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Innovative product optimisation with the AFP2500 filter: a breakthrough in dewatered tailings solutions by FLSmidth

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Abstract

The mineral's processing industry is undergoing a pivotal shift towards safer and more sustainable tailings management. In response to this evolving landscape, FLSmidth (FLS), a leader in minerals processing equipment, has placed a strong emphasis on comprehensive full flow sheet solutions for dewatered tailings, aligning with industry demands for reduced environmental impact and heightened operational efficiency.

Dewatered tailings, more specifically dry stacking, hinge upon the effective utilisation and advancements in filtration technologies. Many of these filtration methods have stood the test of time for over a century, providing a material suitable for environmentally responsible tailings disposal. However, as the mining sector trends towards larger filters to handle the staggering tonnages of tailings generated globally, FLS has undertaken a focused exploration of how to efficiently dewater these tailings at the lowest cost per tonne.

To achieve this objective, the FLS filtration team embarked on a comprehensive product optimisation project. This initiative encompassed a holistic review of our filter press portfolio, addressing critical aspects such as equipment weight, feed pumping efficiency, air consumption, media washing, filter maintenance, and manufacturing efficiencies. The overall goal was to improve the technology while dramatically decreasing the total cost of ownership. The outcome of this extensive review has not only reshaped our design philosophy but also spurred the creation of innovative sensors and autonomous control devices, revolutionising the filtration process.

The crowning achievement of this endeavour is the introduction of the AFP2500 filter to FLS's portfolio. This cutting-edge addition to our product range has already garnered global recognition, with seven units sold and currently in various stages of manufacturing. The AFP2500 filter, embodying the pinnacle of our advancements, offers unprecedented reliability, efficiency, and cost-effectiveness in dewatering tailings, affirming FLS's dedication to pioneering sustainable solutions in the minerals processing industry and achieving our goals of MissionZero mining.

This technical paper presents a comprehensive account of the product optimisation project, the development of the AFP2500 filter, and its potential to reshape the landscape of dewatered tailings solutions in mining.

Keywords: *dewatered tailings, product optimisation, AFP2500 filter, sustainable mining, minerals processing, filtration technology*

1 Introduction

In the past decade, in the wake of multiple catastrophic tailings dam failures, the mining industry has undergone sweeping changes in its regulatory landscape, operational procedures, and guidelines. These transformations are evident across diverse regions, each governed by its regulatory bodies, yet sharing common principles that underscore responsible tailings disposal. A prevailing global directive resonates throughout the industry, emphasising the imperative for mine operators to manage their tailings conscientiously, mitigating the looming risk of future dam failures.

Amidst these changes, an emerging theme intertwines with the industry's evolution – the urgent call for sustainability. Beyond adhering to regulations governing tailings disposal, mining operators worldwide grapple with stringent restrictions on freshwater usage, particularly in arid regions of the globe. It is crucial that mining companies play their part in sustainability as UNICEF predicts water demand to increase by

20 to 30% by 2050 due to population growth and higher living standards as well as food and energy demands (www.unicef.org). This sustainability challenge forces mining companies to explore alternative water sources, such as desalinating ocean water which including transportation to mine location can cost as much as USD 7.50/m^3, resulting in significant economic ramifications. The escalating cost of clean water not only strains operational budgets but also underscores the pressing need for sustainable water management in mining practices. Furthermore, with declining ore grades, an increase in water consumption and tailings generation, as described by Mudd (2009), are also coinciding with investor pressure for more sustainable mining practices (Global Sustainable Investment Alliance 2018; RBC Global Asset Management 2018).

In the current landscape, the mining industry has witnessed the widespread adoption and acceptance of dewatered tailings systems. As numerous filtered tailings systems become established, a wealth of data is now emerging on the operational costs of these facilities. This data is allowing original equipment manufacturers companies like FLSmidth (FLS) to analyse the equipment being provided to the industry and develop ways to strategically reduce operating costs. These reductions are achieved through a dual focus on minimising power consumption and optimising filter technology to lower consumable costs while innovating equipment that provides the client with a streamlined approach to maintenance. This is especially important for installations with large quantities of filters.

With these objectives in mind, FLS has spent the past two years concluding research and development optimisation projects spanning its entire automatic filter press mining filter product range. The primary focus was on diminishing the overall cost of ownership for end-users. In conjunction with a comprehensive update to the product line, the FLS filtration team has successfully conceived and produced the AFP2500 filter press. This filter integrates the latest features and operational control philosophies, while providing the client with the largest volume and filtration surface area of any 2.5 m format filter. The purpose of this paper is to spotlight the key features of the AFP2500 filter, as we anticipate its potential to substantially decrease the operational costs associated with global tailings filter operations.

