Current Trends in Countercurrent Decantation and Thickener Circuit Operability and Control

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ABSTRACT

With recovery being important in optimising the business performance of a laterite and sulfide plant and with water being a precious resource in Australia, there has been increased pressure for companies to improve their methods of improving liquor recovery and improving water recovery in both laterite and sulfide plants.

This has resulted in new control technologies such as the Manta Cube being applied on countercurrent decantation (CCD) and thickening circuits which is necessary to improve stability and optimise the liquor and water recovery in these processing plants.

This paper describes the benefit of applying these new control techniques on CCD and thickening circuits in some of the mineral processing plants in Australia.

INTRODUCTION

In recent years, new mineral processing plants have been constructed and commissioned throughout the world. These new plants have been constructed and operated with tight budgets and with strict environmental limits.

With the environmental and financial pressure to ensure that liquor recovery is optimal in a CCD circuit and that water recovery is optimal in a tailings thickener circuit, it has been necessary to implement new control techniques to stabilise the washing and thickening circuits in these processing plants.

Manta Controls, an Australian based company has been engaged to optimise 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.

OVERVIEW OF THE MANTA CUBE

Manta Controls has developed a control technology called the Manta Cube. This process control technology utilises 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:

1. the Cube – this determines the operating mode of the unit process such as a CCD/thickener,
2. the Cube expert decision matrix – this describes what is required to get the CCD/thickener back to the required operating band,
3. the Cube engine – this is a fundamental control structure utilising multivariable and decoupling techniques, and
4. the Cube optimisers – there are various optimisers developed to ensure that the system is optimising the control objective such as inventory or liquor recovery.

The primary advantages of the Manta Cube are:

- 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. Any system developed using the Manta Cube maintains the robustness and integrity of the original site control system as it is developed without reliance on any communication to third party computer processors.
- The system utilises the dynamics of the process in the design of the control strategies. Coupled with traditional expert system type approaches and new control techniques developed by Manta Controls, the overall system is very robust.
- The underlying architecture of the Cube engine is structured utilising a modular framework making maintenance and upgrades very easy.

The business objectives are defined in the strategy design of the Manta Cube and the optimising logic continuously drives to achieve these outcomes.

IMPLEMENTATION OF THE MANTA COUNTERCURRENT DECANTATION/THICKENER CUBE

Manta Controls has Cube systems for the various processing units found in a minerals processing plant including, but not limited to, semi-autogenous grinding (SAG) mills, ball mills, classification circuits, flotation circuits, CCD circuit and thickening circuits. In this section the make up of the Manta CCD/Thickener Cube will be described.

The Manta CCD/Thickener Cube is made of two parts:

1. the Manta Underflow Cube, and
2. the Manta Flocculant Cube.

Both the Underflow and Flocculant Cube have been further developed to utilise the measurements of heavy mud level, interface settling band and the overflow clarity that are obtained from an online analyser called a Smart Diver.

A Smart Diver is capable of providing a very robust measure of the entire density profile within a CCD or thickener.

Sites that want to take the next step and operate their CCD or thickening circuit to achieve optimal performance require to know what is happening inside the depths of their CCD or thickener. Advances in CCD and thickener measurement technology have produced online instruments/analysers that do just that. A common thickener density profile analyser used in Australia and around the world is the Smart Diver.

The measurements of the heavy mud, interface settling band and the overflow clarity are only some of the measurements

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obtained from a Smart Diver. A Smart Diver is capable of providing the entire density profile of a CCD or thickener. These three additional measurements are essential together with the normal measurements of rake torque, bed pressure and underflow density to understand and operate a CCD or thickener optimally. A photograph of a Smart Diver installed at Gold Fields, St Ives, is shown in Figure 1.

FIG 1 - A photograph of a Smart Diver installed at Gold Fields, St Ives.

The two parts that make up the Manta CCD/Thickener Cube will be discussed next.

The Manta Underflow Cube

The Underflow Cube utilises the:

- heavy mud level,
- rake torque,
- bed pressure,
- underflow density, and
- feed to the CCD/thickener as control and constraint variables with the underflow flow rate as the main manipulated variable.

