ADVANCES IN SLUDGE DEWATERING: A MINING SOLUTION FOR COUNCIL OPERATORS

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ABSTRACT

Sludge dewatering technology in the Australian and New Zealand water treatment industry is currently undergoing a technological revolution. This is driven by more stringent dry solids requirements for transportation and disposal, and reduced operations input.

Industrial processes (such as mining) utilise advanced filter press technology for dewatering to ensure maximum water removal.

Examples of advancements in filter press dewatering technology are units which include the following features and advantages:

- Pressurised membrane squeeze cycles, hence higher dry solids of the resultant cake;
- Shorter cycle times and faster turn over;
- Cake release mechanisms which minimize the risk of cake hang-up;
- Full automation and as such, reduced operator attendance;
- Reduced chemical dosing requirements.

This paper examines the advancements in sludge filter press technology applicable to the water treatment industry. It concentrates on a case study on a major New Zealand water treatment plant (WTP) and the reasons leading to the first installation of this particular filter press technology in the New Zealand water treatment industry.

KEYWORDS

Sludge dewatering, filter presses, water treatment, trials.

1 INTRODUCTION

Filter presses are used across a number of industries for dewatering various types of sludges and slurries, including metal, chemical, paper industry, mining, water and wastewater. The filter press design applied is dependent on a number of factors, such as the throughput, abrasiveness of the sludge/slurry and washing requirements.

A number of driving forces have instigated modifications to the traditional filter press design. In recent times, technological advancements enable fully automated operation and produce sludge cake with higher dry solids content for disposal.

Filter presses can be a significant capital cost to WTPs; therefore selection of an appropriate unit (traditional or advanced filter press) is crucial to providing cost effective solution.

2 FILTER PRESSES IN INDUSTRY

The first use of a filter press was for obtaining oil from seeds in 1853, and since then filter presses have been included in many different industrial processes for slurry dewatering and/or filtrate acquisition. Due to the processing requirements in these industries, filter press technology has greatly evolved since the first installation of a fully automated filter press in 1960 (Shirato, 2010).

Industries with particularly high processing requirements include mining, food and beverage production, and metallurgical processing. Requirements in such industries have helped develop the technology which can now be applied in other processes. These advances in filter press technology are discussed in Section 5.0.

3 TRADITIONAL FILTER PRESSES

The traditional filter press process involves closing and clamping of the filter press plates to form chambers lined with filter cloth. The sludge is then pumped into the chambers, with the feed rate slowing as the chambers fill with solids trapped by the filter cloth. The pressure of feeding more sludge into the chambers forces the filtrate to filter out of the sludge and permeate through the filter cloth. The feeding cycle is continued until the filtrate flow rate tappers off, indicating that further feeding will be ineffective. The plates are then opened and the sludge cake formed drops by gravity into a skip, trailer or bund beneath the filter press.

A schematic of the feeding process is illustrated in Figure 1.

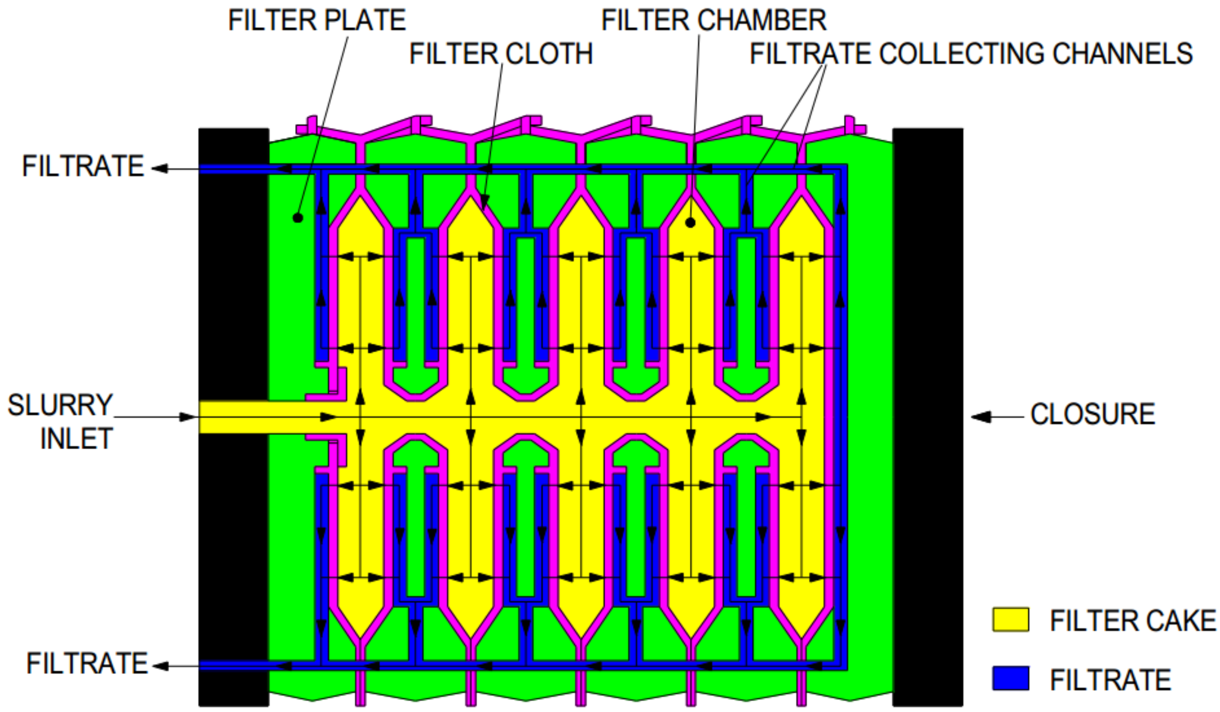


Figure 1: Sludge feeding to filter press chambers (Latham International Ltd, 2010).

