OPTIMISING CONTINUOUS OPERATIONS

BACKGROUND

Many of Wysowl’s clients are continuous operations. Metallurgical plants, cement plants, petrochemical plants, along with a variety of crushing/screening/washing plants such as are found in industries as varied as iron ore mining and fertiliser production all furnish examples.

As we would expect, there are several dimensions to optimising a continuous operation. One important field involves the technical aspects. Controlling particle size, chemistry and air flow in a metallurgical float circuit or a cement plant are two examples. Another is operational aspects, chief amongst which is the uniformity of flow of material through the circuits.

Little’s Law. Little’s Law states that, all other things being equal, as variation in flow of material through a circuit is reduced, throughput rises. This increases productivity and reduces cost per tonne. In our experience, many continuous plants operate at between 5% and 10% below their true capacity, and that variation in flow of material through the circuits and over-control are chief amongst causes for this reduced performance. Of course, this is a generalisation that will not apply to all plants, but they are by far the most common throughput issues discovered in continuous operations in our thirty years of experience. Little’s Law is a law, not just a good idea. We can guarantee that if variation in flow is reduced, cycle time (or residence time) will fall and either Work-In-Progress will fall or throughput will rise, or some combination of both; not sometimes; always.

CASE STUDIES

The remainder of this newsletter is given over to case studies. Much detail is omitted, to spare the reader a document that protects itself from being read by its sheer size. In each case, a before and after situation is indicated, along with a brief synopsis of the key work undertaken to achieve the results noted.

A COMMON APPROACH.

No two projects are quite alike, but there is a common theme that runs through many projects that successfully transformed a continuous operation. In most cases the improvement was made in two phases; stabilise the plant, followed by reducing stoppages.

Stabilising the plant by itself will reduce variation and increase throughput. A flow-on benefit is that once the plant is stable cause and effect relationships that were once concealed by the “noise” in the system become visible. This helps managers and technical people correctly identify the root causes of both quality and productivity issues, which in turn helps them to further improve both quality and productivity.

Once the plant is reasonably stable, it is normal for a second phase, improved reliability, to follow. Improved reliability increases run hours, and therefore productivity.
GOLD MINING/MILLING CASE STUDY

The first case study comes from a gold mining and milling operation in Australia. The chart at Figure 1 shows a dramatic increase in productivity immediately after the red arrow, which marks the arrival of a new site manager, Mr Bernie Cleary.

**FIGURE 1**

*Daily Wet Tonnes Milled - 3 Dec 14 to 16 Apr 16*

In Mr Cleary’s own words, the drivers for this improvement follow.

“The key to improved plant performance was reducing the variation in plant feed. This was achieved through the implementation of ore blending strategies and a systems thinking approach where the mine and mill are considered one process. We talked about a quality and systems approach to business from day one until I left that operation some 15 months later, I would often ask the miners how their decisions would affect the mill and remind them that stability of the mill was as much the mine manager’s job as it was the mill manager’s job.

In the first few days on site we reduced variation in the mill by creating fingers on the ROM to separate ore by fragmentation. You can see that in the charts. I recall on about the 3rd day on site going to the mill and noticing that the throughput was about 50tph lower than the day before, when I asked the supervisor why he said the dirt was hard. I found the mine manager and asked him to show me this hard dirt. He explained that the ore wasn’t any harder than the day before it was just that they had started mining the top flitch of a blasted bench which due to the nature of blasting is naturally less fragmented than the bottom flitch. The difference in fragmentation between the top and bottom flitch was like night and day. We discussed if it was possible to place the top flitch material in a finger separate to the bottom flitch to enable the loader to blend the well and poorly fragmented material evenly. He said, ‘Sure can! It is just that no one has ever asked before.’

From that day on blending was implemented and it only improved as more ideas were thought up on how to predict blending strategies that would stabilise the plant further. Blending stabilised the plant which in turn made the many operational issues such as shift to shift variation and over control easy to see. While increased production occurred immediately, eliminating the noise from the data and incrementally removing constraints that were mostly operational lead to the optimisation of the process plant”

One example of this over-control was that the Concentrator control system was periodically robbing the process of water. The second was significant over-control at the mill discharge hopper that caused the classification circuit be unstable. Once these issues were addressed, variability fell and tonnes throughput rose, as noted in Figure 1.

