INNOVATIVE SURGE BIN DESIGN FOR MINERAL SANDS PROCESSING PLANT

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ABSTRACT

Mineral Technologies carried out the mineral processing test work and developed the flow sheets for a mineral sands project in the Murray Basin, Australia. Mineral Technologies then completed the detailed engineering design for the project.

The ore body required a processing plant that could operate efficiently over a wide range of conditions:

- Slimes up to 30%
- Feed Rate from 500 to 750tph
- Heavy Mineral in situ from 12 to 19% w/w

The mined ore was to be stockpiled and blended to achieve this operating range. The material was to be screened and scrubbed to liberate the HM from the clays. The feed was then pumped to the Feed Preparation area of the Concentrator. The concentrator utilised gravity separation and wet magnetic separation to produce a Heavy Mineral Concentrate. The separation can cater for some slimes but anything more than about 3% will affect mineral recovery. The feed preparation utilised a set of cyclones to remove the majority of the clays and presented the upgraded feed to the surge bin. The cyclone overflow was then treated in thickeners for disposal with the tailings.

The Surge Bin was designed to have mass flow characteristics allowing material to be stored for up to an hour with a consolidation in excess of 80%w/w. The material is withdrawn using slurry pumps to feed to the spiral separators. Various forms of dilution water are injected into the bin to assist in the density control of the slurry.

The bin has a storage capacity of 350 tonnes and delivers the slurry to the spirals at a constant density.

This bin design utilises the work of Jenike and the University of Newcastle, Australia to determine the critical dimensions of the Surge Bin to ensure that there is mass flow. This work has been applied to particulate dry solids in silos previously but not to slurries. However, in fact, the slurry acts more like a solid in this situation rather than a liquid.

INTRODUCTION

In Australia, mineral sands mining began on the beaches of the east coast during the 1950's and 60's. These were generally dredging operations, consisting of a floating dredge pumping the sand slurry along a float line to the concentrator plant. At the concentrator plant the feed slurry would be screened in a trommel from which the underflow would fall directly into a surge bin and from where it is pumped to the separation equipment. It is characteristic of dredge mining operations that they result in substantial fluctuations in feed rate to the plant, including periods of interrupted feed. By making the surge bins relatively large it was expected that they would contain enough material to even out the variations in feed rate to the plant and maintain feed when dredge feed is interrupted. Early designs gave little consideration to the physical flow properties of the material in the bin, and how this would affect discharge rate. Initially the bins were designed with relatively low wall angles of around 45 degrees above the horizontal. This resulted in a number of material flow problems regularly occurring in surge bins, including material hang-ups, slumping and rat-holing. These issues caused the feed rate and slurry density to the separation equipment to vary considerably resulting in reduced concentrate grades and reduced mineral recoveries in the concentrator plants. Furthermore the separation equipment; Reichert cones and trays, and later spirals required slurry be presented at relatively high density for optimum performance, which was not always achievable with conventional bin designs.

Conventional slurry bins weren't designed for mass flow there would be funnel flow with a rat-hole in the middle of the bin allowing the incoming feed to pass straight through the bin. Interruptions in feed caused the consolidated sand hanging up on the bin sides to slough off sending high density slugs forward to the processing plant. If these were severe enough it would result in slurry line blockages in the plant. The plant would have to be shut down to clear the blockages resulting in excessive downtime. Generally the operators were very reluctant to carry excess sand in the bin for fear of material slumps and as a result the full benefit of having a surge bin was not being realised.

