MORE THAN A DECADE OF EXPERIENCE

WITH

CONTINUOUS FALCON CONCENTRATORS

AT

THE TANTALUM MINING CORPORATION OF CANADA'S

LAC DU BONNET OPERATION

by

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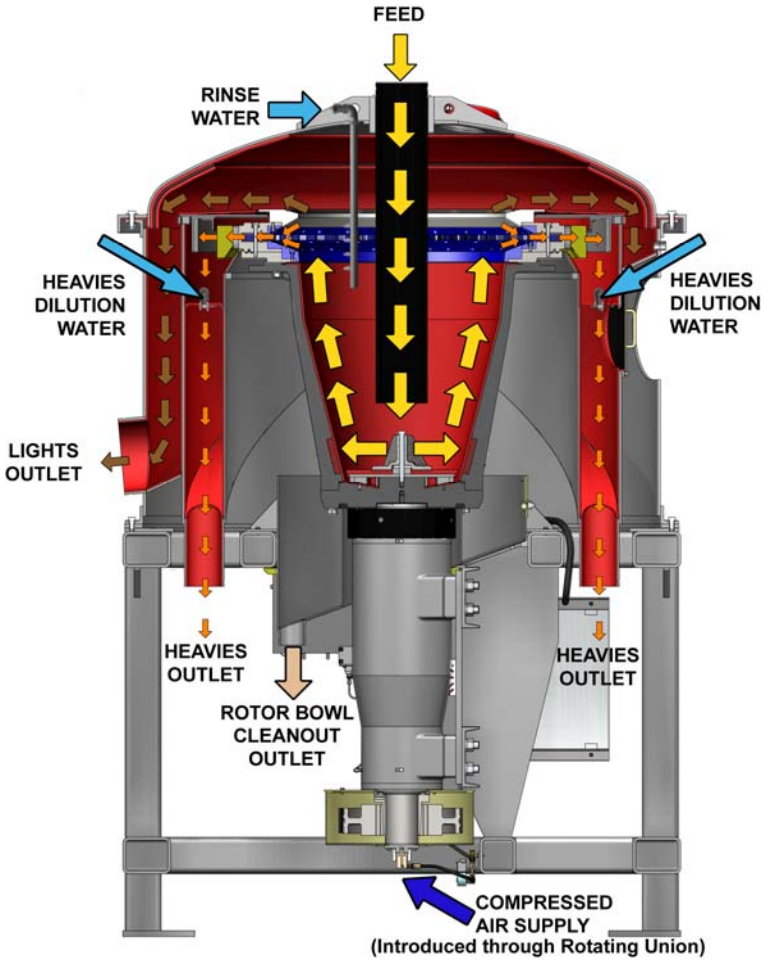
Chief Metallurgist



Continuous Falcon Concentrator

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Background

Tantalum minerals break down into extremely fine particles when undergoing size reduction via crushing and grinding. After grinding, gravity concentration is typically used to recover Tantalum. Conventional gravity concentration technology operates at 1 G or less and had been found to be inefficient for recovery of tantalum fines at Tanco.

Tanco conducted an evaluation of its 'sand' circuit (Particle sizes in the range of 300µm x 20µm) in 1994. The results showed that there were losses due to the limitations of the conventional gravity separation equipment that consisted of a combination of Holman sand tables and spirals. Even though four separate particle size classes were created and treated separately, losses were substantial. These losses were characterized in order to evaluate whether any of the new (at that time) enhanced gravity concentration technologies could be used to scavenge Tanco's sand circuit tailings thereby improving overall plant recovery.

Three technologies were considered, the Kelsey Jig, Knelson Concentrator and Falcon Concentrator. It was determined that the Falcon Continuous concentrator was best suited for Tanco's application. The Kelsey Jig had good metallurgical performance however the need for frequent and extensive maintenance along with the distant location of the parent company made it unattractive. The Knelson Concentrator was found to have inferior results due to low weight recovery.

This Paper summarizes Tanco's efficiency (recovery) improvements and extensive, hands-on operating experience with Falcon's enhanced gravity concentration technologies since its initial selection back in 1997. Falcon Concentrators inc. renamed itself as Sepro Mineral Systems Corp. in 2009. For clarity, Sepro is used to indicate the manufacturer of the Falcon Concentrator throughout this Paper.

