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# Comparative performance evaluation of Weir Minerals' Cavex® CVX and Cavex® DE hydrocyclones for optimised sand generation in tailings dam construction

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## Abstract

*This study presents a comparative evaluation of the performance envelope of the Weir Minerals Cavex® CVX standard cyclone and the Weir Minerals Cavex® DE two-stage separation cyclone, focusing on their effectiveness in tailings classification for sand generation, a critical component in tailings dam construction. Full-scale cyclones were tested in a pilot plant under controlled conditions to assess the impact of key operational variables, including feed pressure and feed dilution, on the quality of the cyclone underflow. Particular attention was given to the fines content of the sand material produced as it directly influences the structural integrity of sand constructed tailings dams.*

**Keywords:** *tailings, cyclone, re-cyclone, embankment, construction*

## 1 Introduction

### 1.1 Overview

This paper explores the comparative performance of two cyclones, the Weir Minerals Cavex® CVX standard cyclone and the Weir Minerals Cavex® DE two-stage separation cyclone, in the context of tailings classification for sand generation, a process essential to constructing stable tailings embankments. Recognising the importance of producing high-quality sand material with appropriate fines fractions is critical to maintaining the structural integrity of such embankments from a geotechnical point of view. This study investigates the cyclones' operational efficiencies under controlled pilot plant conditions. By varying key operational parameters such as feed pressure and feed dilution (and therefore flow rate) insights are provided into how each cyclone impacts the fines content in the underflow. These findings contribute to a deeper understanding of how a two-stage cyclone can assist in generating a more stable sand product compared to a conventional cyclone frequently used for tailings embankment construction today.

It is common for some mining operations that use the sand fraction for tailings embankment construction to feed cyclones direct from the processing plant without the use of thickeners or any tailings management system that can control surges and slurry density. This means that the feed parameters related to tonnage, pressures, %solids and rheological conditions can vary, impacting the efficiency and performance of a sand/slime classification. The reasons for writing this paper, and the investigation conducted herein, was in response to such issues occurring at a large copper mining operation having very high sand constructed tailings embankments using on-crest conventional cyclones. The mine feeds various on-crest cyclones direct from the plant, delivering high variability in the flow rate and %solids content. This impacts the pressure and subsequent classification efficiency. The consequence of this is an inefficient air core operation leading to

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roping and fishtailing that can be managed by the operation from a deposition point of view, but the changes in fines content of the underflow cannot be controlled and can lead to 'off specification' material being placed in the embankment. This is common and to some degree expected due to the natural variability of a processing plant operation. Having a thickener between cyclones and a processing plant can help to absorb some of this variability, but many operations still operate without thickening, particularly those in water-abundant areas.

This paper helps to demonstrate the improved efficiency of using a Cavex DE cyclone versus a conventional cyclone for a range of feed conditions.

## 1.2 What is the Cavex DE cyclone?

The Cavex DE cyclone, developed by Weir Minerals, is an advanced classification unit that integrates two stages of separation within a single piece of equipment. This design enhances classification efficiency by reducing the bypass of fines to the underflow and minimising the misplacement of coarse particles in the overflow. The cyclone comprises a primary cylindrical hydrocyclone directly connected to a secondary cylindrical-conical hydrocyclone, eliminating the need for intermediary pumping, piping or sumps. An adjustable cone between the two stages allows precise control over the flow split to the secondary cyclone, optimising performance and reducing wear in the transfer zone (López & Cepeda 2015). The inner workings of the Cavex DE cyclone are shown in Figure 1.

