A Short History of Deep Cone Thickener Development

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ABSTRACT

Deep cone type thickeners were first conceptualised in the 1960s. Work was done to develop the concept by the British National Coal Board, but the goals at that time were never achieved. Developments in flocculant technology since then made a major difference in how thickeners can operate. Alcan pursued the technology and developed it commercially for their alumina plants and began marketing it for other alumina plants. In the mid 1990s Eimco licensed the technology from Alcan to commercialise in areas outside the alumina industry as well as work with Alcan on further development. Dorr-Oliver Eimco has now installed well over 100 deep cone thickeners (DCTs) in applications ranging from pre-leach to charge-coupled devide (CCD) circuits to tailings disposal, and in industries such as alumina, kimberlite, copper, gold, platinum, lead/zinc, and mineral sands. The technology continues to evolve as improvements are being made in rake design, feedwells, geometry, tank design and instrumentation and control. The largest practical size has steadily increased over the last decade as well and we continue to look at larger sizes and higher throughputs. The technology is becoming widely accepted for a broad variety of markets and applications.

1 INTRODUCTION

In the 1960s and 70s the British National Coal Board (NCB) developed and installed a number of deep cone thickeners (DCTs) to process coal flotation refuse. They were designed to take advantage of modern flocculants that were newly developed at that time, and discharged onto a conveyor belt. They were operated for a number of years at a number of collieries. They were designed to generate underflow solids concentrations high enough to be discharge onto a conveyor belt. This wasn't always successful; but for a first cut, these units operated remarkably well.

Alcan built on the technology for red mud washers, but pumped the underflow and used dry tailings disposal methods (Robinsky, 1978) with the thick mud. These were used in the red mud washing circuits and improved counter current decantation efficiency with great success. Alumina remains the market with the highest level of penetration for the technology.

It wasn't until the mid 1990s that the technology expanded outside of either the coal or alumina industries. Eimco Process Equipment licensed the technology from Alcan at that time and began to develop it for other markets in the minerals field. Around the same time, Inco and Dorr Oliver developed the PPSM, which uses some of the same principles and is also designed to produce paste type discharge rheology.

Previously, work had been done to improve the performance on thickeners by operating with a deeper bed. These high density units designed and built by both Outokumpo and Eimco were generally designed with higher torque and 2 or 3 m of bed depth compared to a typical 1 m bed depth, but usually with a conventional 1:6 floor slope. They typically produce higher underflow concentrations than achievable with standard thickener designs, but a bit lower than achievable with a DCT.

There are now well over a hundred DCTs and the technology continues to be developed. There is over 25 years of development of Alcan Deep Thickener Technology in the alumina industry and 10 years in applications outside the alumina industry. The list of applications and markets is growing rapidly as operators move to take advantage of the technology.

2 PRINCIPLES

The production of a thickener underflow of a maximum density can be achieved with practically any gravity sedimentation device, given enough area, settling time, and raking capability. The differences noted with the

DCT are in the design details which are directed towards achieving this limiting concentration at a very high loading in terms of solids throughput per unit area. Five factors enter into this picture:

- The optimisation of flocculation procedures.
- Relatively deep pulp depth.
- Relatively steep floor slope.
- High torque and raking capacity of the mechanism.
- The use of mechanical devices, such as rakes and pickets, to "work" the compacting slurry.

Deep cone thickeners were originally developed to take advantage of advances in flocculant technology. Good flocculation is a key to the successful operation of a DCT and conditions which promote this action should be followed. This includes selection of the best reagent for the particular tailings, the introduction of the reagent at a very dilute concentration in order to promote better mixing, and most importantly, the optimum solids concentration of the feed slurry. Generally, this concentration is usually lower than the normal process concentration and dilution of the slurry with recycled overflow will be necessary for minimum flocculant use and maximum solids settling rate.

Good flocculation results in the solids passing very rapidly through the normal concentrations associated with "zone settling" which ordinarily would determine the thickener size. In the case of DCTs, the sizing procedures generally must take into account the volume of thick pulp within the thickener, as a substantially longer than normal retention time is necessary for the solids to obtain high concentrations. It is more economical to provide this volume by using a relatively deep bed of pulp rather than a greater area with a shallow compaction bed. This increase in depth also provides bed compression, where the weight of solids above helps compress and dewater the mud to higher concentrations.

The added depth results in greater loads being imposed on the raking mechanism, particularly since the thick mud will be found even at the perimeter of the thickener. This results in a substantial increase in load on the drive and it is necessary to use as much as an order of magnitude more torque for the drive mechanism as would be used on a similarly sized thickener producing a "normal" underflow concentration. In addition, the design criteria for the drive is significantly different from normal minerals duty. The torque will be consistently high, but will not be subject to as many peaks. Due to the high pulp depth, there is not much to be gained by including a lifting mechanism, since the pulp depth is typically much higher than the rake lift height.

As the thickened mud approaches a limiting concentration, it becomes less and less like a fluid, and has little tendency to flow to the underflow withdrawal point. Therefore, steep floors of 30 to 60 degrees and rakes designed to overcome the yield stress of the mud are used to transport the thickened mud to the outlet. By contrast, standard thickener design calls for a slope of something less than 10 degrees and a raking capacity of about 20% of the total underflow volume, measured at the limiting point, the innermost blades.

When a pulp reaches the compression zone, mechanical action, such as by the raking mechanism itself, contributes to the rate of water removal from this compacting mass. Since DCTs operate with pulp depths which generally extend well above the rake structure, the mass of material located in the zone is not exposed to a similar mechanical action. Therefore, it is helpful to add pickets, usually consisting of posts or blades which project into this mass, in order to create channels and assist in water removal.

