PRESSURE DECANTATION TECHNOLOGY: THE KAISER GRAMERCY EXPERIENCE

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Abstract

As part of the project to rebuild their digestion circuit, the Kaiser Gramercy Alumina refinery opted for a version of a Double Digestion circuit which was developed jointly with Alcan International. The Double Digestion circuit makes use of Pressure Decanters operating at digestion temperatures and pressures to separate the mud from the first digestion stage and to redigest the separated mud in a second digestion stage. Gramercy refinery operates on Jamaican bauxite, which is well known for its poor settling and compaction characteristics.

This paper will outline the basic features of the Pressure Decantation Technology, describe the testing program and the results obtained in order to size and predict the performance of the full size vessels. Then the paper will present some of the distinctive features of the installed units. It will finally present results obtained from the operation of these pressure decantation units and compare these results with the predicted performance based on laboratory/pilot scale tests.

1. Introduction

In order to maintain cost competitiveness and the increasing demand for alumina, the refineries need to improve their productivity, stretch their present capacity by debottlenecking different sections of the plant, while keeping capital cost at a minimum and eventually proceed to an expansion which most probably will take the form of a brown field expansion.

Increasing caustic concentration in digestion and operating as closed as possible to alumina solubility concentration are two relatively inexpensive means to achieve some of the above objectives. In the case of boehmitic bauxite, converting to a double digestion technology constitutes an attractive solution in order to reduce energy consumption, avoid investment for additional high pressure steam power generator and the use of exotic material of construction for some of the very high temperature section of the plant. Pechiney recently reported about conversion of one of their digestion circuit into a double digestion system.

The limitation to the operation at a ratio that approaches the solubility of alumina is coming from the high risk of reversion and alumina precipitation further down the circuit and mainly in the mud settler as the liquor is cooled down and often diluted with lower caustic and colder liquor. For those considering the conversion of their digestion circuit to a double digest flowsheet, a large proportion of the energy benefits would be lost if the digested slurry were first blown down prior to mud separation. When considering a brown field expansion, the plants are often confronted with physical space limitation within the plant boundaries and there is a need to identify smaller diameter equipment.

In addition to the limitations enumerated above, processing Jamaican bauxite presents an additional difficulty. As well known, the settling rate of Jamaican mud is relatively low and the digested mud slurry is particularly sensitive to breakdown upon flashing.

The pressure decantation technology does provide a solution to many of the limitation cited above.

A number of patents and papers have been published over the recent years on the subject. In 1989, Harrington and Dancose reported the results of work performed in 1984 on a modified vertical digester at the Alcan's Jonquiere alumina refinery in Canada. Although the unit tested was not equipped with any raking mechanism or stirrer, the results obtained gave a clear indication that such an equipment was perfectly capable of rapidly separating a red mud slurry with a very high throughput.

In 1999 the Kaiser Aluminium Corporation decided to rebuild the digestion circuit of their Gramercy alumina refinery and were looking at a technology capable of handling their current as well as their future anticipated bauxite feed which is expected to contain a higher concentration of boehmite. Jointly with Alcan, a number of potential double digestion flow sheets were considered. A cross-flow double digestion circuit, including pressure decanters for the separation of the low temperature digested mud slurry was finally evaluated at the bench scale level and the concept was retained for the future circuit.

This paper will outline the features of the Alcan pressure decantation technology, present the pilot test work that led to the design parameters for the full size units and finally will report on the initial results obtained on the pressure decanter units in the initial months of operation.

2. Pressure Decantation Technology

As indicated above, Pressure Decanters have been described in various papers and patents. A relatively complete disclosure and description of the technology can be found in the US Patent 5,407,561 by Iida, Stewart and Puxley entitled "Pressure Decanter". It is described as a cylindrical pressure vessel, preferably with a conical bottom section, a closed upper end, a deep feedwell for incoming pressurised slurry and an enlarged section at the bottom of the cone to facilitate removal of solids from the decanter.

The apparatus includes a "stirrer" inside the bottom section to maintain an active mud bed zone in the lower section of the tank and improve the dewatering process of the thick compacted mud. This "stirrer" and/or dewatering device includes a drive shaft which extends outside the vessel at the top through a pressure seal, an horizontal arm attached to the drive shaft in its lower section and vertical or near vertical rods or the like are mounted diametrically opposite each other. The drive shaft is preferably turned by a variable speed device powered hydraulically or electrically.

