

Is your processing plant a jigsaw?

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Jigsaws were designed in the 1700s to puzzle and educate children with a map spread across a board and cut up into disparate pieces for reassembly.

Over the past 100 years, they grew to become a full-blown craze, perplexing even bleary-eyed adults who ignored mealtimes and bedtimes, shooing off marauding children and pets until they triumphantly locked into place the last of sometimes thousands of pieces.

The designers and builders of today's mineral processing plants can appreciate such dedication.

Now, more than ever, mineral processing plants are a jigsaw of hugely sophisticated dimensions, with resources, skills and technology, coming from a range of project partners to be fitted together with immense skill.

Unlike a jigsaw, however, it is not always immediately apparent when a vital piece of the mineral processing puzzle is missing. Sometimes only subtle variations in quality and quantity of output will alert engineers that something is not ideal in their particular mechanical mosaic. In some cases, shortcomings are

only apparent by comparison with performances achieved by other plants.

Some of the common causes of sub-optimal performance and a strategic map designed to systematically tackle them are presented in this article.

The Problems

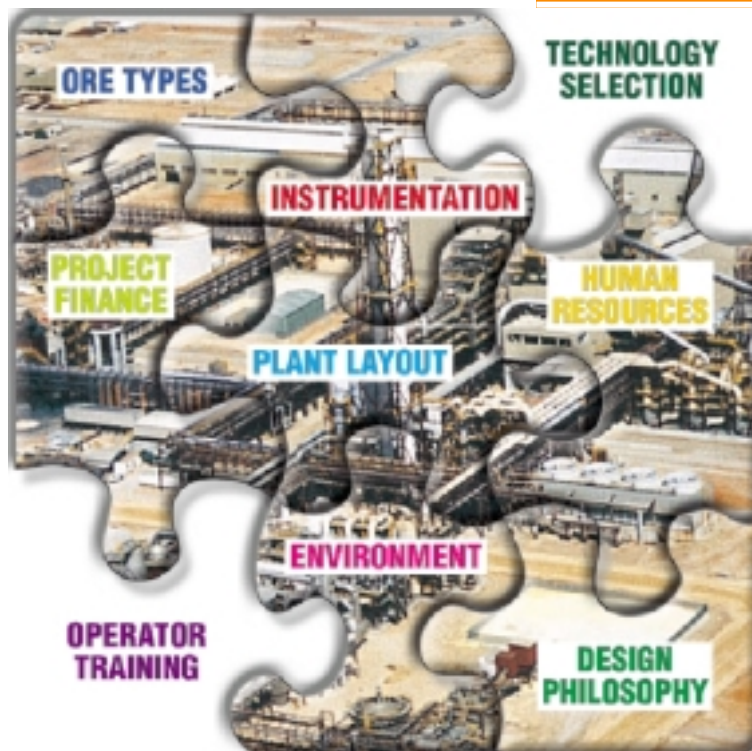
Many of the problems which impact upon plant profitability build slowly over time. Initially a new plant is generally well staffed and operates in accordance with a carefully conceived plan. Over time conditions change and inefficiencies creep in.

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The more common problems that develop include:

- > Lack of operator training, both process and mechanical. Often this is the result of staff turnover.
- > Ore type or equipment duties changing without a corresponding review of the capability of the equipment involved.
- > Inadequate instrumentation and/or control strategies.
- > Poor plant layout, often caused by plant capacity upgrades.
- > Improper installation, commissioning or process optimisation.
- > Outdated technology.
- > Original design philosophy being disregarded.
- > Lack of human resources to address the above.

The cost of these problems can be measured by considering the associated loss of metal recovery from the resource.

The table below indicates the potential values involved for different metals.