About the Author

Claude Deveau, P.Eng. (APEGM)

- Currently employed at Tanco as Chief Metallurgist
- Started with Tanco in 1988 as Plant Metallurgist
- Graduated from Technical University of Nova Scotia 1987(Bachelor of Mining Engineering)
- Author of 3 Technical Papers on enhanced gravity concentration
- Responsible for the purchase (under five separate Purchase Orders) and installation of 5 Falcon concentrators (2 x Model C1000, 2 x Model C400, 1 x UF600) at Tanco for treating Tantalum.
- Completed nearly 500 metallurgical evaluations of operating Falcons and Falcon prototypes at Tanco.
- Supervised more than 275,000 operating hours of continuous Falcon Concentrators
- Played an integral role in the development of Falcon's UF technology.

Author's Overview
Through laboratory tests, plant trials, and commercial operating experience, the author acquired extensive knowledge of metallurgical performance aspects of mineral processing equipment and also skill in assessing its mechanical and operational characteristics. Both are critical for obtaining optimal plant operation.

New mineral processing prototypes are best evaluated in a plant. This environment not only allows evaluation of the equipment's metallurgical efficiency, but also uncovers mechanical or operational weaknesses, which are difficult to foresee by a designer with minimal operating experience.

The concept of the continuous Falcon concentrator has not dramatically changed over the years, however, some of the key components have undergone extensive upgrading, resulting in higher mechanical availability and lower operating costs. Personnel at Tanco have always had great belief in the concept of the continuous Falcon concentrator. After the more than 250,000 hrs of total operating time on continuous Falcons (4 units) at Tanco, design issues have been resolved by a team-like approach between Falcon Concentrators Inc (now Sepro) and Tanco.

The following is a typical scenario for the resolution of issues, which were encountered with any of the continuous concentrators:

The Tanco team, with its extensive operating experience, would identify an operating issue while simultaneously providing a possible solution to Sepro. The problem and potential solution were reviewed by Sepro, then input for a possible solution was also added by Sepro. New prototype parts were then designed and supplied by Sepro. These could then be tested and evaluated at Tanco. This iterative process has created a very robust concentrator with low operating costs.

History of Continuous Falcon At Tanco

Tanco's first Falcon Continuous Concentrator ultimately became the Model C1000). It was tested as a rental unit in June and July of 1997. Over 50 tests were completed during this 2-month period on circuit feed and reject in order to assess performance of the concentrator. These tests included assessing the effect of varying g-force and weight recovery to concentrate. Since the sand circuit reject normally reported directly to plant reject, the goal of the test was therefore to produce the lowest value of tailings from the sand circuit. It was determined that the best way to attain this was to place the C1000 in a scavenger configuration treating the reject from the conventional equipment.