Traditional filter presses are typically work horses; large, heavy units which require long feed times to produce suitability dry cake (approximately 8 hours). These filter presses typically involve manual input from the operator, with each cycle manually initiated and often the cake drop requires operator supervision and assistance to ensure all cake is released.

Complete cake release is important to avoid partial sealing of filter plates, which can lead to blow-outs. This is when a filter plate fails to seal completely and the build-up of pressure from feeding sludge into the chamber causes the sludge to be released from the filter press. This often results in a spray of sludge hitting building walls and/or equipment nearby.

A traditional Edwards and Jones filter press installed in the 1980s is illustrated in Photograph 1.

Photograph 1: Edwards and Jones filter press.

4 DRIVERS FOR CHANGE

Transportation and disposal costs for dewatered sludge are reduced when the dry solids content high. This puts greater emphasis on effective sludge dewatering at WTPs. Traditional filter presses are capable of achieving approximately 25% dry solids content. Modern filter presses are able to achieve greater dry solids contents (due to the technology discussed in Section 5.1), and in some cases this can be as high as 50% dry solids content.

As discussed in Section 3.0, operation of traditional filter presses is a manual process and therefore requires a lot of operator input. Operators in New Zealand are often responsible for a number of plants and this limits the amount of time they have available at each site. With reduced operator availability, there is a pressure to automate operations. The level of control available for filter presses includes manual, semi-automatic and fully automatic. This enables installations to have the appropriate level of automation based on the operator availability.

5 ADVANCED TECHNOLOGY

As previously mentioned, in recent years more advanced filter press technology has been introduced. There are a number of features which can be included in filter press design to enhance and automate the performance. These options are discussed in the following sub-sections.

5.1 MEMBRANE SQUEEZE

A membrane squeeze cycle can be added to the conventional filter press process. This is a well established and proven addition, with the technology continuing to improve, resulting in drier sludge cake and shorter cycle times.

The membrane squeeze cycle will follow the feeding process to remove further filtrate from the sludge cake. The membranes are located behind the filter cloth and in front of the plates. During the squeeze cycle the membrane chambers are filled with a pressurizing medium (compressed air or preferably water) compressing the sludge cake and forcing additional filtrate from the sludge. A filtration process with membrane cycle is illustrated in Figure 2.

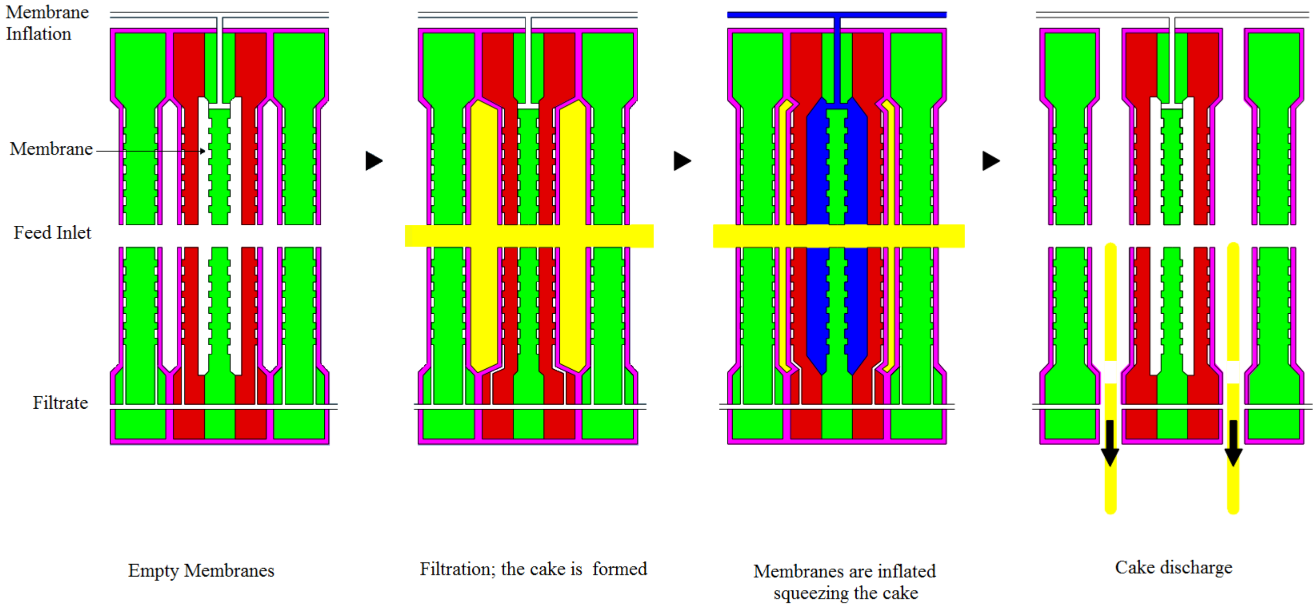


Figure 2: Filter press process with a membrane squeeze cycle (Latham International Ltd, 2010).

The inclusion of a squeeze cycle results in higher dry solids content in the sludge cake and reduced cycle times, i.e. improved throughput. This is illustrated in Figure 3.

