Leveraging an Innovative and Unique Particle Size Measurement Technology in a Copper Concentrator: Transforming Data to Knowledge to Actionable Decisions

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ABSTRACT:

The adoption of transformative process measurement technologies in industrial plants, including mineral processing concentrators, does not follow the pattern of the rapid development and adoption, that for example, information technologies follow. These technologies regularly morph into new features and functionality, that provide ever increasing speed and access to information at our fingertips that can be converted into knowledge and action.

In most concentrators, traditional "near-line" particle size measurement systems have been in place for several decades and have typically been inadequate for reliable use in automatic control and process optimization initiatives. However, these conventional systems have limited capability to provide operators and metallurgists with key information that would help transform information into knowledge that could mitigate variability and increase production. CiDRA Minerals Processing Inc. has developed a unique technology that provides a highly reliable system for "on-line, real time" measurement of the particle size in the overflow of individual cyclones. This innovative technology, the CYCLONEtrac™ Particle Size Tracking (PST) system, is based around a wetted sensor design with no moving parts and provides a real-time trend of the desired target grind size parameter.

The purpose of this paper is to: (1) explore why transformative technologies are slow to be adopted in the minerals processing industry, (2) provide a case study of how a copper concentrator, an early adopter of the PST technology, leveraged the value of real time information - not attainable with traditional technology - and how they transformed information into knowledge thereby increasing operating efficiency and net metal production, and finally (3) describe how this transformative technology can be an enabler for concentrators to 'cross the chasm' and capitalize on new trends in the industry for coarse particle recovery.

INTRODUCTION:

The adoption rate of transformative technologies is a compelling topic for any industry. Many of the same factors influence technology adoption regardless of industry. If so, why then are copper and gold concentrators, for example, slower to adopt new technologies than other industries such as the banking and financial industries? Before one explores the answer to this question in more detail, we must start with the premise that the rate of adoption is relative. An industry such as minerals processing may be perceived as a "slow adopter" from the outside, but from the inside it might consider itself to be a fast adopter in the industry it serves.

For example, many mines continue to invest in 'new and improved' technologies for the mineral extraction process, whether it be flotation cells, cyclones, and instrumentation for example. However, most of these technologies, while perhaps innovative, are not transformative in the sense that they are able to create a step change in terms of process improvement and domain knowledge. In fact, there comes a time in a product technology's lifetime where no matter the level of investment, there is little change in the performance and value-add to the end customer. This construct is illustrated below as the technology "S" curve which shows that as a product technology's life cycle is more mature, any investment produces only incremental change in performance and value to the end customer. Whereas with a completely new technology, investments along the early stages of the product technology's life cycle bring greater and greater changes in performance and value-add to the customer.

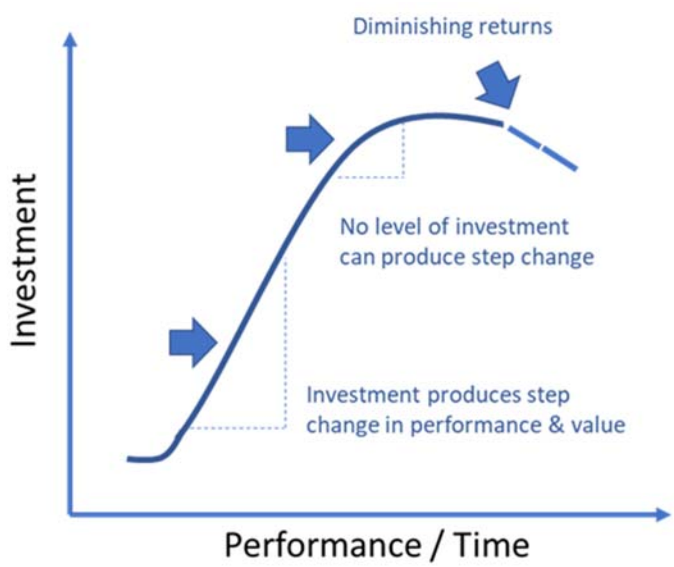

Figure 1: Technology "S" Curve

Besides delivering step change performance and value, new technologies can bring something much greater than performance alone…... knowledge.

