Counter Current Decantation

A review of current control philosophies and research on alternative control methods or philosophies.

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1. ABSTRACT

This thesis will examine the 750TPH Counter Current Decantation (CCD) circuit that has just been constructed at the Kamato Copper Company in the Katanga province of the Democratic Republic of the Congo. The control of the CCD circuit is based on tried and tested methods utilizing PID controllers and control philosophies developed over the years. The intent of this thesis is to examine the existing control philosophy, demonstrate an in-depth understanding of the current control system, identify problems with the system controllers, research alternative control systems and philosophies to better improve the efficiency of the CCD circuit and finally conclude as to whether there are viable alternatives to controlling the CCDs other than using traditional control methods.

Throughout this report the author will investigate the origins of the CCD circuit, how the control systems have evolved over the years and what the latest trends are. Research will be piloted to find means to improve the control system of the CCDS thus attempting to eliminate inherent control failings of large CCD circuits.

The authors' involvement in this project is; he was appointed by Glencore to manage the construction of the Counter Current Decantation Circuit, specifically with focus on the Electrical and Instrumentation aspect of the project, the author has over thirty years' experience in the E&I profession in the mining industry with primary education in Instrumentation and Control and further education in Electrical Engineering. The installation and commissioning of the overall project is not at all part of this research paper. It was most fortuitous the plant was commissioned by the author while completing the Master of Engineering in Industrial Automation. After commissioning the process had to go through an optimization phase as it was known that there would most likely be problems with the operation of the plant. The timing of the plant optimization and that of the thesis paper was a perfect opportunity for the author to get involved in the plant optimization and to prepare this paper.

The author worked on the team made up of process operators and the plant metallurgists during the optimization stage and was regarded as the Electrical Instrumentation & Control specialist on the team focusing on the Instrumentation and Control of the plant optimization. The core of this paper is to demonstrate the authors understanding of the process and direct contribution and involvement with developing the new control architecture of the CCD.

It is noted and accepted that all the work performed and results obtained on the CCD circuit, by an employee, remains the Intellectual Property of Glencore and KCC.

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## 2. **TIME LINE**

<table>
<thead>
<tr>
<th>Date/Period</th>
<th>Activity</th>
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<tbody>
<tr>
<td>February /March 2018</td>
<td>Articulate the CCDs to a point that the audience, who are not familiar with CCDs, understands what the CCDs do and how they operate.</td>
</tr>
<tr>
<td>March 2018</td>
<td>Identify problems with the existing CCD process and what could be done to resolve these problems.</td>
</tr>
<tr>
<td>26-28 March 2018</td>
<td>Present initial thesis presentation to the review panel.</td>
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<tr>
<td>April / May 2018</td>
<td>Research, testing and implementation of theories. Document outcomes</td>
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<tr>
<td>21-27 May 2018</td>
<td>Present paper to the review panel.</td>
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<td>June 2018</td>
<td>Final preparation of paper</td>
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<td>24 June 2018</td>
<td>Final Submission</td>
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3. **INTRODUCTION**

The Glencore Group, Kamoto Copper Company (KCC), Luilu Plant (Map1), is designed to recover copper and cobalt from oxide and dolomitic concentrates produced at the Kamoto concentrator. The operation uses, leaching, and precipitation circuits to produce copper solution, this is passed to an Electrowinning plant to produce Copper metal. The principle of operation of the Luilu Plant is to use acid to leach copper from the oxide concentrates. Balancing the amounts of oxide concentrates minimizes the amounts of neutralizing agents or sulphuric acid needed to control the acidity of the process solutions and reduces the plant operating costs. Consequently, the proportion in which the ores are mined, concentrated and presented to the refinery is a key process parameter. Process flowsheets, process design criteria and mass balances were developed for the plant. The major change compared to historical operation is the implementation of a process control system which constantly monitors the process conditions in the plant. It is expected that this change, if correctly implemented, will positively impact overall metal recovery and product quality. It was strongly recommended that after the Luilu Plant has reached stable operation after phase 1 plant start-up, a detailed process review is performed to verify plant operation based on the developed process design criteria and mass balance and update the design if required [1].

