# STABILIZATION OF LEAD AND ZINC FLOTATION CIRCUITS AT GALMOY MINE, KILKENNY, IRELAND

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## ABSTRACT

Galmoy Mine, owned by Arcon Mines Limited, has operated since 1997, and is one of three operating lead/zinc mines in Ireland. Changes in ore type starting in mid 2002 created challenges to metallurgical operations at Galmoy. This resulted in unacceptable lead and zinc flotation performance, which prompted initiation of a formal plant review and a subsequent stabilization programme. This involved a structured review of operational practices, development of a new Standard Operating Procedure (SOP) which in turn led to significant changes in process control equipment needs in conjunction with extension of zinc flotation cell residence time.

This paper will describe the metallurgy of the Galmoy operation. Reasons for the poor metallurgy experienced in 2002 will be described, as well as the solutions identified to overcome these problems. By the second quarter of 2003, these solutions had been implemented and recoveries had risen to record levels.

## INTRODUCTION

### GENERAL

Galmoy Concentrator is located in County Kilkenny (Refer to Figure 1 below) and was constructed during 1996 and commissioned in 1997.

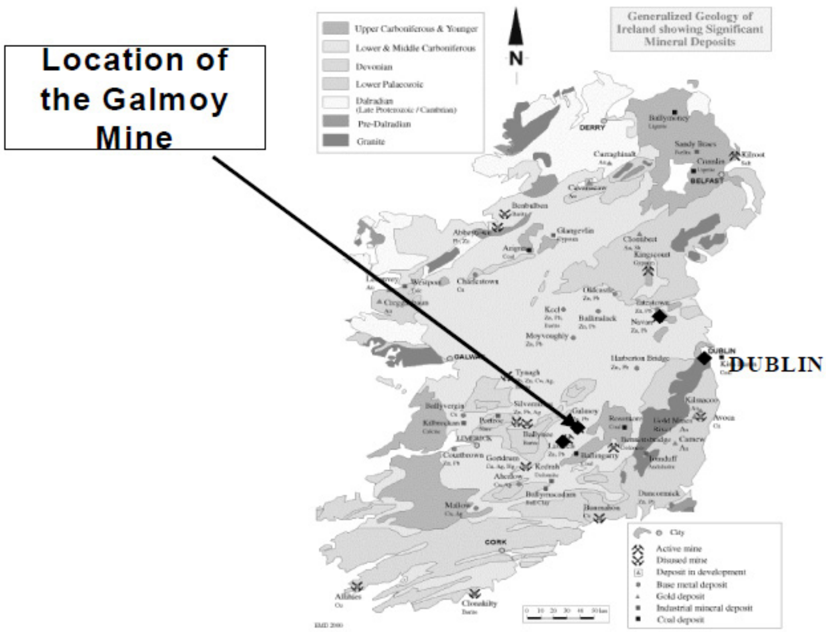


*Figure 1: Geographical location of Galmoy Mine*

The concentrator at Galmoy had been designed initially to treat 650,000 tonnes per annum of primarily CW ore type. The main mineral of economic significance was sphalerite (Typically 10 to 11% Zn) with some minor galena (0.7%Pb) in a dolomite (Magnesium Carbonate) host rock.

The only other competing sulphide mineral was pyrite (Circa 3 to 5% Fe in Mill Feed. This CW ore type predominated the first 6 years of production, but in August 2002, the ore mineralogy changed due to significantly higher levels of pyrite rich G ore body being blended in with CW ore.

### HEAD GRADE

Figure 2 below shows the head grade of Galmoy Concentrator from start up until July 2003.

It is clear from the above figure that the quantity of pyrite in the feed to the concentrator increased significantly

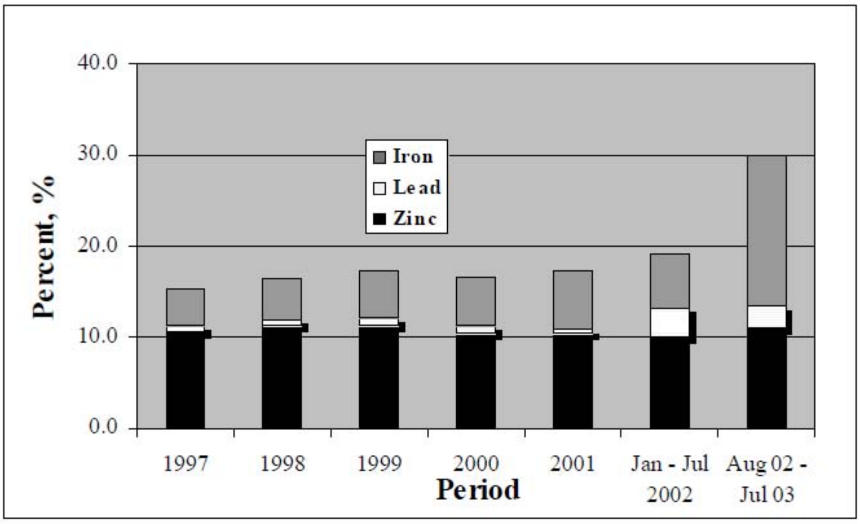


*Figure 2: Galmoy Concentrator Head Grade Versus Time*

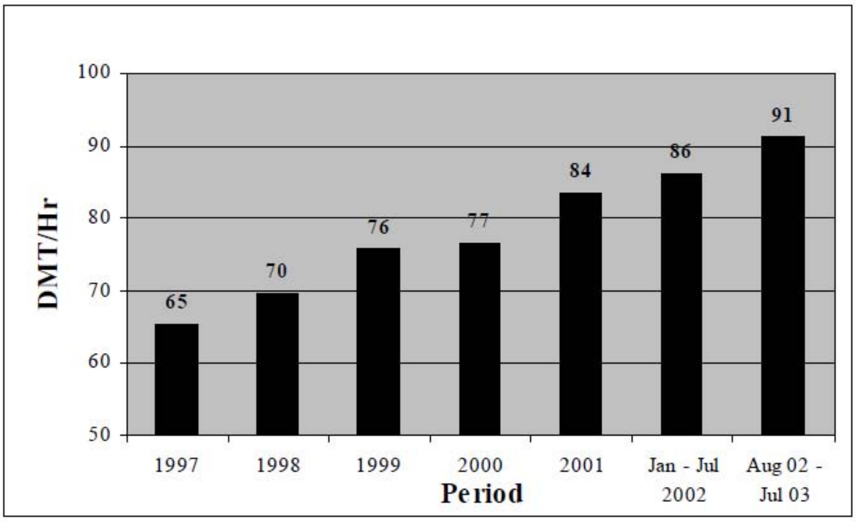


*Figure 3: Throughput Versus Time*

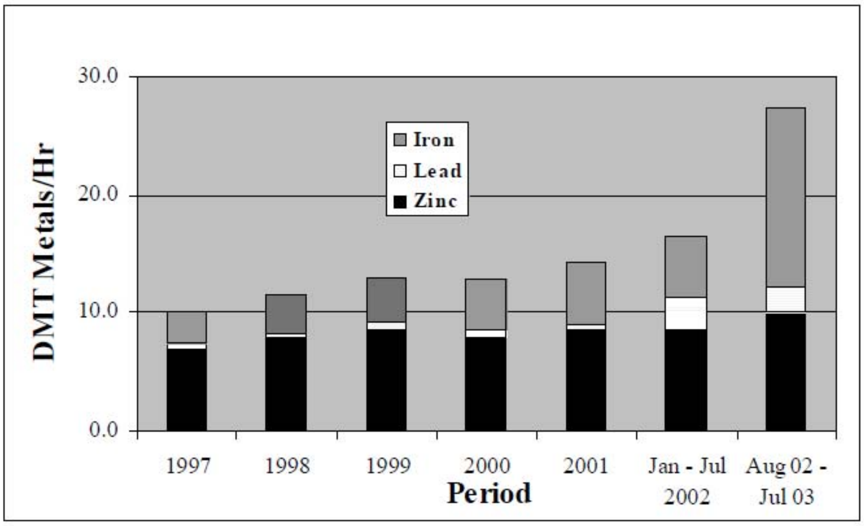


*Figure 4: Tonnes of Metals/Hour Versus Time*

(240%) from 5% to 17%Fe as and from August 2002. The head grade continued this profile during the period through to July 2003.