The comminution process is highly variable and complex requiring a domain knowledge not easily attainable unless through many years of experience. Process instrumentation become the 'eyes' into the process, and in many cases instrumentation, particle size analyzers for example, were developed for other industries, such as pharmaceutical, chemical, food and beverages - even ground coffee. There will be further discussion later in this paper regarding particle size analyzers, but many of these instruments provide only data, and are sometimes the cause of variation in the process. New instrument technologies do exist that can transform data into a newfound knowledge that can help to eliminate process variation and at the same time increase net metal production.

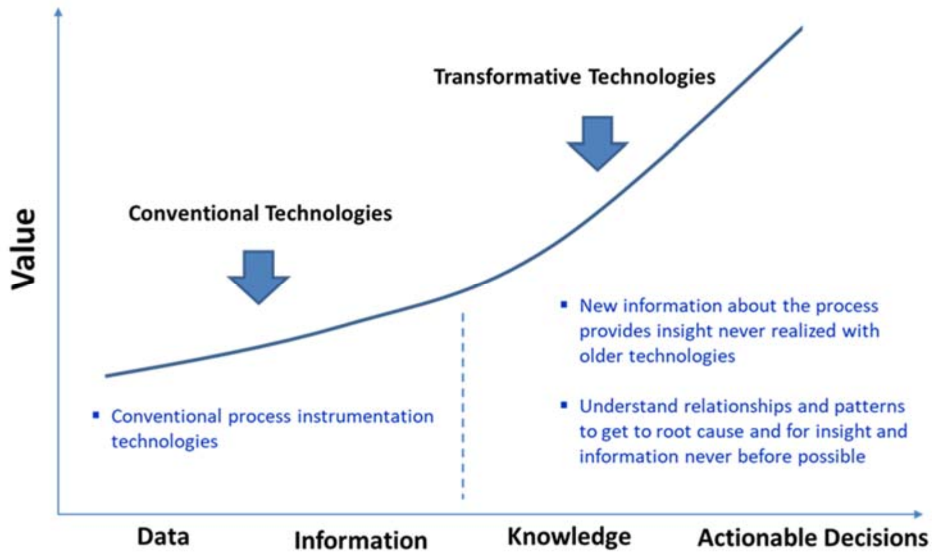

Figure 2: Transforming data and information to knowledge

In the next section we will briefly explore why the rate of the adoption might be slower in the mining industry relative to other industries. In the sections following that, we will describe a case study of an early adopter of a step-change technology in its concentrator. In the last section of this paper we will reveal how this technology can be an enabler for near-future transformative technologies relating to coarse particle recovery.

ADOPTION RATE IN THE MINERAL PROCESSING INDUSTRY

As mentioned earlier, the adoption rate of new technologies is relative depending on one's perspective. The mining industry is an adopter of new technologies. Many mines have seen quick returns from the basic use of high precision GPS (Global Positioning Systems). Few sites would agree that their full potential, in terms of the breadth of available data and the fluid integration of the operational efficiency information being collected by these front-end systems, is being fully utilized.[1] Overall, the capital investment for mining and minerals processing, whether it's in the mining operation, comminution, tailings or the environment, is both large and intensive, requiring years of utilization of those technologies to realize payback.

However, the adoption rate of new, transformative technologies for mining operations is slower *relative* to other industries. The factors that drive the adoption decision for new technology are basically the same. A few of these are outlined below.

Familiarity of the Technology
"Better the devil you know than the one that you don't know", is a well-worn cliché but is thoroughly human nature. People have a tendency to resist change, even when they know the new technology is superior, for many reasons: risk profile, afraid of the technology replacing hard earned experience, skills and job security. There are also instances where a conventional technology may have been recently purchased and the decision is made to run it through its useful life, even if it is providing much less value than the newer technology would.

Risk of Adoption
Trying to assess the value that a new, transformative technology will bring to the organization, relative to its cost is a difficult one. Some companies follow the classic example of "Crossing the Chasm".[2] Some are early adopters, others are fast followers, still others, late adopters. Typically, early adopters are in the minority because of the risk and uncertainty related to new technologies. This in itself slows the adoption rate tremendously. Not only does the adoption of the technology by the 'early adopter' process take time, what follows is an even longer time period whereby other operators in the industry become aware and comfortable that the technology is reliable, provides high value, and is fully supported by the manufacturer.

