Flotation Simulation & Modelling Software

THE KINCALC®FLOTATION KINETICS CALCULATOR AND ORGANISER

AND THE SUPASIM® FLOTATION SIMULATION MODEL

BRIEF DESCRIPTION, CAPABILITY AND VALUE

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1. INTRODUCTION: FLOTATION, KINETICS AND KINCALC®

In a flotation plant the separation of mineral from waste is only about 85-95% efficient and is dependant upon a myriad of parameters encompassing the quality and characteristics of the ore, the operating environment, the reagents and the mechanical effectiveness of the flotation cells.

How much mineral is recovered (and how much revenue is generated) is primarily driven by the characteristics of the ore which dictate what the operating conditions should be, such as the fineness of grind, what reagents to use and the pH etc. The efficiency of the equipment (mills and flotation cells) also has an influence on mineral recovery. How the various economic minerals occur in the ore – i.e. in what way they are associated with each other and the various components of the host rock – is determined by the ore's geology which is measured by a mineralogist. How these associations affect recovery by flotation is measured as the ore's flotation kinetics. The diagram below outlines the pivotal role that flotation kinetics plays in characterising the ore, understanding why it performs (or behaves) the way it does and what size and configuration of circuit is best to treat it and to maximise recovery and revenue.

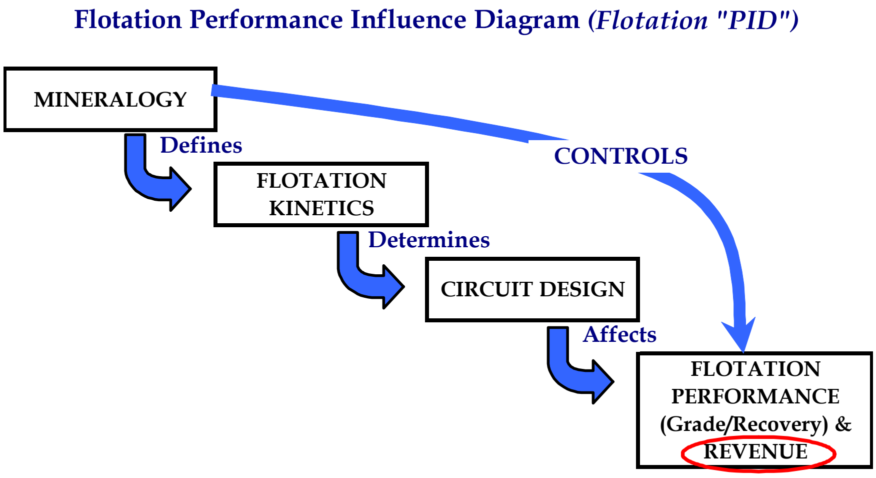


Figure 1 Flotation Kinetics, Circuit Design and Performance

1.1 Kinetics

How an ore responds to milling and flotation is determined by laboratory-scale batch milling and flotation tests. Under chosen conditions a flotation rate test is performed which generates a recovery, grade and concentrate mass profile over time. A graph showing typical recovery-time profiles of two "good" ores and one "bad" ore is shown in Figure 2 below. The shape of these profiles and the relationship between recovery, grade and mass with time is described mathematically by Kelsall's equation where R equals recovery and t equals time. The equation describes fast and slow floating components which relate to material that is easily and quickly recovered at the beginning of the process and material that is not (i.e. the slow and difficult to recover component).

The equation has four unknowns (collectively known as kinetics), a fast fraction, a fast rate, a slow fraction and a slow rate. These are estimated from the testwork data in Excel by using the Solver facility. Accuracy is improved by use of additional algorithms derived from experience.

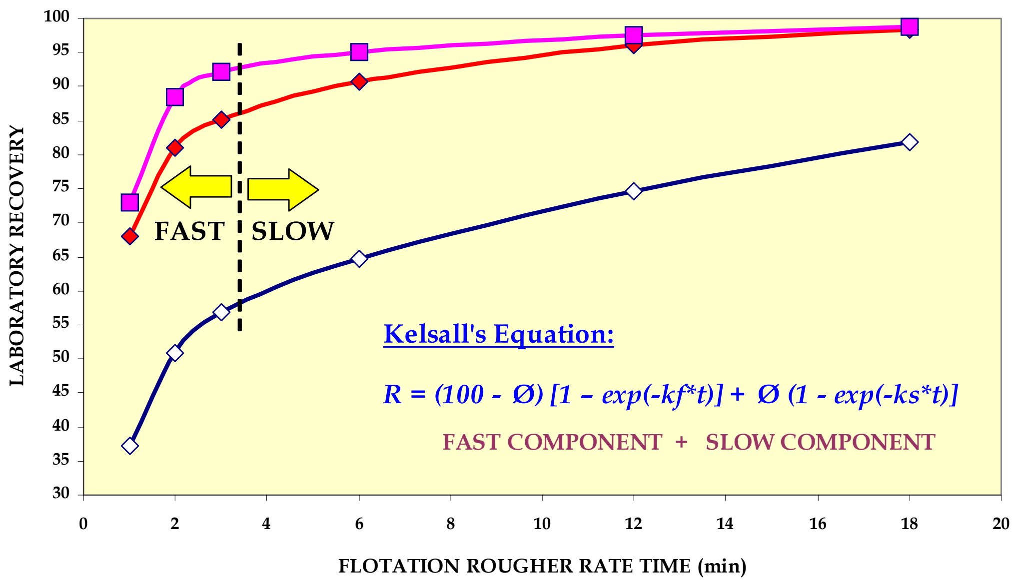


Figure 2 Results from a Flotation Rate Test and Kelsall's Equation

The outcome of using Kelsall's equation is that the behaviour and response of the ore as in Figure 2 is now described by a set of numbers or kinetics. The various components of the ore that have been measured by assay (floatable gangue, economic metals and minerals and other gangue or metal contaminants if desired) each have their own set of kinetics. An example is shown below in Table 1. If each set of kinetics was put back into Kelsall's equation then it would recreate the lines as in Figure 2.

