



A different approach to teaching Hydrometallurgy

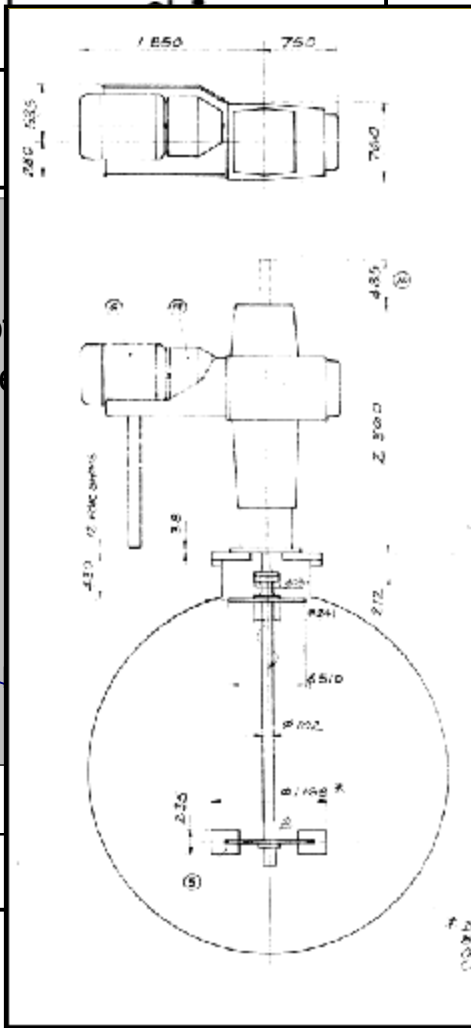
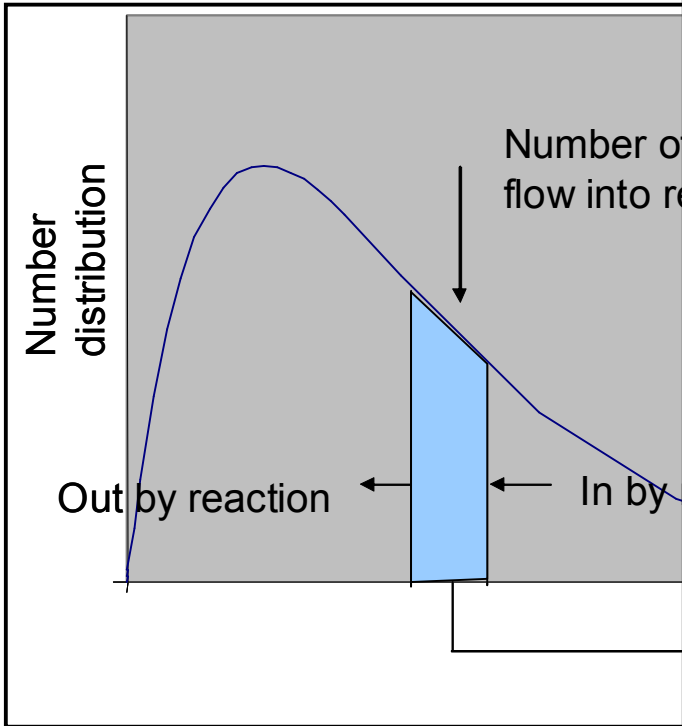
June 2009

Presentation...

- Presentation is not overly technical ...
- ...but describes a portion of a journey we have embarked upon as the Processing Division of Anglo Platinum
- It will focus on the efforts of a team of young engineers participating in the Anglo Graduate Development Program (AGDP)
- AGDP entails a two year program consisting of varied plant experience across process division, supplemented by, discipline specific, examinable course work (UCT) culminating in an operational based plant survey
- Today it is my privilege to share with you a part of our story...

2009 AGDP Hydromet Plant Survey

$$n_{in} = n - \frac{\bar{t}G_l}{l} \frac{\partial n(l^*, L^*)}{\partial l^*} - \frac{\bar{t}G_L}{L} \frac{\partial n(l^*, L^*)}{\partial L^*}$$



Objectives

- AGDP students **increase relevant skills** base on a “**real working operation**”
- **Consolidate** previous fundamental **learnings** attained through course work **in an applied manner** to make “sense” of operational plant “challenges”
- Experience the **powerful value** associated with a **collaborative** approach to **problem solving**

Novel approach to learning advanced concepts in hydrometallurgy

- Hypothesis framework – Clearly outline a problem to be solved which adds value to the organization



Contextualize the work – not just an exercise

- No pre-prepared lectures or notes



Test the ability to complement previous learnings with available knowledge bases

Novel approach to learning advanced concepts in hydrometallurgy

- Build an *a priori* model to describe the behavior of the plant or unit operation to be studied



Test the ability to apply knowledge to fundamentally recreate the problem from first principles – acid test for demonstrating understanding

- No use of commercial modeling or simulation packages to solve the math



Excel would be used to build the model – universal technical language which can also acts as a knowledge repository

Novel approach to learning advanced concepts in hydrometallurgy

- Test the hypothesis - validating the model by collecting and comparing it to actual operational data



First hand experience that operational systems do behave according to the laws of physics – dismiss mythology

- Conduct the whole exercise in two and a half weeks

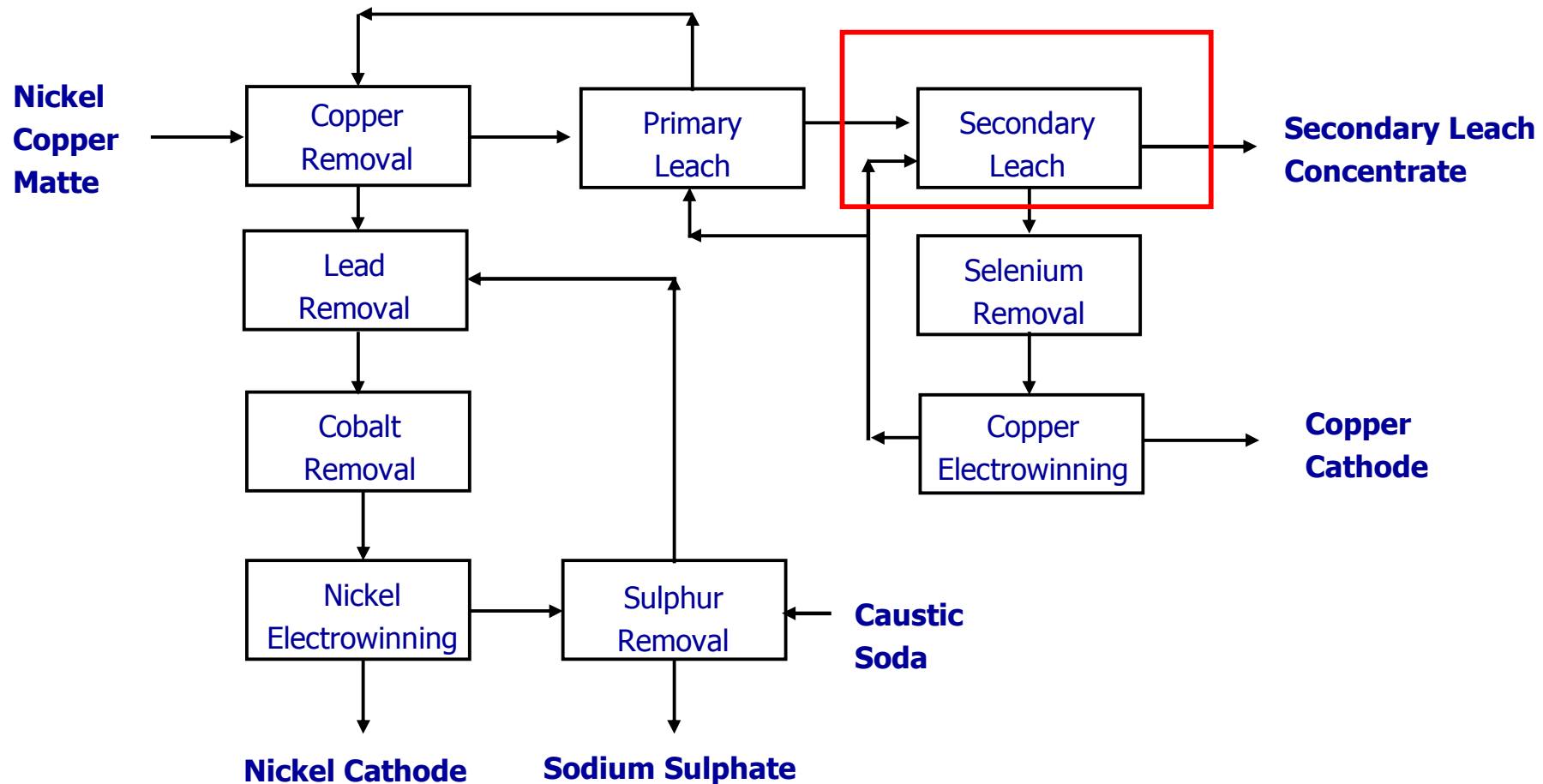


Demonstrate that the only possible way for achieving success in this situation would be that of a collaborative approach

