DEPARTMENT OF MINES AND ENERGY

SOUTH AUSTRALIA

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THE AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES

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The Director,
Department of Mines,
Box 38, Rundle Street P.O.,
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DEPT. OF MINES ADELAIDE

USE OF WHITE CLAYS FOR WALL TILES

PROGRESS REPORT NO. 1

To 31st March, 1967

Investigation and Report by: D.E. Holloway

Officer in Charge, Ceramics Section: D.C. Madigan

P.A. Young
Director.

M.D.E.
for attention

Amount Authorised:	$4,000
Amount Spent to 31/3/67:	$3,675

1. INTRODUCTION

Following discussions with Mr B. Stadler of Australian Ceramic Industries, and Mr R. Adam of the Department of Mines, this project was initiated for the purpose of investigating raw materials and developing suitable blends for the manufacture of ceramic wall tiles. The work was to include washing, settling rates, tile forming, dry and fired characteristics, development of fast once-fire technique, glazing, spray drying and assessment of equipment at Port Pirie uranium plant.

2. REVIEW OF PROGRESS

Selected raw materials were washed to remove soluble salts, screened, ground, and blended in various proportions to make a series of twelve earthenware blends. The blends were fired glazed and unglazed. Characteristics at various stages of processing were recorded and used to determine the optimum mixture with respect to colour, shrinkage, cold water absorption and warpage. Each blend was tested for its suitability for the fast once-fire technique. Settling rates with and without flocculants were determined for the Hesso clay. Efforts were made to determine the feasibility of spray drying. Fired tiles were tested for hardness and compared with a standard commercial tile.

The Port Pirie plant was visited and a close inspection made of suitable equipment. Details of materials preparation methods were discussed with Mr Stadler and technical representatives of an Italian Ceramic machinery supply company (Societa Impianti Termo-elettrici Industriali) with a view to utilising existing equipment at Port Pirie.

3. WORK IN HAND

Investigation of talcs as an alternative to Tumby Bay talc, screening and firing tests of Mount Magnificent silica, investigation of known reserves of ball clays and kaolins and dilatometry of the earthenware blends considered most likely to be used.

4. MATERIALS EXAMINED

Materials tested for their possible use in earthenware blends were:

a. <u>Clays</u> - Hesso, Georgetown, Cromer "C", Cromer, Pine Point, Yatina, Cowell, Davenport, Murraytown, Crystal Brook, Booleroo, and Pauls (Pt Augusta).

b. <u>Talcs</u> - Mount Fitton 2nd grade, Tumby Bay 1st grade and Tumby Bay 2nd grade

5. EQUIPMENT USED

Pan type planetary mixer, Pascall mill, screw press, stoneware jar mills with porcelain balls, semi-muffle oil burner kiln, open wound electrical wire resistance kiln, Vickers diamond pyramid hardness tester, Kestner centrifuge spray dryer, Watson Marlow flow inducer and Cenco moisture balance.

6. EXPERIMENTAL PROCEDURE AND RESULTS

6.1 Raw Materials Preparation

The clay samples were carefully chosen as truly representative of the exposed areas of the deposits. Each sample was broken down in a planetary mixer and then a representative sample taken out by quartering. The final sample was ground in the Pascall mill to minus 18-mesh BSS and then water added to give a solids content of 23%. The slurry was allowed to settle for 16 hours and then the free water was syphoned off. The balance was screened to minus 170-mesh BSS. The oversize was dried, weighed and recorded as a percentage of the total dry weight (See Table 1).

6.2 Earthenware Mixes

Twelve earthenware mixes were prepared (see Table 2) by blending the screened clays with the other ingredients by wet grinding in a jar mill for eight hours. The ground slurries were oven-dried at 105°C and the dried cake powdered in the Pascall mill. Water was added to the powder by spraying to give a moisture content suitable for semi-dry pressing (See Table 3). The mix was then granulated by screening to minus 12-mesh BSS.

6.3 Semi-dry Pressing

Tiles were formed in a 2 in. x 2 in. mild steel die fitted to a hand-operated screw fly-press. The feed was weighed in at 20 grams to give a finished depth of 5/32 in.

The pressed specimens were air dried for one hour, oven dried at 45°C for two hours, and stored at 105°C in preparation for glazing and firing. Drying shrinkage was negligible and was ignored for this report.

6.4 Bisque Firing

A composite bisque firing of 20 tiles covering ten mixes was carried out in the semi muffle oil burner kiln. The tiles were brought to 1070°C in 6 hours and soaked at that temperature for one hour.

The fired specimens were measured for shrinkage. They were also tested for hardness on the Vickers tester and the 24-hour cold water absorption was determined. Results of these tests are shown in Table 4.

6.5 Glazing and Firing

An unfired tile from each mix was sprayed with a boron-felspar clear glaze previously developed by Amdel. The glaze weight was held at 30 oz. per pint, approximately 55% solids. The glaze was not adjusted to fit each mix but was used as a trial to determine the general characteristics of the fired glazed bodies, such as bubbling, crawling, blistering, colour, etc. Results are given in Table 5.

6.6 Single Fast Firing

As a consequence of the results achieved in six hours' firing in the muffle kiln a shorter firing cycle was decided on. The open-wound electric kiln was used to fire a single tile setting to 1070°C in approximately one hour, plus up to 15 minutes' soaking period. The kiln was cooled to 100°C at two hours from switch-on. The first results were satisfactory, and subsequent firings followed the same procedure. Firing details are given in Table 5. See Table 5 also for cold water absorption of glazed tiles.

7. EXPERIMENTS WITH MATERIALS PREPARATION

7.1 Spray Drying

An attempt was made to determine the feasibility of spray drying Hesso clay to a pre-determined moisture content of approximately 6%.

The clay was washed, screened to minus 170-mesh BSS and blunged at 35% solids content for two hours. The slip feed to the dryer atomiser was metered through a Watson Marlow flow inducer. The atomiser was operated at a constant speed. The variables in the system were feed rate, heat input, air inlet and outlet temperatures.

Many setting combinations of the system's variables were tried for the purpose of achieving an end product of suitable granular form and having a moisture content around 6%.

The underflow from the drying chamber was removed at every change of setting and tested for moisture content. The highest moisture attained was 3%. At higher values the clay built up rapidly on the chamber walls. This condition was found to be so at any setting where the moisture content exceeded 3%. The underflow from the dryer excludes the fines which are taken off at a point in the flue system. The fines were weighed and found to be 16.8% of the total dry weight of dryer output.

7.2 Pressing Spray-dried Clay

A sample of spray-dried clay removed from the dryer underflow at 3% moisture content was pressed in the 2 in. x 2 in. tile die and was found to be an excellent pressing material. The pressed specimen was hard, very smooth-textured and free from any air pockets, folding or laminating. An attempt was made to press the same type of clay at 3% moisture after normal oven drying, but without any success. The material laminated badly and showed very poor bonding.

7.3 Settling Rates

The equipment used for this test included two graduated 500 ml cylinders with an inch scale attached and one cylinder fitted with a 1 r.p.m. rake. The slurry was prepared by blunging and screening as for normal production. The solids content was found by trial and error to give the best results at 15%. However, the settling rate was still too slow to achieve an economical output of washed clay and further tests were conducted using various flocculating agents. The best results were obtained with Aerofloc and zinc sulphate to give a 24-hour (dry weight) output for the 100 ft dia. thickener of 170 tons with the feed at 15% solids, and 123 tons, with a feed solids content of 22%. The underflow from the thickener would be 35-40% solids.