2 AFP2500 initial development

When designing the AFP2500 filter press, the filtration team took a holistic approach to not only the existing FLS M2525 filter, but also to the ancillary equipment that surrounds the filter allowing for its continuous operation.

The target objectives for the development project were as follows:

1. Reduce the weight of the filter, while maintaining the well-established FLS engineering safety factors.
2. Reduce the amount and cost of maintenance on the cloth shaking system.
3. Improve filter media life and streamline filter media maintenance.
4. Optimise the opex per tonne of material dewatered.

To effectively complete the R&D project, a stage gate process was utilised consisting of various stages including idea generation, laboratory testing, prototype development, pilot testing, industrial testing and finally product acceptance. Focus teams were created and tasked with analysing each of the target objectives. Regular brainstorming sessions were held in which each of the focus teams would present their findings and testing results to the filtration group for analysis and direction.

Once the analysis was completed for each of the objectives, and industrial testing results had been validated the team set out on updating the filters predecessor, the M2525, with the latest technologies and philosophies that had been developed during the R&D process.

2.1 Objective 1: weight reduction

Dewatered tailings facilities require large buildings and structures which take up a lot of real estate. This is especially so in current times as ore grades diminish and the daily throughput tonnage of concentrators increase. The industry is seeing pre-feasibility and feasibility studies being completed in which 10 or more filter presses are required to meet the daily throughput. Tailings filters are often up to 40 m long and require enclosed buildings with multiple levels to accommodate the discharge conveyors, the filters, and elevated platforms for maintenance to be conducted on the equipment. The cost of these buildings is significant to the mining company, and it was for this reason that FLS decided to look at ways to reduce the weight of the filters, without compromising on strength or durability.

When manufacturing a filter press, the main areas that contain weight are the head, follower, crosshead, and sidebar (Figure 1). For many years, the head, follower and crosshead have been fabricated from welded plate steel. Standard plate steel thicknesses were used and elaborate lengths of weld were completed to build the box section of each component, usually in a waffle pattern to provide simplicity of fabrication. When the engineering team performed finite element analysis (FEA) and analysed the results of the existing welded fabrications, it was found that if plate steel of a certain thickness was required to overcome the stresses in the front of the component, oftentimes that same plate thickness was not required in the back of the component where the stresses didn't exist, essentially meaning that material of this thickness is providing no benefit in this area. It is wasted money and weight.

Figure 1 The major structural components of a filter press

The engineering team embarked on designing the filter using cast structural components as opposed to a fabricated design. This would allow for a reduction of waste material as the steel would be placed exactly where it is needed to overcome the stresses, while utilising geometry that provides the greatest strength for each component. The FEA indicated that fatigue was engineered out of the design as a mode of failure, and the filter design was finalised. After a rigorous vendor selection process was completed, a vendor was selected, patterns made and test castings were poured. The completed components were then analysed and assessed through the FLS QA/QC protocols as seen within Figure 2. This portion of the R&D project was then finalised and the project was deemed successful with a weight savings of approximately 30% being achieved. In addition to the filter weight reduction resulting in less structural steel required to support it within the filter building, the reduction in fabricated weight also led to a decreased capital cost for the filter which is passed on to the client. Furthermore, by casting the components, a large portion of welding labour has been eliminated and less steel is being consumed.

In addition to the weight savings within the cast components, FLS also optimised the sidebars, transitioning from a solid piece of machined plate steel to a fabricated box beam construction. The box beam provides increased strength and rigidity, while decreasing the overall weight of the sidebars.

Figure 2 The AFP2500 cast follower being inspected by a quality officer

2.2 Objective 2: shaker optimisation

A team was formed to thoroughly investigate the optimisation potential of our shaking system. The first step was the engagement of several FLS customers to discuss the maintenance requirements of their filters, what they like and disliked, and what components accounted for the largest portions of their annual maintenance costs.

There was a common theme from the client's feedback which pointed in the direction of the cloth shaker. The complaints were not that the shaker didn't function properly. In fact, on all accounts, it was said that the shaker was extremely effective. The problem was that the shaker had many moving components, all of which required lubrication, and the Lincoln pneumatic auto lube system was not reliably providing grease to all the components, leading to premature failure. The compounding effect on operational costs was that large amounts of labour were then required to replace these components.

