
The Knelson Continuous Variable Discharge (CVD) Concentrator

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The Knelson “Batch” Concentrator was invented in 1978 by Byron Knelson (1), and developed and refined by Knelson Concentrators in the 1980’s and 1990’s. Currently, there are approximately 2,500 operating units around the world. The batch concentrator has found its major use in hard rock gold milling circuits. These machines are situated in the grinding circuit and process a portion (usually 10-50%) of the cyclone underflow where they recover a large portion of the “gravity recoverable gold” present in the circulating load. This has well understood benefits to the operator in terms of gold recovery and operating costs. Other applications of these units currently in operation include the recovery of platinum group metals and native copper.

The Knelson Batch Concentrator is a spinning centrifuge that separates and recovers particles with respect to their specific gravity (figure 1). The heart of the unit is a fluidized cone (figure 2), which is fed slurry up to 75% solids. The cone spins at a rotational speed required to give 60 times the force of gravity. The walls of the cone are angled outwards, promoting slurry flow up the wall. As the particles of slurry accelerate, the difference in specific gravity is magnified. The walls of the cone have fluidized “rings” which allow the heavier particles to separate and be captured according to their specific gravity. The lighter particles exit out of the top of the cone and report to the tailing launder. Gold, PGM’s and other heavy metals and minerals concentrate in the bed over a period of time, generally in the range of 20-120 minutes in most applications. As the grade and thus the density of the fluidized bed increases over time the driving force for separation of metals and mineral diminishes. A graphical plot of grade versus time will eventually show an asymptote after which the concentrate grade in the fluidized bed no longer increases. For this reason, the batch units periodically shut themselves down to flush a high grade concentrate from the fluidized rings to a separate collection tank. The process of flushing the concentrate is fully automated, and takes only a few minutes.

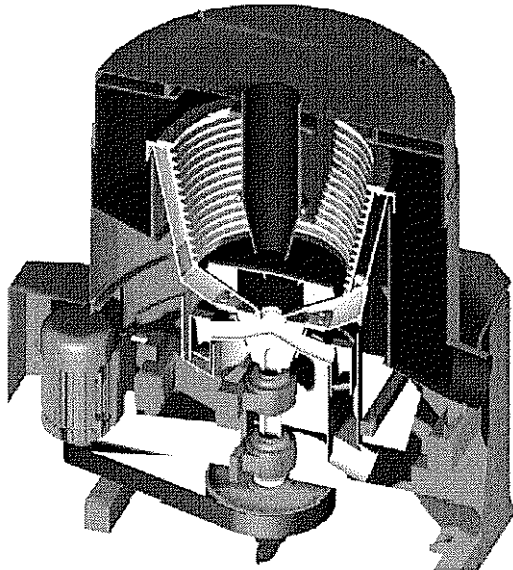


Figure 1. Knelson Batch Concentrator

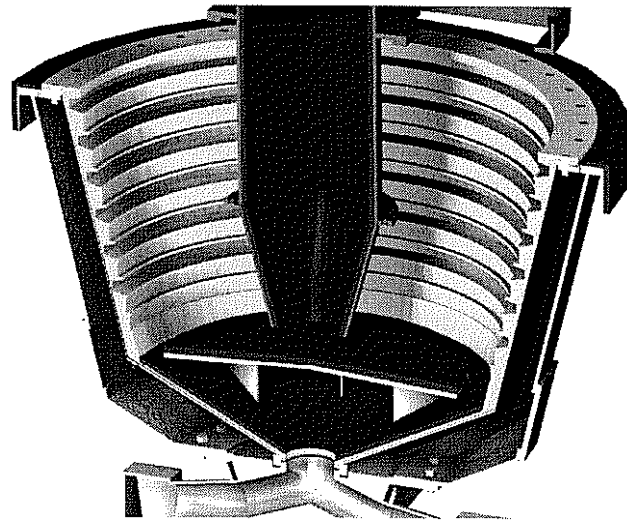


Figure 2. Fluidized Cone

This operational sequence works extremely well when the target metal (in most cases gold) is present in small amounts. The amount of concentrate produced relative to the feed (known as mass yield) is extremely small, typically in the range of 0.01%-0.1%. For example, the largest batch concentrator available is capable of processing 165 tons/hour of feed. If the batch cycle time was set to 30 minutes, this machine would flush approximately twice per hour, yielding about 220 lbs of concentrate, for a mass yield of 0.06% of the feed. If the amount of target metal or mineral is present at percentage levels instead of parts per million, the fluidized bed would increase in grade very rapidly, and the driving force for continued metal or mineral separation would diminish quite quickly. This would prompt the operator to set the batch cycle to a very short interval, perhaps as short as a few minutes. As the flush cycle itself is normally 1-3 minutes long, the availability of the machine from a production standpoint would be extremely limited. Thus, a better way of removing concentrates from the concentrator was needed.

