r.p.m.	Filtration Rate lb./sq.ft./hr. of Dry Clay — Centrifuge Feed	Centrifuge Effluent
1/16	5.1 (average of four)	2.3
1/12	5.4	2.6
⅛	7.1 (average of two)	3.2
Average of three speeds	5.9	2.7

This comparison is faulty to the extent that filter cakes from the centrifuge feed are much thicker than those obtained from the centrifuge effluent. If the thickness of the cakes from the centrifuge feed was reduced to that from the centrifuge effluent, then the filtration rates from the centrifuge feed would average considerably above the figure of 5.9 lb./sq.ft./hr. used in the comparison.

Then using from the above data:

(1) Centrifuge overflow contains 39% of the solids originally contained in the centrifuge feed.

(2) Filtration rate of centrifuge feed is 5.9 lb./sq.ft./hr. filtration rate of centrifuge overflow is 2.7 lb./sq.ft./hr.

Then the time to filter the overflow using the same filter conditions is 85% of that required to filter the whole feed.

If similar cake thickness for the filter cake from filtration of both centrifuge feed and overflow are assumed, it is probable that the time to filter the whole of the feed would be less than that required to filter the centrifuge overflow under the conditions of the tests.

There is a considerable saving in consumption of aluminium sulphate and tetrasodium pyrophosphate. The centrifuge overflow requires 30 lb./ton of aluminium sulphate, which it equivalent to 11.7 lb./ton for the whole of the clay. This compares with 25 lb./ton used for centrifuge feed, and represents a saving of about 54% of the aluminium sulphate.

On a similar basis, because the centrifuge overflow contains 39% of the feed, then consumption of tetra-sodium pyrophosphate for redispersion will be only 39% of that required for the whole of the feed.

The saving in cost of chemicals by use of the centrifuge appears to be—

Filter Feed	Aluminium Sulphate per ton Clay £	Tetra-Sodium Hyrophosphate per ton Clay £	Total Chemicals per ton Clay £
Whole of pulp	0.52	0.32	0.84
Centrifuge overflow	0.24	0.12	0.36
Saving due to centrifuge	0.28	0.20	0.48

The use of tetra-sodium pyrophosphate is applicable only for the drying of a dispersed pulp such as required as feed to a steam or spray dryer. If drying of the flocculated filter cake is to be considered the costs of the dispersant would not apply.

From the filter tests quoted above, the average moisture of a filter cake from the whole of the pulp is 47.7% moisture, and that from the centrifuge overflow is 59.6% moisture.

The average moisture content of the combined centrifuge products prior to drying is then—

Product	Proportion of Solids in Original Pulp	% Moisture
Centrifuge discharge	61	45
Centrifuge overflow	39	59.6
Feed to drier	100	50.7

Use of a centrifuge therefore increases the moisture content of the clay to be dried from 47.7% to 50.7%.

The cost of coal to dry the respective products can be estimated from data previously given.

Feed to Drier	Cost per ton of Clay (£) Overall Fuel Efficiency 25%	30%	40%	50%
Whole of clay, ex centrifuge	2.8	2.4	1.8	1.5
Whole of clay, not centrifuged	2.5	2.1	1.6	1.3
Extra cost due to centrifuge	0.3	0.3	0.2	0.2

Assume an average of these figures, viz. £0.25 per ton of clay as the extra cost of drying.

Cost of a centrifuge is perhaps £10,000. Assuming capital charges, amortization operation and maintenance to amount of 30% p.a. over production of 10,000 tons of clay per year, then the economics of a centrifuge for partially dewatering clay R.361 become—

	Cost Per Ton of Clay
Cost of centrifuge	£0.30
Plus extra cost of drying	£0.25
Less saving in chemicals	£0.48

Then extra cost of using centrifuge is £0.07 per ton of clay.

It would seem that use of a centrifuge on clays similar to R.361 is marginally uneconomic as a dewatering means. If at the same time, it is desired to produce a coating clay, then this can be readily done with the centrifuge at more or less nominal cost.

Clay R.368

Pilot plant filter tests were carried out on whole feed and centrifuge overflow pulps of clay R.368, produced by normal pilot plant methods.