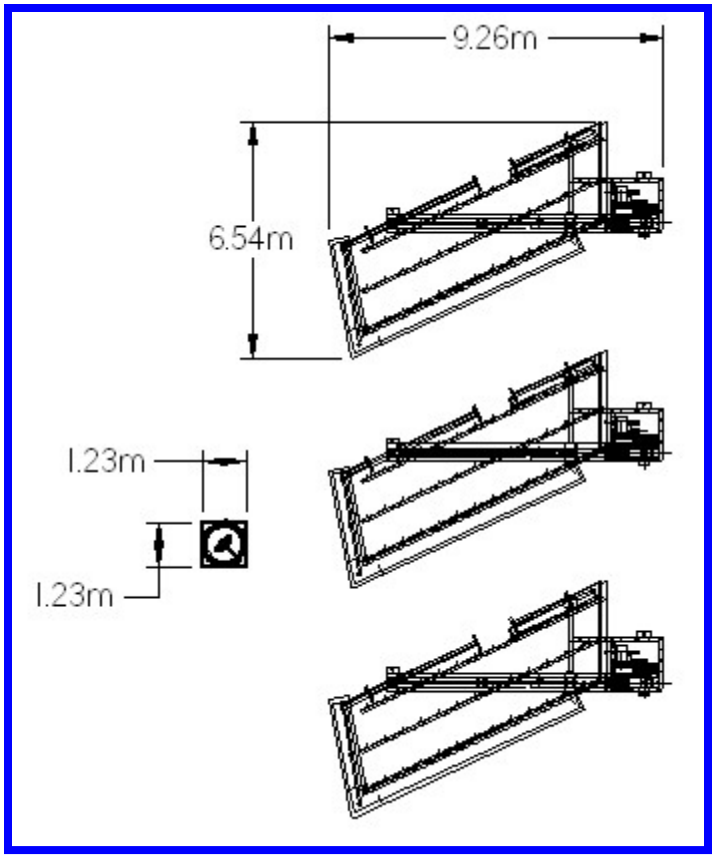

Figure 1: Floor Space Comparison: C400 vs. 3 Double Deck Shaking Tables

Optimal results were attained with approximately 25% weight recovery to concentrate. For initial tests, only the finest size fractions from the sand circuit were treated. This consisted of approximately 12 mt/hr. Through previous testing, it was determined that the optimal feed tonnage for a Holman table treating this type of feed was approximately 0.5 mt/hr. 6 Holman tables from our existing 12 were utilized to treat the concentrate from the C1000. This however created an overload situation on the remaining 6 tables and also set up a circulating load of tantalum since the Holman table as a cleaner was not as efficient as the Falcon C1000 at recovering fine tantalum.

Success with the C1000 led to purchase of a smaller machine to clean concentrate from the C1000. The smaller machine was the predecessor of today's Model C400 Falcon Concentrator. The table in Figure 5 clearly shows the benefit of using a 2-stage approach. Both recovery and grade were improved. The C400 replaced 6 Holman tables (3 double deck) that require approximately 750 ft^2 of floor space. A C400 requires 25 ft^2 (5' X 5'). Figure 1 shows a scale representation of the Falcon C400 vs three double deck Holman tables. The new C400 was installed at Tanco in September of 1998.

Upon installation and commissioning of the C400, the plant experienced an additional 4% recovery.

Tanco is unique in the fact that it has ability to operate 3 separate processes for 3 very distinct minerals at one site. The initial installation of Falcons (C1000 & C400) was completed on the tantalum circuit. Tantalum is also recovered as a by-product within the Spodumene operation. This led to trials with the Falcons on this circuit as well. Several trials were completed with the continuous Falcons from the Tantalum circuit on a targeted stream from the Spodumene circuit. Results showed that payback time for a similar installation was relatively short. A new C1000 and C400 were purchased and installed in order to recover Tantalum from the Spodumene circuit in November 1999.

Fig 2: Four Continuous Falcons in Operation at Tanco.

Metallurgical Performance of the Continuous Falcon

The tantalum circuit C1000 and C400 have been placed in a spiral-scavenging application. Their duty is to recover tantalum in the +20, – 300µm range which has not been recovered by a previous stage through conventional spirals and shaking tables. Figure 3 demonstrates continuous Falcon performance in a scavenging application treating tantalum ore.