Line	IPF	kPF	kPS	IGF	kGF	kGS
Pink	0.9011	1.6263	0.1158	0.0496	0.3586	0.0063
Red	0.7705	1.8396	0.1493	0.1062	0.2201	0.0021
Dark Blue	0.5135	1.1383	0.0554	0.2493	0.5582	0.0043

Table 1 Flotation Kinetics

Where,	I	= fraction
	k	= rate
	P	= Platinum Group Metals (PGMs)
	G	= Gangue

Thus, IPF = fast floating fraction of PGMs and kGS = slow floating rate of gangue.

The usefulness of flotation kinetics is that the flotation response of both minerals/metals and gangue can be reduced to a set a numbers. Different ores will have a different set of flotation kinetics as will the same ore under two different test or operating conditions. This makes benchmarking of one ore or one condition against another possible and it then becomes easy to determine which the better is by simply comparing one set of numbers against the other.

Taking this further, each parameter of rate and fraction has a specific physical meaning in terms of recovery, grade and mass in the laboratory test. Since the laboratory-scale test cell is merely a scaled-down version of much larger cells in operation in the industry, then the kinetics are also an accurate description of the ore under *full-scale, continuous plant conditions* when allowance has been made for the difference in efficiencies between laboratory-batch and plant-continuous modes. The difference between batch and continuous systems is described by a set of scale-up factors. An illustration of the link between each kinetic parameter and operating plant design and performance is shown in Figure 3).

The importance of flotation kinetics is that understanding of the flotation process, whether in the laboratory, pilot plant or operating plant, is increased and the process can then be optimised[1]. Laboratory flotation kinetics are used by Eurus Mineral Consultants to simulation plant performance (see Figure 4).

[1] Using the SUPASIM™ flotation model to diagnose and understand flotation behaviour from laboratory through to plant. Proceedings 37th Annual Meeting of the Canadian Mineral Processors Conference, Ottawa 2005.