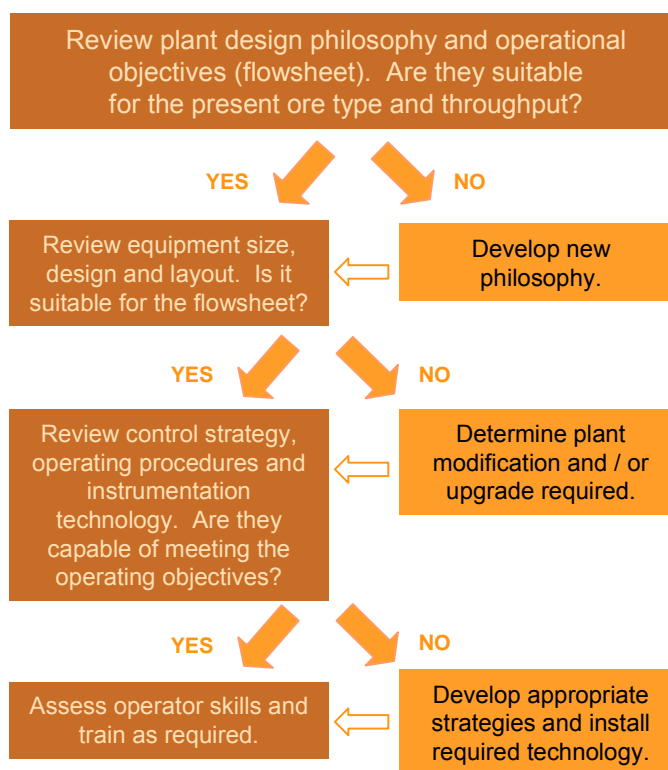
Plant Type	Lost Recovery p.a.		
	1%	2%	3%
Cu 1% head grade	\$296,000	\$592,000	\$888,000
Au 2g/t head grade	\$369,000	\$738,000	\$1,107,000
Ni 0.5% head grade	\$652,000	\$1,304,000	\$1,956,000
Zn 8% head grade	\$1,198,000	\$2,396,000	\$3,594,000

Throughput assumed to be 1Mtpa, metal prices in USD on 01/06/02 exchange rate 0.55USD/AUS

The Solution

While it is not possible to generalise, because modern mineral processing plants demand such remarkably diverse inputs, it is possible to draw on Australian and worldwide experience to identify a course of action that can address these common problems in a systematic manner.

A Way Forward



Optimising In-House and Outside Expertise

Productive review of plant efficiency usually involves both in-house and outside expertise. Naturally one of the most valuable resources any company has is its own operational staff; the people operating the process know its strengths and limitations best. Frequently these in-house experts will have a host of practical suggestions to make when consulted on how a process might function better but will have neither the time nor a broader view of a project's potential, particularly in terms of "global" experience and performance benchmarking, to drive the optimisation process.

Where outside expertise, or technology partners, can assist is by complementing the mine owner's specific project knowledge with the breadth of experience gained from working on many projects over a long period of time.

Technology partners must develop the capacity to provide services such as:

- > Auditing existing operations and comparing them to original design.
- > Designing and delivering operator training, both mechanical and process.
- > Implementing improved control technologies.
- > Implementing technology improvements to existing equipment.
- > Designing and implementing ongoing maintenance and support programs.

The success of any plant optimisation will depend upon the ability of the driver to pull the pieces of the puzzle together and position them in their correct places. The challenge is recognising that no one individual or organisation has all of the pieces.

Flotation Cells - Is Bigger Better?

Author: Andrew Okely

The answer to this question is generally YES, but like all good generalisations, there are limitations. The benefits of using large flotation cells are mostly economic, although in some cases there are also some significant process advantages.

Likewise, the potential for process problems occurring if cells are too large must be understood. This article will demonstrate the economic advantages of selecting larger cells through an example and then discuss the process considerations.

Economies of Scale

Consider a plant requiring 1200m³ of rougher/scavenger volume. Three possible scenarios for the provision of this volume can be considered:

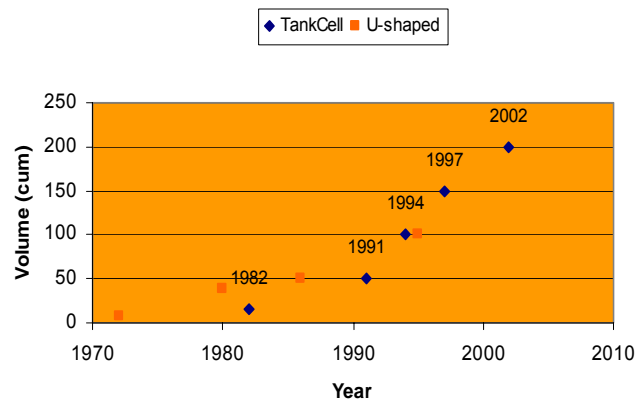
- > 12 x 100m³ cells, in 2 rows of 6
- > 8 x 150m³ cells, single line of 8
- > 6 x 200m³ cells, single line of 6

The following table indicates the relative capital cost (ex works), installation footprint, installed power and air requirement.

