Tailings dewatering and dry disposal: case studies of the successful application of full-function, automated filter presses

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Abstract. Tailings slurry storage and management continues to be a significant consideration for the safe and environmentally complaint operation of a coal processing facility. Further, as the scarcity of, and stringent application requirements for, raw water sources increase in this country, it is becoming ever more important to critically account for every litre of water lost from a processing plant. These requirements, among others, have driven the need for development of techniques and technologies to minimise water losses from every stream exiting a coal plant. A major contributor to such water losses arises from the slimes slurry which has traditionally been stored in tailings dams. Typically, significant quantities of water are lost from these facilities due to evaporation and seepage, placing pressure on raw water make-up sources as well as polluting, rivers, dams and ground water. One solution at the forefront of this technological development drive is the incorporation of filtration technologies into the slimes slurry streams. Competent, low-moisture filter cake can then be safely and compliantly stored in dry facilities or, in the case of a filtered froth flotation concentrate, blended and sold as additional tons along with the coarse product. The filtrate water is then directly returned to the processing plant, eliminating water losses to the environment. This paper considers 3 case studies of the successful application of plate and frame filter presses.

1 Introduction

Filtration technologies play a major role in the successful treatment and handling of ultra-fine coal slurries in coal processing plants [1]. In the last 20 years these technologies, and specifically filter presses, have advanced significantly, becoming widely employed in mineral processing plants [2]. Filter presses have proven to be highly efficient in solids recovery, moisture reduction and in the production of competent filter cake with characteristics suitable for downstream materials handling, dry disposal [3] as well as effective blending of high-quality filter cake such as froth flotation concentrate into a coarse product stream. Additionally, under certain circumstances, the low moisture tailings filter cake can also be sold as an additional revenue generating commodity. It is important to note that not all

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filtration technologies are applicable to all dewatering duties and that each type of technology has its inherent benefits and drawbacks [1]. This paper presents 3 case studies discussing the successful application of full-function plate and frame filter presses on arising ultra-fine coal slurries at various collieries across South Africa, each targeting a different desired outcome.

2 Filtration technology for tailings dewatering applications

There exist many filtration technologies in the mineral processing field today, each operating on differing principles, excelling in differing applications and each with its own benefits and drawbacks. These technologies make use of various combinations of dewatering driving forces such as vacuum pressure, centrifugal forces, mechanical and pneumatic pressure as well as compressed air drying. This paper specifically considers the use of full-function, plate and frame filter presses, a brief overview of this technology is presented in the following section.

2.1 Full-function plate and frame filter presses

Although filtration technology has been around for a long time, the application thereof has historically been associated with lower throughput applications. Recent demand from industry as well as safety and environmental requirements has likely driven the development of these filtration techniques to achieve higher efficiencies, improved reliability as well as greater throughputs. [4]. Of the many dewatering technologies available, the plate and frame filter press has proven to be highly effective in the dewatering of coal tailings slurries [3] and froth flotation concentrates. The quick, initial formation of filter cake against the filter cloth inside a closed chamber creates a secondary filtration medium for the remainder of the filter cycle [5]. This means that batch process, plate and frame filter presses achieve near perfect solids recovery and negligible material recirculation, without the need for flocculation.

The plate and frame filter press is a batch process technology, requiring several steps to complete the filtration process. The steps involved in the full cycle of the filter press have evolved over the years to include specific steps deemed essential for ensuring competent filter cakes as well as achieving the lowest possible moisture consistently from every cycle of the operation. The major steps included in the modern full-function plate and frame filter press is illustrated in Fig. 1.

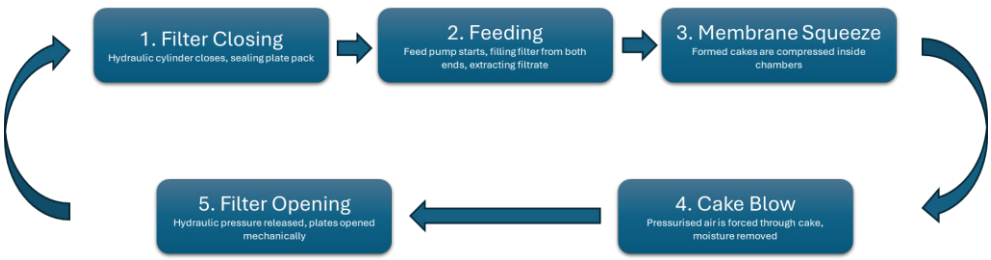

Fig. 1. Full-function filter press cycle steps [3].