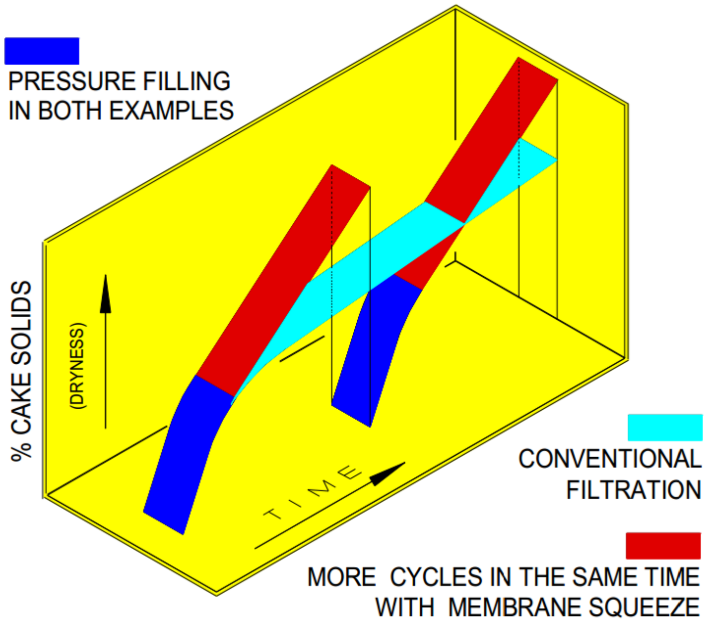


Figure 3: Graph displaying improved throughput achieved with a membrane squeeze cycle (Latham International Ltd, 2010).

Inclusion of a membrane squeeze cycle increases the amount of auxiliary equipment required.

If the squeeze medium is water the following auxiliary equipment is required:

- Squeeze water tank and pump to supply water to pressurize the membranes.
- Compressed air for a membrane chamber blow to drain the membrane chambers of water following the squeeze cycle.
- Vacuum system to ensure no residual water remains in the membrane chambers and pull the membrane chambers back into position following the compressed air blow.

If the squeeze medium is compressed air then the WTP's compressed air plant must have sufficient capacity to also meet the filter press' requirements. If this is not available a dedicated compressed air plant is required for the filter press. Plant service air is normally between 6 – 7 bar. Membrane squeeze cycles are executed at higher pressures, so would normally require a dedicated compressor.

In terms of health and safety risks, compressed air has stored energy so it potentially dangerous. Therefore using water in the squeeze system is safer.

In terms of handling leaks in the squeeze system, using water as the squeeze medium is advantageous as opposed to compressed air. A leak will be immediately noticeable with a drop in pressure as water is incompressible. Water is also visible, therefore locating the leak is easier. When using compressed air a leak will cause a localized drop in pressure and there may be no visible sign where it is being released, making it harder to detect and locate.

5.2 CAKE RELEASE MECHANISMS

It is important that all cake is removed during the cake drop. Any cake pieces which remain (commonly referred to as cake "hang-up") may inhibit the development of a proper seal when the plates are closed.

Traditional filter presses rely on cake drop by gravity, requiring manual assistance from the operator to ensure no cake hang-up remains. With more recent filter press technology, there are a number of options available to ensure cake hang-up is minimized; cloth shakers, tilting frames, plate shaker, cloth scrapping devices and cloth travelling systems. These options are discussed further in the following subsections.

Even with the assistance of these cake release mechanisms, polymer dosing is often required to further minimize cake hang-up. The polymer helps to bind the sludge and produces a more stable cake, therefore aids in full release from the filter cloth.

The cake is usually discharged one chamber at a time or one section of chambers at a time. Some filter presses are capable of releasing the entire load simultaneously, however this is not common.

5.2.1 PLATE OR CLOTH SHAKERS

Plate or cloth shakers are the most commonly used cake release mechanism. Plate and cloth shaking can be undertaken one plate at a time or with a set of plates at once.

Plate shakers are a well established mechanism. There are a number of different plate shaker devices, such as vibration bar systems, camshaft shaker mechanisms and hydraulically actuated devices. The shaker can be installed on a frame separate to the main body of the filter press to minimize vibration damage to other items.

The "bump" plate shaking method is illustrated in Photograph 2 below. This method uses a hydraulically actuated cradle to lift the plate. The impact when the airborne plate lands dislodges cake remaining on the filter cloth. The plate can be "bumped" a number of times depending on the stickiness of the cake.

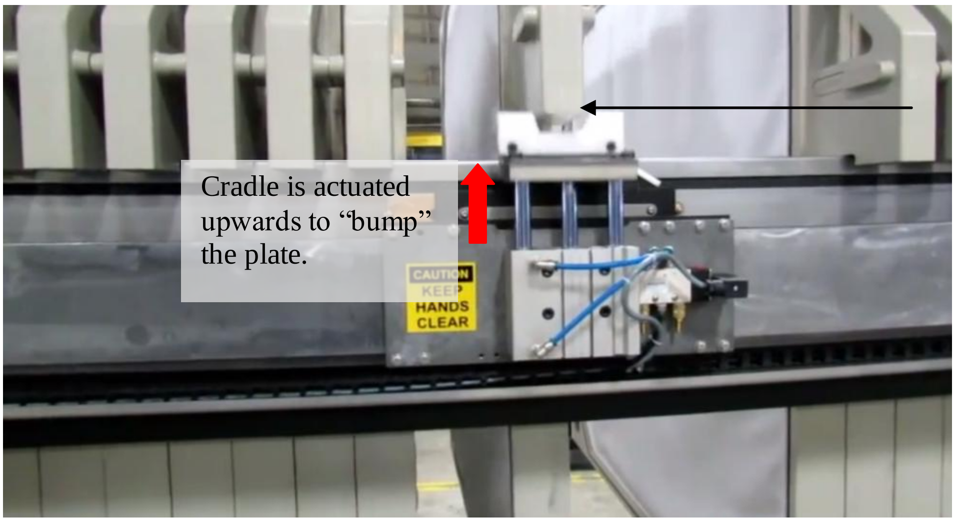


Plate is lifted up and bounces down, with the impact dislodging residual cake.

