PAPER 31

Improving Fine Particle Gravity Recovery through Equipment Behavior Modification

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ABSTRACT

Studies on the performance of Falcon batch type concentrators treating ultrafine tantalum at Tanco have revealed that very fine heavy minerals are concentrated within certain areas of the concentrate bed. This information led to the design of a bowl which would allow entrapped lighter low grade particles to escape while providing more space for heavier particles to be recovered in the bed.

Numerous tests were then completed with a modified batch-type and non-fluidized Falcon bowl in which the diameter of the discharge lip was adjusted downward manually in steps. This allowed for the gradual building of a higher grade concentrate bed.

This work ultimately led to the design of a new Falcon with an automated continuously variable lip. In April 2005, Tanco commissioned the first Falcon UF600.

This paper will discuss laboratory scale results and also plant performance of the Falcon’s UF technology.

INTRODUCTION

Tantalum Mining Corporation of Canada, also known as Tanco, is a wholly owned subsidiary of Cabot Corporation based in Boston, Mass. Operating since 1969, the underground highly mechanized room and pillar operation produces tantalum, lithium and cesium minerals and is located a 2 hour drive east-northeast of Winnipeg Manitoba, Canada.

At Tanco, tantalum is recovered using conventional gravity concentration, enhanced gravity concentration and flotation. This paper will discuss how the need for improved equipment to treat very fine tantalum particles was filled by a machine which was modified to the point of creating a completely new technology.

In November 2003, Tanco began the investigation for the potential use of a high g-force smooth walled concentrator for treating ultra fine tantalum produced by its flotation circuit. Until then, the tantalum flotation concentrate had been treated by a circuit which consisted of a Mozley Multi-Gravity Separator 902 (MGS), a Mozley MGS 900 and a Bartles cross belt concentrator. Through QemScan analysis, it was found that the majority of the losses from this circuit were of an extremely fine nature which exceeded the recovery limits of equipment on hand. Mean particle size of the tantalum losses was less than 10 µm.

Lab Test Program

With a small test unit on loan from Falcon Concentrators Inc., initial work with a smooth walled concentrator treating flotation concentrate material yielded impressive results even though 80% of the tantalum in the feed was finer than 20 µm.

This test machine operated on a batch method where concentrate is collected by the concave wall of the rotor over a period of time while the machine was running. The concentrate was manually
removed from the rotor after the run time had elapsed and the machine stopped. Test results showed that the unit had improved performance treating lower stream pulp densities such as the one found with the tantalum flotation concentrate as opposed to the higher feed densities which are required for other enhanced gravity concentrators. Tantalum flotation concentrate typically had a pulp density of 6 – 8%. Through tests with a lab scale machine, we were able to show that a single pass with a smooth walled concentrator was as efficient as the complete current gravity circuit treating the flotation concentrate. Figure 1 illustrates the flotation gravity circuit.

Figure 1: The gravity circuit treating tantalum flotation concentrate
From the laboratory tests, it had been noted that weight recovery was a critical indicator for the tantalum recovery. This could be adjusted from each test by varying the run time since the weight of the concentrate formed by the bed would remain relatively constant. This was providing that all other conditions such as feed tonnage and pulp density also remained constant. Figure 2 demonstrates the effect of weight recovery on tantalum recovery for the lab-scale smooth wall concentrator.

It was decided that the lab tests on the small machine were favorable enough to warrant testing on a larger scale. Using the chassis of a Falcon SB250, Falcon Concentrators Inc. provided a machine which was an up-scale version of the smooth walled concentrator used in lab tests. This model had the advantage of an automated rinse cycle which would clean the concentrate from the bed instead of being manually cleaned as with the lab model.

Test results quickly revealed that the larger smooth wall concentrator performance was sensitive to throughput. Figure 3 clearly demonstrates that performance would deteriorate with feed rates greater than 100 kg/hr.
In order to allow for longer run-times between rinse cycles while maintaining constant weight recovery, a new lip ring with a smaller internal diameter was constructed and installed. As a result, a larger concentrate bed was successfully produced. Test results also showed that even
though the weight of concentrate trapped in the bed had increased with the lip of smaller internal diameter, there was no improvement in the tantalum recovery of the machine. The data in Figure 4 which shows this effect was generated by running at several operating times for each of the larger and smaller lip ring.