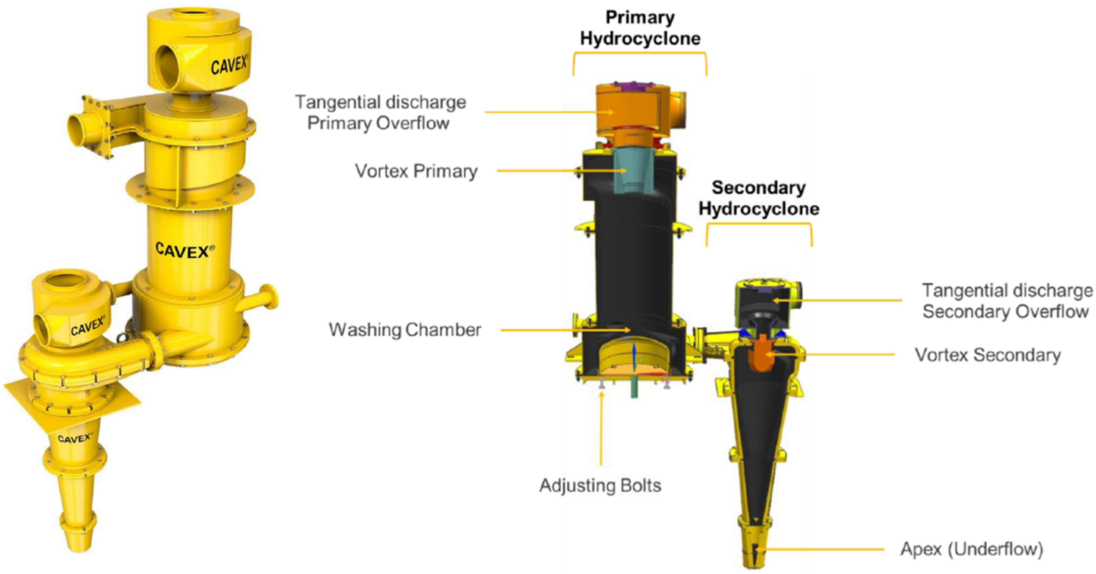


**Figure 1 Cavex DE cyclone (courtesy of Weir Minerals)**

One of the key features that sets the Cavex DE cyclone apart from past double classification equipment designs is its innovative cleansing chamber (or washing chamber). Positioned in the lower part of the primary hydrocyclone, this chamber includes a water injection system and a movable inverted dart valve. This adjustable valve precisely regulates the annular space between itself and the hydrocyclone wall, allowing optimal control over the pulp flow, enhancing separation efficiency and improving overall equipment performance.

The purpose of the cleansing chamber is to modify the viscous layer created as the pulp flows upward, close to the hydrocyclone wall, during the water-cleansing process. As observed by researchers Bloor & Ingham (1976) and later by Concha et al. (1994), this boundary layer along the hydrocyclone wall contains both larger particles and a fraction of fine particles that statistically tend to become trapped in the viscous region. The studies highlight how particle behaviour within the mixing zone at the inlet head is influenced by this viscous layer (López & Mogollones 2016). This viscous layer is disrupted or altered within the Cavex DE cyclone, allowing fine particles to escape and enter the classification zone, where they are drawn into the central upward flow and discharged as overflow. Larger, denser particles, which have greater energy, overcome the cleansing water's tractive force and proceed toward the transition zone, where they continue along their downward path (Castro et al. 2009).

The adjustable annular space in the Cavex DE cyclone effectively alters the inlet area, modifying the acceleration rate of both the liquid suspension and the upward-moving particles, similar to a variable apex design. This variability controls the cut size between cyclones and, consequently, the mass partitioning within the cyclone.

Fundamentally the objective of the double cyclone technology is to produce a steeper final underflow particle size distribution curve (as shown in Figure 2) compared to that of a conventional cyclone.