Photograph 2: Hydraulically actuated plate shaker (bump method) (Watermark, 2013).

The vibration bar system is illustrated in Figure 4 below. This method relies on the contact between the bar and the top of the plates to induce sufficient vibrations in the plate to dislodge any residual cake.

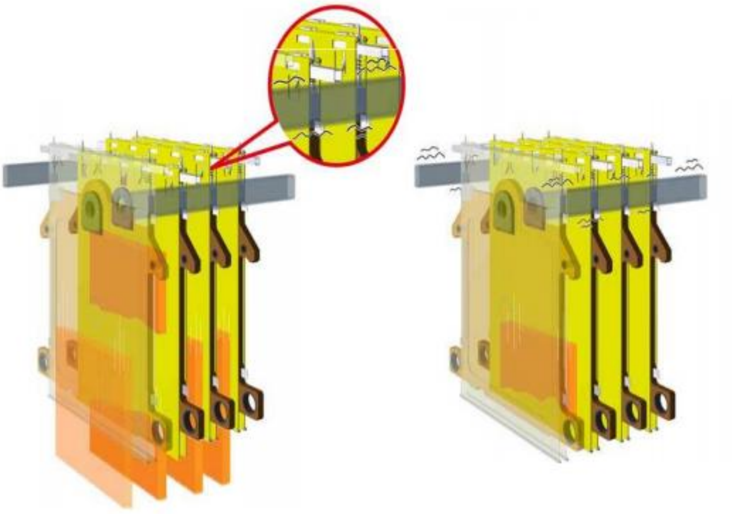
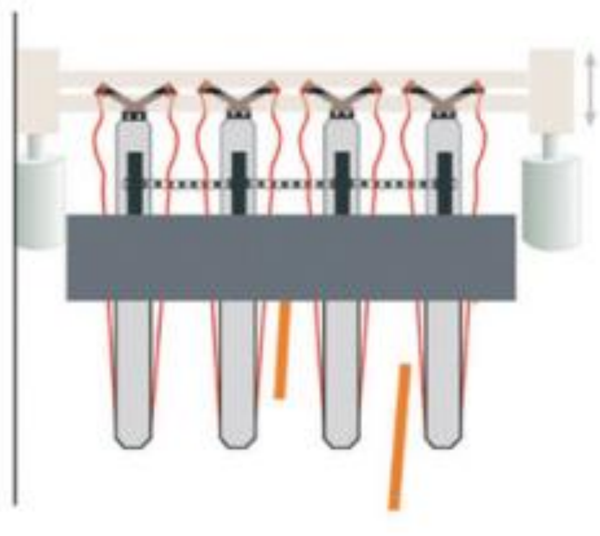


Figure 4: Vibrating bar plate shaker (Ishigaki Company Ltd, 2013).

With cloth shaker devices, the filter cloth is directly vibrated. This can be achieved by a number of different methods (for example; pulley device or a hydraulically actuated shaker) to encourage any remaining cake to release.

A schematic of two separate cloth shaker mechanisms are illustrated in Figure 5.



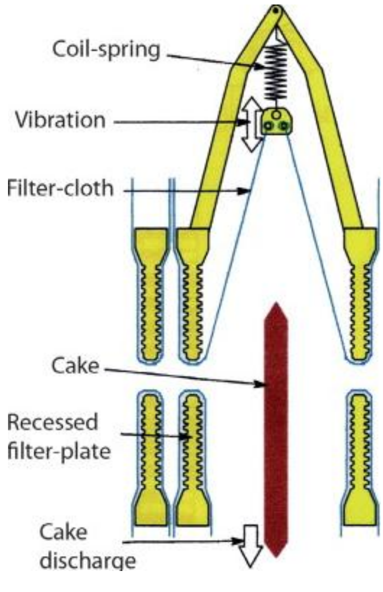


Figure 5: Cloth Shaker Cake Release Mechanisms; via hydraulically actuated shaker (left) (Andritz Group, 2014) and pulley vibration shaker (right) (Shirato, 2010).

5.2.2 TILTING DEVICES

Tilting devices are also a common method of encouraging cake release. This mechanism involves tilting the taut filter cloth with fixing devices to assist cake release. This is undertaken chamber by chamber, as illustrated in the schematic in Figure 6 (focusing on the progress of the chamber highlighted in the red box).

The angle of the tilt can be adjusted as is required for the specific applications, i.e. a larger angle is required for sticky sludge cakes.

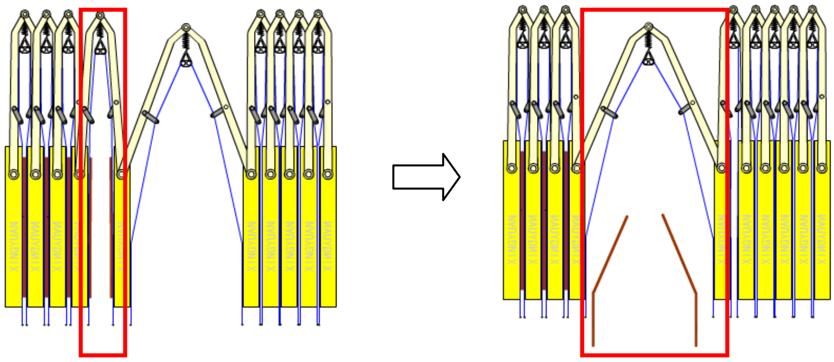


Figure 6: Tilting cloth cake release mechanism (Xingyuan Filter, 2014).