Figures 1 and 2 respectively show the settling curves for 15 and 22% solids content.

The thickener capacity was calculated according to the method given in "The Design of Continuous Thickeners for Flocculated Materials" by R.A. Couche and L.H. Goldney, AIMM Publication No. 191, September, 1959.

8. DISCUSSION

8.1 Washing

All clays tested showed a marked colour improvement after washing and no difficulties were encountered with glaze adhesion. In view of the high salt content of most of the clays tested, it is strongly recommended that all clays listed in this report be washed before blending, particularly if the fast once-fire method is to be used.

8.2 Materials

The only clay found to be completely unsuitable for whiteware was from Pauls deposit near Port Augusta. The best kaolins are considered to be Pine Point, Cromer "C", Cromer and Cowell. Of these, Cromer "C" or Cromer would be first choice on quality. However, the reserves are unknown. The reserves at Cowell of approximately 20,000 tons are considered to be insufficient for initiating production in a new industry. Pine Point gives excellent results, but has a low clay yield at the pit. The overburden of 60 ft could also be a deterrent to a new industry. It is recommended that Cromer reserves be fully investigated. Mount Fitton Talc, ex Rodda, graded as T.L.U., would be suitable for tiles, but is less white and shows indications of containing more flux than second grade Tumby Bay talc.

8.3 Earthenware Mixes

All the mixes shown in Table 2 have good pressing and firing characteristics, but are not all suitable for wall tile production due to low porosity. This can, of course, be adjusted by introducing more refractory material into the mix without upsetting the other qualities. Mix No. 7, CE 2000, would be the simplest and cheapest blend, but would have to be adjusted to increase porosity. This blend has been tested on a production scale in Italy and was found to be mechanically weak when subjected to high-speed pressing and ejection. For this reason samples of all clays used in this project have been dispatched through Mr Stadler to Italy for production line testing.

8.4 Fast Firing

Results indicate that clay blends as constituted for this project are suitable for fast firing by the single or twice-fire process. Care must be taken to ensure thorough mixing and milling. It is also important that the pressing powder be stored in such a way that the granules are not destroyed, as any lumps entering the die will upset the flow of the granules and result in serious density variations. The five-minute soaking period at 575°C (Column 3, Table 5) reduces risk of cracking during quartz conversion expansion.

8.5 Spray Drying

The results of the spray drying investigation were not conclusive, but were sufficient to indicate the feasibility of this form of drying. An industrial dryer having a much greater chamber diameter would be more suitable for the higher moisture content required. The success of the pressing at 3% moisture content would be confined to ball clays or other plastic materials. However, the quality of the pressed spray-dried Hesso clay was excellent and would apply to all earthenware materials having the correct moisture content.

8.6 Port Pirie Plant

The slurry holding tanks in the leaching plant are considered to be ideal in capacity and agitator speed for slip storage or blending. The digestors could be of definite interest for an expansion programme. The raw materials hopper, conveyor belt and slurry tanks are suitable for initial clay preparation. The large thickeners are considered to be quite suitable for large-scale beneficiation. In the extraction plant a few items are of interest for the casting shop. The vacuum filter drums could all be used for preparation of casting slips, particularly the large drum, which has a capacity of approximately 1200 lb dry weight per hour. The settling tank in the extraction plant could also be used for preparation of casting slip. The six small agitator vats adjacent to the dryer would be suitable for blending coloured slips or as casting slip holding tanks. Other items of interest would include drying ovens, small filter presses, water treatment plant, motors and pumps.

The power house services would be adequate for the whole plant. All services would have to be connected to the pentad building. Sundry vats mounted outside the extraction plant would be of interest for wet or dry storage.

TABLE 1: COARSE MATERIAL, % PLUS 170 MESH BSS

CE No.	%
1929	1.0
1930	1.0
2036	10.0
1935	48.0
1939	2.44
1938	1.45
2026	53.8
2027	69.0

TABLE 2: EARTHENWARE TILE BLENDS

Ingredients		Mix No.	1	1A	2	3	4	5	7	8	9	10	12	13
Material	CE No.	CE No.	1999	1999A	2019	2020	2038	2021	2000	2001	2018	2039	2050	2051
Hesso	1930		95		57	57	38	40	57	50		40	57	57
Hesso	1929			95										
Cromer 'C'	2036				20									
Pine Point	1935					10	10	12		40				
Georgetown	1939										60			
Yatina	1938											40		
Cowell	2026												20	
Davenport	2027													23
Talc (Tumby Bay)	-				20	30	40	40	40	7.5	40	18	20	20
Silica (Rodda)	-		5	5	3	3	2	2	3	2.5		2	3	
Whiting "	-							6						
Feldspar "	-						10							

TABLE 3: MOISTURE CONTENT FOR PRESSING

CE No.	%
1999	8.5
1999A	7.8
2019	5.0
2020	7.0
2038	9.0
2021	7.0
2000	4.8
2001	7.9
2018	6.4
2039	7.0
2050	5.5
2051	6.4

TABLE 4: FIRED CHARACTERISTICS OF BISQUE TILES

CE No.	Cold Water Absorption, %	(Penetration) Hardness	Shrinkage %	Colour
1999	11.31	2.9	3.96	Off-white
1999A	16.8	4.1	1.98	White
2019	14.8	3.0	3.96	White
2020	13.3	3.2	3.46	Off-white
2038	12.7	3.8	2.47	"
2021	17.5	4.1	1.98	"
2000	13.1	3.8	3.46	"
2001	17.1	5.0	3.96	White
2018	18.6	5.0	1.98	Off-white
2039	15.0	4.0	3.96	"
Commercial Tile	17.8	2.1	-	"

TABLE 5: ONCE-FIRED TILES AT 1070°C

CE No.	Soak at 575°C	Firing Time	Glaze Coverage	Glaze Texture	Tile Quality	Shrinkage %	Cold Water Absorption,%
1999	5 mins.	1 hr. 15 min.	Complete	Fine orange peel	Good	4.68	10.8
1999A	"	1 hr. 10 min.	"	Smooth satin	Cracked	0.8	16.4
2019	"	1 hr. 10 min.	"	"	Good	1.6	15.4
2020	"	1 hr. 10 min.	"	"	"	3.1	11.5
2038	"	1 hr. 5 min.	"	"	"	1.6	11.2
2021	"	1 hr. 15 min.	"	"	"	0.8	14.9
2000	"	1 hr. 10 min.	"	"	"	3.12	10.2
2001	"	1 hr. 5 min.	"	Fine orange peel	"	4.6	14.3
2018	"	1 hr. 15 min.	"	Smooth satin	"	1.56	17.7
2039	"	1 hr. 10 min.	"	High gloss	"	2.4	14.1
2050	"	1 hr. 10 min.	"	Smooth satin	Cracked	4.6	16.4
2051	"	1 hr. 10 min.	"	High gloss	"	3.1	14.0

<u>Note</u>: British Standard for wall tiles requires 12-18% absorption.