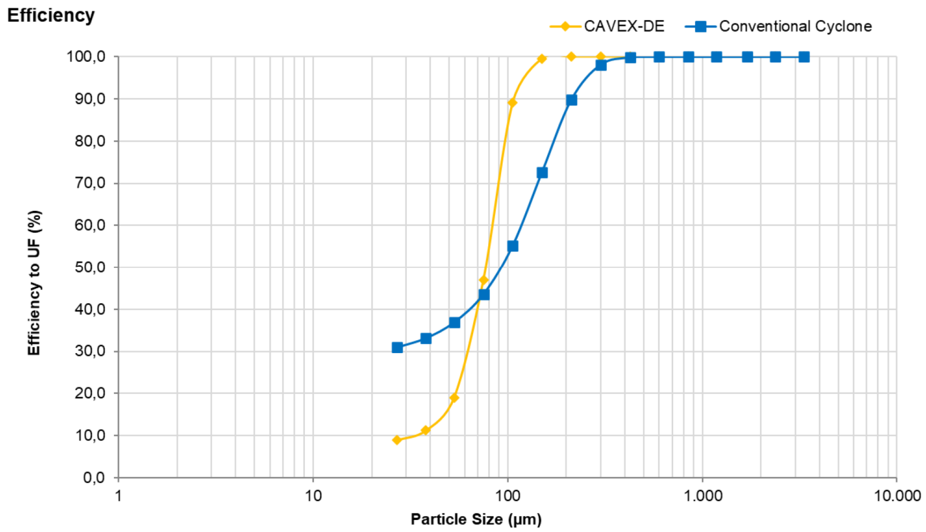


**Figure 2 Cavex DE cyclone classification efficiency (courtesy of Weir Minerals)**

## 1.3 Cavex DE cyclones for tailings embankment construction

In the last five to 10 years, the Cavex DE (also known informally as a re-cyclone) is becoming more commonly used for sand/slime classification specific to tailings embankment construction (where the sand fraction is used as a compacted or uncompacted construction material). Cavex DE cyclones are usually mounted in a radial cluster close to the tailings embankment that is progressively raised during operation (if needed). The sand fraction is usually pumped, or gravity fed, to a series of spigots or single point discharges located along the crest where the sand is deposited and then reworked with mechanical equipment (in most, but not all cases). Tailpro is aware of 11 projects where these cyclones are used for tailings sand deposition and embankment construction, with the majority used for high production rates (over 90,000 t/d). Figure 3 provides a typical Cavex DE cyclone cluster set-up used for tailings embankment construction.

**Figure 3 Cavex DE cyclone cluster set-ups (courtesy of Weir Minerals)**

Figure 4 shows a larger Cavex DE cluster set-up used for tailings embankment construction at a mine in Chile, utilising 2 x 22 x 500/400CVX-DE cyclones to generate 32,800 t/d of sand for embankment construction. The feed is 35–40% solids by weight with a requirement to produce sand having < 15% fines passing 75 microns (Tyler Mesh 200). This requirement is fairly common in Chile, and other seismically active areas, to ensure geotechnical stability.

**Figure 4 Cavex DE cyclone cluster for a large mining operation in Chile (courtesy of Weir Minerals)**

# 2 Cyclone pilot plant trials

## 2.1 Configuration

Tailpro has several cyclone set-ups at its lab, consisting of Weir, Krebs and other vendors. For this paper a Cavex 250/150CVX-DE cyclone set-up was tested in parallel with a standard Cavex 250 CVX cyclone, both mounted on a 3 $m^3$ tank required to provide the adequate volume for a continuous sand/slime classification process without reducing pressures that would impact the fines fraction assessment. The feed was recirculated on a constant basis and samples taken once pressures had stabilised. Figure 5 provides an overview of the cyclone pilot plant area (Figure 5 a), with the rig on the left used for mill grind assessment and the central tank showing the Cavex DE mounted on a 3 $m^3$ tank with the Cavex 250 CVX behind. The tank on the right is a backup feed tank but was not used for these experiments. The Cavex DE experimental flow sheet is also provided in Figure 5b.

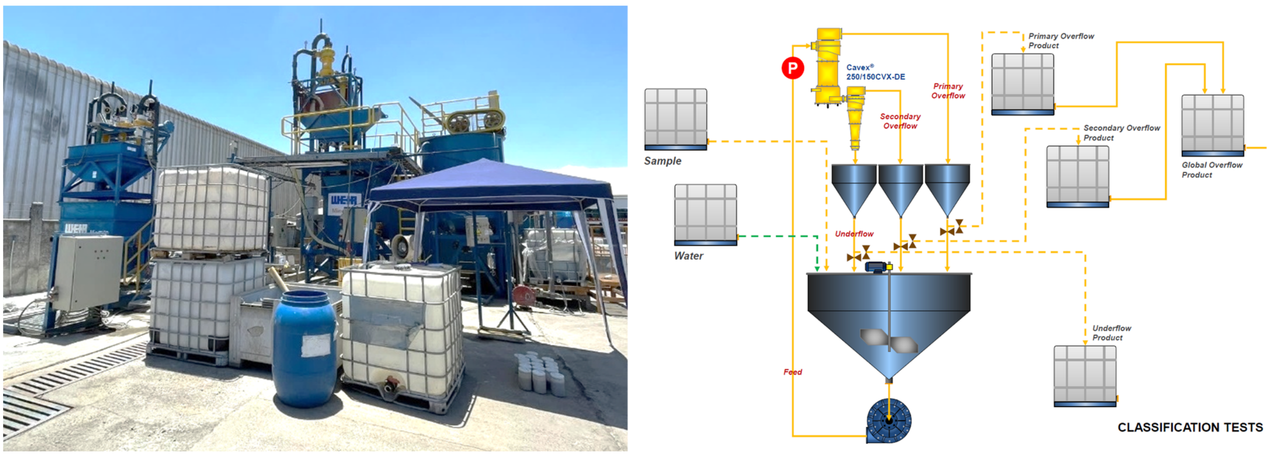


**Figure 5 (a) Tailpro cyclone pilot plant operations; and (b) Cavex 250/150CVX-DE flow sheet**

## 2.2 Tailings feed, operating parameters and sampling

A sample of final copper flotation tailings (i.e. combined rougher, scavenger and cleaner tailings) from a large open pit porphyry project in Chile was used in the pilot plant trials. The sample, having a $P_{80}$ of approximately 180 microns and being considered as a medium to coarse grind, was run through both cyclones under the same feed parameters. The sampling was conducted once the cyclone was operating in a continuous stable condition. Samples were collected simultaneously from the underflow and overflow of the cyclones (both overflows in the case of the Cavex DE) and tested for %solids to assess the mass concentration, and the particle size distribution was determined using laser diffraction to correctly identify the fine fraction.