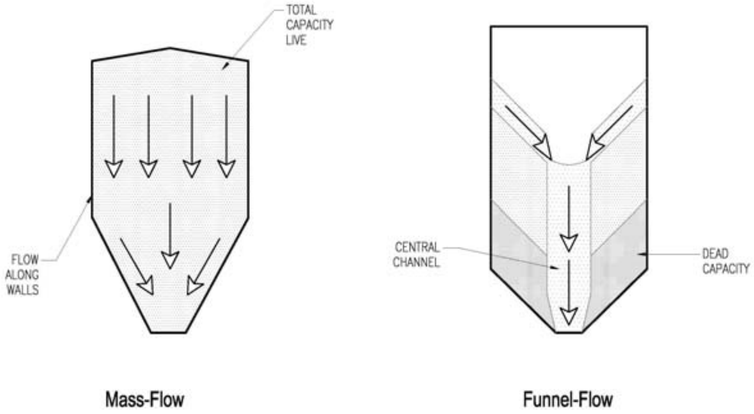
To overcome the identified material flow problems the surge bin designs were changed in a number ways over the years. The bin side walls were steepened to around 60 degrees and agitation water injection was added around the base of the pump suction to fluidise the slurry. Later a system was introduced to draw water off the top of the bin and into the pump suction. In principle the density of the slurry could be regulated by throttling the water flow through this bypass using valves. It was found that this system could operate reasonably well for a narrow range of surge bin levels, but that outside of this range the pressure differential between the slurry suction and the bypass suction made density control difficult. Furthermore, as technology in variable speed pump drives, flow meters and nucleonic density meters developed these were introduced along with control systems to improve plant stability.

Even with these improvements steady state operation of surge bins was not readily achieved using conventional surge bin designs. Having reliable discharge from the surge bin to the concentrator plant was identified as fundamental to improving the overall throughput capacity and mineral recovery rates.

MASS FLOW BIN DESIGN

Conventional thinking tended to treat bins containing a water sand slurry mixture as a viscous liquid storage system. In fact storage of slurry in a surge bin is better described as the storage of a bulk solid under saturated conditions rather than the containment of a liquid. This change of thinking resulted in the investigation of the behaviour of saturated bulk solids as analogous to the well studied and documented behaviour of dry bulk solids in bins.

There are two types of flow patterns that can form when the solids are withdrawn from a bin or a hopper. (Refer Figure 1). If on withdrawal all particles commence and maintain motion, including those along the bin wall, the bin can be defined as a mass flow bin. If on the other hand a “rat hole” forms within the stored material itself the bin would be classified as funnel flow. Generally the wall angles of mass flow bins are much steeper than those for funnel flow bins.



Mass-Flow

Funnel-Flow

Figure 1.

The design parameters for bins storing dry solids were investigated by Jenike[i] and involved the evaluation and comparison of both the consolidation stresses and the stresses causing the stored material to fail.

A water media affects the behaviour of the solid particles during flow by the effects of buoyancy and viscosity of the liquid. As the sand settles and consolidates in the bin it causes water to be displaced from the particle interstices and to rise towards the bin overflow. Similarly as the solids move through the bin towards the outlet the particles will need to dilate from each other. (McLean[ii])

The primary objective in the design of wet solids storage containers is to ensure that the contents will gravity flow at a consistent rate without flow obstructions occurring. The material flow properties need to be determined to allow selection of suitable bin geometry that will ensure that mass flow pattern is promoted (Arnold[iii] and Roberts[iv]). These will depend on whether the bin is axi-symmetrical, such as a conical bin, or is symmetrical about a plane, such as a chisel or wedge shaped bin. (Refer Figure 2) Generally wall angles in axi-symmetric bins need to be steeper to achieve mass flow than for plane flow bins.

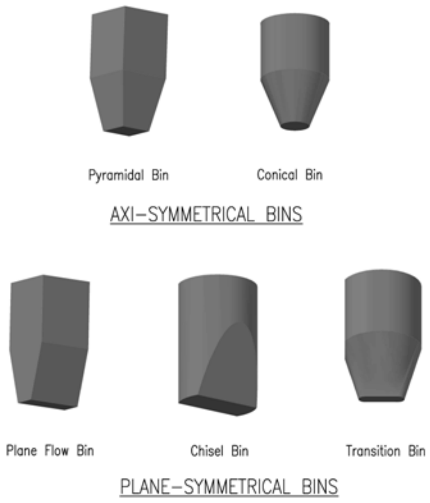


Figure 2.