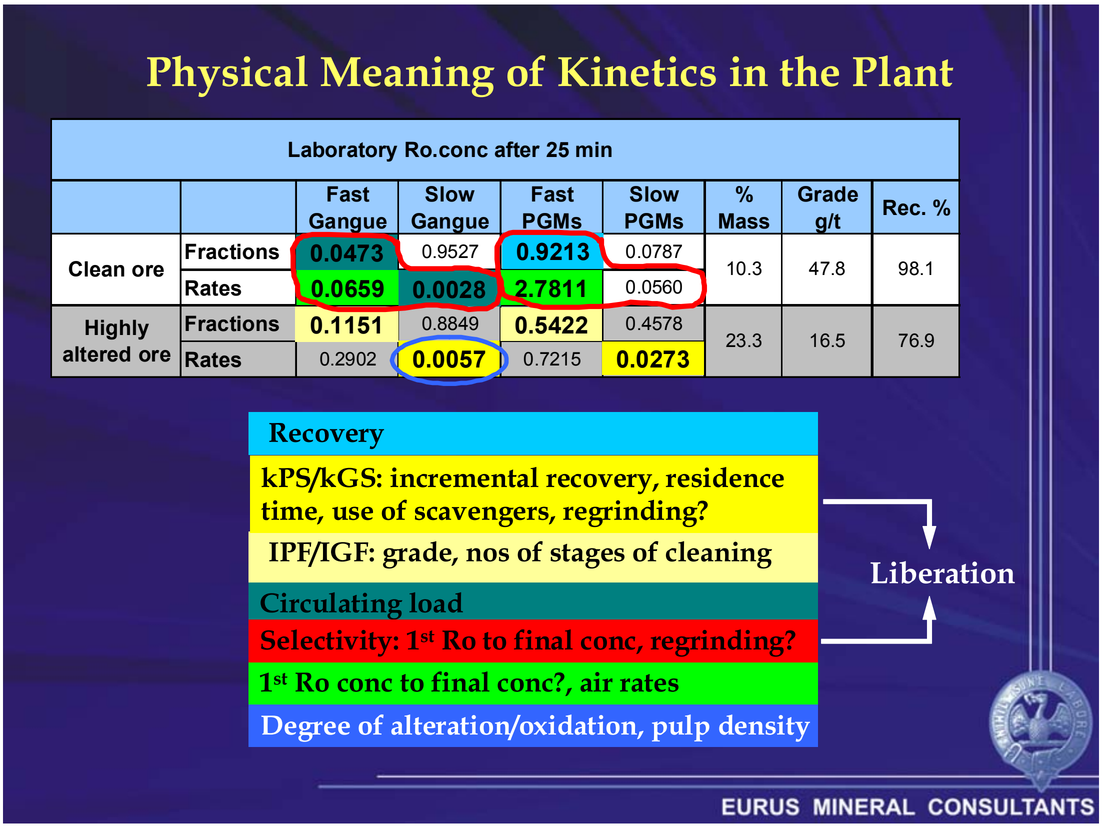


Figure 3 Physical Meaning of Kinetics in the Plant

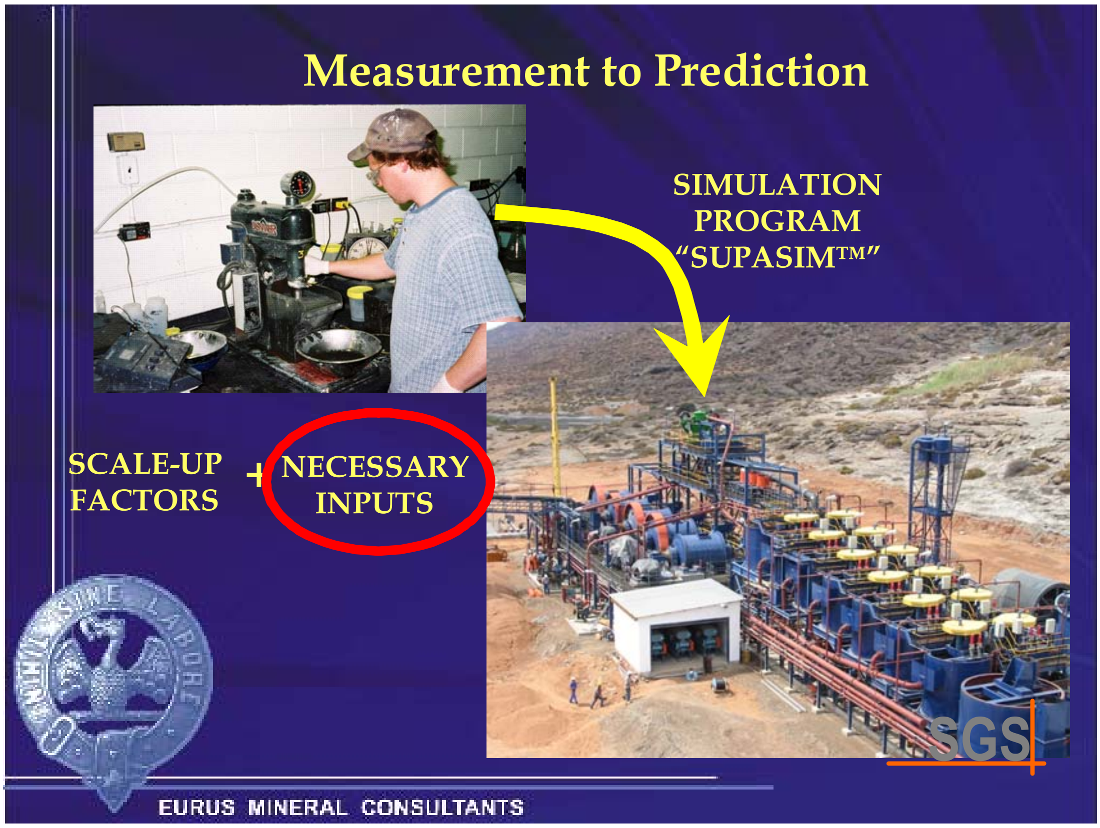


Figure 4 Simulation of Plant from Laboratory Data

2. WHAT KINCALC® DOES

2.1 Functions

KinCalc® calculates flotation kinetics from laboratory float test data in excel format. The program has the facility to automatically import data (test data and conditions etc) by identifying the cells or range of cells where the data occurs. This is done by setting-up a format which can be customised for any arrangement of data in an excel worksheet/spreadsheet including multiple data sheets per worksheet and multiple worksheets per file. **KinCalc®** can be set-up to handle the importation and processing of multiple files in a folder. There is no limit to the number of files and/or data sheets that can be imported and processed in one batch; however in practice it is best to restrict importation to about 200 data sheets at one go.

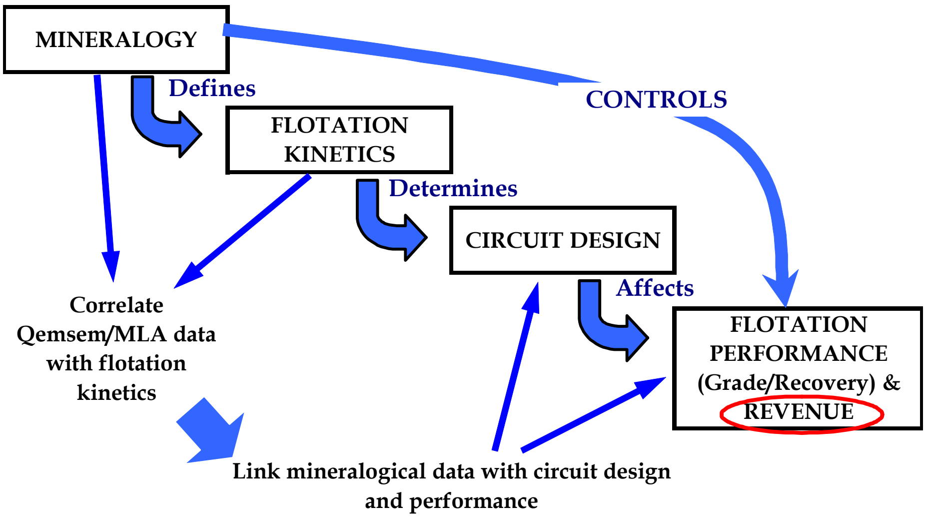
If data exists in hardcopy, software exists (from others) to convert these data into excel format.

