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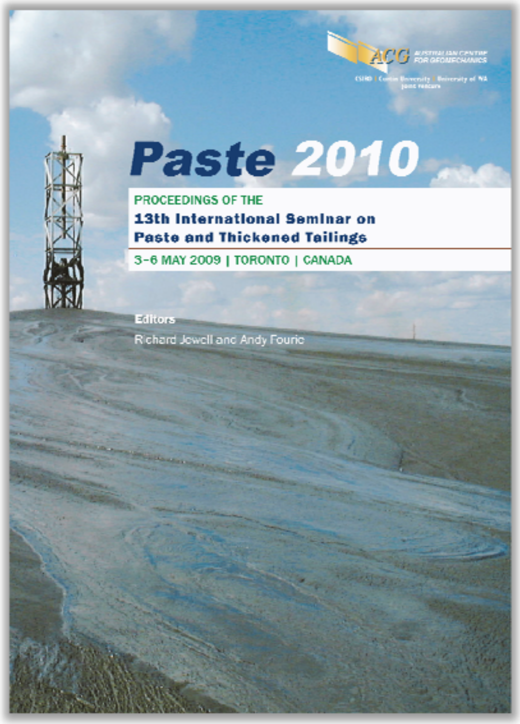

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Thickening/mud stacking technology — an environmental approach to residue management

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Abstract

Environmental pressures, economic consideration and 'visual' preoccupations have imposed on industry the need to address the issue of the disposal of their process residues with much greater attention and in the respect of the neighbouring communities. Rio Tinto Alcan who has pioneered the development and the use of Deep Thickeners for the production of paste slurries since the early 1970s, has over the years, taken a more global approach to the problem of thickening and disposal techniques and continues to maintain a very active research and development program on this topic.

In designing a new paste system or retro-fitting an existing sector of a plant, Rio Tinto Alcan has realised that attention must be focused on feed material compatibility, operation simplicity, space optimisation and of course capital cost. Approaches that address these key concerns have been developed and are being outlined. They include dedicated evaluation program, specific design of thickening units and auxiliary equipment, control system, adapted removal and mud transfer system. The overall solution does include in addition the operation and management of the mud disposal site.

Some insights on future developments and directions will also be presented.

1 Introduction

In the mineral industry, the management of solids or semi-solids process residues has always been a challenge. Large-scale mineral processing operation became the norm in the second half of the 20th Century. Initially, the disposal of residues was a relatively rudimentary operation and minimum attention was devoted to it. More recently, although the size of the operation kept growing, environmental preoccupations began to emerge, triggered in part by ecological incidents or accidents that some industries had to face, including numerous breakdowns of dams (CIM, 1999) holding dangerous fluids and many reports of contaminated soils and streams associated with inappropriate liquid containment.

During that same period, urbanisation has expanded, reaching area just next to industrial disposal sites with one of the consequences that further expansion of many of these disposal sites became a controversial issue. The establishment of 'protected' areas, the necessity to obtain permit and to abide to very strict environmental regulations for any change in the nature or size of a given site has brought the cost of expanding or developing new disposal sites exorbitant. As mentioned in the Preface of 'Paste and Thickened Tailings - A GUIDE', published by the Australian Centre for Geomechanics (ACG, 2002), *"The mining industry is coming under increasing environmental pressure to minimise the risks associated with a tailings incident such as an unplanned release…"*

It becomes clear that the industry needed to consider different approaches to the management of these residues, from an environmental as well as a capital cost point of view. To that extent, the publication cited above indicates that a preferred approach is to consider solutions involving the reduction of *"... the amount of fluid stored behind containment structures. This is manifested by the growing interest in environmentally superior alternatives to conventional tailings storage facilities. Paste and Thickened tailings (P&TT) provide an opportunity to reduce the volume of water reporting to tailings storage…"* (ACG, 2002).

Although the solution appears now almost 'obvious' and somewhat simple, the proper design and operation of a paste and thickened tailings system requires:

- a very good knowledge and understanding of the behaviour of each 'building block' of the system
- the proper characterisation of the feed material with its history
- the know-how and experience to integrate one into the other.

Failure to 'master' any of the three elements above can easily lead to deceptive results and costly modifications.

The object of the present paper is to describe, based on Rio Tinto Alcan's experience, the key components of a paste and thickened tailings system and illustrate through examples, the importance of the key factors in the proper design of such a system and point out areas of potential problems. The paper will review some fundamental concepts and will describe the evolution of the technology mostly through the Rio Tinto Alcan experience. It will then describe the various elements of the technology as implemented in our facilities, indicating the critical factors to be taken into consideration when designing a Paste and Thickened Tailings system and the impact of the nature of the feed material. Finally, the paper will provide some trends and directions observed with respect to this technology.

2 Initial development

2.1 Thickeners

The paste thickener probably originated in the coal industry with 'deep cone thickener'. Many of the ideas and concepts developed in the coal industry served to pioneer a lot of the concepts used today, (Abbott, 1973). This is an excellent example of cross fertilisation in a world where, *"... if it is not invented here it will not work in my plant"*.

The initial development work at Alcan began in the 1970s in Jamaica and coincided with the development and commercialisation of synthetic flocculents that were effective in highly alkaline liquors. In 1976, Dr John Chandler (Chandler, 1976) of Alcan Jamaica Ltd presented a paper comparing the effectiveness of these polymers over the conventional natural flocculants in the separation of red mud. In this paper the author indicated that, *"Synthetic flocculation gives high mud compaction with low mud volume and short mud retention time."* These progresses led Dr. Chandler to develop vessels having a much narrower diameter and a height to diameter ratio close to '1' to generate slurry at the underflow with half the water content and thick enough to be disposed of by the thickened tailing disposal method. At the time, the "deep thickener", as he called it and which had been in operation since 1979, did not include any raking mechanism. The mechanism of solid/liquid separation, as it occurred in these vessels, was studied and reported by Dr. Chandler (Chandler, 1983).