MINE OREBODY

The mine is located in the South West corner in the State of Victoria, Australia.

The ore body is a series of mineralised sand strand lines containing quantities of the Valuable Heavy Minerals (VHM) Rutile, Zircon, Ilmenite, Leucoxene and minor quantities Cassiterite in a host of non-economic materials of silica sand, rock and clays. Total Heavy Mineral (HM) is defined as the fraction of material greater than a specific gravity of 2.85gm/cm^3. The in-situ average grade of heavy mineral was 13.9% HM, the heavy mineral assemblage consists, on average, of 44% Ilmenite, 12% zircon and 8% rutile & leucoxene.

The ore processing operations at the Douglas mine site consist of two main sections, the Mining Unit plant and the Wet Concentrator Plant (WCP). (Refer Figure 3). The mining unit plant was designed to slurry the run of mine ore at a rate upto 750tph and remove oversize rock before being pumped overland to the WCP. The WCP consists of a number of gravity, magnetic and classification stages designed to separate and upgrade the zircon, rutile, leucoxene and cassiterite minerals into a concentrate for downstream processing at the Hamilton mineral separation plant.

The Surge-bin (Feed bin) is central to the operation and control of the entire beneficiation process. It receives slurried ore from the MUP and is required to perform three major operational functions:

1. Provide surge capacity between the two remotely located and independently operated mining and wet concentrator plants,
2. Provide, a stable feed rate and density control to the gravity, magnetic and classifications unit operations of the WCP,
3. Provide a secondary classification for the continuous removal of clays from the spiral concentrators feed.

The practical result of combining the above functionality is the stable operation of the key mineral separation equipment ie the Spiral separators and the wet high intensity magnetic separators (WHIMS), thereby promoting conditions for optimum mineral separating efficiency.