The larger machine also gave us a better opportunity to visually inspect the bed of concentrate created inside the rotor compared to the lab scale machine. Varying zones of concentration of tantalum could be seen when the concentrate bed was manually excavated. There appeared to be a definite accumulation of higher-grade tantalum located at the base of the bed. There also appeared to be a skin of higher-grade material moving through the entire height of the bed. This was verified by sampling. The results are shown in Figure 5, which demonstrates the cross-section of the bed as it is found in the rotor.

![Diagram of cross-section of bed in rotor]

**Figure 5: Cross-section of the bed as it is found in the rotor**

From this information, it can be seen that low-grade material is trapped by the concentrate lip. Trapped low-grade material also prevented the higher grade material from migrating to the wall of the rotor in upper regions of the bed. It is with these thoughts that the idea of a variable lip on a rotor was conceived. If the bed were produced with the concentrate lip having the same diameter as the rotor wall, no gangue material would be trapped allowing higher grade material to line the wall of the rotor. By reducing the concentrate lip inner diameter as time progressed, this would allow the gradual escape of gangue materials as the bed is filled with heavy minerals.
from the bottom up. As a result, a bed with rings of concentrate similar to those found in the cross section of a tree would be formed.

In order to test the efficiency of a variable versus a fixed lip, a new rotor was constructed for use with the chassis of Falcon Concentrator Inc’s lab test rig. Flat steel rings of varying inside diameter were used as lip rings. See Figure 6. By manually interchanging the lip rings between several predetermined running periods, the effect of a continuously variable lip could be attained. The feed to the smooth walled concentrator was circulated back to the feed drum during the ring change. Up to 8 rings with ID increments of 1 mm were used.

Since the first ring had a 0mm lip, a very thin bed was formed as in Figure 7. After having gradually built a bed using all the rings, a 7mm bed would be formed since the last ring had a lip of 7mm. Figures 8 and 9 show the bed with and without the lip ring. Note that the bed extended down to the bottom of the rotor.
**Figure 7:** Bed formation with 0mm lip ring

**Figure 8:** Bed formation with 7mm lip ring
Figure 9: Bed formation with 7mm lip ring. Lip ring removed

During trial runs, tailings samples for each of the lip rings were collected separately. This allowed us to observe any fluctuations in tailings values as the rings were being interchanged. An increase in tailings value would indicate that the bed was full and that tantalum was escaping to tailings. The first trials were completed with even time intervals between lip ring changes. The loss distribution showed that most of the losses were occurring early in the trial. This seemed reasonable since the initial lip rings had the largest ID’s creating the smallest bed and taking the least time to fill. Run times were adjusted accordingly so that the largest ID lip rings were run for the shortest period of time and as the lip ring ID’s progressively got smaller, the run time for each was increased. This way, the magnitude of loss was more proportionate to the time run. Figure 10 shows the effect of run time with each lip ring on loss distribution. Only six lip rings (up to 5mm) were used in the trial shown by the graph.
Overall, excellent results were attained with a smooth walled concentrator by varying the concentrate lip diameter as the test progressed.

**Falcon UF600**

Falcon Concentrators Inc’s next challenge was to construct a machine which could automatically simulate the effect of interchanging concentrate lip rings of varying internal diameters at full scale. The new Falcon UF600, which was the product of experience and innovative thinking, was unveiled as a smooth walled concentrator with a continuously variable concentrate lip ring. This machine was designed for total automation. Every operational aspect was controlled by a user friendly PLC.

The new Falcon UF600 was commissioned at Tanco in April 2005. The Falcon UF600 was installed in the circuit in order to treat the flotation concentrate. The initial goal of the new installation was to verify that the full-scale variable lip technology was successful. The mid to long term goal for the Falcon UF600 would be that it could be used in a more complex multi-stage operation.

To allow for batch feeding the flotation concentrate, a surge tank and a feed pump were installed with the capability to re-circulate the feed to the surge tank while the concentrator was in rinse mode. A concentrate surge tank and pump were installed so that the concentrate from the Falcon UF600, which is also intermittently produced, could be pumped at a constant rate to the MGS900 in order to maximize grade and recovery from the circuit. Operation of the MGS 902 and Bartles...
Cross-Belt concentrator was discontinued for the application of recovering tantalum from the flotation concentrate.

