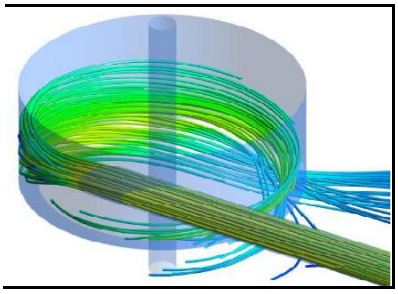
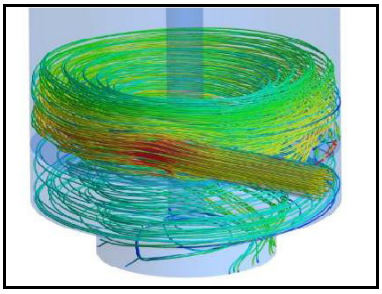
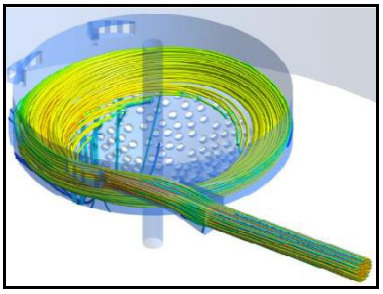
UNIT PROCESS CONSULTING

TECHNICAL DESCRIPTION

1.1 UPC Vector® Feed System

1.1.1 Development

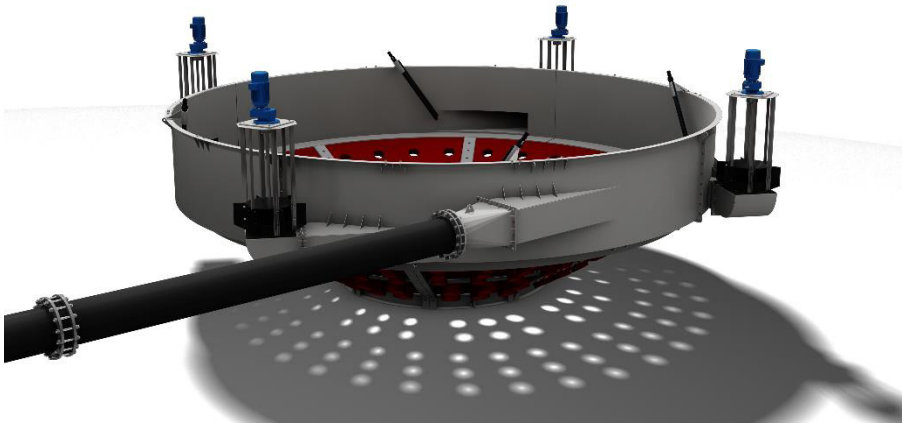
Open bottom designed feedwells are inefficient and typically suffer from short circuiting. The incoming feed lacks adequate mixing energy and sufficient contact with the flocculant and dilution water. Segregation then occurs causing the coarse material to settle and disperse to one side of the thickener floor, with the fine material then pluming towards the surface creating froth and resulting in dirty overflow. Since the development of CFD modelling, the more recent technology of the closed bottom designs has now also been discovered to short circuit. This usually leads to excessive flocculant consumption and poor performance with the thickener failing to meet the process objectives such as underflow densities and overflow clarities.

Open Feedwell Design	Closed Feedwell Design	Vector® Feedwell Design
		
		
Limited mixing and distribution	**Improved mixing but poor distribution**	**Optimal mixing and distribution**

There became an apparent need to design a feed system that can operate in variable feed conditions, while still maintaining the correct amount of mixing and dilution that is required for

optimal solids contact. It is also critical to develop a system that can control the exiting velocities and trajectory angle of the flocculated material, to ensure it is not over sheared and is distributed over the entire thickener floor.

The Vector® feed system has been specifically designed using lighter but more wear resistant materials. It has also been designed using a cyclone flow pattern and Vector® technologies as these combined produce efficient mixing, maximum de-aeration and allow the particles to distribute into the thickener tank through Vector® ports without over-shearing.