In the months that followed Mr Cleary’s arrival several issues arose, including leach tanks coming off line for maintenance, some trommel issues and ore that was extremely difficult to treat. Nevertheless, in less than a year Mr Cleary reliably increased production by about 12%, which equates to about 14,000 ounces of gold or around $21 million a year in revenue.
CEMENT PLANT CASE STUDY

At Figure 2 is the daily tonnes output from an Australian cement plant. The plant had a history of process related stoppages which limited production tonnes. Not long after a plant upgrade a variability reduction project was launched by the production manager, and led by the senior engineer. At the same time as some commissioning issues (post upgrade) were addressed. The combined effect of these initiatives can be seen in Figure 1, where output rose from 2,500 TPD to 4,300 TPD. Not only did tonnes output rise immediately, but also quality improved and the reduced noise in the data made many other improvements possible. In the initial phase of the project the only two aspects to receive significant attention were reducing variation in inputs to pyro-processing and reducing over-control and differences between operators and shifts. Subsequent work by the senior engineer and his variability reduction team both reduced stoppages and solved some quality issues. This plant run for over a year without losing a whole day’s production due to stoppages of any kind, and produced record tonnes that drove down unit costs.

FIGURE 2
DAILY TONNES OUTPUT FROM A CEMENT PLANT

PETROCHEMICALS CASE STUDY
Vinyl Chloride Plant

Mr Robert Guttentag took over the Port Botany VCM plant despite its reputation for ruining careers. The corporate folklore joked that the plant was a graveyard for careers, and that no manager had ever been promoted out of the VCM plant. Nevertheless, Rob Guttentag accepted the challenge. At Figure 3 can be seen the fruits of his assignment to the plant. The breakthrough was discovering that the single biggest cause of variation in the plant was over-control, by operators, maintenance people and by the chemical engineers. Unnecessary control actions and other tampering with the process led to significant variation. When Rob Guttentag eliminated this over-control, tonnes output rose to record levels, unit costs fell dramatically and quality improved. He had demonstrated that reducing variation improves quality, output capacity and profitability.

FIGURE 3
DAILY TONNES OUTPUT – VCM PLANT
LEINSTER NICKEL OPERATIONS

Leinster Nickel Operations was transformed shortly after a new Resident Manager, Mr Peter Smith, arrived. The metallurgical plant was without a plant manager, so Mr Smith, a miner, moved into the metallurgical plant manager’s office and directed milling operations himself. Initially, his two main changes were the elimination of over-control and unnecessary adjustments to the plant circuits and the campaigning of the different ore types. Figure 4 shows how throughput, recovery and concentrate grade all increased.

FIGURE 4
LNO – Tonnes, Recovery and Concentrate Grade

The next step was to create blended stockpiles of all four ore types. This was done so the harder ores could assist metal liberation from the softer ores in the SAG mill. Again, recoveries improved and throughput increased, as noted in Figure 5.

FIGURE 5
LNO Recoveries – Blended Ore
CPL POTASH FERTILISER CASE STUDY

In this example potash fertiliser is mined in northern England by Cleveland Potash Limited. This fertiliser presents as an ancient marine deposit, and it contains impurities that must be removed by the process plant. The two most significant impurities are salt and insolubles (clay). When either of these is higher than normal, quality and mill density problems are encountered and the production rate falls as plant personnel struggle to ensure the impurities are eliminated and do not contaminate the product. When salt levels are high, the higher recirculating load of salt restricts the plant throughput.

A statistical study proved the expected relationship between the levels of salt and/or clay and the production rate. In early 2015 a period of unusually high mined tonnes produced significant surface stockpiles of potash. The Surface Operations Manager, Mr Rob McConnell, was presented with a rare opportunity to conduct a trial where the plant was fed blended material that eliminated the “spikes” in salt or clay content. Until that point in time, he had insufficient stock to blend the material before processing. In effect, Rob McConnell’s blending trial reduced the variability in the raw material presenting to the circuits. The result of this trial (conducted in March 2015) can be seen in Figure 6.

FIGURE 6
Wet Tonnes Milled - Blended Potash Trial - March 2015

During the month of the trial, production rose by 15% when compared to the previous two months. Cost per tonne fell and the reduced marginal cost of the additional tonnes produced meant that profitability rose to the tune of millions of pounds sterling per month.

Further trials were conducted, under even more exacting conditions. These trials further demonstrated that as variation in ore was reduced, plant stability improved and plant performance became more predictable. In particular, mill densities and recirculating loads improved. In turn, output capacity increased, as did profitability.

In Rob McConnell’s own words:

“The key point for us in this trial was the establishment of a stable circuit, which then facilitated the incremental step increases in plant throughput. Due to the stability of the feed it was clear that the NaCl circulating load reduced, which from a potash processing perspective is key as this reduced the middling’s load on the flotation circuit.”

