

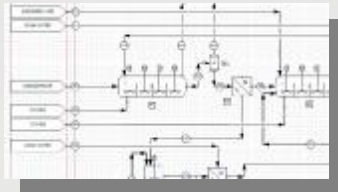


Design and simulation of metallurgical operations

Frank Crundwell
CM Solutions (Pty) Ltd

Simulation software for the metallurgical industry

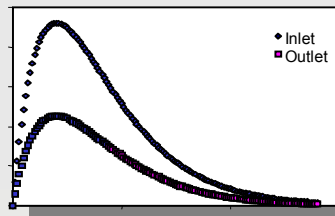
This talk is divided into four topics:



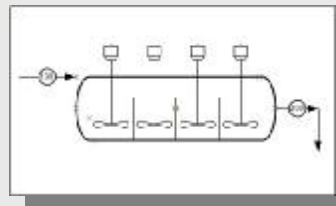
Drawing Environment and Outputs



Mass and Energy Balances

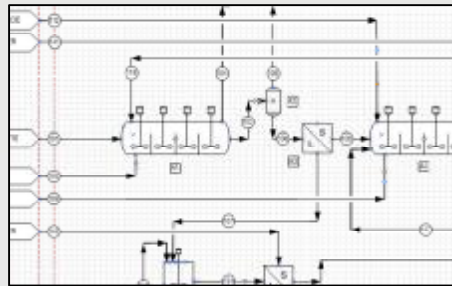


**Particle Size Distributions
and Population Balances**

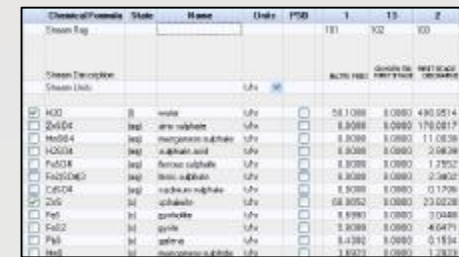


Dynamic Simulation

Cycad Process combines process simulation with sophisticated drawing capabilities to produce detailed reports

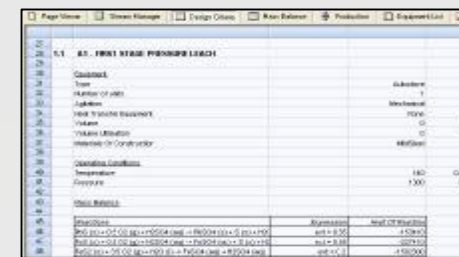


Engineering-quality Drawing



Stream ID	Stream Name	Units	PSD	1	10	2
Stream 101				101	102	103
Stream Description:						
Stream Unit: LAu						
<input type="checkbox"/>	H2O	kg	water	0.1	0.0001	4.902514
<input type="checkbox"/>	ZnSO4	kg	zinc sulphate	0.0001	0.0001	179.0417
<input type="checkbox"/>	H2SO4	kg	hydrogen sulphate	0.0001	0.0001	11.0838
<input type="checkbox"/>	H2O2	kg	hydrogen peroxide	0.0001	0.0001	2.0428
<input type="checkbox"/>	H2SO3	kg	hydrogen sulphite	0.0001	0.0001	1.7952
<input type="checkbox"/>	H2SO4	kg	hydrogen sulphate	0.0001	0.0001	2.2822
<input type="checkbox"/>	ZnSO4	kg	zinc sulphate	0.0001	0.0001	2.1798
<input type="checkbox"/>	ZnO	kg	zinc oxide	0.0001	0.0001	23.0228
<input type="checkbox"/>	H2O	kg	water	0.0001	0.0001	2.0488
<input type="checkbox"/>	H2O	kg	water	0.0001	0.0001	4.6471
<input type="checkbox"/>	H2O	kg	water	0.0001	0.0001	0.1834
<input type="checkbox"/>	H2O	kg	water	0.0001	0.0001	1.7924

Process Simulator



Page View	Stream Manager	Design Criteria	Area Balance	Production	Equipment List
S1 AS - FIRST STAGE PIONEER LEACH					
1	Quantity				
2	Unit				Substance
3	Number of units				1
4	Location				Mechanical
5	Unit Transfer Equipment				None
6	Volume				0
7	Volume Reduction				0
8	Interface of Controller				None
9	Operational Conditions				
10	Temperature			140	Cou
11	Pressure			1.00	04
12	Other Details				
13	Equation				Unit of Equation
14	$H_2O = 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg}$				kg = 500
15	$H_2O = 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg}$				kg = 500
16	$H_2O = 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg}$				kg = 500
17	$H_2O = 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg} + 100.00 \text{ kg}$				kg = 500

Detailed Reporting

Cycad Process' drawing interface follows familiar standards for graphical user interfaces

The screenshot displays the Cycad Process software interface for a drawing titled "Pressure Leach REV E 7 November 2008 a.cycad". The interface includes a menu bar (File, Edit, View, Edge, Format, Tools, Settings, Mass Balance, Help), a toolbar, and a main drawing area with a grid. On the left, there is a "Process Library" pane with various equipment icons. On the right, a "Properties" pane is open for the selected equipment, "Autoclave1_2 (Autoclave)".