Table 1 provides the feed inlet conditions that were tested to assess the cyclone product performance. It should be noted that feed pressures in excess of 15 Psi (103 kPa) in an industrial application are common, however, the purpose of the paper is to assess the fines content of the sand when abnormal conditions occur such as tonnage and flow rate reduction, which lead to lower inlet pressures and greater air core instability.

**Table 1 Cyclone feed inlet conditions tested**

| Feed inlet conditions | Value |
|---|---|
| Feed %solids (w/w) | 25%, 30%, 35% |
| Feed inlet pressures | 5, 10, 15 Psi (34, 69, 103 kPa) |

Sample cuts were taken three times at each product point to ensure representativity, as drastic variations between the two cyclone operations was not expected and precision was required in the reporting. An average result was taken of the three cuts in the event that the measurements were similar. Where variations occurred, the process was repeated.

As part of the Cavex DE set-up, since there are two vortex finders and technically two apex (one apex and the cleansing chamber), the vortex to apex ratio was experimentally changed to different values compared to the standard Cavex 250 CVX using a vortex finder of 60 mm and apex of 30 mm that provides an underflow sand having less than 20% fines in the underflow for the sample tested (for over 15 Psi). Weir Minerals provided assistance with the start points, based on its modelling and experience, and finally a vortex finder of the same ratio (60 mm, and an apex of 30 mm) was used on the secondary cyclone as an initial mass balance match between the two cyclone configurations. The experimental ranges of both cyclones were reviewed using these ratios to prevent drastic instability to the air core that would have voided a particular cyclone technology.

Finally, it should be noted that the washing inlet to the cleansing chamber (see Figure 1) was not used in these experiments to further provide a direct comparison with a conventional cyclone operation. Had the washing inlet been considered, a further reduction in fines would have been expected. This water inlet addition also allows the Cavex DE to operate at a higher %solids feed compared to a conventional cyclone.

## 2.3 Experimental data

The higher feed solids concentration of 35% was the original start point for the tests and, as the sample was recycled, the feed tank was diluted with process water to obtain data for the lower feed inlet concentrations. The sample collection was kept to a minimum during the process to prevent changing the sample properties for posterior operations. Once the slurry was recirculating and stable (usually within a few minutes), samples were collected with a sample cutter from the underflow and overflows (both overflows independently, in the case of the Cavex DE). The samples were measured for particle size distribution (2 mm to 0.01 microns), with the percentage of fines passing 75 microns (Tyler Mesh 200) in the underflows, and all samples were dried to understand the %solids.

### 2.3.1 %Solids feed concentration

The first test runs considered feeding both cyclones at 35% solids for the three feed inlet pressures analysed as part of this testing campaign. The following graph provides the results of the underflow in terms of the measured underflow density and also the percentage passing Tyler Mesh 200 (75 microns).