A graphic of the Manta Underflow Cube limits page is shown in Figure 2.

The Manta Flocculant Cube

The Flocculant Cube utilises the:

- overflow clarity,
- interface Settling band, and
- as control and constraint variables with the flocculant addition rate as the main manipulated variable.

A graphic of the Manta Flocculant Cube limits page is shown in Figure 3.

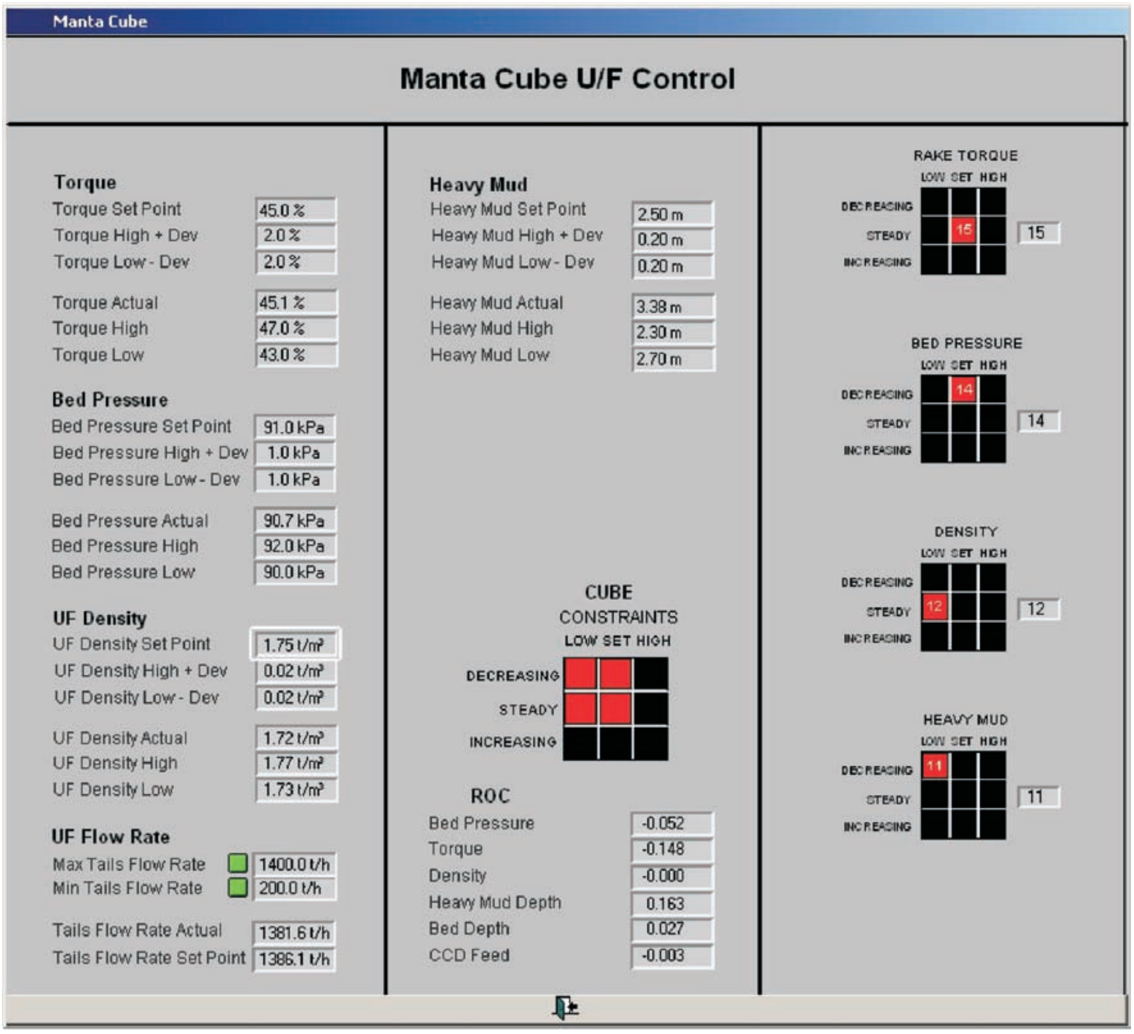

FIG 2 - A graphic of the Manta Underflow Cube limits page.