Ease of Adoption
The technology should create a sustainable and competitive advantage and should easily be adapted into the current process with low 'switching costs' for the operator. The new technology should not be complex but easy to learn and simple to maintain.

Outside Forces
Change is often affected by environmental constraints and pressures, costs and government regulations. In the last section of this paper, we will note how new, transformative technologies can meet these challenges with the potential to disrupt century-old technology and processes.

Reputation of Supplier
The decision to acquire new technology depends, in large part, on the supplier: does it have a long history of providing step-change and reliable technology to the industry? Does it have a reputation and capability to support the product technology in an industry that operates 24x7x365? Is the company viable with a sustainable business model?

In the next section, we provide a case study of a copper concentrator who became an early adopter of a unique particle size measurement system that was specifically designed for the minerals processing industry to address the need for real-time, reliable in-line measurement of each cyclone overflow pipe in a ball mill circuit.

CASE STUDY

This section focuses on one of the larger mines in the Balkan copper belt that mines and processes copper and gold-containing ores. The company is a leader in the Bulgarian mining industry and an active member of such organizations as the Bulgarian Chamber of Mining and Geology and the Scientific and Technical Union of Mining, Geology and Metallurgy. It represents the modern business and has an active civil position and a responsible approach towards the environment and the social issues of the regions where it is operating.

Like many concentrators, this company utilized conventional particle size analysis instrumentation and like most other concentrators, they were not able to utilize the measurements in automatic control applications for determining the final product particle size. Because of the nature of this conventional instrumentation - slurry sampling and the transport system - these systems require frequent maintenance and therefore their availability is low. In this specific case, as in others, the equipment was removed from service and the company performed manual sampling.

In March of 2017, the company learned of a new and unique particle size measurement technology called, CYCLONEtrac™ Particle Size Tracking (PST) system. This technology had already been proven in several large copper and gold commercial installations, in North and South America, demonstrating near 100% availability with minimal maintenance, thus overcoming the limitations of the conventional technologies. Unlike conventional particle size analysis systems that take periodic samples from the consolidated stream of the overflow from a cyclone, the PST particle size measurement technology is capable of tracking particle size on each *individua*l hydrocyclone overflow stream, providing never-before insight into the comminution process and improved process stability and plant performance. In addition, the PST particle size measurement systems real-time reporting enables automatic control of the circuit. A summary of the feature comparison between the PST particle size measurement system and the conventional sampling systems is shown in Figure 3.

	CYCLONEtrac PST	***Traditional Approach*** *(Sampled Consolidated Cyclone Overflow)*
Real time measurement	✓	✗
Enables closed loop control	✓	✗
Full stream analysis	✓	✗
No sampling system required	✓	✗
Low maintenance	✓	✗
>95% availability	✓	✗
Full particle size distribution*	✓	✓
Performance monitoring of individual hydrocyclones	✓	✗

***** Up to 5 output sizes***

Figure 3: Feature comparison between CYCLONEtrac PST and conventional sampling systems

In the third calendar quarter of 2017, the company purchased a PST system for two of their single cyclone batteries. Their goal with this purchase was to improve their process and particle size measurement and prove that this new technology provided the value and reliability it required before it instrumented its remaining cyclones. The PST system was installed and commissioning on two of the batteries in November 2017.

After operating the PST system for approximately one year, the company reported the following: *"The main virtues of the system are its easy maintenance, that there is not any sampling, the measurement is continuous and without any multiplexing of the flows. It provides the necessary accuracy, and finally, but not in the least of importance, the system is compatible with our running SCADA system for management of the grinding process.*

The CYCLONEtrac PST operation for one year confirmed our initial expectations. We were able to improve our automated management of the process, increase the grinding production, achieve stable particle size distribution at the each of hydrocyclones outflow, and increase the metal recovery within our flotation process. During our collaboration, CiDRA has definitely shown that they are trustable and reliable business partner." The company also reported that it learned things about their process they never knew before and this helped them uncover the root cause to reduce plant variability.

This testimonial nicely supports the factors that drive the adoption decision as outlined in the above section. This company is truly a classic early adopter of technology.