**THROUGHPUT**

In addition to the above phenomenon, plant management were attempting to increase throughput rates even higher than before in order to attempt to maximize metal production due to the poor zinc metal prices currently being experienced at this time.

Figure 3 shows the ramping up of tonnage treated from start up in 1997 to July 2003 inclusive.

**TONNES OF METAL IN CONCENTRATOR FEED**

The increased throughput rate in conjunction with the increased total metal content in the concentrator feed resulted in the tonnes of metal in feed increasing from 13 tph to 26 tph, this effectively doubling the content of metals entering the plant. This trend is shown below in Figure 4.

**LEAD METALLURGY**

The culmination of the increased tonnage and pyrite loading on the grinding and flotation plants resulted in unsaleable lead concentrates being produced due to higher iron deportment to lead concentrates. This was primarily due to the lead circuit only having one stage cleaning. Figure 5 shows the downward trend in lead recoveries and note that at times of lower head grades during 2001 and 2002, the lead circuit was not operated.

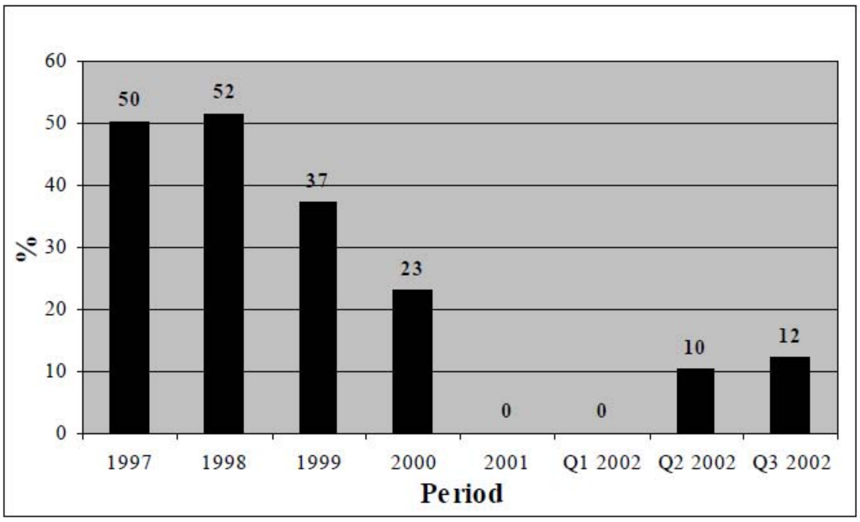


*Figure 5: Lead Recovery Versus Time*

Figure 6 shows the concentrate grade trend versus time. Traditional lead concentrates have always been relatively low grade due to the low head grade and lack of multiple stage cleaning circuit.

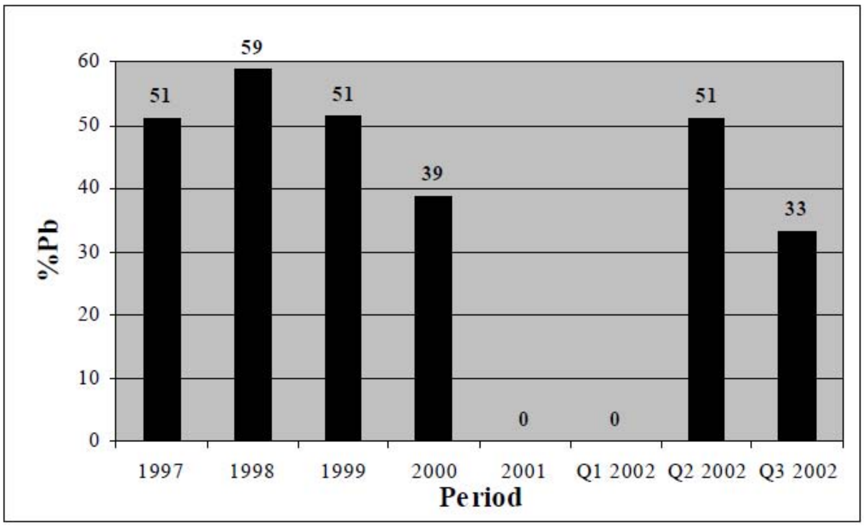


Figure 6: Lead Concentrate Grade Versus Time

**ZINC METALLURGY**

Figure 7 shows the fall in zinc recovery in the third quarter of 2002 from traditional levels of 83% to 78%.

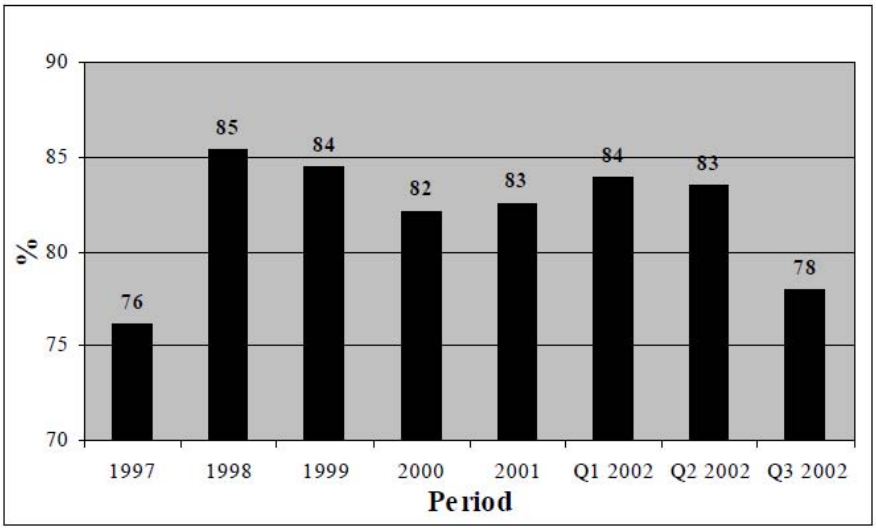


*Figure 7: Zinc Recovery Versus Time*

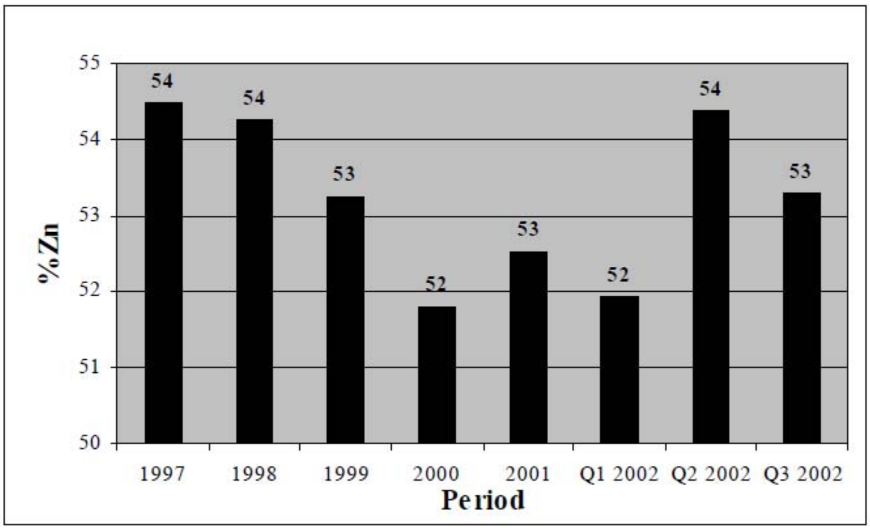


*Figure 8: Zinc Concentrate Grade Versus Time*

However, the traditional zinc concentrate contaminant finger print (Normally MgO driven) changed to a lead driven issue. Refer to Figure 9 below.