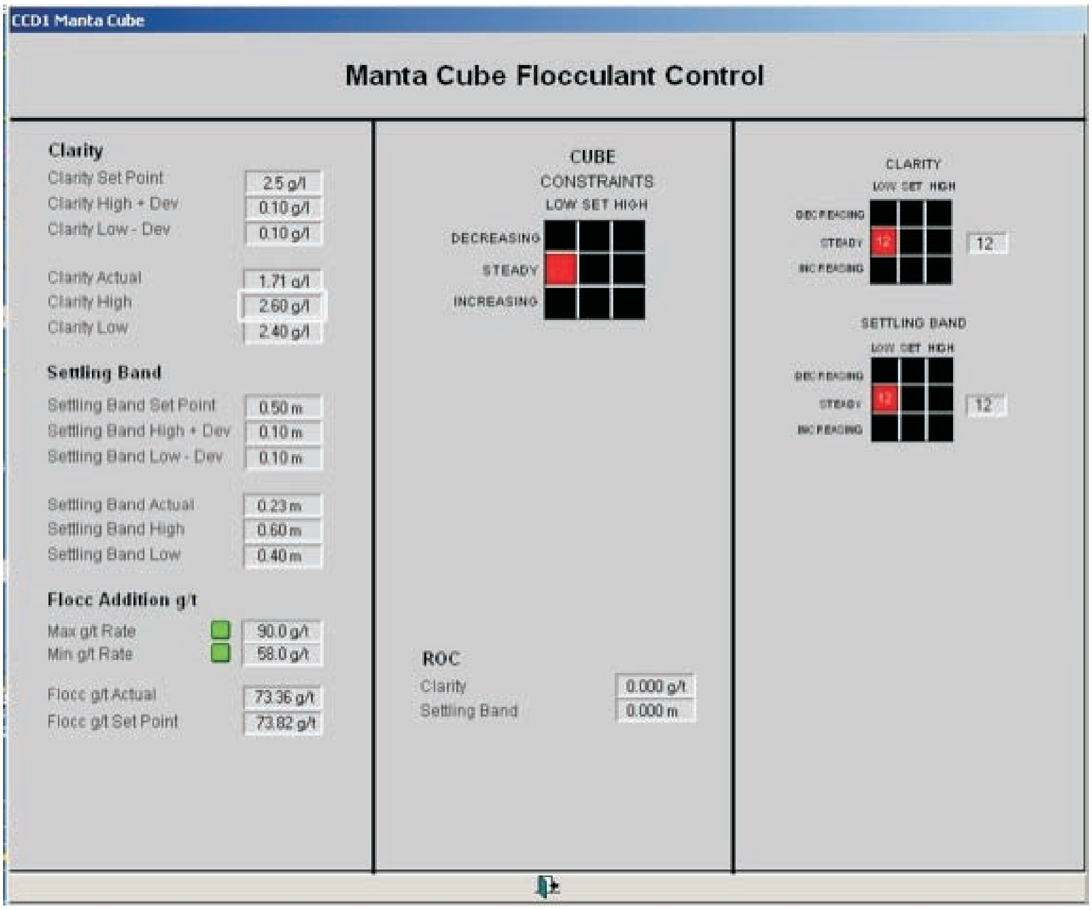

FIG 3 - A graphic of the Manta Flocculant Cube limits page.

Both the underflow cube and flocculant cube work together to ensure that a CCD or thickener is operating at the highest practical inventory level and optimum settling band whilst operating at or below the allowed torque limit. Some thickeners have a clarometer installed at the feed well that provides a settling time of the solids in the feed well. This measurement can also be used by the flocculant cube as an early warning to changes in solids settling. The actual settling band is ultimately a measure of how the solids are settling inside the depths of a CCD or thickener.

A case study describing the benefits of applying the Manta Thickener Cube on the tailings thickener at Gold Fields, St Ives, will be discussed next.