Centrifuge performance was:—

Test No.	Product	Pulp Density % Solids	Pulp Rate gals./hr.	Pulp Rate lb./hr. of Solids	% Recovery of Solids
12	Discharge	55	7.5	62.7	75
	Effluent	13	14.8	21.0	25
	Feed	31	22.3	83.7	100

Data relating to pilot plant filtration of the effluent are:—

Pulp density: 13% solids.
Bleaching with 0.5% chlorine as hypochlorite.
Aluminium sulphate: 50 lb. per ton.
Temperatures: 10°C.
Filter cloth: Multi filament nylon No. 206.
Submergences: 37½%.
Vacuum: 15 inches mercury.

Filter Speed r.p.m.	Filtration Rate lb./sq.ft./hr. of Dry Clay	Moisture Content of Filter Cake	Remarks
1/7⅚	3.0	60	Average of two tests.
1/2¾	5.8	....	All comb discharge: Very thin cake.

Filter cloth 206 allowed some clay to pass through, and a total of 13% of the clay originally in the feed was recovered in the filtrate. This is similar to, but more pronounced, than batch tests using cloth 212. The cloth was not available in sufficient quantity for use on the 3′ x 1′ filter.

As before, it is difficult to arrive at a correct basis of comparison of filtrate rates. An approximate comparison can be made from the data extracted from earlier tests, using similar filter speeds.

Pilot plant tests on R.368 whole feed gave filtration rates of 5.7 and 6.5 lb./sq.ft./hr. which were obtained at filter speeds of 1/6½ and 1/6⅓ r.p.m. respectively. Average rate 6.1 lb./sq.ft./hr. On centrifuge overflow of R.368, a filtration rate of 3.0 lb./sq.ft./hr. was obtained at a filter speed of 1/7⅚ r.p.m.

At higher filter speeds, using comb discharge of filter cake, respective rates were:—

(*a*) Whole feed, rates of 8.3, 8.5 and 9.1 lb./sq.ft./hr. for speeds between 1/3¾ and 1/2¾ r.p.m. Average rate 8.6 lb./sq.ft./hr.

(*b*) Centrifuge overflow 5.8 lb./sq.ft./hr. for filter speed of 1/2¾ r.p.m.

An average of the two sets of rates gives—

Filter Speeds	Filtration Rates lb./sq.ft./hr. Whole Feed	Filtration Rates lb./sq.ft./hr. Centrifuge Overflow
Medium speeds 1/6-⅛r.p.m.	6.1	3.0
High speeds 1/2¾-1/3¾ r.p.m.	8.6	5.8
Average	7.4	4.4

As before, with this comparison the filter cakes from the centrifuge feed are much thicker than those obtained from the centrifuge effluent. If similar cake thicknesses were compared, then the rates for filtration of the feed would be appreciably higher than the average figure of 7.4 lb./sq.ft./hr. used in the comparison.

Using the Data Above, viz.,

(1) Centrifuge effluent contains 25% of the solids contained in the original feed.

(2) Filtration rate of whole feed is 7.4 lb./sq.ft./hr. Filtration rate of overflow is 4.4 lb./sq.ft./hr.

Then the time to filter overflow using the same conditions is about 42% of that required to filter the whole feed. (Aluminium sulphate for whole feed 45 lb./ton solids. Aluminium sulphate for centrifuge overflow 50 lb./ton solids. Tetra sodium pyrophosphate 5 lb./ton solids).

As in the case of R.361 above, it is possible to estimate the savings in chemicals due to the centrifuge for clay R.368 as:—

Filter Speed	Aluminium Sulphate £ Per Ton of Clay	Tetra Sodium pyrophosphate £ Per Ton of Clay	Total Chemicals £ Per Ton of Clay
Whole of pulp	0.90	0.32	1.22
Centrifuge overflow	0.26	0.08	0.34
Saving due to centrifuge	0.64	0.24	0.88

The average moisture content of the combined centrifuge products prior to drying is then:—

Product	Proportion of Solids in Original Pulp	% Moisture
Centrifuge discharge	75	45
Centrifuge overflow (Filter Cake)	25	60
Feed to drier	100	48.8

Average moisture content of whole of filter cake is 46.3% from the two pilot plant tests on R.368.

