A HISTORY OF EURUS MINERAL CONSULTANTS AND DEVELOPMENT OF KinCalc® and SUPASIM®

The South African Mining Industry in the 1990s

Eurus Mineral Consultants developed as a result of a specific need in the minerals industry. Prior to 1996, the leading Mining Houses in South Africa historically held a large contingent of engineers and in-house consultants which was a repository for the industry's substantial and valuable technical knowledge that had been built-up over many decades. Following global trends and rising costs, these departments were axed over a number of years and from about 2000, the industry consultant became an integral part of the Mining landscape, often as a SME (small to medium enterprise).

The Development of KinCalc and SUPASIM in the 1980s

The use of flotation kinetics and the development of KinCalc® and SUPASIM® began in 1985 in Gold Fields Laboratories [GFL] (now SGS, Lakefield Laboratories) with the arrival of the first commercially available desk top PC. The MS-DOS system allowed programming in Turbo Pascal on a low resolution green and plasma yellow screen. At that time, Gold Fields of South Africa [GFSA] (unbundled in 1998 to form Gold Fields Limited, GFL) had acquired the Northam PGM property down-dip from JCI's (now Anglo Platinum) Amandelbult mine. It later transpired that this was quite a coup and the result of an intriguing and stealthy dawn raid on lapsed exploration and mining rights on the London Stock Exchange. Until the new millennium the platinum industry maintained an often fanatical level of secrecy. Bringing the deposit into production posed some major issues which were not resolvable with current knowledge or techniques as they existed at that time.

The deposit began at about 1,200m, a total of only 60kg of borecore was available for designing the plant and no plant operating data, equipment sizes or test data was available for guidance and benchmarking. Together with Mining house employees, mill, flotation cell and pump suppliers were subject to legal action if they divulged any information to a third party. The problem was how to size a plant and predict final concentrate mass, recovery and grade for an ore for which there was no plant scale data from other operations and no Bond work index tests could be done as this would consume at least a third of the core sample.

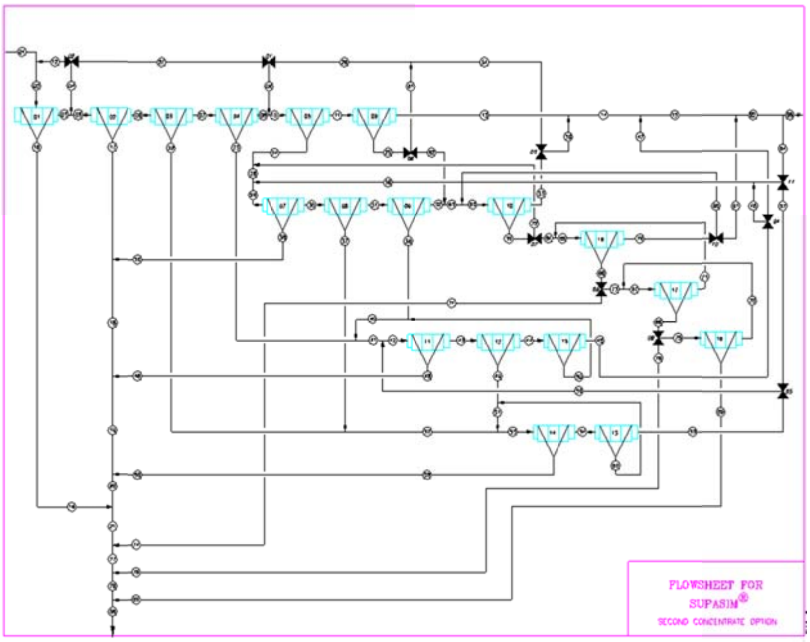
The JK test on borecore for mill sizing was a decade away from being developed. Sizing float plant from 1kg laboratory rate tests was based on various thumb-suck methodologies using scale-up factors linking plant and laboratory final concentrate recovery derived from case studies on ores of particular characteristic. Due to the lack of opportunity to widely benchmark, scale-up factors from these limited case studies were considered to be universally correct, whereas they actually varied widely and were mostly conflicting.

Necessity and Invention

Mill and float circuit sizing and prediction of flotation performance was one of either take a complete guess and attempt to dress it up as a scientific procedure or develop new methodologies – the latter being a classic situation of "necessity is the mother of invention".

Using samples from Gold Fields gold and base metal operations, methods were developed using 1kg samples to determine operating work index using GFL's laboratory mill and flotation kinetics from a standard rate test in a 2.5l Denver D12 float cell. Outlier samples with particularly low/high Bond work index and ones possessing high mass pull and low/high metal recovery during previous pilot plant campaigns were obtained from Mintek on a no-name basis. These provided extreme points and facilitated modelling from which various scale-up factors were determined from laboratory to plant. 8 case studies of gold, pyrite, copper, polymetallic base metal and tin operations validated the methodologies.