The engineering team had a very clear directive; 'design a shaker that provides the exact same shaking action with the same cloth amplitude at the exact same frequency, while significantly reducing the number of moving parts. Utilise parts that are readily available to the client.'

The team then developed four concepts, of which two were chosen to move forward into a pilot-scale test. The test unit was manufactured and full-scale 2.0 × 2.0 m plates were installed into the units adorned with filter media. Comprehensive testing of the energy imparted on the cloth, as well as bearing types and wear pad materials of construction were completed. Only after testing of all components had been completed over a two-month period did the team make the decision to move forward with the new shaker design. The new shaker design was fabricated and fitted to a client's filter, where it was closely monitored to ensure that the rate of wear of the wear pads and bearings matched the results witnessed during the pilot testing campaign.

Since the completion of the project, the new shaker design has been implemented on over 10 filters, all of which are proving that the project was a success. The final design incorporates over 80% less moving components and utilises standard short lead time components. The original shaker (Figure 3) consisted of a hydraulic motor driven camshaft that ran the length of the filter. This shaft was fitted with two roller lifters for each 20 filter cloths. As the camshaft rotated, the roller lifters, supported by thrust bearings, would raise and lower a bar that rested beneath the cloth shaker bars, resulting in a shaking action to the cloths. The new shaker design (Figure 4) consists of a series of elliptical pipes, each long enough to rest under the shaker bars of 20 cloths. Each elliptical pipe is connected to the next with its 'top dead centre' location 15° offset from the previous. This series of elliptical pipes is supported by bearings which allow it to be rotated by a single hydraulic motor. As the elliptical pipe sections rotate, they raise and lower each of the sets of 20 cloths sequentially. This significant reduction in moving parts and lubrication points has led to the removal of the pneumatic lubrication system altogether. Simple electro-chemical auto lubrication canisters are now utilised at each of the lubrication points on the filter, reliably supplying the correct amount of grease to each, increasing reliability, and reducing time to perform maintenance.

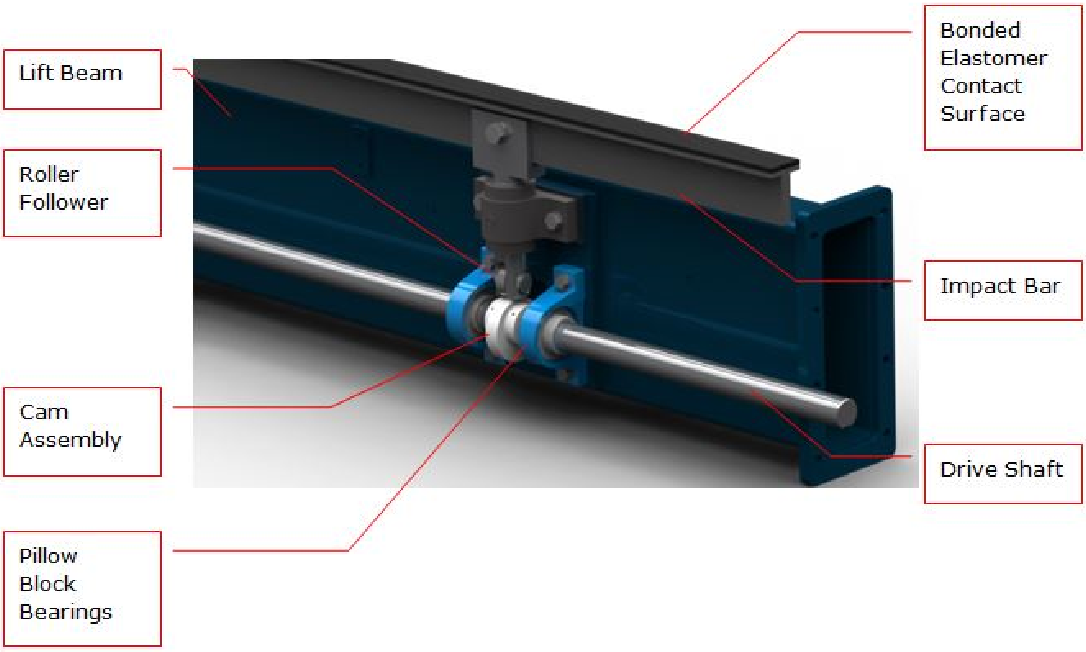


Figure 3 **Photograph showing a section of the original shaker design and its multitude of moving components**