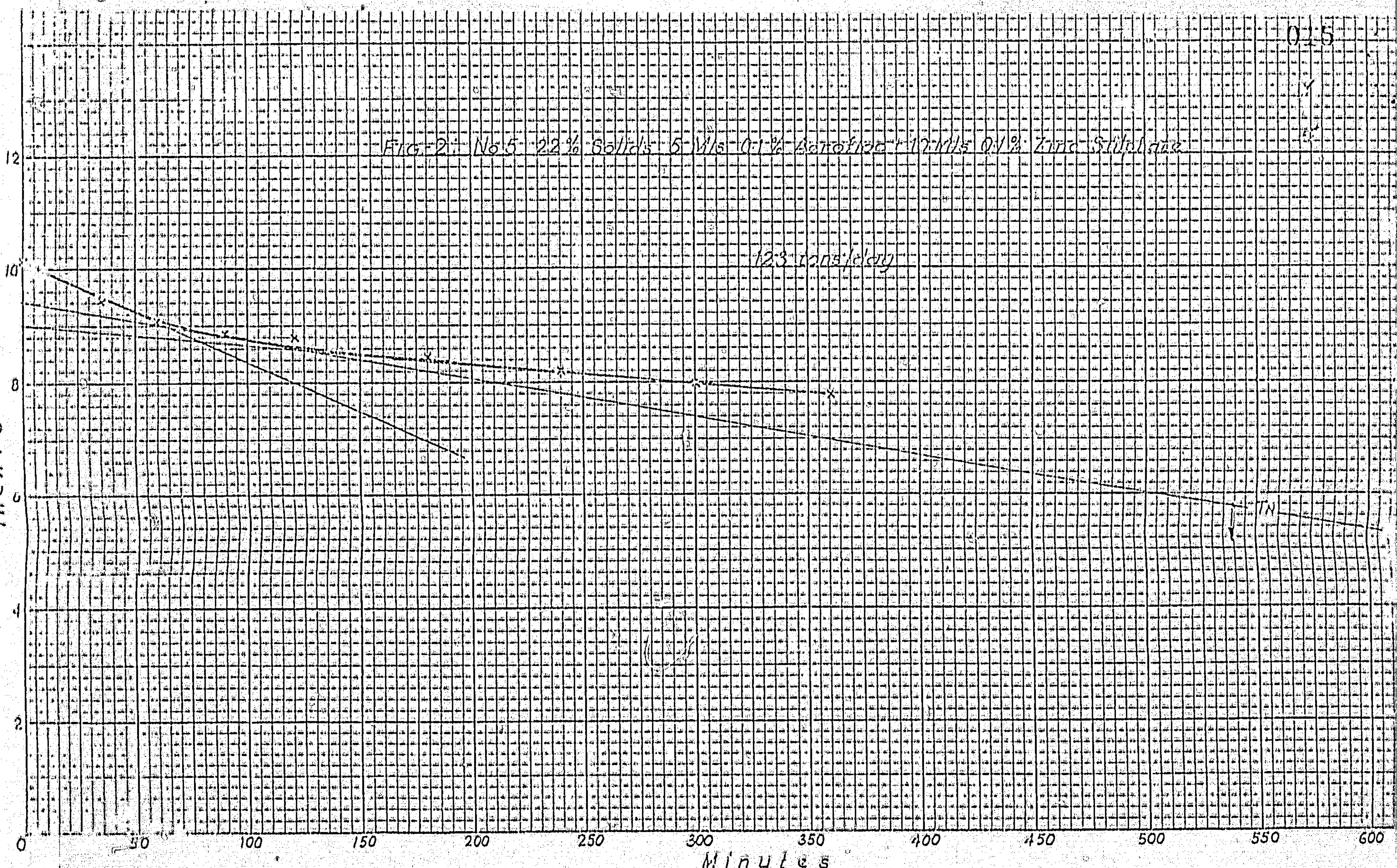
Fig. 2. No 5 22% Solids 5 Mls 0.1% Aerofloc + 12 Mls 0.1% Zinc Sulphate
123 tons/day
12
10
8
6
4
2
0
50
100
150
200
250
300
350
400
450
500
550
600
TN
Minutes

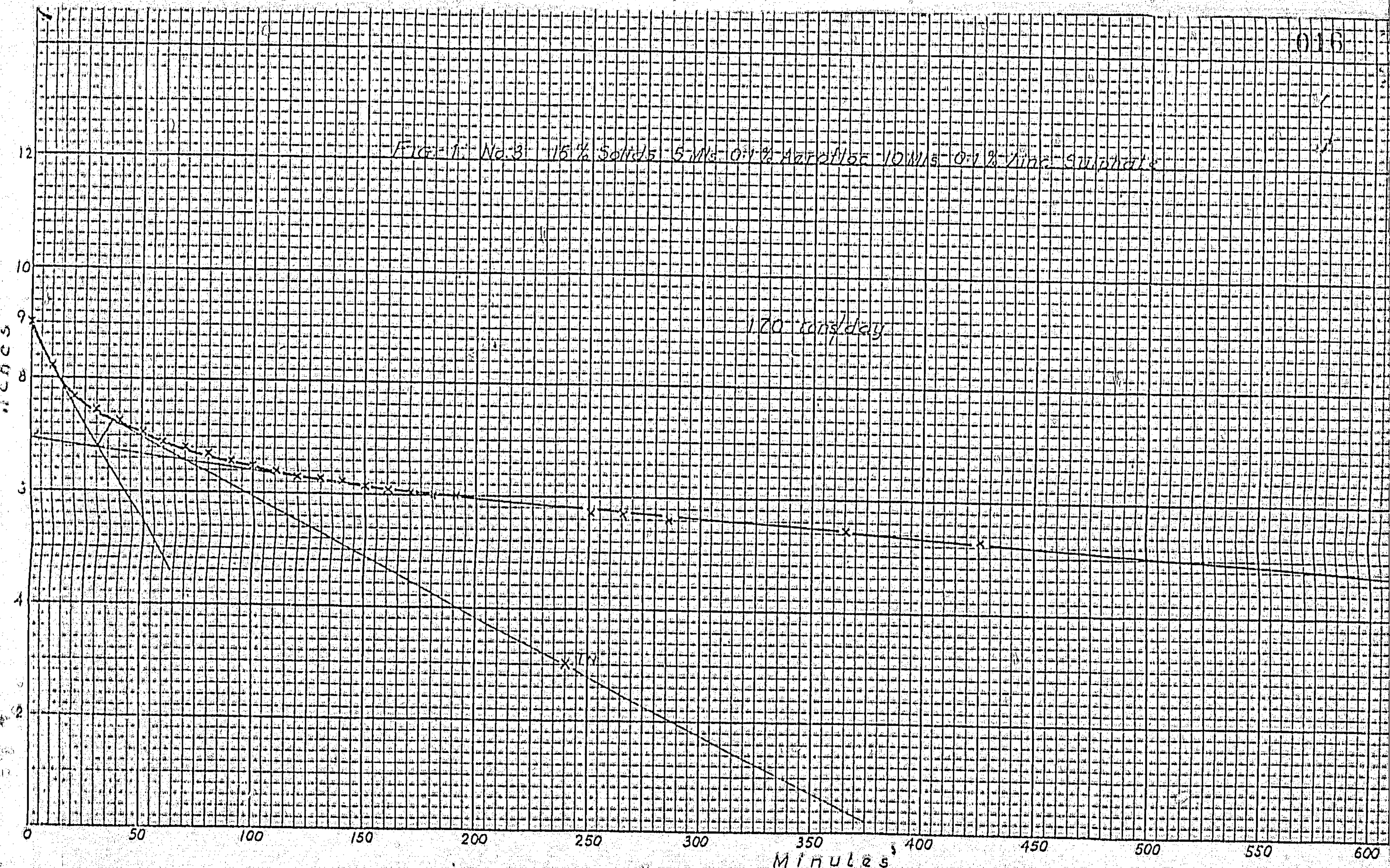

Fig. 1 No.3 15% Solids 5 Ml/s 0.1% Aerofloc 10 Ml/s 0.1% Zinc Sulphate
170 tons/day
Inches
12
10
9
8
6
4
2
0
50
100
150
200
250
300
350
400
450
500
550
600
Minutes