The centrifuge thus increases the moisture content of the feed to the drier from 46.3 to 48.8%.

The cost of coal to dry the respective products can be estimated as:—

Feed to drier	Cost Per Ton of Clay £ Overall Fuel Efficiency			
	25%	30%	40%	50%
Whole of clay, ex centrifuge	2.6	2.2	1.7	1.3
Whole of clay not centrifuged ..	2.4	2.0	1.5	1.2
Extra cost due to centrifuge	0.2	0.2	0.2	0.1

Assume an average of these figures, viz. £0.2 per ton of clay as the extra cost of drying.

As before, cost of the capital, amortization and maintenance of the centrifuge per ton of clay can be estimated at £0.30.

Now filter area required to filter centrifuge overflow as shown above, is only 42% of that required to filter the whole of the pulp. The capital charges of filter plant to treat the whole feed was previously estimated at:—

Pulp Temperature	Estimated Cost/Ton Clay	
	5 Day Week	7 Day Week
Atmospheric	£1.12	£0.79
Heated to 60°	£0.57	£0.40

A saving of 58% of this cost amounts to an amount between £0.23 minimum and £0.65 maximum. Assume an average of £0.44.

Then the economics of installing a centrifuge become:—

	Cost Per Ton of Clay
Cost of centrifuge	0.30
Plus extra cost of drying	0.20
Total extra cost	0.50
Less saving in chemicals	0.88
Less saving in filter costs	0.44

Overall saving due to centrifuge is £0.82 per ton of clay.

In this the saving due to a centrifuge is substantial.

On the basis of these preliminary figures on clay samples R.361 and R.368, it appears that use of a centrifuge will show a small loss in cases similar to that of R.361 examined, and will show a substantial gain on clay similar to the case of R.368 examined. Maximum economic gain would appear to be attained when the centrifuge is used to produce the maximum proportion of solids in the discharge.

Apart from the above considerations, use of a centrifuge allows the separate production of a coating grade clay. If there is any substantial market for coating grade clays, then installation of a centrifuge becomes attractive.

The preliminary nature of the above discussion relative to the merits of the application of a centrifuge should be emphasised.

APPENDIX I.

Evaluation of clays from the South Mount Cameron deposits
Evaluation of weathered granite in terms of Paper Clay

The method originally used by A.P.P.M. was briefly:—

(1) Weigh 250 grams of the previously dried but uncrushed sample into a tall beaker.

(2) Cover with six inches of water, containing 10g. of sodium silicate.

(3) Allow to stand overnight, if possible.

(4) Agitate violently for one minute with a stirring rod and let stand for five minutes.

(5) Decant the top three inches of pulp.

(6) Rebulk to 6-inch mark, stand for five minutes, and again decant.

(7) Repeat until a total of five decantations have been made.

(8) Flocculate pulp with one gram of alum, and let stand.

(9) Decant clear liquor, filter settled solids, and dry at low temperature.

(10) Dry and weigh residue.

(11) Evaluate the separated clay for yield, brightness, ignition loss, grit, &c.

This method of evaluation, with settling times of five minutes for the depth of three inches has been found to give a size separation slightly in excess of 20 microns. The clay produced has a maximum particle size comparable with high quality, commercially prepared paper filler clay.

The method can be modified in some respects without affecting the evaluation.

(A) It is usually more convenient to use semi-wet as received crude clay for evaluation. The yield and quality of the clay is unaltered.

For example:—

Sampel No.	Condition of Crude Clay as Tested	Separated Clay		
		% Yield	Brightness	Ignition Loss
R.361/4	Wet, as received	35.5	78.0	13.2
R.361/5	Wet, as received	35.6	77.6	13.1
R.361/6	Dry	36.8	77.8	13.1

(B) Quantity of sodium silicate used for dispersion can be reduced to 1.0 grams without alteration to quality of clay separated.

