Cost-effective alternative for ultra-fine coal recovery

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Abstract. Conventional flotation circuits struggle to recover valuable ultra-fine coal particles (less than 45µm), leading to significant losses. Conventional technologies typically discard these ultra-fines, sacrificing valuable resources to tailings. Eriez's StackCell® and Flotation Column technologies have demonstrated superior efficiency in the area of ultra-fine coal recovery compared to conventional methods, thanks to their application of wash water over deep froths. When deployed as part of Somerset International's patented Sub325® Fine Coal Recovery System, which captures a very high proportion of ultra-fines to product, total recovery and yield is maximised, thereby also reducing tailings waste. The fine coal recovery system flowsheet offers significant advantages by creating revenue from a waste stream and reducing tailings volumes reporting to tailings storage facilities.

1 Introduction

Recovering ultra-fine coal particles (< 45 µm) has long been a challenge for coal processing plants. The increased production of fine coal is driven by greater mechanisation in mining and more intense material handling [1]. As higher-quality coal reserves are depleted, more extraneous rock must be mined alongside coal, leading to greater coal degradation during transport. Additionally, satellite resources away from infrastructure are promoting additional rehandling, further reducing the average particle size of raw coal. As a result, coal preparation plants are now handling significantly more fine coal for cleaning and recovery. These have led to increased fine coal generation and losses.

Vacuum filters have been a traditional method for fine coal recovery, offering a relatively simple and established technology. They are effective at separating solids from liquids, which allows for the dewatering of fine coal slurries, offering high solids recovery over 95%.

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However, they have significant drawbacks in terms of operability, particularly when including thermal drying, including higher manpower demand, high maintenance and downtime, particularly when dealing with ultra-fine particles [2]. In addition, it has limitations in handling high volumes of fine coal, leading to fine coal losses to the tailings.

Alternatively, screen bowl circuits are a durable technology that requires less labour but discards about 50% of the minus 45 μm in the feed, with a recovery rate of 80 - 90% [3]. In addition, recycling screen drain can overload the fines circuits, cause further degradation, and limit recovery. This recycles stream makes up about 10% of the screen bowl feed, with an average of 20% to 40% w/w solids content. Consequently, it increases as the equipment wears. This inefficiency is significant, and the fine coal is still valuable in many metallurgical coal plants as a source of fine carbon. These inefficiencies not only waste a key resource but also increase tailings, creating greater environmental and storage challenges.

Technological advancements, such as Eriez StackCell® and Flotation Column, coupled with Somerset's Sub325® solid bowl centrifuge technology specifically developed for mining applications, have significantly improved ultra-fine coal recovery. Somerset International has developed a novel service-based model that integrates Eriez and Somerset's advanced recovery technologies, enabling coal producers to profit from previously wasted ultra-fine coal.

This paper examines this innovative approach, outlining its operational framework and assessing its economic and environmental benefits through a case study. By linking these advancements to real-world applications, the paper demonstrates how this partnership creates value while addressing longstanding challenges in coal processing.

2 Maximising recovery, minimising waste

2.1 Somerset International

Somerset International is recognised globally as a leader in sustainable mineral handling and processing, providing innovative technologies and expertise to the mining industry. With decades of experience worldwide and over 30 successful operations globally, Somerset International works with mining companies to reduce their tailings waste footprint while enhancing product recovery.

Somerset's business model is built around providing integrated service-based solutions for tailings management and fine mineral recovery for producers. This performance-based service agreement covers design, capital expenditure, installation, operations, and maintenance of the fine coal recovery systems, typically with no or low upfront costs to the coal producers. Somerset International has partnered with Eriez globally to provide flotation solutions from its suite of advanced technologies. Somerset International will complete all metallurgical due diligence necessary to develop the customised flowsheet to deliver maximum value for the client. This often includes on-site pilot test work to evaluate the metallurgical performance of the technology involved in any fine-coal recovery project.