Shortly after, the customer purchased the CYCLONE PST systems for the remaining batteries which are now commissioned with the PST systems.

Finally, the earliest adopter of the PST technology, a copper mine located in the United States, noted that CYCLONEtrac PST systems are proving to be very effective in enabling grind circuit optimization and has led to value-based control strategies *incorporating throughput, particle size, and recovery trade-offs.* Improvements in the grind circuit efficiency from the new grind control system have led to reduction in grind size of around 30% at the same throughput, or when upstream is not constraining the ball mill circuit, a throughput increase of up to 10% at the same grind size have been achieved.[3]

In the final section to this paper, we will explore how the last factor influencing the adoption decision, *outside forces,* is one of the catalysts driving the trend towards another transformative technology – coarse particle recovery.

TREND TOWARDS COARSE PARTICLE RECOVERY

Environmental, sustainability concerns and governmental regulations can be the largest influencers regarding how and where capital is allocated and deployed by mining companies. Typically, these outside forces stimulate and steer new technology development in the private sector. Programs such as water conservation, tailings pond remediation and reducing power to drive SAG and ball mills are all high on the strategic road maps of the mining industry.

In this section we will describe how the PST technology is one enabler to a truly transformative technology that will allow concentrators to 'cross the chasm' and capitalize on a new trend in the industry towards coarse particle recovery.

Final ground particle size determines plant throughput and recovery, and thus the production of valuable metal that drives cash flow. The absence of a reliable real-time particle size measurement has for decades limited the implementation of automatic particle size control strategies that can enable mineral concentrator plants to maximize the production of valuable metal.

The new, highly reliable PST real-time particle size measurement technology now enables plants to implement control strategies that permit them to grind coarser, increase throughput, and optimize metal production, thus more closely approaching process limits while monitoring and controlling product size to avoid downstream problems.[4]

As explained in the previous section, the PST technology allows for a real time particle size measurement to be used in the control system of a ball mill circuit. Having the ability of real particle size control provides enhanced value to the enterprise by optimizing Net Metal Production (NMP). This value analysis methodology, illustrated in Figures 4 and 5, shows that to achieve the maximum increase in NMP, which is directly linked to net cash flow from the operation, throughput, in this example, should be increased and the final product size coarsened, despite a possible decrease in recovery.

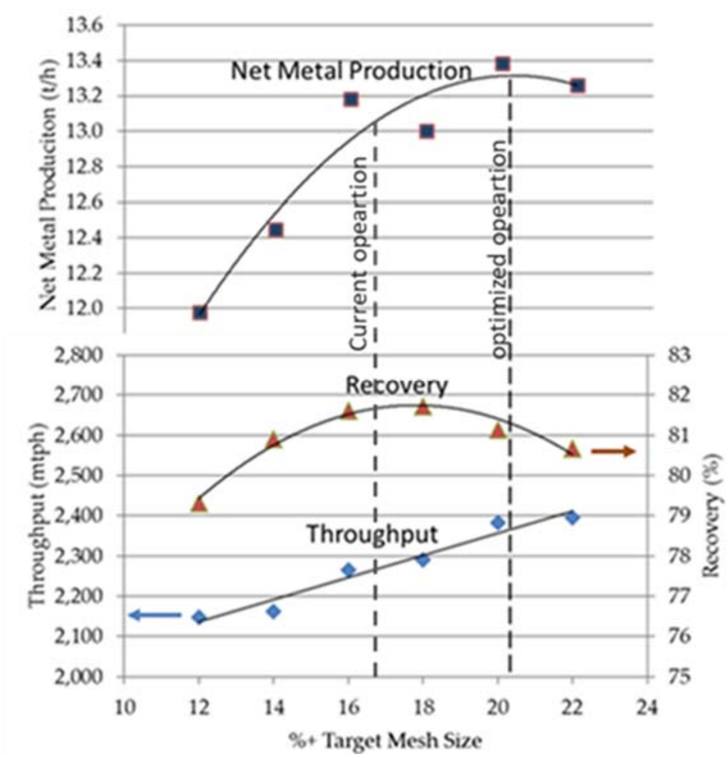

Figure 4: Throughput & Recovery with Net Metal Production (NMP) objective function.