The velocities through the Vector® ports are controlled by the size and configuration reducing the exit velocities into the thickener tank. The size and configuration of the vectors along with the feedwell body, have been designed to accommodate a range of flows and a targeted operating window. The operating window is wider than our competitors, allowing the unit to operate efficiently with a range of feed concentrations and a broader range of throughputs (turndown and increases in throughput). The energy above the Vector® ports is maintained utilizing cyclonic principals to promote mixing and solids contact with dilution water and flocculant. Computational fluid dynamics (CFD) modeling has shown that the Vector® feed system distributes feed with a high degree of uniformity. The trajectory and distribution of the flocculated particles is uniform throughout the entire exiting region as shown in Figure 1, and Figure 2. This is critical to reduce pluming and to ensure the settled bed is not disturbed. Reducing the flocculant shearing significantly reduces flocculant consumption.

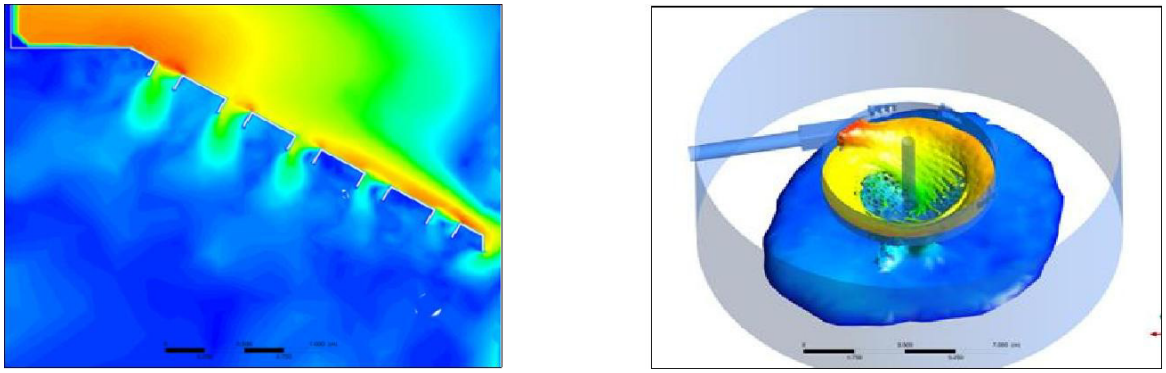


Figure 1: Velocity through Vectors® showing the even distribution into the thickener

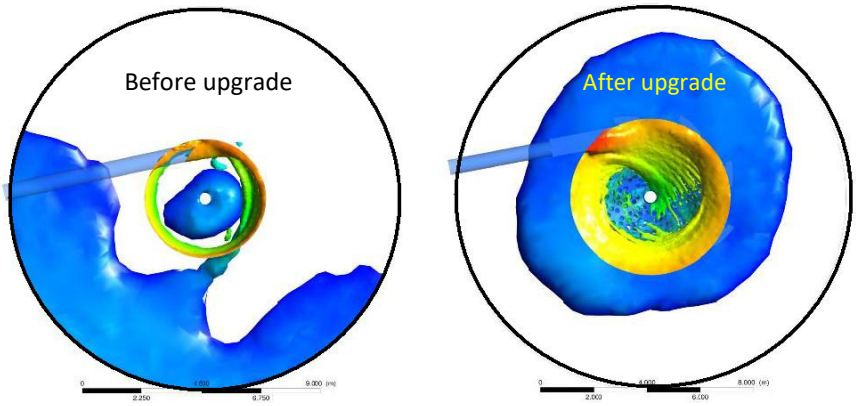


Figure 2: CFD models of even distribution into the thickener – Before and after Vector® upgrade

1.1.2 Operation

The distinguishing operating features of the Vector® feed system is its mixing efficiency utilizing a cyclone flow pattern, an in-stream flocculant injection method and its passive self-regulating or active forced dilution systems. Feed enters through the feed pipe at a higher velocity than the typical industry standard. This velocity promotes a vortex flow pattern inside the Vector® feedwell where flocculant at the desired strength is injected at pre-selected locations with the diluted feed. Particles that are not fully flocculated recirculate until they bridge with other floccules and gain enough mass to settle to the lower part of the feedwell body. The heavier floccules then leave the feedwell through the Vector® ports where the energy is controlled and dissipated in preparation for settling in the thickener tank. This proven method allows maximum solids contact while minimizing any shearing of the formed floccules.

