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Red Mud Filtration Test Results using AFP IV™ Automatic Filter Press

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Abstract

The results of pressure filtration testing demonstrates that a standard design FLSmidth AFP IV™ filter press can dewater red mud from initial feed concentrations of between 30 - 44 wt% and produce final cakes containing 67 - 70 wt% solids. This paper outlines various factors affecting the filtration rate and final cake solids concentration such as feed solids concentration, slurry temperature and feed pump delivery rate/pressure relationship as well as the configuration of the filter plates. The results are presented for different bauxite grades. Additional testing was performed to obtain filter cakes containing 75 wt% cake solids by evaluating high-pressure filtration at 30 - 60 bar using both recessed plate and membrane plate configurations. The tests demonstrate that high-pressure filtration above 30 bar can produce 75 wt% solids.

Keywords: Filter Press; Red Mud Filtration, FLSmidth; Pressure Filtration

Introduction

An FLSmidth pilot AFP IV™ filter press was set up at the client's facility during 2002 to evaluate the feasibility of using pressure filtration to dewater the red mud. The objective of the testing was to evaluate the following variables;

1. Bauxite Ore Variations
2. Feed Pressure/Feed Rate
3. Plate Type, Recessed vs. Membrane
4. Feed Concentration
5. Air Blowing of the filter cake

During these evaluations, due to test conditions, feed temperature was also observed to have an effect on the test outcome.

The treatment objectives were to process the material to produce a cake that would be friable and transportable by truck or conveyor. An initial target of 70+ wt% was desired, but was later increased to 75 wt% solids based on subsequent geotechnical considerations (soil compaction coefficient, stability when wet, etc.). The tests showed that filtration using conventional filtration with pressures up to 15 bar will produce final solids of 68-71 wt%, depending on other process conditions. At solids concentrations above 68 wt% the cakes meet the original friable and transportable criteria, but do not meet the geotechnical requirements.

To meet the revised target for cake solids additional testing was performed in the Dorr-Oliver Eimco (now FLSmidth), USA laboratory in Salt Lake City, Utah during January 2003.

Test Procedures

Testing was performed using an FLSmidth -Eimco Model 470FB-225 filter press. Feed from the last washer underflow was delivered to an agitated feed tank. The slurry was pumped to the filter press using feed pumps. Initially, two stage centrifugal pumps were used to deliver the slurry, simulating a full-scale system. After initial testing a positive displacement pump was used to deliver the slurry because it was found to be simpler to control pressure and feed rate within the pilot scale system. The full-scale system should use centrifugals because of the pumping rates that will be involved.

The slurry was delivered to the filter, at a selected terminal pressure until the flow rate dropped below a selected point. The slurry temperature was what was available in the feed tank. When using the centrifugal pumps the temperature increased due to recirculation of the slurry for feed and pressure control. The temperature ranged from about 20 - 52 °C during different periods of the testing program. The feed rate and filtration pressure were measured during this period.

When the filter chamber was filled the feed was discontinued. For membrane plate evaluation the plastic membranes were expanded to final pressure of 15.5 bar for a set time period, generally 3 - 5 minutes.

Air blowing of the cake was evaluated by delivering air through the filter cake for a period of time following the filtration period. The time and airflow rate were measured.

After the filtration, membrane and or air blow periods the filter was opened and the filter cake discharged. The cakes were collected and sampled for analysis of the wet cake density and the cake solids content. The feed slurry was also sampled to determine the feed solids concentration.

In selected tests the feed slurry concentration was reduced from the typical 40 - 43 wt% received from the process to 35 - 38 wt%. The objective was to determine the impact on the filter performance and the filter size.

Laboratory testing was also performed with a small bench scale filter test unit. The same data as obtained from the pilot tests was collected.

Discussion of Results

Bauxite grades

Four different bauxite grades from various major deposits and mixtures thereof have been evaluated during the pressure filtration tests. Due to confidentiality the individual bauxite grades are not disclosed in this paper.

Cake density

The filter cake density produced does not vary significantly between the ore types. The dry cake density for feed conditions of 15.5 bar or greater is 1.26-1.32 t/m³. The variation is less than +/- 1.7%, which is considered minimal with variations in ore types and solids densities. The difference is probably associated with the solids density.

Filtration time

The filtration time during the tests varied from 7 - 20 minutes. The reason for the variations includes the filtration temperature (related to the liquor viscosity) and the feed solids concentration. The effect due to temperature/viscosity is shown in Table 1. The effect is that for a feed concentration of 40 - 44-wt% and a slurry temperature of 35 °C or greater the filtration time is between 5 - 8 minutes, provided the pump capacity is not a limiting factor. A design for 7 minutes is suggested.