The Knelson Continuous Variable Discharge, or CVD Concentrator was developed specifically to address the limitation with respect to mass yield of the batch concentrators. The CVD Concentrator uses similar principles of mineral separation and recovery to that of the batch machine, but allows the concentrate to be ejected from the fluidized bed continually. A series of pinch valves, located at the base of the fluidized rings, are kept closed by air pressure. By releasing the air pressure periodically, concentrate can be ejected without an interruption in production. Figure 3 shows a graphic of the cone of the machine, with the pinch valves visible at the base of the rings. The mechanism of separation and recovery is thought to be quite similar to the batch machine.

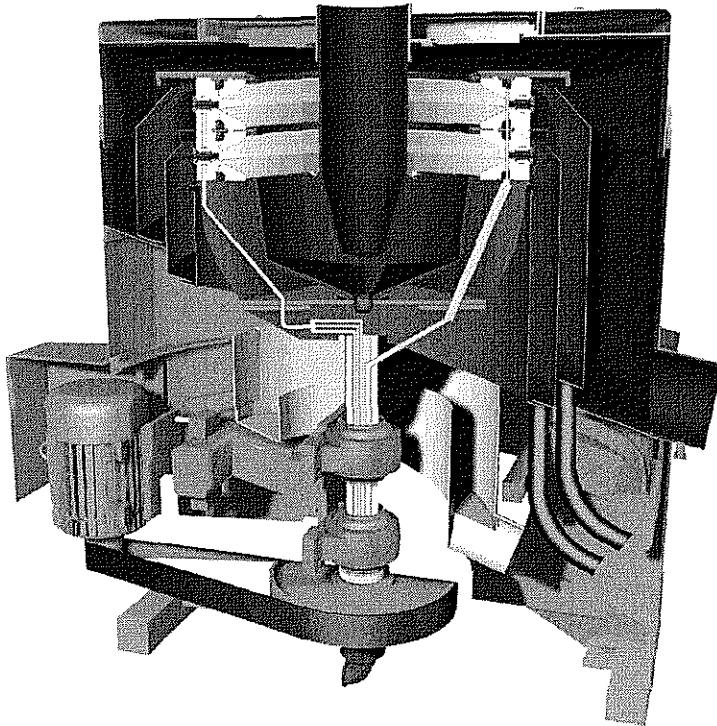


Figure 3. **Knelson** CVD Concentrator

Mechanically, the batch machine and the CVD share many similarities. The model range of CVD Concentrators has in fact been derived from the existing frames sizes of batch machines. The rotating assembly of the CVD is where the machine differs. Due to the pinch valve geometry and the requirement to fit pinch valves at the base of the rings, the fluidized rings of the batch machines are significantly larger than those of the batch machines.

As the pinch valves are the most significant difference between the batch and CVD concentrators, they presented their own unique design challenges. The original design was tested at Knelson's facility in Langley, BC, where several materials and geometries for the valve and valve sleeves were cycled to failure. The best of these were chosen and field tested, where further refinements were made. The current design utilizes a cartridge type assembly where the entire valve body can be quickly and easily changed, typically in an hour or two, and the machine can be put back into production. The original set of valves removed from the machine can then be re-fitted with a new set of replaceable sleeves at the customer's leisure, ready for the next change-out interval. Apart from routine lubrication, this will be the most frequent maintenance task on the machine. The lower cone itself is lined with Linatex®, as are the launders, and the fluidizing rings are manufactured from urethane. This is a similar design philosophy that is used for the batch concentrators. The drive components, frame assemblies, and many of the instrumentation and control components of the two families of machines are similar.

The CVD Concentrators have several machine selectable operating variables. All machine functions are operated via an integrated PLC interface to an HMI, which can be located on the machine, or installed remotely. Three operating variables are selectable from the PLC/HMI; fluidization water flow, gravitational force (RPM), and pinch valve cycle times.

Fluidization water can be varied according to the process requirements. The fluidization water is introduced at the base of the rings in order to keep the bed of particles in suspension. This allows the terminal velocity of the settling particle to be kept in balance with the inward water flow to allow the separation and recovery of minerals to occur. In general, the fluidization flow is optimized to give the best balance between metallurgical recovery and water balance in the rest of the circuit. Fluidization flow is not normally the governing operating variable, so long as there is sufficient fluidization of the bed to promote particle separation and recovery.