Option	Relative Cost	Footprint	Installed kw Power	Vol m ³ / min	Pressure
12 x 100m ³	1.4	483m ³ (38 x 12.7)	1800	216	42
8 x 150m ³	1.1	336m ³ (52.5 x 6.4)	1400	160	52
6 x 200m ³	1.0	301m ³ (43 x 7)	1320	138	55

From the table we can see that the use of 200m³ cells (presently the largest available)

leads to a significant reduction in capital cost (of up to 40%) when compared to using 100m³ cells. A decrease in plant area of 38% and savings of 27% and 36% respectively for power and air requirements are also attainable. It is sobering to consider that such savings have been made available, through the development of larger cells, in less than 10 years (refer to chart below for historical progression of cell size).



Interestingly, the incremental improvement achieved by going from 150m³ to 200m³ is less than that observed when moving from 100m³ to 150m³. This suggests that an

optimal economic maximum cell size exists somewhere above 200m³.

Process Engineering Considerations

Demand for larger cells has in part been driven by the desire to exploit larger, lower grade ore bodies. Economies of scale like those demonstrated overleaf have made lower cut-off grades for ore bodies feasible despite a decrease in the real value of most metals. In many equipment items, larger equipment has meant a compromise on process design. Plant surges, lack of circuit flexibility and lack of redundancy have been difficult issues for large throughput circuits.

However, the use of larger flotation cells for low grade ore bodies has provided a distinct process advantage, namely greater froth stability.

Froth Stability

Froth stability is critical to good flotation performance and is almost impossible to achieve without a minimum level of mineralisation in the froth. Thus, on low grade ores, reducing the overall froth surface area and the mineral mass required to stabilise that froth, provides for significant improvements in flotation cell performance. One useful feature of flotation cells is that the ratio of froth

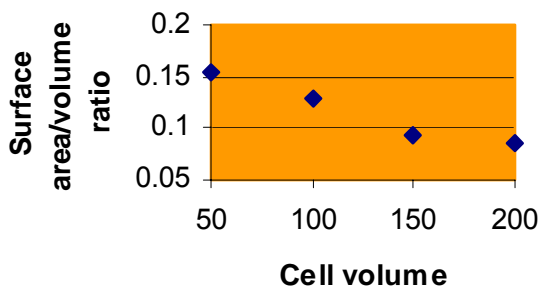


surface area to cell volume decreases as cells get bigger. This means the larger the cell we use, the lower the froth surface area we need to stabilise. A word of warning, the reverse also applies. Higher grade ores need more froth surface area to remove sufficient froth to maximise recovery. There exists a limit to the mass of mineral a froth can carry out of the cell, exceed this and your recovery will suffer.

Where's the Limit?

Like all things in mineral processing, the answer depends upon the ore. As a rule, caution should be exercised and froth surface area considered more rigorously when selecting cells for ore bodies where the headgrade is 10% of the concentrate grade or greater.

Surface area/volume ratio for Large Tank Cells



Thickener Testwork Really Does Matter

Author: Mark Surace

When it comes to predicting the appropriate size of a thickener and the flocculent dosage for a dewatering plant, there are two ways you can go – Static Cylinder Settling or Dynamic Bench Scale testing.

The static cylinder settling test has been the traditional method for obtaining indicative data for the sizing of conventional thickeners (Coe & Clevenger, Kynch, Talmage & Fitch methods). However, the sizing and prediction of the performance of HRTs using data generated from static settling tests can be quite inaccurate, since it utilises static settling data and a mathematical construction method to predict a dynamic system. One example of how misleading conclusions can be reached, particularly in the hands of inexperienced practitioners, is the relationship between thickener flux rate and underflow density. Because it is possible to use the Talmage and Fitch construction to calculate a thickener area for any desired underflow density, you can arrive at a thickener size even if a specified density cannot be achieved in practice. Dynamic testing will tell you what density can be achieved in practice.

Other drawbacks of using static methods are the unreliability of information on overflow clarity, and flocculant consumption.