5.2.3 CLOTH SCRAPPING DEVICES

For exceedingly sticky sludge filter cloth scrapping devices can be used. Cloth scrapping devices involve a mechanical arm fixed with scrapers, which travels down and up over each plate separately, forcing the sludge cake off the filter cloth. This is illustrated in the schematic in Figure 7.

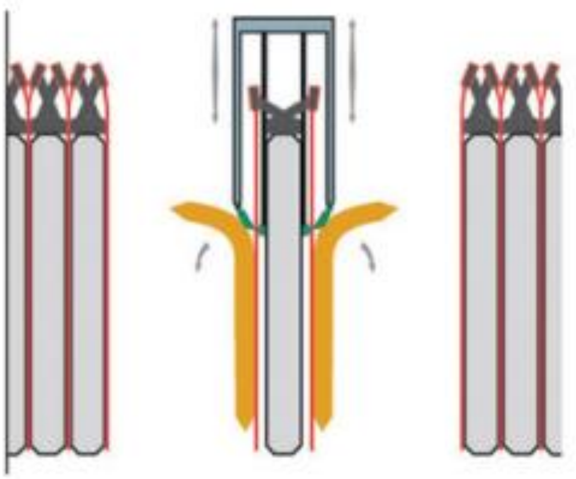


Figure 7: Scrapping cake release mechanism (Andritz Group, 2014).

5.2.4 CLOTH TRAVEL SYSTEM

The cloth travel system provides positive cake release. The cake drop involves the filter cloths being pulled down out of the chamber and around rollers. If any cake remains on the filter cloth after the chambers are open, it will be forced off when the filter cloth passes around the rollers. The entire length of the cloth passes around the rollers, ensuring there are no regions in which cake could remain stuck to the filter cloth.

This method of cake discharge enables all chambers to be dropped simultaneously, greatly reducing the time required to perform a cake drop.

A schematic of cake drop with the cloth travel system is illustrated in Figure 8.

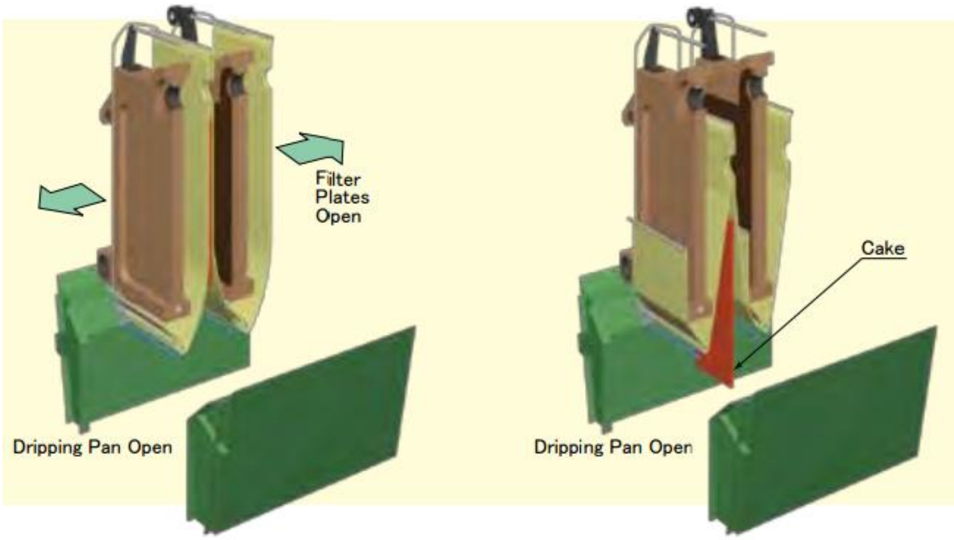


Figure 8: Cloth travel system cake release mechanism (Ishigaki Company Ltd, 2014).

5.3 CLOTH WASH SYSTEMS

Cloth washing is important to maintain filter cloth condition, and hence sustain optimum filtration, and reduce cloth replacement frequency. If the filter cloths are not washed, sludge build-up can inhibit filtration and reduce the efficiency of the dewatering process. Uncared for filter cloths become difficult to clean and maintain, therefore more frequent cloth replacement is necessary.

Traditional filter presses do not commonly have automatic cloth washing systems and washing is undertaken by operators by periodically water blasting the filter cloths. There are a number of cloth washing options available for more advanced filter presses, including high and low pressure systems.

Figure 9 illustrates two different methods of high pressure (spray of up to 100 bar) cloth washing. Both of these systems clean the filter cloth one plate or chamber at a time.