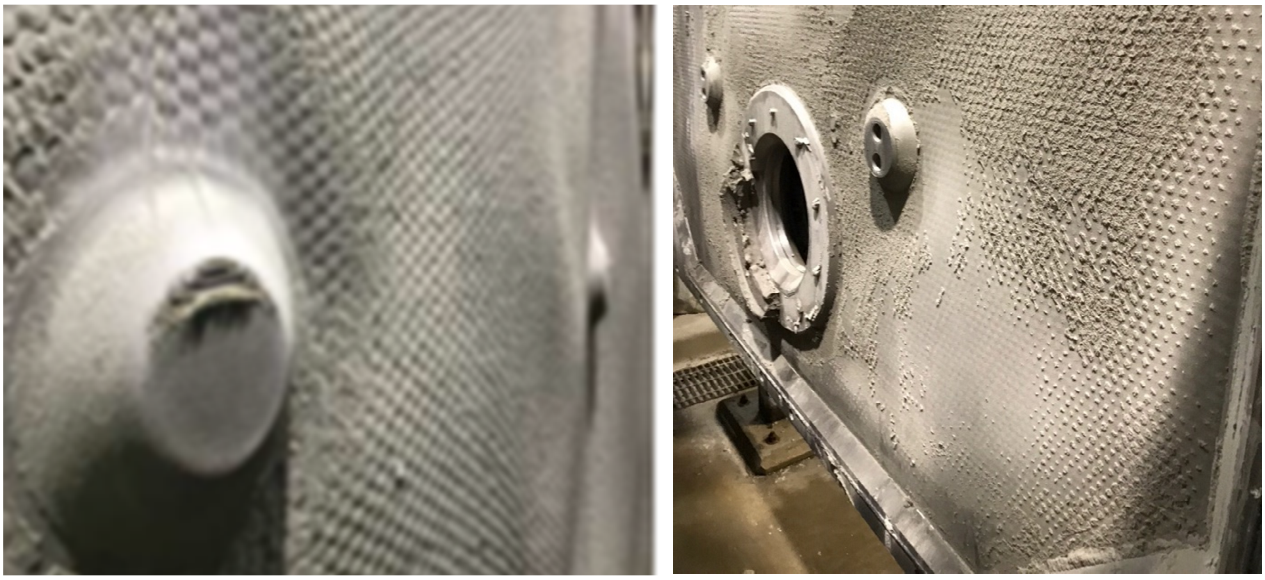
Figure 4 **Photograph showing a section of the rotating elliptical pipe that forms the cloth shaker. As the pipe rotates, the shaker bars are raised and lowered**

2.3 Objective 3: improve media life and streamline maintenance

Anyone who has ever operated a filtration plant understands that the one of the highest operational costs resides with cloth maintenance. FLS has been working since 2016 to understand the different modes of media failure to strive to increase the life of media within filter presses. To achieve this, FLS funded two PhD students at the Karlsruhe Institute of Technology in Germany, which is a leading institution in the field of filtration. In addition to the university, FLS also partnered with several leading media suppliers as a source of different fabrics with different weights, weave types and materials of construction would be required.

The result of this research was the development of several proprietary tests that can be performed in a laboratory to assist with the selection of filter media. Since the conclusion of the program, a database has been formed detailing the performance of different media configurations on different types of slurry with their unique particle size distribution and mineralogies.

FLS then conducted field testing of different media types at several of our filter installations, collecting data daily, and analysing the life of the media. It was found that there are two main modes of media failure; the first being through mechanical abrasion and the second being through media 'blinding' or 'plugging' (Figure 5), in which the apertures of the media become blocked with small particulate. On three of the four testing locations, it was found that the media would in fact fail through blinding well before the media was showing any signs of mechanical damage. X-ray diffraction analysis of the slurry and scanning electron microscopy (SEM) of the blinded media indicated that this blinding was being caused by fine swelling clays that were present both in the raw slurry sample and trapped within the labyrinth of the media weave. In one case the SEM microscopy revealed that the media was not being blinded by any of the constituents of the slurry itself, but in fact was blinded by a salt that was precipitating out of the cloth washing water. This revelation led the client back to a chemical that was being added to the plant process water for the control of algae. The cloth blinding issue was then able to be mitigated.



(a) (b)

Figure 5 Photographs showing (a) mechanical failure of the media through abrasion and (b) an example of material beginning to stick to the media surface indicating media plugging

To mitigate the blinding problem, FLS conducted air permeability tests on both virgin filter media and blinded media to determine the level of flow degradation. The blinded media samples were then put through a series of high-pressure washing tests to determine if the media could in fact be rejuvenated for further use, as they were not showing signs of mechanical damage.