1/31/11

June, 1967

SOUTH AUSTRALIAN GOVERNMENT DEPARTMENT OF MINES

Amdel Report

No. 536

USE OF WHITE CLAYS FOR WALL TILES

by

D. E. Holloway

Investigated by: Ceramic Section
Officer in Charge: D. G. Madigan

P. A. Young, Director.

THE AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES
Adelaide South Australia

CONTENTS

SUMMARY

History

In response to an application for assistance from Australian Ceramic Industries Pty Ltd, the South Australian Government Department of Mines requested Amdel to investigate local raw materials and carry out other necessary work for the development of Ceramic wall tiles.

Objectives

It was desired to prove the suitability of local white clays, the development of blends for the semi-dry press method of production, development of single fire process and evaluation of equipment at the Port Pirie Uranium Plant.

Summary of Work Done

Clays and talcs were examined and processed, suitable blends were developed, pressed and fired using the fast once-fire process. Equipment at the Port Pirie Plant was assessed.

Conclusions

The investigation has shown that not less than eight clays and three talcs are suitable as major ingredients in earthenware.

The twelve earthenware blends listed in Table 2 are not all suitable for wall tiles due to low porosity of the fired mix and low green strength and it may be necessary to introduce up to 10% of highly plastic ball clay to achieve the green strength required for high speed pressing.

All blends listed are suitable for the fast once-fired process and would not be expected to present any problems on a 3-hour cycle.

Most of the slurry and settling tanks at Port Pirie are ideally suited to clay preparation and slip blending.

It will be necessary to investigate the standardisation of the rail link to the plant as the exisiting lines may be unusable when the main line is removed from the main street of Port Pirie.

Recommendations

The following topics remain to be investigated:

a. Proof of clay and talc reserves.

b. Screening and firing tests of Mount Magnificent silica.

c. Detailed listing of unwanted equipment at Port Pirie.

1. INTRODUCTION

The project was initiated for the purpose of investigating raw materials and developing suitable blends for the manufacture of ceramic wall tiles.

The work was to include washing, settling rates, tile forming, investigation of dry and fired characteristics, development of fast once-fired techniques, glazing, spray drying and assessment of equipment at Port Pirie Uranium Plant.

2. MATERIAL EXAMINED

Materials tested for their possible use in earthenware blends were:

a. Clays. Hesso, Georgetown, Cromer "C", Cromer, Pine Point, Yatina, Cowell, Dvaenport, Murraytown, Crystal Brook, Booleroo, Pauls (Port Augusta) and Stokes Sections 12 and 90.

b. Talcs. Mount Fittan 2nd grade, Tumby Bay 1st and 2nd grades, Truro, Joe's Hill (Truro) and Lyndoch.

3. ANCILLARY MATERIALS

The feldspar and silica used in the blends are stock materials ex S. N. Rodda and Co. (SA) Pty Ltd. The feldspar is mined at Broken Hill and the silica in Victoria, (the locality of the mine was not sought).

4. EQUIPMENT

The following equipment was used:

Pan type planetary mixer
Pascall edge-runner mill
Screw press
Stoneware jar mills with porcelain balls
Semi-muffle oil burner kiln
Open-wound electric wire resistance kiln
Vickers diamond pyramid hardness tester
Kestner centrifuge spray dryer
Watson Marlow flow inducer
Cenco moisture balance.

5. EXPERIMENTAL PROCEDURE AND RESULTS

5.1 Raw Materials Preparation

The clay samples were carefully chosen to be truly representative of the exposed areas of the deposits.

Each sample was broken down in a planetary mixer and then a representative sample taken by quartering.

The final sample was ground in the Pascall mill to minus 18-mesh BSS and water added to give a solids content of 23%. The slurry was allowed to settle for 16 hours and then the free water was syphoned off. The remaining slurry was screened to minus 170-mesh BSS. The oversize was dried, weighed and recorded as a percentage of the total dry weight (see Table 1).

5.2 Earthenware Mixes

Twelve earthenware mixes were prepared (see Table 2) by blending the screened clays with the other ingredients by wet grinding in a jar mill for 8 hours. The ground slurries were oven dried at 105°C and the dried cake powdered in the Pascall mill. Water was added to the powder by spraying to give a moisture content suitable for pressing (see Table 3). The mix was then granulated by screening through 12-mesh BSS.

5.3 Semi-Dry Pressing

Tiles were formed in a 2 x 2-inch mild steel die fitted to a hand operated screw fly-press.

The feed was weighed in at 20 g to give a finished depth of $^5/_{32}$ in.

The pressed specimens were air dried for 1 hour, oven dried at 45°C for 2 hours, and stored at 105°C in preparation for glazing and firing. Drying shrinkage was negligible and was ignored for this report.

5.4 Bisque Firing

A composite bisque firing of 20 tiles covering 10 mixes was carried out in the semi-muffle oil-burner kiln. The tiles were brought to 1070°C in 6 hours and soaked at that temperature for 1 hour.

The fired specimens were measured for shrinkage. They were also tested for hardness on the Vickers tester and subsequently the 24 hour cold water absorption was determined. Results of these tests are shown in Table 4.

5.5 Glazing and Firing

An unfired tile from each mix was sprayed with a boron-feldspar clear glaze previously developed by Amdel. The glaze weight was held at 30 oz per pint, approximately 55% solids. The glaze was not adjusted to fit each mix but was used as a trial to determine the general characteristics of the fired glazed bodies, such as bubbling, crawling, blistering, colour, etc. Findings are given in Table 5.

5.6 Single Fast Firing

As a consequence of the results achieved in 6 hours firing in the muffle kiln, a shorter firing cycle was decided on. The open-wound electric kiln was used to fire a single tile setting to 1070°C in approximately 1 hour, plus up to 15 minutes' soaking period. The kiln was cooled to 100°C in 2 hours from switch-on. The first results were satisfactory, and subsequent firings followed the same procedure. Firing details are given in Table 5. See Table 5 also for cold water absorption of glazed tiles.

5.7 Spray Drying

An attempt was made to determine the feasibility of spray drying Hesso clay to a predetermined moisture content of approximately 6%.

The clay was washed, screened to minus 170-mesh BSS and blunged at 35% solids content for 2 hours. The slip feed to the dryer atomiser was metered through a Watson Marlow flow inducer. The atomiser (centrifuge) was operated at a constant speed. The variables in the system were feed rate, heat input, air inlet and outlet temperatures.

Many setting combinations of the system's variables were tried for the purpose of achieving an end product of suitable granular form and having a moisture content around 6%.

The underflow from the drying chamber was removed at every change of setting and tested for moisture content. The highest moisture attained was 3%.