Of the five major steps included in the filter press cycle, test work and operational experience has shown that two of these steps are critical for consistently achieving lowest moisture, competent filter cakes, cycle after cycle. These two steps are of even greater importance when there is a risk of fluctuations in the feed slurry characteristics. The critical cycle steps discussed in the following section specifically address such feed material

fluctuations, eliminating the effect thereof and ensuring filter cakes meet all necessary geomechanical requirements for further handling.

2.1.1 Membrane Squeeze

Low feed slurry densities, fluctuating PSDs and high ash contents can affect filter feeding performance [2]. This can be due to cloth blinding, material segregation or feeding control systems which cannot adapt to changes in feed characteristics to name a few. This typically results in improper filter press chamber filling which then results in incompetent filter cakes and very high moisture contents associated with the porosity and high saturation ratios of such cakes. This type of poorly formed filter cake causes major downstream material handling issues and can typically not be used in the construction of dry stacked tailings storage facilities (TSF) or be blended in with other product streams due to the detrimental effect moisture has on product quality.

Fig. ***2*** illustrates the mechanism of filter press membrane inflation, or Membrane Squeeze, which reduces the individual filter press chambers' volume through the introduction of pressurised air or water into the hollow core of the filter plates. This inflation occurs after the initial filter filling which means that any cake which has already formed within the filter press is further compacted to increase the bulk density, ensuring that the filter cake achieves a competent, handleable form.

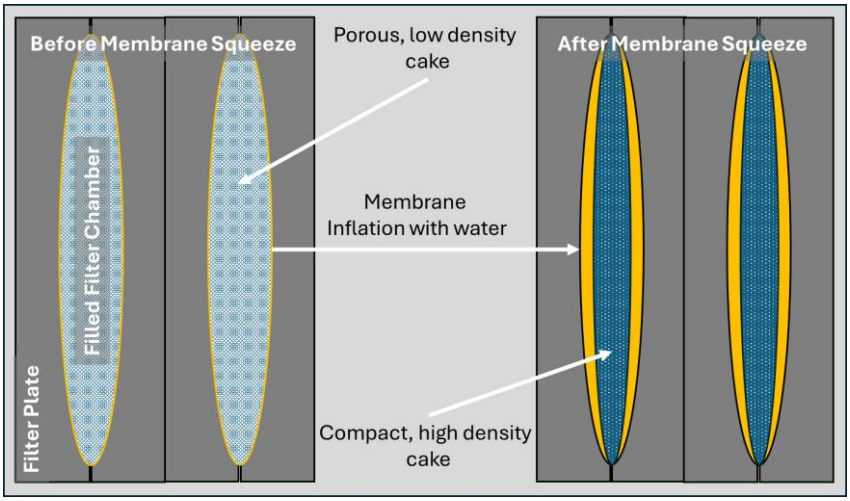

Fig. 2. Illustration of Membrane Squeeze mechanism [6].

While the membrane squeeze functionality does reduce the cake moisture to a small extent, the main function thereof is to ensure competent filter cakes irrespective of feed slurry characteristics and without the need for flocculation.

2.1.2 Cake Blow

Arguably the most important property of a formed filter cake is the moisture contained within the cake. This moisture represents water being lost from a processing plant, is indicative of the likelihood of materials handling and blending challenges downstream of the filter press, while also dictating whether a filter cake can be used to construct a filtered stack TSF.

While very low cake moistures can be achieved by employing thermal drying, this technique is energy intensive and becomes increasingly difficult for lower moistures contents [7]. This is usually not economically feasible for a tailings dewatering application. A more cost-effective method of driving filter cake moisture down is using dry, compressed air. The Cake Blow step of a filter press forces dried air at pressures of approximately 6 Bar through the formed, squeezed filter cake. This breaks up capillaries within the filter cake and drives out residual surface moisture. This process is illustrated in Fig. 3.