Having found Kelsall's two-component equation specifying fast and slow fractions and rates in a 1961 paper and a similar equation in a paper by Jowett in 1960, a program (later called KinCalc) was written in Turbo Pascal by John Foxcroft to input rate test data and determine flotation kinetics. A mass balancing program was then written for a flotation circuit with a degree of flexibility. Inputs were flotation kinetics, feed tonnage and pulp density, head grade and number and size of flotation cells. This was eventually called SUPASIM. John was a graduate chemical engineer whose programming skills were taught to him by his wife who happened to be one of the early and few women computer programmers at the time. They emigrated to Edmonton, Canada in the late 1980s - one of the many loses of high calibre skill to other countries that remains a dilemma for South Africa.



1986: SUPASIM in Turbo Pascal. A fixed flowsheet, but banks of cells could be switched on/off and valves direct flow

SUPASIM was validated using test and plant data from the pyrite, copper, polymetallic base metal and tin flotation circuits detailed in the case studies. Some false starts highlighted the need for a relationship between float cell air rate and a water rate constant. In wide-ranging plant trials on UG2 and Merensky ores in the mid-1990s this was later expanded to include flotation kinetics to maintain prediction accuracy of recovery-grade-mass profiles at very low and very high air rates. The first conclusions that emerged were;

a) Scale up factors for the various fractions and rates of mineral and gangue were consistent and not ore or circuit dependant and
b) Fast floating fraction of mineral (or metal) was the primary decider of circuit recovery and represented the only 1:1 relationship between laboratory and plant performance.

These proved very convenient and made prediction of plant performance a much simpler task than originally anticipated. Point a) was later seen as obvious, because scale up factors are a function of the efficiency of particle-bubble contact and subsequent particle recovery and not the type of mineral and gangue being treated.

20 Months of Aspirin

A brief thought experiment over coffee concluded that, logically, there should be a relationship between each kinetic parameter and some physical aspect of a plant's mass balance of recovery, grade, mass pull, stream pulp density and flow rate. There indeed was, but it took the best part of 20 months to fully define these correlations. For each ore type different circuit configurations, each kinetic parameter was incrementally changed and a mass balance generated. Each time the mass balance had to be printed out, the result noted and the next change run. With 4 kinetic parameters for each of the economic minerals and 4 for gangue; 8 ore types each with an average of 2 economic metals, 2 input streams for kinetics (roughers and cleaners) and 3 circuit configurations per ore, making 7 changes per kinetic parameter the number of scenarios to be analysed totalled 5,376. At about 14 mass balances a day, it took much paper, perseverance, two Christmas breaks and many cups of coffee to define these relationships.

Today, with the Windows operating system, solver, goal seeker and what-if functions in Excel or using Monte Carlo simulation software this could probably be completed in a few days – about 125x quicker!

First Applications – Maranda and Northam

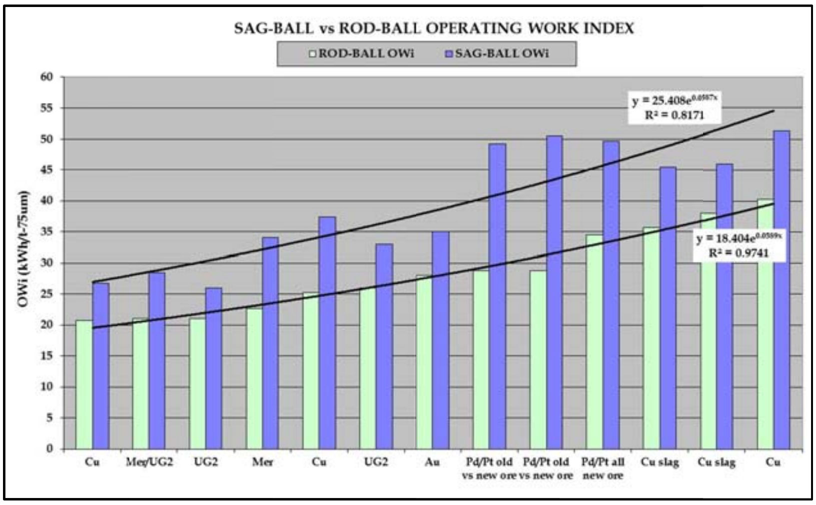
In 1988 bench and pilot scale data were used to size and simulate the sequential Cu-Zn flotation circuit for the Maranda deposit owned by Metorex. Flotation performance was as per simulation.