Once imported, **KinCalc®**

1. Calculates flotation kinetics with and without boundary algorithms,
2. Generates five standard graphs,
3. Produces a summary sheet containing test descriptions; kinetics; laboratory test results; cumulative recovery, grade and mass pull; headgrade and various kinetic ratios,
4. Allows for kinetics to be calculated manually via scroll bars set-up for each kinetic parameter. This is done in that part of the program called ScrollCalc™,
5. Allows any set of data to be averaged and its kinetics calculated,
6. Allows one button generation of correlation coefficient tables and histograms which are time consuming to generate each time by manual application of the relevant excel function,
7. Stores all data in Access or SQL where searches can be set up to collate all data according to requirements such as ore type, reagent type, test date…. Etc. The data can be dumped into excel for data mining or statistical processing.

Overall, the value of **KinCalc®** to the client/user is that **KinCalc®** is an integrated system capable of handling and organising large amounts of data. With mineralogical Qemsem or MLA data it also provides a facility to dump both kinetic and mineralogical data into Access in order to generate correlations as per the diagram below.

Flotation Performance Influence Diagram (*Flotation "PID"*)



This "add-on" facility increases **KinCalc's®** usefulness as many clients perform a lot of mineralogy but have not generated the association with kinetics and plant design and performance.

The value of **KinCalc®** lies in clients/users being able to,

1. Calculate kinetics from float tests they have performed and as a result be able to benchmark one test, ore type or set of test conditions against another,
2. Automatically import, process and store data,
3. Have a customised graphing facility and one touch generation of r^2 correlation tables and histogram/ cumulative frequency graphs,
4. Use **KinCalc®** to graph test data and determine r^2 correlations without having to use the kinetics calculation section of the program,
5. Conduct an array of statistical analysis on the data having previously been conveniently arranged in the **KinCalc®** summary sheet or in the Access database,
6. Load Qemsem mineralogical data into the Access database and link with the associated kinetic data for a particular test. This provides the possibility of being able to correlate Qemsem data with flotation kinetics which are correlated with plant design and performance,
7. Collate all tests into one database and vehicle for easy access and processing,
8. Generate tables and graphs which are report quality and can be copied and pasted to a word document.

Figure 5 to Figure 9 shows details of the functions within KinCalc®.