GOLD FIELDS, ST IVES – TAILLINGS THICKENER CONTROL

Gold Fields commissioned their new gold plant, St Ives, located near Kambalda in, Western Australia, in December 2004.

The St Ives circuit consists of three coarse ore feeders and one soft ore feeder supplying a 10.97 m (36') high aspect ratio single stage SAG mill in closed circuit with 508 mm (20") Krebs hydrocyclones. The SAG mill is powered by an ABB variable speed 13 MW wraparound drive. The grinding circuit feeds directly to a leach circuit without the aid of a leach feed thickener. The tails from the leach circuit report to the 40 m diameter tailings thickener. A schematic of the St Ives circuit is shown in Figure 4.

The site had previously installed the Manta Cube system on their SAG mill and had reported a 6.1 per cent increase in throughput. This increase of throughput had put the tailings thickener under a lot of pressure to perform consistently as it had become one of the main bottlenecks in the plant.

Prior to engaging Manta Controls, the tailings thickener was being operated according to the original control philosophy.

The main goal for Gold Fields, St Ives, was to improve the overall stability of the thickener performance with the aim of improving the stability of the underflow density.

Due to down stream pumping constraints there was no need to increase the underflow density, rather it was more important to reduce the variability of the underflow density and produce a more consistent underflow density that was to be pumped to the tailings dams. With this objective agreed to, the Manta Thickener Cube was then implemented.

Integration of the Manta Cube

The Manta Cube is fully integrated with any DCS or IEC61131-3 compliant PLC system. The Manta Thickener Cube at Gold Fields, St Ives, was configured on an Allen Bradley ControlLogix system and the main graphic is shown in Figure 5. Some other compliant systems include, but not limited to, the Yokogawa Centum CS3000, the Emerson Delta V and the Siemens PCS7 control system.

Performance at Gold Fields, St Ives

Figure 6 shows a performance test of the tailings thickener whilst in Manta Cube control. The performance test includes shutting down the thickener whilst in Manta Cube control and then starting up whilst in Manta Cube control.

From the trends in Figure 6, it can be seen that the thickener operation is very stable. The bed pressure is stable, the rake torque is stable, the bed level is stable and the underflow density is stable. This is how the Manta Cube is designed to operate and this operation is called operating as 'railway tracks', ie steady.