By focusing on sustainable tailings management and maximising plant recovery, Somerset ensures improved processing efficiency while reducing waste. This model has proven effective in unlocking value from waste streams and addressing environmental challenges associated with traditional coal processing methods. The opportunity framework of Somerset International's service-based solutions for tailings management and fine mineral recovery is shown in Fig. 1.

Fig. 1. Opportunity framework of Somerset International's service-based solutions for tailings management and fine mineral recovery.

2.2 Eriez Flotation Division

Eriez's Flotation Division (EFD) offers cutting-edge engineering, metallurgical testing, and innovative flotation solutions for the mining and mineral processing industries. EFD is a global leader in mineral flotation systems with expertise and installation in various commodities worldwide. Its advanced technologies, including the HydroFloat, StackCell®, and Flotation Column, are designed to tackle complex flotation challenges across various particle sizes, from coarse to fine fractions. This work specifically focuses on the StackCell® and the Flotation Column.

2.2.1 Eriez StackCell® technology

The Eriez StackCell® technology enhances fine particle recovery by optimising energy input to improve flotation kinetics. It can achieve superior metallurgical performance with significantly smaller unit sizes than traditional methods. This is made possible by the innovative two-stage internal design, which separates the particle-bubble attachment and separation phases. Key benefits include over 40% energy savings, more than 50% reductions in plant height, footprint, and foundation loads, enhancing the flotation kinetics and, most importantly, reducing the overall capital cost of the project [4].

The design features two tanks: a contacting chamber and an outer separation chamber. The slurry travels into the contacting chamber, which uses a rotor-stator assembly and a rotating lid to create a high-energy environment for rapid bubble-particle interaction. All the necessary bubble-particle attachment will happen in the contacting chamber before the aerated slurry flows into the low-energy separation chamber. This quiescent separation chamber promotes the separation between the pulp and the froth. The slurry level can be adjusted inside the separation chamber to provide deep froth that can be washed, which provides a high-grade product. An illustration of the StackCell® is shown in Fig. 2.

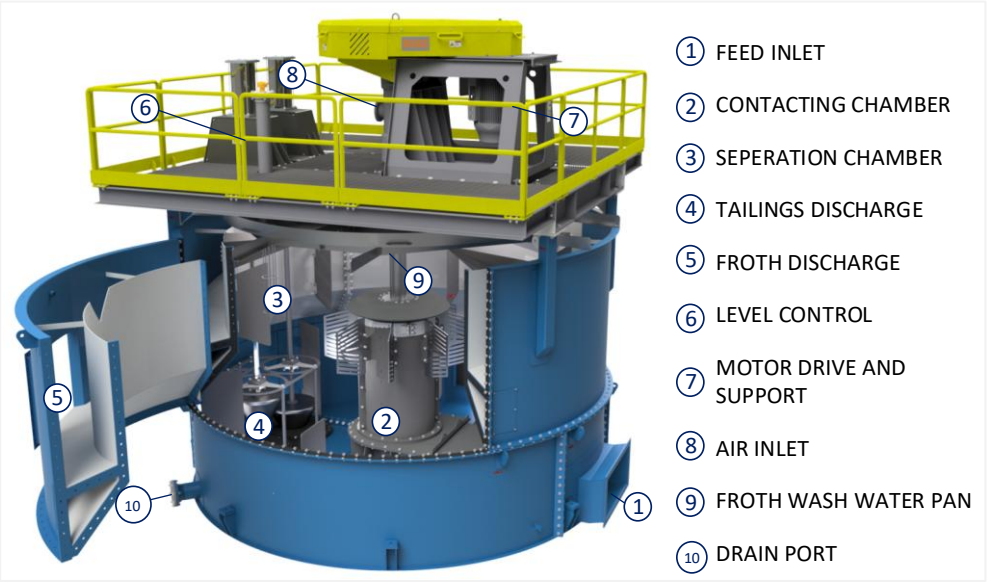

Fig. 2. A schematic illustration of the industrial scale StackCell®.