1.1.3 Flocculant Injection

The activated flocculant, after dilution to correct strength, is injected directly into the stream of the feed and slurry dilution water. The injectors are designed to prevent blockages and are easy to replace. Valves are fitted along with flexible hoses to enable easy connections and adjustable flows. Figure 3 presents the slurry rotation and the flocculant injection points.

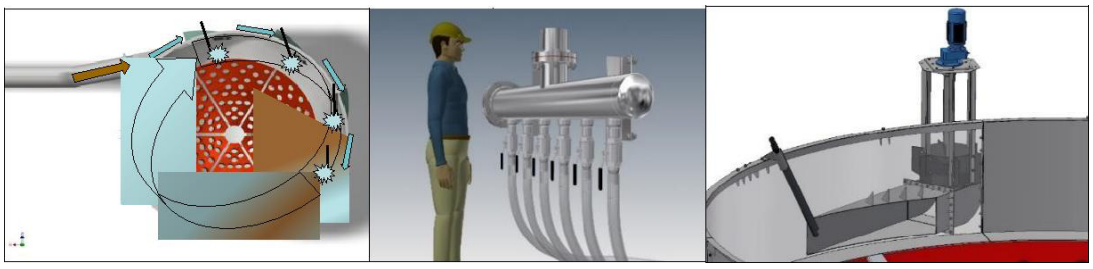


Figure 3: Slurry rotation within the Vector® feed system and the flocculant injection points

1.1.4 *Feed Dilution*

Diluting the feed to a selected concentration is critical for efficient flocculant and solids interaction. The Vector® feed system is fitted with either a HydroPort (passive) feed dilution system, or a HydroForce (active) controllable feed dilution system depending on the application. Both units dilute the incoming feed to the optimal concentration.

The HydroPort self-regulating dilution system utilizes the difference in specific gravities between the incoming slurry on the inside of the Vector® and the supernatant water on the outside. This differential head causes water outside to transfer inside thereby diluting the feed as shown in Figure 4. Uni-directional ports are used to ensure feed does not escape when the inside slurry density becomes too low and liquid levels start to equalize. This method is unique in design and **no other vendor** provides an effective one direction passive dilution system.

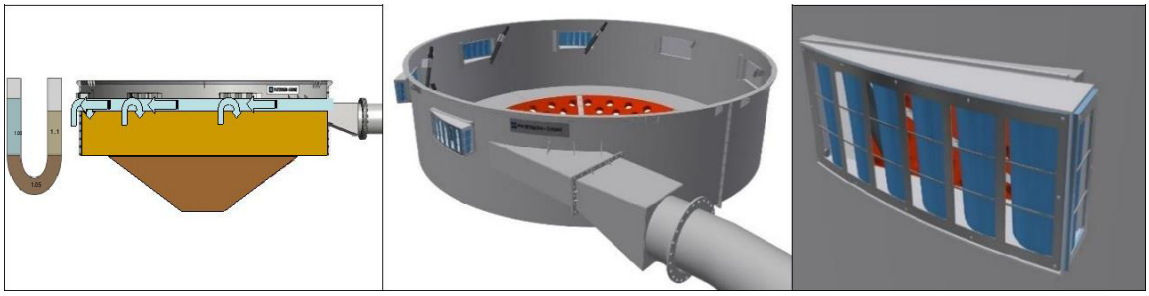


Figure 4: HydroPort - Self-regulating Uni-directional dilution system

The HydroForce controllable feed dilution system utilizes a variable speed axial flow pump to provide the desired volume of dilution water required. This is drawn from the thickener surface to prevent disturbing the settled bed or disrupting the dynamics within the thickener. This unit is accurately controlled via a locally mounted variable speed drive and control loop provided from the existing DCS. These interact with a control panel and output display that is mounted on the thickener bridge. There are typically two or three units mounted on each feed system depending on the application, as this provides flexibility to ensure a wide range of feed dilution can be achieved and also can be used to increase or decrease the mixing energy as the feed changes.