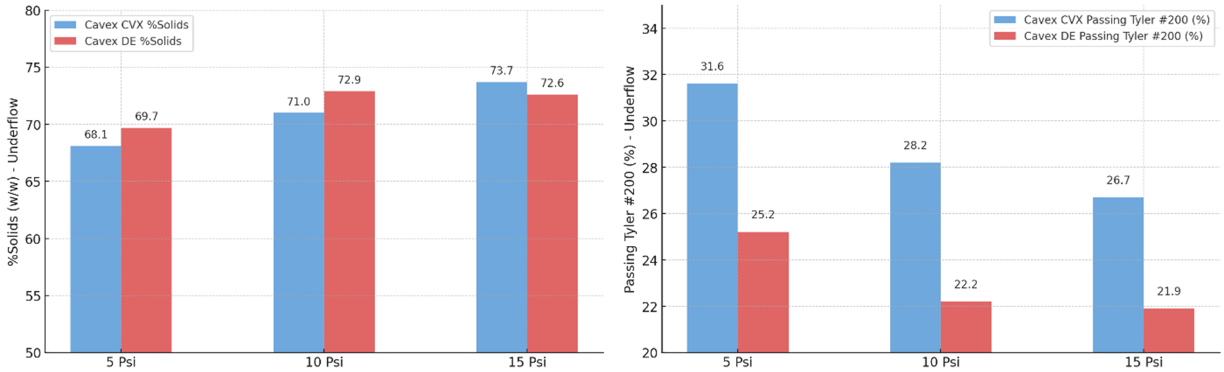


**Figure 6 35% solids feed concentration – underflow density and percentage passing Tyler Mesh 200**

As can be seen, the amount of fines is less in the underflow for the Cavex DE cyclone. The following provides the full particle size distribution curves for 5 and 15 Psi to reduce graph saturation.

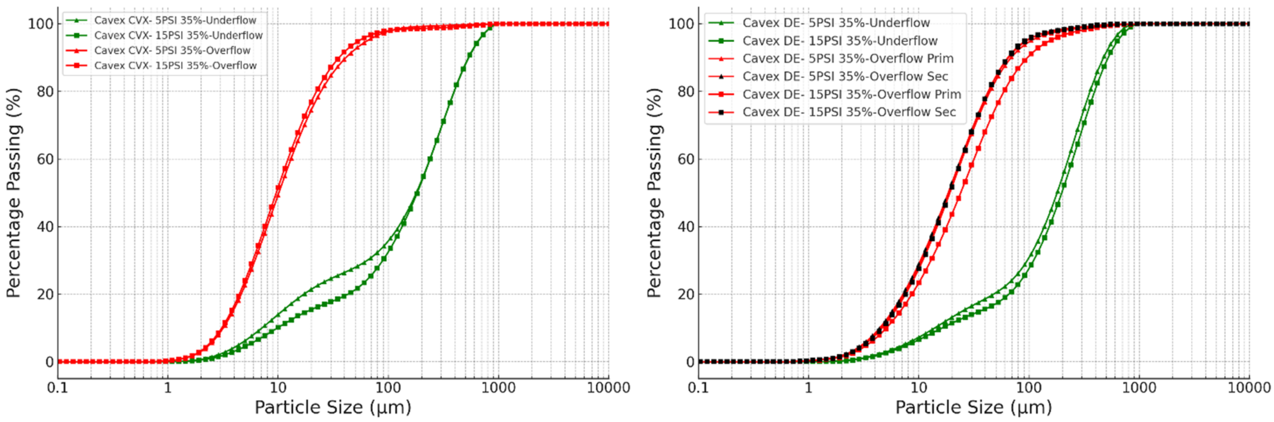


**Figure 7 35% feed dilution underflow and overflow variations (5 and 15 Psi)**

### 2.3.2 30% solids feed concentration

Reducing the feed density and applying the same three feed pressures generated a similar tendency in the 35% feed concentration results, as shown in the following graphs (Figures 8 and 9).