Dynamic laboratory thickener with continuous feed, overflow and underflow streams for accurate full scale simulation.



Advantages of Dynamic Thickening Tests

The main advantages of dynamic testing are:

- > Unlike Static Cylinder Settling tests, it's possible to establish a direct relationship between feed solids flux, flocculant dosage requirements, underflow density and overflow clarity.
- > The degree of feed dilution, if required, can be accurately determined.
- > In some low feed solids applications, the effect of recirculating underflow can be determined.
- > It is not necessary to apply a safety factor, providing the feed is representative run-of-mine or 'worst case' material.

All of these factors make the dynamic test superior to the traditional static cylinder test.

An Example

To illustrate the importance of accurate test data, consider a situation where dynamic test data yields a flux rate of 0.8 t/m²h to achieve a density of 60% w/w solids, and the required plant throughput is 375t/h. This results in a 25m HRT, at an installed capital cost of approximately \$1.1m.

From the static settling data, assume that an underflow density of 65% w/w is specified and that this yields a flux rate of 0.65t/m²h. With a safety factor of 20%, this results in a thickener of size 30m diameter – the resulting cost would be \$1.6m, but despite the larger thickener size, the underflow density of 65% w/w may not be achieved (see above) and hence the extra \$0.5m cost incurred is wasted.

On-Stream Analysis - The Need for Performance

Author: Brandt Henriksson

The on-stream analyser has become a crucial tool for optimising the recovery of valuable minerals from fine bulk ores, particularly in the case of metal flotation circuits. On line assays are able to indicate process disturbances that can be dealt with both manually and in many cases through automated control to optimise grade and recovery thereby maximising the economic value of the ore body.

Output from the analyser is used to manipulate flotation process variables such as level, air rates and reagent dosage to achieve the optimum grade setpoint and thus maximum economic recovery. In this type of control, assay based trends are important in both determining the course of action to be taken and the success of this action. Two factors of importance in this process are assay precision and speed.

As with any control system, error in the measurement instrument and delay in measurement cause inaccuracy and sluggishness in the control. Hence, there is a direct relationship between revenue lost and assay accuracy and speed. The greater the error and slower the response, the larger is the loss of revenue. The key to accurate and fast analysis, and the heart of all metal analysers, is the x-ray tube and detector system.

WD and ED Detectors – What's the Difference?

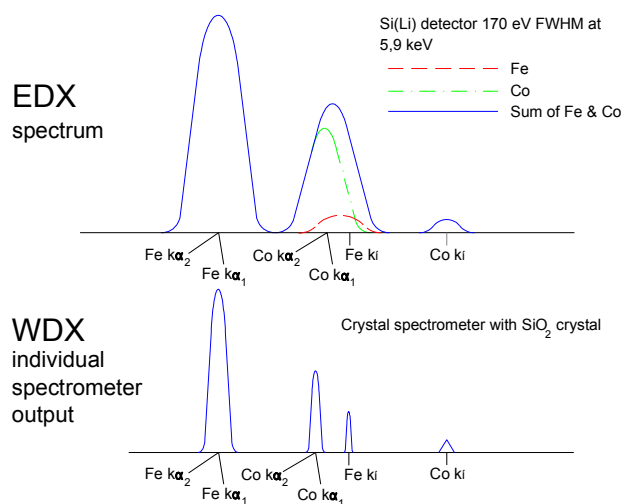
When energy in the form of radiation “excites” an atom, inner shell electrons are knocked out of the sample atoms. An electron from a higher energy shell then fills the electron vacancy and in doing so releases energy as a fluorescent photon.

The wavelength of this photon is characteristic of the particular element and the number of photons represents the concentration of that element present in the measured sample. This is the principle of XRF analysis.

With WD (wavelength dispersive) detectors, a spectrometer is used to isolate the fluorescent radiation from a specific element. The technique is highly selective with excellent resolution. By comparison, ED (energy dispersive) detectors measure the entire spectrum of elements. Resolution is relatively poor and count rates are spread over many elements.

As a result, WD systems are able to be both selective in their analysis of individual elements and detect lower concentrations with greater accuracy and speed due to higher count rates.