At higher values the clay built up rapidly on the chamber walls. This condition was found to be so at any setting where the moisture content exceeded 3%. The underflow from the dryer excludes the fines which are taken off at a point in the flue system. The fines were weighed and found to be 16.8% of the total dry weight of dryer output.

5.8 Pressing Spray-Dried Clay

A sample of spray-dried clay removed from the dryer underflow at 3% moisture content was pressed in the 2 x 2-inch tile die and was found to be an excellent pressing material. The pressed specimen was hard, very smooth-textured and free from any air pockets, folding or laminating. An attempt was made to press the same type of clay at 3% moisture after normal oven drying, but without any success. The material laminated badly and showed very poor bonding.

5.9 Settling Rates

The equipment used for this test included two graduated 500 ml cylinders with an inch scale attached and one cylinder fitted with a 1 rpm rake. The slurry was prepared by blunging and screening as for normal production. The solids content was found by trial and error to give the best results at 15%. However, the settling rate was still too slow to achieve an economical output of washed clay and further tests were conducted using various flocculating agents. The best results were obtained with Aerofloc and zinc sulphate to give a 24-hour output for the 100 ft diameter thickener of 170 tons dry weight with the feed at 15% solids, and 123 tons, with a feed solids content of 22%. The underflow from the thickener would be 35-40% solids.

Figures 1 and 2 respectively, show the settling curves for 15 and 22% solids content.

The thickener capacity was calculated according to the method given in "The Design of Continuous Thickeners for Flocculated Materials". [1]

5.10 Dilatometry

Five mixes were dry pressed to form specimens 3 x 1½ x ½ in. and fired in the Dilatometer Furnace at 100°C per hour to 1100°C, soaked at that temperature for 3 hours and allowed to cool.

Figures 3 to 7 show the heating and cooling curves. The "Y" axis indicates dilation and the "X" axis the temperature. One division on the Y axis is equal to 0.5% linear expansion. The coefficients of expansion calculated over the range 0-500°C, were:

Figure		Coefficient of Expansion	Fired Shrinkage at 1100°C, %
3	CE1999A	6×10^{-6}	4.7
4	CE2018	8×10^{-6}	3.6
5	CE2001	10×10^{-6}	6.5
6	CE2021	8×10^{-6}	2.95
7	CE2019	8×10^{-6}	5.9

5.11 Alternative Talc

Three talcs have been test fired and compared with Tumby Bay talc. They are, Mount Fittan (ex Rodda), Truro talc and Joe's Hill talc (Truro). The fired specimens indicate that Mount Fittan and Joe's Hill talcs are suitable for white ware. The Truro talc fired brown and could not be used for white ware. Mount Fittan talc would be available from S.N. Rodda. Joe's Hill reserves have not been proven.

6. DISCUSSION

6.1 Washing

All clays tested showed a marked colour improvement after washing and no difficulties were encountered with glaze adhesion. In view of the high salt content of most of the clays tested, it is strongly recommended that all clays listed in this report be washed before blending, particularly if the fast once-fired method is to be used. In some deposits there are indications that the salt content decreases at lower levels. It is suggested that salt determinations could be made when the selected deposits are being worked.

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1. COUCHE, R.A., and GOLDNEY, L.H., (1959), AIMM Publication No. 191 September.

6.2 Materials and Reserves

The only clay found to be wholly unsuitable for white ware was from Paul's deposits near Port Augusta. The kaolins in order of preference would be:

Cromer "C"
Cromer
Stokes Sections 90 and 12
Pine Point
Cromer.

The reserves at Cowell of approximately 20,000 tons are considered to be insufficient for initiating production in a new industry. Pine Point gives excellent results, but has a low clay yield at the pit. The overburden of around 60 ft could also be a deterrent to a new industry.

It is recommended that Cromer reserves be fully investigated and if found to be insufficient the reserves of Stokes Sections 90 and 12 should be proved and transport costs to Port Pirie investigated. Mount Fittan talc (grade TLU), ex S.N. Rodda, is suitable for tiles, but is less white and shows indications of containing more flux than second grade Tumby Bay talc. Mr John Jarvis has stated that he would not be able to supply ground Tumby Bay talc at Port Pirie for less than 40-45 dollars per ton but he is prepared to grind other talcs nominated by the manufacturer. Joe's Hill (Truro) talc is off-white when fired to 1100°C and is considered to be quite satisfactory for tile bodies. It is recommended that reserves be proved before any commitments are made with Mount Fittan suppliers.

6.3 Earthenware Mixes

All the mixes shown in Table 2 have good pressing and firing characteristics, but are not all suitable for tile production due to low porosity. This can, of course, be adjusted by introducing more refractory material into the mix. Mix No. 7, CE2000, would be the simplest and cheapest blend, but would have to be adjusted to increase porosity. This blend has been tested on a production scale in Italy and was found to be mechanically weak when subjected to automatic high speed pressing and ejection. For this reason samples of all clays used in this project have been despatched through Mr Stadler to Italy for production-line testing.

6.4 Fast Firing

Results indicate that clay blends as constitued for this project are suitable for fast firing by the single or twice-fire process. Care must be taken to ensure thorough mixing and milling. It is also important that the pressing powder be stored in such a way that the granules are not destroyed, as any conglomerates entering the die will upset the flow of the granules and result in serious density variations. The 5-minute soaking period at 575°C reduces risk of cracking during quartz conversion expansion.

6.5 Spray Drying

The results of the spray drying investigation were not conclusive, but were sufficient to indicate the feasibility of this form of drying. An industrial dryer having a much greater chamber diameter would be more suitable for the moisture content required. The success of the pressing at 3% moisture content would be confined to ball clays or other plastic materials. However, the quality of the pressed spray-dried Hesso clay was excellent and would apply to all earthenware materials having the correct moisture content.

6.6 Port Pirie Plant

The slurry holding tanks in the leaching plant are considered to be ideal in capacity and agitator speed for slip storage or blending. The digestors would be of definite interest for an expansion programme. The raw materials hopper, conveyor belt and slurry tanks are suitable for initial clay preparation. The large thickeners are considered to be quite suitable for large-scale beneficiation. In the extraction plant a few items are of interest for the casting shop. The vacuum filter drums could be used for preparation of casting slips, particularly the large drum, which has a capacity of approximately 1200 lb dry weight per hour. The settling tank in the extraction plant could also be used for preparation of casting slip. The six small agitator vats adjacent to the dryer would be suitable for blending coloured slips or as casting slip holding tanks. Other items of interest would include drying ovens, small filter presses, water treatment plant, motors and pumps. Sundry vats mounted outside the extraction plant would be of interest for wet or dry storage.

The power house services would be adequate for the whole plant. All services would have to be connected to the Pentad building.

Work shop equipment, spares stores, laboratory and office equipment could be fully utilised.