The testing indicated that high-pressure washing in some instances could return the permeability of the blinded media back to approximately 90% of the permeability of the virgin media. With this information, FLS conducted media rejuvenation trials at site on an operating filter press. The goal of the test was to determine the following:

- If the media achieves 2,500 cycles before blinding, how many additional cycles can it achieve post-rejuvenation before blinding is experienced again?
- If rejuvenation is successful, how many times can the media be rejuvenated before the media fails through mechanical damage?

After a year of site testing at this particular site, it was found that virgin media would blind at ~2,500 cycles. The media, once rejuvenated, could be placed back into service and achieve another 2,000 cycles before becoming blinded. The media had not yet failed but was displaying signs of mechanical damage causing the test to be stopped.

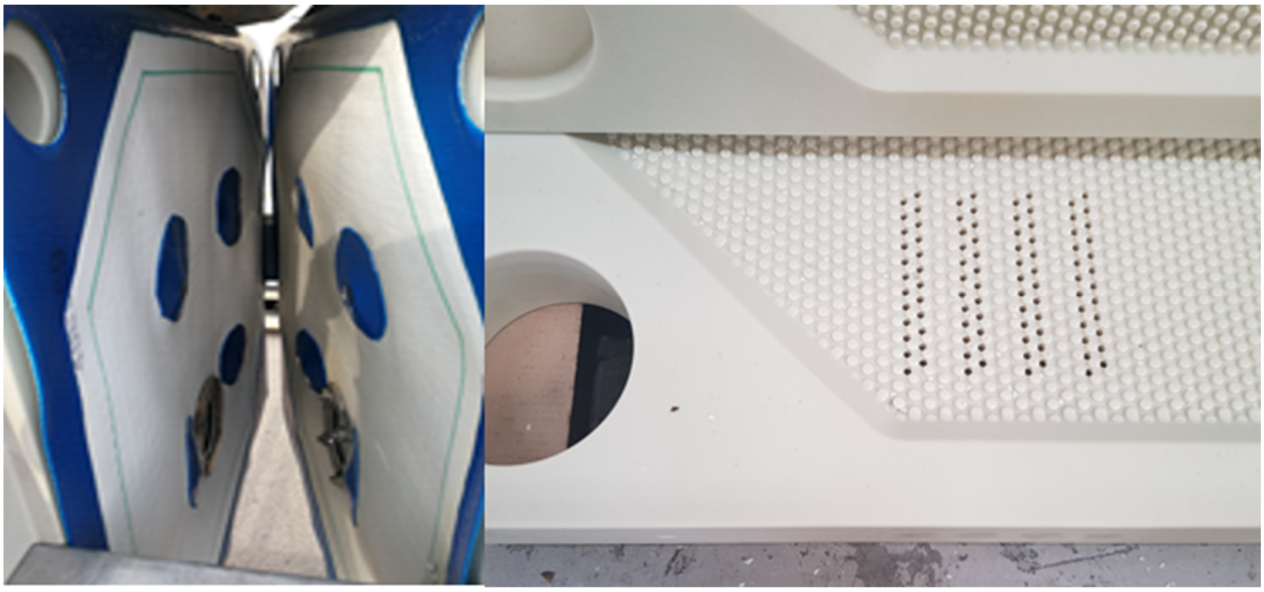
Knowing now that mechanical damage was being seen at 4,500 cycles at this particular site, FLS investigated the root causes. As more and more media was tested and run until mechanical failure, there were trends occurring on where the damage was occurring. It was found that the media would fail consistently in the locations on the plate where the falling cake would collide with a hard corner or transition within the filter plate. These locations are the top corners of the stay bosses (Figure 5) and the transition from the chamber to the sealing surface at the bottom of the filter plate. In addition, patterns of failures were seen in other locations of the plates where there were obvious changes in plate geometry, specifically regarding media support grid as seen within Figure 6.

With this data, the FLS filtration team embarked on a plate redesign to ensure that the filter media was supported properly in all locations, and that filtrate ports were sized adequately to provide the correct filtrate and air velocities, while still maintaining full media support. The transition areas of the plate were also smoothed to properly support the media. The filter plate design is known as the FLS Maxa™ plate and is installed on every filter that is manufactured.

To overcome the abrasion that is inflicted on the media at the tops of the stay bosses and lower sealing edge, the filtration team relied upon the knowledge of our FLS wear parts division, and a proprietary wear coating was developed, to coat the media in the known wear location. This wear coating provides protection to the media filaments from falling cakes, while not affecting filtration performance as it is not applied within the filtration zone. This product has been named FLS Maxa media and is available for all filters within the FLS portfolio.