2.2.2 Eriez Flotation Column technology

Eriez Flotation Column is an efficient and cost-effective solution for recovering fine coal. Unlike mechanical flotation machines, Flotation Columns do not use mechanical agitation and allow deep froth operation, as shown in Fig. 3. This enhances selectivity and aids in the recovery of valuable material. Generally, the slurry enters the column at the entry point at the third of the Flotation Column height. The slurry descends against a rising swarm of fine bubbles the sparging system generates.

In this case, SlamJet sparging technology is used with the Flotation Column. This sparging system uses a series of removable air lances, including a single orifice at the end of each sparger. High-velocity air is injected into the Flotation Column to create a rising swarm of fine bubbles. The particles-bubbles attachment occurs here and then rises to the top of the Flotation column. Wash water is added from the top of the Flotation Column, percolating through the froth and displacing any unwanted impurities from the froth product, resulting in superior ash removal compared to conventional flotation cells [5].

Fig. 3. The picture of the Eriez Flotation Column cell with the SlamJet Sparger system.

3 Case study: Stanmore's South Walker Creek fine coal recovery project

Stanmore's South Walker Creek (SWC) is a coal mine in the Bowen Basin, Australia, that has been in operation since 1995. The mine includes a coal processing plant with the capacity to handle approximately 8.4 million tonnes of raw coal per year. This single-module plant utilises standard material separation techniques to produce around 6.0 million tonnes of high-quality, low-volatile pulverised coal injection (PCI) coal annually.

The Coal Handling and Preparation Plant (CHPP) follows a structured process, as illustrated in Fig. 4. First, a loader feeds raw coal into a crusher, reducing its size to a maximum of 50 mm. The crushed coal is then sorted into three separate processing circuits based on particle size: coarse coal (> 1.4 mm), middling coal (0.25 mm – 1.4 mm), and fine coal (< 0.25 mm). Each circuit uses specialised methods to maximise coal recovery while removing impurities.

Coarse coal, which comprises about 70% of the feed, is treated in a dense medium cyclone (DMC) to separate impurities. The clean coal is further dewatered through a coal screen and a coarse coal centrifuge before being sent to the product handling facility. Meanwhile, the reject material is dewatered across a coarse reject screen before being sent to the reject handling facility. The mid-size coal fraction makes up about 15% of the total feed and has the functionality to be beneficiated using spirals or reflux classifiers. The mid-size product is then dewatered through fine coal cyclones, fine coal sieve bends, and fine coal centrifuges

before being directed to the product handling facility. The mid-size reject is dewatered using a cyclone high-frequency screen combination before being dry stacked with the coarse reject.

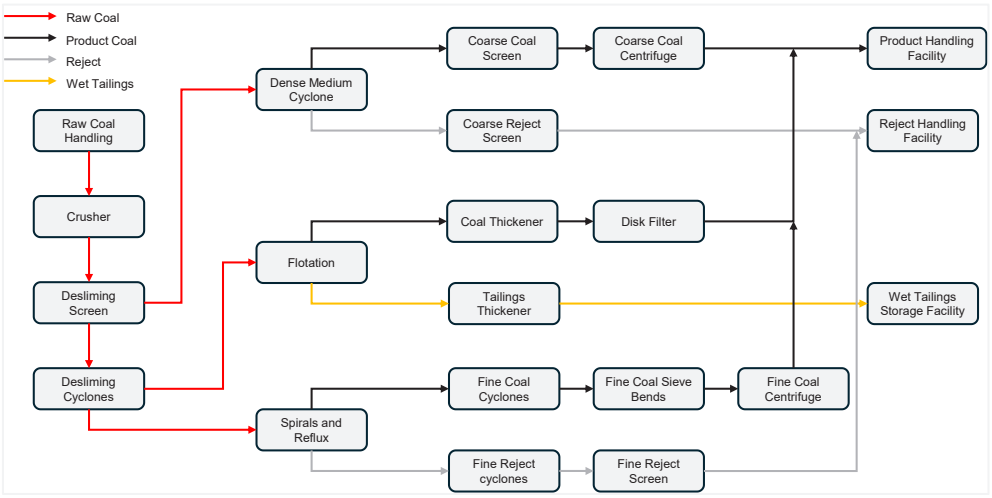

Fig. 4. The process flow diagram of Stanmore's South Walker Creek CHPP before installing Somerset's fine coal recovery circuit.