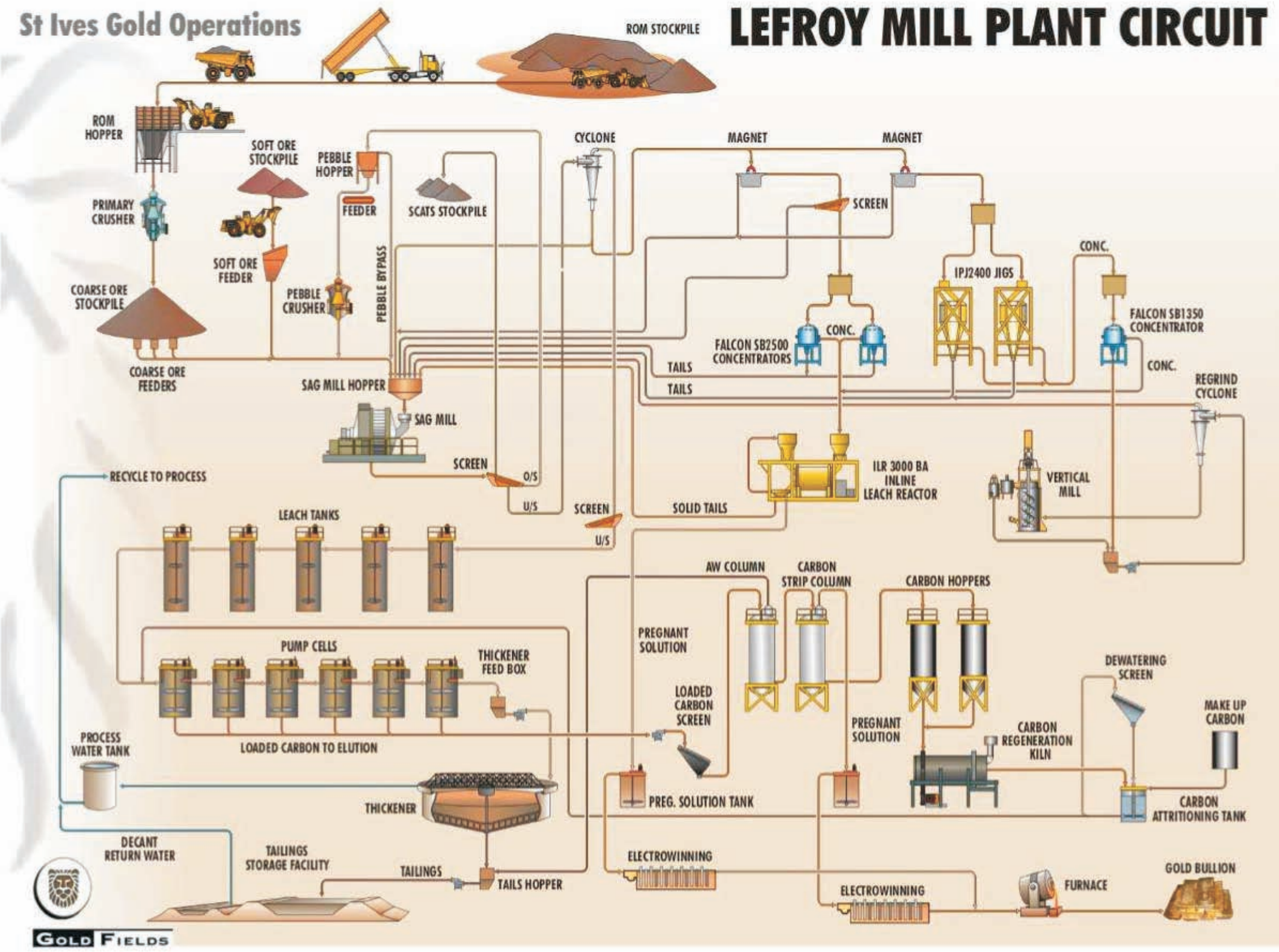

FIG 4 - Schematic of the Gold Fields, St Ives, circuit.

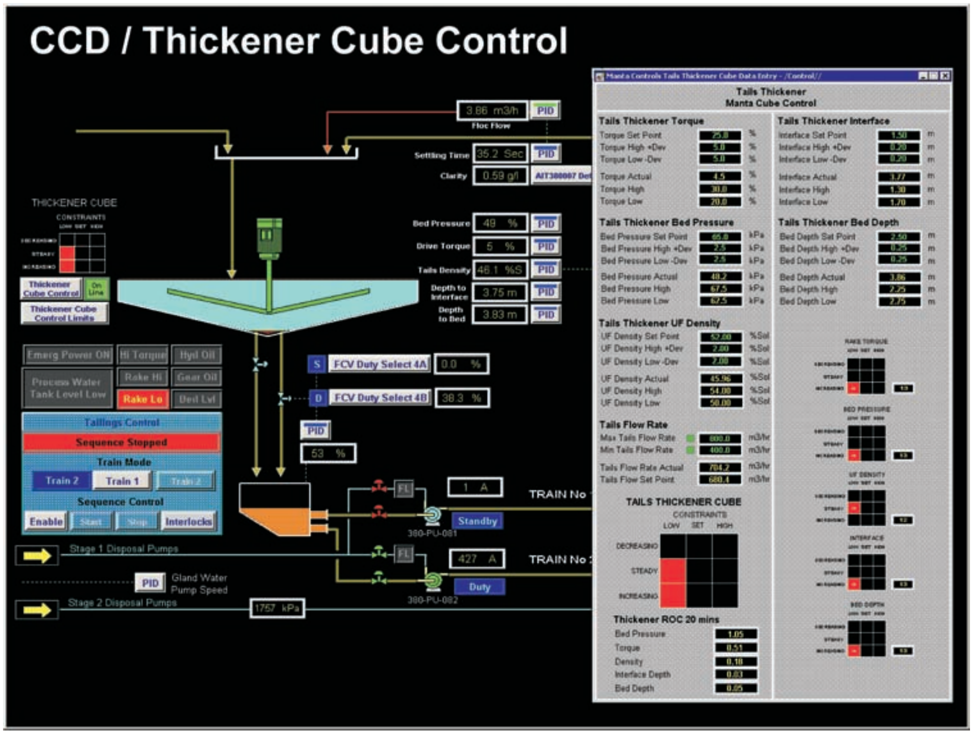

FIG 5 - Manta Cube integrated on an IEC61131-3 compliant control system at Gold Fields, St Ives.