Advantage of using a privileged asset

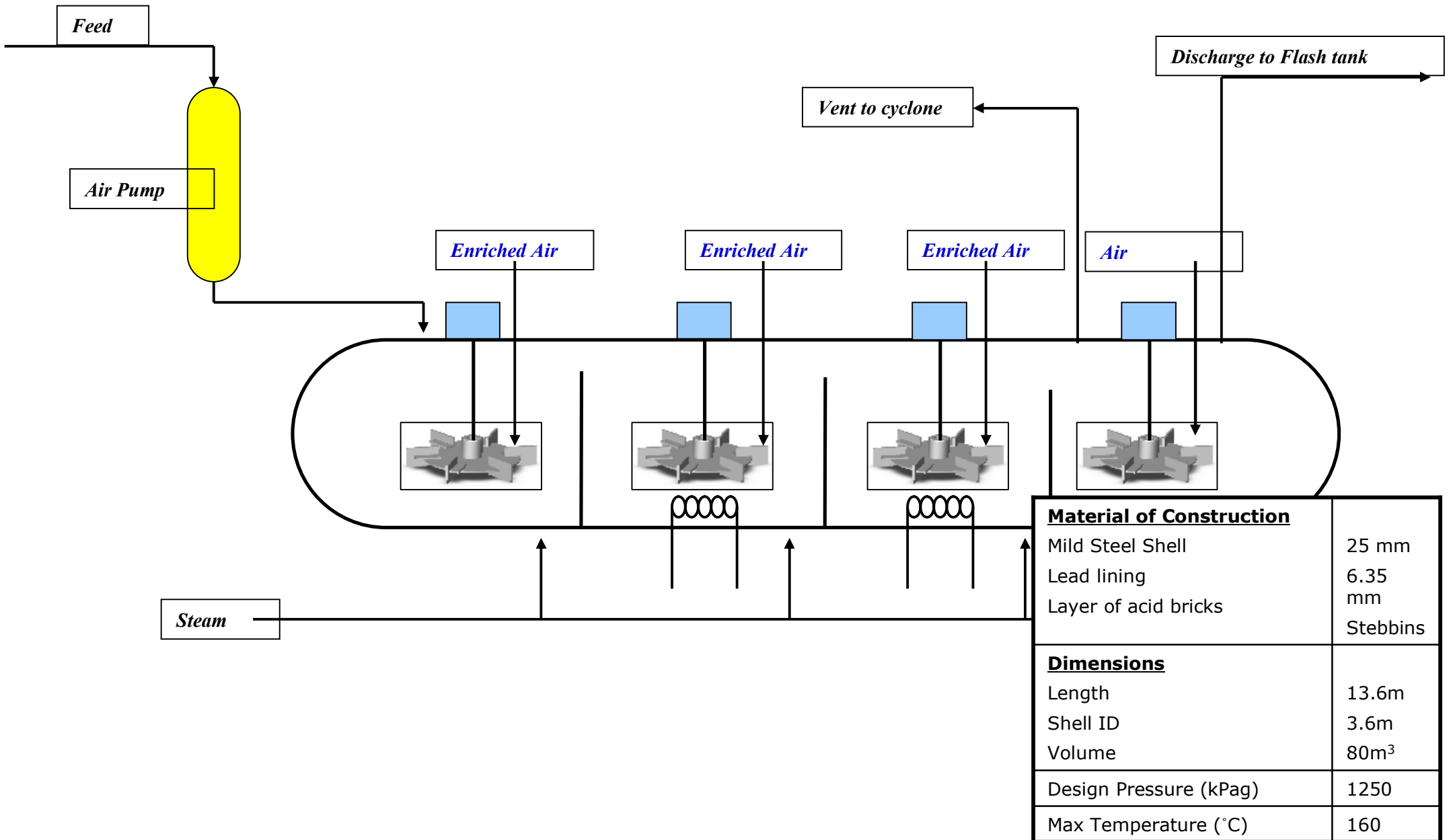
- From a hydrometallurgical perspective oxidative leaching, on a continuous basis, in a pressure autoclave is one of the most exciting unit operations to study or operate
- Hence it was decided use the BMR's secondary leach autoclaves as a basis for the survey
- In conjunction with these valuable assets BMR has excellent technical and engineering library facilities

Problem... Secondary leach is under capacity constrained...why?



- Current capacity 21 ktpa Ni equiv. with 3 x 80 m³ autoclaves
- Objective: 21 ktpa Ni equiv with 2 x 80 m³ autoclaves (Hofirek and Nofal 1994)

Secondary Leach Autoclave



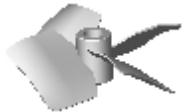







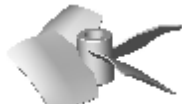









Knowledge collation : Actions

- Familiarization with the principles of leaching with respect to the secondary leach
- Collection and collation of mechanical equipment specifications – both current and original Sherritt Gordon
- Review the control philosophy
- Review works instructions and meet plant operating staff
 - Business Manager
 - Operations Manager
 - BMR technical staff
 - Control room operators etc
- Review and be trained and declared competent in sampling and analytical methodologies

Knowledge collation : Major finding

- Since commissioning in 1982 the secondary leach autoclave agitators type have been changed resulting in 3 autoclaves with different agitator configurations:

	Comp. 1	Comp. 2	Comp. 3	Comp. 4
Dual				
Secondary 2				
Secondary 3				
Original				

- Rushton Turbine 
- A315 

Why?

The concept of an "*a priori*" model

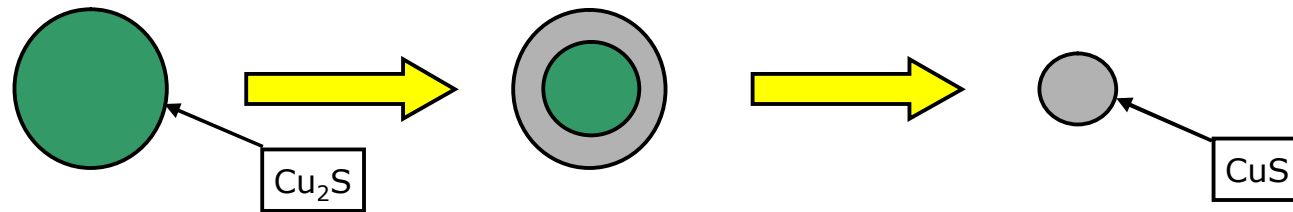
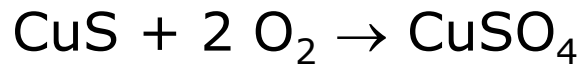
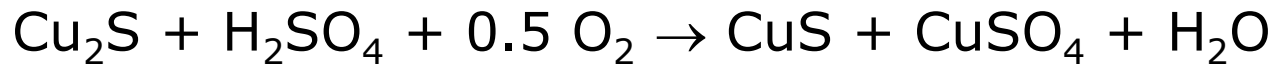
- Entrenches a "back to basics" approach
- For a modelling exercise to be instructive in terms of understanding a system it needs to include all the pertinent fundamental building blocks which may manifest themselves in the day to day, month to month, and year to year operation of the system:
 - Day to day : Flowrate or residence time
 - Month to month: Feed characteristics e.g. PSD
 - Year to year : Mechanical equipment e.g. agitator types
- Most published work to date (academically rigorous) characterising continuous leaching unit operations are solved and partially or totally fitted to actual operating data

So what needs to be considered in the model

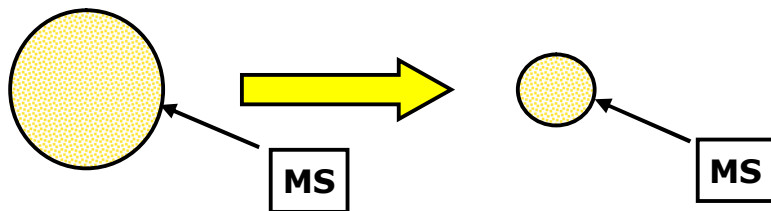
- Predominant or rate limiting reaction(s) vs. overall reaction?
- Continuous three phase dispersed kinetic systems
- Gas-liquid phase mass transfer kinetics and interpret it in terms of agitator type and performance
- Batch kinetic data and how to manipulate it into a useful form to model continuous reactors
- What assumptions to make and what numerical methods to use to solve the above systems in Excel

Reaction Mechanism

- Sequential reaction mechanism:

