The Knelson™ Concentrator

A Genuine Canadian Success Story

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Thirty years ago a pursuit to discover a ‘better way’ would revolutionize the application of gravity separation in the gold mining industry.

Today, this application continues to improve cash flow for operations around the globe.

The Knelson™ Concentrator – A Genuine Canadian Success Story

The history of gold is moveable feast. Every year new treasures and coin hoards turn up under the plough or the archeologist’s trowel unveiling fresh insights. The dawn for gold as a revered metal was long regarded as being in Mesopotamia or Egypt around 3000 BC. That theory evaporated with the discovery in the 1970s of gold axe-sceptres, bracelets, necklaces and hundreds or beads fashioned by goldsmiths before 4000 BC in an ancient necropolis at Varna on the Black Sea coast of Bulgaria. That debut in turn was revised in 2004 when the British museum put on show a simple gold wire bracelet dated 4475 BC that an expedition to Nubia had unearthed in a grave in the Wadi Allaqui, an early source for Egypt’s gold (Green, 2007).

It is widely believed that the source of gold used to create these early artifacts came from alluvial gold deposits and that in all likelihood, simple methods of gravity concentration was used to recover the gold. Thousands of years later, it was the lure of alluvial gold that also drove one Canadian entrepreneur, Benjamin (Byron) Knelson, to seek his fortune in the goldfields of Canada’s Yukon in the mid 1970’s.

Like many of his contemporaries, at the end of WWII Byron decided to leave his native Saskatchewan to seek his fortune on the west coast. With his life savings of several hundred dollars in his pocket, Byron made his way to Vancouver. Managing to make ends meet by taking on odd jobs Byron eventually found himself selling Kirby vacuum cleaners and later selling cars for a young entrepreneur of the same era named Jim Pattison.

After marrying in 1962, Byron settled down in the Burnaby area where he started a family. After an unsuccessful foray as a building contractor, he started an excavation business known locally

as Backhoes Unlimited. Although Byron sold the excavation business in 1998 it was through his connection to the excavation business that led to his involvement in a placer gold mining operation in the Yukon in the mid 1970s at an alluvial gold mine at Eureka Creek. There Byron Knelson witnessed a crude, but widely used sluicing operation that would recover coarse nugget gold but was ineffective for the recovery of the accompanying fine gold grains. He spent a total of five days at the site then returned to his home in Burnaby B.C. and set out to find a better means to recover fine gold. Little did he know his pursuit, would later revolutionize the application of gravity separation for the gold mining industry.

In 1976 Byron tested the first crudely built fluid-bed prototype centrifugal concentrator at an aggregate plant in the Fraser Valley. Although the first unit lacked mechanical refinement of today's carefully engineered units, the metallurgical performance of the unit set Byron Knelson on what would become an exciting and passionate 25 year journey that resulted in the commercialization of what has become an icon in the mineral processing industry in Canada and abroad – the Knelson™ concentrator.

Over the 30+ years since the first crudely manufactured Knelson™ concentrator was produced, the machine has become a fixture in many of the world's most prominent gold mines.

Theory of Operation:

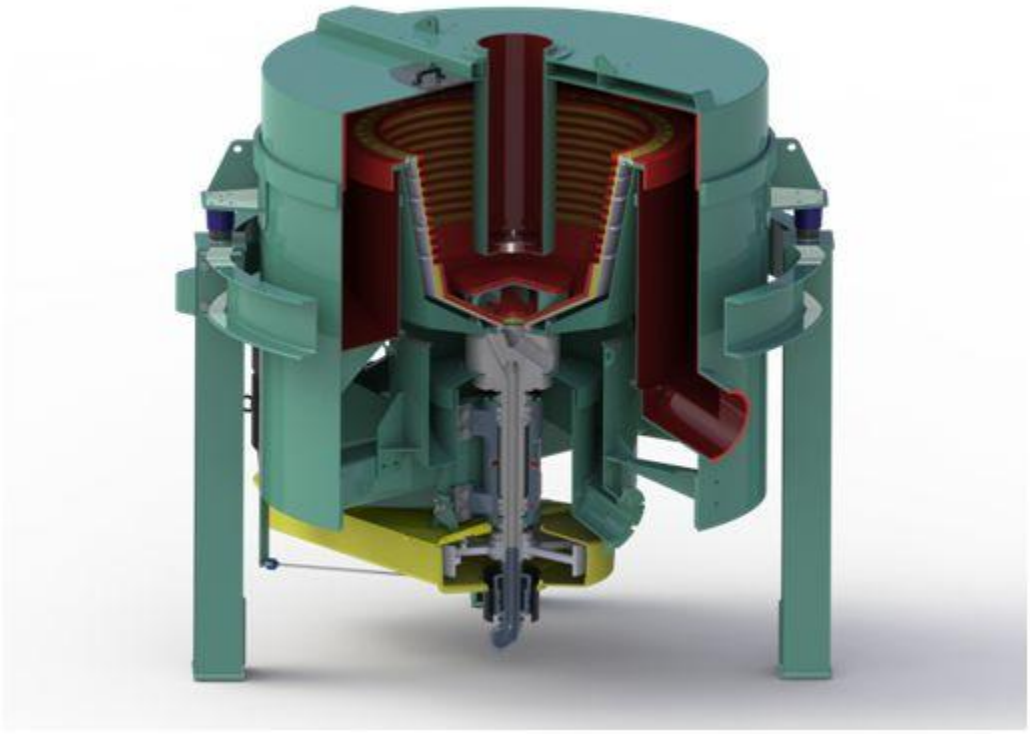
The Knelson™ concentrator is a centrifuge that combines enhanced gravitational force with a patented water injection process to create a fluidized concentration surface into which fine gold grains, due to their high specific gravity, can penetrate and become trapped. The original device operated at 60 G forces; and 30 years later extensive research has proven that for 90% of traditional gravity gold applications, 60 G's has proven to be near optimum.

Automated Process Control – A Major Breakthrough

Due to the fact that the original Knelson™ concentrator was developed for the alluvial gold mining industry, automated process control was not seen as a feature of critical importance. The original Knelson™ concentrator was called the MD, or Manual Discharge Series. The machine would operate for a fixed cycle time generally ranging between 6 to 8 hours at which time the feed to the plant would be stopped, the machine would be shutdown, a drain plug removed and gold-laden concentrates would be manually rinsed from the concentrating cone. While this

procedure took only a few minutes to complete, it presented serious operating concerns, personal safety issues and security risks to the much more sophisticated hard rock gold mining fraternity. This problem was overcome in 1992 with the advent of the Centre-Discharge feature which enabled the hands-off operation and fully automated control of the removal of concentrates and all process variables.

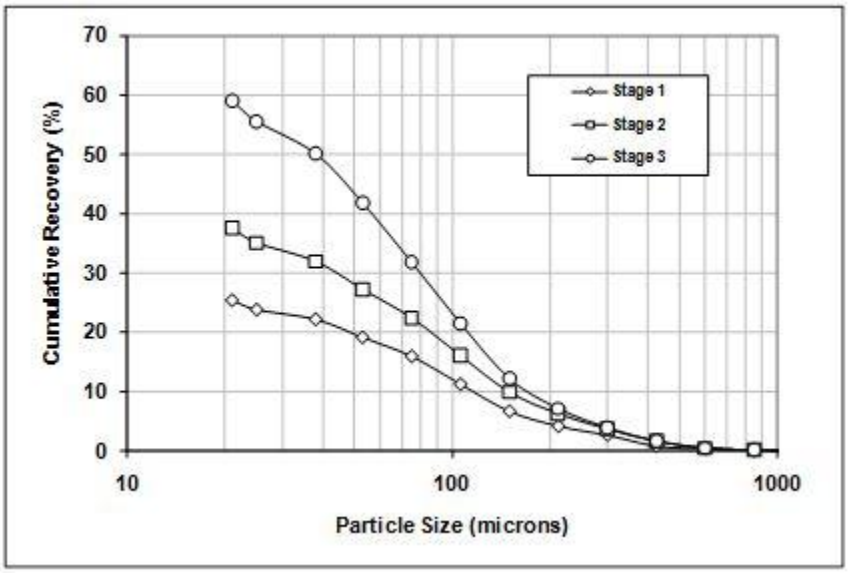
In the mid 1990's, the Center-Discharge, or CD Series Knelson was advanced by the introduction of the eXtended Duty, or XD Series. The XD had some features not available in the CD Series, mainly for ease of maintenance and longevity. In 2010, Knelson's newest design, the Quantum Series, was introduced, which again advances the design further, while also reducing the cost. In the late 1990's, the Knelson Continuous Variable Discharge, or CVD Concentrator was commercialized. This concentrator is designed to produce a continuous stream of concentrate and targets higher mass yield applications such as gold sulphide and heavy mineral recovery where higher mass to concentrate is required. Today, Knelson still manufactures all series of concentrators, from a much improved MD to the CVD to the newest Quantum Series.