TABLES 1 TO 5

FIGURES 1 TO 7

TABLE 1: COARSE MATERIAL, % PLUS 170 MESH BSS

CE No.	%
1929	1.0
1930	1.0
2036	10.0
1935	48.0
1939	2.44
1938	1.45
2026	53.8
2027	69.0

TABLE 2: EARTHENWARE TILE BLENDS

nts l	CE No.	Mix Number											
		1	1A	2	3	4	5	7	8	9	10	12	
		CE No. 1999	CE No. 1999A	CE No. 2019	CE No. 2020	CE No. 2038	CE No. 2021	CE No. 2000	CE No. 2001	CE No. 2018	CE No. 2039	CE No. 2050	C 20
	1930	95	-	57	57	38	40	57	50	-	40	57	
	1929	-	95	-	-	-	-	-	-	-	-	-	
'C'	2036	-	-	20	-	-	-	-	-	-	-	-	
nt	1935	-	-	-	10	10	12	-	40	-	-	-	
wn	1939	-	-	-	-	-	-	-	-	60	-	-	
	1938	-	-	-	-	-	-	-	-	-	40	-	
	2026	-	-	-	-	-	-	-	-	-	-	20	
rt	2027	-	-	-	-	-	--	-	-	-	-	-	
Bay)	-	-	-	20	30	40	40	40	7.5	40	18	20	
	-	5	5	3	3	2	2	3	2.5	-	2	3	
	-	-	-	-	-	-	6	-	-	-	-	-	
	-	-	-	-	-	10	-	-	-	-	-	-	

TABLE 3: MOISTURE CONTENT FOR PRESSING

CE No.	%
1999	8.5
1999A	7.8
2019	5.0
2020	7.0
2038	9.0
2021	7.0
2000	4.8
2001	7.9
2018	6.4
2039	7.0
2050	5.5
2051	6.4

TABLE 4: FIRED CHARACTERISTICS OF BISQUE TILES

CE No.	Cold Water Absorption, %	Penetration Hardness	Shrinkage %	Colour
1999	11.31	2.9	3.96	Off-white
1999A	16.8	4.1	1.98	White
2019	14.8	3.0	3.96	White
2020	13.3	3.2	3.46	Off-white
2038	12.7	3.8	2.47	Off-white
2021	17.5	4.1	1.96	Off-white
2000	13.1	3.8	3.46	Off-white
2001	17.1	5.0	3.96	White
2018	18.6	5.0	1.98	Off-white
2039	15.0	4.0	3.96	Off-white
Commercial tile	17.8	2.1	-	Off-white

TABLE 5: ONCE-FIRED TILES AT 1070°C
Soak at 575°C: 5 minutes
Glaze Coverage: Complete

CE No.	Firing Time Hour	min	Glaze Texture	Tile Quality	Shrinkage %	Cold Water Absorption, %
1999	1	15	Fine orange peel	Good	4.68	10.8
1999A	1	10	Smooth satin	Cracked	0.8	16.4
2019	1	10	Smooth satin	Good	1.6	15.4
2020	1	10	Smooth satin	Good	3.1	11.5
2038	1	5	Smooth satin	Good	1.6	11.2
2021	1	15	Smooth satin	Good	0.8	14.9
2000	1	10	Smooth satin	Good	3.12	10.2
2001	1	5	Fine orange peel	Good	4.6	14.3
2018	1	15	Smooth satin	Good	1.56	17.7
2039	1	10	High gloss	Good	2.4	14.1
2050	1	10	Smooth satin	Cracked	4.6	16.4
2051	1	10	High gloss	Cracked	3.1	14.0

Note: British Standard for wall tiles requires 12-18% absorption.