The main drawing area shows a process flow diagram with various pieces of equipment and streams. The equipment includes a reactor (R1), a separator (S1), a condenser (C1), and a dryer (D1). Streams are labeled with numbers (1-10) and names like "VENT", "TAILING", "SULPH", and "IRON REMOVAL". A scale bar at the bottom indicates a length of 108.7207%.

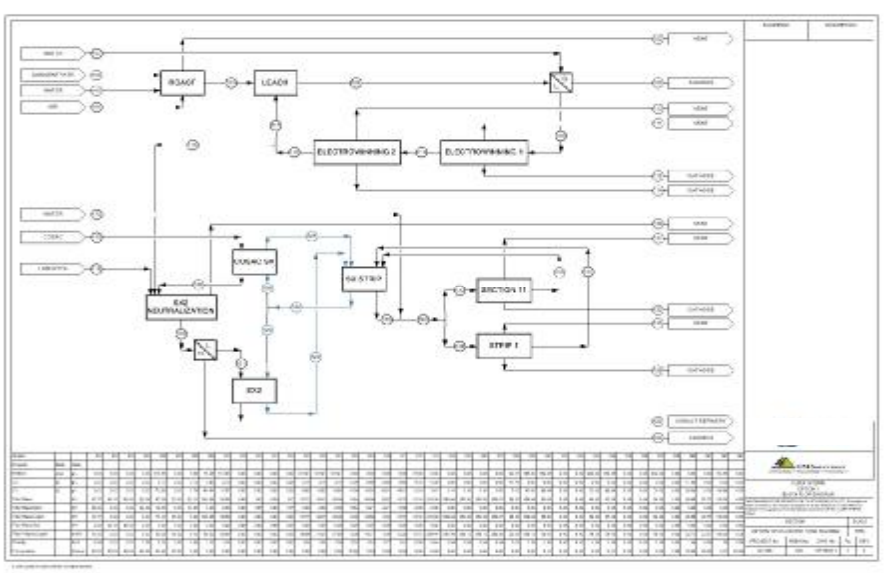
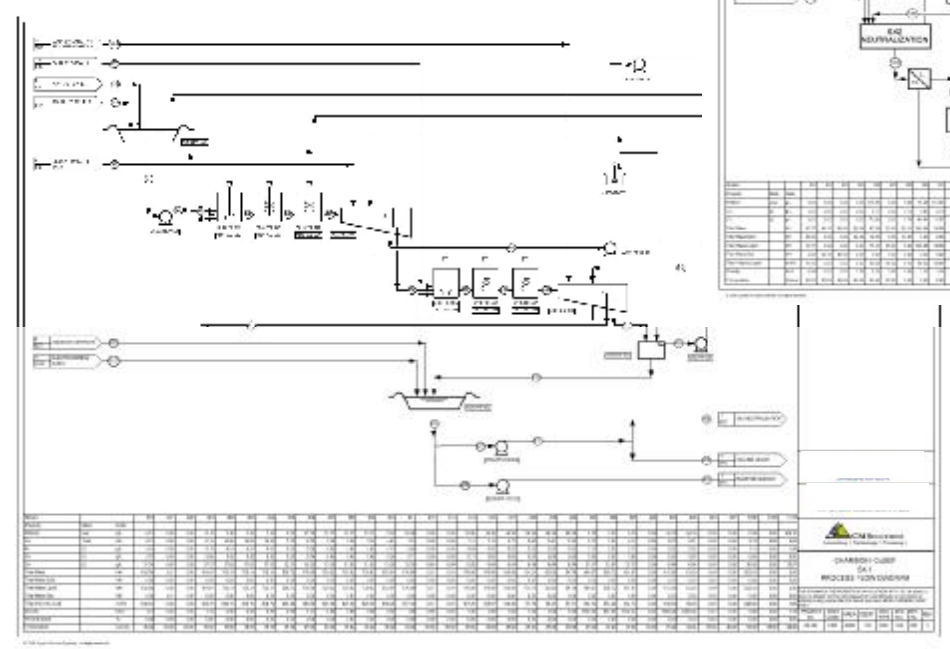
The "Properties" pane for "Autoclave1_2 (Autoclave)" contains the following information:

Category	Property	Value
Appearance	DrawAsBlock	False
	Opacity	1
	PinPoint	
	Size	3.697633 cm, 1.1136
	Style	
Calculation	DesignMode	Design
	EvaporationRate	0.0 t/hr
Energy Balance	Reactions	Reactions
	EnergyBalance	Isothermal
	HeatLoss	0.0 MW
	HeatTransfer	Heat Transfer Inform
Equipment	HeatTransferDuty	10.249 MW
	ShaftWork	0.0 MW
	AgitationEquipment	Mechanical
CompartmentWalls		True
NumberOfAgitators		4

Below the "Properties" pane is an "Overview" pane showing a small thumbnail of the drawing. At the bottom of the window, the status bar displays: "Ready", "Rect: (6.22 in, 1.92 in, 7.68 in, 2.58 in)", "Size: (1.46 in x .66 in)", and "Por: (31.54 cm, 10.63 cm)".