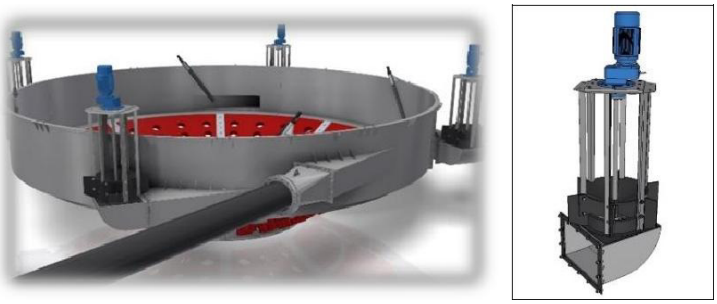


Figure 5: HydroForce – Controllable feed dilution system

1.1.5 *Froth Management Systems*

The HydroForce feed dilution system has been designed to not only control the feed solids concentration, but to also manage any froth that is generated on the thickener surface as shown in Figure 6. The Vector® has been proven to significantly reduce froth by deaerating the incoming feed and by having an efficient mixing velocity that captures and flocculates solids within the froth. In applications that have excessive froth, the HydroForce is typically configured to capture, deaerate, dilute, flocculate and then inject the froth below the incoming feed stream. This provides an efficient method for destructing any froth that would usually carry solids to the overflow system.

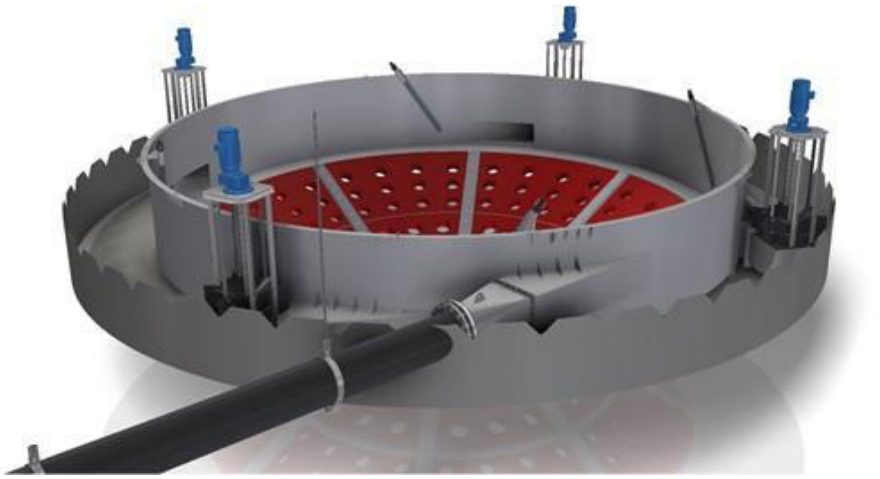


Figure 6: HydroForce – Froth management system

1.1.6 *Process Benefits*

The Vector® has been proven to provide more efficient mixing which significantly reduces the flocculant consumption and maximizes the settling properties of the floccules. The floccules are then discharged with a controlled velocity through each Vector® port to reduce over shearing. The void spacing between the Vector® ports allows water to be released during the discharge process and provides a pathway for the unhindered migration of the water towards the surface.

We have seen a significant reduction in froth after installing Vector® feed systems. The design considers deaeration in the process, but also allows for the collection and destruction of froth within the HydroForce feed dilution system.

The Vector® sectors are specifically designed for each application to suit the incoming slurry properties. The Vector® ports are designed to have a particular quantity, size and configuration to meet the application requirements. In the unlikely event of a blockage occurring, an inside rotating scraper can be provided that is attached to the driveshaft and will clear the obstruction.

1.1.7 *Maintenance Benefits*

The Vector® sectors are fabricated of a wear and scale build-up resistant urethane material which can be selected to suit each specific application if required. In the unlikely event that any damage occurs, these sectors are easily replaced manually by two persons with minimal downtime. A different Vector® sector configuration can also be designed, supplied and easily installed if required.

1.1.8 *Comparisons*

Physical comparison: The P&C Vector® feed system offers less interference with existing structures and typically has a smaller diameter than its equivalent standard feedwell counterpart. Because of its smaller diameter and wear resistant urethane components, it is also much lighter. Figure 7 presents a visual comparison of the Vector® feed system and an equivalent standard feedwell with a similar duty.