Knelson Quantum Seriers Concentrator Cut-Away Graphic

The Gravity Recoverable Gold (GRG) Test:

This test was pioneered by the late Dr. Andre Laplante Associate Professor of Mineral Processing at McGill University (Laplante, 1998). The test uses one stage of crushing, followed by two additional stages of grinding. Each size reduction stage is followed by a gravity recovery step using the Knelson laboratory concentrator. Concentrates from each stage of processing are analyzed and cumulative recovery is plotted on a line graph.



Cumulative GRG Recovery as a Function of Particle Size

The Conventional Flowsheet Incorporating Gravity

Since the advent of the Knelson™ concentrator and the subsequent development of the industry standard GRG test, virtually all new gold projects are evaluated for the presence of gravity recoverable gold and in cases where the test results return values in excess of 20% GRG, the additional capital cost of including a gravity circuit can be economically justified. Over the past 20 years, many of the most prominent and prolific gold and copper/gold mines in the world have installed and have benefitted from Knelson technology.

Knelson Gravity Circuit

The Benefits of Gravity Concentration in Today's Gold Plants

The main benefit of gravity concentration in today's modern gold plants is dependent on the type of downstream processing. For plants with downstream flotation, overall gold recovery increases typically between 1-10%, (Yeomans, Fullam, & Duncan, 2006) (Froehling, Mohns, Rajwani, & Fullam, 2007) and occasionally up to 20% (Espinosa, 2011). There is also an average of 2-3% additional gold payment if gold dore bars are poured on site. If the downstream process is leaching, the overall recovery benefit is generally more modest, at 1-3% (Chong, Folinsbee, Millions, Fullam, & Grewal, 2006). This is attributed to early recovery of gold at the front end of the circuit. By capturing gold particles as they are liberated from the host rock reduces the potential loss of these values due to any inefficiency of the downstream processes. Other benefits include reduction in reagent usage, improved security, reduction of gold lock-up in the grinding circuit and subsequent improved cash-flow.

Applications

The original hard rock application for the Knelson was recovery of GRG from primary grinding, and this remains true today, as most Knelson Concentrators are installed in primary grinding. Over the years, other applications have been developed, such as Knelsons installed in flotation

regrind circuits for fine GRG recovery, to avoid over-grinding of the gold to increase overall gold recovery. Cleaning applications are also quite common, where fine GRG is removed from flash, rougher, or final flotation concentrates. Batch Knelsons are also installed for recovery of platinum group metals (PGM's) and in fact the single largest Knelson installation globally is at the Norilsk Metallurgical Facility in Siberia, Russia.

A Renaissance in Gravity Concentration

Thanks to the willingness of the Canadian mining industry to adopt and embrace the benefits of gravity concentration, there has been a resurgence of interest in gravity separation particularly in the gold industry. Over the past 15 years a number of new Canadian-based centrifugal gravity devices have entered the market including the Hy-G concentrator and the Falcon Concentrator. Falcon's enhanced gravity concentration technology began as a hobby for Steve McAlister in the late 1970's and early 1980's. The original machines were very crude, having to be built with an extremely small budget during spare time. Eventually, prototypes were sufficiently robust and effective to be trialed in an operating gold mill. The first commercial installation was made in British Columbia's Blackdome Gold Mine in 1986. This first application was shown to provide a measureable improvement in global plant recovery by treating ground shaking table tailings to produce a smeltable concentrate. Falcon now manufactures the Semi-Batch (SB) fluidized batch concentrator, the Falcon Continuous (C), designed for high mass yield applications, the Falcon Ultra Fine (UF), for ultra-fine applications, and the i-Con, designed for small scale miners. Falcon Concentrators Inc. changed its name to Sepro Mineral Systems Corp. in 2008 after it acquired a grinding mill and scrubber manufacturer in England

Similar devices have also emerged in Brazil, Australia and China further reinforcing the demand and acceptance of this genuine Canadian success story.

On August 29, 2011, Byron Knelson succumbed to complications arising from his battle with cancer and passed away at the age of 80. In his honour, his son, Brett Knelson and son-in-law, Doug Corsan created the Byron Knelson Memorial Scholarship. This scholarship supports the next generation of mineral processing professionals.

Knelson continues to operate today under the ownership of FLSmidth, who purchased the company on September 19, 2011. Brett and Doug remain a significant part of the company, continuing the proud legacy Byron left behind.

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