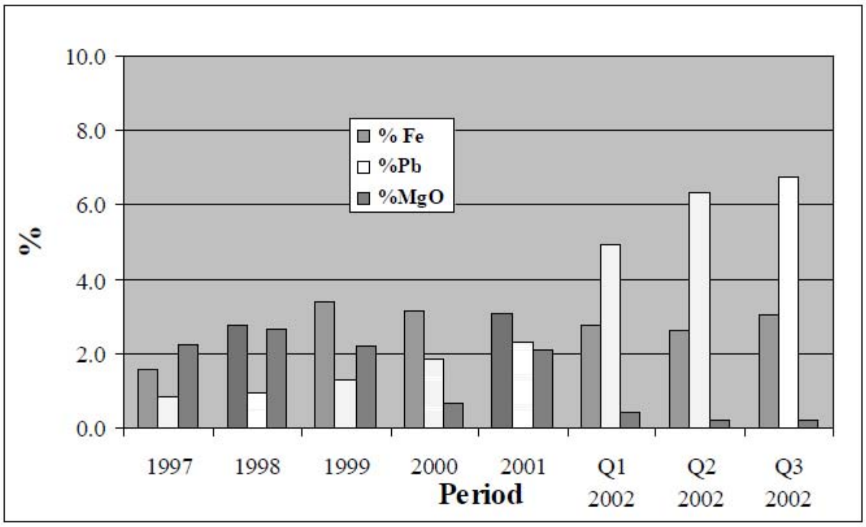


*Figure 9: Zinc Concentrate Contaminants Versus Time*

The main reason for this was the lack of adequate lead cleaning capacity, which resulted in a fine balance being drawn between minimizing zinc loss to lead concentrates and recovery of lead from the circuit upstream of the zinc circuit.

Iron levels in the zinc concentrate remain at traditional levels despite the significant increase in iron entering the plant.

**REAGENT DOSAGES**

Referring to Figure 10 below, note how the collector additions to the circuit (PAX and AP3894 to the zinc circuit and SIPX and AF242 to the Lead circuit) decreased with time. PAX (Strong collector) was being dosed to the zinc circuit whilst SIPX (Medium strength collector) was being dosed to the lead circuit. As a consequence, recovery of lead was higher in the zinc circuit than in the lead circuit.

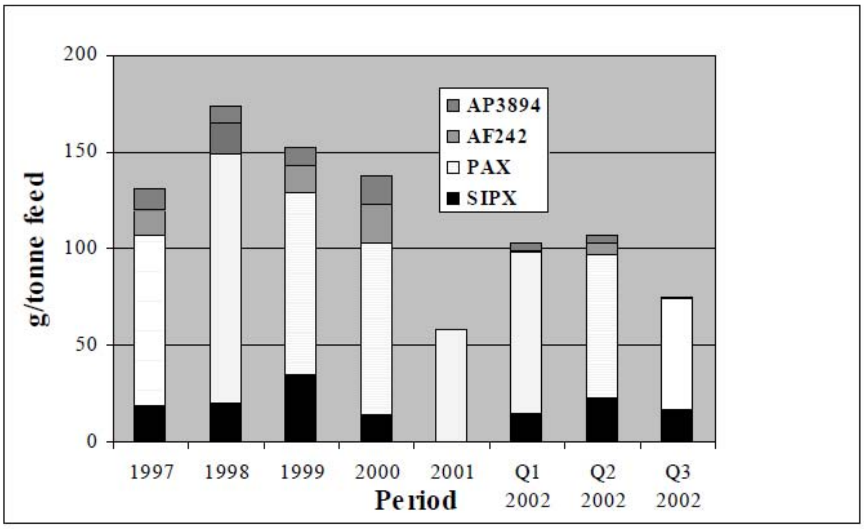


*Figure 10: Collector Dosages Versus Time*

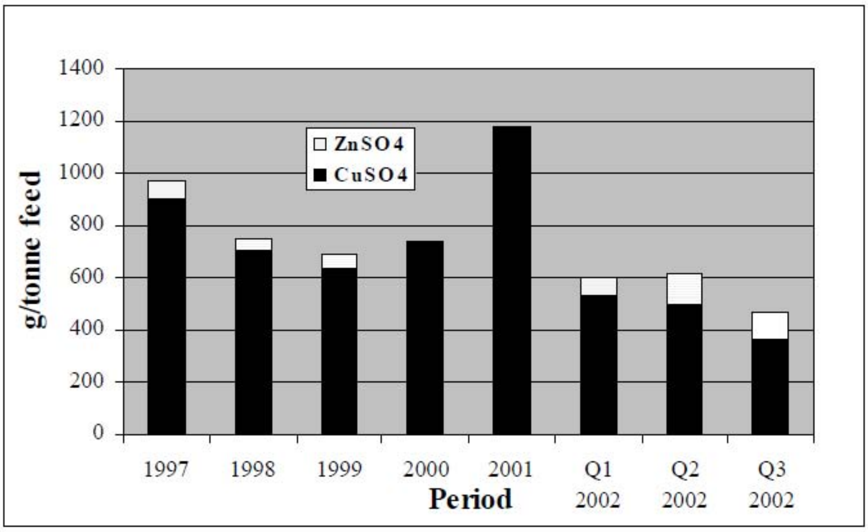


*Figure 11: Zinc depressant and Activator Dosage Versus Time*

Note in Figure 11 above, how the zinc activator dosage reduced over a period of time whilst zinc depressant dosage increased.

Referring to Figure 12 below, the MIBC dosage remained relatively static post 1997.

## PLANT AUDIT - SEPTEMBER 2002

Due to the problems experienced with cessation of Lead Production, but more specifically, with poor zinc recovery (Zinc Revenue at the time was responsible for the majority of Arcon's revenue) and high lead levels in the zinc concentrate, SGS were requested to carry out a formal review in September 2002. This ultimately led to a metallurgical management contract whereby all metallurgical development was managed by SGS from October 2002 to July 2003. The remit was to focus on the zinc circuit since 99% of revenue came from the zinc circuit.

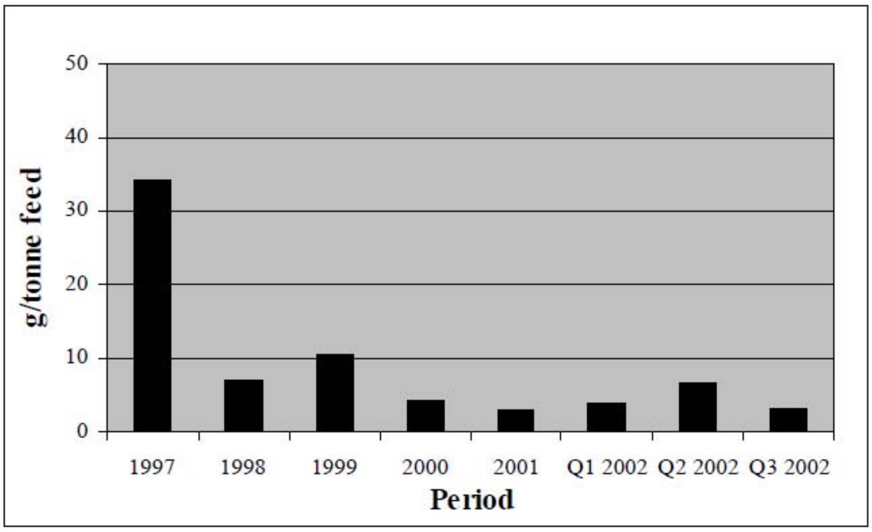


*Figure 12: MIBC Dosage Versus Time*

A fundamental issue with Plant Optimization is that this can only be carried out if the plant is running in a stable manner. Plant Stability is the platform from which plant optimization can be carried out and as a consequence, plant reviews tend to focus on both plant stability initially followed by Plant Optimization later. A nice analogy of trying to optimize a plant that is not running in a stable manner is like spending money on customizing the paintwork on a car, that has no engine or wheels yet !