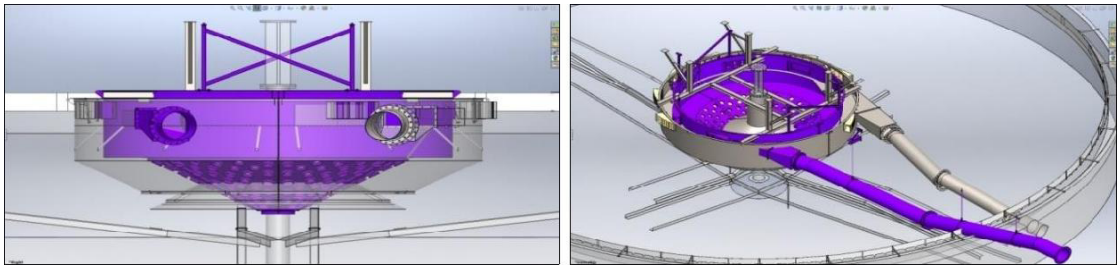


Figure 7: Vector® feed system (purple) and an equivalent standard feedwell (grey)

Process comparison: Installing a more efficient feed system can not only improve performance but can also reduce operating costs. P&C recently installed two Vector® feed systems for a leach concentrate and a flotation tailings thickener. Both thickeners were operating poorly with froth build-up on the surface, dirty overflow causing blockages, excessive flocculant consumption, low underflow densities and very poor control. On the concentrate duty the froth build-up and dirty overflow resulted in a loss of valuable concentrates, if not immediately captured it would recirculate back to the mill where it would be over-ground and lost in flotation.

Both units were installed in three days during a scheduled mill reline. Once commissioned, the units produced excellent results in both recovery and overflow clarity with no froth. The flocculant consumption was also significantly reduced (17% to 20%) and both thickeners were much easier to control and operate.

1.1.9 *Vector® Feed System Upgrade*

The latest feedwell designs from thickener vendors are often too cumbersome weighing more than the original standard designs, especially when upgrading existing thickeners that have increased their duty. This makes it difficult to retrofit to an existing thickener where the bridge or feed system support structure has only been designed to accommodate the original components. However, with a feed system that distributes the diluted slurry into the thickener tank more efficiently, existing thickeners can be easily upgraded accommodating greater throughputs and can utilize the same bridge design without modifying the structure. The result is a less expensive upgrade that can be installed in less time with improved performance. Figure 8 presents the preliminary design overlaid on an existing thickener. presents one of the installations that was completed in three days. Figure 9 presents one of the installations that was completed in three days.

Figure 8: Vector® feed system & 3D model and then overlaying on the existing equipment

Figure 9: Vector® feed system upgrade to a gold tailings thickener

Figure 10: Vector® feed system upgrade to an ultra-fine coal tailings thickener

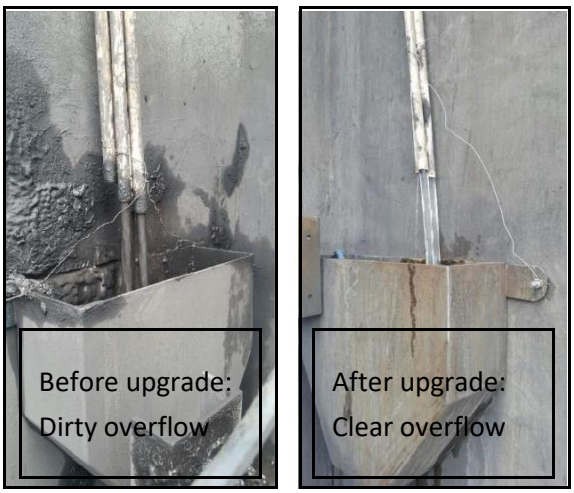


Figure 11: Ultra-fine coal tailings thickener: Before and after Vector® feed system upgrade

Description	Original Value	Upgraded Value	Improvement
Throughput (t/h)	196.9	275.7	+ 40.0%
Underflow solids concentration (%m)	42.2	48.6	+ 15.2%
Overflow clarity (ppm)	20,000	50	- 99.8%
Flocculant consumption (g/t)	70	35	- 50.0%
Water recovery (m^3/h)	870.41	1,270.78	+ 46.0%

Figure 12: Ultra-fine coal tailings thickener: Results after Vector® feed system upgrade