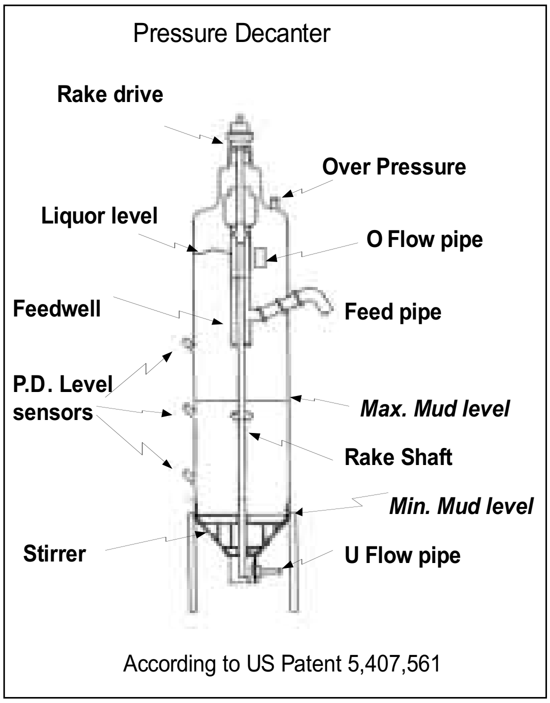

Figure 1

Pressure Decanters used in Bayer process applications are normally elongated cylindrical vessels made of mild steel having a height to width ratio varying between 2 and 6.

The Pressure Decantation Technology developed and patented by Alcan International operates under similar principal as the High Rate Decantation technology described in previous Alcan patents. Four important factors control the compaction of the mud as applicable to the High Rate Decanters:

- the static pressure from the column of mud above
- the residence time of the compacted mud in the decanter
- the compressibility of the mud itself which is a function of each individual bauxite and the nature and dosage of synthetic flocculent
- the de-watering action of the rake and de-watering rods

With respect to the addition of synthetic flocculent it is recommended to provide at least two points of additions, one in the feed line and the other in the feedwell. The exact point of additions of flocculent are dictated by the velocity, the turbulence of the slurry in the line as well as the specific geometry of the pipework. This is why some testing is necessary at the plant site on the final installation in order to optimise the use of the synthetic flocculent.

3. Initial Pilot Evaluation

In the fall of 1999, Alcan International was asked by Kaiser Aluminium, following the selection of the flow sheet for the new digestion circuit, to evaluate the settling behaviour under pressure decanter conditions of two bauxite samples identified as current and future bauxite supply for the Gramercy refinery. As mentioned earlier, the pressure decanter was intended to be part of a newly conceived double digestion flowsheet jointly developed by Kaiser and Alcan.

The set-up of the Alcan pilot unit is shown schematically in figure 2. Figure 3 is a picture of one of the experimental pressure decanters installed at the Alcan Bayer Experimental Centre located in Jonquiere, Canada. The bauxite samples have been supplied by Kaiser and were coming from the Kaiser bauxite reserves located on the north coast of Jamaica. The bauxite analysis as well as the liquor analysis used for this pilot evaluation are presented in Table 1 and Table 2 below.

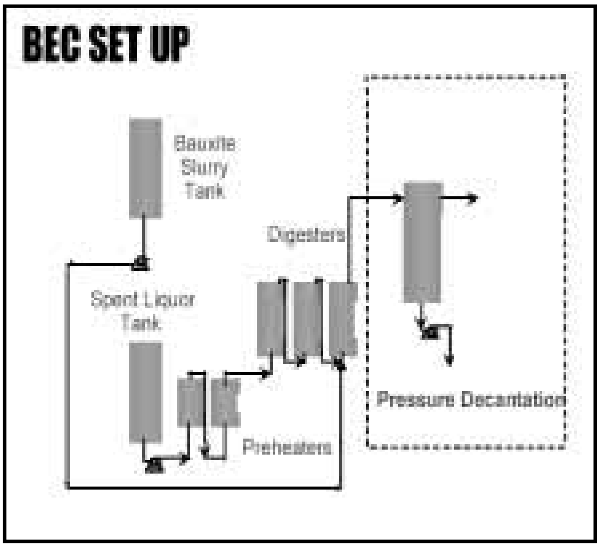

Figure 2 — Pressure decanter experimental set-up

Figure 3 — Pilot Pressure Decanter

Table 1 — Bauxite analysis — pilot test work

Elements	Bauxite #1 % by XRF	Bauxite #2 % by XRF
Al_2O_3	47.5	50
Fe_2O_3	18.5	18.5
SiO_2	1.2	1.3
TiO_2	2.33	2.37