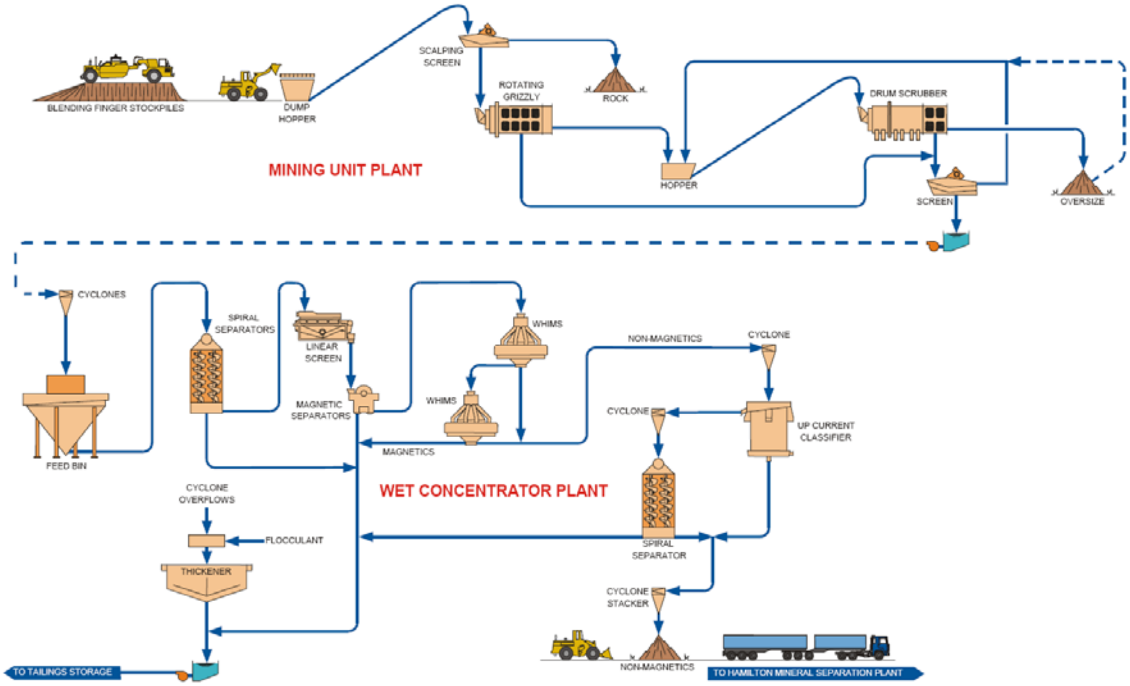


Figure 3. Schematic Flow Diagram of the Douglas Mining and Wet Concentration Plants

SURGE BIN DESIGN

The surge bin had the following basic design requirements:

- It had to accept screened slurry nominally in the size range +53µm to -2500µm.
- The feed slurry was delivered as a cyclone underflow at 75% solids w/w.
- Residual -53µm material in the cyclone underflow had to report to the bin overflow.
- The bin had to have a live capacity of 350 tonnes of solids.
- The discharge pump had to deliver the solids to the plant at a consistent 35% w/w density.
- A nominal discharge rate of 350tph was required.

In the bin design the incoming feed from the cyclones is spread out over a 3 metre by 1.7 metre feed box then tumbles through a series baffles into the bin. There the wash water jets wash the slimes free of the sand and it is carried toward the bin overflow. The bin overflow water containing the slimes reports to the thickener. The sand is then left to fall through the bin and pass through the consolidating zone to a layer of maximum consolidation. In doing this water is squeezed out of the slurry rising towards the overflow joining with the wash water. Further down the bin the sand must dilate to allow it to flow towards the outlet. As the sand dilates fluid must be drawn into fill the expanding voids. This may be drawn from the water above or below if the sand is permeable enough. However dilation water is injected at this level to ensure that the sand movement is not obstructed.

The main parameters to be used for the surge bin design were determined from the establishment of material flow properties by TUNRA Bulk Solids Handling Research Associates. (Refer Figure 4 and Figure 5). The bulk density value is used to determine the volume required to be contained within the bin (Refer Figure 6 and Figure 7). The storage volume required was determined to be about 180m^3.

The final shape of the bin was determined by using a plane flow insert allowing the bin angle to be 63 degrees above the horizontal (refer Figure 5). An axi-symmetrical section was placed above this which required the wall angle to be 73 degrees above the horizontal. The slurry is withdrawn from the bottom of the bin by a pump suction. The consolidated sand is fluidised with water injected through a plenum. This assists in moving the sand towards the outlet and reduces the % solids to a more dilute mixture.

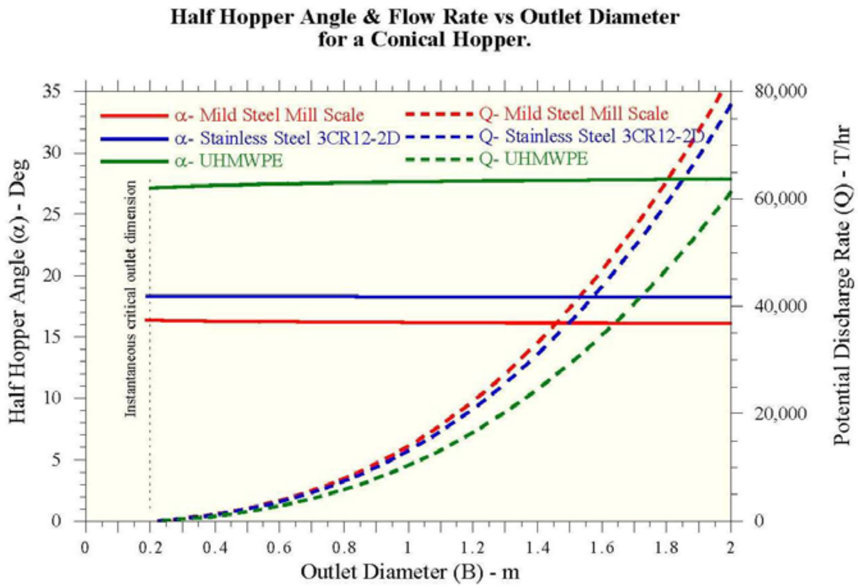


Figure 4.