The development activities continued both in Jamaica and in other Alcan facilities and led to the introduction of a new type of rake that had different purposes than the ones used in conventional decanters and settlers. As explained in the US patent 4830507 (Bagatto and Puxley, 1986), the use of the internal rake is intended to *"... improve the dehydration of the mud and prevent an excessive accumulation of thick, inactive mud in the tank that could otherwise block the bottom outlet or reduce fluctuations in the solids content of the thickened mud."*

With these developments, the scientific community is moving away from the concept of Coe and Clevenger (1916) where tank sizing was essentially determined by the initial settling rate of the solids to take into consideration:

- the dynamic rise rate
- the mud bed residence time as well as the rheological properties of the material.

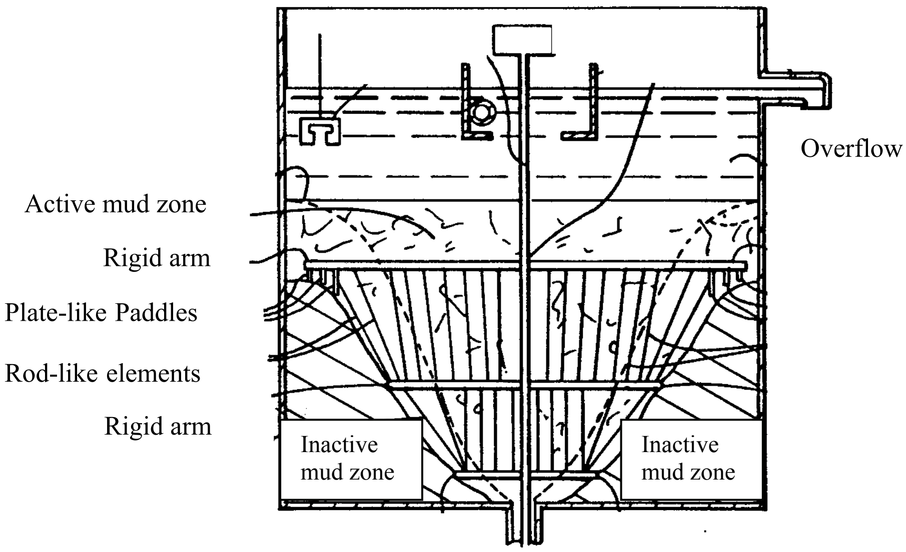

Figure 1 Principle of the Alcan Deep Thickener (based on US patent 4830507)

2.2 Mud disposal

In parallel, work was initiated also in the 1970s under the guidance of Dr. E. Robinsky (Robinsky, 1975, 1979) to produce thickened tailings for surface disposal. The aluminium industry was very instrumental in developing this concept and adapting it to its needs.

Figure 2 Sloped bed – solar drying

At Alcan, in the mid 1980s, extensive work went on in Canada at the Jonquière alumina refinery as well as in Jamaica. At the Ewarton refinery an experimental site was put in place to study various modus operandi which were soon found to be dependent on the raw material feed, the geographical environment as well as on the local climatic conditions.

Jamaica selected the solar drying approach with a sloped bed (Figure 2) and successive thin layer of mud as described in a paper presented by Chandler (1988).

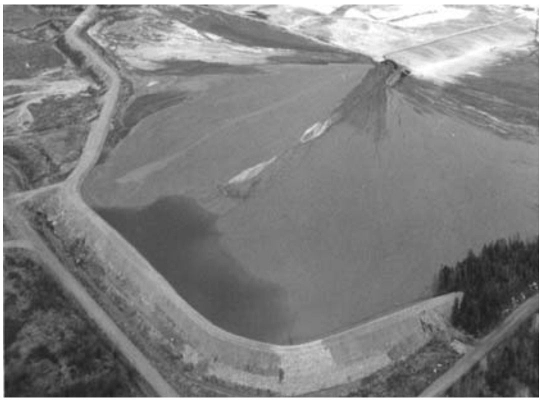

Figure 3 Conical bed with central discharge

The Jonquière refinery elected to go with a central discharge system (Figure 3) with a conical bed (Paradis, 1992). In the early 1990s, the Gove refinery decided to use multiple discharge points distributed throughout the disposal site.

Figure 4 Conical beds with multiple central discharges

2.3 Initial learning

As these first developments were put into application, Alcan realised that in order to get the most out of this technology it was essential to better understand the underlying principle governing each of the key components of a good paste and thickened tailing system:

- paste thickener operation
- paste extraction out of the thickener, pumping and transportation system
- mud disposal site management.

To improve our understanding of these underlying principles, excellent characterisation methods are needed to:

- describe the feed material
- measure the properties and behaviour of feed material.

3 Rio Tinto Alcan approach to thickening technology

At Rio Tinto Alcan, the paste thickened tailing technology is more than just a tank, it is a complete system which includes a gravity settling equipment (settler, decanter, thickener, etc.) that we will group under the generic term ‘thickener’, the mud extraction and transportation arrangement and the disposal management scheme.

3.1 Thickener and control system

3.1.1 Tank geometry

Figure 5 Original Gove Deep Thickeners

In current designs the high rate paste thickeners are elongated vessels having generally a height to diameter ratio close or slightly greater than 1, equipped with a conical bottom and a central discharge section. The cone angle is partly function of the settling material and their size distribution, but normally varies between 15 and 45°. It should be remembered that if paste consistency has been reached with the unit, the thickener should not handle a segregating material like in a conventional decanter, but a paste that is far more homogeneous and has a better consistency.

3.1.2 Decantation area

The diameter of the paste thickener is calculated from either:

- rise rate as measured by a dynamic cell analyser
- mud bed residence time.