Table 2 — Liquor analysis for bauxite digestion-pilot test work

		Test with Bauxite #1	Test with Bauxite #2
Total Caustic (as Na_2CO_3)	g/l	246	238
Al_2O_3	g/l	106	82
Na_2CO_3	g/l	55	55
A/C ratio		0.43	0.34
Causticity	%	81	81

3.1 *Process conditions*

The pilot trials were preceded by a series of laboratory settling tests to determine the type and range of flocculent dosages to use as well as the range of feed solids concentration to aim for.

These tests indicated that the mud can be settled satisfactorily using a poly-acrylate polymer with essentially a linear response in the range of 50 to 400 g/t of active flocculent per ton of mud, the clarity being maintained in the range of 100 to 150 mg/l.

The process conditions used for the pilot tests are summarised in Table 3 and the typical results are summarised in Table 4 below

Table 3 — Range of Feed Slurry Conditions: Pilot unit

Parameters		Test with Bauxite #1	Test with Bauxite #2
Feed rate to decanter	L/h	75–230	75–200
Feed solids concentration	g/l	60	60–70
Feed Liquor Temperature	ºC	155–160	155–160
Range flocculent dosage “active”	g/T	150–400	80–450

The pilot pressure decanter used for this test program had the following geometry.

- Diameter: 0.2 meter
- Straight wall height 1.3 m
- Cone angle 45 degree

Table 4 —Typical Results for Pilot Pressure Decanter operation

		Test A Bauxite #1	Test B Bauxite #1	Test C Bauxite #2
Throughput	($t/m^2/day$)	30	45	40
Throughput	($m^3/h/m^2$)	20	30	25
O’Flow clarity	(mg/l)	150	200	80
Synfloc dosage	(g/T_{mud})	200	325	270

Inserts of various diameters were installed in the upper half of the decanter to allow operation at different liquor rise rates while keeping manageable feed flow rates. The pilot decanter is equipped with a scanning gamma probe, which allows detection of the mud level within the decanter.

The effect of the synthetic flocculent dosage on the net annular rise rate was studied and the results show that this rise rate increases relatively linearly with an increase in the flocculent dosage. The graph of Figure 4 shows this relationship.

The underflow solids obtained from this pilot pressure decanter are normally not indicative of the underflow solids to be expected from a full size decanter because the residence time of the mud in the pilot decanter is too short, the height of the mud bed is small and the rake has not the same structure and efficiency. On the other hand based on compactibility of the mud determined from the yield stress measurement on the mud at various solids concentration, we can anticipate this mud to consolidate at a value varying between 26 and 32%.

Based on the results obtained on the pilot unit and the anticipated plant data given by Kaiser, the process performance expectation were provided for the final design and construction of the Pressure Decanter units. (**Table 5** below)