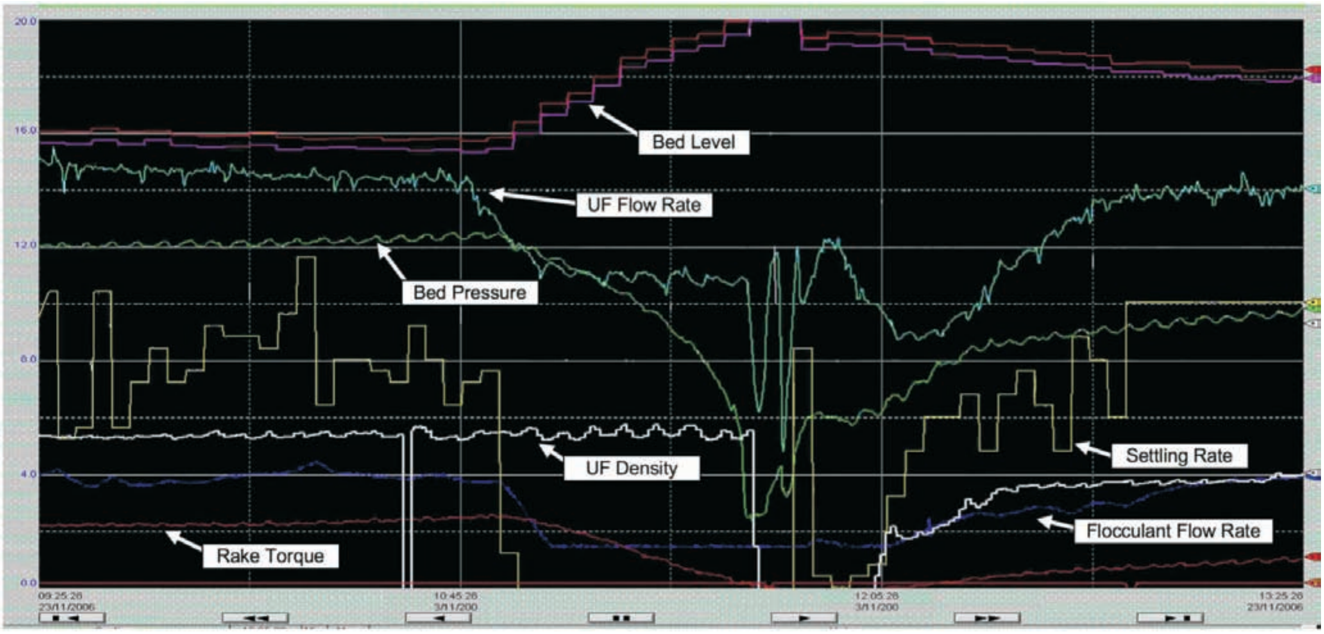

FIG 6 - Performance trends of the Gold Fields, St Ives, thickener during a shutdown and start-up.

As a test of how robust the Manta Cube is, the thicker was first shutdown and then started up with the Manta Cube online. Although this is not normal practice, it is a test that is performed to test the robustness of the system. Due to the system being robust, some sites do shutdown and start-up their thickeners with the Manta Cube online.

The trends show that whilst the thickener is being shutdown, it can be seen that the underflow flow rate reaches its minimum set flow and that the bed pressure, bed level and rake torque drop as the thickener is being emptied. This is what is expected of the Manta Cube on a shutdown situation.