Cycad Process produces engineering-quality Block Flow Diagrams and Process Flow Diagrams

Block Flow Diagrams



Process Flow Diagrams

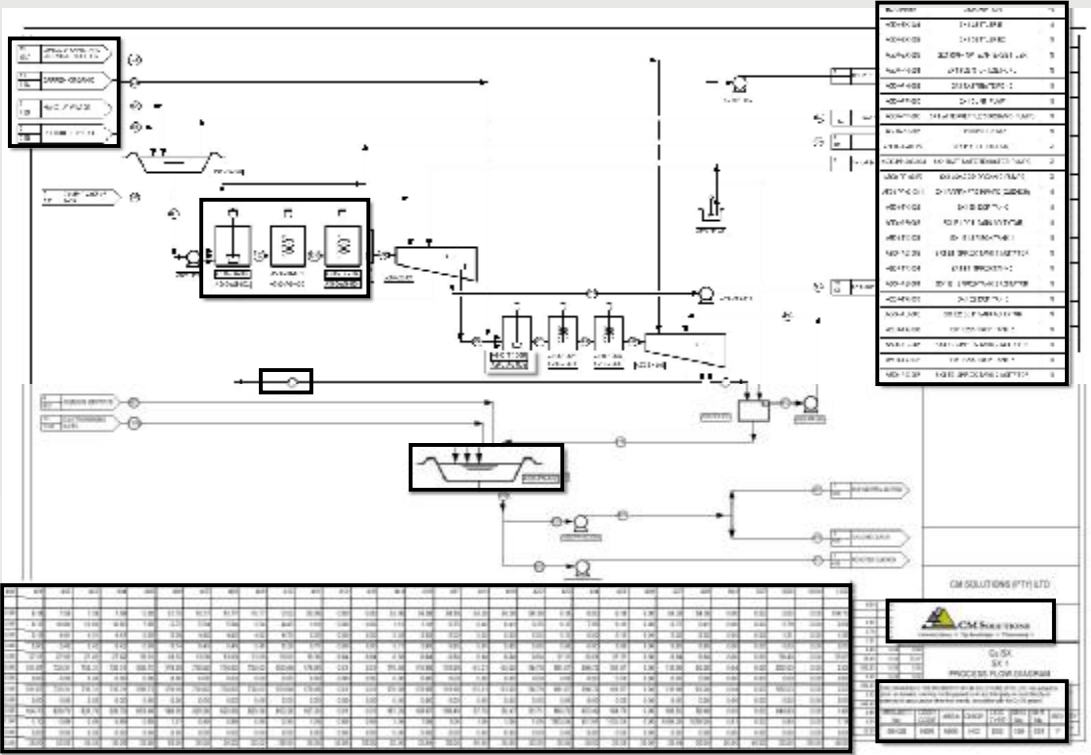
The main features of the Process Flow Diagrams drawn using Cycad Process are shown

Intelligent
Flags

Detailed
Equipment
Options

Flexible
Stream
Tags

Mass balance
Table



Equipment
List

Equipment
Tags,
Including
Agitators

Company
Logo

Drawing
Details



Cycad Process produces four standard reports for each flow sheet

Page Viewer | Stream Manager | Design Criteria | Mass Balance | Production | Equipment List | Dashboard

1.1 A1 FIRST STAGE PRESSURE LEACH

Equipment

Type

Number of units

Appln

Heat Transfer Equipment

Volume

Volume Utilization

Miscellaneous Construction

Operating Conditions

Temperature

Pressure

Mass Balance

Reaction

$PbS (s) + 0.5 O_2 (g) + H_2SO_4$
 $PbS (s) + 0.5 O_2 (g) + H_2SO_4$
 $PbS_2 (s) + 3.5 O_2 (g) + HCl (l)$
 $2 FeSO_4 (aq) + 0.5 O_2 (g) + H_2$
 $0.5 FeSO_4 (s) + 1.5 Fe_2SO_4 (s)$
 $3 Fe_2SO_4 (s)_{(aq)} + 12 H_2O (l)$
 $ZnS (s) + 0.5 O_2 (g) + H_2SO_4$
 $MnS (s) + 0.5 O_2 (g) + H_2SO_4$
 $CuS (s) + 0.5 O_2 (g) + H_2SO_4$

The conversion of reaction 1 F

The conversion of reaction 2 F

Flow to Stream 102 is adjusted

Appln Settings

Design Criteria Report

Reagent and Production Report

Page Viewer | Stream Manager | Design Criteria | Mass Balance | Production | Equipment List | Dashboard

REAGENT AND UTILITY REQUIREMENTS

NUMBER	DESCRIPTION	AMOUNT	UNIT
1	CALCIUM HYDROXIDE		
2	SLURRY		
3	TOTAL CALCIUM HYDROXIDE		
4	CONCENTRATE		
5	WASTE FEED		
6	TOTAL CONCENTRATE		
7	OXYGEN		
8	OXYGEN TO FIRST ST		
9	OXYGEN TO SECOND		
10	TOTAL OXYGEN		
11	SULPHURIC ACID		
12	SULPHURIC ACID MA		
13	ACID MAKEUP TO GR		
14	TOTAL SULPHURIC ACID		
15	WASH WATER		
16	WASH WATER TO L		
17	WASH WATER TO R		
18	TOTAL WASH WATER		
19	WASTE		
20	LIQUEUR WASTE FL		
21	TOTAL WASTE		
22	ZINC DUST		
23	ZINC DUST		
24	TOTAL ZINC DUST		