If the temperature is in the 20 - 30 °C region the filtration time increases to 10 - 15 minutes and the design filtration time would be 12 or 13 minutes, reflecting a reduction in the filtration rate and resulting in an increase in filter size by 50 %, due to the effect of the temperature reduction.

Table 1: Feed Temperature Comparison

Slurry temperature	° C	+35	20 - 30
Filtration time	min	7	12
Discharge time	min	3	3
Cycle time	min	10	15

If the slurry concentration is less than 40 wt% the filtration time also increases as shown in Table 2. The relative change will be proportional to the difference in liquid volume that needs to be removed.

Table 2: Feed Concentration Comparison

Slurry concentration	wt%	41	35
Cake solids concentration	wt%	69	69
Liquid volume removed	kg/kg solids	0.99	1.41
Filtration time	min	7	10
Discharge time	min	3	3
Cycle time	min	10	13

Filtration pressure

Filtration pressures are selected based on process requirements, process temperature, pump sizing (flow rate and pressure requirements), plate types, and material of construction. Generally recessed plates can be filled at pressures up to 15 bar and temperatures up to 40 - 50 °C. Above this temperature the filtration pressure may need to be reduced to protect the plates from damage.

Membrane plates typically have a thinner plastic web and therefore filtration pressures are further limited. Normally a high pressure pumping system would not be selected along with a membrane plate. These comments are provided to understand the possible plate limitations when evaluating some of the data collected using a combination of high-pressure fill and membrane squeeze.

Filtration pressures between 7 - 15 bar were evaluated. The effect of increasing the feed pressure (and the associated feed rate) is to increase the cake solids and reduce the filtration time. The impact on cake solids is an increase of about 1 - 2 wt% in the final cake solids content by increasing the feed pressure from 7 bar to 15 bar, for a specific bauxite ore. Figure 1 shows the data for all ores tested. There is a slight increase in the cake solids. This will result in a slightly higher solids density and thus lower filter volume being required at the higher pressure.

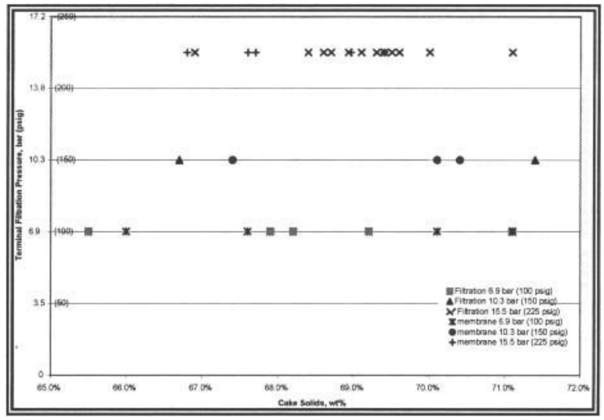

Figure 1: Pressure vs. Cake Solids

The feed pressure affects the rate at which the liquid passes through the cake. Figure 2 shows the relationship for a specific red mud sample. When the filtration pressure is greater, a higher filtration rate and shorter filtration time occurs. The relationship is nearly inversely proportional to the filtration pressure, only subject to differences in the cake resistance being formed at the different pressures. Basic relationships may be understood by reviewing Equation 1 which is the basis for the filtration theory.

Equation 1

$$\frac{1}{A}\frac{dV}{d\theta} = \frac{\Delta P}{\mu\alpha\omega V/A + R_m}$$

V = Filtrate Volume

θ = Cake Formation Time

ω = weight of solids per unit volume of filtrate

α = Average Specific Cake Resistance

μ = Liquid Viscosity

R_m = Resistance of Media or other system resistance

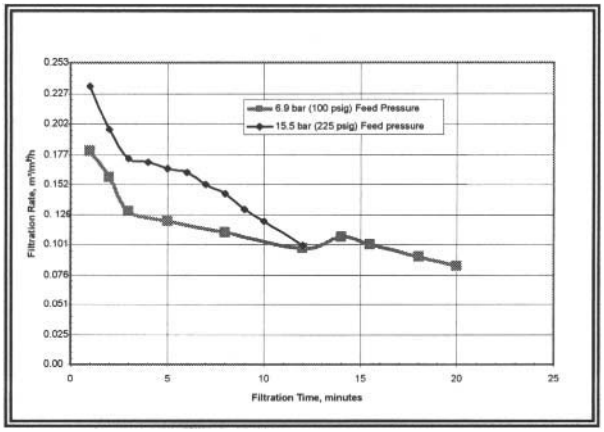

Figure 2: Filtration Rate vs. Pressure

The pump sizing requires evaluation of a pump curve, and then relating that curve to the filtration rates and pressures for which the filtration time is determined. A pump capable of delivering 0.27-0.29 $m^3/m^2/h$ of filter area at 10.3 - 12.4 bar is required using recessed plates. If this pumping capacity is not available then the filtration time will be longer, and the cake solids concentration may decrease.