Fine coal consists of 15% of the total feed and is treated in the flotation circuit. The flotation circuit consists of 3.0 x 10.0 m Eriez column cells where valuable coal is recovered and transferred to a 20 m diameter coal thickener, with the underflow being dewatered by a vacuum disc filter before being sent to the product handling facility. The remaining reject material is processed in a tailings thickener before being sent to the wet tailings storage facility. As is common in the coal industry, a desire for higher feed rates and a high proportion of fines in the plant feed result in the flotation circuit operating at or overcapacity a lot of the time. Somerset International proposed a service-based business model to address this issue to help Stanmore improve resource recovery and reduce tailings volumes.

3.1 On-site pilot test work program

A pilot test program was conducted at Stanmore's SWC CHPP in late 2022 to assess the potential for additional fine coal recovery from its tailings stream. The on-site pilot program utilised one Eriez pilot scale StackCell® unit as a scavenger and one 500 mm diameter Eriez Flotation Column as a cleaner, as shown in Fig. 5.

Fig. 5. The pilot scale StackCell® and Flotation Column installed at Stanmore's South Walker Creek CHPP during the pilot test work campaign.

Over the course of the pilot testing, the scavenger feed quality observed ranged from 30-60% ash (ad) at 1.5 - 4.5% solids wt. This range reflected the typical long-term ranges seen at SWC, where the average tailings ash for the 12 months prior was 50%. In testing this range of scavenger feed quality, an observed trend emerged between scavenger feed ash and scavenger concentrate ash, as illustrated in Fig. 6.

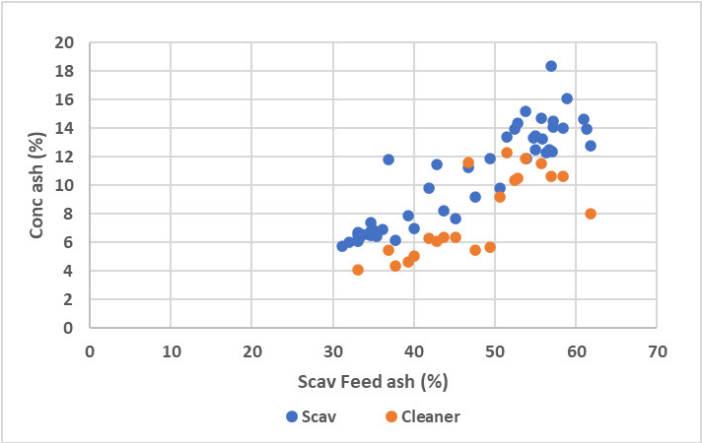

Fig. 6. Pilot scavenger feed ash vs scav and cleaner concentrate ash relationship.

The results demonstrate the StackCell®'s ability to recover < 38 µm material. Notably, the average scavenger concentrate sizing comprised of 20.3% mass passing < 38 µm, peaking at 40% in Test 40 (Fig. 8). These findings indicate that the StackCell® can recover a significant amount of valuable fine coal from the < 38 µm size fraction, which would have otherwise been lost to tailings. When the scavenger feed ash exceeded 40%, an increase in the scavenger concentrate ash was observed. Scavenger concentrate ash by size analysis indicated a significant contribution of the ash was from the < 38 µm size fraction, as seen in Fig. 7. This presented an opportunity to further optimise concentrate ash through the use of the cleaner column cell.