Plant stability can be defined when a plant is running with flows and tonnages in equilibrium and steady state. Unstable plants never reach equilibrium and the cause for this is sometimes due to fundamental flow sheet design but mainly due to poor control of key factors that cause oscillations in flow and tonnages. A poor operating strategy can also provide an unstable circuit due to over operation and/or mis-understandings of causation- effect.

Operational problems associated with cell level control, reagent mixing/dosing and holed vortex finders in the primary hydrocyclones amongst others were creating an unstable process and this was exasperated by dramatic reagent changes (“On/Off”). Collector dosages were at an all time low whilst metals entering the plant were at an all time high!!. This type of operating strategy created more instability in the plant and complete operator confusion.

## FLOTATION CELL LEVEL CONTROL

The lead circuit contained two level controllers whilst the zinc circuit contained seven level controllers. The problem with the existing design level controllers was that the floating plastic ball connected to a target plate was encapsulated in a tube. The tube was continuously becoming scaled up with froth and exasperated by lime scale in the zinc circuit. As a consequence the ball would stick in the tube and the dart valves would open, promptly dumping the contents of the cells downstream. This occurrence would happen at least once a shift on one of the nine level controllers within the plant.

As a consequence, we designed a tubeless floating ball system (refer to Figure 13) with target plate and ultrasonic detector and installed this in the lead rougher cells in November 2002. The trial was so successful that within a week, the operations group demanded all the others to be retrofitted. This was completed by January 2003 and instability due to level control became a thing of the past.

## REAGENT MIXING AND DOSING

No checking of solution strength and clarity was been carried out which ultimately led to varying strengths of reagent and crystals of PAX and SIPX frequently blocking the reagent dosing lines. The frequency of blockages was at least one reagent line per shift with catastrophic effects on OSA tailings assays. Line blockages occurred more frequently immediately after reagent


*Figure 13: New Level Control system and old tube type system alongside*

mixing. The mixing tank feed hopper had no trash screen.

Reagent dosing was via manually controlled valves placed on horizontal manifold being fed directly from the holding tank.

Due to the lack of attention to reagent strength and particularly reagent crystal dissolution, solids were being introduced into the dosing system with disastrous consequences. The lack of good reagent pumping system compounded the problem.

Reagents were dosed to the head of each circuit only and was acceptable with low pyrite levels on CW type ore, but the significant increase in pyrite in the ore required a new dosing regime that doses small amounts frequently (ideally down each mechanism air suction hole). This new dosing regime tended to break the one larger reagent flow down into smaller solution flows that in turn tended to block even more than the larger flows. Operators were finding that the flow of SIPX and PAX was continually dropping back over a period of their two-hour checks.

The above problems made achievement of our new reagent dosing (based upon metal units entering the plant) regime extremely difficult and as a consequence a complete review of reagent mixing and dosing was undertaken in October 2002.

Hydrometers were ordered immediately and the reagent mixing procedures changed to facilitate manual sampling of reagent re-circulation stream as it was being mixed. This provided the reagent-mixing operator with ability to check on strength (using new hydrometer) and clarity (so as to ensure crystal dissolution was complete) prior to pumping up to the header tank that in turn fed the dosing manifold.

The mixing tanks were fitted with new hoppers with integral trash screens and the re-circulation stream was re-routed so that it poured onto the trash screen thus enabling lumps of crystalline Xanthate to be washed through the screen, reducing the risk of blockages whilst also facilitating easy sample point for reagent strength and clarity checking.

The dosing manifolds were all re-designed from horizontal to vertical with a drain valve placed at the bottom for easy drainage of crud back to the mixing tank. The collector was dosed in a “cascade down” the bank arrangement (e.g. 40, 30, 20 and 10% to each consecutive flotation cell in a bank of four cells) in order to maximize kinetics of sphalerite flotation.

On October 3rd 2002, the primary collectors (PAX and SIPX) were switched such that PAX was
dosed to the lead circuit and SIPX dosed to the Zinc circuit. This rationale was due to the fact that lead tends to slime readily during grinding and required

stronger collector than the zinc circuit. Lead recovery increased immediately and lead contamination of zinc concentrates was significantly reduced.

In December 2002, Watson Marlow supplied a peristaltic reagent pump (one in their new range) for plant trials (refer to Figure 14 below).

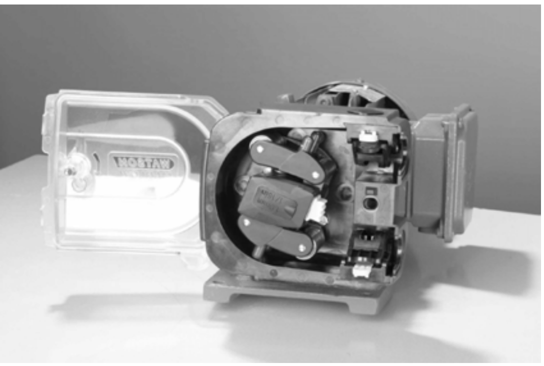

Figure 14: Watson Marlow 520 Peristaltic Pump 520 Series

This was used to pump collector to a newly purchased Clarkson Rotary Distributor (refer to Figure 15 below), which in turn fed SIPX to the rougher cells individually. 50% of the mainstream SIPX was still manually gravity fed via manually controlled valve, the remaining 50% being fed via the rotary distributor in a cascade down the bank arrangement throughout the second bank of four rougher cells.

Based upon this experience with the trial pump, in December 2002, eight new Watson Marlow Peristaltic pumps were ordered in order to ensure that all reagents were being dosed via metering pump.


Figure 15: Clarkson Rotary Feeder

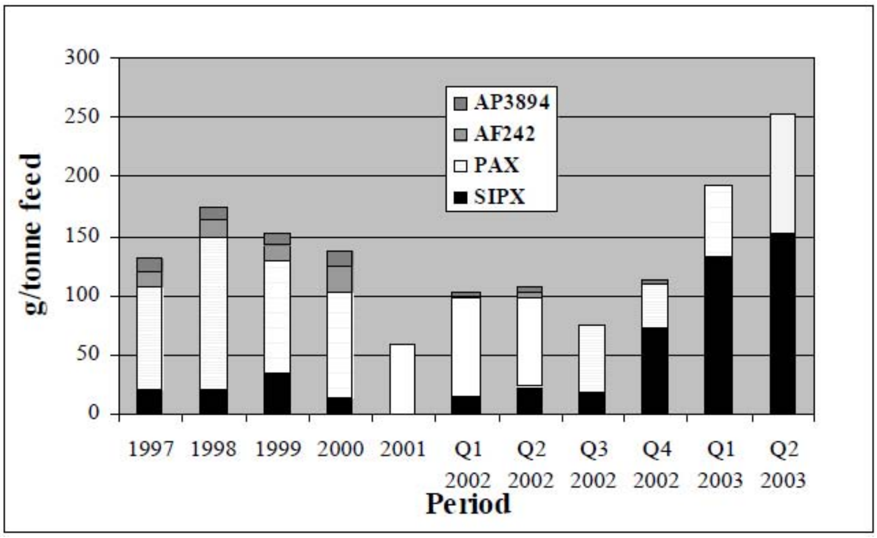


Figure 16: Collector Dosage Ramp up as New Reagent Pumps arrive Q1 2003

Figure 16 above clearly shows the impact of installing the new reagent pumps in the first quarter of 2003.