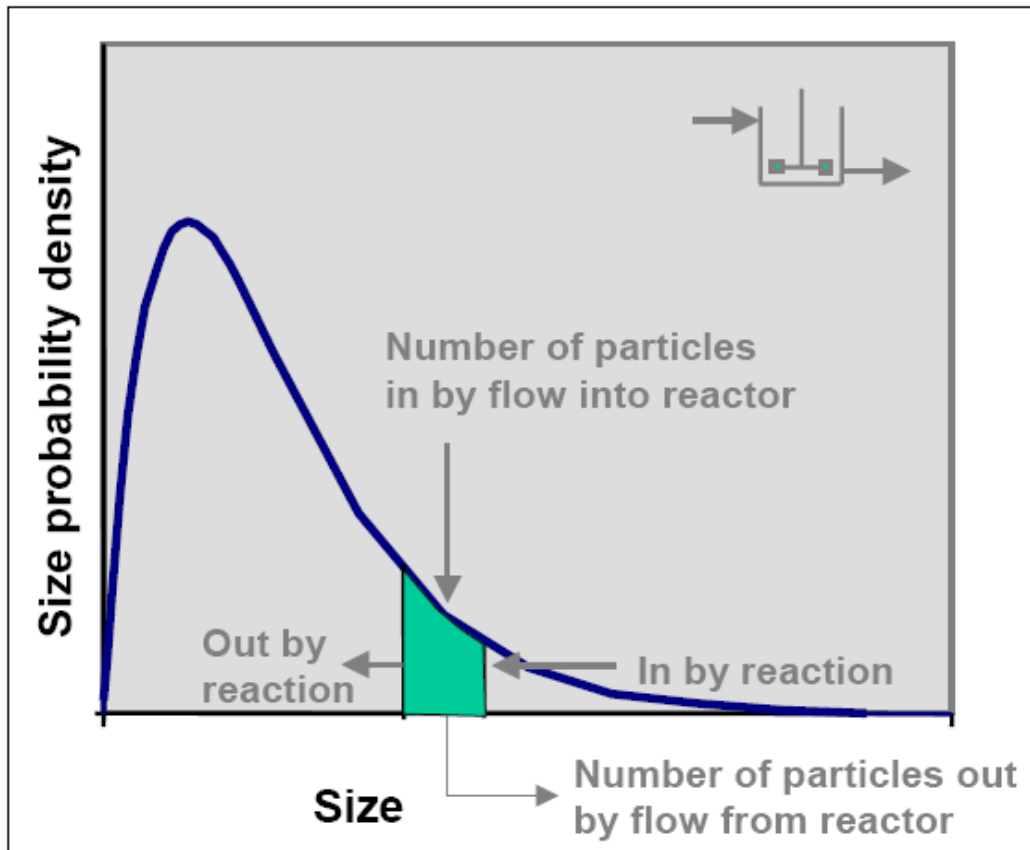


- Overall:



Attempting to apply the population balance methodology from batch data...

$$\left(\begin{array}{l} \text{Number of particles} \\ \text{into the reactor and} \\ \text{into the size class} \end{array} \right) = \left(\begin{array}{l} \text{Number of particles} \\ \text{out of reactor and} \\ \text{out of the size class} \end{array} \right) + \left(\begin{array}{l} \text{Net number of particles} \\ \text{out of size class due to} \\ \text{shrinkage by reaction} \end{array} \right)$$



$$n_{in}(\ell) = n_{out}(\ell) - \frac{d\left(r_s t n_{out}(\ell) \right)}{d\ell}$$

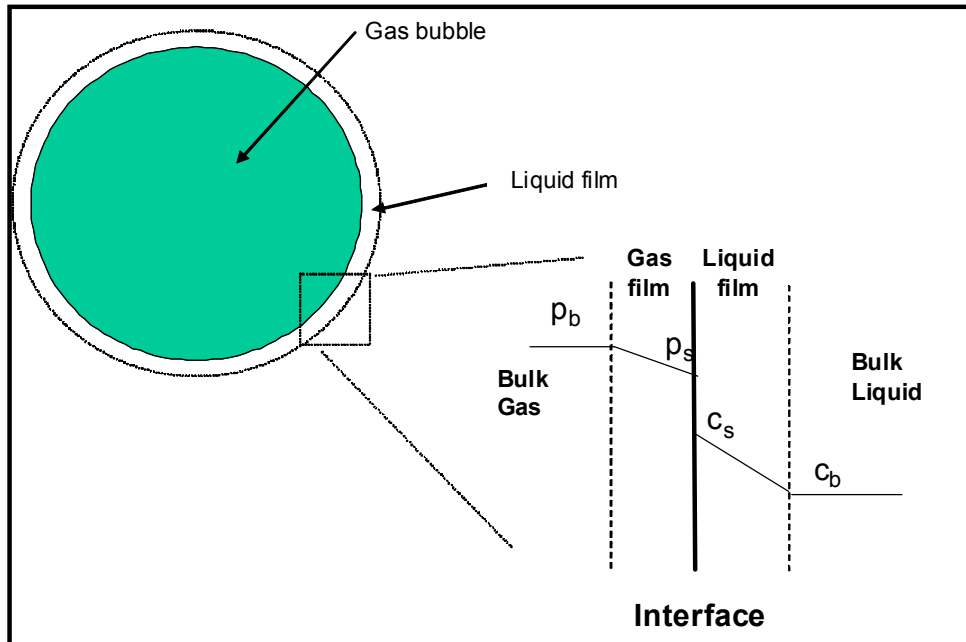
$$1 - (1 - X)^{1/3} = \frac{r_s t}{L}$$

NB!!!

$$k C_{O_2}^n \exp(-E_a/RT) = r_s$$

Gas - Liquid Mass Transfer

Mass Transfer



mass transfer coefficient (m/s)

specific surface area (m^2/m^3)

$$\text{rate} = k_L a (c_s - c_b)$$

The partial pressure in the gas phase and the concentration in solution at the surface are in equilibrium, described by Henry's law:

$$c_{\text{sat}} = \frac{p_s}{H}$$

Agitator Performance

$$P = N_p N^3 D^5 \rho$$

P = power applied to impeller (W)

N = impeller speed (1/s)

D = impeller diameter (m)

ρ = fluid density (kg/m^3)

N_p = impeller power number

$$k_L a = k \left(\frac{P}{V} \right)^\alpha u_s^\beta$$

$k = 0.002$

$\alpha = 0.7$

$\beta = 0.2$

Rushton N_p : 5.75

A315 N_p : 0.75

Oxygen Gas and Liquid Phase Heterogeneous Balance

- Liquid phase steady state oxygen balance:

$$QC_{O_2,o} = QC_{O_2,i} - k_L a(C_{O_2,s} - C_{O_2,i})V + r_{O_2}V$$

but

$$r_{O_2} = \frac{5}{2}r_s$$

- Gas phase steady state oxygen balance

$$\dot{n}_{O_2,o} = \dot{n}_{O_2,i} + k_L a(C_s - C_i)V$$

$$p_{O_2,o} = \frac{\dot{n}_{O_2,o} RT}{\dot{V}}$$

- Both of which need to be solved simultaneously together with the population balance
- 3 unknowns : r_s , $C_{O_2,o}$ and $p_{O_2,o}$

How can "normal" people do this in Excel?

- Population balance:

No. of Particle Balance:

$$IN_{flow} + IN_{rxn} = OUT_{flow} + OUT_{rxn}$$

$$n_1(l) = \frac{n_0(l) + n_1(l + \Delta l) \cdot rate \frac{\tau}{\Delta l}}{1 + rate \frac{\tau}{\Delta l}}$$

Converting back to mass population:

$$m_1(l) = n_1(l) \cdot l^3$$

Conversion:

$$X = 1 - \frac{\left(\int_0^{\infty} m_1 dl \right)}{\left(\int_0^{\infty} m_0 dl \right)}$$

Trapesoidal Rule:

$$Integral = \left(\frac{y_1 + y_2}{2} \right) \cdot \Delta l$$

- Simultaneous equations in Excel

```
Sub Button1 Click()
```

```
  a1 = False
```

```
  a2 = False
```

```
  While a1 = False Or a2 = False
```

```
    a1 = Worksheets("Summary").Range("D6").GoalSeek(0.00001, Worksheets("Summary").Range("B6"))
```

```
    a2 = Worksheets("Summary").Range("D7").GoalSeek(0.00001, Worksheets("Summary").Range("B7"))
```


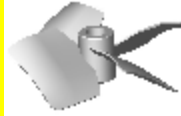
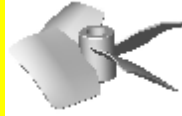

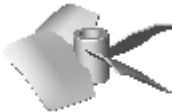
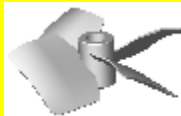
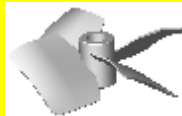

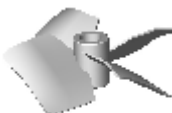
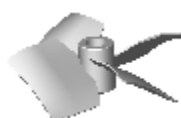

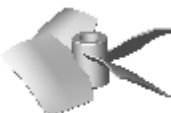
```
  Wend
```

Ok...so what happened?