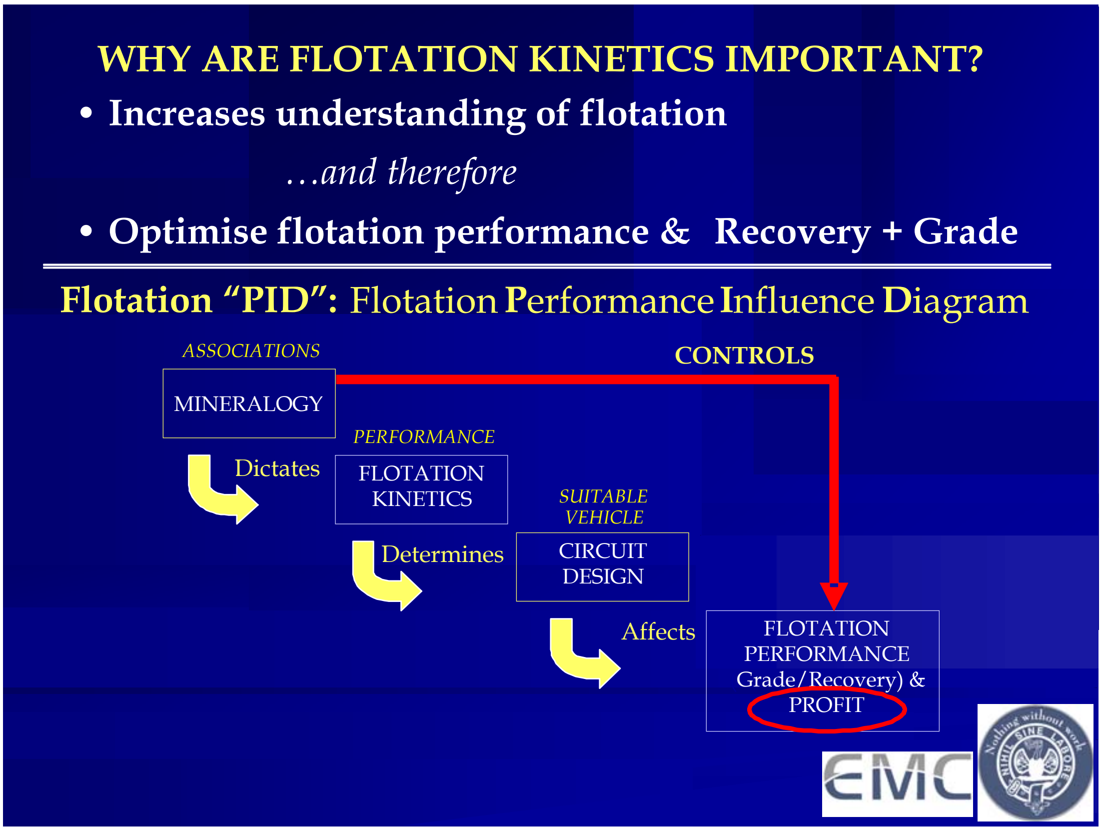


Figure 5 Flotation "PID" Diagram

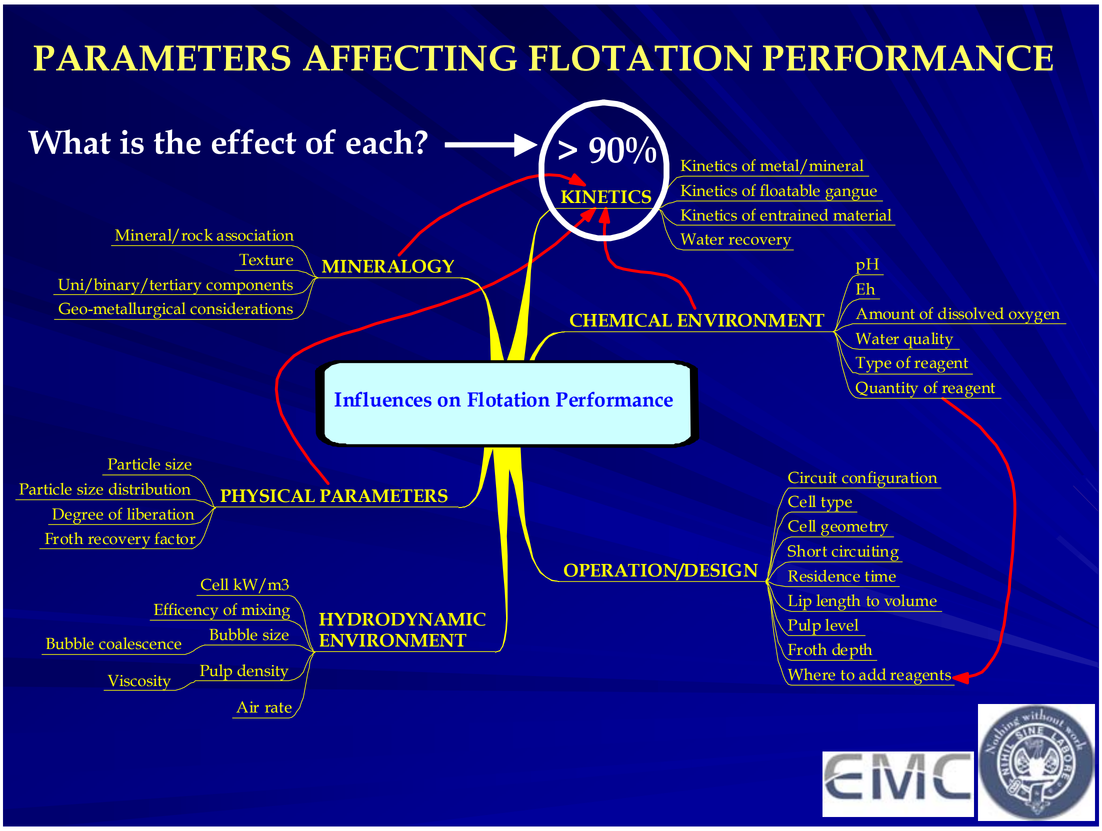


Figure 6 Factors Affecting Flotation Performance

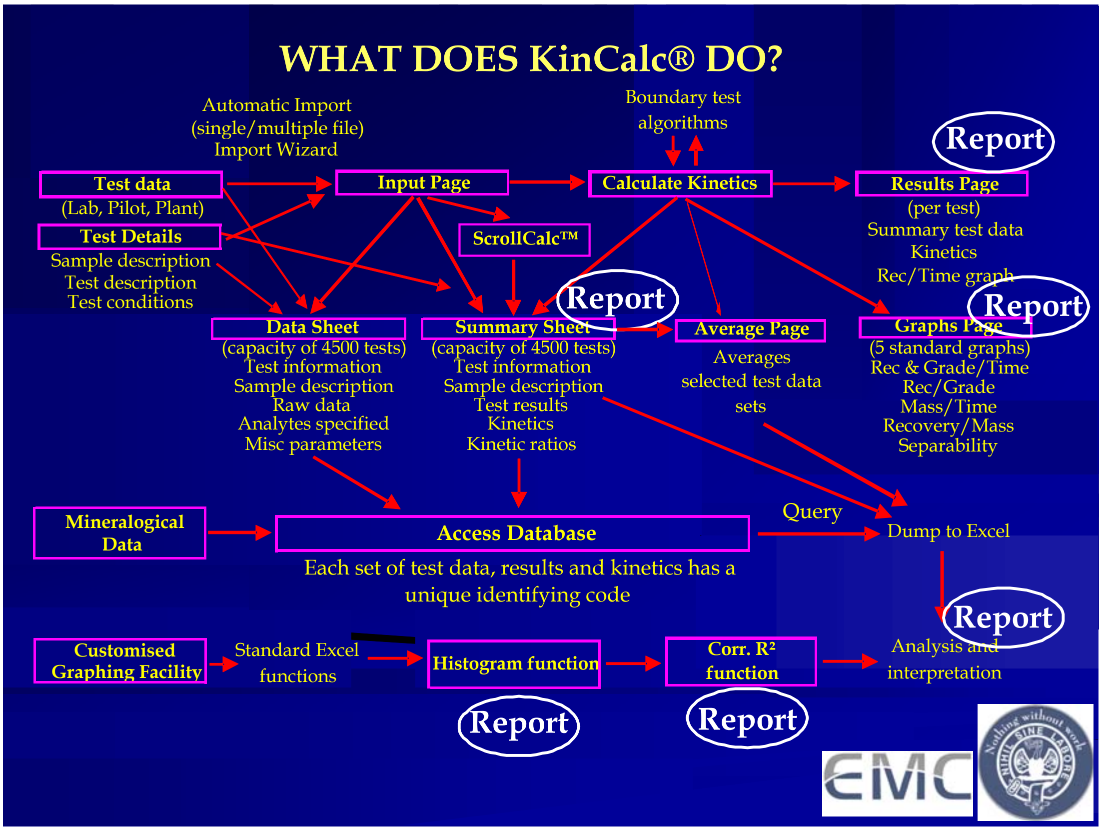


Figure 7 Organisation of KinCalc® Functions

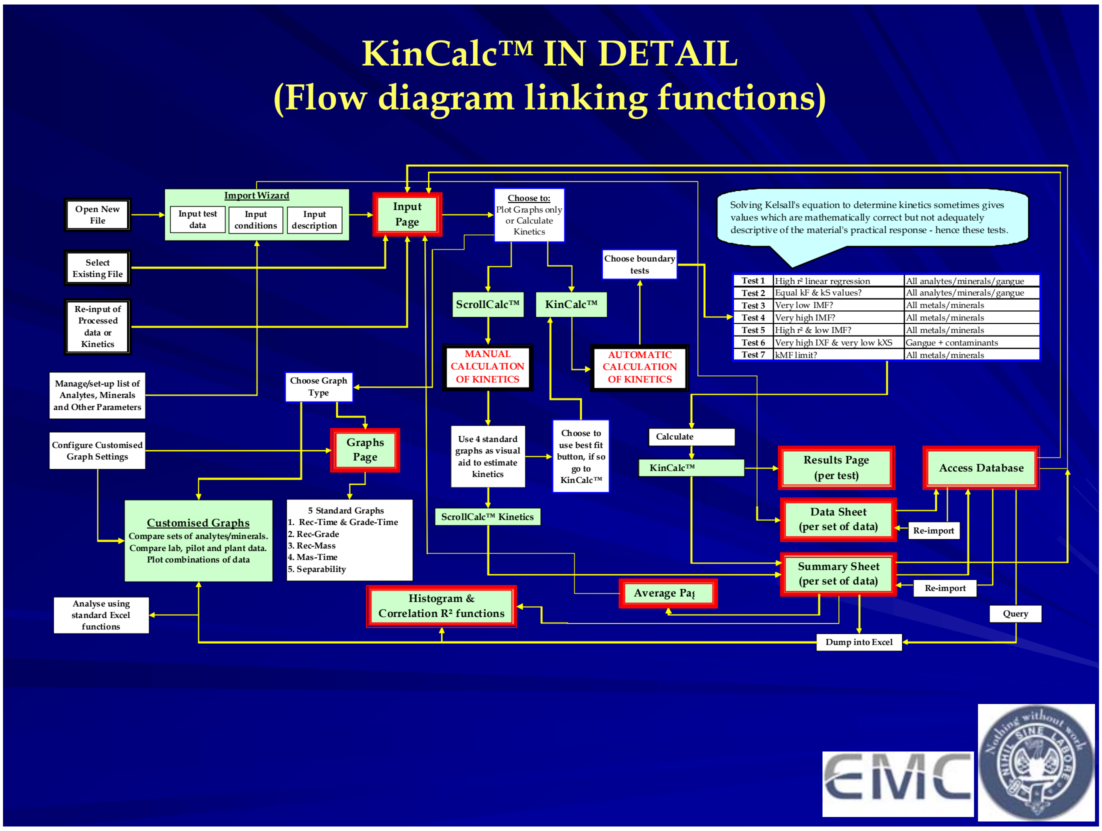


Figure 8 Flow Diagram of KinCalc® Functions

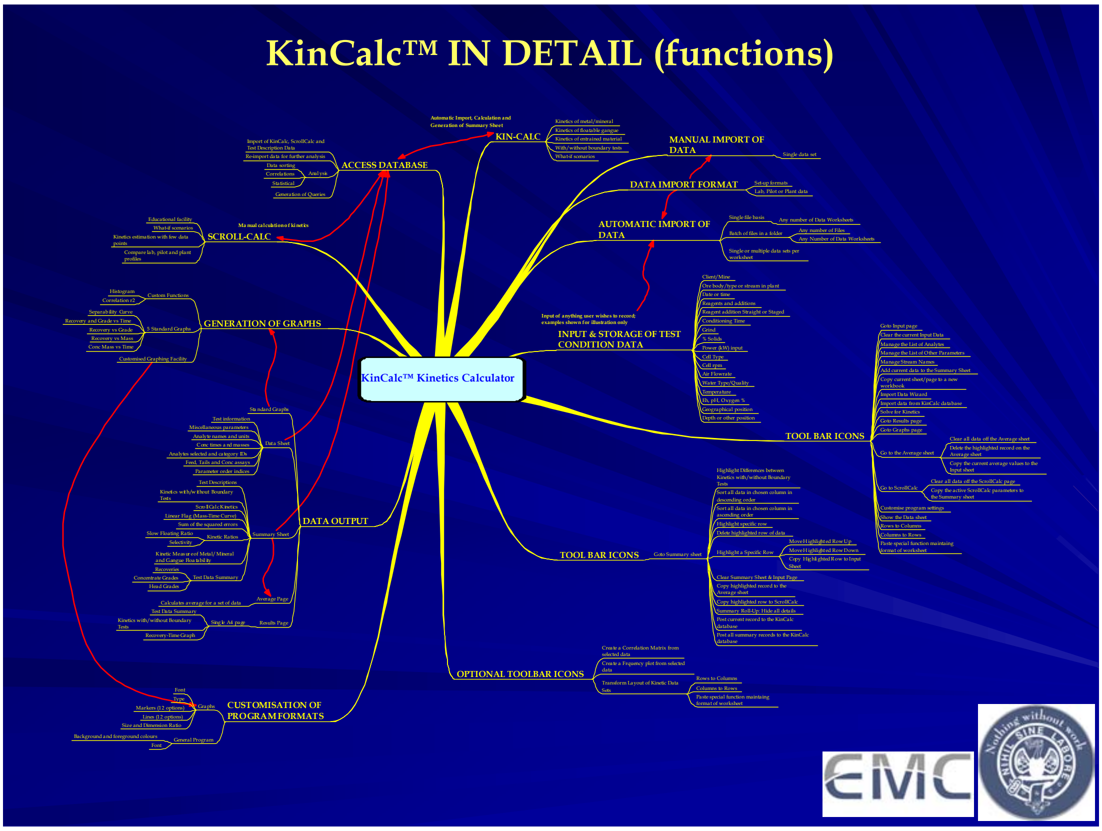


Figure 9 Detail of Interconnection of All KinCalc® Functions

2.2 Linear Correlation and Histogram Functions

Examples of one-touch button generation of linear correlation coefficient tables and a histogram are shown in Table 2, Table 3 and Figure 10. Associations are identified by an elevated coefficient between like parameters, for example between fast floating fractions and rates and slow floating rates of Nickel and Cobalt (lNiF vs. lCoF, kNiF vs. kCoF and kNiS vs. kCoS) and fast floating fractions of Nickel and Gangue (lNiF vs. lGF) in Table 2. In Table 3, a more altered Nickel ore has elevated coefficients between slow floating rates of Nickel and gangue (kNiS vs. kGS) which are more pronounced for fines than for coarse.

Correlation Matrix
BMS Ore Composite Rougher Rate Tests 1-20: EMC Rates

	kGF	kGS	INiF	kNiF	kNiS	ICuF	kCuF	kCuS	ICoF	kCoF	kCoS		
IGF	0.0115	0.0784	**0.4357**	0.0081	**0.7213**	0.2184	0.0060	0.1145	**0.6038**	0.1364	**0.5266**	0.260	**0.169**
kGF		0.1499	0.0065	**0.4637**	0.0279	0.0044	0.0284	0.0059	0.0001	**0.2685**	0.0013	0.096	
kGS			0.0171	0.2385	0.2355	0.0348	0.0005	**0.3094**	0.0022	0.2353	**0.2781**	0.150	
INiF				0.0605	0.2498	**0.5368**	0.0130	0.1014	**0.8786**	0.0615	0.1231	0.253	**0.199**
kNiF					0.0377	0.0042	0.1436	0.0104	0.0181	**0.6508**	0.0002	0.124	
kNiS						0.0800	0.0035	0.1563	**0.3435**	0.2307	**0.5043**	0.220	
ICuF							0.0458	**0.2577**	**0.3902**	0.0672	0.0863	0.169	**0.142**