Such thickeners will translate into units having volumetric throughputs generally 5 to 10 times greater than the ones achieved by conventional decanters. This is why modern techniques of sizing paste thickeners involve the determination of the rise rate for a given flocculent dosage as explained in the US patent 5616831 (Ferland et al., 1997) using a dynamic equipment such as the C-Floc™ which will be discussed in more details later.

3.1.3 Feed arrangement and flocculation

The feed arrangement includes the feed pipe, the feedwell, the dilution system when necessary, and the flocculent addition points. All these elements need to be carefully determined in order to obtain the best flocculation conditions, a requirement for operation at high rise rates or volumetric throughputs. Inadequate flocculation will lead to major operating problems and the general stability and control of the equipment as summarised in Table 1.

Table 1 Effect of inadequate flocculation

Under Flocculation	Over Flocculation
Floc too small	Floc too large: difficult to dewater
Low volumetric flow	Overflow filtration difficult
Poor overflow clarity	
Low underflow solids concentration	Gelatinous consistency of the underflow: pumping problems
Paste consistency not achieved	Gelatinous consistency of the underflow: sticky and scaling
Rat holing in the thickener	Blockage of underflow

The feed pipe dimension and the feedwell diameter must also be carefully chosen. Gagnon et al. (Gagnon, 2002) have shown (Figure 6) that there is an optimum shear and hence an optimum velocity to be achieved in the feedwell to ensure:

- adequate contact and mixing between the flocculent and the particles
- avoidance of an excessive shear that would result in the breaking of the flocs.

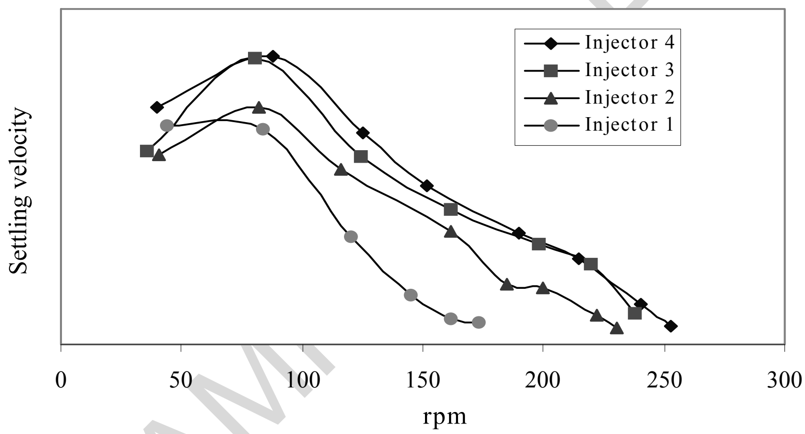

Figure 6 Effect of shear on settling velocity

These considerations also influence the choice for the position of the synthetic flocculent addition point(s) along the feed arrangement system. CSIRO through their collaborative program has brought also significant contribution to the optimisation of the flocculent/particles interactions and the physical arrangement of the feed wells to achieve most efficient use of these additives.

3.1.4 Raking assembly

In conventional thickeners, the main role of the rake is to move the mud and the coarse material to the centre of the tank as efficiently as possible. This is important since these thickeners have a small cone angle and must operate with a very low level of loosely compacted mud at all time.

In paste thickeners the criteria for design are quite different considering that the rake serves different purposes:

- define and maintain an active zone of mud by shearing the mud which is ‘shear thinning’ by nature
- maintain the fluidity of mud within the raked zone and avoid rat holing
- favour movement of the mud towards the discharge opening of the thickener.

The choice of rake structure must take into account the degree of mud compaction anticipated and the size distribution of the material. The nature of the material is also important to consider:

- degree of stickiness of the mud to the structure
- extent of segregation of the coarse fraction
- extent of in situ crystallisation.

Care must be taken in the detailed design of the rake that it does not entrain the whole bed in a rotation movement.

3.1.5 Control system

As stated earlier, the Alcan high rate decanters/thickeners have a settling area about 10 times smaller than conventional equipment. They consequently respond 10 times faster. The use of instruments to control the various operating parameters of high rate thickeners is now much more critical.

The volumetric throughput and the underflow solids concentration are two relatively independent variables and the control system has to reflect this reality.

The volumetric throughput is linked to:

- the settling properties of the material
- the feed rate
- the concentration of flocculent.

One control loop should independently address this variable.

The underflow solids concentration is largely a function of the residence time and the mud bed height. The second control loop should regulate that variable and it is recommended that a mud level tracking assembly be incorporated in the control loop.

3.2 Mud extraction and transportation

As the mud become thicker, it will become increasingly difficult to remove it from the thickener unless special arrangements are being taken.

As the slope of the yield stress curve increases the consistency of the slurry significantly change as can be seen in Figure 7. Depending on the transfer system chosen the consistency of the material exiting the paste thickener will have to be compatible with it. As an example, if a positive displacement pump is to be used for a mud of a 'Slope 2' consistency, the mud being fed to that pump should have a consistency that the pump can cope with.

US patent 6340033 (Paradis and Puxley, 1999) describes a method that allows the mud to be reduced in viscosity while maintaining the mud solids concentration. The technique consists in re-circulating a portion of the mud into the lower portion of the thickener and it achieves two objectives:

- allow thicker mud to be extracted from the thickener
- feed a positive displacement pump with a mud of an acceptable fluidity.