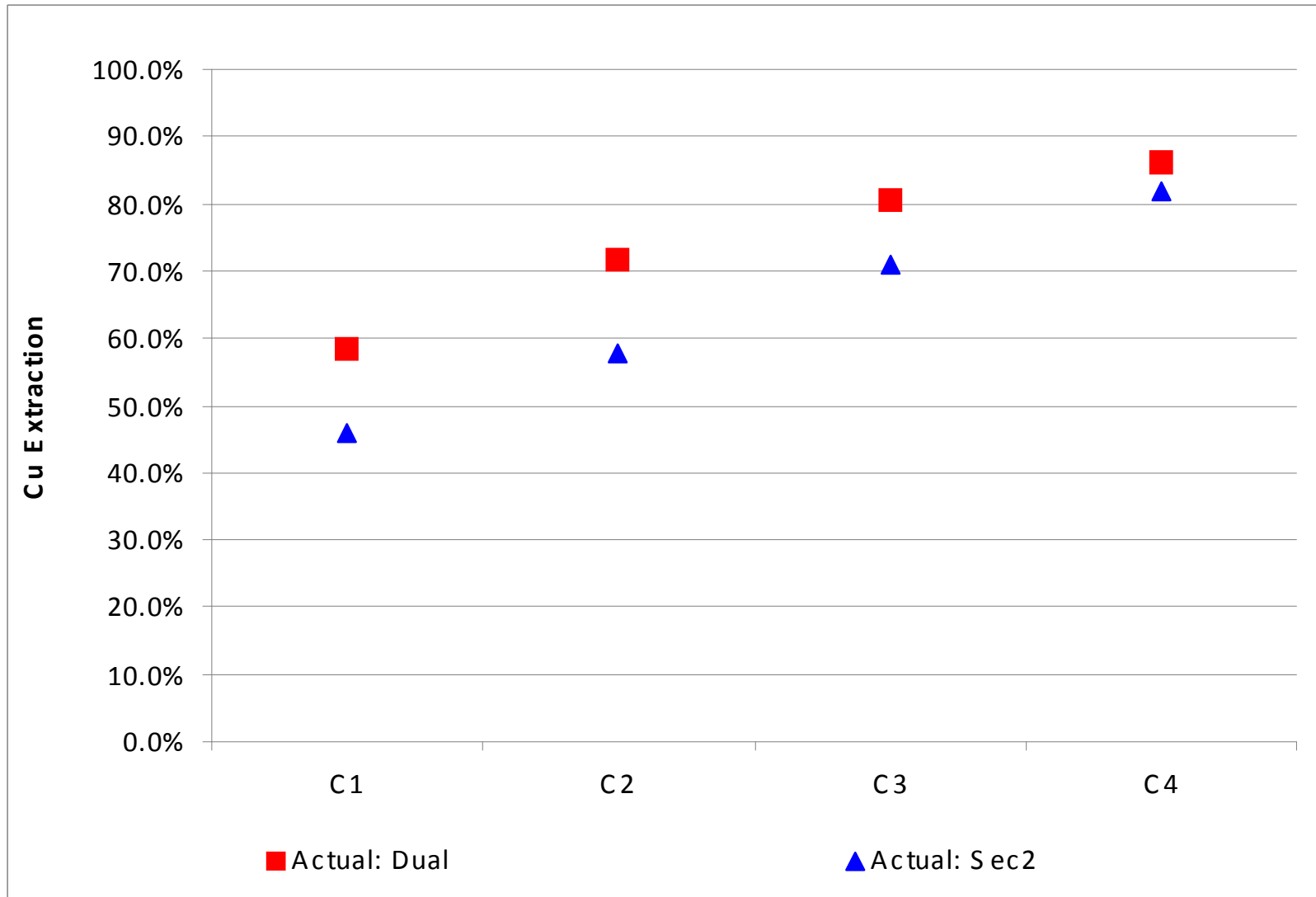


Plant trial

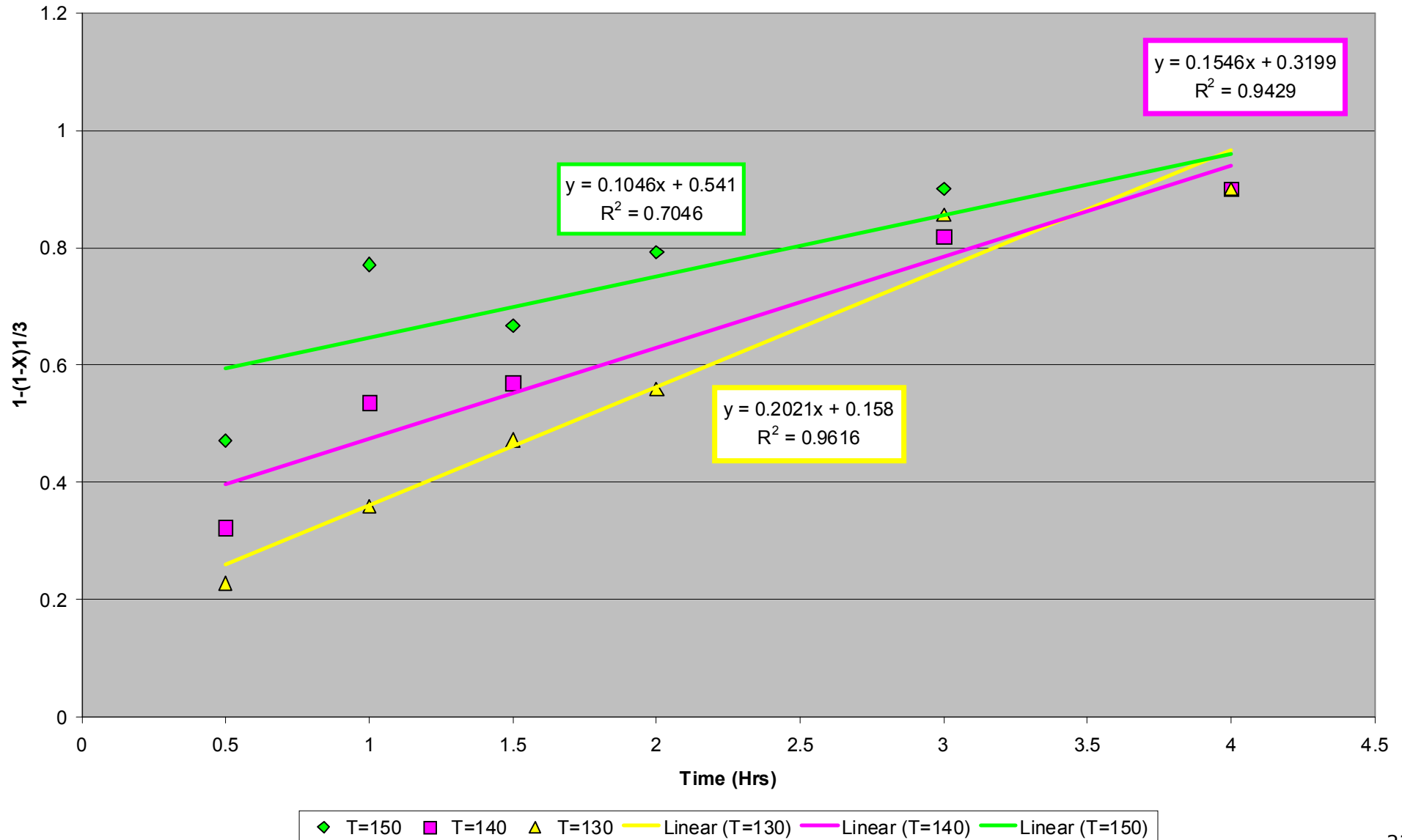
- After preliminary modelling a significant difference was noticed between the performance of an autoclave with Rushton versus A315 impellers particularly in the first compartment hence it was decided to validate Dual versus Sec 2