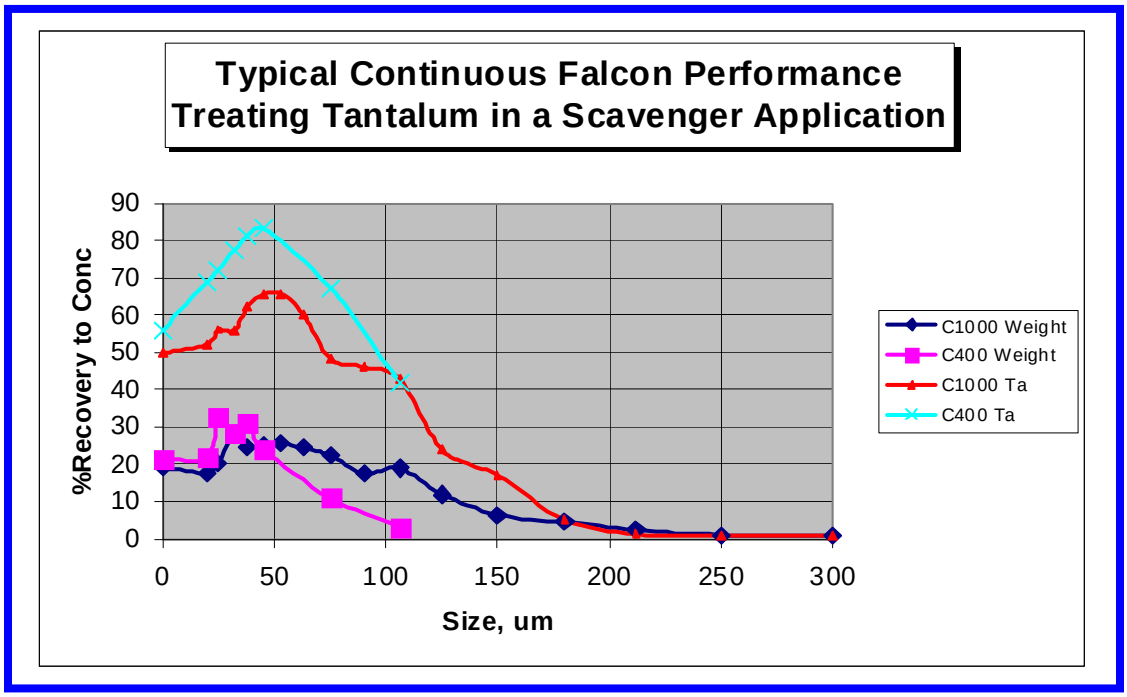

Figure 3: Typical Continuous Falcon Performance in Scavenger Application treating Tantalum.

Both the continuous and UF Falcons use no water for the separation process. Water is only used in helping to dilute concentrate so that it flows better since it is not uncommon to have concentrate densities of well over 70% solids.

The graph in Figure 3 shows us that, as expected, there is very little left to recover in size fractions coarser than 100µm since spirals and tables have removed recoverable minerals in those size fractions. The minerals targeted for recovery in the scavenger stage are therefore the minerals finer than 100µm and coarser than 20µm. (Please note that the 0µm point on the x-axis represents performance of –20µm material). QEM Scan of reject has shown that even though recovery of target mineral is not necessarily very high, there remains **no liberated tantalum in the Falcon continuous Falcon reject**. This case illustrates that the minerals, which make up the reject assay are therefore locked and require further classification and grinding in order to be liberated. It also makes a strong case for the high efficiency of the continuous Falcon.

In Figure 4, we see an application with fresh feed to the continuous Falcon. In this case, adequate recovery extends past 150µm where locking then becomes an issue.

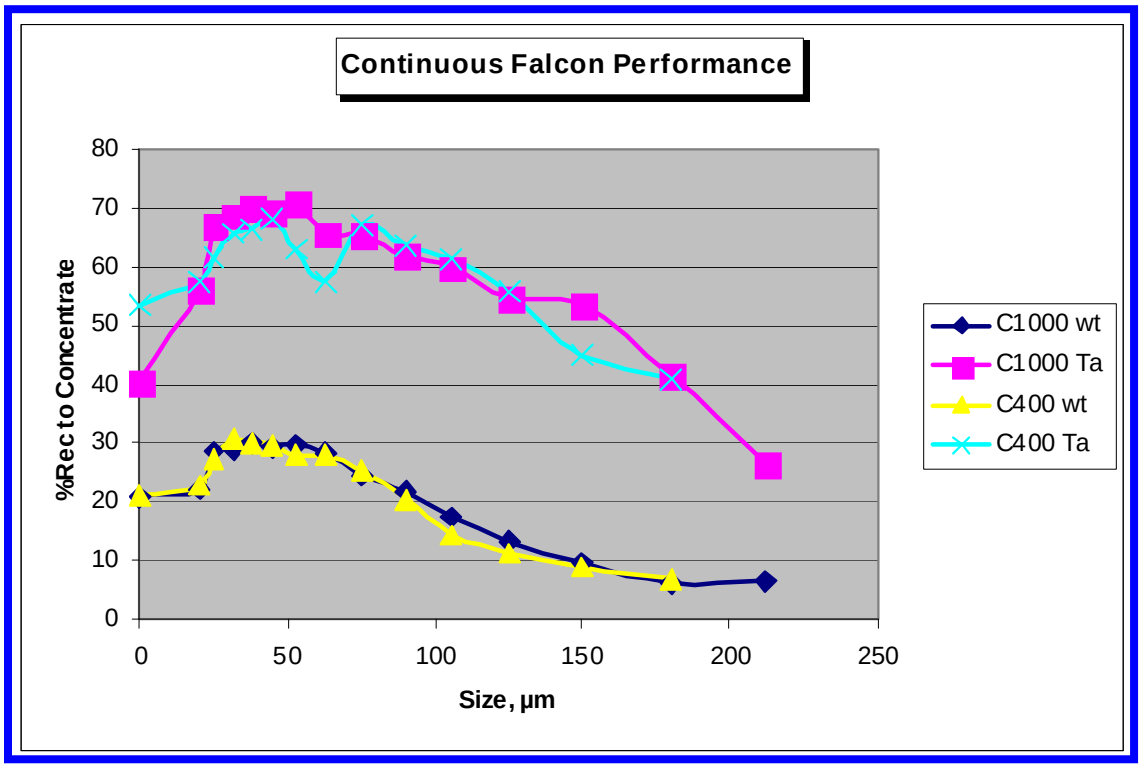

Figure 4: Typical Continuous Falcon Performance in Fresh Feed Application treating Tantalum.