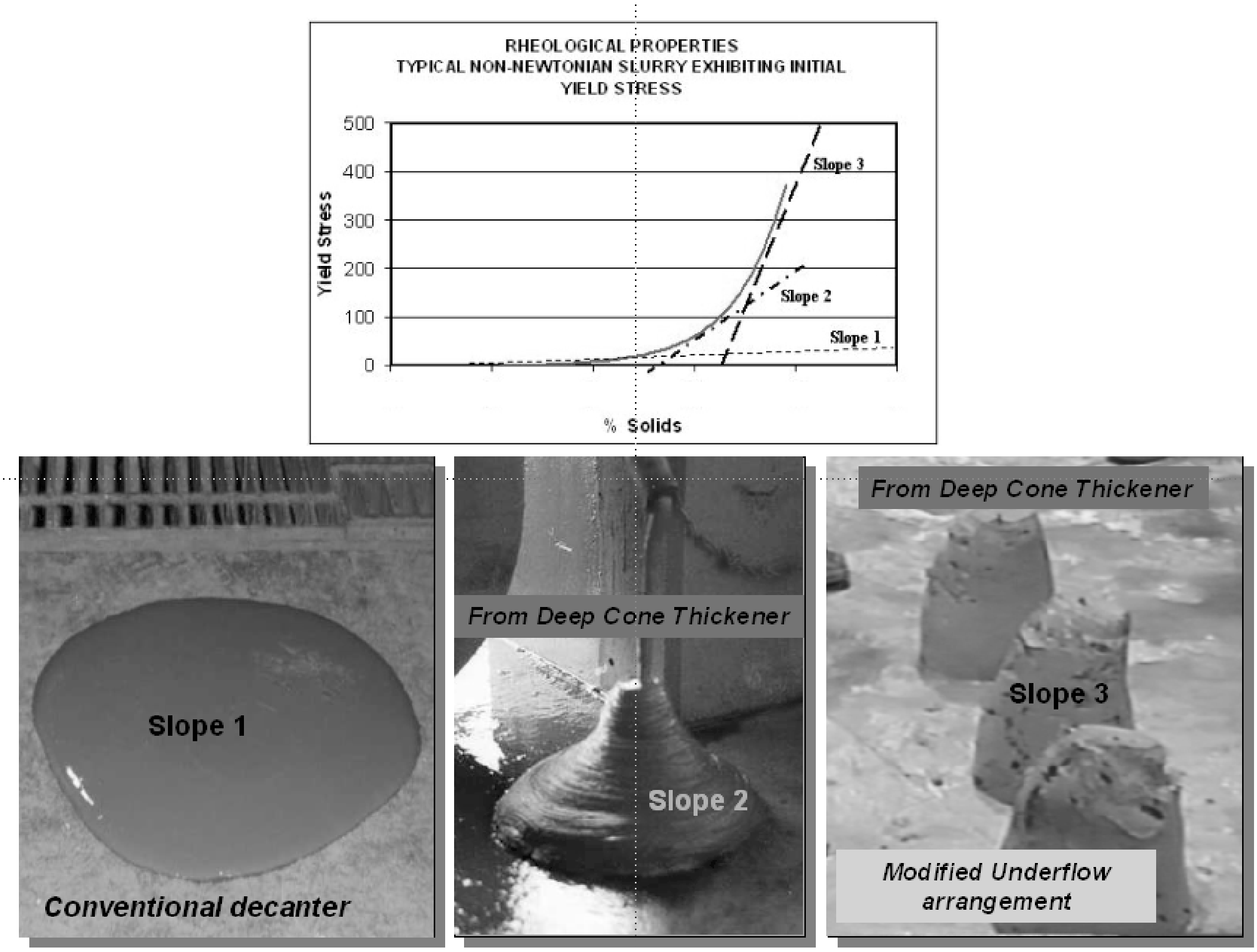

Figure 7 Change in mud consistency (US patent 7473376) (Peloquin et al., 2009)

3.3 Disposal scheme/above ground

Various approaches can be considered for above ground mud disposal depending on:

- area availability and life expectancy
- climatic conditions and net evaporation
- topography of the site.

3.3.1 Conventional one stage stacking

For most application up to now the practice has been to consider a one-stage operation. This is carried out using a central or multiple discharge point and generating a conical or a number of conical stacks.

It can also be operated as a down-valley discharge system. Spigotting is recommended to use the maximum area possible and allow area to densify between applications. The process can be accelerated by 'mud farming'. A variation of this practice is to operate the site by sectors as illustrated in Figure 8. In this case mud is deposited for a given period of time in a sector and then is left to consolidate, while another sector becomes the 'active site'.

Figure 8 Operation by sectors – red mud disposal site

Figure 9 Re-worked area of a residue disposal site

3.3.2 Two stage residue stacking

Stacking of the slurry in smaller area remains a key objective for any operator since the expansion of any stacking area requires significant capital expenditures, especially when space is a ‘limited resource’ near operating sites. In addition, in order to rehabilitate a site before its closing, a higher stack angle is highly desirable. To achieve these objectives, a method called ‘double stacking’ as been proposed (Belanger and Morin, 1999). It consists of taking already ‘matured’ or densified residue, pumped it using various techniques and re-stacked it in a nearby sector with a higher stacking angle. This method normally requires that the residue be remoulded to a certain extent and may necessitate some dilution through the addition of a small quantity of water, a diluted process liquor or even seawater.

3.3.3 Seawater neutralisation

Some plants located near the seashore use seawater (Graham and Fawkes, 1992) to neutralise their mineral tailings prior to disposal. This is particularly the case for the aluminium industry where the alkaline earth cations of the seawater neutralise at least in part the alkalinity of the residue. Although the rheological properties of the mineral tailings are modified by the change in pH (Cooling, 2002), this mineral tailing can still be thickened by a paste thickener and yield a stackable residue (Ferland, 2003).

4 Global approach

4.1 Importance of proper design

When insufficient or incomplete information about the objectives and constraints of a given application are being collected or inadequate material characterisation has taken place, major operational problems, underperforming equipment and disappointing results are likely to occur.

4.2 Flocculent addition control

There are several misconceptions about the control of flocculent addition and corresponding overflow clarity. One of these is that simply increasing the synthetic flocculent dosage will improve the overflow clarity. If the flocculation process is not properly taking place in the feed system (especially in the feedwell), the addition of excess synthetic flocculent will:

- only increase cost
- not cure the problem
- aggravate the situation if the overflow has to be filtered further on in the process.