The Falcon UF600 was installed in a manner at Tanco which would best allow mechanics to have access to some of the machine’s critical areas. The machine was raised from the ground to facilitate access to the drive system. This simultaneously raised the rotor and launderers to a point where they were easily accessible from the floor above. Removable floor sections beside the Falcon UF600 along with a trolley beam above the machine were also installed for ease of maintenance. The Falcon UF600 installation can be seen in Figure 11.

![Falcon UF600 installation at Tanco](image)

**Figure 11: Falcon UF600 installation at Tanco**

During commissioning, several important parameters required establishing for the proper operation of the Falcon UF600. Among these were:

- Run time
- Rinse delay time
- Rinse time
- Drain Time

The run time is critical because it helps to determine the weight recovery to concentrate since the bed weight will always be relatively unchanged. The rinse delay time is the time allowed for the feed pipe to drain into the machine before the rotor begins to decelerate. This was found to be approximately 7 seconds for our application. Rinsing of the rotor with powerful sprays would commence after the rotor has slowed to an acceptable speed. The actual rinse time was determined by observing the effect of cleaning on the rotor wall as the rinse time was varied. In general, 5 seconds was found to be sufficient for an acceptable rinse. Drain time is the time
required for the slurry produced by the rinse to drain from the rotor through holes located underneath the impeller. It was found that the rotor could be drained in just over 10 seconds.

Since the variable lip is also controlled by the PLC, it also required values entered for proper operation. The variable lip, which is controlled by varying air pressure, was set up to be dependent on the run time. The run time was divided into 10 equal segments on the PLC screen and air pressure values were entered for each segment in increasing order. For simplicity, the initial tests were completed with the variable lip continuously reducing its diameter in a linear way. The 10 segment air pressure values were therefore set as follows: 15, 30, 45, 60, 75, 90, 105, 120, 135 & 150 psi.

Treating the entire flow from the tantalum flotation concentrate, the Falcon UF600 generated results comparable to those generated in the lab with the smaller units. Figure 12 demonstrates weight recovery versus tantalum recovery results. Since the flows being treated were so small, the entire streams were collected for a sample.

![UF 600 Falcon Performance](image)

**Figure 12: Falcon UF600 weight vs tantalum recovery to concentrate**

Tests were then completed to assess the effect of changing the rotor speed/g-force on performance. Tests were completed with the rotor speed being varied from 50 Hz to 60 Hz and then to 70 Hz. Since the Falcon UF600 operates on a batch process, the rotor speed was changed during the rinse cycle so that all three tests could be run consecutively without feed interruptions. It was found that, as the speed of the rotor is increased, weight recovery to concentrate actually decreases while the overall tantalum recovery increases. The two trials, which were completed several days apart from each other help to demonstrate the effect of Tanco’s highly variable ore characteristics on equipment performance. Figure 13 helps demonstrate the effect of the rotor
speed change. The Falcon UF600 has since then been operating at 70Hz which generates approximately 475 g’s.

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**Figure 13: Effect of rotor speed on Falcon UF600**

Another test was also completed to verify the effect of the continuously variable lip on overall performance of the Falcon UF600. This was achieved by entering the maximum pressure on the lip at the beginning of the run instead of gradually adjusting the lip pressure as the machine was designed to do. A constant air pressure on the variable lip simulated a fixed lip. This test was completed at 60 Hz on the same feed as the first rotor speed tests shown in Figure 13. The point representing the fixed lip test result has been added for comparison in Figure 14. From this, it can be seen that the performance attained with a fixed lip is definitely inferior to that attained with a continuously variable lip. The weight recovery increased from 24.2% to 27.9% while the tantalum recovery dropped from 71.2% down to 60.8%.
Figure 14: Effect of fixed lip vs continuous variable lip