Upon start-up, the Manta Cube begins to increase the thickener underflow flow rate and then automatically reaches a steady underflow flow rate, ensuring that the bed pressure, bed level, rake torque and underflow density are steady. With the thickener steady, the Manta Cube would then build up the inventory in the thickener to the required set limits. Starting up a thickener using the Manta Cube and achieving a stable response demonstrates the robustness of the Manta Cube system.

It can also be seen from the performance trends that the flocculant was controlling the settling rate of the thickener. Enabling the flocculant system has resulted in the interface of the thickener to be more stable whilst ensuring only the necessary amount of flocculant is dosed to the thickener thus minimising waste and lowering the consumable cost of flocculant. The flocculant system has resulted in fewer interface ‘flares’ to a point where they are now non-existent.

The tailings thickener at Gold Fields, St Ives, has constraints with the downstream tailings pumping system that does not allow an increase in underflow density, however, an increase in thickener stability has resulted producing a lower variability of underflow density similar to that shown in Figure 8.

In summary, the main objective of operating the Gold Fields, St Ives, tailings thickener in a very stable robust manner was achieved.

TYPICAL PRODUCTION PERFORMANCE

The Manta CCD/Thickener Cube has been applied to CCD and thickening circuits in laterite plants, base metal sulfide plants and precious metal plants. An example of general operational data collected for a month prior to the installation of the Manta Cube is shown as histograms in Figure 7. These are:

- rake torque (per cent),
- bed pressure (kPa), and
- underflow density (per cent solids).

A Smart Diver was not installed prior to the Manta Thickener Cube and therefore only the above three measurements will be used for analysis purposes.

It can be seen from this set of operational data that the underflow density varies over a wide range and this is consistent with normal operator control of a CCD or thickener.

After installing the Manta Cube, operator training is provided with each production shift. An example of general operational data collected for a month after the installation of the Manta Cube is shown as histograms in Figure 8. It is noticeable that the underflow density variability decreases. This is typically a key outcome.

The Manta Cube is maintaining a higher heavy mud level and higher bed pressure resulting in the thickener operating at a higher residence time whilst operating at or below the rake torque set point band.

Variations of feed type are also present arising from natural variation of ore types from the mine and due to less ore blending at the mine with direct tipping as being a more common operating strategy. The design of the Manta Cube allows it to self compensate for these variations with the result being a more stable CCD or thickener operation.

It is the ability to operate at a consistently higher residence time and consistent settling band that results in the more consistent and higher underflow density. An increase of one per cent solids to three per cent solids of the underflow density is typically seen as the nett result.

SUMMARY

This paper provides excellent examples of today’s plant design. The emerging challenges presented by streamlined plants demand higher control performance. The Manta Cube successfully overcomes these issues using a unique control algorithm implemented locally on the user’s plant control system.

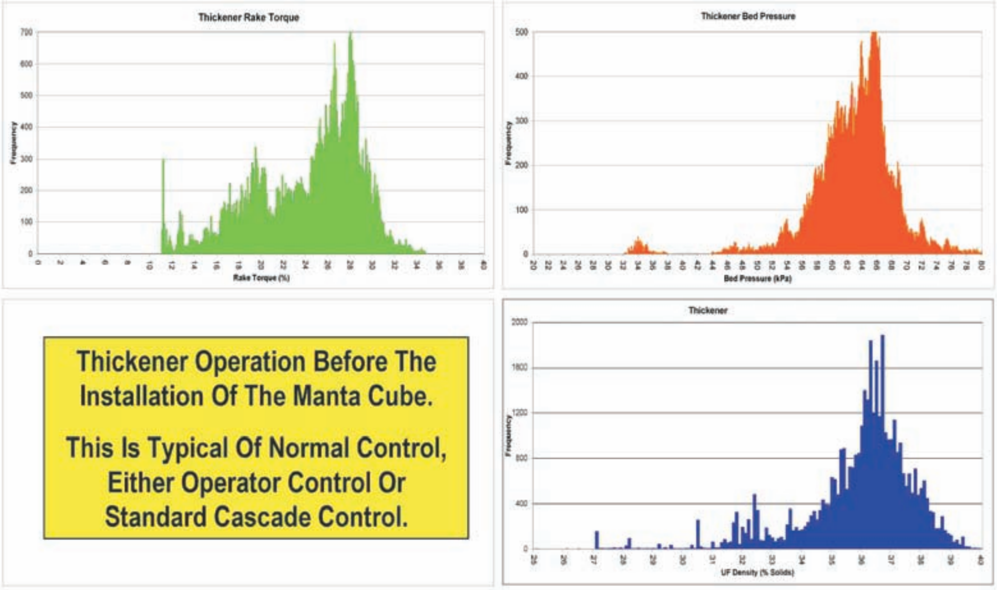

FIG 7 - The performance of a typical CCD/thickener before the Manta Cube is implemented.