	Comp. 1	Comp. 2	Comp. 3	Comp. 4
Dual				
Secondary 2				
Secondary 3				

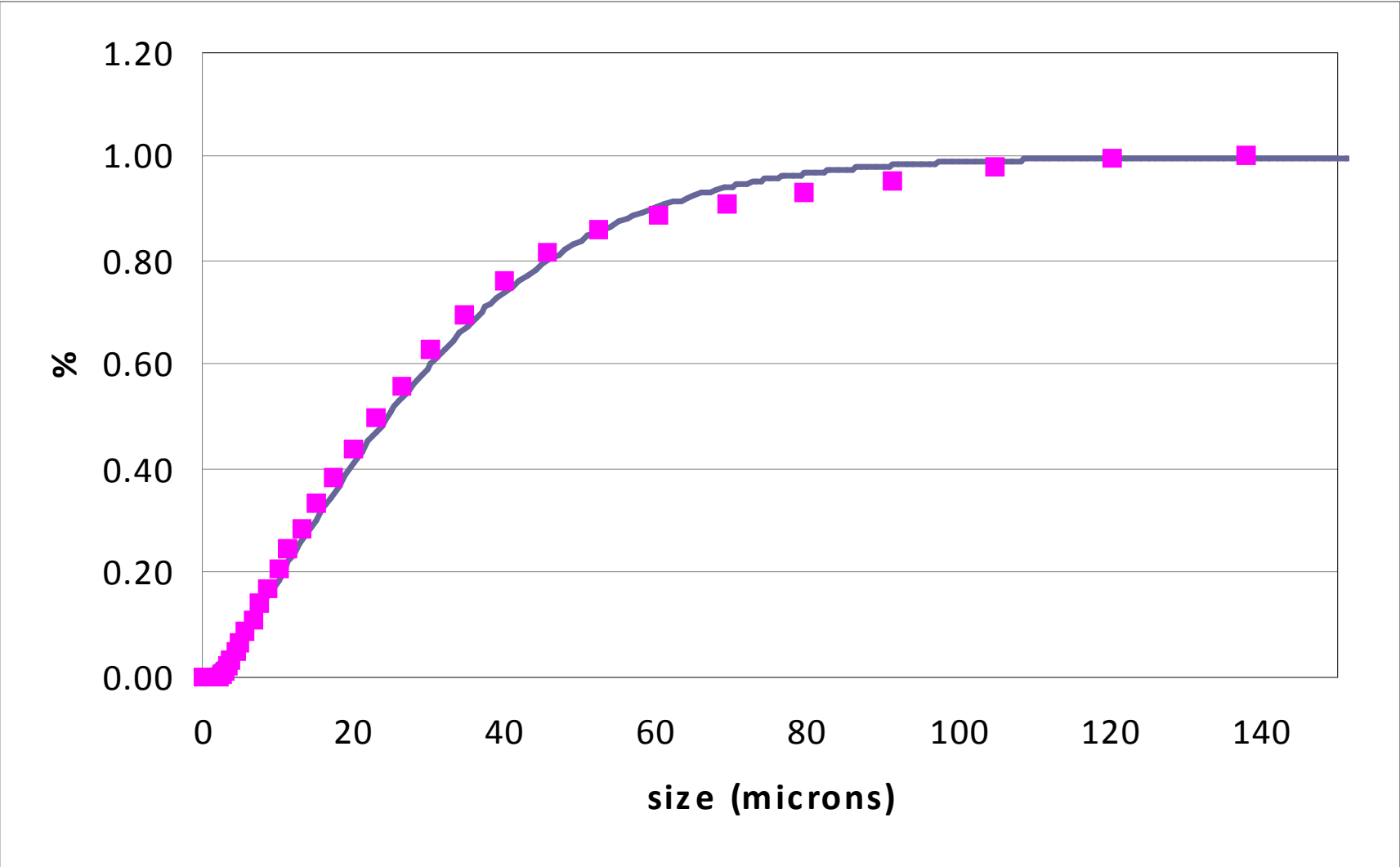
Plant trial results...



Batch Data

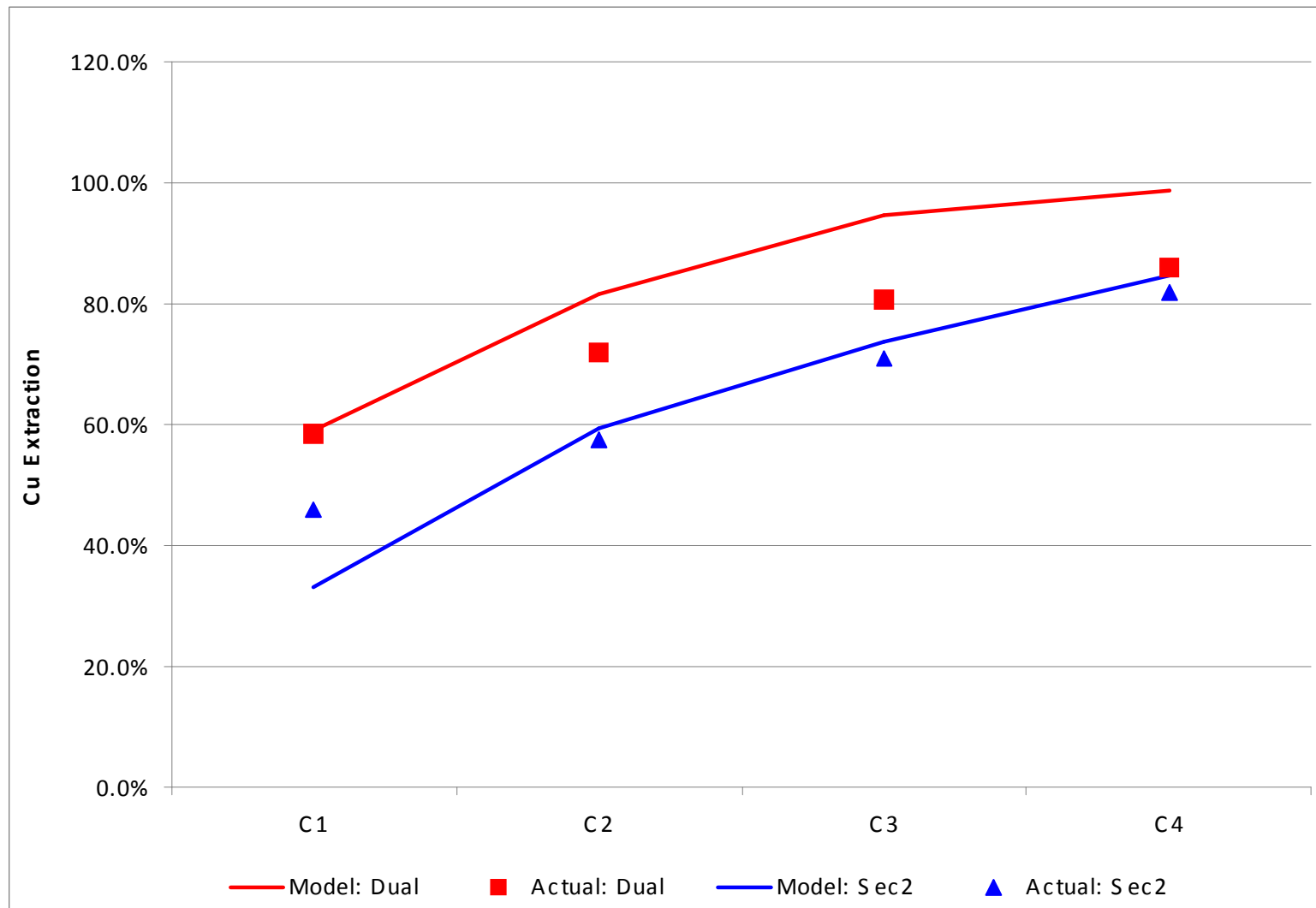


Rosin Rammler Bennett



Modelling results vs. plant campaign

- Feed rate equivalent to 19 ktpa Ni in 2 autoclaves



Did we over simplify the reaction mechanism?

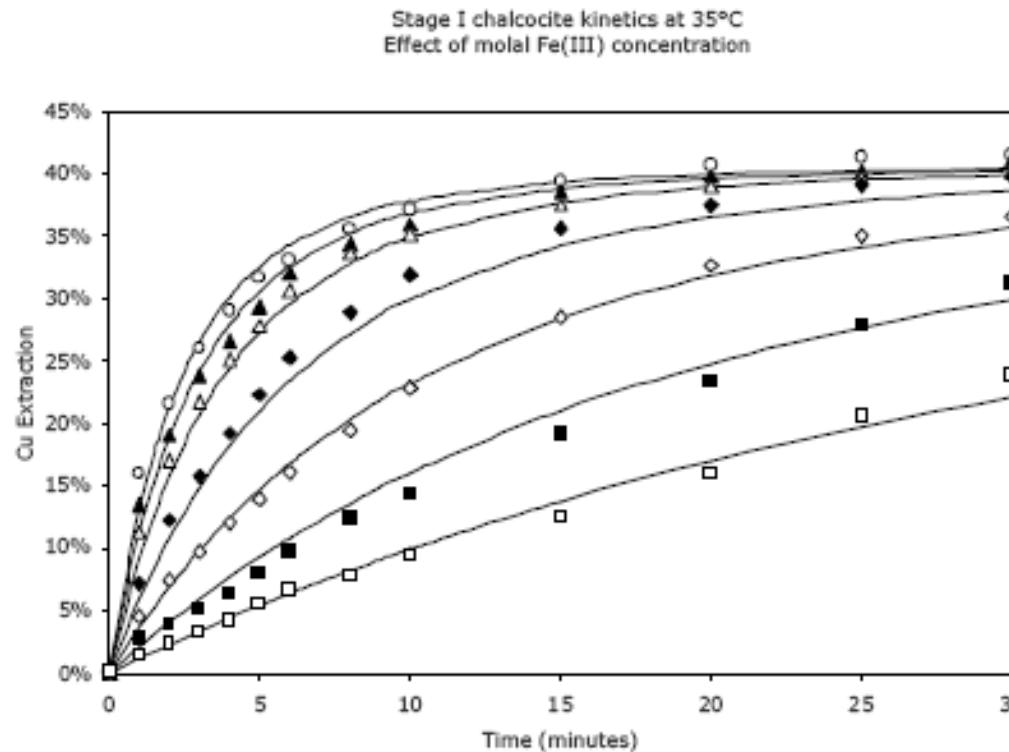


Figure 4 Hybrid model of the effect of ferric concentration on the kinetic chalcocite oxidation (Eq. 27 with $K = 0.125$ and $n = 0.5$)