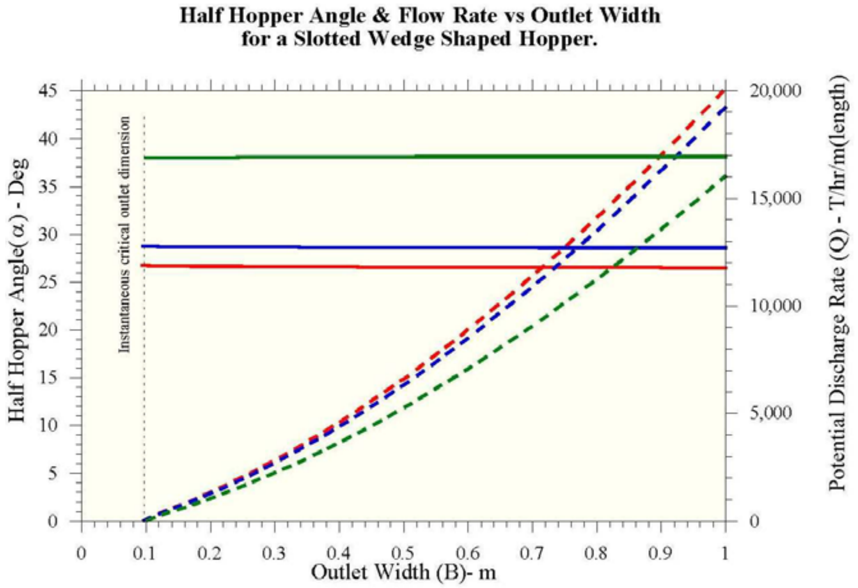


Figure 5.

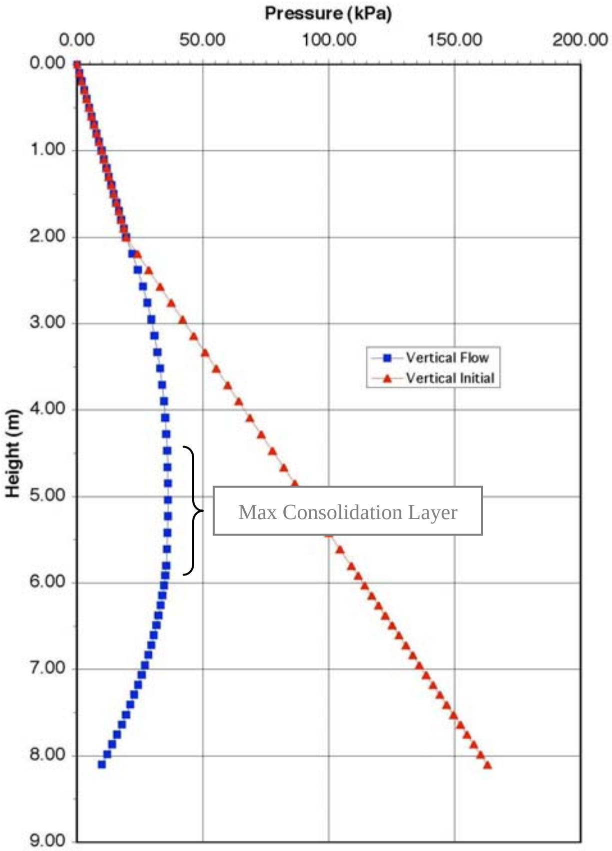


Figure 6.