kCuF								0.0009	0.0665	0.2120	0.0510	0.083	
kCuS									0.0637	0.0657	**0.3941**	0.175	
ICoF										0.1123	0.1176	0.115	**0.060**
kCoF	No of Data Points = 20										0.0046	0.005	
	0.011	0.114	0.153	0.193	0.254	0.146	0.034	0.120	0.263	0.204	0.190		

Table 2 Correlation Coefficient Table: Ni Ore 1

Correlation Matrix

Combined XX Composite + FOT 1-9
XXX Fines Rougher

	kGF	kGS	INiF	kNiF	kNiS
IGF	0.1459	0.1573	0.1566	0.0673	0.1694
kGF		0.1194	**0.3309**	**0.3191**	0.0599
kGS			0.1299	0.1047	**0.7450**
INiF				**0.4224**	0.0619
kNiF	No of Data Points = 26				0.1499

Average Between Fractions :

G & Ni
0.2314

Correlation Matrix

Combined XX Composite + FOT 1-9
XXX Coarse Rougher

	kGF	kGS	INiF	kNiF	kNiS
IGF	0.0711	0.0510	0.2241	0.0001	0.0790
kGF		0.1623	0.0006	0.0527	0.0569
kGS			0.0013	0.1518	**0.5859**
INiF				**0.3411**	0.0023
kNiF	No of Data Points = 32				**0.3388**

Average Between Fractions :