Underflow recycle is used on many Alcan style DCTs to shear-thin the underflow. The thinned underflow (reduced yield stress) is reinjected into the underflow cylinder to aid in removing unthinned mud. The thinned mud acts as a carrier fluid and helps eliminate problems between the underflow cylinder and the centrifugal pumps.

3 HISTORY

3.1 National Coal Board

In the 1960s the British National Coal Board developed technology to take advantage of advances in flocculant technology. This was shortly after modern long-chain polyelectrolytes were developed and found use in place of starch and guar for flocculation. Because of the high settling rates possible with flocculants and the fast compacting nature of the flocculated mud, the deep cone was designed to handle a high rate in a small unit. A steep 60 degree bottom cone was used and a stirrer added to work the mud. Special attention was paid to the makeup and addition of flocculant. They were designed to generate underflow solids concentrations high enough to be discharge onto a conveyor belt. This wasn't always successful, but for a first cut, these units operated remarkably well.

More than 60 of these units were installed and operated at various collieries in Britain. One reason for the large number is that they were installed by directive, not really by market demand. None of these units remain in operation, but this may be due more to the state of that sector of the industry. The largest units were 4.2 m diameter by 6 m tall.

Abbott (1979) discussed control systems developed for use on those deep cone thickeners. It is interesting to note that many of the controls systems used now are very similar to what Abbott recommended. He promoted the use of a differential pressure sensor to control the underflow withdrawal, maintaining a consistent bed mass, and dosing flocculant based on solids mass flow.

The technology was licensed to the Denver Equipment Company by the NCB. Denver promoted the technology for a period with limited success.

3.2 Alcan Technology

Alcan started using deep cone thickeners in about 1978. Tracer studies had shown that the outer areas of conventional washers were not effective and that a large fraction of the solids short circuited through the middle area of the thickener. Based on this, Chandler concluded that a small diameter thickener could be as effective as a larger one and thus the use of the deep thickeners. The first tanks were flat bottom and the mud was allowed to form its own angle of repose. Rakes were considered optional although Chandler preferred operating without them. They generally operated at lower concentrations than the NCB aimed for, so the stirrers were deemed not necessary.

Chandler started by operating rakeless deep thickeners in Jamaica. The first tank was 10 m in diameter and 12 to 14 m high. Using that technology, red mud underflow densities increased from 15-17 wt% to 25-27 wt%. Installation of a rake further improved the performance to 30-32 wt% (Doucet, 1999). It should be noted that Jamaican red mud is particularly fine and difficult to dewater to high concentrations. In other red mud applications, more typical numbers are 25-30 wt% for conventional thickeners versus 40-45 wt% for a deep cone thickener that is a third of the diameter. Bagatto (1989) had compared raked thickeners with rakeless ones and had also determined that the underflow could be controlled using the torque signal.

In 1973, Robinsky pioneered the use of thickened tailings disposal, which has gained steadily in popularity. Alcan began using the method in 1987, which was fed using deep cone thickeners. Vacuum filters are used at some sites, but many of them use discharge from the last CCD stage. High pressure pumps are typically used to transport the thickened tailing to the disposal area. Because of the widespread interest and use of this disposal method and it's suitability for use using DCTs alone, both technologies have benefited.

3.3 Beyond Coal and Alumina

In 1996 Eimco Process Equipment licensed the Alcan Deep Cone technology. Although well known in the alumina industry at that time, the technology was considered new in markets outside the alumina industry. However, the track record and number of existing alumina installations enabled the technology to spread quickly.

There are now installations in alumina, precious metals, coal refuse, trona, lead/zinc, kimberlite, cement, fly ash, gold, mineral sands, copper tailings, pyritic tailings, lead/germanium tailings, phosphate slimes, and silver leach tailings. Over the past 10 years the largest units have steadily grown from 14 m diameter to 24 m diameter, with corresponding increases in throughput. Applications at operating sites include tailings disposal, CCD circuits, underground backfill, sub-aqueous disposal, pre-leach, and kiln feed. Experience in a broad variety of markets and applications is proving the technology to be robust and widely applicable.

4 CONTINUED DEVELOPMENT

Deep cone thickeners were originally developed in order to take full advantage of the benefits of modern flocculants and generate much thicker underflow than achievable with conventional technology. The technology is generally very successful but work on optimising and improving the design continues. Different areas of research include the effect of shear in flocculation, improvements in rake design to optimise dewatering and mud movement, and best methods for removing thick mud from the tank. Deep cone thickeners from various manufacturers may look similar from the outside, but the internals are an area of significant development. Among the areas being investigated and developed are the following:

- K factors – optimisation of the torque requirements particularly for higher densities and yield stresses.
- Feed dilution and flocculation to optimise settling flux and compaction including CFD modelling.
- Rake designs – raking versus floor slope, rake blade designs, low drag arm designs.
- Dewatering pickets.
- Structural improvements.
- Evolution to larger and larger sizes and the sizing and scale up involved.
- Shear thinning and re-injection of the underflow.
- Best methods for handling bed rotation.
- Instrumentation, controls and automation of operation,
- Tank designs utilising FEA modelling, improved FEA models, specific tank designs for particular applications.

In side-by-side pilot testing with multiple manufacturers, large differences in performance have been seen which suggests that differences in the equipment and operation can have a large impact. Based on the list above and the amount of work being done, there is room for optimisation and better performance.

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