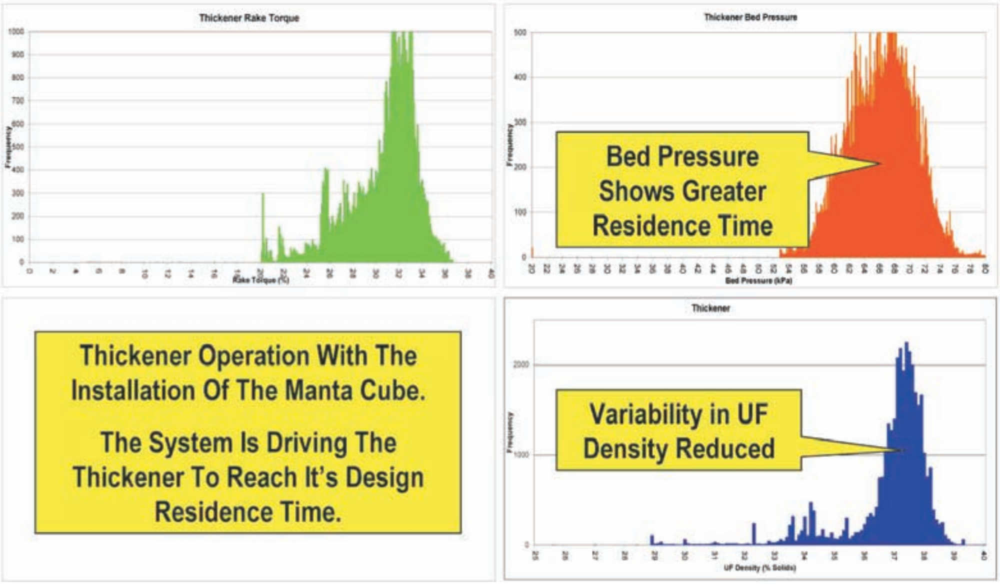

FIG 8 - The general performance of a typical CCD/thickener after the Manta Cube is implemented.

The Manta Cube has proven itself to handle common issues facing CCD and thickener circuits.

The Manta Cube provides additional benefits in operability by working directly on the local plant control system. Being a platform independent control technology, the Manta Cube removes the cost and complications associated with traditional, standalone expert systems. Local implementation provides operators and technicians alike with reliable access to detailed information on their CCDs and thickeners.

The case study described in this paper shows that the stability of the operation and control of the tailings thickener at Gold Fields, St Ives, greatly improved with the implementation of the Manta Cube. By using the Manta Cube, mineral processing sites across Australia have achieved greater CCD and thickener circuit stability, tight bed level control resulting in higher and more consistent underflow densities.

Their CCD and thickener circuits are working harder, continually pushing to maintain the bed level and interface settling band whilst maintaining the rake torque, bed pressure, clarity at safe levels resulting in higher and more consistent underflow density. In general the Manta CCD and Thickener Cube system results in an increase of one per cent solids to three per cent solids underflow density.

The design and construction of new mineral processing plants presents increasing pressure for reduced capital and operating costs with increasing environmental limits being legislated.

High performance control systems such as the Manta Cube continue to prove that they are no longer ‘a nice to have’, but rather a necessity for optimal operation of minerals processing plants.

ACKNOWLEDGEMENTS

The authors wish to thank and acknowledge Gold Fields, St Ives, and other production sites and all of the production and technical teams that have worked with Manta Controls for their valuable input during commissioning of the Manta Cube systems that have made the various projects a success.