Bore Hole No.	Footage Ft.	Grams Sodium Silicate	Yield of Clay	Brightness of Clay	Ignition Loss of Clay
3	4- 8'9"	1	44.1	84.8	13.0
		10	43.4	84.2	13.4
3	15-20	1	40.1	84.6	13.1
		10	40.9	84.8	13.1
19	Surface	1	31.2	83.0	12.7
		10	31.0	83.0	12.8
19	7-12	1	39.8	83.0	13.5
		10	39.4	82.2	13.5
26	5-10	1	54.9	79.2	12.8
		10	53.4	79.0	12.7

The above method has been used in evaluating all weathered granite from Brown's area in terms of paper clays by the Mines Department Laboratory, using semi-wet crude clays and 1.0 gram of sodium silicate for dispersion.

Evaluation of Paper Clays for 30 micron Separation

The method presently used by A.P.P.M. Ltd. is as follows:—

" 30 Micron Separation

> Weight 100 grams of the O.D. sample, (if in lump form DO NOT GRIND but break lumps with fingers), into a milk shake mixer container and add 125 mls. of calgon solution (40 g/litre) + 375 mls. water and disperse on the mixer for about half an hour. Transfer to a tall one litre beaker and dilut eto a mark about half an inch from the top. Stir and allow to settle for five minutes. Syphon the top three inches into a Buchner flask. Refill beaker to mark, repeat the stirring and syphoning process twice more at five minutes settling and four times at two minutes settling time. Combine all decantations add about 10 mls. 10% alum and allow to settle. Decant clear liquor dry residue and weigh as minus 30 micron. The residue remaining in the beaker is allowed to settle and dried and weighed as plus 30 micron."

Evaluation of South Mount Cameron Clays by A.P.P.M.

The deposit at South Mount Cameron was tested by a series of boreholes during 1959. Laboratory test work was carried out by A.P.P.M. to evaluate the deposit as a source of paper filler clay.

Clay separations were made by the 30 micron separation method given above.

The results of this test work are fully recorded in the report of A.P.P.M. dated 21st September, 1959.

Evaluation of some Borehole Samples by the Mines Department Laboratory

Dulplicate samples of some of the borehole samples tested by A.P.P.M. were evaluated in the Mines Department Laboratories by the " Evaluation of weathered granite in terms of paper clay," with the modifications mentioned previously.

Comparison of Evaluations by A.P.P.M. and Mines Department Laboratories

There were some marked differences in yield and quality of the separated clays obtained by the two methods of evaluation. These may be summarized as follows:—

		A.P.P.M.			Department of Mines		
Bore Hole No.	Footage	Yield of —30 Micron Clay	Ignition Loss %	Brightness	Yield of —20 Micron Clay	Ignition Loss %	Brightness
3*	4- 8'9"	51.7	13.0	79	44.1	13.0	84.8
*	9-15	55.5	13.0	78	42.3	13.1	83.8
*	15-20	52.5	12.9	78.5	40.1	13.1	84.6
*	23-25	45.7	12.8	77	34.9	13.0	82.8
6*	10-20	46.5	12.9	79.5	32.7	12.9	82.8
*	20-25	43.5	12.5	76	29.2	12.2	81.2
11*	1-6	48.9	13.5	73 **	35.7	13.5	78.2
*	6-10	52.6	12.7	77	37.7	13.3	81.4
*	10-15	49.5	13.2	75.5	40.4	13.4	83.4
*	15-20	50.4	12.7	76.5	38.1	13.5	83.8
*	20-23	49.8	12.8	77	38.9	13.3	83.8
17*	6-10	52.7	13.2	67 **	42.9	13.7	75.4
	10-15	50.5	12.2	67.5**	37.2	13.7	74.2
*	15-20	49.1	12.8	69.5**	40.3	13.3	75.6
19*	Surface	46.6	12.5	78.5	31.2	12.7	83.0
*	2- 7	49.1	12.7	75.5**	37.4	13.9	80.4
	7-12	51.3	12.5	76.5	39.8	13.5	83.0
*	12-17	50.3	12.7	77.5	40.4	13.3	82.8
26*	5-10	71.5	13.0	76.5	54.9	12.8	79.2
	10-15	47.0	11.4	76	30.0	11.3	78.6
*	15-18	49.3	12.7	79	30.5	12.3	79.0
	22-25	45.0	11.6	76.5	32.4	12.1	81.2
Average of 22 clays		50.4	12.7	75.8	37.8	13.1	81.2

Samples marked * were reported by A.P.P.M. as satisfactory for grit contents. Samples marked ** were reported as bleachable.