Rob McConnell did not rest on his laurels. The work to continue to reduce variation and to improve plant performance continues to this day. His plant set two more records for production in July and September 2015. The operation is now switching from Potash to Polyhalite production, so those records are likely to stand forever.

COPPER/GOLD MINING MILLING CASE STUDY

In many metallurgical plants improving ore grinding is an early priority, for both quality and quantity reasons. In this case a SAG mill at an Australian gold/copper plant was experiencing high levels of
variation in both particle size and throughput. At Figure 5 is a plot of the mill weight and the feed rate for the mill. Note that these two plots are counter-cyclical. When one rises, the other falls, and vice versa. This is generally an indication of unsatisfactory control, whether control be undertaken by an operator or by some sort of expert system, as was the case in this instance. It also represents an opportunity to improve the business.

**FIGURE 5**
**UNSATISFACTORY CONTROL IN A SAG MILL**

In this case an expert contractor was engaged to tune the control system, but the plant manager was unhappy with performance. He called for an expert process control metallurgist who was newly engaged by the company’s metallurgical group, to conduct trials for a week, tuning and altering the control system. The results were as rapid as they were impressive, as noted at Figure 6, which shows the week before and the week of the trials/tuning. Throughput rose by more than 9%, improving productivity, reducing cost per tonne and increasing metal production.

**FIGURE 6**
**IMPROVED CONTROL IN A SAG MILL**

As the plant manager was quick to point out, it would be a mistake to extrapolate these results far into the future. Every miner and metallurgist knows that over time the nature of the ore changes and that changes in ore characteristics can significantly impact on milling operations. Nevertheless, this case study is a good example of how engaging a genuine expert to tune the process control system can result in significant productivity improvements.

**FLOAT CIRCUIT CASE STUDY**

The plant manager noted that after improving the SAG mill performance that the roughers in the float circuit became the bottleneck. One month after the SAG project, the expert process control metallurgist and two team members were asked to return to both finish off the work commenced in the grinding circuit and to commence a project to study and improve rougher performance. Apart from the chemistry and particle size, two of the primary controls for this circuit are air flow (to produce froth which lifts the metal into the launders) and cell (tank) levels. Both were being controlled by an expert system. At the base of four of the float cells is a dart valve. Once any of these valves is fully open, tonnes throughput is at a maximum. Even
though the SAG mill might have spare capacity, a fully open dart valve prevented allow any increase in flow, even if recoveries and grades were satisfactory.

In this case the operating philosophy was changed and tested for a week. Every night shift operated the circuits using the expert control system. On day shifts, it was turned off. The cell levels were set manually and rarely changed. Process control was done using air flow almost exclusively (excluding chemistry). This was done to keep the head difference between the cells constant, which in turn increased the flow which was gravity driven. Another scientist from the company’s metallurgy group, provided this insight. Any increase in the level of a downstream cell reduced the head difference between it and the upstream cell, restricting flow.

Figure 7 shows the change from night to day shift for one day, at about point 250. Towards the end of the night shift, the dart valves for two cells were 100% open, preventing the processing of additional tonnes. The new operating philosophy resulted in increased flow, resulting in some dart valves partially closing, creating capacity for additional tonnes.

Further trials resulted in changes to the operating philosophy and the control system, which resulted in an increase in tonnes processed and therefore profitability.

**ENVIRONMENTAL ISSUES IN A PETROCHEMICALS FACILITY**

The next two examples come from a petrochemicals site suffering from environmental issues. The two most serious issues were mercury and hexachlorobenzene discharges, usually into the effluent stream which discharged into a marine environment. Figure 8 shows the reduction in mercury in effluent and Figure 9 shows the reduction in hexachlorobenzene discharges.
Mercury and hexachlorobenzene in effluent were reduced to about a quarter of their original levels, without capital expenditure. In both cases, stabilising the processes involved was a necessary starting point. Stable systems revealed cause and effect relationships that had previously been hidden by the noise in the data.

Although the work at this site was focussed initially on environmental issues, stabilising the processes improved productivity. Figure 10 shows the throughput of a distillation column (the C3 Splitter) designed to produce polymer grade propylene.

Production increased by 22%, solely by reducing variation.

**SUMMARY**

There are many variables that plant personnel struggle with in any continuous operation. However, experience shows that Little’s Law works. If we can stabilise the flow of material through the process (reduce variation), output capacity rises. In addition, a circuit that is reasonably stable will operate more effectively and efficiently from a technical perspective. This makes intuitive sense. If the tonnes flowing through the process are reasonably steady, control of other aspects such as particle size and chemistry nearly always becomes less necessary and easier to execute when it is necessary.

Improved quality, increased throughput and better recoveries. We can have it all if we understand and know how to reduce variation.