With these two key products developed, further testing has been completed which concluded the following:

- Flood washing of the plate sealing surfaces every cycle is imperative.
- A robust cloth shaking device is required to consistently removed all cake from the filter chamber every cycle.
- Media can be rejuvenated, achieving slightly fewer cycles to blinding than virgin media.
- The number of cycles to blinding is repeatable with each subsequent rejuvenation.
- Media rejuvenation allows media to be reused until it displays signs of mechanical abrasion.
- The use of the Maxa products saw cloth life increase from 2,500 cycles to exceeding 7,500 cycles during this testing period.



(a) (b)

Figure 6 (a) Maxa media showing wear resistant coating over the common failure zones; (b) Maxa plate showing its smooth transitions and consistent media support surface

For the development of the AFP2500 filter, the copious amounts of testing that had been completed drove the design of the new filter plate. FLS has traditionally utilised a lower centre feed eye for its AFP1500 and AFP2000 machines as these plates are relatively small and easy to handle. To change the media on these smaller filters, a cassette of 10 plates is removed completely from the filter, a pre-maintained set is lifted from the maintenance rack and installed into the filter, and the filter is then put back into service, minimising the amount of time the filter is offline and not producing throughput. For the AFP2500 filter, however, FLS wanted to design a filter that would provide our customers with the most filtration surface area and cake volume of any 2.5 m filter currently available. To achieve this, the outside plate dimensions arrived at ~3.2 × 3.4 m in size. This seemed too large and cumbersome to be lifting entire plates out of the filter daily, and for this reason the FLS filtration team decided to use dual upper feed eyes. The use of the upper eyes allows the media to be removed from the filter without the removal of filter plates, allowing the operators to connect a cloth lifting apparatus to 10 shaker bars, which will subsequently lift 20 pieces of media from the filter at one time. The operator can then connect the lifting apparatus to 10 shaker bars in the maintenance rack, containing pre-serviced media and place them back within the filter. The filter can then be placed back into service with minimal filter downtime.

FLS wanted to further improve the maintenance of the components which are most important to cloth life; the flood washing system, the shaker bars, and the media sealing surfaces.

A maintenance system was developed (see Figure 7) and was made up of several specialty racks and fixtures which allow the operators to maintain the media with ease. The system include a high-pressure washing box where media can be rejuvenated and then visually inspected to ensure that no mechanical damage is present before the media is returned to service. This wash box also allows for the testing of the flood washing nozzles, allowing them to be easily cleaned or replaced if they are found to be non-operational. The system ensures that every major system that contributes to cloth life longevity is easy to maintain and inspect, while the filter remains in operation.