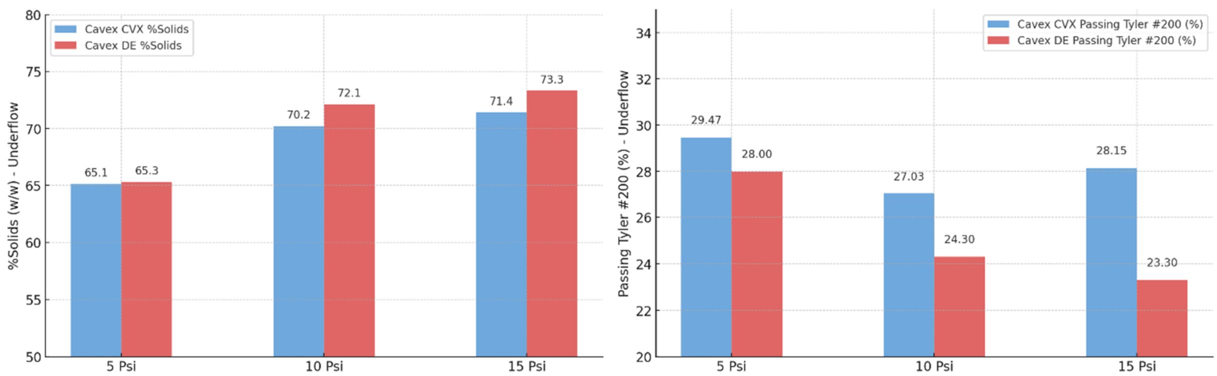


**Figure 8 30% solids feed concentration – underflow density and percentage passing Tyler Mesh 200**

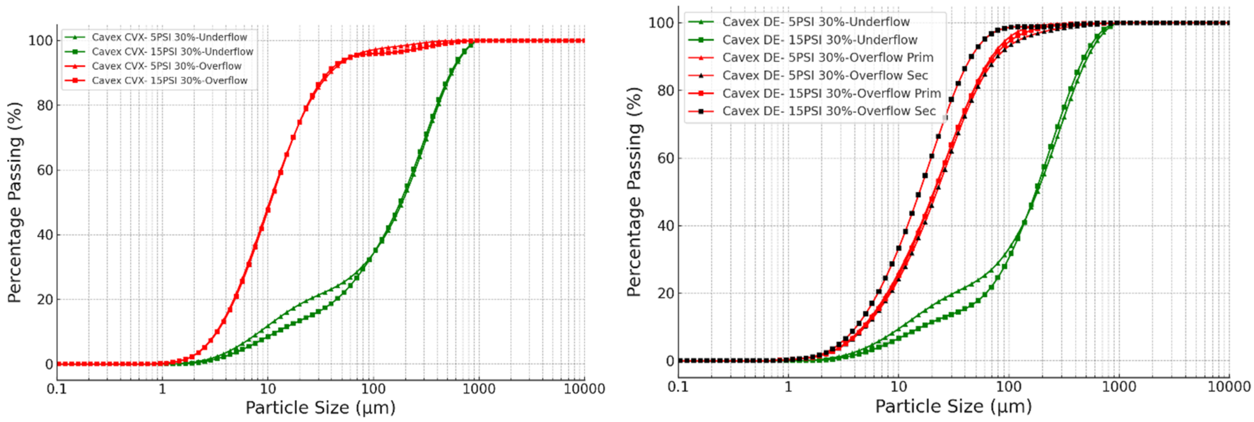


**Figure 9 30% feed dilution underflow and overflow variations (5 and 15 Psi)**

### *2.3.3 25% solids feed concentration*

A further reduction in the feed density and application of the same three feed pressures generated a similar tendency to the higher solids concentrations (see Figures 10 and 11).