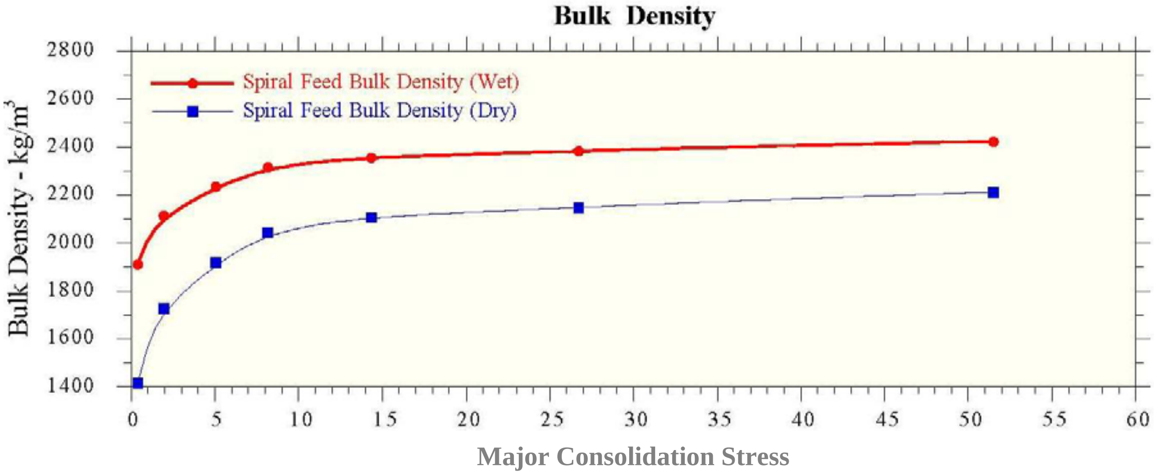


Figure 7.

The operation of the bin is controlled by various water injection functions. Successful bin operation relies on careful use of four dilution waters, which must be individually controlled and are drawn from the clean process water tank. The four points of water injection into the bin are:

Overflow Control

This water ensures the bin is full of water and maintains a constant overflow from the bin. The flow rate of water is controlled by measuring the bin water level. The bin is fed with high density slurry directly from the de-sliming cyclone underflow. The overflow water is injected directly under the feed point to assist in washing residual slimes to the bin overflow. As the slurry further consolidates within the bin, some of the water from the feed should also report to the overflow.

Dilation Water

This water is required to fill the voids formed as the material dilates further down in the bin, going from a higher to a lower level of consolidation. The quantity of water required for dilation is related to the throughput and the expected consolidation stresses lower in the bin. In low permeability bulk solids insufficient dilation water can cause the material to hang up in the bin.

Fluidisation Water

This water is injected at the base of the bin and is required to keep the bin active and the material moving towards the pump suction. This system supplies the majority of the dilution water required to achieve the final discharge slurry density. The flow requirement for fluidisation is kept relatively constant over the anticipated operating range of the plant.

Density Control

This water is fed directly in to the pump suction pipe work. This water is to be supplied by a variable speed pump controlled by flow and density meters in the pump discharge line. In this way the slurry density and feed rate to the spiral plant can be accurately controlled.