ORIGINAL FLOWSHEET				
STAGE	**MACHINE**	**MASS PULL**	**STAGE RECOVERY**	**AGGREGATE RECOVERY**
ROUGHER	C1000 FALCON	8%	30%	30%
CLEANER	SHAKING TABLE		60%	**18%**

REVISED FLOWSHEET				
STAGE	**MACHINE**	**MASS PULL**	**STAGE RECOVERY**	**AGGREGATE RECOVERY**
ROUGHER	C1000 FALCON	16%	60%	60%
CLEANER	C400 FALCON		86%	52%
RE-CLEANER	SHAKING TABLE		79%	**41%**

Figure 5: Impact on circuit performance with addition of C400

Mechanical Integrity of the Continuous Falcon

Mechanical components and wear parts are the most important contributors to mechanical availability and operating costs. Power and maintenance labor are the only other significant considerations.

Due to the predictable life of parts on the Falcon Continuous Concentrator at Tanco, availability is very near 100% since most inspections and preventative maintenance can be scheduled. Maintenance is completed on days where the plant is scheduled to be down.

For reference, C1000 Falcons operate at 300 g's, which translates to a rotor speed of just over 1000 rpm. Since its installation in 1997, the original machine has now completed more than 70,000,000 rotations. This section summarizes Tanco's experience with various parts of the continuous Falcon, which enable it to complete such an achievement under such harsh conditions. The ore at Tanco, which contains a substantial amount of quartz, is considered extremely abrasive.

Figure 6: Tanco Falcon Installation and Maintenance Crew (Electrical and Mechanical)

Wear Parts

The following parts are directly exposed to wear from abrasion. Typical life of parts will be indicated along with a brief history of any design changes which were made in order to reduce or eliminate wear issues. These design changes were made under close scrutiny of the end user that provided the optimal results for the design team at Falcon-Sepro. Parts will be named in the order that contact is made with the slurry:

FALCON WEAR COMPONENT LIFE EXPECTANCIES		
Component	**Expected Life (Hours)**	**Comments**
Rotor & Rotor Lining	>>60,000	Original rotors and linings still in place after >60,000 hours of operation.
Lid & Lid Lining	>60,000	The lid on the first Falcon C1000 was relined after 10 years of operation (61,500 hrs). Three other lids are in good condition, all of which have over 60,000hrs of operation.
C1000 Discharge Trough Liners	~6,000	It has been found that trough liner life is directly proportional to maintenance of sleeves. If sleeves are allowed to wear past a certain point, high wear occurs on trough and hopper liner parts.
C400 Discharge Trough Liners	>40,000	
C1000 Flow Channel Liners	~4,300	Since hopper liners protect the stainless discharge head, it is critical that close attention is paid to the wear rate of the hopper liners. These eliminate major costs that would be incurred if the head were allowed to wear.
C400 Flow Channel Liners	>12,000	C400 channel liner life is approximately 2 yrs at Tanco.
C1000 Impellers	~6,000	In the beginning, impeller life was short at merely two weeks (300 hrs). After a material compatibility study was completed, lined impellers for Falcon C1000's had a life of approximately 6000 hrs. See Fig 7, 8, 9.
C400 Impellers	~40,000	It has been found that impellers for C400's last well over 5 years.

FALCON WEAR COMPONENT LIFE EXPECTANCIES, cont'd.		
Component	**Expected Life (Hours)**	**Comments**
Tungsten Carbide Bushings	>40,000	There are two types of carbide bushings protecting the Falcon from extreme wear. The first bushing encountered protects the stainless steel discharge head as the material crosses from the flow channel liners into the gum rubber sleeves. These parts were not initially used in this application, but since their introduction, there has been no damage to the discharge head and wear of the tungsten carbide bushings has been relatively slow. Only 50 have been required to maintain 72 openings over a 5-year period.
Gum Rubber Valve Sleeves	~3,650	The duty of the sleeve is to throttle the flow of slurry from the bed. This creates cavitation along with the highest particle velocity as they pass through the Falcon. Regular (monthly) inspection is necessary in order to prevent the premature wear of other parts such as the hopper liners.
Valve Bodies	>40,000	Valve bodies currently have lives that can exceed 5 years. Valve body design has dramatically evolved in the recent years. Forces in excess of 300g's are exerted on these parts as they are bombarded by very abrasive slurry. Design changes were also made to the concentrate launder in order to divert the flow of slurry away from the valve bodies. The current design has all but eliminated valve body wear due to abrasion. When the valve body life was extended due to the elimination of abrasion, bond failures within the valve began to occur through fatigue. This problem has also been rectified.