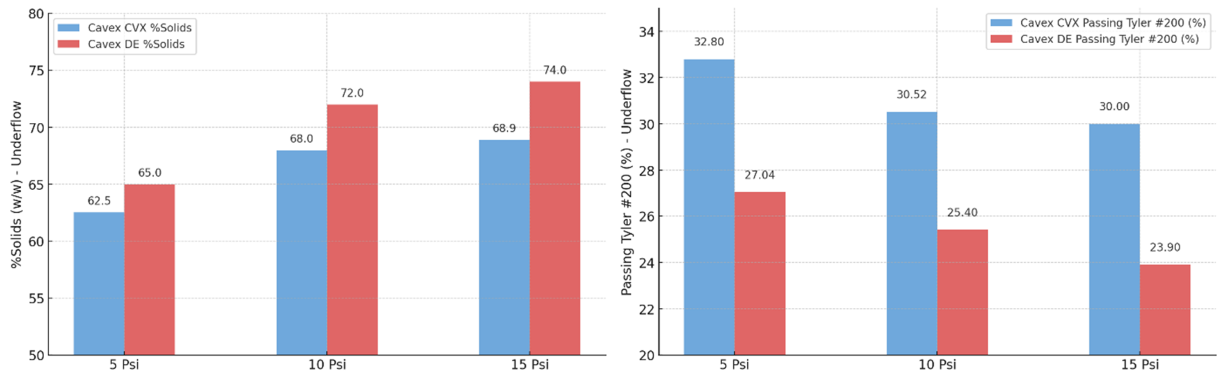


**Figure 10 25% solids feed concentration – underflow density and percentage passing Tyler Mesh 200**

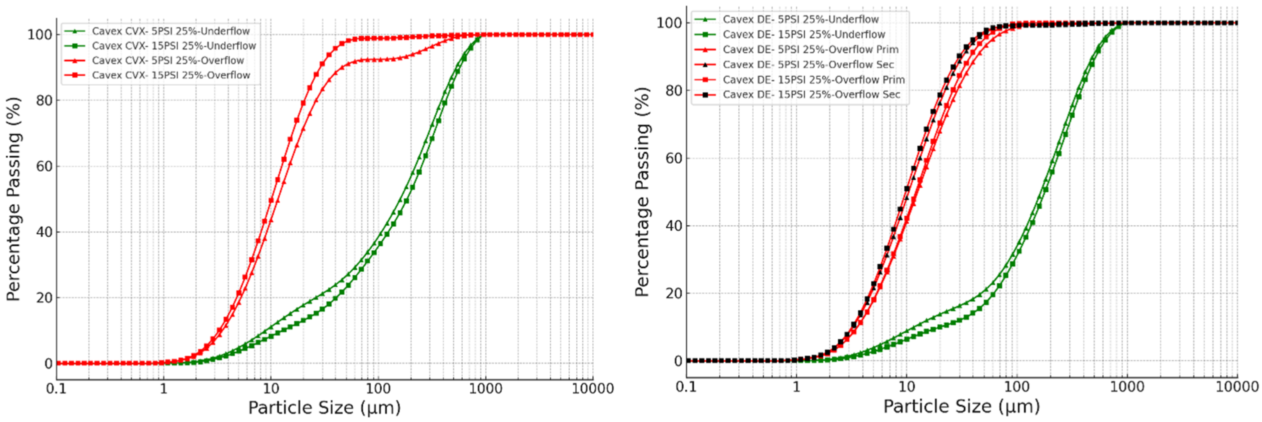


**Figure 11 25% feed dilution underflow and overflow variations (5 and 15 Psi)**

The combined underflow solids for all three feed conditions are presented in the following graph (Figure 12) for comparison purposes. The Cavex CVX had a similar tendency for reducing the underflow concentration as the feed %solids become more diluted, whereas this difference was not as great with the Cavex DE cyclone, which showed an increase in underflow density at the higher pressure of 15 Psi when the feed density was reduced.

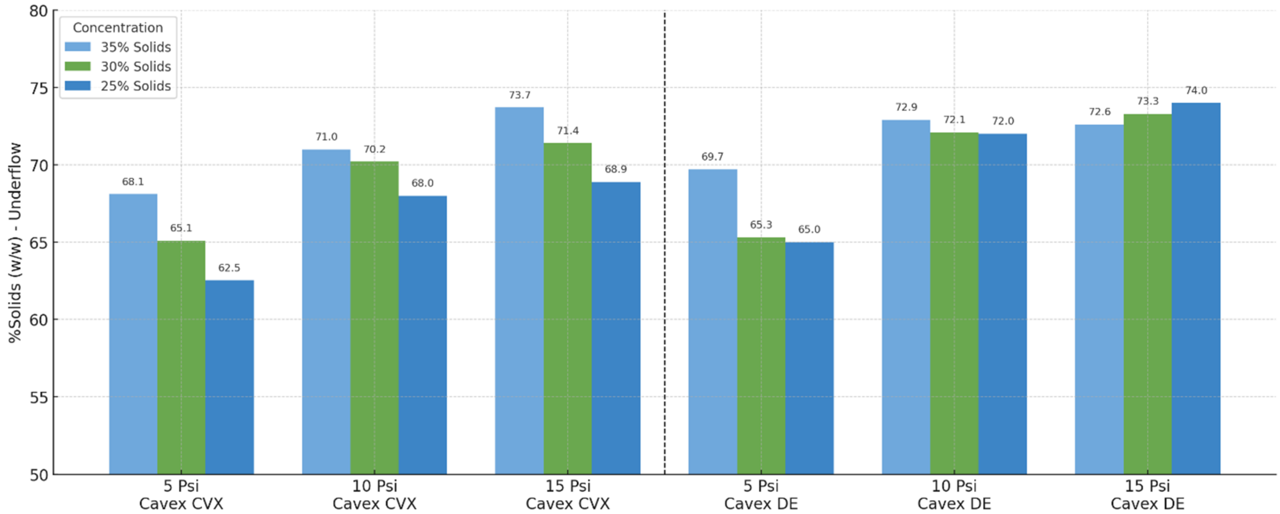


**Figure 12 35, 30 and 25% solids feed inlet concentration – underflow density comparison**

Figure 13 provides the same comparison as the previous graph for the percentage passing 75 microns. The Cavex DE produced less fines in the underflow compared to the Cavex CVX. Even at a very low feed pressure of 5 Psi, the quantity of fines was slightly less than the Cavex CVX operating at three times the feed pressure (15 Psi).