Gravitational force can be varied simply by increasing or decreasing rotational speed of the CVD Concentrator. Again, this variable is one of the operating parameters that are optimized to give the best result to the process. It has been interesting to note that increased gravitational force has not always produced superior metallurgical performance for all types of feeds.

The most critical machine parameter from a metallurgical standpoint is the mass yield. As mentioned earlier in this discussion, this is the amount of concentrate expressed as a percentage of the feed. While batch machines are limited to all practical purposes to a mass yield of about 0.1%, the CVD mass yields can be varied from about 0.1% to 50%, depending on the feed characteristics. The operating variables affecting mass yield are the pinch valve open and close times. Longer open times, and/or more frequent open intervals allow more heavy minerals to report to concentrate. In general, the pinch valve open time is kept within the same range, and the closed time is varied to adjust the mass yield. The open time is generally adjusted to take into account the "hysteresis" of the air supply. The hysteresis is the amount of time the valve takes to close when air is introduced. As this can vary according to machine size and installation, it is important to ensure that the valves open and close completely to eject concentrate.

In general, the CVD Concentrator has the same grade/recovery trade-off as many other types of mineral separation technologies. As one would expect, when the mass yield increases for a particular application, the recovery of the target mineral increases, but at the expense of concentrate grade. As with any piece of recovery equipment, the decision as to the best compromise is usually determined by metallurgical or economic considerations.

The feed rate to the machine and the slurry density also affect the operating characteristics of the CVD. Most applications have been tested at less than 50% solids, as the operating results seem to be favourable at lower solids, with fewer problems related to poor flow of concentrate to the pinch valves. Lower feed rates tend to produce better results metallurgically, but this has to be balanced against the economics of using more (or larger) machines at lower feed rates, versus less (or smaller) machines at higher feed rates.

Early test work used a synthetic ore mixture comprised of silica and magnetite. The size distribution is shown in Figure 4. This synthetic ore has several advantages in that it creates a benchmark of 100% recovery as the best possible result, as it is 100% liberated, and has a reasonable difference between the specific gravities of magnetite and silica (5.2 versus 2.8). In addition, it can be analyzed using magnetic separation techniques, weighed, and then re-combined for the subsequent test work. A pilot plant was constructed at Knelson's facilities in Langley, BC, Canada. The main components were a series of agitated slurry tanks to store the feed, a CVD-6 Pilot Scale Concentrator and control system, as well as miscellaneous valves, pumps, and piping.

Early work with the pilot plant proved that the CVD concentrator was capable of making separations of this synthetic feed, as shown in Figure 5. More recent work with a finer magnetite/silica feed has focused on size-by-size recoveries. The results of these studies are not yet complete.