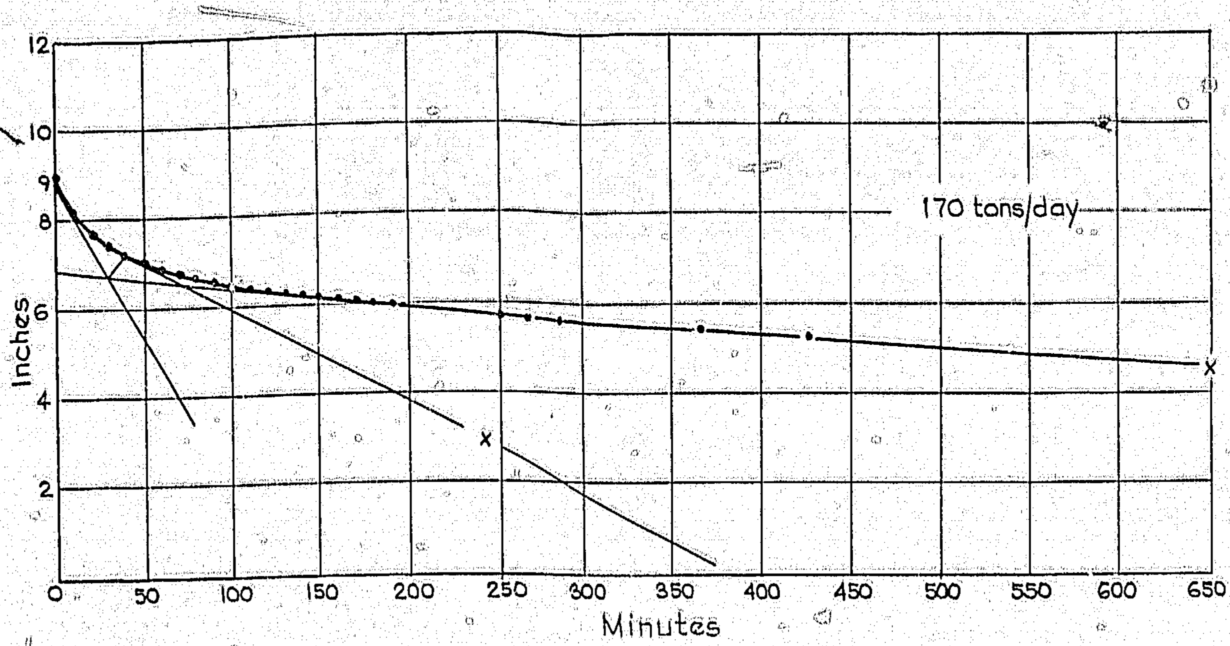

FIG. 1: 15% SOLIDS 5 MILLILITRES 0. 1% AEROFLOC PLUS 10 MILLILITRES 0. 1% ZINC SULPHATE

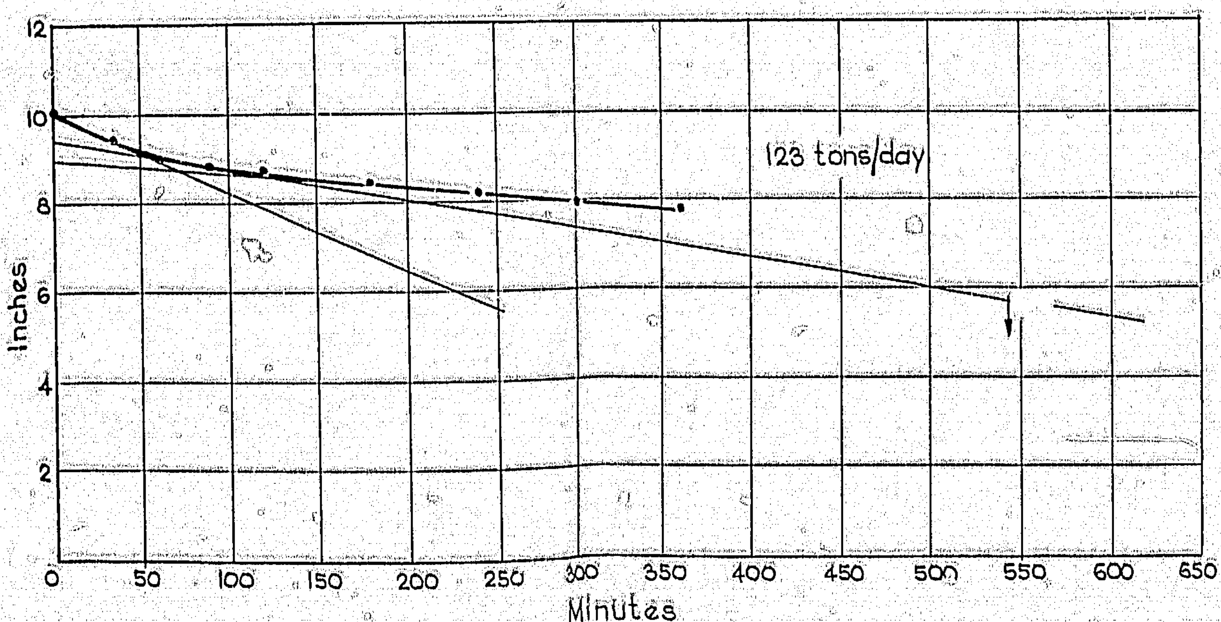

FIG. 2: 22% SOLIDS 5 MILLILITRES 0. 1% AEROFLOC PLUS 10 MILLILITRES 0. 1% ZINC SULPHATE

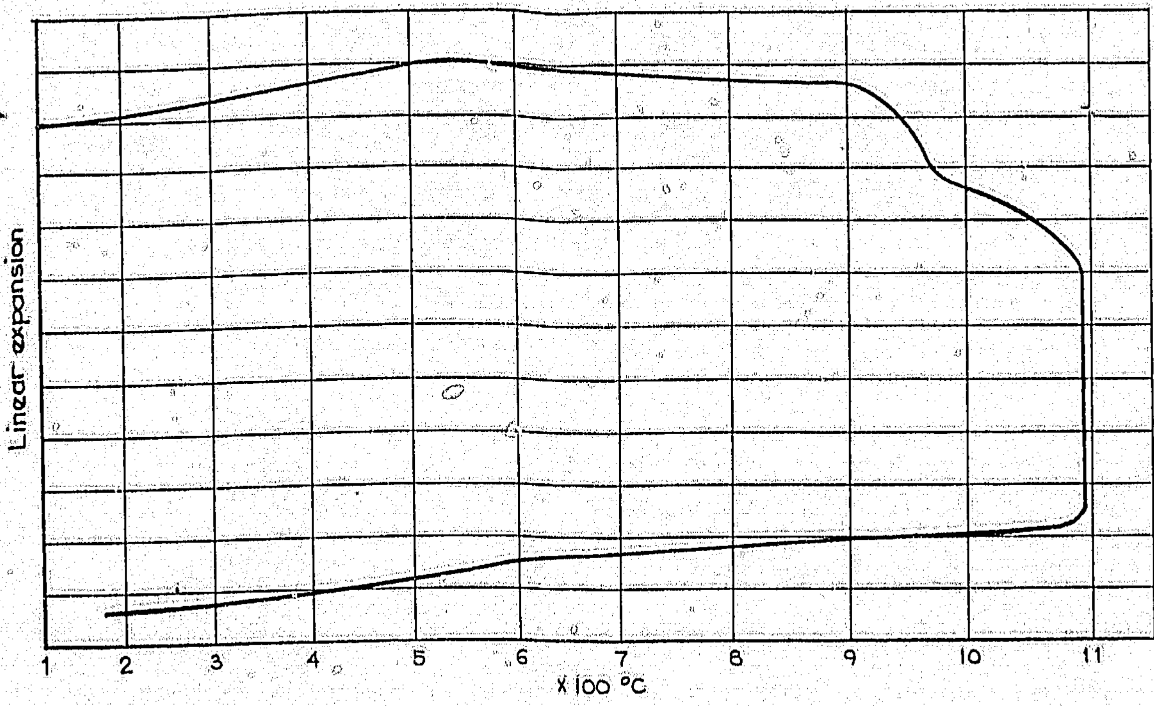

FIG. 3: DILATOMETER CURVE CE1999A MIX NO. 1A