Clarity problems are often related to either:

- too high or too low velocity in the feed line (improper feed line dimension)
- inappropriate feedwell dimension
- inadequate point of addition of flocculent along the feed arrangement
- inadequate choice of synthetic flocculent for the feed material or liquor concentration
- poor quality of the flocculent preparation
- flocculent breakdown during preparation or distribution (high shear pump, etc.).

The excessive flocculent concentration will certainly have an impact on the viscosity of the paste at the underflow, will affect the performance of the transfer pumps and will produce a material that will have very different stacking properties.

4.3 Material size distribution (large coarse size fraction)

Flocculent essentially interacts with the fine particles of the slurry. Particles that are greater than about 50 microns will not be appreciably affected by the flocculent and due to their high density will 'sink' directly to the bottom of the thickener. Under normal conditions, if the thickener produces sufficiently thick residue, most of this coarse material will get incorporated in the paste and will be eliminated with the residue.

The reality is that the bed is not always homogeneous, especially as the unit is being started and significant segregation may occur, even more so when the fraction of coarse material exceeds 10–15%. In these cases it is not uncommon to see a kernel of sand building up with time in the centre of the tank causing eventually obstruction to the flow of residue down the thickener as illustrated in Figure 10. Knowledge of the size distribution of the feed material is very important and the final design of the decanter has to take this fact in consideration.

Alcan has come up with a simple solution to this problem by moving the position of the feed well away from the centre in such a way as to ensure the proper integration of the coarse material in the residue under the action of the rake to homogenise the thickened slurry along with the coarse particles (Peloquin and Simard, 2002).

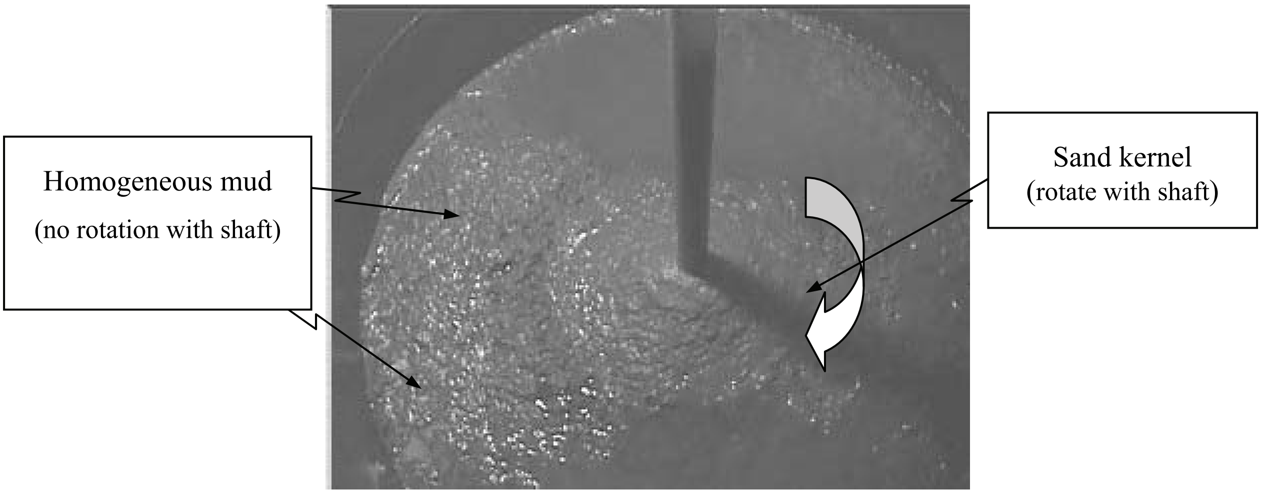

Figure 10 Sand kernel at the centre of a thickener

4.4 Pump and pipe sizing

The target in designing a paste thickener is to produce the thickest mud as possible. As mentioned in section 0 above, the material out of a paste thickener can be at a consistency that makes it almost impossible to remove from the tank under normal conditions. In order for a thickener to properly function it is essential that the design of the thickener comprise the whole transfer line and the pumping system. Although centrifugal pumps can operate with material having very high % solids on relatively short distances, our experience dictates that special considerations have to be taken that are well outside the published boundaries and operating curves for these pumps. It is critical, for example, to clearly define the upper limit for the underflow density. The motor power requirement (HP) and pump head can change dramatically for operation outside the natural limit for the material in question. This is illustrated in Figure 11 for the motor horsepower of a typical underflow pump handling pastes.

Knowledge of rheological properties of the material is essential and more importantly the apparent or dynamic viscosity of the slurry. Unless similar material has been handled before, this information needs to be measured experimentally for the expected range of application.

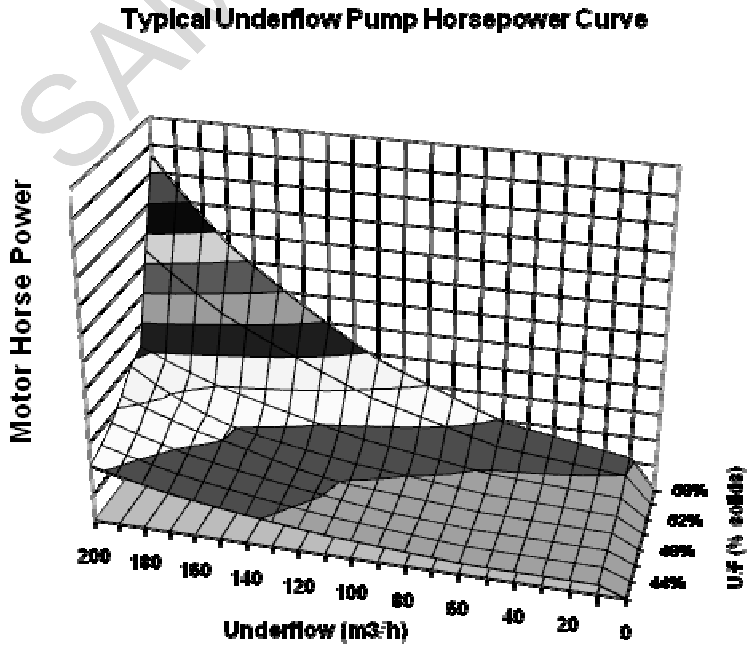

Figure 11 Pump curve for high underflow solids concentration regime

4.5 Prediction of stack angle

More than once we have been asked to *"...design for 50% solids"* in order to have a stackable mud even before:

- the material has been characterised
- the transfer system selected
- the method of stacking finalised.