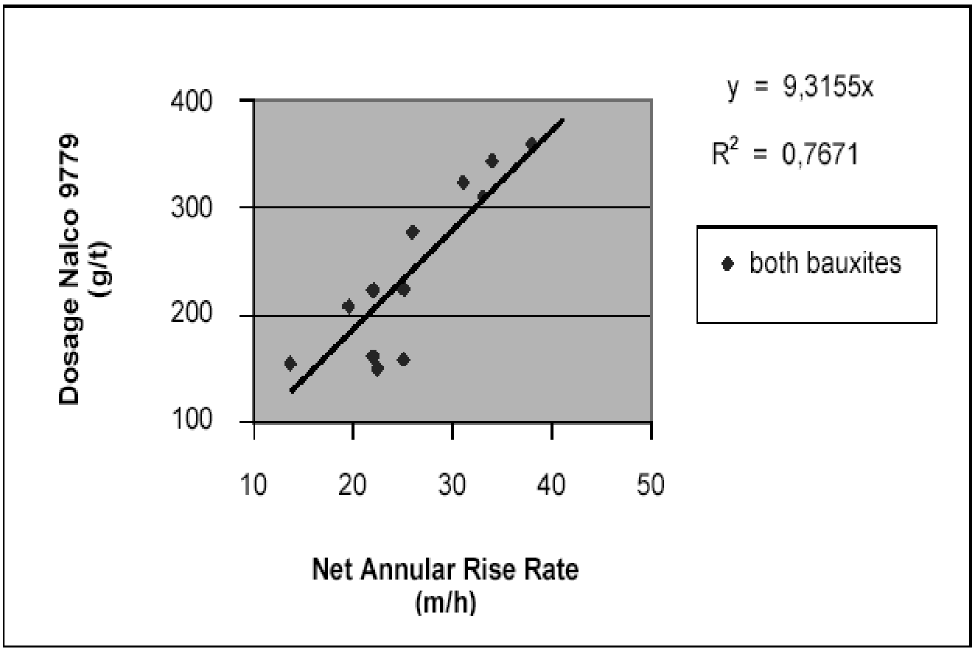

Figure 4 — Effect of Flocculent dosage on Net Rise Rate

Table 5 — Process Design Criteria for Full-size Gramercy Pressure Decanters

Basic Process Assumption	Units	Value
Total Feed rate	USgpm (m^3/h)	2620 (595)
Feed solids concentration	gpl	75
Mud Load	T/h	45
Feed liquor Temperature	ºF (ºC)	320 (160)
Predicted Performance		
Underflow solids concentration	% ± 4	28
Throughput (Volumetric)	$m^3/h\text{-}m^2 \pm 5$	30
Throughput (Mass)	$T/day\text{-}m^2 \pm 20$	52
Flocculent dosage	$g/T_{mud} \pm 50$	250

4. The Pressure Decanters Installed at Gramercy

Following the evaluation and recommendations coming out of the pilot program, Gramercy installed four pressure decanter units, three units to be in operation at any one time and a fourth one as a stand-by decanter to cover normal maintenance services. Each decanter is approximately 50 ft or 15.25 m high including cone and 35 ft or 10.5 m of straight wall with a diameter of about 16.5 ft or 5 m.

The units are equipped with 4 differential pressure cells which measure the pressure exerted by the column of liquor and mud above with respect to a reference cell installed in the upper portion of the vessel. The cells are roughly 4 feet apart. The units are maintained in operation by a continuous purge of process condensate near the pressure cells. By a proper calibration, the operator is capable of monitoring the level of mud in each Pressure Decanter as well as the inventory of mud. Samples of the overflow liquor are taken at regular intervals for analysis as well as samples from the thick mud at the underflow. A density meter (γ-gauge) continuously monitors the density of the thickened mud, thus providing a good evaluation of the solids concentration at the underflow.

The pressure decanters are installed at the end of the low temperature digestion circuit. The decanted mud from the pressure decanters is transferred to the high temperature digestion section of the plant, the overflow liquor is further processed before being mixed with other streams prior to feeding the precipitation circuit. Since the overflow liquor from the pressure decanter is not directed to security filtration, the overflow clarity requirement is not very stringent and a target of 1000 mg/l has been set by Kaiser. For the Start-up period an internal target of 500 mg/l or less was set.

The typical process conditions for the feed liquor going to the Pressure Decanters at the Gramercy refinery are summarised in Table 6 below.

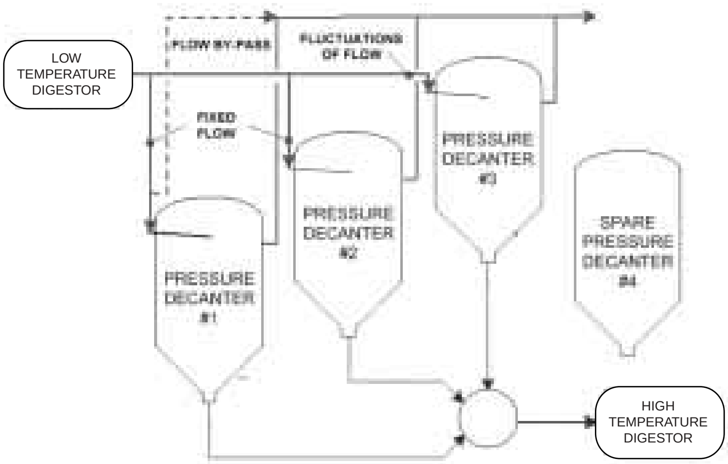

Figure 5 — Pressure decanters arrangement within Kaiser digestion circuit

Figure 6 — Pressure Decanters installation at Gramercy

Table 6 — Range of Feed Slurry Conditions
Gramercy Pressure Decanters (Average Sept. 2001)