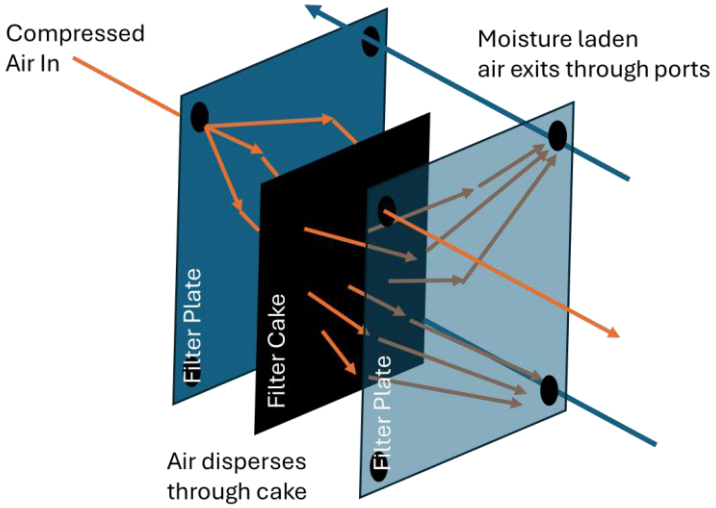

Fig. 3. Illustration of Cake Blow process [8]

3 Case Studies

Three case studies are presented in this paper, highlighting the success of filter presses in dewatering of coal slurries to achieve various outcomes.

3.1 Large scale coal tailings dewatering

This mega coal processing plant in the north of South Africa had previously employed vacuum belt filters on their coal slimes tailings. Vacuum belt filters are typically an attractive option for such an application due to their continuous operation and high throughput per unit [9]. The filter cake produced from this facility is transported via conveyor systems to join an outgoing coarse coal product stream. It had become evident that the installed vacuum belt filters were not able to achieve the required low moisture contents for effective material handling through the conveying system and this was resulting in detrimental production impacts.

To fully understand the challenges of cake moisture and various downstream transfer points, a bulk material handling investigation was conducted to determine critical chute angles for new chutes as well as critical cake moisture limits for existing chute work. Through rigorous on-site pilot plant test work, the plate and frame filter press proved advantageous over the existing filters in achieving the required moisture contents to prevent chute blockages and prevent material recirculation by producing a near solids-free filtrate without the need for flocculating the filter feed slurry. This is accredited to the higher pressures involved in feeding, membrane squeezing as well as forced air cake drying.

This coal tailings plant shown in Fig. 4, which consists of 8'680m2 of filtration area across 14 plate and frame filter presses has been in operation since 2021 and operates at a throughput of 660 dry tons per hour, consistently achieving surface moistures below 18% (w/w)

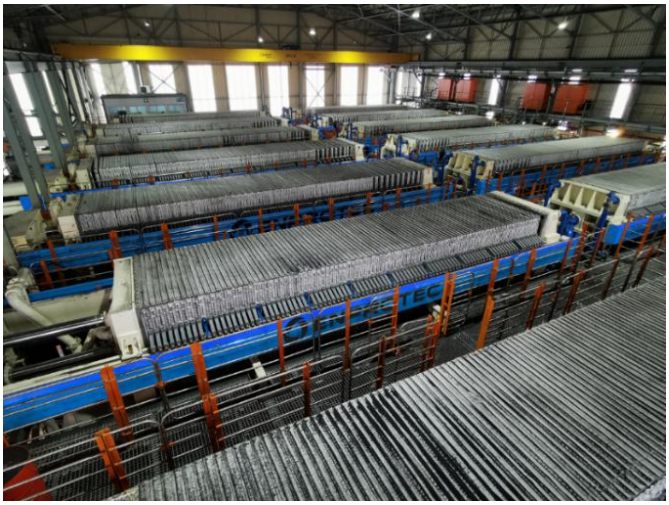

Fig. 4. Large scale coal slurry dewatering facility

3.2 Zero effluent coal processing plant: dewatering flotation concentrate and tails

While filter cakes still contain a certain amount of moisture which is lost form a processing facility, with the application of the correct dewatering technology it is possible for such a plant to minimise water losses and become essentially effluent free. This is becoming of greater importance in water scarce environments such as South Africa where legislative requirements are making water use licences difficult to secure. The colliery in this case study, which also employs froth flotation on their arising slimes stream, constructed two plate and frame filter plants and in 2013 ceased the use of their tailings dam facility. Froth flotation product filter cake is blended in with the coarse product while the tailings filter cake is securely stacked in their TSF. This not only greatly reduced the amount of water required by the processing plant but also reduced the complexity and risks associated with the slurry storage facility previously employed. It is noted that, as this colliery no longer has the option of by-passing the filter plants to store a slurry tailing, the availability of these filter plants is critical. To date, employing a strict maintenance programme, these filter plants have been shown to operate at availabilities exceeding 98%.