The process used for the washing of the copper leach solution from the copper ore is a Counter Current Decantation process with Thickeners supplied by FL Schimdt.

CCD thickener circuits are used to recover soluble metal, Pregnant Liquor Solution (PLS), from ore leached residue. The basis of CCD operation is to concentrate suspended solids, thereby minimizing liquor content in the underflow slurry. The underflow Slurry Liquor flows in the opposite direction to the PLS and is diluted with the PLS, the suspended solids are concentrated again and again. High Density Thickeners (HDT) are designed to use gravity and compression, and minimize the amount of liquor in the underflow thus minimizing the number of CCD stages. Copper is extracted from the pregnant liquor using solvent extraction (SX). The loaded strip liquor from the SX plant is fed to the Electrowinning circuit to produce Copper cathodes. The washing efficiency in the CCD circuit is important to the recovery and hence, the overall copper production. The basis of CCD operation is to concentrate suspended solids thereby minimizing PLS content in underflow slurry. The underflow Slurry Liquor is diluted with wash liquor from the thickener upstream to achieve counter-current washing. Minimizing liquor in the thickener underflow leads to a higher recovery of soluble metal [2].

This paper reviews the process control around the pumping of the PLS and slurry liquor within the CCD circuit and how by optimizing the control philosophy a more effective control could be achieved.
4. **SYNOPSIS**

4.1 **Brief History of CCDs**

As early as 1901, a plant was built in the Black Hills of South Dakota by John Randall, employing the washing circuits attempting to make the process continuous by substituting for flat-bottomed wash tanks with coned bottom tanks which operated continuously, receiving a constant feed and discharging a steady stream of thickened pulp. These cones were operated in series, the thick underflow of the first one forming, with a stream of diluting solution, the feed to the second cone of the series. Barren solution was added to the tank immediately preceding the discharge tank and, after being slightly enriched by the low-grade pulp in this tank, overflowed to form a diluting solution again for the richer feed entering the third tank from the end of the series, and so on back to the richest tank of the series. Clear water was used for the wash in the final tank. This is the principle on which all successful countercurrent decantation plants operate at the present time, but Randall’s plant was not successful because of mechanical difficulties in getting a continuous thick discharge from his cone tanks. A similar plant was built in South Africa although there the washes were not repeatedly used, as in Randall’s case, but were precipitated after each contact with the ore. This also was abandoned because of mechanical difficulties and the cost of precipitating the large quantities of solution that had to be used. For a number of years the process was not used, and it was not until the introduction of the Dorr thickener that the minds of metallurgists began to turn again to the continuous decantation principle.

In 1910, two decantation plants were built making use of flow sheets similar to that used by Randall nine years before, but substituting Dorr thickeners for the cones. One of these was at Mocorito in Sinaloa, Mexico, and was installed under the direction of C. Dupre Smith, while the other was designed by J. V. N. Dorr for the Vulture Mines Co. of Wickenburg, Ariz. While perhaps not perfect at first, both of these pioneer plants were so successful as to encourage further installations, few and scattering at first but in considerable numbers during the past three years.

CCDs have become common processes in the Gold and Copper industries and are extensively used in leaching operations around the world. All the Copper mines Copper mine in the DRC now used large CCD circuits to wash the Copper solution from the Leached ore.

4.2 **KCC Counter Current Decantation**

The supplier for the Thickeners for the KCC project is FLSmidth. FLSmidth did not supply the automation, this is done by an “in-house” team who copied the control philosophy from the ‘Sister-mine” Mumi. A System Integrator (New Africa Controls, NAC) specializing in Siemens, PLC and SCADA systems, was commissioned to program and set up the control network made up of remote I/O panels, “Smart MCCs”, PLCs and SCADA.