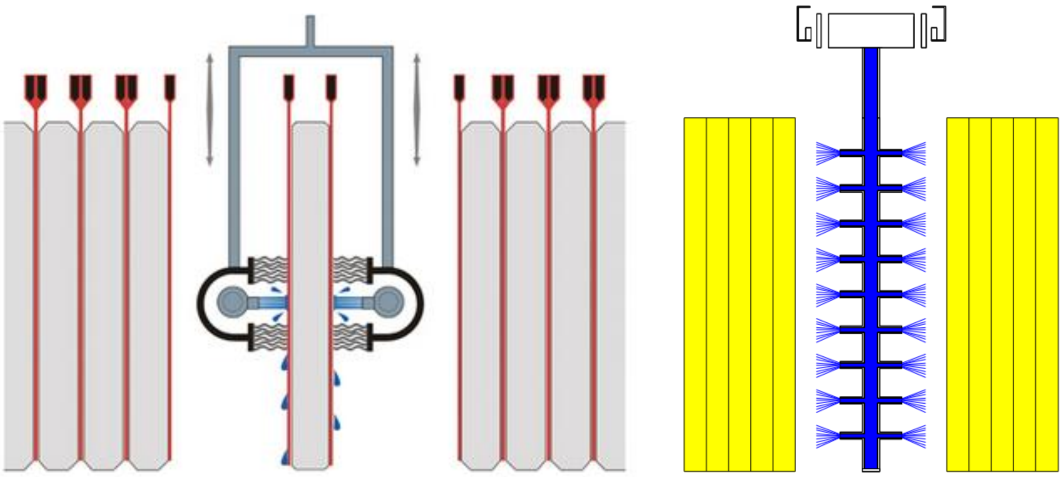


Figure 9: Cloth washing system with dual nozzles cleaning per plate (left) (Andritz Group, 2014) and cloth wash system with multiple nozzles cleaning by chamber (right) (Latham International Ltd, 2010).

Figure 10 illustrates a cloth washing system capable of cleaning multiple plates at one time. These cloth washing systems require nozzles to be installed on each cloth support header (as illustrated in the schematic).

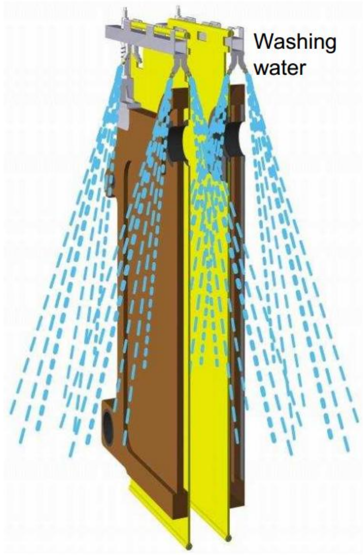


Figure 10: Cloth wash system for simultaneous filter cloth cleaning (Ishigaki Company Ltd, 2013).

If the press is equipped with a cloth travelling system, then multiple filter cloths can be washed simultaneously. These systems involve spraying wash water at the filter cloth as it passes around the rollers. This ensures that each section of the cloth is washed.

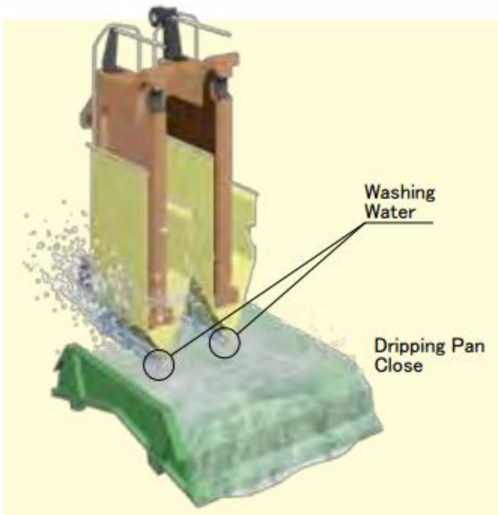


Figure 11: Cloth washing system with cloth travelling system (Ishigaki Company Ltd, 2014).

Drip trays (also referred to as discharge flaps) can be installed beneath filter presses to ensure no wash water from the cloth washing contaminants the sludge cake drop(s). Drip trays also ensure no filtrate or squeeze water (if it is the squeeze medium) leakages drop onto the discharged sludge cake.

5.4 LEVEL OF AUTOMATION

The level of automation provided can be tailored to the operations requirements. If complete cake discharge can be ensured, the control can be fully automated to run through multiple cycles unattended.

However there is greater potential for mechanical failure with the addition of the mechanisms required for full automation (i.e. cake release mechanisms and cloth wash systems). Therefore, although automatic filter presses require less operator attendance, mechanical maintenance requirements may be far greater.

Fully automated or semi-automated filter presses are typically supplied with their own programmable logic controller (PLC). This controls the entire operation of the filter press and if required can be connected to provide remote monitoring.

6 FILTER PRESS SIZING

Manual and semi-automatic conventional filter presses are generally sized to achieve the required throughput within the time frame of a working day or week to ensure operator assistance is available. By determining the capacity this way, there is some spare capacity in the dewatering system should there be a high turbidity event or drain down of a sludge unit upstream is required. In these circumstances the increased volumes of sludge can be dealt with by manual initiation of additional cycles and operators working overtime.

Fully automated filter presses can be sized based on continuous operation to maximize throughput. Unless the filter press capacity has been designed based on the worst case scenario, there will be little spare capacity in the dewatering system. During high sludge events disposal of untreated raw sludge may be required (depending on the sludge storage capacity available onsite).

7 FILTER PRESS TRIAL

Recently Harrison Grierson undertook a large scale filter press trial at one of the major WTPs in New Zealand. This WTP currently operates with traditional filter presses, which have been in operation for 30 years, are prone to “blow outs” and are operator time intensive.

A filter press supplied by Ishigaki was considered to replace the traditional filter presses. The Ishigaki filter press is fully automated and includes a membrane squeeze cycle and a cloth travelling system for cake discharge. However at the time there were no installations of this particular technology in New Zealand or Australian water industries and therefore the operation was not locally verified. A pilot unit was offered by Ishigaki to undertake a series of onsite trials.