Subsequently, reagent blockages are now rare and another form of plant instability was ironed out.

## HYDROCYCLONE MAINTENANCE

As mentioned previously, another source of plant instability was lack of preventative maintenance to hydro cyclones, particularly the primary hydro cyclones. The mechanical department according to their scheduled plans was regularly carrying out maintenance; the problem was that this procedure had no metallurgical input as to when and why the internal components should be changed. The only occasion that the operational group became aware of a problem was when the flotation cell dart valves regularly blocked and the false bottoms below the Wemco cells eventually filled up with sand which subsequently scaled to a proud concrete mix and resulted in very poor cell recirculation of pulp requiring air lances to free up tanks etc. This small attention to detail caused a major downstream instability and wasted effort. As a consequence, the mechanical department would assume that provided the hydrocyclone had a rubber lining and the vortex finder was not holed, then they had done their job. Therefore, hydrocyclone vortex finders regularly holed (see Figure 17 below), and the rubber internals were being changed as the mechanical department saw fit, but this left significant steps in the joints between the new and old components which caused turbulence, increased wear and generated coarser overflow size distributions than necessary.

Another common wear pattern observed

Figure 17: Holed Vortex Finder

on vortex finders in particularly onerous duties is the cutting of the vortex finder around its base which if left unchecked can ultimately result in the vortex finder actually falling off into the hydrocylone vessel itself. This phenomenon is most usually associated with lack of attention to cover plate liner wear. Once the cover plate liner becomes worn around the vortex finder, is creates a strong swirling action locally in this area and rapidly reduces vortex finder life.

As a consequence of the above, the metallurgical group were made responsible for managing hydrocylone maintenance working with the mechanical department. It soon became clear that vortex finder life was circa 3 months with new cover plate liners. The increased focus in this area resulted in a steady flotation feed size distribution and minimized instability within the flotation plant.

Figure 18 captures the problem with vortex finders in December 2002 and shows how relatively stable the flotation feed was post introducing the new hydrocyclone maintenance initiatives in January 2003. Dart valves blocking due to coarse feed and unnecessary losses due to over sized feed distributions became a thing of the past.

## STRUCTURED PLAN AND NEW STANDARD OPERATING PROCEDURE (SOP)

As discussed above, one of the other sources of plant instability is when the concentrator has no set objectives, plans and structured operating philosophy that all four shifts adhere to.

Standard Operating Procedures were introduced at Galmoy based upon the experience gained over the 9-month period whilst the metallurgical development evolved. This included a new encapsulated reagent dosage guide which was based upon the units of metal entering the plant, hydrocyclone operating guidelines, typical key stream size distributions, typical mill unit power draws, typical assays on each stream, typical reagent consumptions. In summary, this provided a new plan for every consumable, operating variable and ensured that Monthly report writing commented on any adversity to plan.

Reagent consumption reconciliation's with physical stocks were increased to weekly so as to ensure that dosage rates recorded on log sheets were realistic.

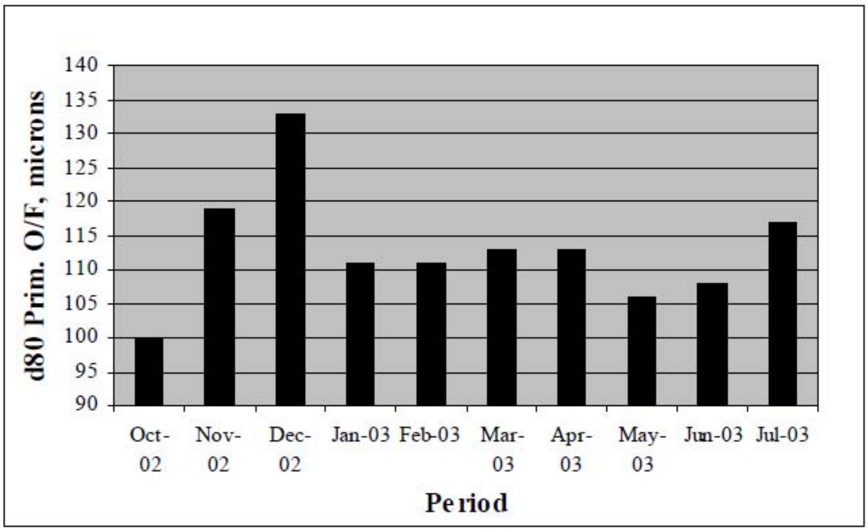


*Figure 18: Primary Hydrocylone Over.ow Average Monthly Sizings*

Daily morning post mortem analysis of the new OSA tailings streams were analyzed and any blips analyzed to understand causation and ensured that these were commented on by shift operators in their shift reports.

Fault diagnosis diagrams were devised to ensure that all four shifts address problems (e.g. Recovery below specification and Concentrate Grade below specification) in the same methodical approach. A similar fault diagnosis chart was devised for Metallurgical problems. This system ensures that the mill is controlled to a set protocol which once engrained becomes the culture.

Finally, critical operating points were documented and became the main focus for operational checks and fault diagnosis. Every plant, independent of which metal it is processing has three to six critical operating points that if diligently checked and adjusted provide 85% chance of successful results. These points can be broken down from overall plant to sectional points that provide a sound form of training and focus for operators. This provides management with a work smart ethic since they focus their human resources on the most effective points and attempt to remove dogma from daily log sheet data collection.

## FLOWSHEET MODIFICATIONS

The salient unique features of the flow sheet are highlighted below.

- The SAG mill - Ball mill circuit did not cater for critical size
- The Lead Circuit only had one stage cleaning in a column
- The Zinc Circuit Rougher and Cleaner Scavenger flotation cells were shared.

The increased throughput rate was resulting in flotation feed d80's of circa 110 microns.

Figure 19 above shows the status of the flow sheet as of September 2002.