The leached Pregnant Slurry is pumped into the Mixing tank of CCD 1, this is mixed with the Pregnant Liquor Solution pumped from the overflow of CC2. The mixed slurry overflows into the Thickener, flocculent is added at a ratios as determined by the solids in the slurry. The thickener acts as both a rinsing and a thickening process, the solids are settled and racked to be pumped away as a thickened slurry and the overflow is enriched with leached liquor and pumped off to the Solvent Extraction for further processing. The underflow is pumped to the mixing tank of CC2 and mixed with the overflow from CCD 3, the overflow from CCD 2 is pumped back to CCD1.
This process of mixing, thickening and rinsing the pregnant liquor from the slurry is continued as the slurry is pumped from CCD1 through to CCD 7, where it is discharged as tailings and the liquor is pumped from CCD 7 to CCD 1 where it is impregnated with the leached copper and finally pumped to the Solvent Extraction for further processing.

4.3 **KCC CCD Control Philosophy**

The Control Philosophy of the CCDs have been based on the philosophy from the Glencore Mumi mine.

The liquor control from CCD 7 to CCD1 is a PID controller controlling the level in the overflow tanks from the thickener, a set point of around 80% (just below the overflow level, is maintained by pumping the liquor into the next (preceeding number) mixer.

The underflow from one thickening tank is pumped into the mixer of the next thickener using a PID controller, the Process Variable is the slurry density controlled by speeding up or slowing down the transfer pumps. The addition of flocculent into the thickeners is based on a fixed ratio for the mass flow of solids into the thickener to ensure a calculated settling rate, this will in turn produce a slurry that settles on the bottom cone of the thickener and is raked into the center to be pumped away as a controlled slurry.
In concept the control philosophy works and under steady state conditions the underflow slurry and overflow liquor is transported without problem from one side of the CCD circuit to the other. This has become the norm for controlling CCDs within the Glencore Copper mines on the Central African Copper Belt.

4.4 The Problem Statement

The Unlike the other “sister mines” in the area, the Ore Concentrator and the Leaching/CCD processing plants, at the KCC mine, is over 7km apart and the Thickeners are much bigger than the earlier designs. The time it takes to pump the ore from the concentrator to the Leach/CCD plant and the large sizes of the CCDs has caused that there are product surges through the plant. With 14 individual PID control loops, the reactionary nature of PID controllers and the long Time-Lags in each of the Thickeners, the control philosophy, as based on the other plants, just does not stand up to the requirements of the operation for the new KCC CCD circuits. Spillage is the mayor concern, cleaning up of the slurry solids from the spillage bunds is a drain on the manpower and operations, spillage of the pregnant liquor is not only wasteful but also an environmental hazard as it is highly acidic.

As can be seen in Image 2 the density management of the thickeners plays a significant role in the outcome of the levels in the CCD circuit. As the level approaches 100% spillage is bound to occur if not caught in time.

The task is to find an alternative control solution for the underflow and overflow of the thickeners utilizing the existing control infrastructure and architecture.

The author will explore current trends for controls of CCD circuits, alternative controls and attempt to model various control philosophies of the CCDs on a process modeling software, Matlab, in order to find a most likely outcome to apply to the operation plant for evaluation.

The management team made it clear from the onset that as this plant is now a fully productive plant disruptions to the operability of the plant would not be accepted.
Image 2 CCD level VS density control
Thickeners forming the CCD circuit.

The Overflow and Underflow pumps, pumping the Aqueous (PLS) and Slurry between the thickeners.
Spillage from the overflow caused by poor control of the transfer between thickeners.
5. LITERATURE REVIEW

The purpose of this literature review is to identify means to control the flow of the PLS (overflow) and ore slurry (underflow) between the thickeners in the CCD circuit.

Various papers and publications have been researched to better understand up-to-date means to control the CCD circuit.