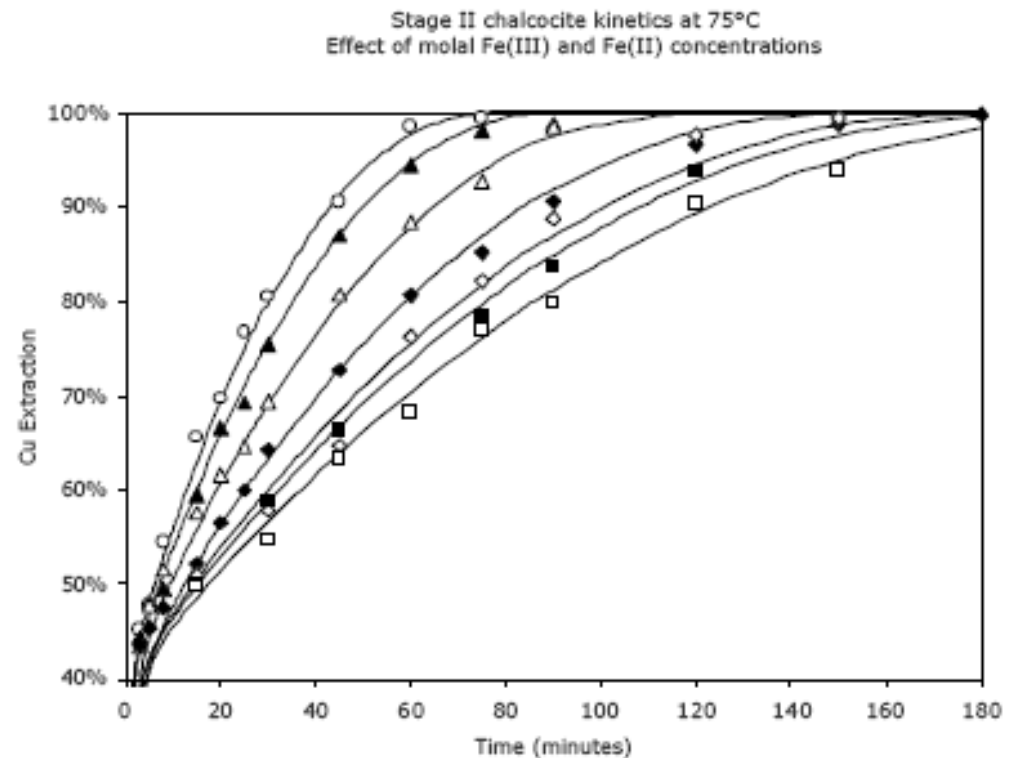
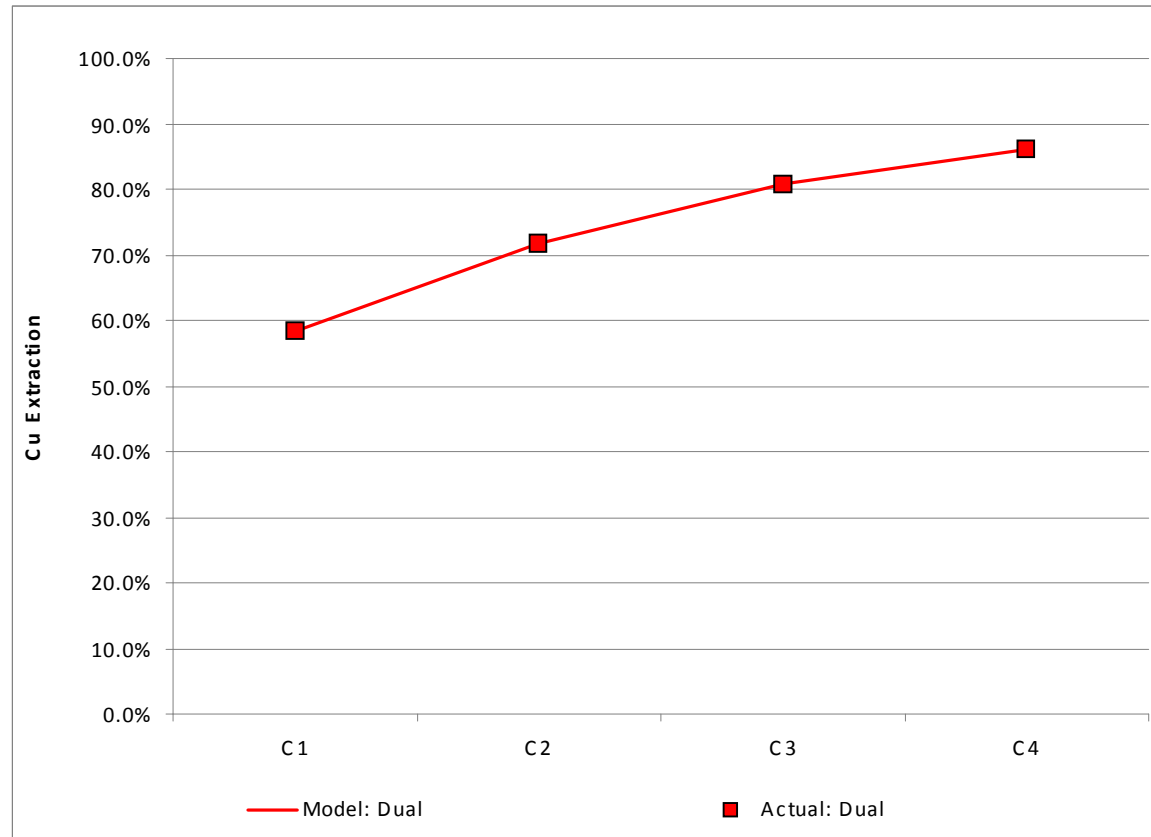


Figure 5 Hybrid model of the effect of ferric and ferrous concentrations on stage II chalcocite oxidation (Eq. 28 with $K = 0.00496$ and $n = 0.375$)

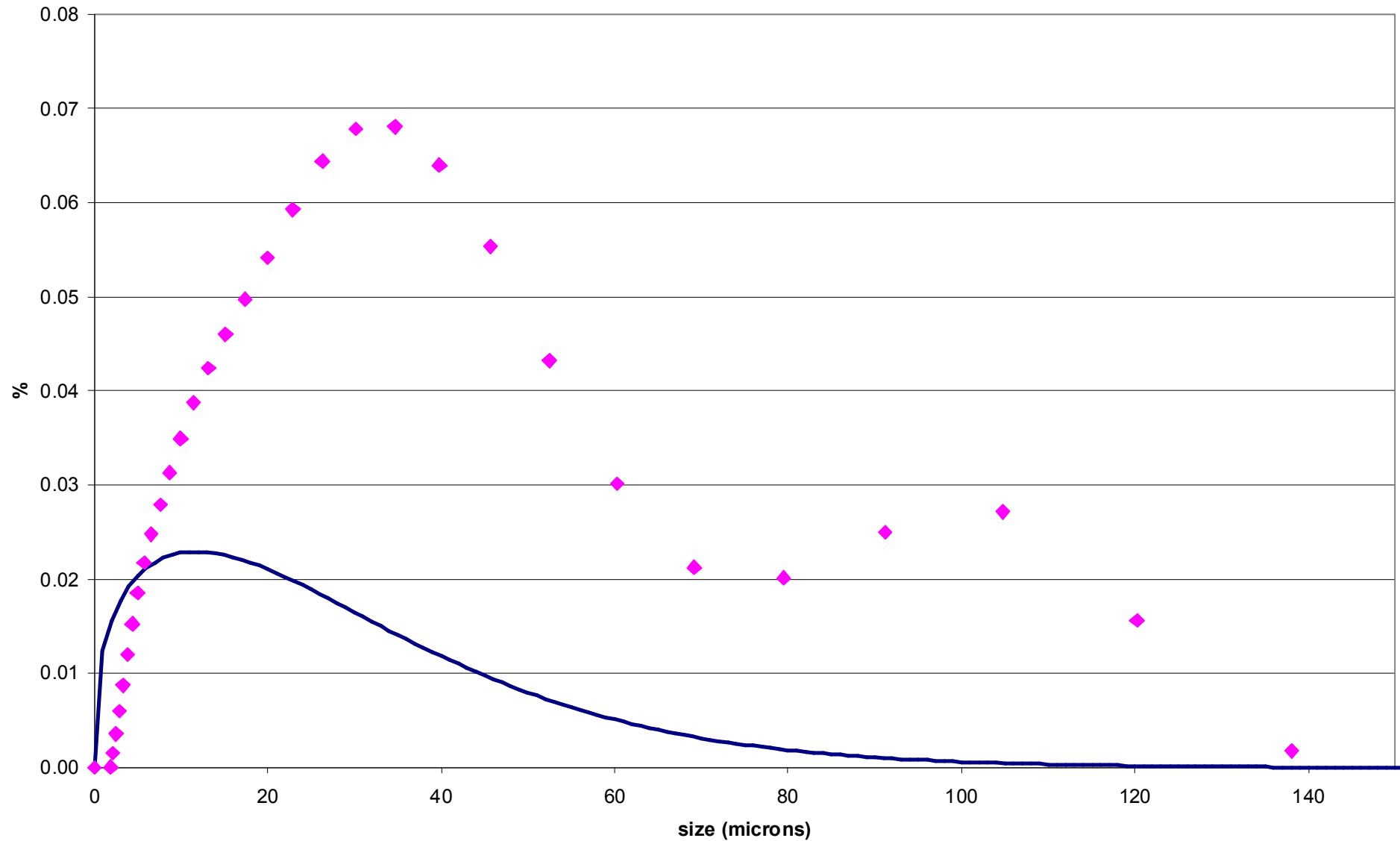
Ref: Dixon and Dreisinger

Fit sequential rates for Cu_2S and CuS to plant data?