The following considerations have to be taken into consideration:

- the intrinsic yield stress of individual material
- the shear history of the material to be deposited (Bélanger, 2001)
- possible 'aging' of the slurry.

As shown in the graph of Figure 12, even for mud coming from the extraction of bauxite, depending on the source of the bauxite sample, the yield stress curve can vary dramatically.

At a given solids concentration (vertical line in Figure 12) a Jamaican bauxite will stack quite readily while a diasporic bauxite will have negligible consistency, insufficient for stacking.

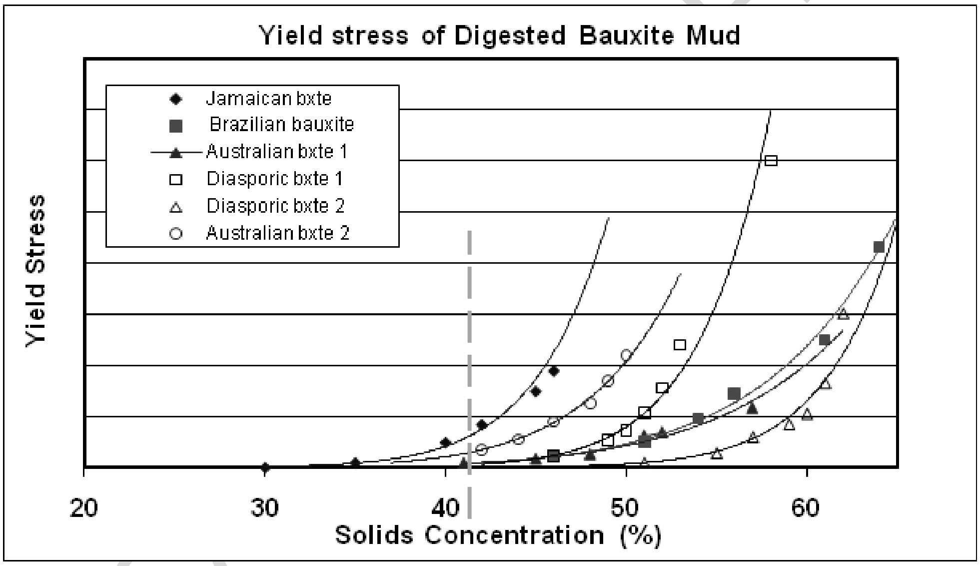

Figure 12 Yield stress measured on different red mud

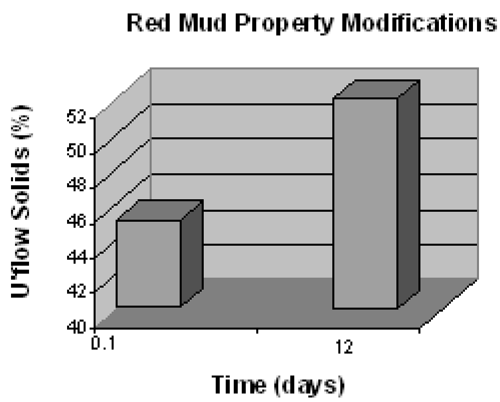

Figure 13 Change in red mud property

Chemical reactions may continue after initial thickening which may modify the stacking properties of slurry as shown in the graph of Figure 13.

The viscosity is given by the ratio of the shear stress to the shear rate. Most of the material we are dealing with exhibit an initial yield stress and are pseudo-plastic. This means that as a slurry is sheared through pumping operation and as it moves through the pipeline, the material will actually 'thin' as it exits the pipe and may show different stacking properties for a given period of time until it regains its original consistency.

The presence of coarse material (also called 'sand') will significantly affect the final underflow solids concentration but not so much the final yield stress of the thickened mud as shown by Doucet (1999).

5 Key activities for an optimum design

5.1 Tailored to individual application

From the above, it can be seen that a paste thickened tailing system is a highly performing system, but where each component of the system is inter-related to the other. It is extremely important to be aware of the key steps required when designing a paste and thickened tailing system.

5.2 Definition of needs

The needs must be fully evaluated. Too often a user would simply copy a system similar to what was seen at another location. The end result must initially be taken into consideration and includes elements such as:

- restoration facility
- chemical recovery
- disposal cost
- local environmental regulation and requirements
- control and availability of water (surplus or excess)
- space limitation
- reuse of existing disposal sites (stretching life of existing site)
- distance limitation
- walk away situation.

Once these are agreed, then a general arrangement and the choice of equipment can be looked at. The choice will have to take into account the following factors:

- area, topography and climatic conditions will dictate the preferred method of disposal
- size and lifetime of site will help determine the need for 'secondary treatment'
- distance will dictate the method of transportation and/or choice of location of final thickener
- desired stack angle will influence in part the target underflow solids concentration and hence the required mud bed height and residence time.

5.3 Material characterisation

Characterisation of the feed material and knowledge of the process history then constitutes the next phase of the design procedure.