A Patent Application, “Method For Controlling Solids/Liquids Decant Unit Operations and Systems” was submitted in Jan 2013. In the patent application the author proposes methods for dewatering a slurry from the leaching of a valuable ore with an aqueous solution of an effective leaching agent via a solids/liquid decantation system, providing an overflow depleted from solids and an underflow rich in Solids that is washed counter-current through a number of Solids/liquid decantation stages, the improvement implementing into the process line utilizing a first Controller for monitoring and steering the leach product thickener and a second Controller for monitoring and steering the counter-current decanter [3]. On investigation, even though this process in almost identical to the CCD circuit at Luilu, it was felt the basic principles of this theory are fundamentally flawed. Two glaring matters with this design is; the recirculating of the overflow aqueous solution to dilute underflow slurry, this defeats the purpose of washing by having a stream of the pregnant aqueous flowing back with the slurry, as a theory it is also believed this will upset the overall water balance in the process; the flow control of the overflow in this proposal has been completely ignored as the existing CCDs in the Glencore mines use level control on the overflow needle tanks, this level control is highly effective in managing the transfer of the overflow aqueous from one thickener to another. It has been concluded that this control philosophy approach in not worth pursuing.

Two further papers regarding the control of CCDs where investigated; “Outotec® Thickening technologies and Current Trends in Counter Current Decantation” and “Thickener Circuit Operability and Control”.

Manta Controls, an Australian based company, had been engaged to optimize the various processing units on sites in Australia and around the world by improving the site process control strategies. This paper describes the improvements in CCD/thickening circuits in Australia that have adopted the new control technology developed by Manta Controls called the Manta Cube. Manta Controls has developed a control technology called the Manta Cube. This process control technology utilizes a variety of fundamental control techniques, including the traditional expert system approach together with new techniques specifically developed by Manta Controls. The Manta Cube is primarily made up of four parts: The Cube - this determines the operating mode of the unit process such as a CCD/thickener, the Cube expert decision matrix - this describes what is required to get the CCD/thickener back to the required operating band, the Cube engine - this is a fundamental control structure utilizing multivariable and decoupling techniques, and the Cube optimizers - there are various optimizers developed to ensure that the system is optimizing the control objective such as inventory or liquor recovery. The Manta Cube is configured locally on the site’s Distributed Control System (DCS) or Programmable Logic Controller (PLC) system using the inbuilt functionality available on these systems. This eliminates the need to maintain new systems, learn a new programming platform and removes additional hardware points of failure [4].

With the Outotec thickeners the control systems are built around two fundamental and simple control loops: The flocculation is controlled by varying the flocculent pump speed to achieve a consistent flocculent dosage rate per ton dry solids feed. Bed level can be used as feedback to control the g/ton set point. Solids inventory is controlled by varying the underflow pump speed to achieve a constant “bed mass”. By controlling flocculation and solids inventory, the thickening process is stabilized and
a consistent underflow density is achieved. For a number of thickeners in series, such as a CCD circuit, the basic control philosophy for each unit remains as described. However, interconnection of control loops occurs down the circuit, leading to increasing disturbances in solids inventory. Solids inventory (The Bed Mass) is under good control in CCD 1, but the variation in control output from CCD 1 amplifies through the CCD circuit, resulting in larger disturbances in the Bed Mass. By the time it reaches CCD 5, the Bed Mass control is subject to unacceptably large fluctuations adversely affecting operating parameters including Underflow Density and Bed Level. The disturbances can be controlled by means of a feedforward algorithm equipped with adaptive tuning functionality to allow optimal feedforward gain to be set. This results in stable solids inventory (i.e. bed mass) control down the circuit, and therefore stable bed level and density control is maintained. Adaptive tuning uses recursive modelling and signal analysis techniques. Depending on plant control system facilities, adaptive tuning is implemented as part of an Outotec thickening control system or it runs on Outotec® ACT expert system platform. This “higher level” control has been developed for both Flotation and Thickener circuits, and is based on Outotec’s extensive experience in plant control methods [5].