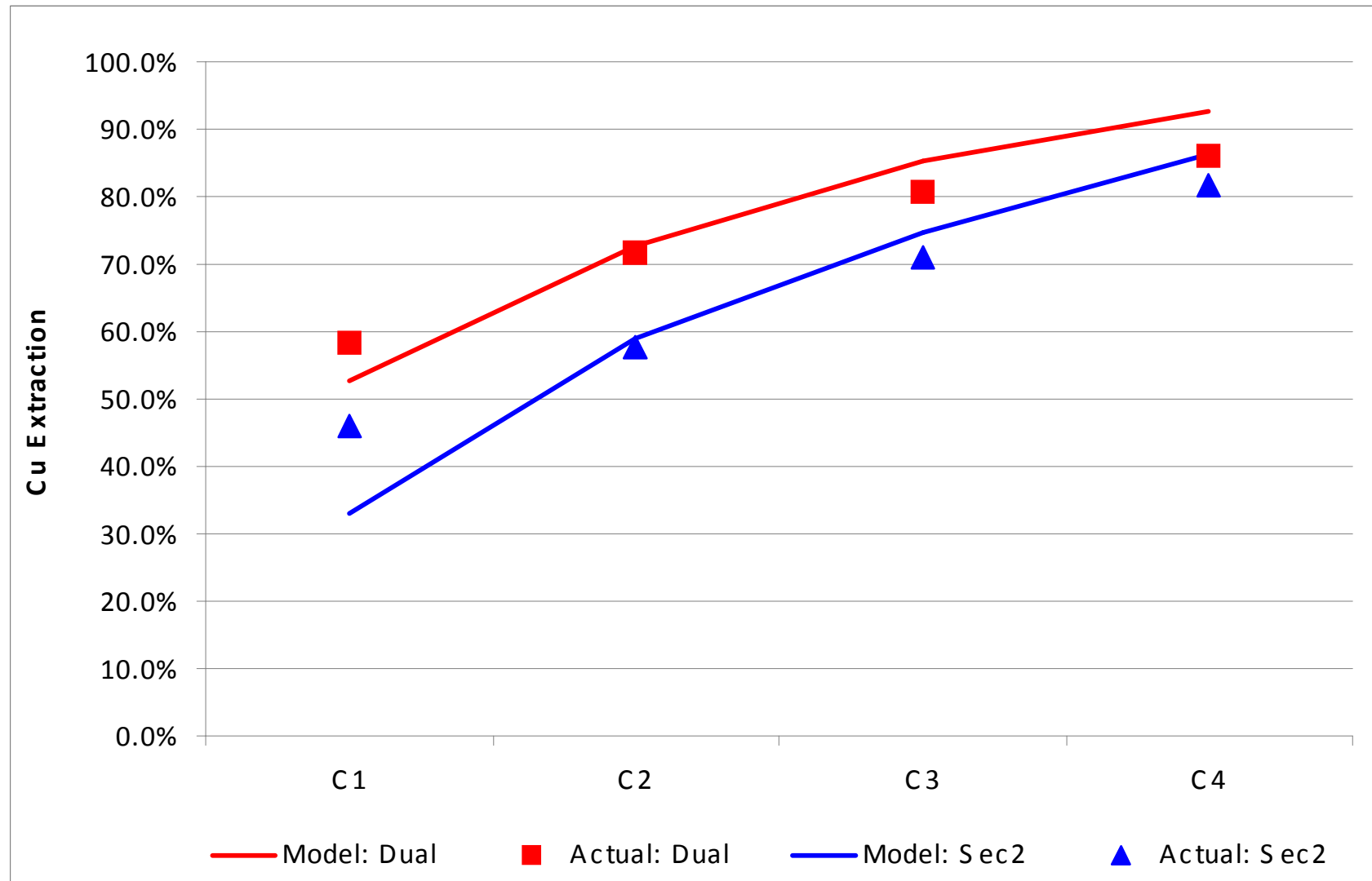


- But how does this account for work done by Hofirek and Nofal 1994?

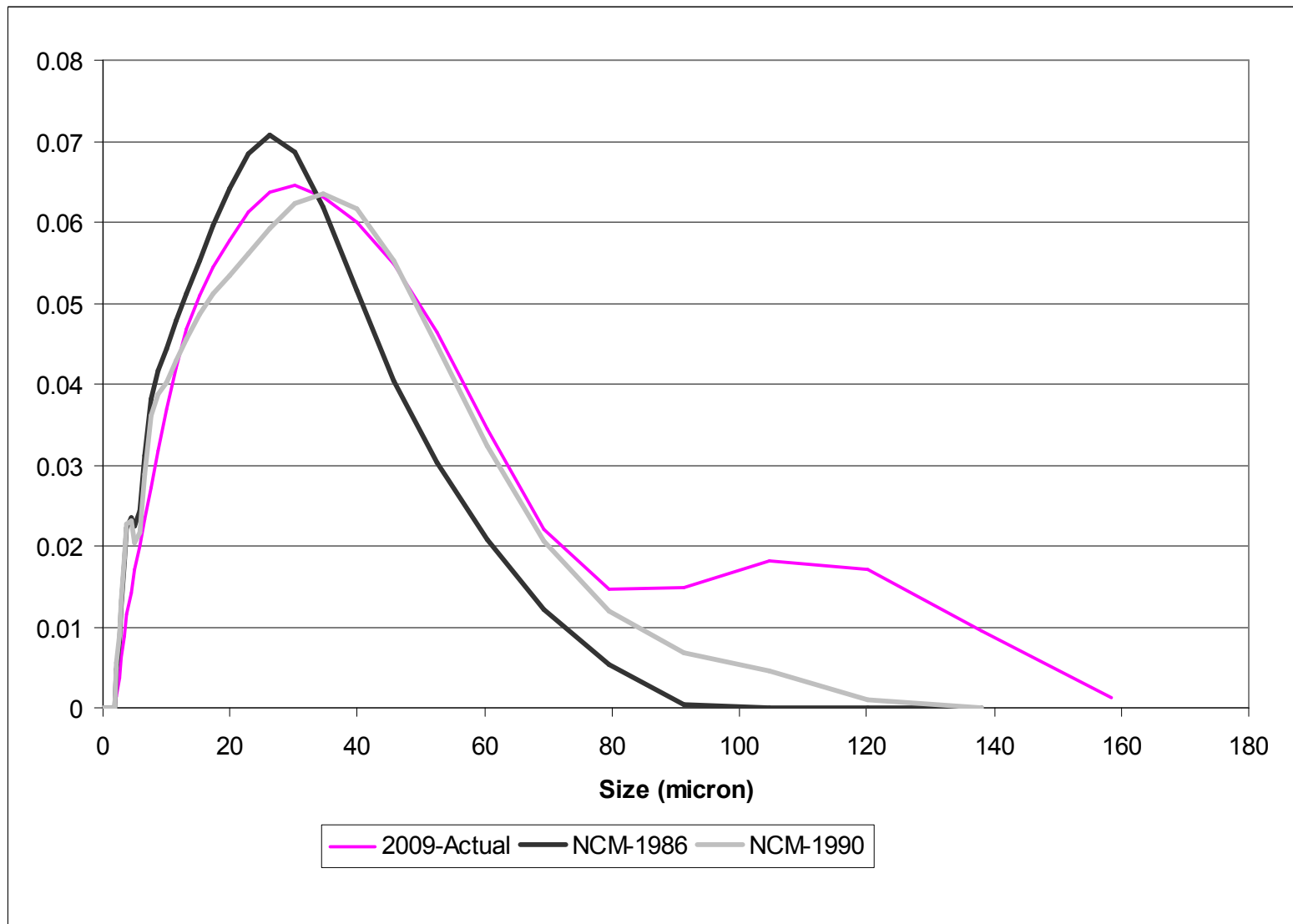
PSD: RRB vs. Actual




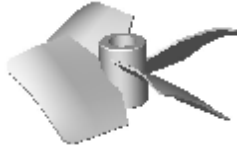
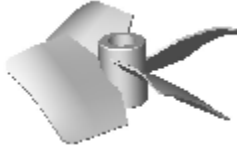