Comparison of the Two Evaluations

A comparison of the 22 samples shows marked variations in yields and quality. Average figures relating to the samples from six bores, more or less taken at random, show:—

Evaluation by	Yield	Separated Clay Ignition Loss %	Brightness
A.P.P.M.	50.4	12.7	75.8
Mines Department	37.8	13.1	81.2

It will be seen that the procedure adopted by A.P.P.M. resulted in a greater yield of an inferior clay. There are several reasons for this:—

(1) The A.P.P.M. method gives basically a minus 30 micron separation, and that used by the Mines Department gives a 20 micron separation.

(2) The A.P.P.M. method requires violent agitation for 30 minutes, as against one minute for Mines Department method.

(3) The A.P.P.M. method requires seven decantations, as against five decantations as used by the Mines Department.

There are some data to indicate that the extra agitation degrades the clay slightly, and that the coarser fractions recovered by the 30 micron separation are of relatively low grade material.

Two lots of duplicate samples were prepared by decantation after agitation with sodium silicate. Test conditions were identical except that one pair of duplicates was agitated for 30 minutes, and the other pair for one minute in the milk shake mixer. Clay was recovered from three decantations, allowing settling times of five minutes each.

Agitation	Separated Clay Yield %	Brightness
1 minute	41.5	73.0
1 minute	41.5	72.8
Average	41.5	72.9
30 minutes	44.9	71.8
30 minutes	44.2	72.2
Average	44.5	72.0

The above table indicates an increase in yield of 3%, and a drop of one unit in brightness.

The residues from the above tests were then decanted further, following the two evaluation methods outlined earlier. For the material agitated for one minute, two further decantations, each of five minutes settling time were made. For the material agitated initially for 30 minutes, four decantations, each of two minutes settling time were made.

Agitation	Final Decantation	Clay from Final Decantations Yield %	Brightness
1 minute	2 at 5 mins.	2.4	70.8
1 minute	2 at 5 mins.	2.2	69.6
Average		2.3	70.2
30 minutes	4 at 2 mins.	5.2	64.8
30 minutes	4 at 2 mins.	5.3	63.4
Average		5.3	64.1

The greatly increased yield of inferior clay was obtained by the A.P.P.M. method.

Total yield of clay by the A.P.P.M. method was (44.5 + 5.3) = 49.8%.

Total yield of clay by the Mines Department was (41.5 + 2.3) = 43.8%.

It is considered that the differences in evaluation of the clays as determined by the two methods are due to results similar to above.

Commercial practice will probably involve agitation with sodium silicate in thick pulps. It is unlikely that intense agitation will take place in the plant. Consequently it is felt that the evaluation involving comparatively mild agitation with sodium silicate will approach plant conditions, and it is felt that evaluation of the deposit by this method gives a more correct assessment of the raw material for production of high grade filler clay.

APPENDIX II

Siliceous Grit Determination

The method consists of digestion of the clay sample with sulphuric acid to decompose the clay and on dilution and boiling with 5% HCl the siliceous grit and silica from the clay are separated from soluble salts by filtration and washing. The silica from the clay is dissolved in hot 5% sodium carbonate solution and the remaining insoluble siliceous grit is obtained by filtration washing and ignition of the residue.

References of the method are:

Treadwell & Hall, pages 421 and 422, 29th Ed.
Associated Pulp & Paper Mills Ltd., Burnie, private communication, 1960.