PROJECT:

Unit

Process Engineer:

Tag	Description
A1	FIRST STAGE PRESS
A2	FIRST STAGE FLASH
A3	FIRST STAGE SL
A4	SECOND STAGE PRE
A5	SECOND STAGE FLA
A6	TAILING SL
A7	IRON REMOVAL
A8	SULPHUR FLOTATION
A9	IRON REMOVAL SL
A10	BZE PRECIPITATION
A11	BZE SIL SEPARATION
A12	CADMIUM REMOVAL
A13	CHILLER
A14	MANGANESE REMOVAL
A15	ZINC ELECTROWINN
A16	SPENT ELECTROLYT
A18	SPENT HEXACHROM

Equipment List

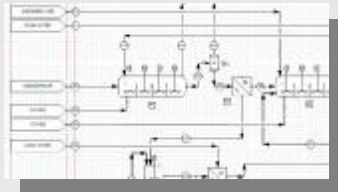
Mass Balance Report

Page Viewer | Stream Manager | Design Criteria | Mass Balance | Production | Equipment List | Dashboard

1.1 PRESSURE LEACH OPTION

Streams Number	991	992	103	104	995	996	107
Streams Description	MAINT FEED	OXYGEN TO FIRST STAGE	FIRST STAGE WASH WATER	FIRST STAGE WASTE	FIRST STAGE WASH WATER	FIRST STAGE WASTE	FIRST STAGE WASH WATER
Property	Unit						
Total Mass	kg	141.380	13.917	768.794	3.774	37.317	735.907
Total Mass Solid	kg	93.240	0.000	75.088	0.000	0.000	75.088
Total Mass Liquid	kg	50.100	0.000	693.196	0.000	0.000	600.854
Total Mass Gas	kg	1.000	13.917	0.000	3.774	37.317	0.000
Temperature	°C	35.000	35.000	140.000	140.000	108.000	100.000
Pressure	kg/cm ²	1.000	2000.000	1.000.000	1.000.000	1.000.000	1.000.000
Total Volume	m ³	68.736	888.648	603.800	438.729	6489.640	601.296
Total Volume Input	m ³	67.310	0.000	689.000	0.000	0.000	600.647
Density	kg/m ³	2.440	0.027	1.272	0.809	0.001	1.335
Gold	kg	65.048	0.000	9.775	0.000	0.000	10.304
Entropy	kJ/K	258.024	0.000	-207.279	-2.897	118.235	-247.944
Component Flowrate	kg	Component Name	Unit				
Zn	kg	zincblende	kg	68.065	0.000	23.623	0.000
H2O	kg	water	kg	50.100	0.000	496.951	0.000
Component Composition	kg	Component Name	Unit				
H2SO4	kg	sulphuric acid	kg	3.000	0.000	5.066	0.000
Element Composition	kg	Unit					
Mn	kg		kg	2.561	0.000	1.087	0.000
Fe	kg		kg	3.934	0.000	14.179	0.000
Zn	kg		kg	48.918	0.000	21.284	0.000
Element Composition	kg	Unit					
Mn	kg		kg	3.000	0.000	6.843	0.000
Fe	kg		kg	3.000	0.000	2.320	0.000
Cu	kg		kg	3.000	0.000	0.000	0.000
Zn	kg		kg	3.000	0.000	123.214	0.000
Cd	kg		kg	3.000	0.000	0.166	0.000

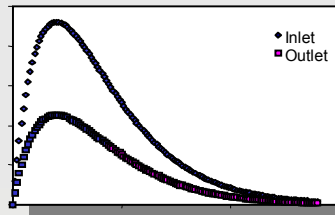
The second topic of this presentation concerns the calculation of the mass and energy balance