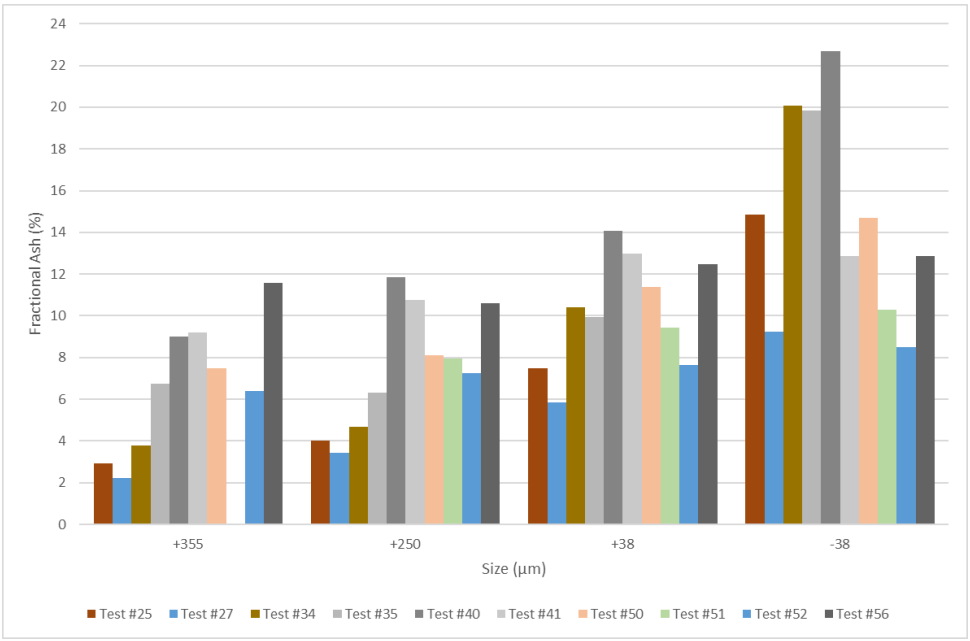

Fig. 7. Pilot scavenger concentrate fractional ash by particle size, treated by the pilot-scale StackCell®.

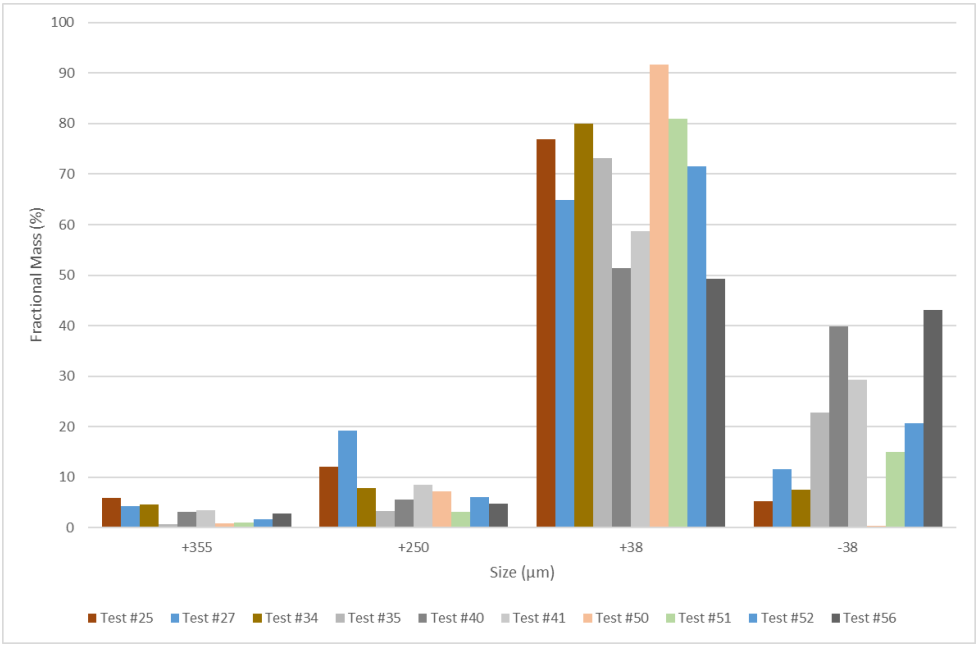

Fig. 8. Pilot scavenger concentrate fractional mass by particle size, treated by the pilot-scale StackCell®.