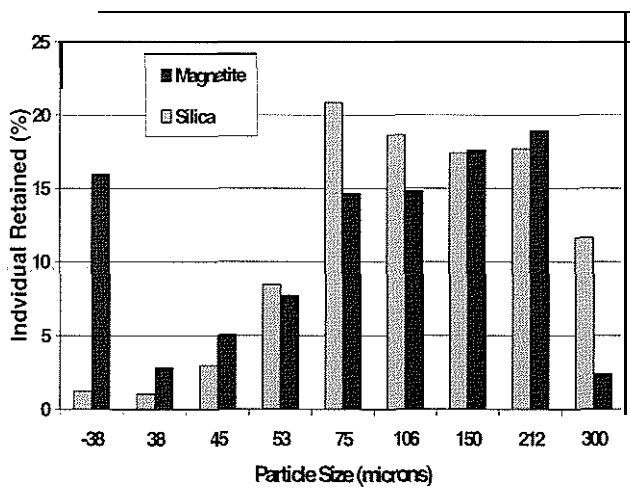


Figure 4. Silica/Magnetite Size Distribution

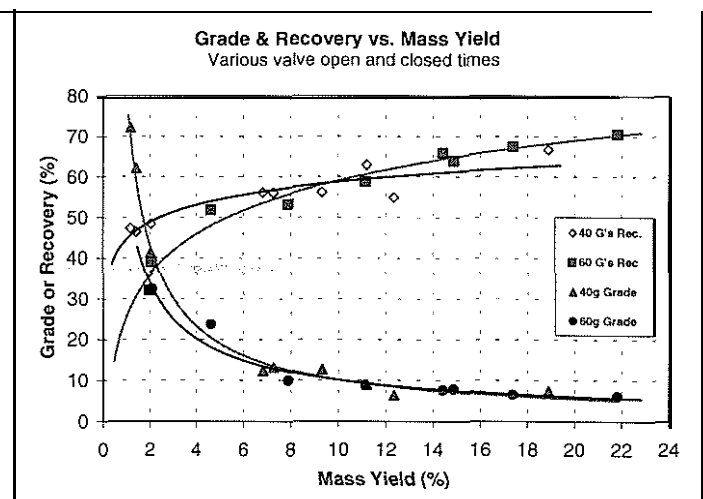


Figure 5. Grade & Recovery of Silica/Magnetite with the CVD

A sample of tantalite ore was also obtained for pilot testing. Two separate streams, consisting of a fine and a coarse feed, were tested. The size distribution of each is shown in Figure 6.

The results from the pilot tests were encouraging, with recoveries of up to 90% in 20% mass yield, and 74% in only 2% mass yield. The results are presented in Figure 7.

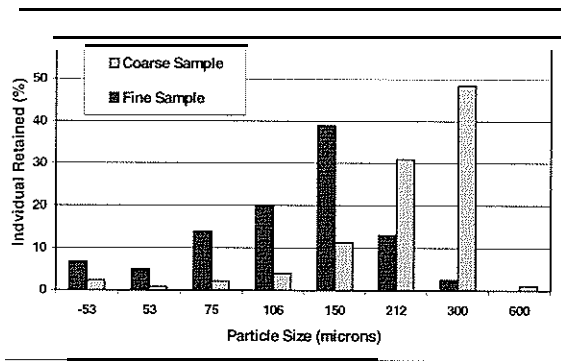


Figure 6. Size Distribution of Tantalite Feed

Table I: Coarser Tantalite Metallurgical Data at 60 G's

Feed Rate (mtph)	Fluid'n Flow (m3/hr)	Grade (ppm Ta)			Mass Yield (%)	Ta Recovery (%)
		Head	Conc.	Tail		
1.6	2.2	114	1335	46	5.2	61.4
1.6	2.1	106	723	30	11.0	74.9
1.5	2.1	143	730	34	15.7	80.1

Table II: Finer Tantalite Metallurgical Data at 30 G's

Feed Rate (mtph)	Fluid'n Flow (m3/hr)	Grade (ppm Ta)			Mass Yield (%)	Ta Recovery (%)
		Head	Conc.	Tail		
0.94	2.0	321.0	2214.0	84.0	11.2	76.9
1.11	2.0	391.0	13212.0	103.0	2.2	74.1
0.93	2.0	396.0	2698.0	70.0	20.3	90.8

Table III: Finer Tantalite Metallurgical Data at 60 G's

Feed Rate (mtph)	Fluid'n Flow (m3/hr)	Grade (ppm Ta)			Mass Yield (%)	Ta Recovery (%)
		Head	Conc.	Tail		
0.92	9.0	305.8	5217.0	66.0	4.9	79.4
1.02	9.0	167.0	675.0	50.0	18.6	75.4

Figure 7. Results From Testing Tantalite Ore

The first commercial application for the CVD involved a “reverse” application for an industrial mineral. Normally we think of the concentrate as the valuable mineral, and the tails as the waste component. A talc operation supplied a flotation concentrate sample where there was iron present as a contaminant. The talc has a low specific gravity of 2.7, with the iron present as hematite (s.g. 5.3) and magnetite (s.g. 5.2). The iron, reporting to Knelson “concentrate”, is the rejected material, while the talc, reporting to Knelson tails goes to the cleaner circuit as the valuable stream. This sample was tested in Knelson’s pilot plant with the results encouraging enough for the client to request a prototype machine for the mine site. The successful results generated by the prototype led to first commercial installation of new unit in the latter half of 2000. Feed to the machine is flotation cleaner concentrate. The reject stream, (the Knelson concentrate) consists of fine liberated iron, as well as unliberated talc with locked iron. In this example, the CVD appears to be preferentially recovering coarse un-liberated material, as well as fine liberated iron. This is seen as an advantage to the customer, as the locked iron in the talc can be re-ground to liberation after recovery by the CVD.

Currently, commercial applications for the CVD include the iron removal, above, as well as recovery of alluvial chromite, and cassiterite recovery. Pilot trials include iron ore recovery, tantalite recovery, alluvial cassiterite/silver recovery, gold slimes from tailings, and gold sulphide recovery.