A paste thickener has a very different internal dynamic to the one of a conventional wide and shallow decanter. Since such units operate with higher volumetric throughput, the settling rate cannot be compared anymore with the settling rate of a batch process. Hence the Coe and Clevenger approach and the jar test method are only indicative and other methods must be preferred.

Alcan is proposing a method using a dynamic cell called C-Floc™ shown in Figure 14. The method uses a dynamic cell continuously fed with the feed slurry that is maintained at required temperature. The C-Floc™ can accommodate numerous point of addition for the flocculent and allows the evaluation of combination of flocculents. The volumetric throughput for a given flocculent dosage and feed rate is determined by recording the minimum amount of flocculent required prior to losing the overflow clarity.

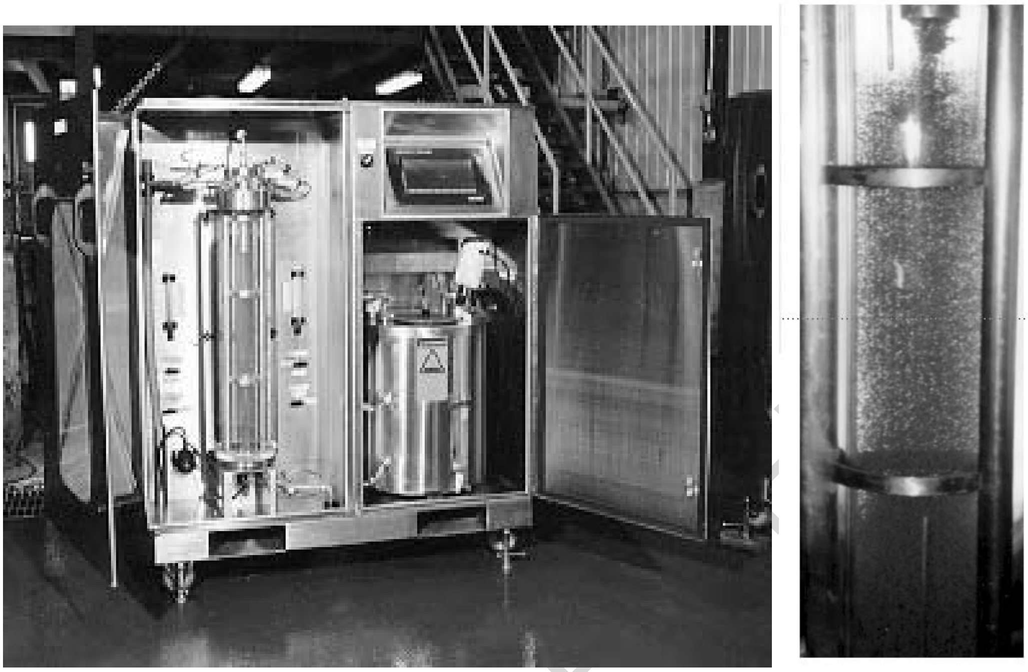

Figure 14 C-Floc™ analyser

Solids concentration obtained from jar test can constitute a fair approximation of the final underflow solids for conventional equipment since average pump down rate adds negligibly to the settling or compaction velocity in determining the final solids concentration.

However in high-throughput thickeners, the pump-down rate adds significantly to the settling or compaction velocity. The prediction of the underflow solids concentration for high rate paste thickeners has to be based on the mud compaction properties and the residence time of the mud. Landman and White have given a good summary of a recommended approach to such determination (Landman and White, 1994).

The rheological properties of the paste are used in the design to determine:

- the underflow density achievable in a paste thickener
- the underflow pump and motor size requirements
- the raking requirements
- the pipeline and the stacking operation.

The laboratory values that are obtained for a specific material are therefore critical in optimising the system. It is critical to have the proper laboratory equipment, the proper laboratory procedures to yield consistent results and to have the knowledge and experience to interpret the results correctly.

5.4 Training program

In Section 0 above, we have described the main features of the paste thickened tailing technology. Although a paste thickener incorporates much of the elements of a wide shallow conventional decanter, the differences are such that the control strategy is quite different and hence a good training program has to be put in place at various level of the organisation (engineers, supervisors, operators, instrument specialists, etc.) in order to benefit from the technology. The program would ideally cover topics and activities such as:

- some fundamental concepts including:
  - understanding of flocculation
  - parameters affecting compaction
  - mud rheology.
- equipment and control system description
- simulation/case studies using computer models
- field training
- refresher program during the first year of operation.

Too often it has been found that the operating personnel tend to apply to a paste thickener the same control philosophy they were following with their conventional decanters. This is even more so when they encounter some unexpected changes or upset in their new unit. For this reason, plants that are to implement the Paste Thickening and Tailing technology for the first time are strongly recommended to put in place a good training and a refresher program in the course of the first year of operation.

6 Innovation, research and development activities

Our knowledge and understanding of the paste thickening process and the way to handle paste material has made huge progress over the past 30 years. We are still trying to push the boundaries. We are aiming at still higher mud consistencies. We are looking at stacking more material in existing space without having to use very high capital cost equipment such as pressure filters. In order to achieve these new goals we have focused our attention to the following area:

- higher throughput equipment
- better instrumentation
- improved transportation and handling system
- better site management.

6.1 Higher throughput

As part of the limiting factors affecting the throughput or capacity of thickeners we can mention:

- the settling velocity of the flocs
- the rate of compaction of slurry
- the effectiveness in extracting the very thick mud out of the decanter.

6.1.1 Settling velocity

Development of higher molecular weight and more 'tailored made' flocculents should help in achieving better settling rate.

Figure 15 Pressure decanters operating on Jamaican bauxite

The use of computational fluid dynamic (CFD) will also contribute to the improvement of design of feed system. This should reduce the consumption of flocculents and hence the cost of operation, making the process more economical to operate.