The method was examined in the laboratory and slight amendments made as a result of the investigation. Adequate digestion and final free fuming with sulphuric acid is essential for concordant results:—

1. To two grams of clay in a 400 ml beaker add 50 ml of water, and carefully add 50 ml of concentrated sulphuric acid. If organic matter is evident, add 2 ml of concentrated nitric acid.
2. Cover and place on a hot plate with an approximate temperature of 130°C. Stir frequently, and slowly increase temperature to about 200°C in 2½ hours.
3. Remove cover and gradually increase hot plate temperature to approximately 250°C, and continue heating approximately three quarters of an hour during which period dense fumes are evolved. Cool, add 150 ml of water and 20ml of concentrated HCl.
4. Cover and heat carefully for half an hour with a hot plate temperature of approximately 130°C, stirring frequently.
5. Dilute to 350 ml with hot water, and filter on a Whatman No. 44 filter paper, washing with hot 2% HCl.

6. Transfer filter paper and contents to original beaker, add 200 ml of water and 10 grams of Na_2CO_3. Heat for 30-45 minutes at a low hot plate temperature of about 140°C, stirring frequently. Filter through a No. 44 Whatman filter and wash with very hot water until the washings do not give a colour with phenolphthalin.
7. Dry and ignite the filter, and weigh the residue as grit.

APPENDIX III

The Associated Pulp & Paper Mills Pty. Ltd. submitted a sample of prepared clay from South Mount Cameron to the Australian Mineral Devolopment Laboratories and a copy of this report is shown below.

"**MINERALOGY AND PETROLOGY SECTION**

23rd September, 1960.

Report No. 3.0.0/1184

MATERIAL:	Clay.
SUBMITTED BY:	Australian Pulp and Paper Mills Ltd.
DATE RECEIVED:	22nd September, 1960.
MARKS or NOS:	Order No. F/5166; Reference KAM:JS; Gladstone Refined Clay.
METHODS OF EXAMINATION:	X-ray diffraction.
INFORMATION REQUIRED:	X-ray diffraction examination.

RESULTS OF EXAMINATION:—

The only minerals identified from the X-ray diffractorgraph of the above sample were kaolin, illite and quartz. The kaolin mineral lies between kaolinite and fireclay in the kaolinite-fireclay-halloysite series. Illite is present in small amounts (only a few per centage), and quartz represents approximately 2% of the sample.

Neither chlorite nor any titanium minerals were detected from the diffractograph.

Under the microscope the sample is very fine grained and only lightly iron stained. Only occasional grains of opaque minerals and rutile were seen but chlorite was not detected. Fine grained aggregates of amorphous titanium oxide were seen and this, together with the trace of rutile, accounts for the presence of approximately 1.0% of TiO_2 as measured on the X-ray spectrograph.

Signed—A. E. TYNAN, Mineralogist."

APPENDIX VI.

Paper Clay—Sth Mt Cameron

Flow Sheet Design

by W. St. C. Manson

Proposal

Production of clay for use in the paper industry from decomposed granite by separation of gravel, sand and grit from the minus 30 micron clay, possible separation of the clay into coarser and finer fractions for reasons of costs and manufacture of both filler and coating clays, bleaching, if necessary, followed by flocculation prior to filtration and drying.

Details relative to specification of the finished product, and investigations into methods of treatment are recorded in departmental investigations R.361, R.364, R.365, R.366 and R.368, and related correspondence, between A.P.P.M., Burnie, Dorset Division of the Storey's Creek Co., Ballarat Clay Co., Chemical Plant and Engineering Co. and Burton and Co. both of Melbourne.

Although the initial production target would be 5000 tons p.a., the plant design is required for a minimum of 100,000 tons p.a.

Stages of Treatment of Mined and Stored Raw Material

A. Feeding to Plant.

B. Pulping with water and dispersion.

C. Removal of coarse sand.

D. Removal of fine sand, trash such as roots, &c.

E. Degritting of clay pulp.

F. Separation of fine and coarse clay.

G. Bleaching.

H. Flocculation and filtration.

I. Drying.

J. Containers and transport.

A convenient treatment would consist of stages A to E inclusive at a feed rate of raw material of 15 tons per hour for 8 hours daily for a production of degritted clay of 40 tons. Stages F to J for continuous operation of possibly a 5 day week to produce 40 tons of dried clay per 24 hours, or 10,000 tons p.a.

This treatment is shown on flow sheet form as follows:—

Solids are shown as tons per hour as 15.

Water is shown as tons per hour as (10).

Hourly feed to plant 15 ton/hr. 8 hr. day/5 day week.