In 1988/9 the circuit to treat Merensky ore for Northam Platinum was sized and simulated. From start-up in 1993, flotation performance was also as per simulation. However, sizing the mills was open to significant error because, unlike flotation, it was not possible to directly measure key parameters that could be used for design. As far as possible 1kg tests in the GFL laboratory mill on known ores were correlated with Bond work index values. Once an operating work index for the Northam run-of-mine ore had been determined and optimum grind established, benchmarking found that the milling circuit at the Chino copper operation in New Mexico, USA was almost an exact fit in throughput, grind and overall operating work index to that envisaged for Northam.

Designing from Laboratory Data – be Prepared to get it Wrong

Chino used a well-established "pancake" SAG-Ball North American milling circuit. This was unknown in South Africa and viewed with much suspicion. The local industry was comfortable with conventional circuits using three stage crushing followed by rod-ball or ball-ball mills and the autogenous ROM "sausage" mill developed for gold plants by Alec Mokken of Gencor in early 1970s and optimised by Peter Bailey into the 1980s. At the back of everyone's mind was the failure of the country's only 9.75mØ pancake mill at Palabora which suffered from a cracked shell.

Further benchmarking and fact finding world-wide of operations treating the same ore with different milling circuits revealed that the difference in operating work index between ROM primary mills and mills treating 10-20mm feed was reassuringly consistent. Large savings in capital and operating cost eventually held sway and a 8.53mØ x 2.95m ROM SAG and 5.50mØ x 6.70m ball mill circuit with variable speed drives was installed. The primary will was designed to treat 225 t/hr to 30% -75µm at 35.8 kWh/t-75µm.



Feedback from the company's Mining Engineers indicated it most likely that ore hardness increases with depth, so the primary mill was sized with a liberal dose of capacity and could operate with a maximum of 18% steel. At full production the primary mill unexpectedly settled into autogenous mode producing 22% -75µm at 25.3 kWh/t-75µm, drawing 900kW (design was 2,400 kW). In terms of effective milling capacity of $LD^{2.5}$ (effective grinding length x diameter inside shell^2.5) the primary mill was some 2.5x over-sized! It later emerged that in that area of the Bushveld ore hardness decreases with depth.

It transpired about 14 years later (Anglo American had since acquired JCI to form Anglo Platinum) that they obtained an interest in Northam. During a period of strike action, Amandelbult trucked some of their stockpiled Merensky ore to Northam to be treated, since there was significant milling capacity available. After 6 hours of operation the primary mill filled-up and had to be shut down and emptied. Unrelated and a few months later Anglo Platinum commissioned EMC to audit all milling circuits in the group. Amandelbult's 6.10mØ x 4.88m primary ROM Merensky mill grinds to 36%-75µm and operates at 39.8 kWh/t-75µm. The Northam primary mill was correctly sized for an up-dip Amandelbult ore which laboratory milling tests on waste samples had indicated, but evidently not for softer down-dip Northam ore. And all because sufficient sample could not be spared for a proper Bond work index test on reef!

Benchmarking – at any cost?

With the amount of risk involved in sizing production-scale plant from laboratory data based on a newly developed methodology, benchmarking was a critical component of the evaluation and design process and to do this properly means obtaining similar ore to test.

During the construction of Northam in the early 1990s, the Mine Manager requested samples from Amandelbult's waste rock dump so that GFSA could perform Bond work index tests to check Northam mill sizing. The pervasive level of secrecy in the Platinum industry in those days evoked some unusual responses. Within a few days razor wire was placed on top of the chain-link fence dividing the two properties and both waste rock dump and tailings dams were patrolled by guards with dogs. In any event, if waste rock had been obtained, no one would have been any the wiser as it would have confirmed mill size according to harder Amandelbult ore.

Obtaining a Merensky sample from another operation for flotation testing was more successful and involved a cloak and dagger approach which has not been revealed outside of the now defunct Gold Fields of South Africa until now. I had described the development of SUPASIM® and the desire to obtain any amount of Merensky ore to a friend (Ian) who was sales manager at one of the major pump suppliers. He suggested an obvious approach of just walking into one of the plants and grabbing material. Being a junior level Metallurgist, and particularly in a back-water of a research laboratory, no one in Head Office was particularly interested in my comings and goings. With this advantage of non-descript employee and under the guise of a trainee, we went off to Rustenburg on one of Ian's routine customer-related plant visits. I was armed with an empty briefcase fitted with thick plastic sample bags and a sample scoop. In the 1980s security may not have been non-existent but it was certainly very laid-back. After Ian's brief conversation with the mechanical supervisor, and being introduced as a trainee learning the ropes, we headed into the plant to do a "service check" on the pumps. The plant was of 1960s origin with 5 milling lines consisting of 9ft primary and 8ft secondary ball mills. Typical of design at that time, the mill feed conveyors began in the bowls of the earth with the tail pulley in a dimly lit chamber below surface level – ideal for sample theft!