Fig. 7: Test Impeller (Provided by Sepro)

Fig. 8: After 1 Year of Operation…

Fig. 9: Optimized Impeller

Fig 10: Plastic head and valve bodies. (1997)

Fig 11: Stainless steel head with new design of valve bodies. (1999)

Fig 12: New Aerodynamic valve design. (Circa 2005)

Mechanical Components
Components below are not subjected to wear through abrasion however they are subjected to the milling industry's harsh operating conditions (i.e. dust & moisture). They consist mainly of the drive train parts:

FALCON MECHANICAL COMPONENT LIFE EXPECTANCIES		
Component	**Expected Life (Hours)**	**Comments**
C1000 Bearings	>40,000 (pillow blocks) est>100,000 (cartridge)	C1000's on site still have pillow block bearings that now have been superceded by cartridge bearings on later versions. Falcon has found cartridges to be superior to pillow Bearings on one C1000 were changed after 21,000 hrs of operation. The same machine has now operated for over 37,000hrs with no problems. Bearings on the other C1000 have been in operation for over 70,000hrs.
C400 Bearings	~50,000 (Flange-Type)	C400's on site have flange type bearings. After 50,000 hrs, a bearing change was completed on one of the two operating C400's. The other C400 nearly has 65,000 hrs with no bearing problems.
UF600 Bearings	Est >100,000 (Cartridge)	The UF600 on site has cartridge bearings which have been in operation for 23,000hrs with no problems.
Belts (All Machines)	~6,000	Synchronous drive belts typically have shown some wear after 6000 hrs of use and should be replaced shortly thereafter.
Rotating Union	~10,000	Rotating unions typically require replacement after 10,000hrs of operation. A spare rotating union is recommended since its failure creates a substantial air loss that prevent proper operation of the continuous Falcon.

History of Ultra-Fine (UF) Falcon Concentrator at Tanco

With the installation of the continuous Falcon at Tanco, issues with recovery of liberated tantalum particles in the 20-300 µm range were all but removed. Attention then turned to areas of the plant treating finer size fractions (-20 µm). At the time, this material was treated with a combination of a Mozley Multi-Gravity Separator (MGS) 902 and crossbelt concentrators. Tantalum recovery in this area of the plant was well below 20% along with yearly maintenance costs greater than 50,000 CAD.

A highly efficient flotation process was then developed by metallurgical staff at Tanco. Recoveries in excess of 90% were achieved with weight recoveries as low as 4%. The new process also had limitations. Even though enrichment ratios were near 25, it was not sufficient to produce a saleable product. An MGS 900 (pilot size unit) was installed to treat the flotation concentrate. Through experimentation, it was determined that a more complex circuit containing the MGS 900, MGS 902 and crossbelt concentrator was only capable of attaining a recovery of 50% with an enrichment ratio of 5.0 from the flotation concentrate.

The following section will discuss the development of new technology in which a very close relationship between the vendor and end user was critical. This demonstrates how Sepro is capable of finding solutions for mineral processing or operational problems faced by their customers.

In November 2003, Sepro was contacted in order to discuss what possibilities existed to recover ultra-fine tantalum that had a mean size of 6 µm from 50 µm gangue minerals. An old prototype (B6) from Sepro was made available for exploratory tests. The Falcon B6 is a small-smooth walled batch concentrator capable of generating centrifugal fields greater than 300 g's. Test results with this concentrator quickly demonstrated its superiority to the existing technology. Soon after, a similar, but larger rotor was designed and installed on the platform of a larger Falcon. Although testing a larger concentrator allowed Tanco to study important aspects of the process including how the bed material collects in the retention zone, results were inferior to the initial prototype. Having understood the potential of these tests, Sepro provided another smaller prototype that allowed Tanco to study the bed formation in more detail. This model was based on Sepro's L40 platform. It was during use of this model that the concept of a moveable discharge lip was developed. With the help of performance data generated at Tanco, the UF600 was constructed by Sepro and installed at Tanco in April of 2005.