15

60% solids — Agitators + (10) + sodium silicate

Classifier + (4.3)—>Sands 6.6 (1.7) to waste

40% solids — Classifier O/F—60 mesh

8.4 (12.6)

Vibrating Screen—>Oversize trash to waste

8.9 (19.2)

—>

Cyclone—————>Overflow

or hydrosizer — Degritted clay

5 (13.3) 27.3% solids

Spigot product

3.9 (5.9) + (5.8)

O/F 0.5 (6.6) Secondary cyclone or hydrosizer

Spigot sands 3.4 (5.1) to waste

Feed rates and volumes

	Tons per hour		Volumes	
	Solids	Water	G.P.H.	G.P.M.
Feed to agitator	15	10	3510	58
Feed to classifier	15	14.3	4470	75
Feed to primary cyclone	8.9	19.2	5050	84
Feed to secondary cyclone	3.9	11.7	2950	49
Degritted clay	5	13.3	3400	57
Water consumption	....	20.1	4500	75
Water requirement, daily 36,000 gallons.				

Degritted clay pulp.

Operating 120 hours weekly/5 days per week.

Tons per hour

1.66 (4.4)

Storage Bleaching Tanks and Antichlor Treatment — Alternate treatment with centrifuge

Bleach — 0.8 (3.6) O/F

Flocculation Tank + aluminium sulphate

Drum Filters

Repulpers & Dispersant

0.8 (0.8)

Dryers

Transport in bags or bulk

Water evaporation per hour 9856 lbs.

TREATMENT UNITS AND MATERIALS OF CONSTRUCTION

A. Feeding to Plant

Ballarat Clay Co. stock piles the raw material close to the treatment plant and feeds a small surge bin with a front end loader. The raw material is fed and elevated via a belt conveyor to agitator tanks. This system is reliable and could be chosen unless more useful methods become known from other installations.

B. Pulping and Dispersion

Two agitators in series fitted with sand bleeds are suggested, and can be made of M.S. with I.R. liners suited for high abrasion resistance, or concrete with the same lining. Propellers would be I.R. covered for the same duty. Two 1000 gallon tanks would be adequate for a minimum of 30 minutes agitation, and agitation time could be reduced by varying the height of overflow. No information is available relative to the time required to pulp the largest lumps that would be in the feed, and tests could be undertaken to determine the requisite pulping period, or the experience at Ballarat and Burnie could be used to determine tank size. A feeder for adding dispersion agent can be driven from the belt conveyor.

C. Removal of Coarse Sand

Various methods can effectively cover this service, and the selection would be affected by cost and perhaps availability of serviceable S.H. equipment. Dorr Duplex classifiers are undoubtedly available from several ore treatment plants. Alternatives are screens and cyclones. Clay from this stage would be nominally minus 60 mesh B.S. size, except roots, bark, &c., which could be much larger.

D. Removal of Fine Sand and Trash such as Roots, &c.

If 30 m.m. hydrocyclones are selected for final degritting of the clay pulp, it is essential to remove all trash such as roots, bark, &c., which could cause blockages in the hydrocyclones, and for this duty an electric vibrating screen is recommended. The screen would be fitted with longitudinal mesh stainless steel screen cloth, and possibly an 80 mesh B.S. equivalent aperature would be required.

E. Degritting of Clay Pulp

A hydrocyclone of 30 millimeter diameter, manufactured by Liquid-Solid Separations Ltd., London, was the only cyclone of this diameter used in the test programme and showed satisfactory performance at high pulp densities. As through-put at 40 p.s.i. was approximately 3 g.p.m., 28 of these units would be required for the estimated 84 g.p.m., and it is probable that the manufacturers produce a multi-block of reasonably high capacity.

Warman & Co. manufacture a X20 multi cyclone of 30 mm. diameter, with a capacity of 60 g.p.m., and priced at approximately £370. Units are available on loan. Should consideration be given to operation of other units than those used in the test work, it would be desirable to check on performance of a unit under the required conditions prior to selection.

D.S.M. cyclones of larger size than 30 mm. were used at Ballarat for final degritting for some years, and have recently been replaced by two 18 ft. diameter hydro-sizers which are reported to be giving better performance than the cyclones.