The pilot cleaner column cell was then used to treat the scavenger concentrate to further reduce the final concentrate ash. The use of the cleaner cell further reduced the scavenger concentrate ash, on average by 3.3 percentage points. This was achieved through employing additional reagents and deep froth washing.

3.2 Installation of the full-scale fine coal recovery circuit

After a successful pilot test work campaign, Somerset International designed and installed a fine coal recovery system at the SWC CHPP in 2023, which was commissioned in January of 2024. The fine coal recovery system is pictured in the foreground of Fig. 9, located between the coal thickener and the product conveyor.

Fig. 9: Somerset's South Walker Creek fine coal recovery system.

The process flow diagram of the fine coal recovery system is shown in Fig. 10. It was designed to recover an average of 10 tph (ar) of additional ultra-fine coal with an annual operating schedule of 8,000 hours, targeting over 95% availability. The system utilises a scavenger cleaner flotation process, comprising of an SC-100 StackCell® for scavenger duty and a 3.5 m x 8.0 m SlamJet Sparger Flotation Column for the cleaner duty. All flotation concentrate is dewatered using Somerset Sub325® solid bowl centrifuge technology and is analysed online for tonnage and moisture prior to being deposited on the SWC product belt.

The StackCell® receives a feed stream of approximately 1,800 m³/h from the existing CHPP flotation circuit. Variable cleaner functionality was built into the flowsheet to optimise concentrate ash and mass recovery. The StackCell® concentrate can be directed to the Somerset Sub325® solid bowl centrifuge for dewatering, the Flotation Column cell for cleaning or to the froth desliming cyclones, enabling slimes cleaning.

As identified during the on-site pilot testing, entrained slimes contributed a significant proportion of the ash in the scavenger concentrate. The froth desliming cyclones were included to isolate high-ash slimes to the overflow for further processing in the column cell, while the low-ash underflow reports directly to the Somerset Sub325® solid bowl centrifuge for dewatering. Flotation Column cell tailings are either recirculated back to the StackCell® feed or directed to the existing tailings thickener deaeration tank.

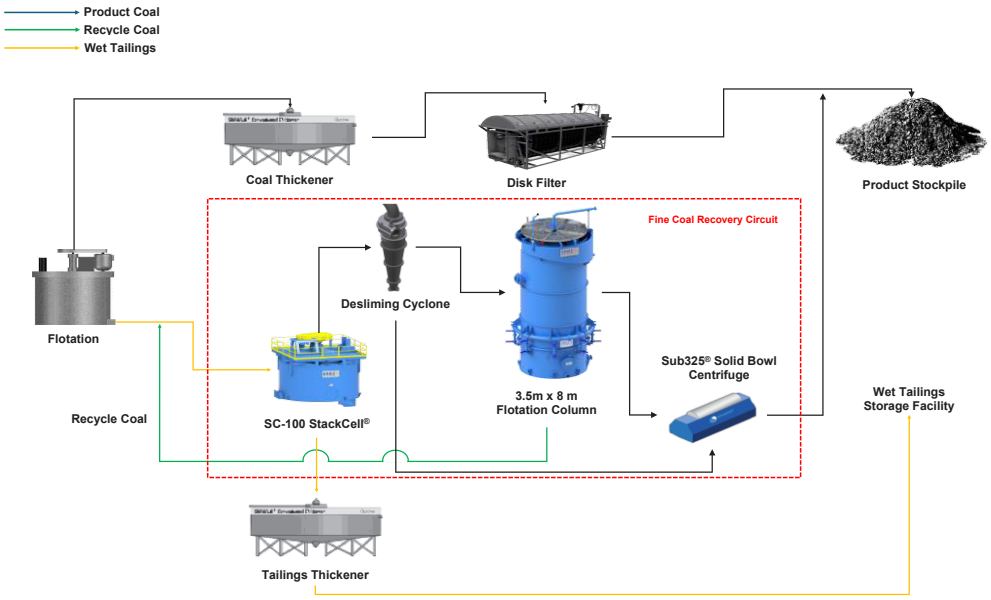

Fig. 10. Simplified process flow diagram of the fine coal recovery system installed at SWC.