Plate type

Evaluations of recessed and membrane plates were made during this study. Recessed plates rely on the feed slurry pump to push liquid through the filter chamber while retaining the solids to compact the solids and produce the final cake solids. Membrane plates allow the feed pumping time to be reduced by needing only a preliminary separation of liquids and solids, followed by compacting the solids using an inflatable diaphragm attached to the plates. The membrane plates, when inflated at 15.5 bar, typically produce a higher final cake solids concentration in difficult filtering materials than recessed plates using a 15.5 bar feed pump. In this application the membranes produced 68 – 71 wt% solids compared to 67 - 71 wt% solids for recessed plates operating at a feed pressure of 15.5 bar.

Additional tests have been carried out in October and November 2002. These results are shown in Figure 3 for comparison. These data show increasing solids concentrations as the feed pressure/membrane squeeze pressure values are increased. Using a membrane squeeze having the same squeeze pressure as the feed pressure results in a cake solids increase of about 0.5 wt% over a simple recessed plate at the same feed pressure. Increasing the filtration pressure from 6.9 bar to 13.8 bar results in an increase of 2-3 wt%. The main issue will be whether the plate material selected for the full-scale equipment can be operated with a 13.8 bar feed pressure at normal operating temperatures.

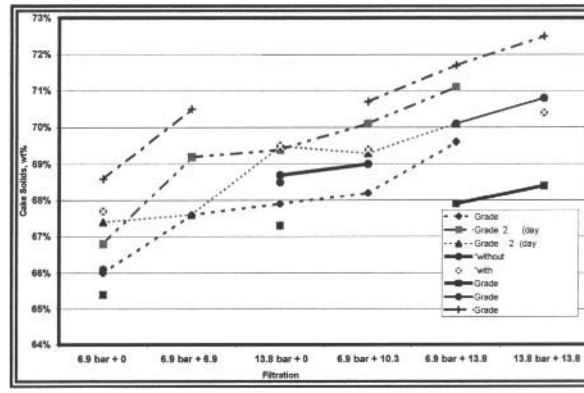

Figure 3: Additional Comparative Results

Historically membrane plates have two disadvantages. They require additional mechanical time to inflate and deflate the membrane. There is a loss of volume due to cake compression. Unless the cake density is appreciably higher using membrane plates, the actual mass of solids in a filter with the same initial chamber volume is reduced by this lost volume. Therefore a filter press equipped with membrane plates will require more chambers than a recessed plate unit because of the difference in operating time and volumes. Also, because of the mechanical method of attachment membranes use up a portion of the plate area, so membrane plates have less area and volume than a recessed plate of the same nominal outside dimensions and cake thickness. Table 3 shows a comparison of the differences in the number of filter plates for a red mud application when the factors of total filtration cycle time; squeeze volume loss and smaller cake volume per chamber are combined.

Table 3: Plate Comparison

		Recessed Plate Filter	Membrane Plate Filter
Filtration time	min	7	6
Membrane time	min		5
Discharge time	min	3	3
Cycle time	min	10	14
Cake solids concentration	wt%	69	69.5
Wet cake density	t/m^3	1.8 - 2.0	1.8 - 2.0
Dry cake density	t/m^3	1.29	1.29
Cake density (filter volume)	t/m^3	1.29	1.25
# chambers/1000 t/day		60	99

Membrane plates also require more accessories (for membrane expansion) than recessed plates. These accessories include extra piping, valves and the means of pressurizing the squeeze medium, either an air compressor or water pump.

The test data for this application demonstrate that there is only a slight increase in the cake solids by using the membrane plates over direct filtration at the same operating pressure. Considering factors of increased filter size, added accessory costs, and operating complexity membrane plates are NOT recommended. However, they may be required to meet the target solids content if filtration using recessed plates falls short of the minimum requirement.