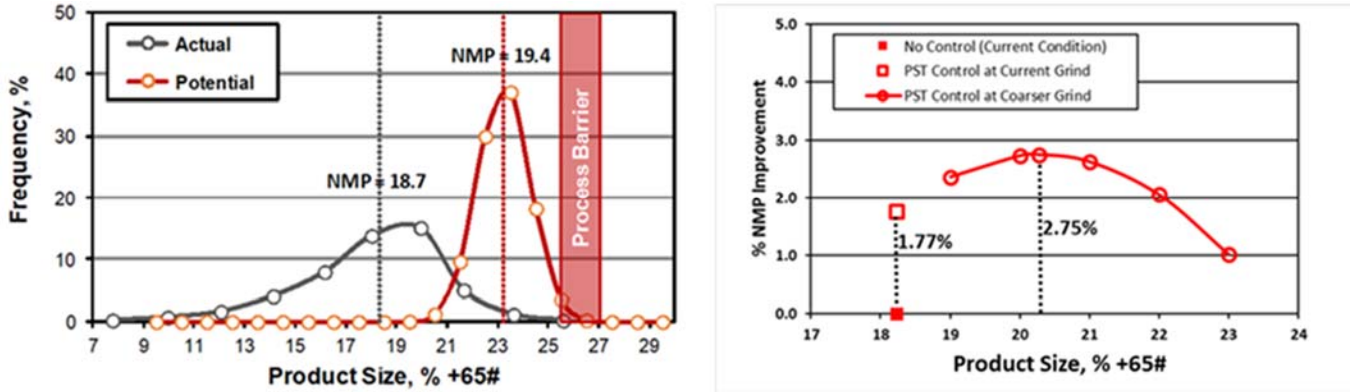

Figure 5: Actual and potential size distribution histograms and resultant NMPs (left) and associated potential percent NMP improvement (right).

In general, an important conclusion that can be drawn from the data, as shown in Figure 4, is that maximum NMP is normally achieved by increasing throughput by coarsening the product size, usually at the expense of sacrificing some recovery. From this important conclusion comes a challenge. How to measure grind size in a continuous reliable way so that these measurements can be incorporated in the automatic control system strategy, and thus prevent violating the downstream process limitations imposed by particle size and or material handling capabilities. Figure 5 (left) shows the actual particle size distribution without real-time particle size control, and the expected reduced variability and increased product size achievable by using real-time particle size control such as PST. Figure 5 (right) shows the potential incremental NMP improvements by only reducing size variability at the current product size, and then coarsening the product size to a higher target size.[5]

The ability to coarsen the grind and control to a specific size leads to our final discussion concerning the trend toward coarse particle recovery as follows.

Coarsening the final grind can significantly increase throughput and reduce specific energy consumption and production cost. The implementation of a coarse particle recovery solution has been hindered by two key limitations:

1. Controlling the final product size to enable the system to approach process barriers in a safe manner requires an advanced process control system that can *achieve the desired target size with low size variability.*
    a. Lack of a real-time, on-line particle size measurement such as the PST technology has been a key factor for achieving this goal.

2. Lower metal recovery in conventional froth flotation due to its limited ability to recover coarse particles
    a. The industry has had to grind to a particle size of less than 150 microns
    b. For over 100 years this limitation is due to the flotation process

CiDRA is in the process of commercializing a novel separation technology, distinct from flotation, which has the ability to extend recovery-by-size relationships with very high selectivity.
Flotation fundamentals dictate that bubble particle interaction (capture, transport, and release) are trade-offs largely driven by kinetics and pulp chemistry. Under this new paradigm, the optimized process can recover particles across a wide size range with high selectivity.[6]

The capability to grind coarse, P_{80} = 280 µm to P_{80} = 520 µm for example, and to have the ability to recover the mineral without the need for flotation, would have tremendous operational, environmental and sustainable value to the mine, the mining community and all stakeholders.

That said, while transformative technologies are slow to adopt, there will always be those 'early adopters' who will take the risks, enjoy the benefits, and gain the early-mover advantage over their competition. These early adopters often serve as lead customers to technology innovators and steer the direction of the technology's roadmap to their strategic initiatives.

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