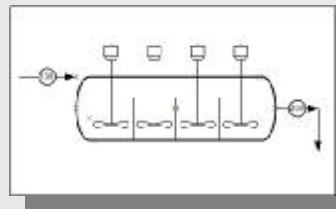
Drawing Environment and Outputs



Mass and Energy Balances

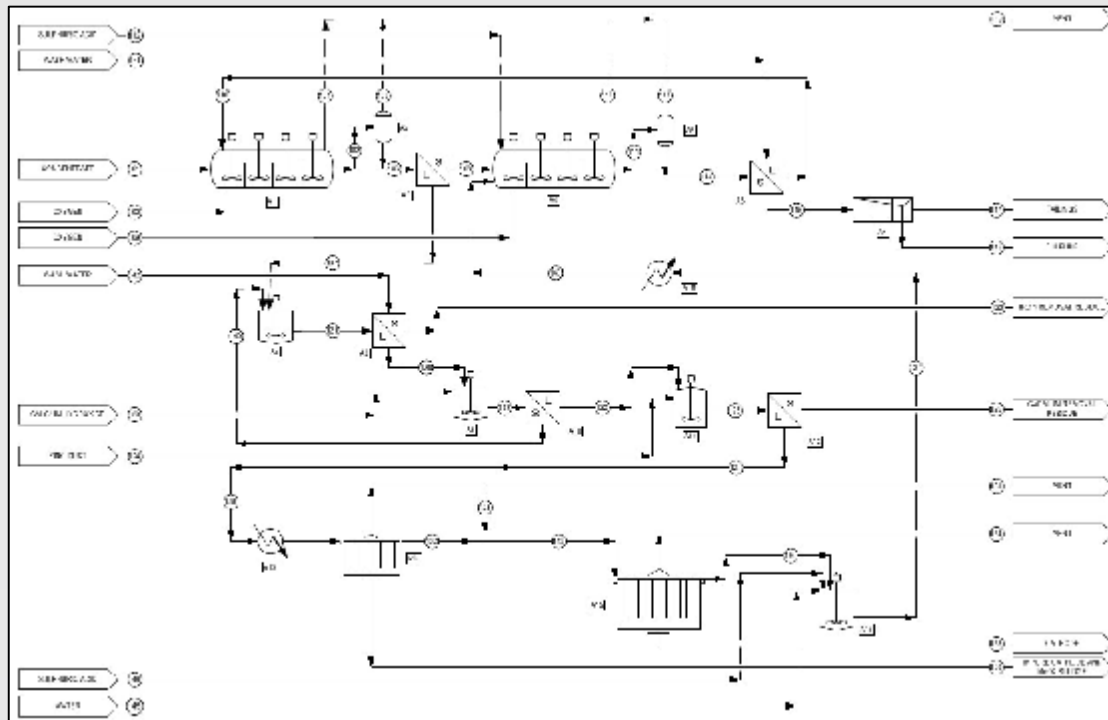


**Particle Size Distributions
and Population Balances**



Dynamic Simulation

The calculation of mass and energy balances is based on well-known methods

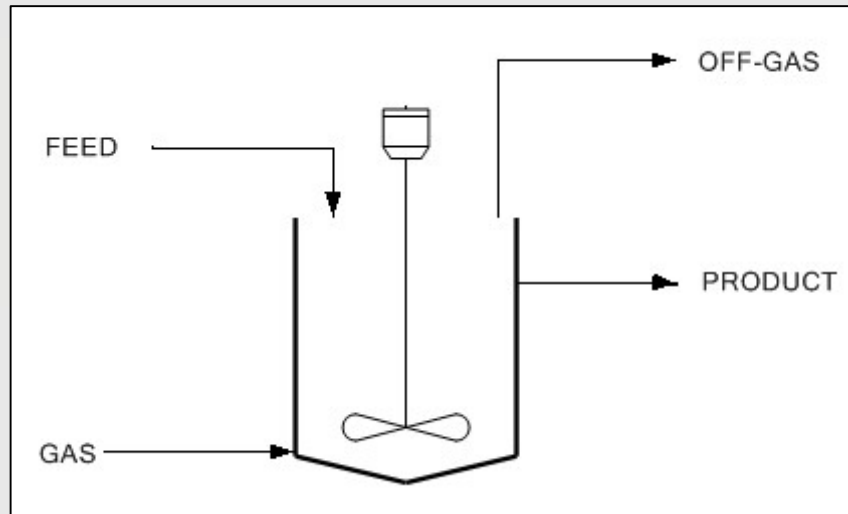


Cycad automatically determines recycle set

Cycad optimizes the order of calculation of the units

No need for user to order unit operations, to number units, or to specify recycle streams

Each unit has a hierarchy of rules that describe its calculation



Example 1:

All gases will be vented if there is a vent stream.

Example 2:

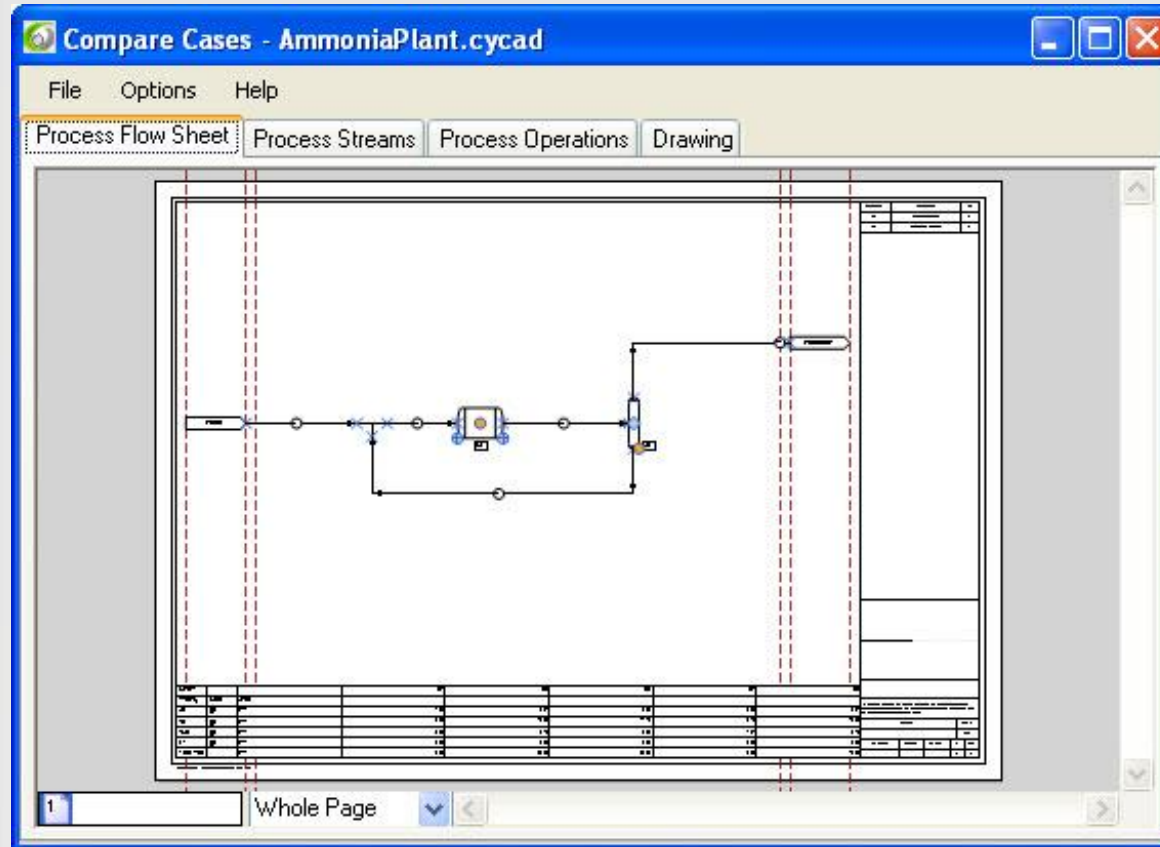
Vent will be saturated in water vapour if there is water in the product stream.

The energy balance is integrated within the specifications for each unit operation

The screenshot displays a process simulation software interface. The main window shows a process flow diagram with several units and streams. The units include a large stirred reactor (A7), a vertical vessel (A2), and two heat exchangers (A3 and A8). Streams are labeled with numbers like 103, 104, 105, 106, 107, 108, 118, 120, 130, and 140. The interface has a menu bar with options like 'Design Criteria', 'Mass Balance', 'Production', and 'Equipment List'. A toolbar is visible above the diagram. On the right side, there is a 'Properties' panel for the selected unit 'Autoclave1_1 (Autoclave)'. The 'Energy Balance' section is expanded, showing a dropdown menu with 'Isothermal' selected. Other parameters like 'HeatLoss', 'HeatTransfer', 'Approach', 'Area', 'ExitTemperature', 'Fluid', 'HeatTransferCoefficient', 'HeatTransferConfiguration', 'HeatTransferEquipment', 'InletTemperature', 'Model', 'HeatTransferDuty', and 'ShaftWork' are also visible. The 'Equipment' section shows 'AgitationEquipment' as 'Mechanical', 'Compartment/Walls' as 'True', and 'NumberOfAgitators' as '4'. The 'Operating Conditions' section is partially visible at the bottom.

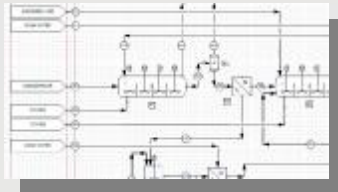
Property	Value
DesignMode	Design
EvaporationRate	0.0, t/hr
Reactions	Reactions
Energy Balance	
EnergyBalance	Isothermal
HeatLoss	Isothermal
HeatTransfer	Nonisothermal
Approach	Adiabatic
Area	0., m2
ExitTemperature	0., Celcius
Fluid	Enter component
HeatTransferCoefficient	0.0, W/m2/K
HeatTransferConfiguration	Countercurrent
HeatTransferEquipment	None
InletTemperature	0., Celcius
Model	Flow
HeatTransferDuty	-13.214, MW
ShaftWork	0., MW
Equipment	
AgitationEquipment	Mechanical
Compartment/Walls	True
NumberOfAgitators	4
Operating Conditions	

A “Compare Cases” function allows an automated comparison between different revisions



An extremely useful function when working on flowsheets of hundreds of streams and units

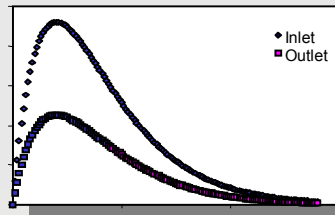
The third topic of this presentation is the capability of Cycad Process to describe particulate processes