With much fear and as rapidly as possible, material was frantically scooped from the mill feed belt into my plastic lined briefcase, levelling after each scoop. Luckily no one saw – although down there it was highly unlikely – and I went to find Ian, swinging my briefcase in as nonchalant a fashion as possible with the idea that any observer would immediately note that my briefcase was obviously light and held nothing more than odd papers. The trouble with doing something you know is wrong is that you think everyone you see automatically focuses on the item of one's crime.

I had managed to obtain just short of 4.5kg. Back at Gold Fields Laboratories this was enough to do a rougher and cleaner rate test, produce some batch final concentrate and test mill 1kg to estimate operating work index. Bristling with success and when enthusiastically informed, GFSA management was horrified and forbad any mention of the escapade.

Despite the fact that today this level of secrecy and paranoia is considered unnecessary and even crazy, the reality at that time was that there would have been serious consequences had I been caught. Two other hasty grab samples had also been obtained from other operations; but under the circumstances it was best not to mention this. The engrained system of old style management expected conformity rather than initiative from a Metallurgist at D1 Paterson grade.

TEST NO	GRIND (%-75µm)	CMC (g/t)	NEW VALUES (calculated via KINCALC) Lab															
			IPF	kpf	IPS	kps	IGF	kgf	IGS	kgs	INiF	kNif	INiS	kNiS	ICuF	kCuf	ICuS	kCuS
RA1	60	150	0·8957	2·0182	0·1043	0·0574	0·0852	0·2701	0·9148	0·0027	0·4847	1·4536	0·5153	0·0124	0·8253	2·6326	0·1747	0·0277
RPMU1	"	"	·7161	1·6578	·2839	·0773	·1467	·2105	·8533	·0061	·3841	1·0575	·6159	·0201	·7792	2·5307	·2208	·0395
RPHM1	"	"	·7963	1·7137	·2037	·0520	·0673	·3618	·9327	·0044	·4443	1·4985	·5557	·0131	·7796	1·9194	·2204	·0414

1988: Flotation kinetics for 3 samples of Merensky ore from other operations.

No Excel spread sheets then!

The first "sortie" had been into the Frank concentrator in Rustenburg and the others into Mortimer south of Amandelbult. Flotation circuit size and configuration, feed tonnage and recoveries were approximately known so, importantly for program development a further three validations could be claimed.

Whilst auditing Anglo Platinum milling and flotation plants in 2004/5, I stood in the same spot as in 1988 by that tail pulley in Frank concentrator and mused over the contribution that sample had made to the initial development of SUPASIM®. Together with other small plants in the area with high operating cost, the Frank concentrator was decommissioned in 2009.

The Establishment of EMC and Development of KinCalc® and SUPASIM® in the 1990s and 2000s

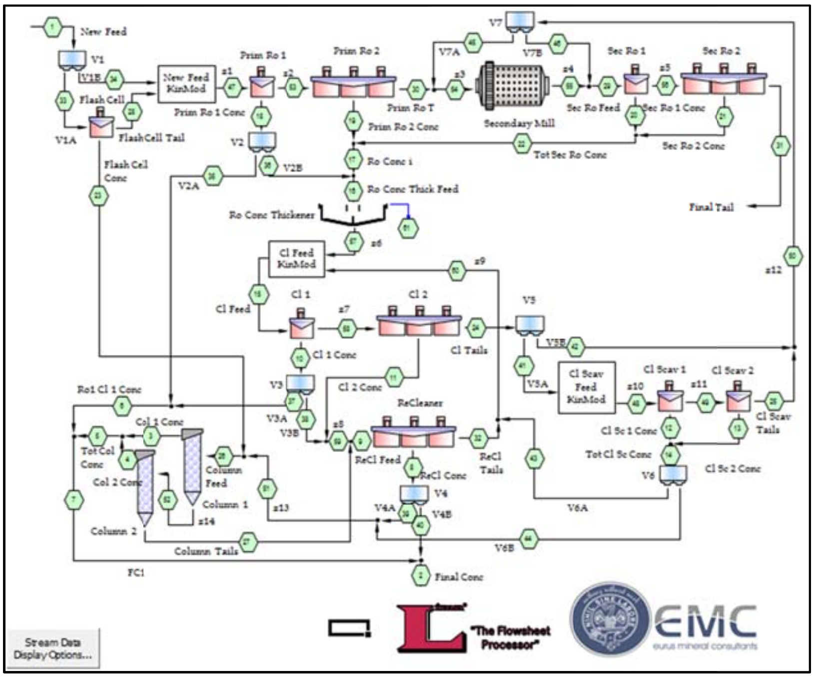
SUSPASIM® continued to be developed, but more as a side-line, in the 1990s whilst Consulting Metallurgist at Lonmin. Average PGM recovery for the company's concentrators increased at the rate of 0.75% per annum. The company's management style and strong emphasis on high operating standards were the main driving factors. KinCalc® and SUPASIM® played a part by enabling the flotation process to be better understood and being able to simulate and modify proposed changes. Lonmin's slag treatment concentrator built and commissioned in 1995 at the Western Platinum smelter was designed and performance simulated from laboratory scale tests using SUPASIM®.