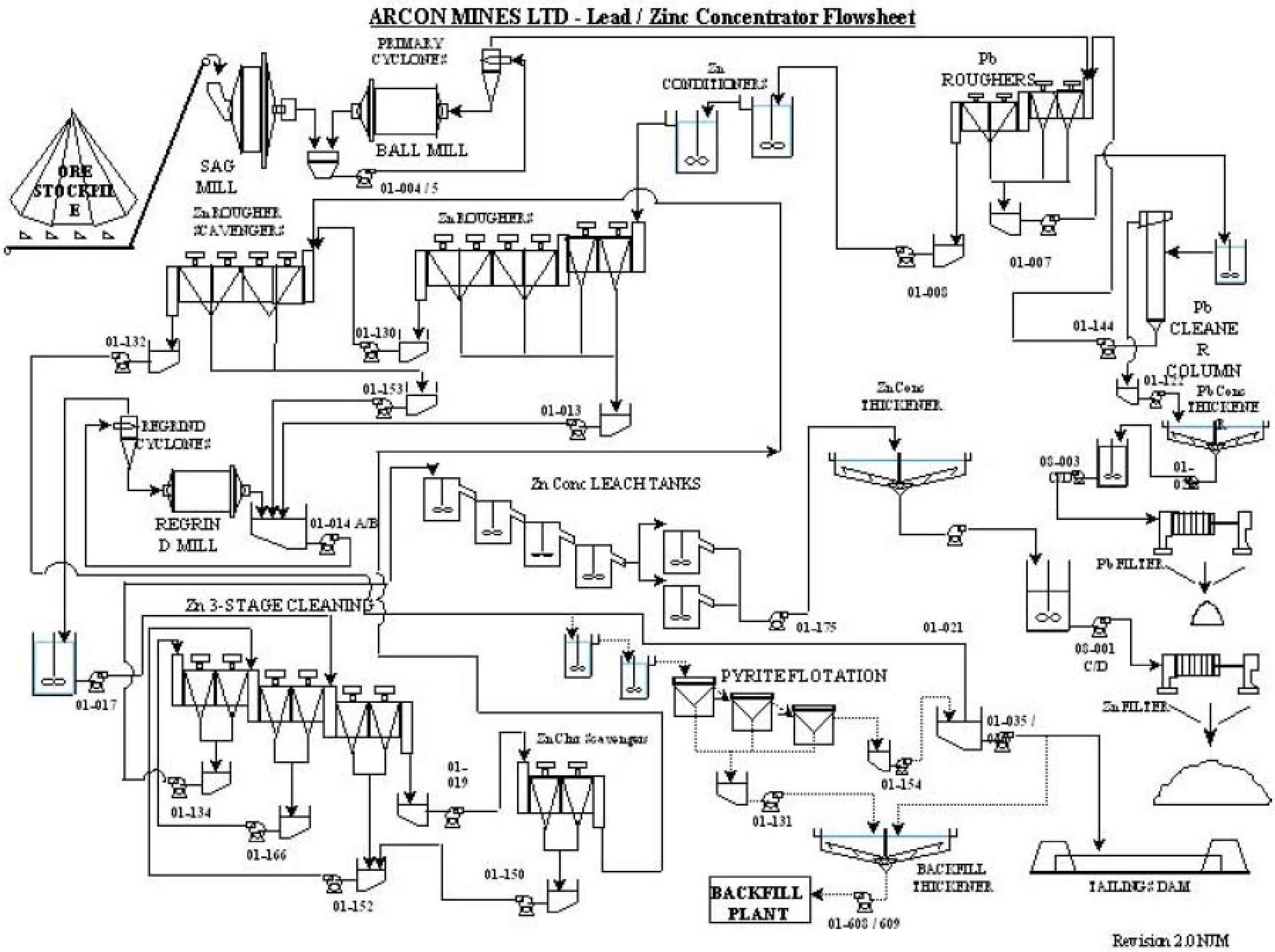


*Figure 19: Flow sheet as of September 2002*

**LEAD CIRCUIT**

The single cleaner lead circuit was unable to produce saleable concentrate grade and the attempts to build up a circulating load of lead between the lead rougher and lead column in order to attempt to make saleable lead grade were futile. The lead column level control and air spargers were a constant source of operational instability and the frequent dumping of the column contents back into the lead rougher caused significant lead contamination in the downstream zinc circuit. As a consequence, it was decided at an early stage, to iron out this instability and cease futile attempts to make lead concentrate grade. As a consequence, the lead rougher concentrate was pumped directly to the total tailings box via the OSA .

**ZINC CIRCUIT**

Size/Recovery data generated on bulk monthly composite data (refer to Figure 20) and the final zinc concentrate zinc distribution by size (refer to Figure 21 below), indicated that the majority of the zinc was floating below 50 microns.

A significant proportion of the zinc is in the minus 9 micron fraction.

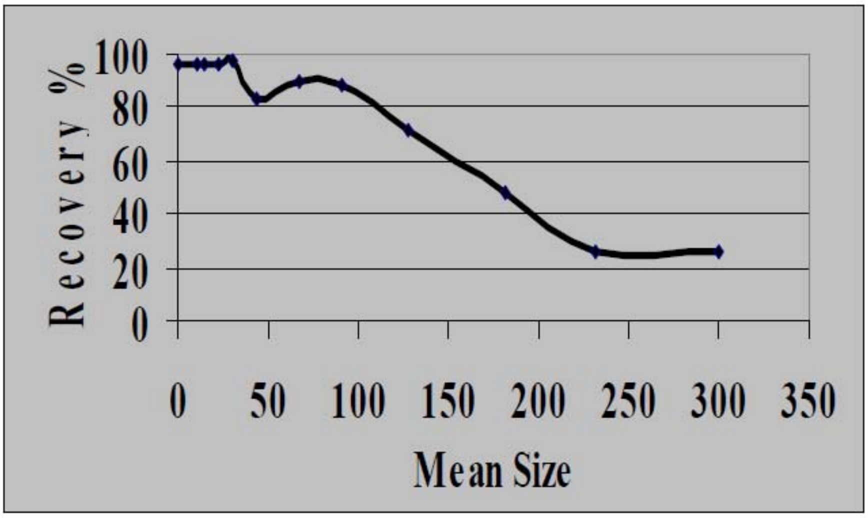


*Figure 20: Zinc Recovery to Zinc Rougher Concentrate*

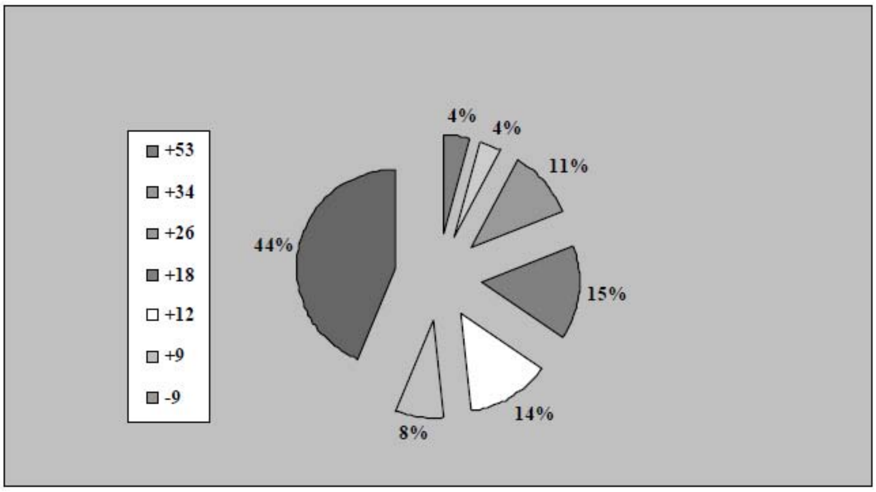


*Figure 21: Final Zinc Concentrate Zinc distribution by Size*

The total zinc tailing Monthly composite sample for August 2002 is shown below (refer to Figure 22), and clearly shows that the zinc assay by size is relatively constant across all size fractions, suggesting that the flotation process was incomplete.

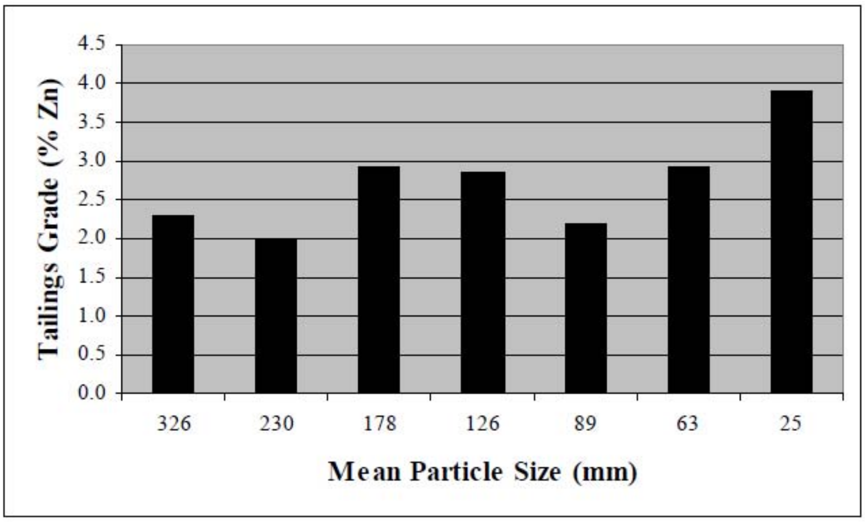


*Figure 22: Total Tailings Zinc Grade by Size*

Subsequent mineralogical examination of September mill composite samples supported the fact that the majority of the zinc losses were liberated sphalerite and supported the feeling that the plant was operationally unstable and lacked cell residence time. Subsequent laboratory flotation test work carried out on existing cleaner scavenger and zinc rougher tailings prior to them being combined and pumped through the shared flotation bank indicated that Process Control data from the On Stream Analyzer was limited and only gave total zinc recovery information. This restricted the capability of the operators when it came to real time decision-making.