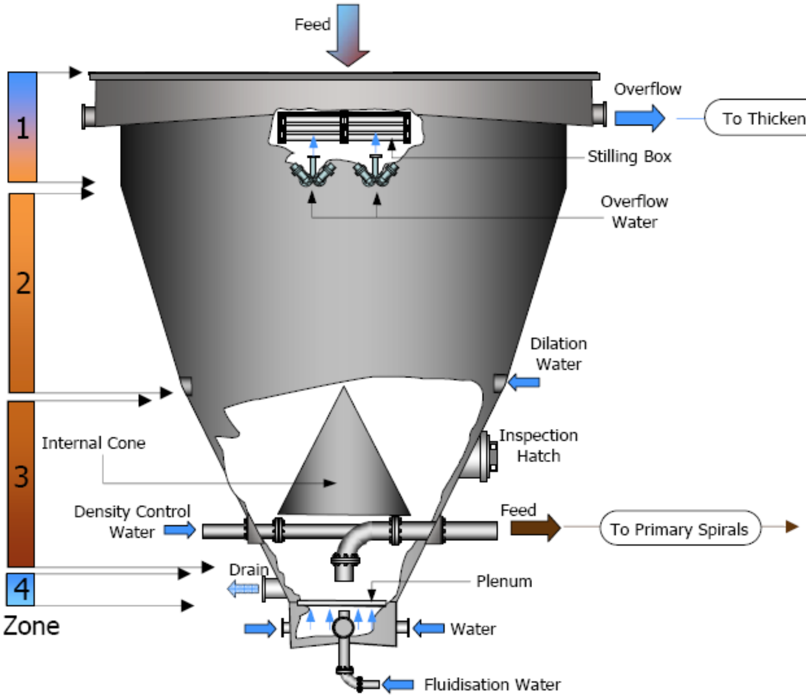


Figure 8.

OPERATIONAL PERFORMANCE

The success of this unit is best illustrated by the spiral feed pump slurry density. (Refer Figure 9) The slurry density at the inlet to the pump suction obviously varies over time but the response of the density control water pump is more than adequate to maintain the density at the set point. If the bin was rat-holing and the solids slumping then a stable output would not be achieved. This consistency of feed allows the plant settings to be optimised to provide maximum recovery (MacHunter[v]). The slurry level in the bin falls over the first 2 hours. During this period the density control water reduces suggesting that the slurry density at the pump suction has reduced. Similarly from 3 hours to 6 hours the slurry level in the bin increases the density control water requirement also increases. However over the range of slurry levels the spiral feed slurry density is held to an SG of 1.3 +/- .001. At hour 7 the operator increased the feed rate set point from 330 tph to 350 tph which caused the feed density to rise appropriately with no change in overall flow rate.

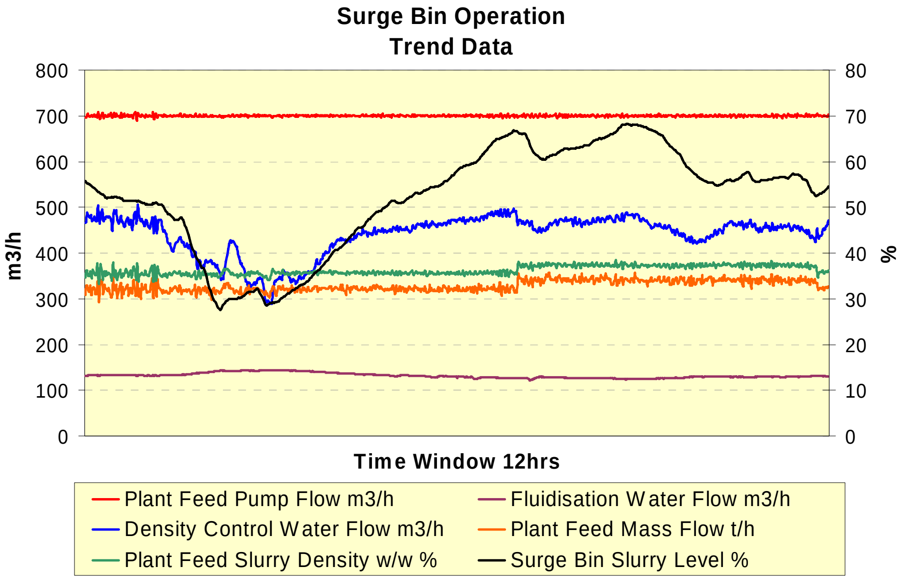


Figure 9. Surge Bin Operation Over a 12 Hour Period

CONCLUSION

This paper has given a brief outline of the application of the bulk solids flow design procedure for providing reliable discharge for a surge bin feeding a mineral sands processing plant. In comparison to a number of alternative designs the mass flow surge bin design provides significantly improved feed stability and reliability across a range of bin levels. The bin performance is enhanced by the responsiveness of the control system.

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