EMC was started in February 2002 in response to changing conditions in the local mining industry as described at the beginning of this history. The company was fortuitous enough from day 1 to start with five clients who provided 90% of the work for that calendar year; Anglo Platinum, Cluff Platinum (became Ridge Mining who were bought later by Aquarius Platinum), Harmony Gold, O'Okiep Copper and Venmyn Rand (later renamed Venmyn).

Another fortuitous event was meeting Dave Wiseman, the developer of LIMN, at the Flotation 03 conference in Helsinki. Later in the year the old Turbo Pascal KinCalc® and

SUPASIM® programs were translated into more user friendly Excel spread sheet format by Dave. In 2004, EMC bought LIMN which Dave customised to accommodate SUPASIM®. Customisation continued over the next two years with the addition of other functions and calculation routines. EMC refers to the customised version of LIMN as SUPASIM-in-LIMN, or SIL.

The MS Excel version of KinCalc® was a vast improvement on the old Turbo Pascal program but could only accommodate 8-10 sets of test data before it slowed-up. The translation into MS Excel format had been done rapidly by Dave on a rough-and-ready basis which made it usable but required a great many new functions. As processing of client data grew, flotation rate test data would arrive in batches of 20-60 and several hundred sets of test data were being processed per annum to determine flotation kinetics. These data then had to be manually tabulated with associated kinetic ratios calculated. Apart from this becoming an onerous task the possibility of data input error was always a factor. A new version of KinCalc® was required which would be largely automated.



2011: SUPASIM in LIMN (SIL). A long way from the Turbo Pascal version of 25 years earlier.

A third fortuitous event was coming into contact with Adrian Jardin who, like Dave Wiseman, was a Metallurgist by degree but had augmented this with high-level programming skills. Adrian sat in EMC offices for the best part of 11 months whilst KinCalc was upgraded into Visual Basic. The project was supposed to take 3 months but as each new version came out, testing on the latest set of client data highlighted the need for extra functions. A few of these were,

- Sorting and ordering of data in specific ways,
- Highlighting individual data sets to be transferred to an average page and the result put back into the input page for re-estimation of kinetics,
- A facility to change g/t into % to accommodate clients who reported base metal assays in ppm instead of %,
- The facility to re-run a data set with certain analytes excluded via a tick-box.

The first time saver was to develop an import wizard to automatically transfer data in any excel format into KinCalc following which the program would calculate, tabulate and graph the subsequent results and kinetics. Probably counter-intuitively, this proved to be amongst the biggest headaches. Character and word recognition functions had to be programed in to accommodate client's use of acronyms, abbreviations, aliases, spelling mistakes and foreign language alphabet.

The fourth fortuitous event, was meeting Andy Holloway at the annual Canadian Mineral Processors conference in Ottawa, 2004 (another quality South African Metallurgist who had decided to move to Canada). Andy introduced me to the scroll bar facility of Excel. This became one of the largest and most useful components of KinCalc as the "ScrollCalc" function. With two exponential functions, Kelsall's equation fits a specific shape of recovery-time curve. Due to mineral composition and mineral-gangue associations not all ores adhere to this profile, especially nickel ores where the metal can be distributed between fast, medium and slow floating nickel-bearing minerals. ScrollCalc is a manual means of adjusting the visual fit between calculated and actual profiles.

EMC, KinCalc® and SUPASIM® owes much to others

Serendipity and the input of others has enabled a company to be formed that, based on the continuing work received, provides a useful service.

Isaac Newton famously remarked in a letter to his rival Robert Hooke dated February 5, 1676 that:

> "*What Descartes did was a good step. You have added much several ways, and especially in taking the colours of thin plates into philosophical consideration. If I have seen a little further it is by standing on the shoulders of Giants.*"

Source: Wikipedia