Within a short period of time, the system was fully optimised, recovering the forecast tonnage, as shown in Fig. 11. Including commissioning and up until November 2024, the system had recovered an additional 60,000 tonnes (ar) of product, generating new revenue and reducing tailings disposal volumes by 14%. The reduction in tailings is significant as it extends the life of the tailings disposal facility, defers capital expenditure for tailings facility expansions, and lowers the environmental footprint of coal processing.

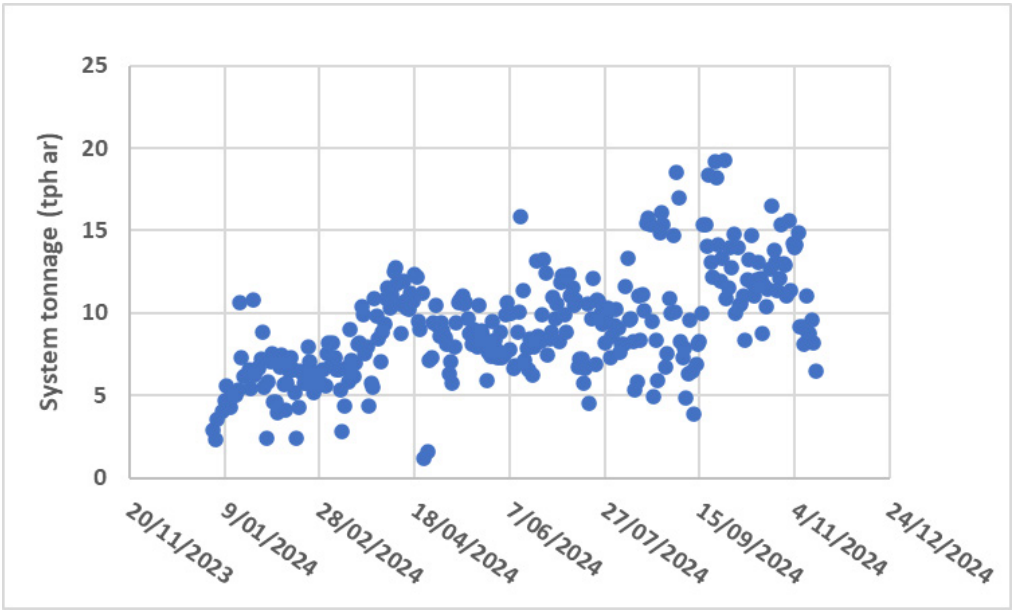

Fig. 11. Somerset South Walker Creek fine coal recovery system operating tonnage, daily.

During the first few months of operation the system was constrained by froth management limiting air rates in the StackCell®. Once additional controls were put in place, air addition was unconstrained, allowing operators to maximise recovery and air rates in the StackCell®. The standard operating mode is slimes cleaner flotation, producing an average ash of 10.0% (ad) up to November 2024. The advanced design incorporates cutting-edge technology such as online ash measurement on the scavenger feed stream, allowing operators to optimise the recovered tonnage and quality from the system.

4 Conclusion

Implementing Somerset's Sub325® Fine Coal Recovery System, integrated with Eriez flotation technology, represents a significant advancement in coal processing efficiency and sustainability. The innovative system not only enhances the recovery of fine coal particles, which were previously lost to tailings, but also improves environmental outcomes by minimising the waste footprint of mining. Eriez flotation technology ensures the system can achieve high recovery rates and optimum product quality due to its superior separation capability. Somerset's fine coal recovery system is a testament to how technological innovation can drive both operational excellence and environmental stewardship.

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