Table 1 illustrates a high-level water balance for this operation, indicating the reduction in water losses arising from the ultra-fine (-212um) fraction with the introduction of the filtration plants.

Table 1. Water loss reduction after installation of filtration plants

	Units	DMS thickener underflow	Slurry dam water loss	Flotation product filter cake	Flotation tailings filter cake	Reduction in water loss
Dry coal	***tph***	56.3	0.0	36.6	19.7	62.4%
Water	***m3/h***	104.6	41.8	9.1	6.6	
%Solids	***w/w***	35.0%	0.0%	80.0%	75.0%	

It is of interest to note the difference in performance of the two filtration plants in this case study, i.e. Flotation Product and Flotation Tailings. The froth flotation process produces a high quality, low ash product which is easier to process through the filter press compared to the low quality, high ash content tailings. This higher ash content typically increases filtration time but also, as can be seen in the mass balance in Table 1, results in higher filter cake surface moistures. This factor is important to be aware of when designing filtration plants and the associated downstream handling systems.

Between the two filtration plants, a total of 5 filter presses and 1'900m2 of filtration area processes a total of 75tph at surface moisture contents of 20-25% (w/w). Fig. 5 shows the tailings dewatering filter plant at this colliery consisting of 3 filter presses.

Fig. 5. Zero-effluent, tailings slurry dewatering plant

3.3 Minimizing impact on natural water resources

A typical coal processing plant will require anything between 200 – 400liters of raw make-up water per feed ton to operate [10]. This water must be taken from natural resources in the plant's vicinity which, can become a tall order to fill. The processing plant in this case study was faced with this challenge to the extent that the plant frequently had to stop operations in the dry winter months due to the water storage dam running dry. In 2012, a plate and frame filter plant was constructed at this facility and up until the colliery ceased operations in 2024, the plant had not been required to stop for water shortages again. A high-level, overall plant water balance is shown in Table 2, illustrating the reduction in make-up water required by this operation after the installation of the filter presses.

Table 2. Make-up water requirement reduction

	Units	Plant feed	Coarse product & discard	DMS thickener underflow	Slurry dam water losses	Filter cake	Reduction in make-up water
Dry coal	***tph***	400.0	370.0	30.0	0.0	30.0	30.2%
Water	***m3/h***	25.5	60.2	55.7	27.9	9.0	
%Solids	***w/w***	94.0%	86.0%	35.0%	0.0%	77.0%	

Fig. 6 shows the low-moisture filter cake being stockpiled from this facility which produces 30tph filter cake from 2 filter presses, at surface moistures below 23% (w/w)

Fig. 6. Low-moisture filter cake produced by plate and frame filter presses.

4 Filter press operability

Although the case studies shared indicate effective dewatering and filtration, the key success for such processes often lies not only with the technical viability, but also with the operability of the process. This includes operational costs (OPEX), equipment availability, filter cloth life and the consistency of process automation. Table 3 summarises these considerations for the case studies presented.

Table 3. Operability summary

	Unit	Case Study 1	Case Study 2	Case Study 3
OPEX	USD/t	0.54	0.83 – 0.92	1.21
Availability	%	>95	>95	>95
Filter cloth life	cycles	5500	5000 – 7500	6000
Automation		1.Fully automatic operation 2.Manual cloth washing		

5 Conclusions

The scarcity of water as well as the stringent safety and environmental requirements being placed on the handling and storage of tailings slurries is driving the development of alternatives to traditional slurry storage dams. In recent decades, filtration of arising slurries for purposes of dry stacking, as well as the dewatering of froth flotation concentrates for blending with coarse product streams, has become a major competitor in this field. Through the correct, considered selection of the appropriate filtration technology it is possible to reliably and consistently produce filter cakes with sufficiently low moisture contents for further downstream handling. This paper considers 3 case studies in which full-function, plate and frame filter presses have been successfully employed to dewater unflocculated ultra-fine coal slurries to produce low-moisture filter cakes and near solids-free filtrate which can be directly recirculated back to the processing plant. These applications have proven to reduce overall plant water consumption while producing competent filter cakes over a wide range of tonnage throughputs.

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