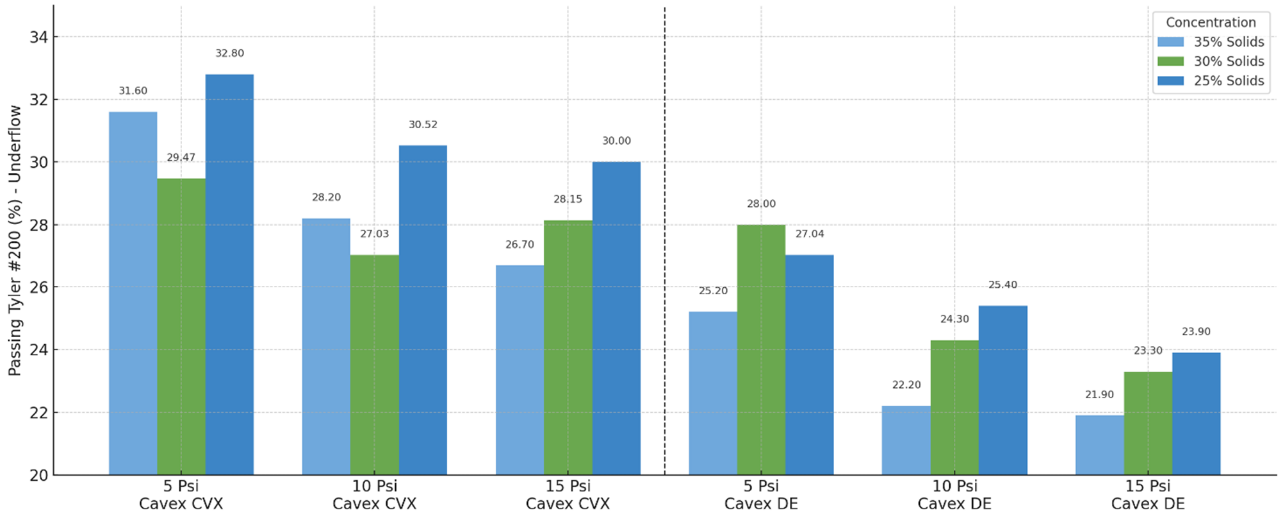


**Figure 13 35, 30 and 25% solids feed inlet concentration – percentage passing Tyler Mesh 200**

One key observation is that the actual mass split between underflow and overflow remains unknown, as it was impractical to measure flow rates during testing due to the high flow rates involved. Even if flow rate measurements had been feasible, they would likely have caused instability in the recirculated feed, thereby affecting the cyclone feed pressure and particle size distribution. To address this, future studies could leverage simulation modelling tools, such as the JKSimMet software package, to analyse mass split variations under the studied scenarios and gain insights into the resulting sand inventory fluctuations.

# 3 Conclusion

This paper presents experimental data from a pilot plant operating under identical feed and operating conditions, comparing a conventional cyclone (Cavex CVX) and a double separation cyclone unit (Cavex DE) for processing medium to coarse ground copper tailings. The experiments aimed to determine whether the Cavex DE cyclone could reduce the quantity of fines passing through Tyler Mesh 200 (75 microns) under varying feed conditions; particularly low pressure, where cyclone efficiency is reduced. The results successfully demonstrated this capability for the tested sample characteristics. Notably, the Cavex DE also exhibited a surprising stability in underflow conditions when inlet feed dilution increased and operating pressures were reduced.

From a geotechnical perspective, one critical aspect of cyclone sand tailings embankment construction, especially in seismic regions, is maintaining a fines content below a required value (typically less than 20%). The performance of the processing plant directly influences the cyclone feed. In cases where intermediate infrastructure, such as thickeners or surge tanks, is unavailable, the fines fraction in the sand used for construction is prone to variability and can lead to ‘off specification’ material being placed in the embankment shell. Routine fluctuations in processing plant operations make it impractical for tailings operators to mitigate reductions in feed flow pressure and density by adjusting parameters such as the number of operating cyclones in real time.

The Cavex DE cyclone offers the additional advantage of water injection into the cleansing chamber, providing flexibility in the reduction of fines reporting to the underflow when needed. This feature minimises operational risks associated with changes in tailings properties, such as finer grinds or the presence of clays due to variations in ore mineralogy. The injection water can assist in reducing the amount of such fines reporting to the underflow, providing better operational control and compliance with sand specification. It can also aid with providing more flexibility in the apex/vortex ratio for sand deficit operations to push more mass to the underflow while using the cleansing chamber to force the fines to the overflow. Furthermore, this water injection capability allows the cyclone to handle feeds having a higher %solids density, which is particularly beneficial for some operations that may look to thicken tailings to enhance water recovery at the processing plant prior to pumping to the tailings storage area that can often be several kilometres away.

During the writing of this paper, Weir Minerals is developing a new system called Air Core Booster to further improve the efficiency of the fines to meet the underflow content target.

## Acknowledgement

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