As a consequence of the aforementioned issues with residence time and poor real time data, work commenced in scoping out a flow sheet modification whereby the zinc rougher tailings would be scavenged separately to the zinc cleaner tailings.

The idea was to use the three redundant Wemco 20M3 Smart cells as zinc scavengers leaving the existing shared bank of scavenger cells dedicated to cleaner scavenging. This would also provide the ability to untangle rougher and cleaner scavenger tailings OSA streams thus providing operators with a complete breakdown of zinc losses.

Figure 23 below shows the proposed flow sheet which was subsequently costed (Circa 150,000 Euros) and was easily justified by the predicted 5% increase in zinc recovery, not too mention the "Knock - On" benefits on process control and metallurgical accounting.

This new zinc circuit was hydraulically designed and layout drawings prepared by SGS and a local Irish Engineering Company fleshed out the detail and installed the modifications under our supervision.

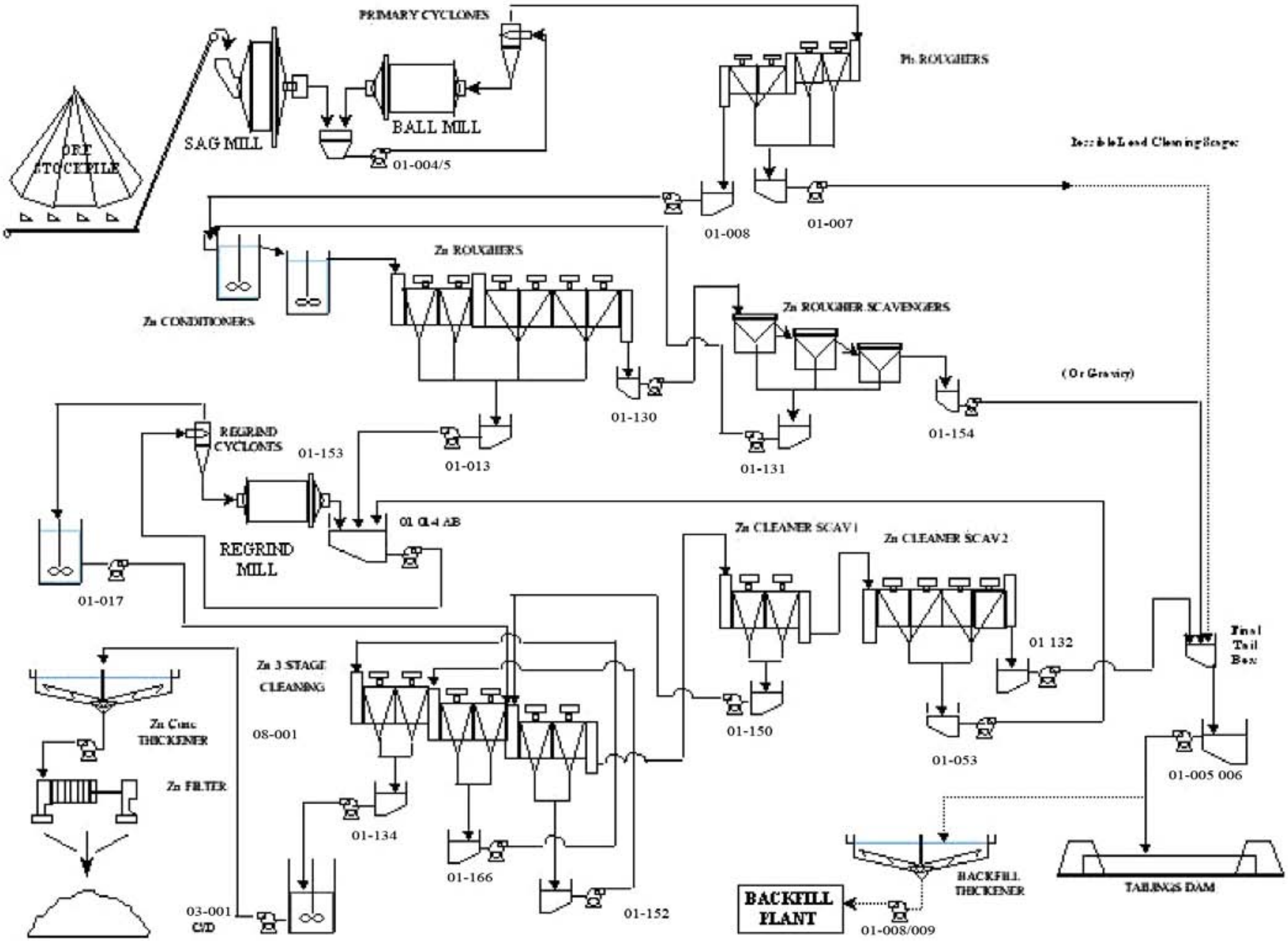


*Figure 23: New Flow sheet Separating Cleaner and Rougher Scavenger Circuits*

## RESULTS OF PLANT STABILISATION AND FLOWSHEET MODIFICATIONS

The throughput of the plant continued to run at record levels as seen in Figure 24.

The plant head grade remained at circa 12% Zinc, 3% Pb but with record high (18%) iron levels resulting in combined metals in feed increasing to record mine levels as clearly shown in Figure 25.