The trials involved variation of parameters; feed cycle duration, squeeze cycle duration, squeeze cycle pressure, chemical dosing (poly and PAC) and aging of the sludge feed.

The trial results of interest were: dry solids throughput (kh/day), cake dry solids concentration, cake thickness, filtrate flow rate and quality, and cake hang-up.

7.1 TRIAL UNIT

The Ishigaki trial unit used was temporarily installed onsite, where there was easy access to the WTP’s sludge and chemicals, which were used to achieve the most representative results. The unit was enclosed within a standard container (12 m by 2.3 m), as shown in Photograph 3 below.

Photograph 3: The Ishigaki filter press trial unit.

The unit consisted of:

- PLC;
- Feed tank and mixer;
- Diaphragm feed pump and associated air compressor unit;
- Six chamber filter press;
- Squeeze water pump;
- Washwater pump;
- Washwater tank (also provided the water for the squeeze cycle), and;
- Air compressor for actuated valves.

7.2 METHODOLOGY

The trials were undertaken in two sets, with the trial unit modified in between to increase the squeeze cycle pressure from 10 bar to 12 bar.

The first set of testing was largely based on the methodology of another filter press trial carried out at the same WTP. This involved pressing raw (from two different sources in the sludge plant process) and chemically dosed sludge with varying feed and squeeze cycle times.

The second set of testing was recommended by Ishigaki and involved grouping the tests into three series. Each series had a constant feed cycle duration with varying squeeze cycle durations, as follows:

- Test Series 1 (30 minute feed cycle) with squeeze times of 45, 60 and 90 minutes;
- Test Series 2 (45 minute feed cycle) with squeeze times of 60, 75 and 105 minutes;
- Test Series 3 (60 minute feed cycle) with squeeze times of 60, 75, 90 and 120 minutes;

7.2.1 PARAMETER MEASUREMENT PROCEDURES

Dry Solids Content:

Three different methods were used to determine the dry solids content in the sludge feed and cake:

- Moister analyser – approximately 10 g of the sample placed in the analyser for up to 4 hours;
- Oven – samples of 200 – 300 g were baked over night in a laboratory class oven with weighing pre and post;
- Laboratory analysis – select samples were sent to a laboratory to verify the moister analyser and oven results.

Dry Solids Throughput:

The dry solids throughput was calculated for the 'solids in' and the 'solids out', and these values were compared to verify the measurements taken and calculations applied. The average of the 'solids in' and the 'solids out' was used as the throughput value.

The 'solids in' were determined based on the following measurements:

- Dry solids content in the sludge feed – measurement taken from the bottom of the tank directly after the feed cycle;
- Volume of sludge fed – measurement based on the level drop in the tank following the feed cycle.

The 'solids out' were determined based on the following measurements:

- Dry solids content of the sludge cake – measurement based on representative pieces of cake which were selected for analysis;
- Mass of cake dropped – measurement based on weight of the cake dropped.

Filtrate Flow Rate:

The filtrate flow rate was monitored throughout each cycle at five minute intervals and provides an indication of how the filter press cycle is progressing. The method for measuring the flow rate involved timing the duration required to fill a fixed volume (10 L bucket).

Filtrate Quality:

The filtrate turbidity was measured from a sample taken at the end of each squeeze cycle. This provided an indication of the filter cloths capability at capturing the sludge solids. A hand held turbidity meter in the WTP's laboratory was used to measure the turbidity.

Cake Hang-up:

The filter cloths were examined each run to verify if the cake drop was successful.

7.3 OUTCOMES

The dry solids concentrations achieved throughout the trial were encouraging; with sludge cake consistently measured between 38 – 40% dry solids concentration with no aid of chemical dosing. As illustrated in Figure 12, the dry solids concentration increases with increasing cycle time.