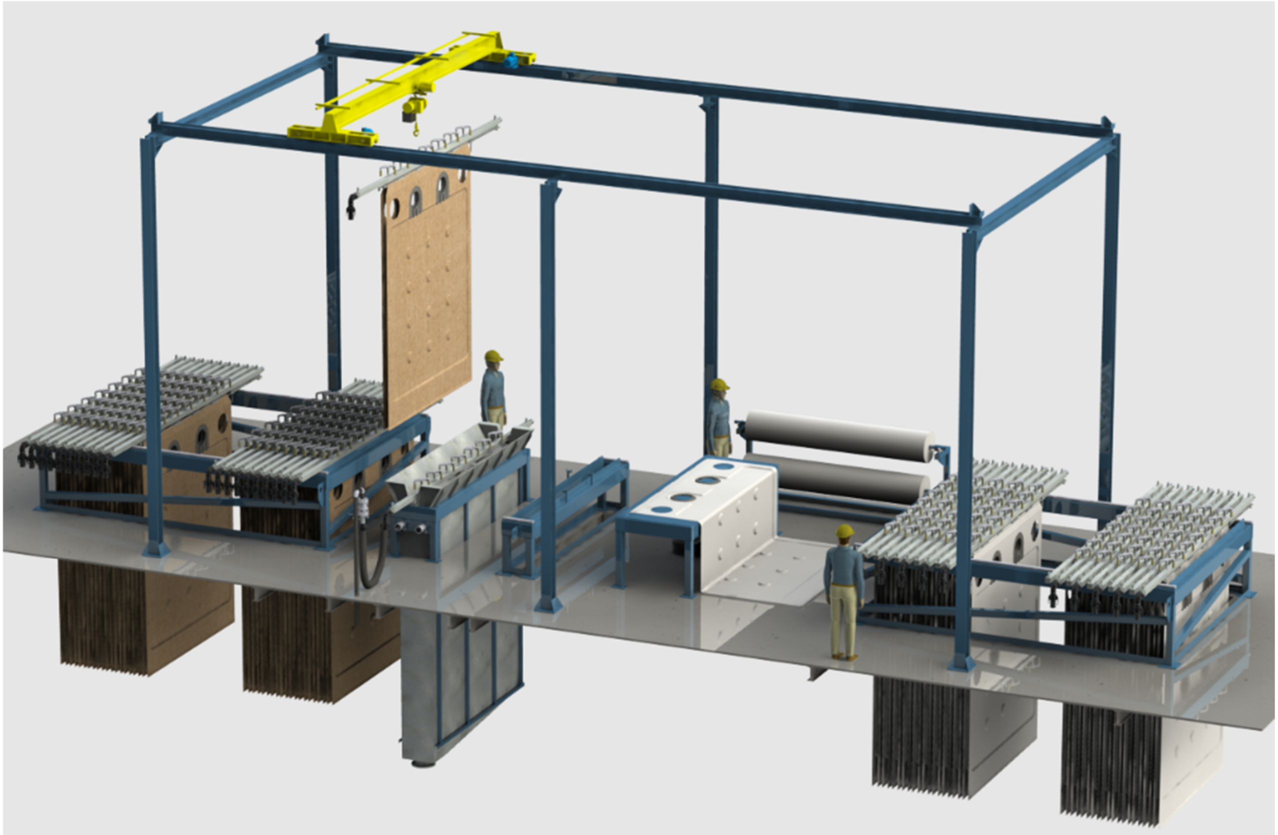


Figure 7 Rendering of the cloth maintenance system that has been developed for ease of maintenance and extended cloth life

2.4 Objective 4: optimise opex per tonne of material dewatered.

Optimising the operational costs of dewatered tailings facilities will lead to the adoption of dewatered tailings by more mining companies, as they compare the costs with those of traditional tailings disposal methodology. Tailings are a waste stream and not all mine sites suffer a shortage of water supply, meaning that for these sites, water savings are in fact not an incentive and the dewatered tailings solution needs to be comparable in total cost of ownership (TCO) as the traditional tailings storage facility.

The TCO of a dewatered tailings facility is certainly affected by topics that have been previously detailed within this paper; installed filter weight, cloth maintenance and filter maintainability. The success of the filter plant relies heavily on the availability of filters, and their ability to consistently meet the required throughput tonnage and target filter cake moisture.

To optimise on operational costs within these facilities, FLS conducted large volumes of lab scale testing, field testing and desktop studies to investigate and develop an array of ancillary technologies, all designed to either improve availability or minimise energy wastage.

These technologies are as follows:

- The patented FLS Intelliplate™ automated cloth failure detection device.
- The patented FLS Automatic Moisture Analyzer.
- The FLS Blue Box: automated machine control system.

2.4.1 Intelliplate

The Intelliplate automated cloth failure detection device is designed to be fitted to all FLS filter plates (see Figure 8). It is capable of communicating wirelessly with the machine control system, and will provide the plant control system with an alarm if a piece of media fails. The operator will be notified that a piece of media has been breached on any of the installed filters. By walking the length of the filter, he will instantly see the plate with the failed media as a red LED light will be blinking on the plate with the failed media.

The Intelliplate is not just useful for minimising downtime when an unexpected failure occurs. The device will also track how many cycles each piece of media has completed, storing and trending this data within the machine control system. This data is then used to track filter media life, advise operators of when a cassette of media is nearing the number of cycles in which media maintenance is required. The operators use this as a tool to schedule their daily cloth maintenance activities, ensuring that all media is maintained in a preventative manner, and not using a reactive methodology. The device is also able to provide an alert if premature media failures are continuously being observed on a certain plate, or within a certain region of the filter press, allowing operators to investigate and replace any out of specification components.