From available information on the operation of the hydrosizers, and test work with the 30 mm. cyclone, there appears to be little preference in either method of final degritting. Factors relating to cost and reliability of operation would be major factors in making a decision on the selected equipment.

F. Separation of Fine and Coarse Clay

Centrifuge tests show effective separation, and our report covers a discussion on economics of drying with and without a centrifuge. Installation of a centrifuge would allow the production of coating clay as well as a filler clay, and a market survey should be made to assess whether the installation is justified.

G. Bleaching

To ensure a high quality brightness, it is necessary to provide for bleaching and plant design, and materials of construction should be suited for this treatment with gaseous chlorine. In addition, provision should be made for antichlor treatment prior to the next stage.

Feed to the holding tanks for storage and/or bleaching would amount to 40,000 gallons produced in 8 hours for de-watering treatment, &c., over a period of 24 hours, or about 1700 g.p.h.

To provide for testing of the degritted clay and detention for bleaching and antichlor treatments, consideration could be given to installation of say 4 holding tanks of sufficient capacity for the daily operation, plus a margin for repairs and consideration for 4 tanks of 12,000 gallons each is suggested. Agitation will be required. Materials of construction of the tanks have been investigated and the following were suggested for consideration.

(*a*) Asbestos cement lined M.S. tanks, with probable improvement by painting the A.C. linings with sodium silicate.

(*b*) Rigid P.V.C. lining of steel tanks.

(*c*) Concrete.

Valves recommended for the tanks are Saunders Q type, hard rubber lined obtainable from Stewarts & Lloyds of 157-165 City Road, South Melbourne. To provide against corrosion in subsequent treatment by traces of chlorine compounds, or low pH conditions caused by the addition of aluminium sulphate, I.C.I. suggest flanged polythene pipes.

H.

A tank for flocculation can be designed from Ballarat experience.

Filtration rates will vary with the nature of the clay, temperature, and density of the pulps. Indicated filtration rates range from 3 to 9 lbs./sq.ft./hr. of dry clay. On a conservative basis without applying heat and operating with cake discharge on strings at say 3 or 4 lbs./sq.ft./hr. a filter area of 1100 sq. ft. would be required. Cost of this operation has been estimated at £1.35 per ton of clay for 5 day operation.

Tests on heating the pulp to 60° C indicated a reduction of required filter area to 560 sq. ft., with a reduction in cost of £0.35 per ton of clay. If provision is made to heat the clay pulp for filtration two 250 sq. ft. filters would provide the indicated capacity.

Higher filter rates have been shown with higher filter speeds with comb discharge, and it is recommended that the results of these filtration tests be submitted to manufacturers for comment, particularly relating to comb discharge.

To provide against corrosion, it is recommended that filter parts subject to contact with pulp be of rubber lined steel.

I. Drying

Spray drying tests by C.P & E. Ltd. have indicated some prospect of application of this method. However, further work is required to ensure that the process does not damage brightness under conditions of high thermal efficiency. If high thermal efficiency cannot be guaranteed without brightness damage, steam drying with resultant higher cost is suggested as the most reliable method.

Either steam or spray drying would be processed with a dispersed pulp which may be more useful to A.P.P.M. than a dried flocculated clay. The Proctor type dryer would no doubt operate by extrusion of flocculated filter cake, and would thus require the addition of dispersant by A.P.P.M. before use in their plant. The addition of sodium tetra phosphate would be a factor in cost of production for either spray or steam drying.

If steam drying is not selected it may still be necessary to allow for a smaller steam boiler for heating clay pulp prior to filtration.

J.

Three main methods for packing the clay can be considered.

(*a*) Transport as a 50% pulp in rail tankers. This means would firstly have to meet approval of the consumers, and the total chargeable cost of tankers and transport of double the tonnage would require to be not greater than the cost of drying, bags, bagging and transport of the dried clay.

(*b*) Bulk containers.

(*c*) Paper bags.

In both these cases it would be a choice of the lower cost.

Decisions on methods of treatment will require to be finalised before the company will be in a position to plan the treatment plant.