G & Ni
0.1280

Table 3 Correlation Coefficient Table: Ni Ore 2

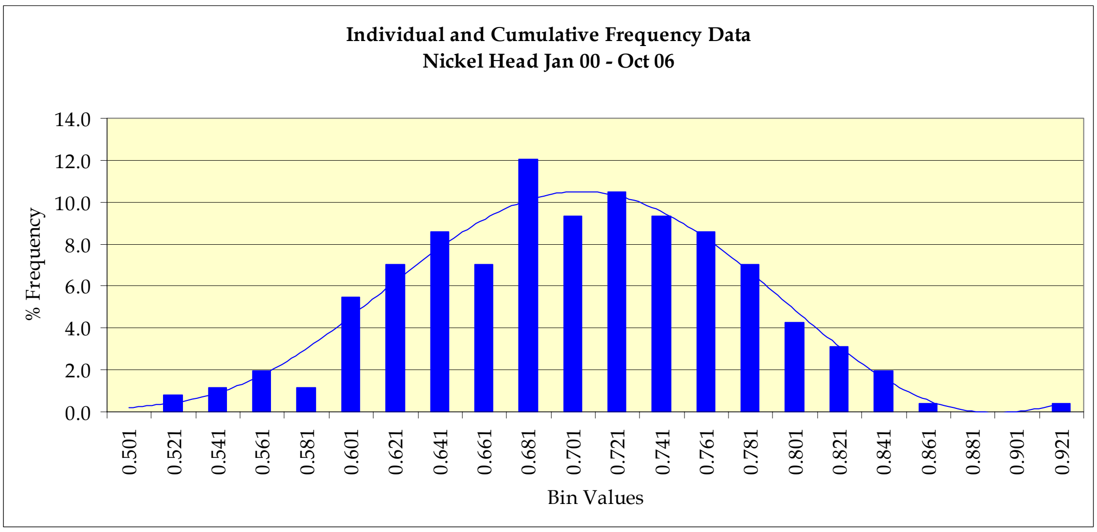


Figure 10 Histogram

3. ACCURACY OF SUPASIM®

To date over 60 case studies (validations) have been done where the flotation performance of operating plant have been simulated from laboratory batch rate tests. This covers PGM, Base Metal Sulphide, Phosphate, Pyrite, Graphite and Cassiterite ores and furnace slag and tailings dams. These include a variety of circuits from MF1, MF2 and MF3 configuration with/without regrinding of rougher concentrate and cleaner tails.

Figure 11 shows the good agreement between predicted and actual plant recovery where predicted concentrate grade is at or close to that of the plant. The graph includes secondary metals and contaminants such as Copper and Nickel in UG2 and Merensky PGM ores and Copper in a Zinc circuit etc.

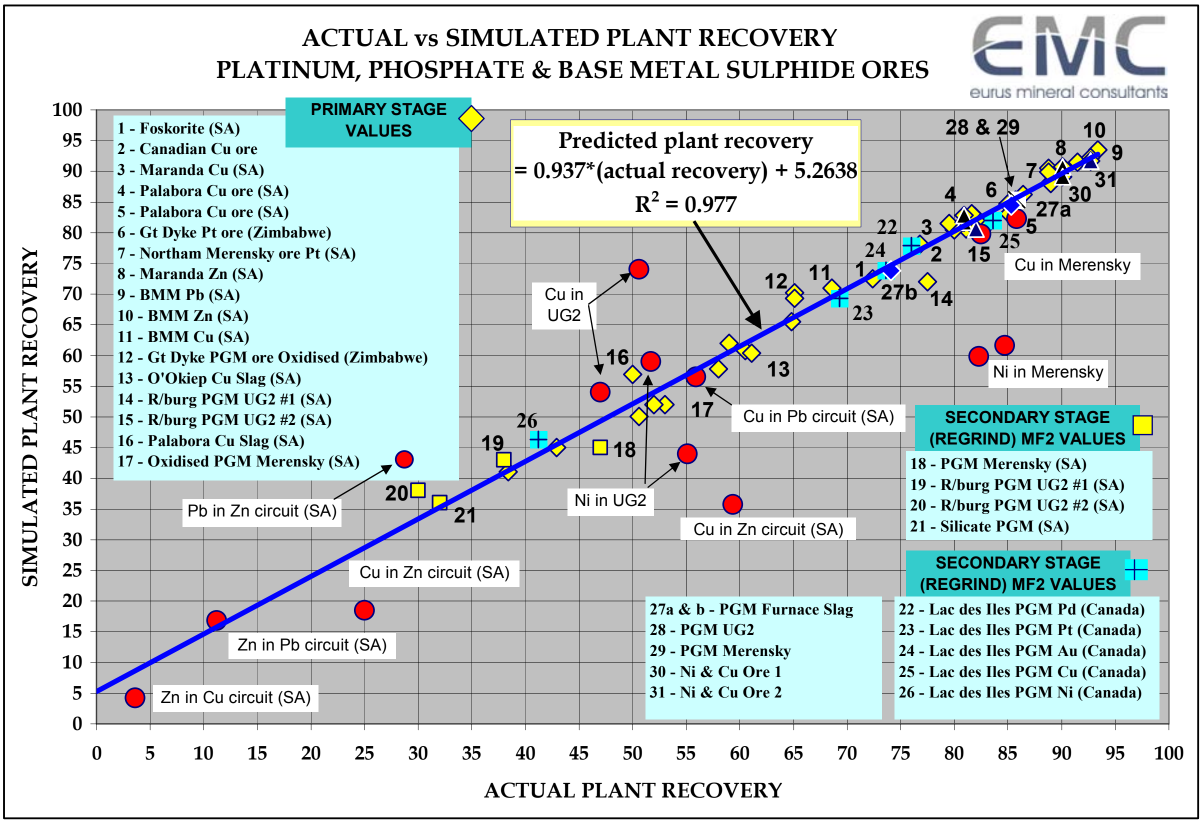


Figure 11 Predicted vs. Simulated Plant Recovery