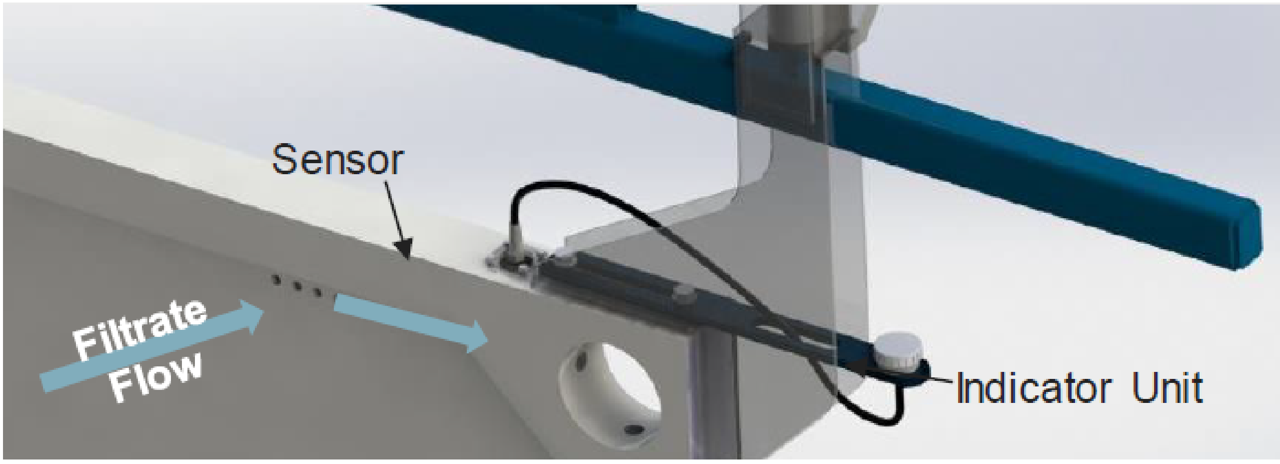


Figure 8 Rendering of the sensor mounted within a filter plate

2.4.2 Automatic Moisture Analyzer

The Automatic Moisture Analyzer seen in Figure 9 was developed out of a need to accurately measure the performance of a filter and ensure that material of the correct moisture is being delivered to the tailing's storage facility, while not being affected by material variability.

For decades, filters have been placed upon load cells to weigh the empty filter, monitor the increasing weight as the filter is filled with slurry, then to watch the decrease in filter weight as air is used to inflate the membranes and filtrate is squeezed and blown from the formed filter cake. The problem with using load cells is that the data provided is contaminated by noise and when talking with filter operators who have experience in the use of them, oftentimes only allows them to form rules of thumb, as opposed to providing a concise accurate dataset. The Automatic Moisture Analyzer is designed to capture a representative sample from the transfer chute underneath the filters, measure the moisture, and provide feedback to the machine control system. The FLS Blue Box machine control system will then autonomously optimise the filter control setpoints to allow it to meet the target moisture and throughput tonnage. As ore bodies and grind sizes change within the plant, the filter is now able to automatically adapt to the new feed conditions. In the case that the cake moisture is lower than target, the cake blow timer will be automatically adjusted and observed until the target is reached, saving on air consumption, pumping energy, component wear and various other services that the moisture data allows the machine to autonomously control. Initial testing of this device showed excellent moisture readings, however, a few minor issues were observed with the mechanical collection auger. A second prototype of this device has been manufactured and is being prepared for field testing.

Figure 9 The first prototype Automatic Moisture Analyzer being prepared for site testing

2.4.3 The FLS Blue Box: automated machine control system

In addition to facilitating the integration of Intelliplate and Automatic Moisture Analyzer interfaces, the FLS machine control system places a strong emphasis on enhancing the ease of filter operation and maintenance.

The control system is equipped with an integrated asset health management system, meticulously monitoring every valve and cylinder on the machine. It tracks their operations, analyses trends in the data, and promptly notifies the operator through the plant control system in the event of any changes in the operation of the filter or ancillary components. The notification includes guidance on where to investigate the issue.

This comprehensive data capture enables the identification of even the slightest changes in the operation of each component. This proactive approach allows for the early detection and investigation of small problems before they escalate into unexpected failures. While some issues may be promptly addressed, others may serve as indicators of underlying concerns that, if left unattended, could lead to significant downtime. The system empowers operators to schedule necessary maintenance during planned plant shutdowns, preventing unforeseen failures and minimising disruptions to throughput.

3 Conclusion

Following the successful completion of this development project, FLS has secured orders for seven AFP2500 units across three distinct contracts. These achievements are directly attributed to the detailed efforts outlined above.

The machine is designed to offer approximately 2,100 m^2 of filtration surface area, coupled with a maximum chamber volume exceeding 44 m^3. Preliminary desktop studies conducted during the development and optimisation phase indicate that this filter can efficiently dewater tailings at costs below USD 0.80 per tonne.

With five of the seven filters set for commissioning in the upcoming year, the FLS team has already validated the estimated production costs of the machine and is eagerly anticipating the analysis of real-time operational cost saving data from these plants. This analysis aims to validate the completed work and provide insights for further optimisation efforts.

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