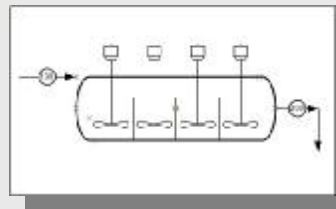
Drawing Environment and Outputs



Mass and Energy Balances

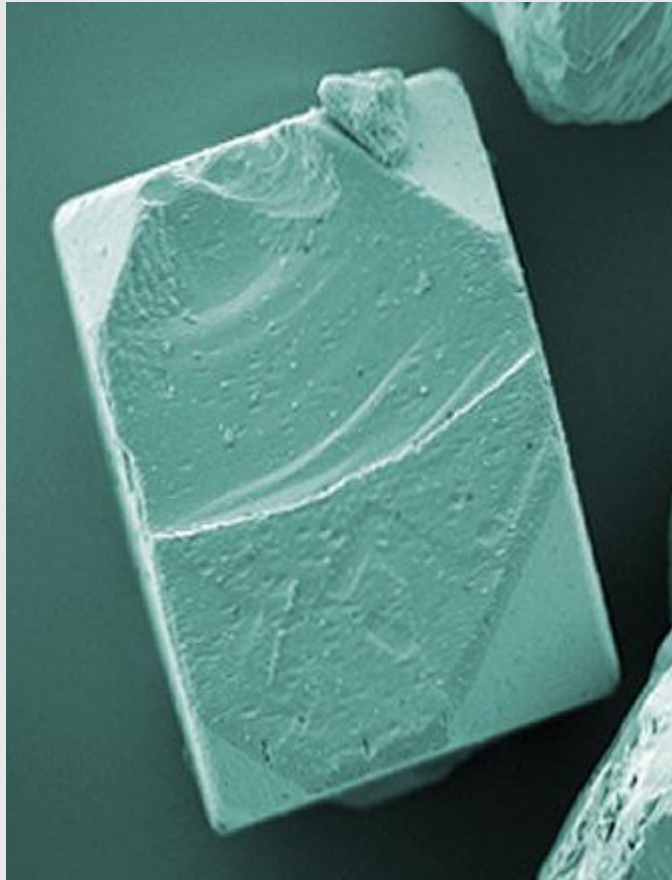


Particle Size Distributions and Population Balances



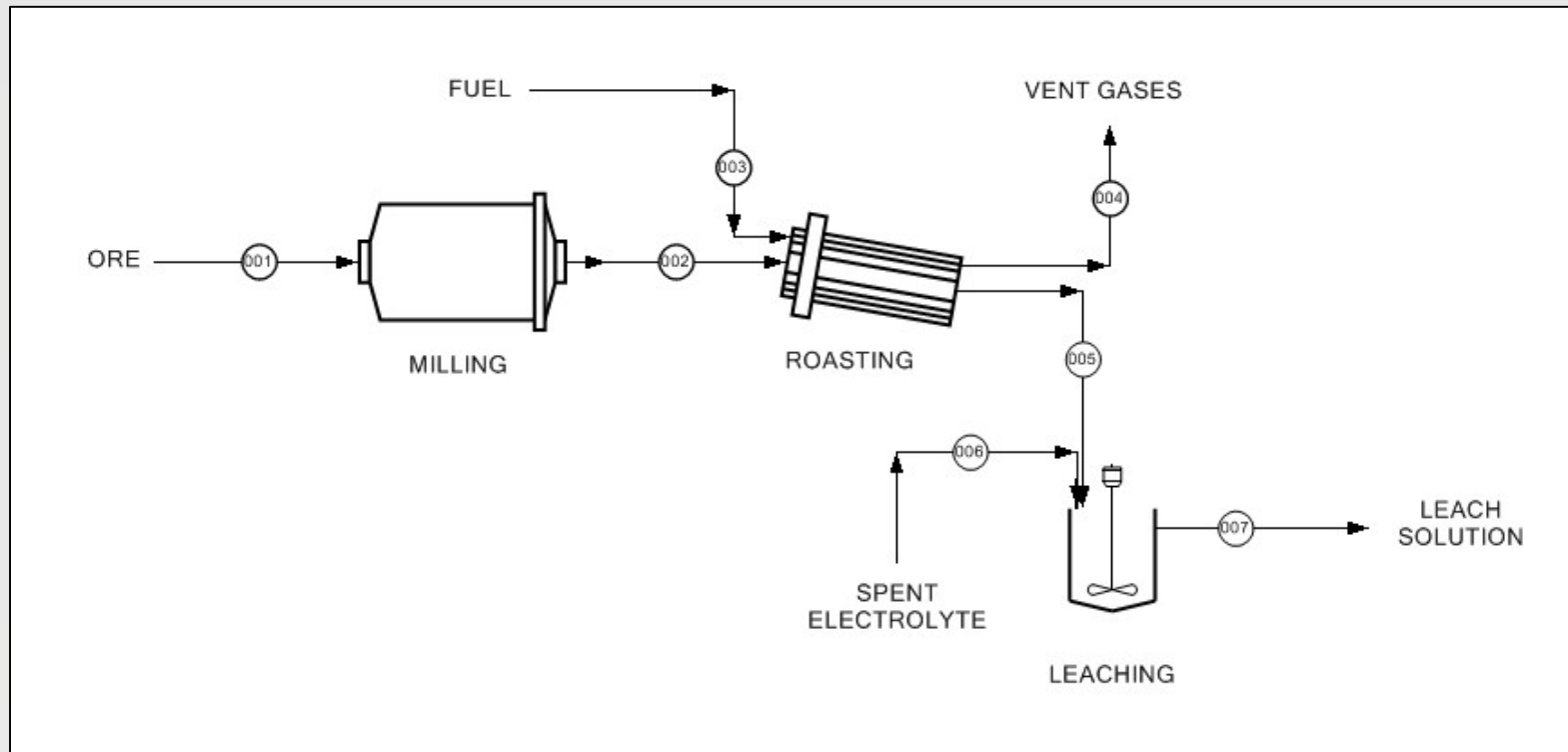
Dynamic Simulation

Most metallurgical and more than 40% of chemical processes treat solids in which particle size is important