The issue with both these solutions is that they are propriety solutions with little information on how the thickeners and CCDS are actually controlled. This is however understandable as these companies have spent a lot of time and effort in their R&D and rightfully expect return on their investments. However as KCC did not purchase the CCD circuit from Outotec their system was not available. A decision was made that to rather develop the control philosophy “in-house” as apposed paying for a “Black Box” solution.

What has come out of the research is mention of adaptive tuning using recursive modelling and signal analysis techniques. From the paper “Recursive Modeling of Stateflow as Input/Output-Extended Automaton”, Simulink/Stateflow [6] is a popular commercial model based development tool for many industrial domains, such as power systems, aircraft, automotive and chemical plants. Simulink is much better for handling continuous systems, whereas Stateflow is much better for handling state based problems. Owing to the correctness, safety, security, etc. requirements of such systems, methods to analyze the system designs are needed. Simulink/Stateflow however has originally been designed for the simulation of the designs, and does not provide a model that makes it amenable for formal analysis such as verification and validation [7]. From this research paper and the work of Messer’s Meng Li and Ratnesh Kumar, it is clear there is an opportunity to model the CCD circuit as constructed at KCC to identify the best possible control philosophy using the Recursive Modeling of Stateflow in Matlab, the author of this paper will utilize this method as part of the development of the KCC CCD modelling.

From all the papers the author has researched, it is clear that the control philosophy of the CCDs is a very closely guarded technology. There is abundant information on the operation, the technology and the physics of the thickeners, however when the thickeners are placed in series to form a CCD circuit the operation of these circuits are held within the operators and suppliers for the CCDs. This leaves the author of this report ample opportunity to research and trial new methods to stabilize the operations of the CDDs, as constructed at KCC, Luilu.
6. INVESTIGATIONS, RESEARCH AND FINDINGS

6.1 Theoretical modeling of the plant

As part of this review the intent is to model the plant in a modelling program like Matlab. The process of the CCD is mainly made up of a series of Level Indicator Controller loops on each of the Thickener Tanks, these LIC loops all feed into each other with the output of the first being the cause of the disturbance to the next, these loops that control the overflow wash water of the CCD flowing counter to that of the underflow slurry. The underflow of the CCD is controlled with a sequence of Density Indicator Controllers, these DIC loops control the slurry flow from one Thickener to the next.

As this is a running plant producing 150TPA of Copper in solution the plant management was not happy to use this plant as a “trial and error” test study, however was happy that the author did ongoing studies to identify possible ways of improving the operation of the plant as long as production was not interrupted and implement a proposed control idea if it had significant merit and was easily reversible in the event of it not working. The first exercise as part of this research was to emulate the real-time controllers in Matlab [6].

Although setting up the individual density and level controllers in Matlab was not a problem, emulating the fluid flow in both the level controller and density controller across all the Thickeners in the CCDs was problematic, prior advice was that it will not be easy to model the process as a whole and this was proven to be true, the author spent a large amount of time trying to emulate the CCD process in Matlab, to no avail.

Although there are process add-on modules in Matlab and other modeling programs for process modeling, for instance SysCAD, on investigation these modeling programs however came at a personal expense and the time frame at hand to achieve a real outcome and the time available for this research paper did not avail its self to further peruse the need to effectively model the plant.

The standalone controllers in practice acted in a very predictable manner in the plant when only water was pumped through the CCD. During the initial test there was no slurry introduced into the circuit, these initial tests proved the controllers were able to successfully control the overflow water level and the underflow water through the thickeners with very little or no spillage of water.

6.1.1 Real-Time System Identification

The control problems manifested once slurry was introduced into the CCD system. When slurry is introduced into the first thickener along with flocculent, at a ratio per ton of suspended solids, as determined by the plant metallurgist, the settling time of the slurry in the first thickener is 5.5 hours, by which time the slurry is thick enough to be pumped to the next thickener. The controller on this pump will speed up or down the pump to adjust for the slurry density so as to keep a constant density to the next thickener. This pumped slurry is mixed with the overflow water from the preceding thickener and more flocculent to aid settling in the next thickener. It is steamily the density control of the underflow slurry that was causing the level surges in the following thickener. The level controllers of the overflow had to work hard to counter that of the output from the density controller, even though the density of the slurry was relatively stable.