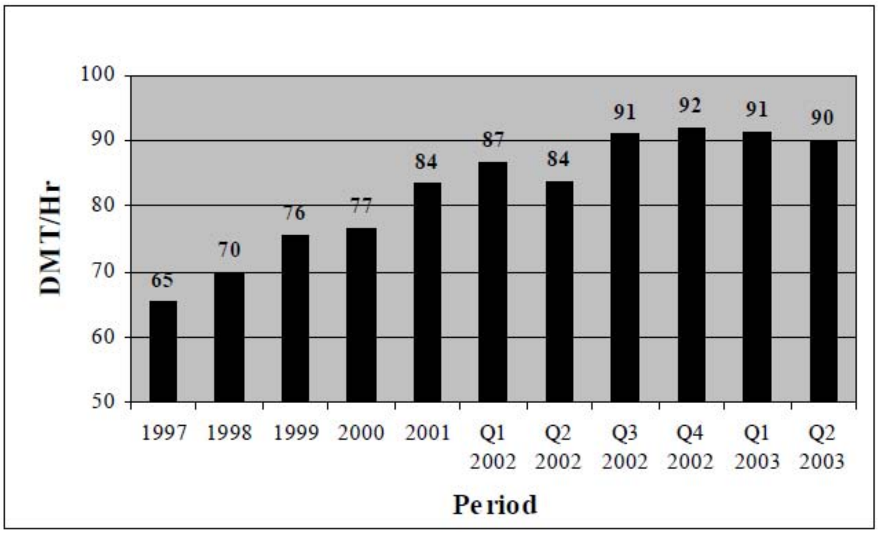


*Figure 24: Throughput rate versus time*

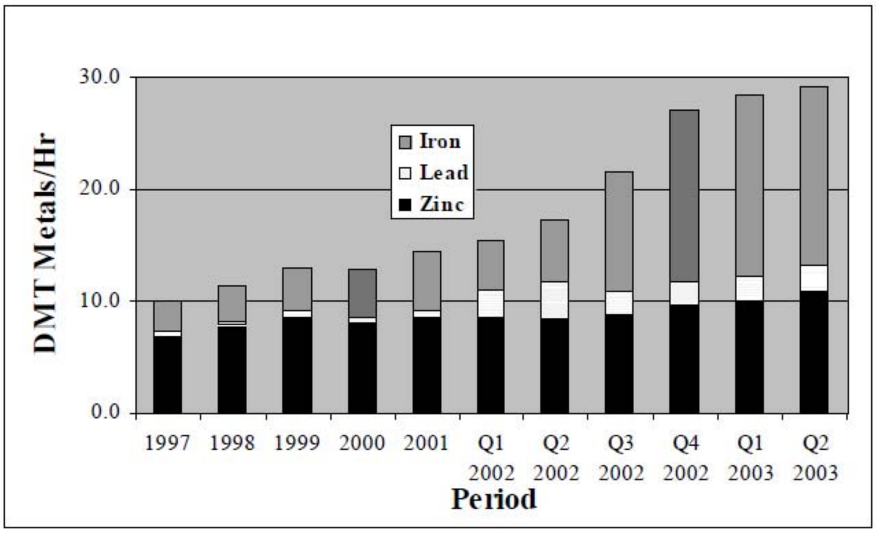


*Figure 25: Combined Metals/hr in Plant feed Versus Time*

The zinc concentrate grades have not been significantly affected by the increased throughput as seen below in Figure 26.

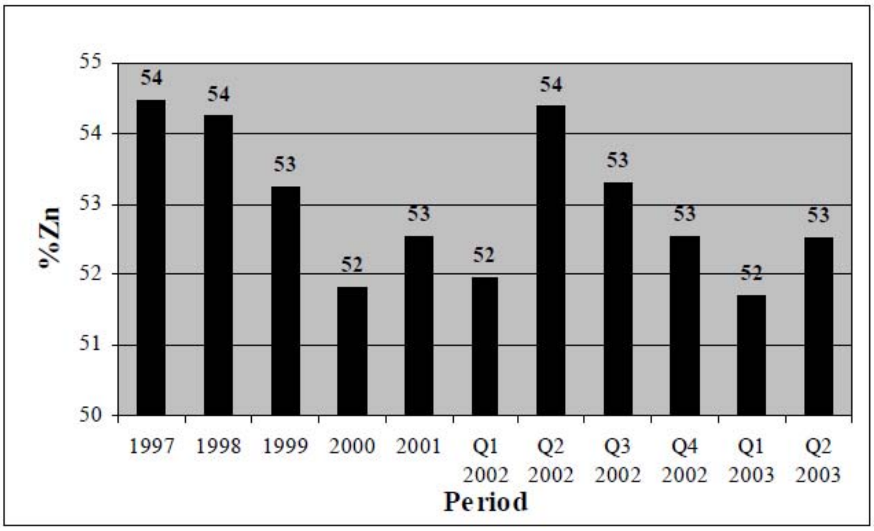


*Figure 26: Zinc Concentrate Grade Versus Time*

Figure 27 shows how the traditional MgO type fingerprint of Galmoy Concentrates has changed to an Iron/ Lead fingerprint. The contaminant levels are acceptable for smelters.

Last but far from least, the ultimate testimony to the success of the

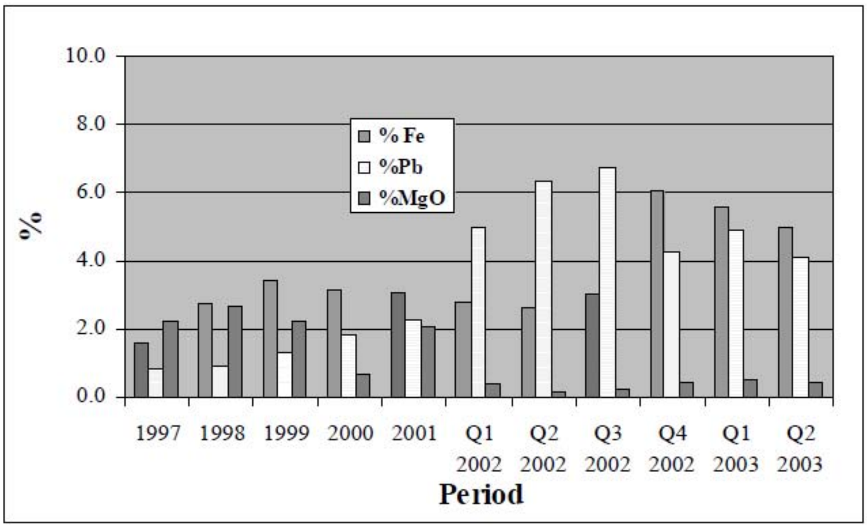


*Figure 27: Zinc Concentrate Grade Contaminants Versus Time*

flowsheet modifications and increased plant stability is demonstrated in Figure 28.

Despite the record ever throughput rates and significantly higher iron (and total metals) entering the circuit, the zinc recovery was increased from 71% in August 2002 to 90% in July 2003.

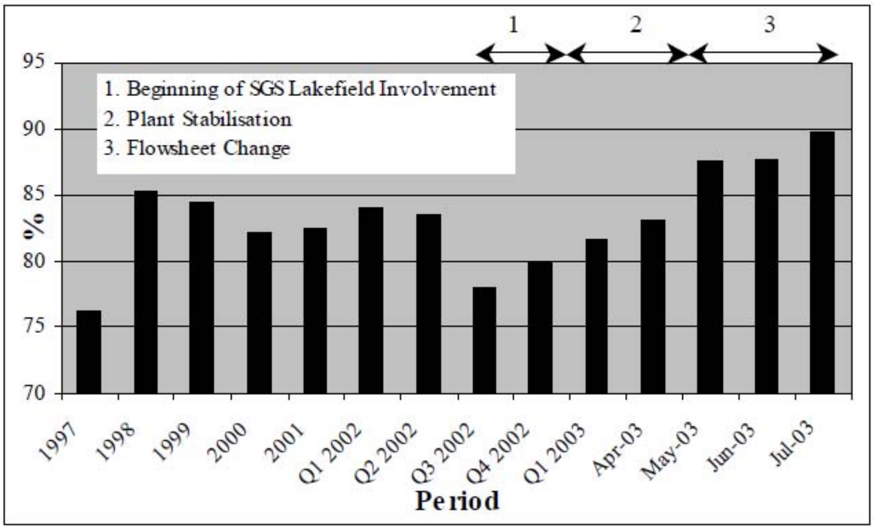


*Figure 28: Zinc Recovery Versus Time*

## CONCLUSIONS

- Plant instability can have a major effect on the efficiency of mineral processing plants and this case study shows that zinc recovery was increased from 78% in the last quarter of 2002 to 83% by April 2003 purely by reducing plant instability associated with cell level control, flotation feed sizings, reagent mixing/dosing and providing the operations group with a coherent operating strategy. These solutions were very low cost compared with the revenue gained.
- The additional flow sheet modification that increased zinc flotation residence time provided the additional recovery gain up to circa 90% (7% gain in zinc recovery) that had a payback of 6 weeks on capital cost.
- The optimization of this circuit and the introduction of a lead cleaning circuit will be the subject of a subsequent paper.

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