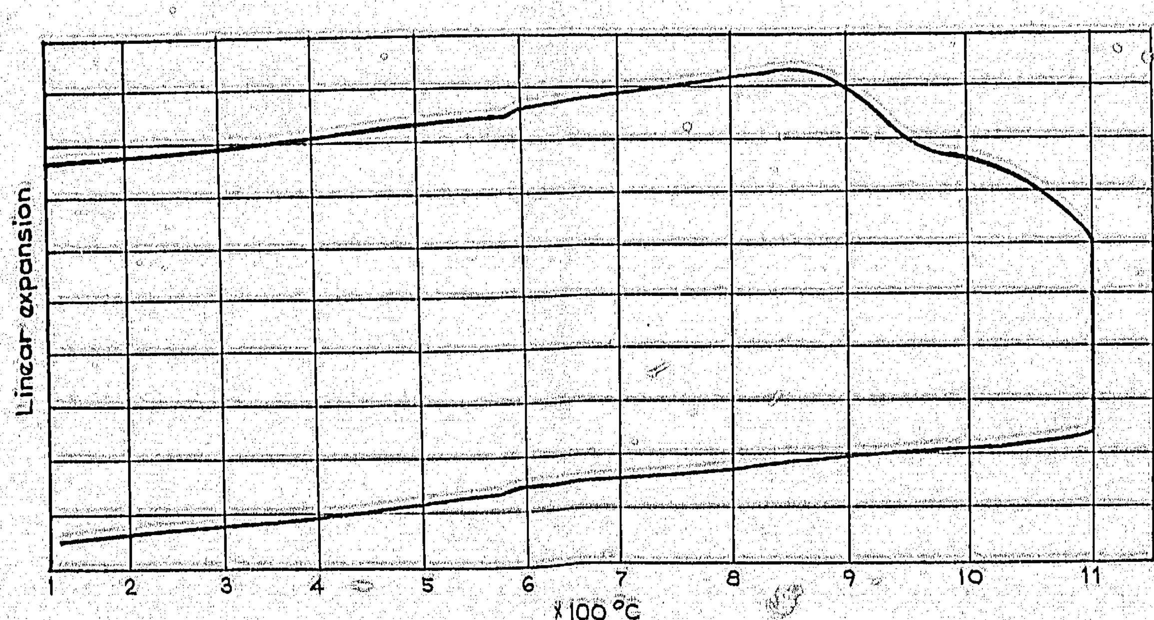

FIG. 4: DILATOMETER CURVE CE2018 MIX NO. 9

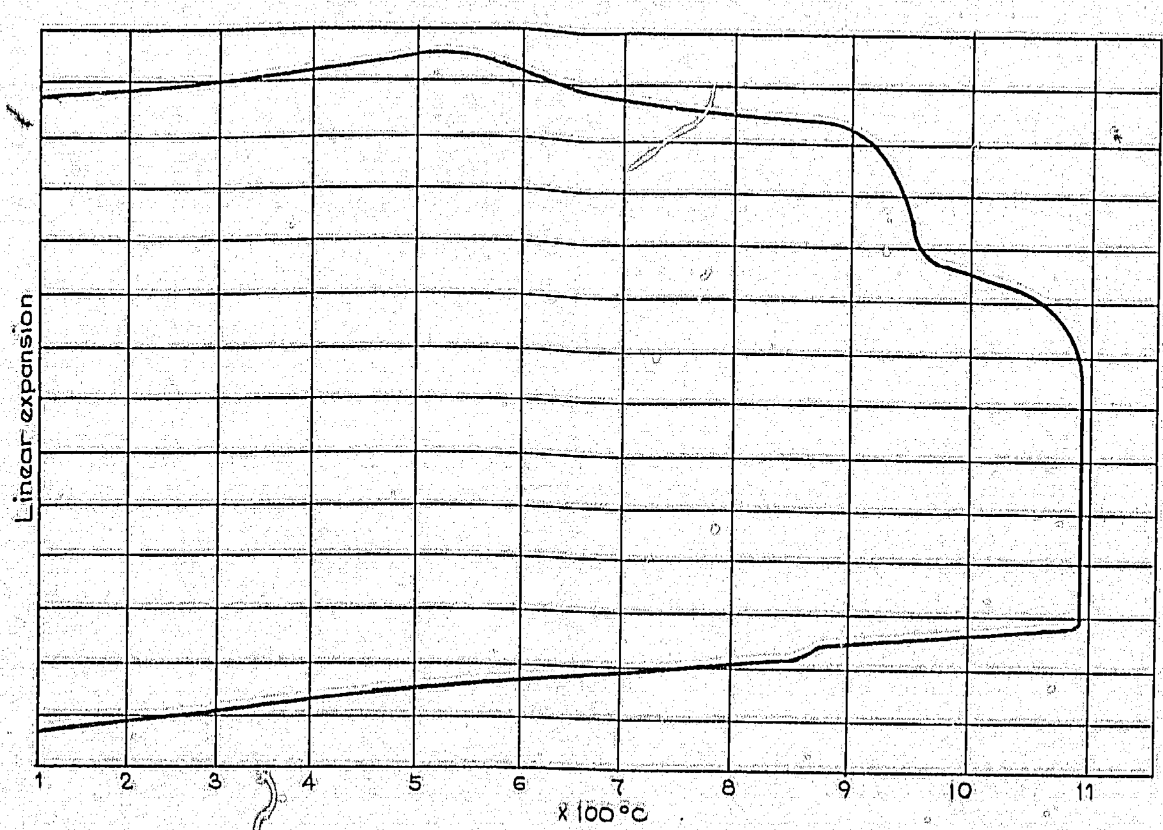

FIG. 5: DILATOMETER CURVE CE2001 MIX NO. 8

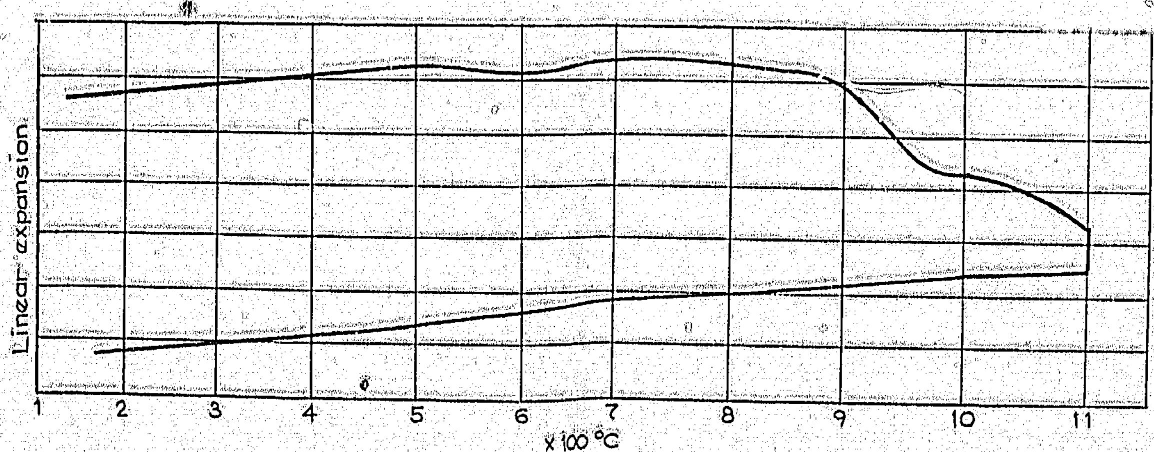

FIG. 6: DILATOMETER CURVE CE2021 MIX NO. 5

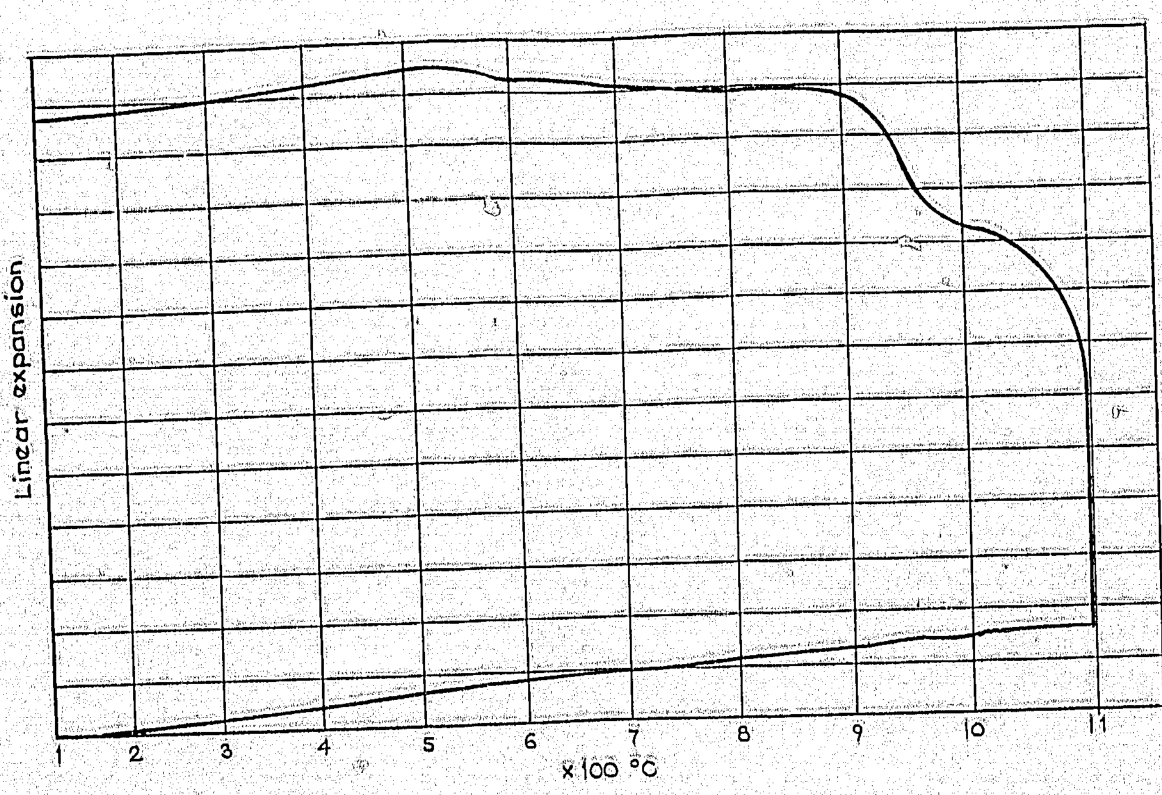

FIG. 7: DILATOMETER CURVE CE2019 MIX NO. 2