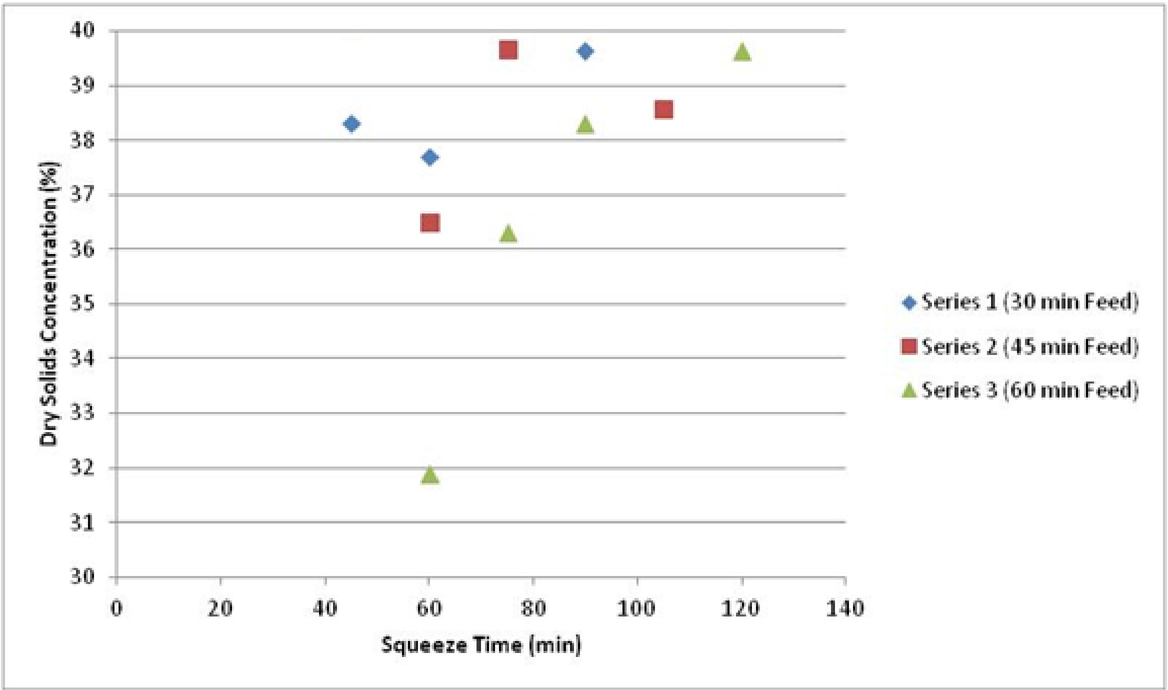


Figure 12: Dry solids concentration with varying cycle time.

As illustrated in Figure 13, the throughput increased with decreasing cycle times, with the highest throughput (kg/day) for raw sludge achieved by the shortest test times (30 minute feed cycle and 45 minute squeeze cycle). This is because the shorter cycle times enabled more cycles to be completed over a given period of time.

Optimisation of the throughput needs to take the required dry solids concentration into consideration, due to their opposing trends.

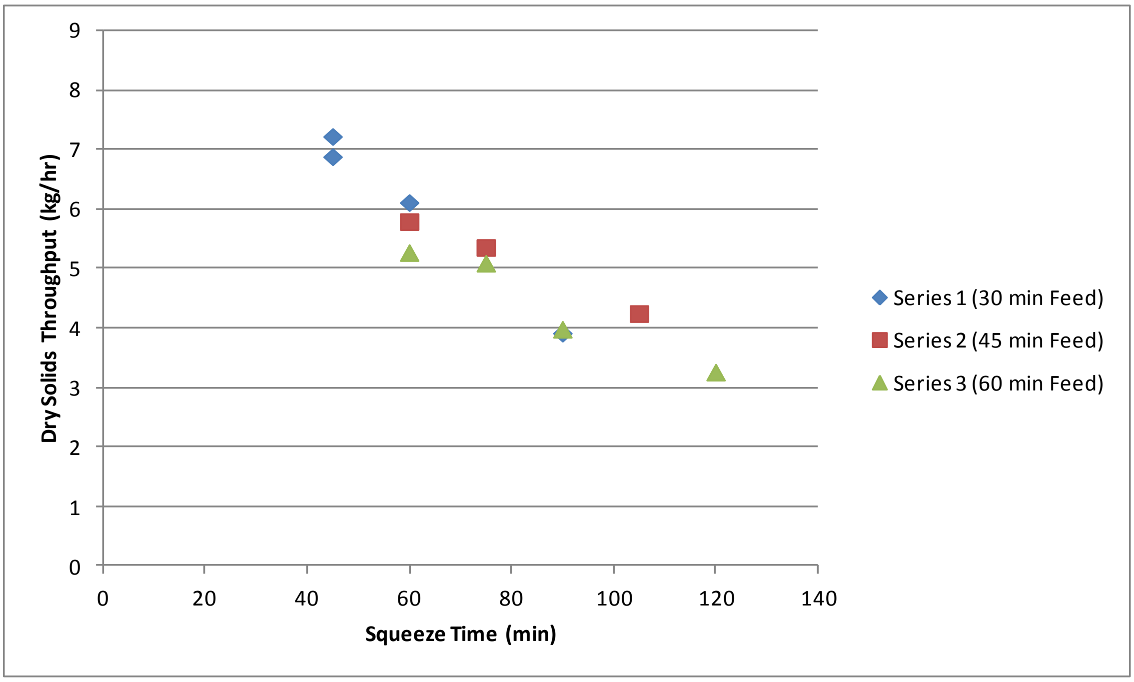


Figure 13: Dry solids throughput with varying cycle time.

Dosing powder activated carbon (PAC) at a 0.7:1 weight ratio with the dry solids content resulted in 91% improvement in throughput. The addition of PAC aided in filtration through the sludge, increasing the throughput and confirming that press capacity would not be adversely affected by periods of time when PAC dosing is required (i.e. when the sludge feed has a higher solids loading due to added PAC).

Another notable outcome of the trial was successful cake release during the cake drop procedure, with no cake hang-up issues experienced regardless of chemical dosing. Polymer dosing was not found to significantly increase the dry solids content, throughput or improve cake release, indicating that polymer dosing is not necessary for the successful operation of this filter press.

Following a competitively bid tender process, this type of filter press has been selected for installation and this will be the first in the New Zealand water treatment industry.

8 CONCLUSIONS

Filter press technology has evolved significantly over the past couple of decades to accommodate the processing requirements of the many industries that filter presses are utilized in. These improvements are also applicable to dewatering sludge in the water industry, which is currently undergoing a technological revolution to achieve higher dry solids while requiring less operator time.

The operation of a filter press with membrane squeeze and travelling cloth has been verified through a pilot unit trial and this has lead to selection of this type of filter press for a full scale installation within New Zealand.

Each filter press installation needs to be considered on a case by case basis to evaluate what features are required and if any associated limitations are tolerable. Manual, semi-automatic and fully automatic filter presses have their own pros and cons, and these need to be considered for each specific situation.

ACKNOWLEDGEMENTS

Many thanks to the Ishigaki Filter Press Trial project team.

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