Satisfied that the performance of the Falcon UF 600 was comparable to the lab scale version, trials were designed to reflect the operation of a multi-stage operation. Since the Falcon UF 600 is based on batch operation, much larger throughputs would be required when using a single machine for a multi-stage operation. Several trials completed with a substantial increase in tonnage while treating tantalum flotation concentrate clearly showed a performance drop. This appeared as a drop in weight recovery to concentrate which also equated to a substantial drop in tantalum recovery. Figure 15 helps to demonstrate the effect of high tonnage rates.
Figure 15: Effect of high tonnage rates on the performance of the Falcon UF600

Multi-Stage Operation

Minor circuit changes were also made which allowed the Falcon UF600 to retreat the concentrate as a cleaner in a closed circuit. This was part of the long-term plan for the Falcon UF600. The cleaner stage operation was temporary and for test purposes since material could only be fed to the Falcon UF600 through manual operation of several valves. A tantalum recovery of 64% along with an enrichment ratio of 10 was attained with the rougher/cleaner stage operation treating tantalum which was 80% finer than 20 um.

During cleaner trials with the Falcon UF600, it was noticed that performance did not deteriorate at a higher throughput as had been the case with the rougher stage treating flotation concentrate. The Falcon UF600 did not experience a weight reduction in the bed at an elevated tonnage rate. Performance was in fact slightly improved over rougher stage operation at lower throughputs. The weight recovery to concentrate had substantially dropped when treating in excess of 200 kg/hr in the rougher stage application. It is believed that a combination of higher tonnage along with the low density would cause the bed to be eroded therefore reducing the weight recovery. Rougher stage concentrate had a pulp density of approximately 8% solids. This is more than double the rougher stage feed density. This was an indication that the Falcon UF600 was much more sensitive to volumetric flow rate than tonnage rate.
Due to the voluminous nature of tantalum flotation froth, water sprays had been required in the flotation concentrate launder so that the launders would not be overcome by the froth. This had reduced the flotation concentrate pulp density from 7% down to 3% solids. With an average feed rate of approximately 130 kg/hr, the 3% feed pulp density had not been a problem for the Falcon UF600. At higher tonnage rates, as would be required for a multi-stage operation, the low feed density was creating a problem.

Having extensive experience dealing with voluminous froth, an enclosure with a special impeller was designed to beat the froth so that no launder water would be required. This new piece of machinery was successful at eliminating froth problems and allowed for a pulp density increase to 7%. Several tests showed that the Falcon UF600 was capable of treating up to 400 kg/hr with a 7% pulp density on the rougher stage. With the increased capacity, the Falcon UF600 could successfully operate as a single machine, multi-stage operation.

Figure 16 demonstrates the circuit with the Falcon UF600 operating in a multi-stage operation. The surge tanks, which levels’ are manually controlled by operators, allow for only one operation at a time. The remainder of the valves along with the operation of the Falcon UF600 is controlled by the PLC.

It was found through earlier tests that the cleaner tank would hold up to eight concentrate batches from the Falcon UF600. The flow of the material through the circuit for one complete cycle would be as follows:

1. Rougher stage – concentrate to concentrate tank, tailings to scavenger tank
2. Scavenger stage- concentrate to concentrate tank, tailings to final tailings
3. Rougher stage- concentrate to concentrate tank, tailings to scavenger tank
4. Scavenger stage- concentrate to concentrate tank, tailings to final tailings
5. Rougher stage- concentrate to concentrate tank, tailings to scavenger tank
6. Scavenger stage- concentrate to concentrate tank, tailings to final tailings
7. Rougher stage- concentrate to concentrate tank, tailings to scavenger tank
8. Scavenger stage- concentrate to concentrate tank, tailings to final tailings
9. Cleaner stage- concentrate to final concentrate, tailings to rougher tank
10. Begin new cycle
CONCLUSION

It is believed that tantalum recovery for the completed circuit with the use of one concentrating machine will well exceed 70% with enrichment ratios of approximately 10. This is a substantial improvement over the previous gravity circuit which recovered just over 50% of the tantalum with an enrichment ratio of 5. The installation of the Falcon UF600 at Tanco is a good example of how older technology can be adapted or modified to fill current needs of the industry. The relatively trouble-free installation has also shown that experience and innovation along with communication between vendors and end users is critical for the successful development of new technology.

ACKNOWLEDGEMENTS

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