Parameters	Units	Gramercy Feed
Total Caustic (as Na_2CO_3)	g/l	200–215
Al_2O_3	g/l	140–160
Na_2CO_3	g/l	40–50
A/C ratio		0.74–0.76
Causticity	%	80–83
Feed rate to decanters main header	m^3/h (USgpm)	1930–2160 (8500–9500)
Feed solids concentration main header	g/l	75–110
Feed Slurry Temperature main header	ºC (ºF)	150–160 (300–320)

The first pressure decanter was put in service around the 18 July 2001 and within ten days three Pressure Decanters were in operation. Unit #4, which was the first one to be started, was stopped for some modifications and re-started on August 21. The graph of figure 7 illustrates the time it took to reach stability after start-up. In this case it can be seen that after less than 5 days, the decanter generated consistent clear overflow liquor. By then, the underflow solids concentration had reached approximately 27% for that Pressure Decanter.

In order to evaluate the performance of the Pressure Decanters the behaviour of Pressure Decanter #4 has been closely monitored for the month of September 2001. Particular attention was paid to the overflow solids concentration of the decanted liquor, the underflow solids content as well as the throughput of the unit during that period.

The narrow band on the graph of figures 8 and 9 are the control zone for each the given parameters. As can be seen by the variation of the solids throughput in figure 9, the feed liquor to that Decanter (feed solids conc. **X** flow) has varied