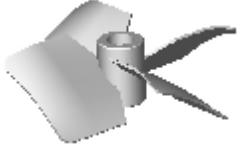
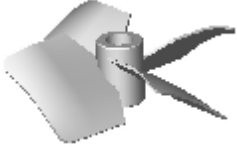
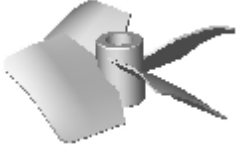

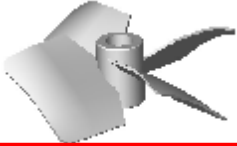


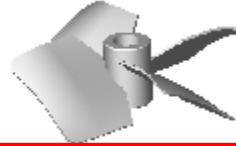




Using actual PSD in population balance



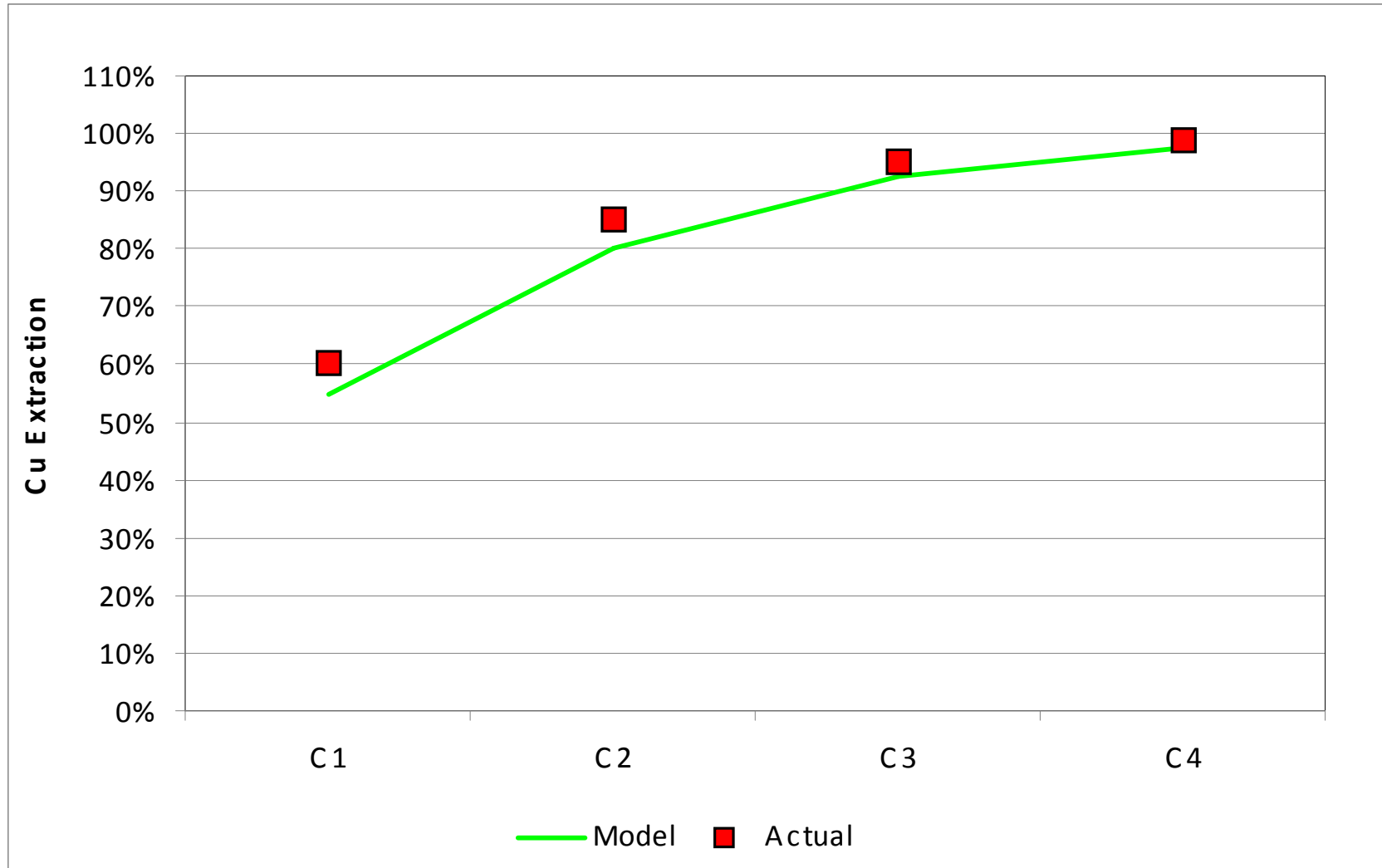
Pre-1994 PSD



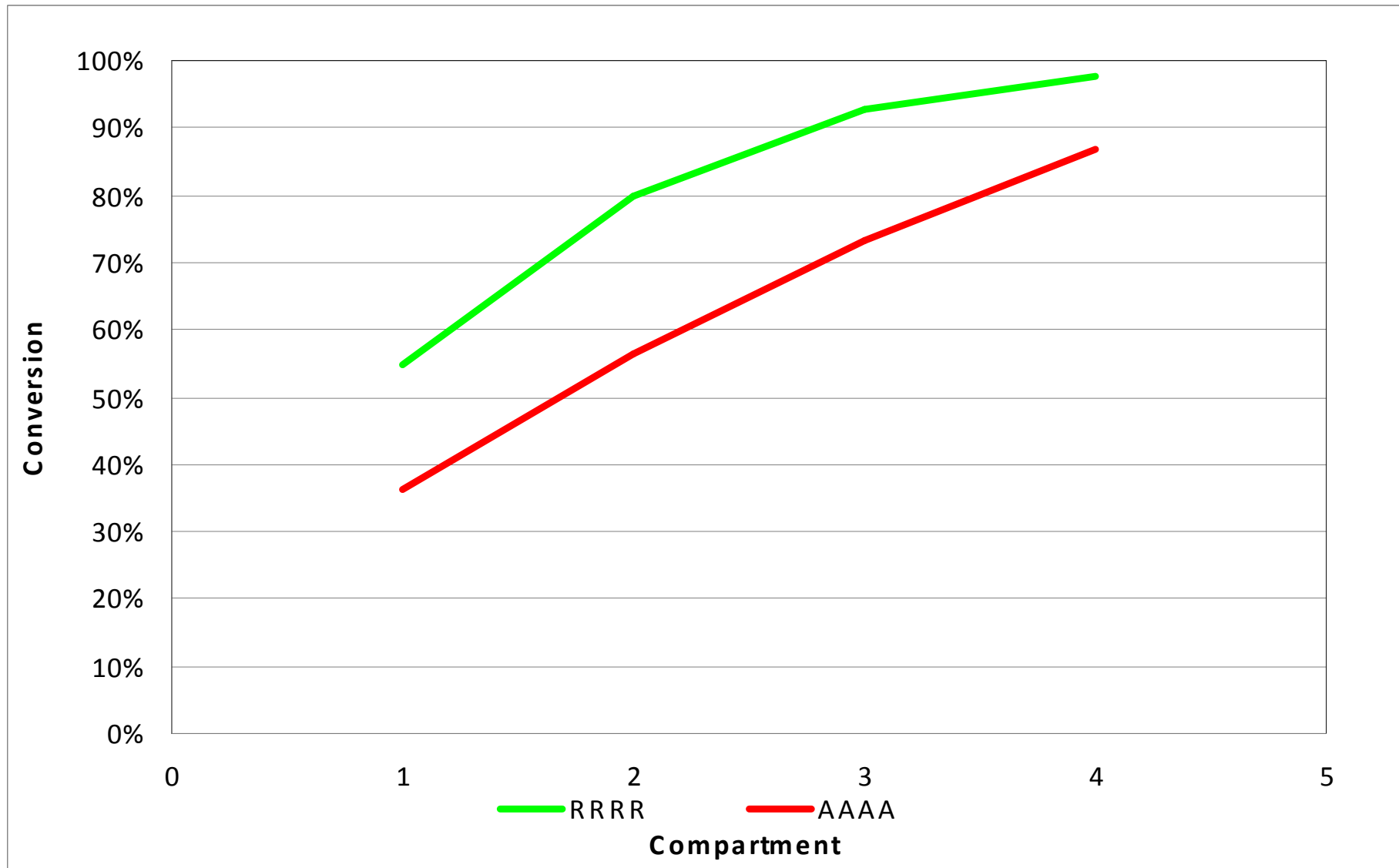
Agitator Configuration: 1994

	Comp. 1	Comp. 2	Comp. 3	Comp. 4
Secondary 1				
Secondary 2				
Secondary 3				
Original				

Hofirek and Nofal 1994 vs. Model



Hofirek and Nofal 1994 vs. Model: Effect of Agitator type



Outcomes

- Rushton turbines appear to perform better when high gas to liquid mass transfer rates are required under highly gassed conditions – a program has been initiated to return to Rushton turbines in the first two compartments of our secondary leach autoclaves
- PSD can have a significant effect on leach performance – commissioning of a new matte milling section (end 2009) will be monitored with interest especially with respect to our secondary leach performance
- Building “a priori” type models, using a hands on approach, in an operational context is a superior medium for knowledge transfer

The Team