Fig 11: Newly installed UF600

After further tests, the UF600 was adapted to multi-stage operation where one machine is used for a four-stage operation. This was accomplished using agitated tanks, pumps and valves supplied by Tanco. The system was controlled by a PLC supplied and programmed by Sepro.

Performance of the UF Falcon Concentrator Treating Very Fine Tantalum

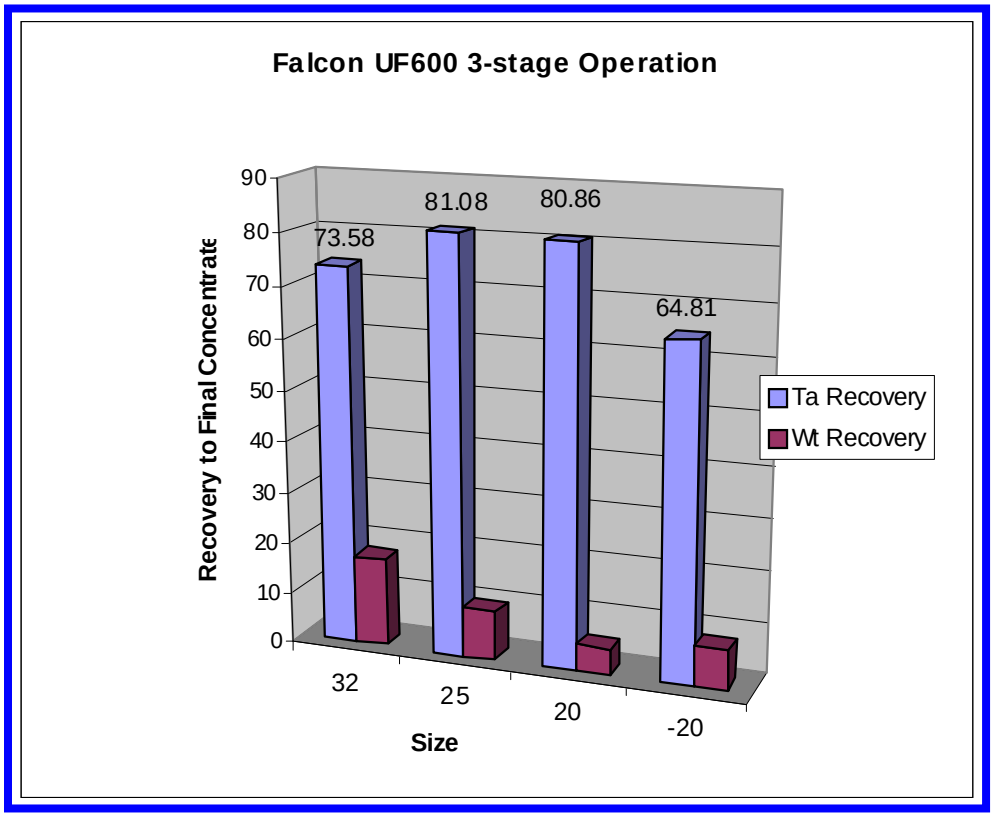

Fig 14. Falcon UF600 Performance with 3-stage operation

Mechanical Integrity of the UF Falcon Concentrator

After over 23,000hrs of operation, the only parts that have required replacement are a rotating union and one impeller.

Fig 15: Note special attention to ergonomics for easy access.

Conclusion

The newly innovated UF technology has demonstrated Sepro's commitment to solving the customer's problems by helping to develop novel yet robust technology that extended the range of enhanced gravity concentration to below 10 Microns.

A close relationship between the vendor and customer (Sepro and Tanco) has resulted in a net gain for both companies. The shared developments have created highly efficient, robust pieces of equipment for the gravity separation industry.

One may ask, "Why would a customer have so much interest in helping a vendor improve its product?" The answer lies in the fact that the customer in this case will also greatly benefit by being able to more efficiently make use of the concept. This environment creates a win-win situation where the customer maximizes its return on investment and the vendor produces a superior product.

The need for design changes in the continuous Falcon concentrators have all but been removed today; however, it is still critical that operators and potential operators maintain a close relationship with Falcon since they are the most knowledgeable in the design and operation of the machine. These close relationships will ensure that enhanced gravity separation technology will continue to improve.