Air blow

Air blowing of the filter cakes was evaluated on selected tests. The need for air blowing is only related to transport characteristics of the filter cakes. Once the solids are transported to an impoundment and environmental water penetrates the pores of the cake, the material will ultimately return to the same solids concentration found in the filter press cake prior to air blowing. Having said this, the use of air blow on the pilot unit did not increase the final cake solids significantly. The limited data taken showed no statistically significant difference in final cake solids concentration. The air blow was limited to about 18 $Nm^3/m^2/h$ of plate area delivery rate by the available air pressure on site. Normally, this amount of air, if passed through the cake should result in a significant moisture reduction. But the physical appearance and solids content of the cake was the same as without air blow. So it appears that the filter cake was highly resistant to air flow and most of the measured air actually passed around the edges of the cake rather than directly through it.

Air blow can still be effective in cleaning the drainage channels of free liquid, but a minimal amount of air is all that is needed for this application.

Ultra pressure evaluation

When the geotechnical considerations indicated that the minimum solids concentration needed to be 75 wt% solids rather than 70 wt%, additional tests were conducted using a bench-scale sized filter in the FLSMIDTH, USA lab in Salt Lake City, Utah. These tests were run with a high-pressure membrane test unit that was capable of producing squeeze pressures up to 61 bar. The tests demonstrated an increasing pressure up to 61 bar produced a corresponding increase in cake solids concentration up as shown in Figure 4. For the sample tested, high pressure filtration will produce a final cake solids concentration of 74 - 76.4 wt%.

Based on the similarity in filtration characteristics found in the earlier work, it is likely that this same correlation will carry over to the different ore mixtures that were tested earlier. By the same logic, and the relatively small differences we saw in the earlier work for direct filtration vs. membrane squeeze filtration at 15.5 bar, the final cake solids using a recessed plate, 61 bar filtration system will likely be in the 73 - 75 wt% range. However this option needs further evaluation with a high pressure feed pump that has flow capacity, at least 1.22 $m^3/m^2/h$, and output pressure matched to either the pilot unit or the bench unit to verify the exact final moisture content. This size and type of pump was not available at the time of testing.

At the present time membrane plate technology is limited to operation up to about 41 bar. Membrane life at these higher pressures will become a major factor in operating costs of the equipment. Above this pressure the mechanical application experience has been limited to direct filtration. With these considerations, and since it is very probable that direct filtration will produce nearly equivalent final cake solids with a less complex filter press system, FLSmidth recommends using direct filtration on recessed plates to achieve the target solids concentration.

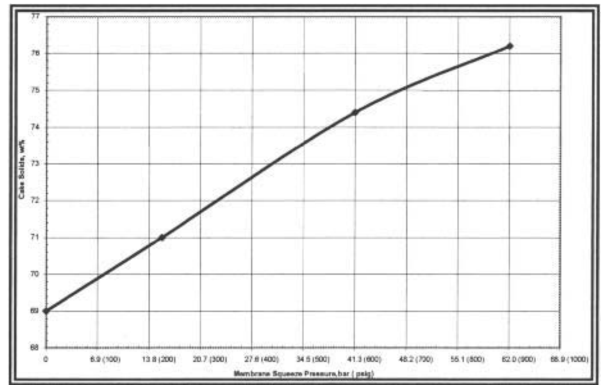

Figure 4: Cake Solids vs. Membrane Squeeze Pressure

Conclusions and recommendations

The Red Mud can be dewatered with an FLSmidth AFP IV™ filter press to produce a final cake containing 68 - 71 wt% solids using a 15.5 bar filtration pressure. The filter size can be minimized by ensuring a feed solids concentration of at least 40 – 44 wt% and using the highest possible operating temperature after considering the mechanical strength limitations of the filter plates. An FLSmidth AFP IV™ filter press design is suggested to reduce the discharge time and maximize the processing rates for the filter. The basic design conditions are:

Table 6: Design Summary

		Best Case	Worst Case
Slurry concentration	wt %	40 - 44	35
Slurry temperature	°C	30 - 40	20 - 30
Filtration time	min	7	14
Discharge time (AFP IV™ only)	min	3	3
Cycle time	min	10	17
Dry cake density	t/m^3	1.29	1.29
Wet cake density	t/m^3	1.84 - 1.92	1.84 - 1.92
Cake solids	wt %	67 - 70	67 - 70
Filter volume required for a feed of 1000 t/day dry solids	m^3	5.37	9.12

If the cake solids content must be increased to 75 wt%, there are two options:

- Use a specialized high pressure recessed plate filter press and special high pressure pump that allows filtration up to 60 bar, but with the same nominal filter size as above;
- Use a specialized high pressure filter press and membrane filter plate configuration, with a 35 - 40 bar squeeze pressure. This will require additional processing time and the filter will have about 50 % more filter plates than the other options.