Due to the large time lags in each thickener the “osculation” of the slurry was exacerbated throughout the 7 thickeners in the CCD system and caused the thickeners to overflow into the catchment sumps. The osculation’s stabilized when the slurry feed was stopped and only water was being pumped in both the forward and counter direction throughout the CCD circuit.
A means had to be found to counter the level surging caused by the density control.

**6.1.2 Problem solving**

There are seven thickeners in the CCD circuit all with the same design. The thickeners are designed with a predetermined settling rate of the solids from the feed slurry, this is aided with the addition of flocculent. The typical application of the thickeners is to separate the solids from the slurry, for this reason, the primary Controlled Variable of the thickener underflow is density. Separation is the fundamental principal of the individual thickeners, however as a series of thickeners, in the CCD circuit, the real purpose is to wash the copper enriched Pregnant Leach Solution from the slurry. During this study, the question was asked, is density control that important within the thickeners in a CCD circuit?

The response from the process Metallurgists was that density is important to ensure proper transfer of slurry from the thickener to the next but not that important within a singular thickener as long as there is enough settling inside the thickener to transfer the slurry and the slurry comes in contact with the counter current wash water to remove the leached solution from the slurry. The thickeners are designed using High Density [2] technology and are of the largest thickeners designed by FL Schimdth. This said there is ample capacity in the thickeners to cope with density fluctuations, however level control is key to preventing overflowing of the thickeners.

**6.2 The Breakthrough**

With all the information at hand and a much better understanding of the dynamics of the CCD circuit it became apparent that density control was not the most effective way of controlling the underflow slurry of the circuit. The level controllers acted in a very predictable manner and was very easy to set up using traditional and well documented methods when there was no slurry in the system. The introduction of slurry was the catalyst of causing the thickener level control to oscillate. So what was the underlying factor on the level controllers? The density controllers would speed up or down in order to manage the Density PV around the SP, this would then change the flow of the underflow flow rate of the CCD circuit, as a result the overflow pumps would have to compensate for the new level of the thickener, and so on. This multiplied by fourteen other controllers all working together or against each other was causing the level fluctuations.

Why do we not stabilize the flow rate in the underflow of the whole CCD circuit? A simple proposal by the author was to program into the CCD circuit, flow controllers to control the underflow flow rate between each of the thickeners. Going back to control basics, a Cascade FIC was incorporated into the Slurry control, the intention was to incorporate flow control into the slurry loop so as to better control the flow. The cascade control loop received a Density SP from the operator, the output of this DIC became the SP of the FIC and in turn the OP of the FIC directly controls Variable Speed Drive running the slurry pump. The System Integrators, NAC, was commissioned to program in the Flow controller and set up the FIC and DIC in a Master/Slave cascade format into the PLC and SCADA.

One distinctive advantage of PID controllers is that two PID controllers can be used together to yield better dynamic performance. In cascade control there are two PIDs arranged with one PID controlling the SP of another. A PID controller acts as outer loop controller, which controls the primary physical parameter, such as fluid level or velocity. The other controller acts as inner loop controller, which reads the output of outer loop controller as SP, usually controlling a more rapid changing parameter, like the flowrate. It can be mathematically proven that the working frequency of the controller is increased and the time constant of the object is reduced by using cascaded PID controllers [8]

The new flow Controller and configuration can be seen Illustration 3.
Even though the flow PV was stable around the desired SP from the master controller, as the SP changed from the OP of the master DIC the flow still varied, causing the level in the thickener to fluctuate, nothing much had changed, it was clear the cascade controllers were not the correct solution for the thickener application.

Realizing the Cascade control was not a viable option but now with a dedicated flow controller in the PLC the question was posed to the team. Can we just control flow in its own right and ignore the density? After brainstorming this idea got traction. There was no foreseen problem in ignoring the density and just focusing on the flow controllers.