The difference between the two techniques is illustrated by considering the measurement



EDX vs WDX Resolution for measurement of cobalt and iron

of cobalt in low concentrations when in the presence of high levels of iron. While WD detectors can separate the Co and Fe peaks, it is virtually impossible to detect cobalt with ED detectors in this situation due to the closely overlapping peak of the dominant iron element.

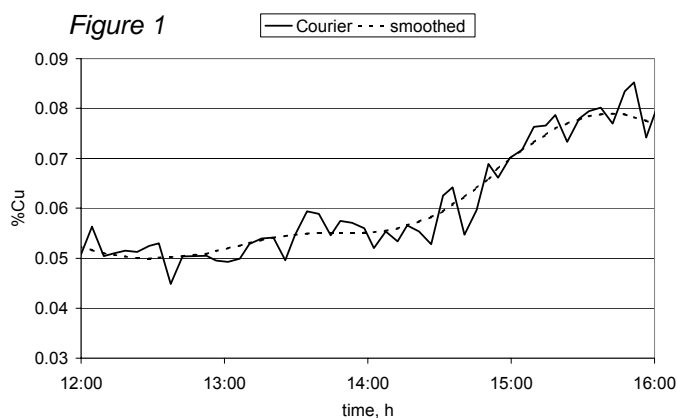
WDX also has an advantage over EDX systems when looking at the minimum detection limit in slurries. While WDX systems can typically measure down to 10ppm, EDX systems with solids state detectors can only see 100ppm and PIN detectors may see only 200-500ppm. This can have significant implications for dilute metal concentrations such as tailings and for samples containing elements whose atomic numbers are closely spaced.

What does it Cost to have Inaccurate Assays?

Saloheimo (2001) estimated the economic significance of running a plant with inaccurate assays as opposed to real concentrations. This comparison is reproduced below;

Let us pose the question: how much money do I lose at the plant if I run it according to inaccurate analyser assays, instead of real concentrations?

Figure 1 below shows an actual plant trend produced by a high-powered on-stream



analyser with a 5-minute cycle time. The smoothed line has been reconstructed from the trend data, to simulate the ‘actual concentration’, and the fluctuations around the line amount to ca. 0.0025% standard deviation, or around 5% relative precision.

If the tailings assay is noisy the control makes setpoint changes only when a change is clearly larger than the noise level. A good measure of the noise is the 2-sigma or 95% limit – when the signal gets above that value there is only 5% probability that no change ever happened. This means that, on an average, the control is behind the actual changes of the process, the difference being one sigma error on average.

To quantify this economically, let us assume for simplicity that the control can adapt to concentration changes accurately and promptly so that the recovery can always be held, say, within 0.5% of the optimal point. The measurement error adds to the fluctuations around the optimal operating point. If we assume that for most of the time the recovery is drifting somewhere between the optimal point and the 2-sigma limit, the loss is, on average, one sigma below what it could be with an ideal system.

Some numerical examples of the value of lost metal, scaled to 1 Mton/a ore feed, are given in Table 1. Two analyser examples are used with the relative accuracies,

- > Analyser 1: 3% in concentrate, 3% in feed, 5% in tailings
- > Analyser 2: 3% in concentrate, 5% in feed, 10% in tailings

In the calculation, average metal prices and treatment charges of Q4/2000 and typical transport costs have been used as base data.

Case	Recovery	1-sigma error in recovery		Value of metal lost USD/annum due to analysis error	
		Analyser 1	Analyser 2	Analyser 1	Analyser 2
Cu circuit with 1.5% feed, 23% concentrate and 0.12% tails	93%	0.5%	0.9%	\$28,000	\$81,000
Ni circuit 1.5% feed, 15% concentrate and 0.20% tails	88%	0.9%	1.7%	\$136,000	\$397,000
Zn circuit 4% feed, 45% concentrate and 0.45% tails	90%	1.0%	1.9%	\$84,000	\$221,000

This simple exercise has shown that there is significant value in understanding the performance of the analyser system with respect to accuracy and timeliness of analysis. In the above example, Analyser 1 performance is typical of a system utilising WD detector technology combined with a high powered x-ray tube. Analyser 2 performance is typical of a system utilising ED detectors and a low powered x-ray tube or radiation source.

Clearly, in today's modern concentrators where sophisticated control and optimisation systems are becoming the norm, assay quality in addition to reliability of on-stream analysers must be carefully considered.



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