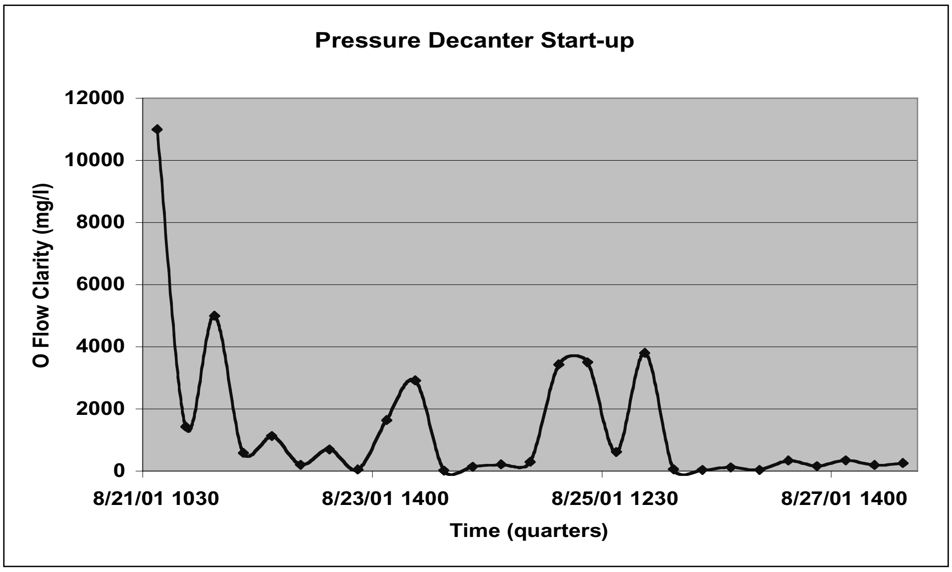

Figure 7 — O'Flow clarity on Start-up for Pressure Decanter #4

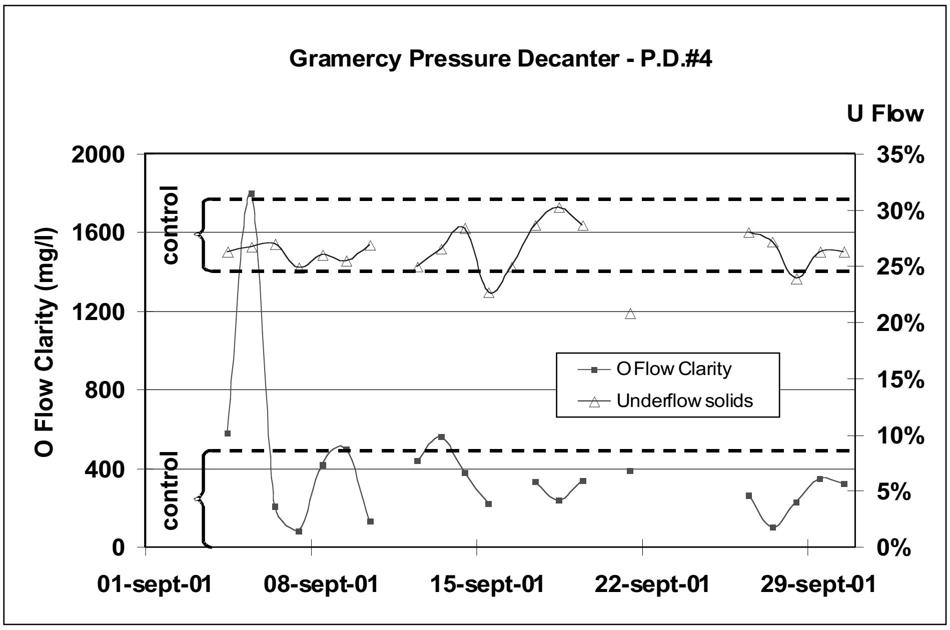

Figure 8 — P.D.#4 Operating Results — Overflow and Underflow — Sept. 2001

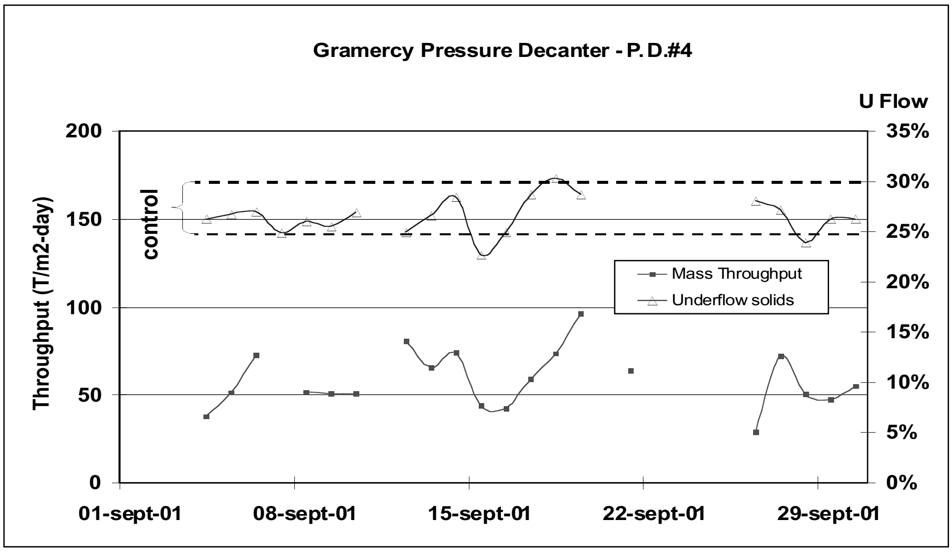

Figure 9 — P.D.#4 Operating Results — Throughput and Underflow — Sept. 2001

significantly over that period. Despite these changes this Pressure Decanter unit was kept under control even when the throughput exceeded the design figures as for the period around 18 September, reaching close to 100 T/day-m^2.

5. Discussion

We have shown that the Pressure Decanters based on the Alcan design as installed by Kaiser at the Gramercy Alumina refinery are well suited for the separation of Jamaican mud under pressure and this mud can be further directed to the high temperature section of the Gramercy double digestion circuit without loss of pressure.

Prior to the rebuild of the Gramercy digestion circuit, Kaiser operated one 37 meter (120 feet) diameter decanter to settle the mud at an underflow solids concentration of 20% solids for a total surface area requirement of more than 1075 m^2. This meant solids throughput of about 2.5 T/day-m^2. With the newly installed Pressure Decanters, the area required for these units is only 80 m^2 in total and the throughput achieved is of the order of 50 to 70 T/day-m^2 on average. The dramatically higher handling capacity of the PD is achieved with a mud that has been subjected only to Tri-Hydrate digestion conditions, so that its settling characteristics might be expected to be poorer than those for Gramercy's former Mono Hydrate and sweetening processed mud.

It is also important to mention that the pilot work predicted well the Pressure Decanters performance and allowed for the proper sizing of these vessels.

Now that Kaiser has completed the rebuild of their Gramercy alumina refinery, some optimisation of the units need to be addressed, mainly in the area of flocculent utilisation where consumption tends to increase with time. Better in-line instrumentation also needs to be developed to follow more closely the solids concentration of the overflow. This type of information is critical, as it can constitute one of the early warning signals that a Pressure Decanter is out of control.

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