A consequence of setting the underflow pumps to control the flow rate rather than density was that the density throughout the whole system would now fluctuate and oscillate depending on the input slurry density and the different settling rates in each of the individual thickeners, the consensus was that this would most likely not be a problem as the thickeners are very large with sufficient surge capacity within the whole circuit and unless there is a total failure of the system, what comes in will eventually come out.

Each of the underflow pumps would be used to control the flow from the one thickener to the next, the same flow SP would be used to set all the underflow pumps to the same volumetric flow rate. Individual pumps would have all have individual controllers as each pump and Variable Speed Drive dynamic will be different thus resulting in different PV but one flow rate throughout the whole CCD system. A flow control SP input will be available for the operator to set SP to match the incoming flow into the CCD circuit, and further enabling individual settings to fine tune the overall balance within the circuit.

### 6.3 Implementation

It was widely accepted that this idea could have merit and management approved to give it a try. The System Integrator was commissioned to program in a flow controller for each underflow pump in the PLC and new GUIs for the Flow Controllers on the SCADA screens. A further enhancement was that the operators could select between the original controllers and the new flow controllers, thus always have the ability to revert back to the original design if anything went wrong. The flow controllers were set up using tried and tested tuning methods while the plant was on water.
Illustration 4: KCC Thickener Controllers with flow controllers in standalone control mode

The direct result of the underflow FICs was that the flow is constant across all the thickeners thus eliminating the surge in levels across the thickener circuit. The development is still in the very early stages of implementation, yet the signs are extremely positive. As expected the density in the thickeners does fluctuate across the circuit with the different settling times in each thickener, however we are not seeing a buildup or loss of product across the circuit implying what is being pumped in is being pumped out and the whole circuit is balanced. The recovery of copper in the PLS is as expected thus not being influenced by the internal density fluctuations through the circuit.

In execution various set points were used for the underflow between the thickeners in order to stabilize the levels across all the Thickeners. The hypothesis for this was that the level controllers and the settling rates in each thickener is different and without flow monitoring in the overflow it was not possible to see what was flowing in the counter direction to the underflow. However with the constant levels across all the thickeners it is clear the overall flow through all the thickeners is balanced.

The outcome is that with the stable level control and the lack of level surges thought the CCD circuit, overflow spillage during normal operations have been eliminated. Spillage still does occur under exceptional circumstances, for instance power failures, however these events are beyond the scope of this paper and will be addressed during subsequent operational enhancements. As can be seen in Image 3, with stabilized flow control the levels in the thickeners is very consistent. With a well-controlled level there is no spillage during normal operation.
Image 3 Flow and Level control

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7. CONCLUSIONS

Overall this has been a very positive exercise with early signs of success. Spillage has been reduced in the CCD circuit with all the obvious benefits; environmental benefits, labor and manpower reduction and lower production losses.

This CCD circuit is a very large, world leading, copper project that is in its infancy, with operation only into its fifth month. The current CCD circuit is the first of two stages to be constructed with the second due to be commissioned at the end of 2018. There will be ongoing developments and fine tuning of the operational circuit with the Metallurgists also doing ongoing work to maximize the copper recovery. The work from this research has gone a long way to stabilize the process, making it easier for the Mets to find ways to improve recovery and will be fine-tuned over the next few months. The initial results are promising to the point that these new underflow FICs will be implemented into stage 2.

This research by no means is the conclusion of the improvement of the control but rather the start of learning how to better control very large CCD circuits.

The improvement of control was achieved without any significant plant interruptions, all the changes to the control system was performed in such a manner that if we encountered any problems we could always, at the click of a button revert to the earlier control philosophy.

Glencore, the owners of KCC have been making very high level international news lately (not all good) regarding the KCC mine and processing plant, the author has been reminded that, as an employee of KCC (Glencore), his research for this report is the Intellectual Property of KCC/Glencore and not for public information.
8. REFERENCES