For certain applications, when it is possible to operate at high temperatures even above the normal boiling point, the pressure decanter is an "extension" of a paste thickener and offer major advantages (Figure 15). For more than eight years now, a plant operates Pressure Decanters (Doucet et al., 2002) processing Jamaican bauxite renowned for their poor settling characteristics. While previously they were achieving a mud throughput of about 3 T/ (m^2 day) and 22% underflow solids concentration, this plant now achieves at least 60 T/ (m^2 day) and 28% underflow solids.

Pressure decanters are now used commercially in four alumina refineries with different feed material.

6.1.2 Mud compaction

We have now a better understanding of the overall thick mud dynamic, the compaction mechanism and the dewatering of that mud in the paste thickener.

The paper by Leclerc et al. (2005) outlines a method to determine the residence time distributions of solid particles through gravity settlers.

But we are getting close to the limit to which mud can be thickened by a gravity settling vessel. The challenge is more with the extraction of the mud from the thickener as we make it thicker and thicker.

Recent developments have allowed Rio Tinto Alcan to stretch out the performance of high rate decanters by using a screw inside the unit to extract the paste (Peloquin et al., 2008).

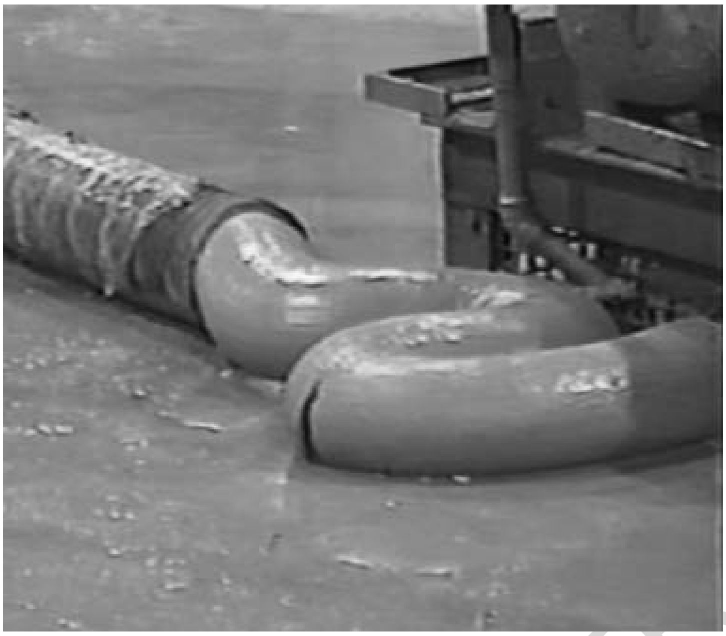

Figure 16 Mud from the high solids decantation technology

US patent 7473376 provides a description of the new thickener (Figure 17).

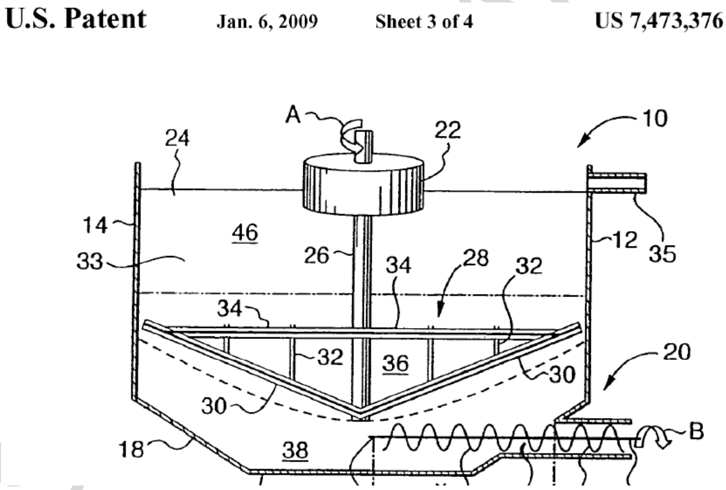

Figure 17 Cross-section of high solids decantation technology thickener

6.2 Instrumentation and control system

Compared to conventional thickeners, the high rate paste thickeners have a residence time that is on average 10 times shorter. When dealing with pressure decanters we are even getting residence time which is of the order of 15 minutes. In order to fully benefit from the gain these thickeners can provide us important progress will need to take place for on-line instrumentation that can provide continuous and accurate data to feed to the control system.

Measuring devices are being tested on commercial pressure decanters to evaluate performance, reliability and lifetime.

Expert systems will also improve the overall control of the paste thickeners and insure more stable operation.

6.3 Disposal area management

The disposal site constitutes a drying zone, especially in area where there is a net evaporation on an annual basis. The requirement for better disposal area utilisation will call for development program that will make use the drying capacity of the disposal area to achieve higher solids concentration and better stacking angle.

In colder countries such as Canada, the freeze/thaw cycles can be beneficial in consolidating stacked residues. Jonquière make use of this advantage to use some of the consolidated residue as building material for internal dykes.

7 Conclusion

Thirty years of development, operation and research have allowed Rio Tinto Alcan to contribute to the progress of the paste and thickened tailing technology. Today Rio Tinto Alcan has reached a stage where the Paste and Thickened Tailing technology is mature enough and its field of application wide spread enough to make it a Benchmark technology, at least within the aluminium industry.

Far from reducing efforts in research and development, Rio Tinto Alcan is maintaining its efforts focusing on key areas to improve:

- fundamental understanding of the process with leading universities and research organisations
- equipment reliability
- process control
- mud stacking technology.

Meanwhile, over the years one important finding has been to realise the strong inter-dependency of each component of the paste and thickened tailing technology. Neglecting one will affect the whole system. Rio Tinto Alcan believes that it is fundamental for the success of an application using the paste and thickened tailing technology to:

- adequately define the problem and the objectives
- properly characterise the feed material
- identify appropriate and knowledgeable resources for the design and choice of equipment
- adequately train the operating personnel.

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