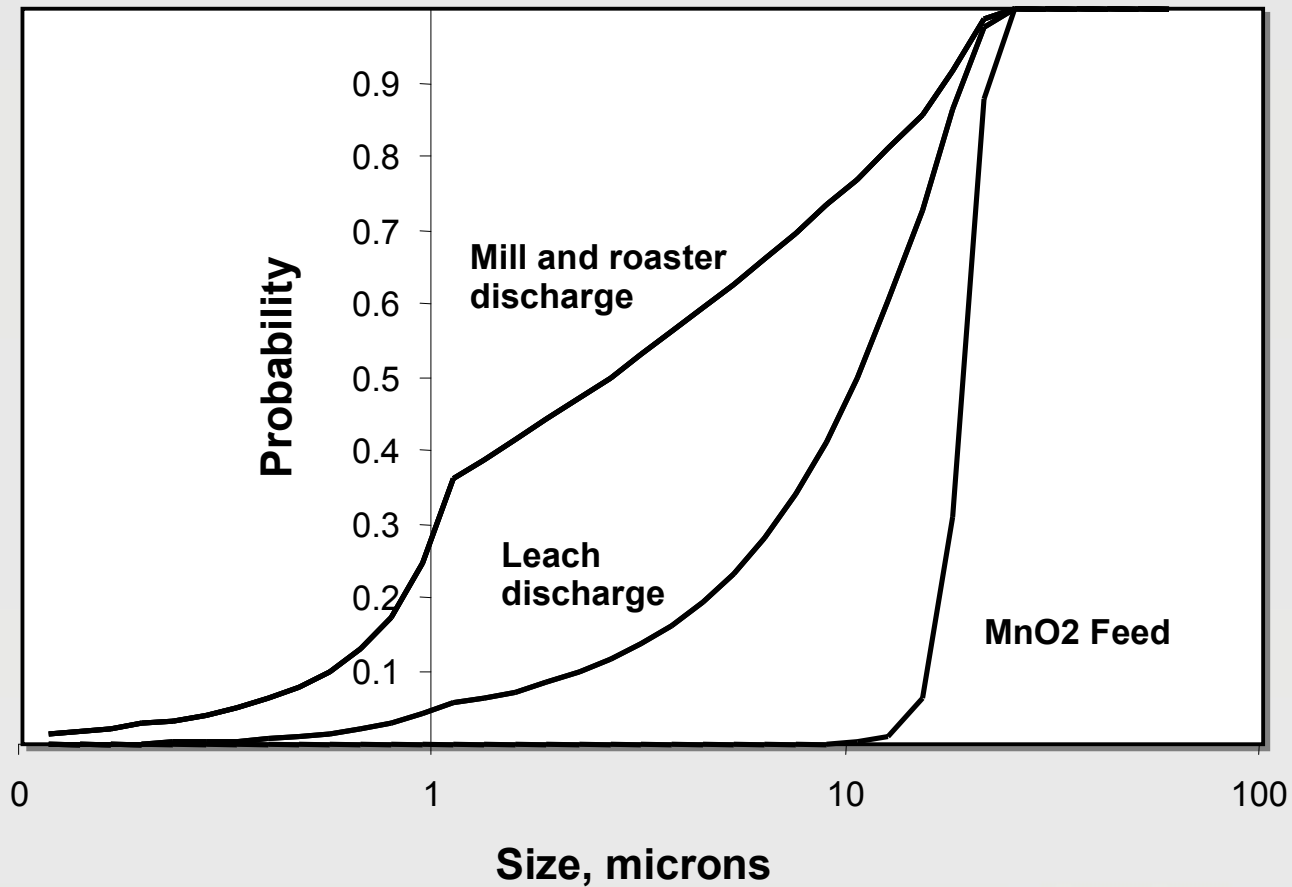


- Roasting
- Leaching
- Precipitation
- Crystallisation
- Agglomeration
- Flotation
- Crushing
- Grinding
- Screening
- Filtration
- Thickening

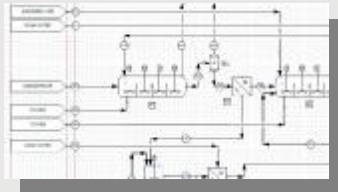
Consider a process with a front end of milling roasting and leaching



A trade-off between milling and leaching exists, which can be more rigorously evaluated



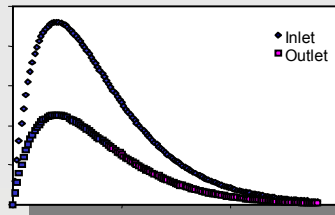
The fourth and final topic of this presentation is the use of Cycad Process to describe dynamic processes



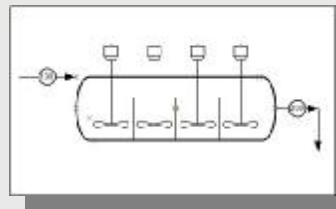
Drawing Environment and Outputs



Mass and Energy Balances

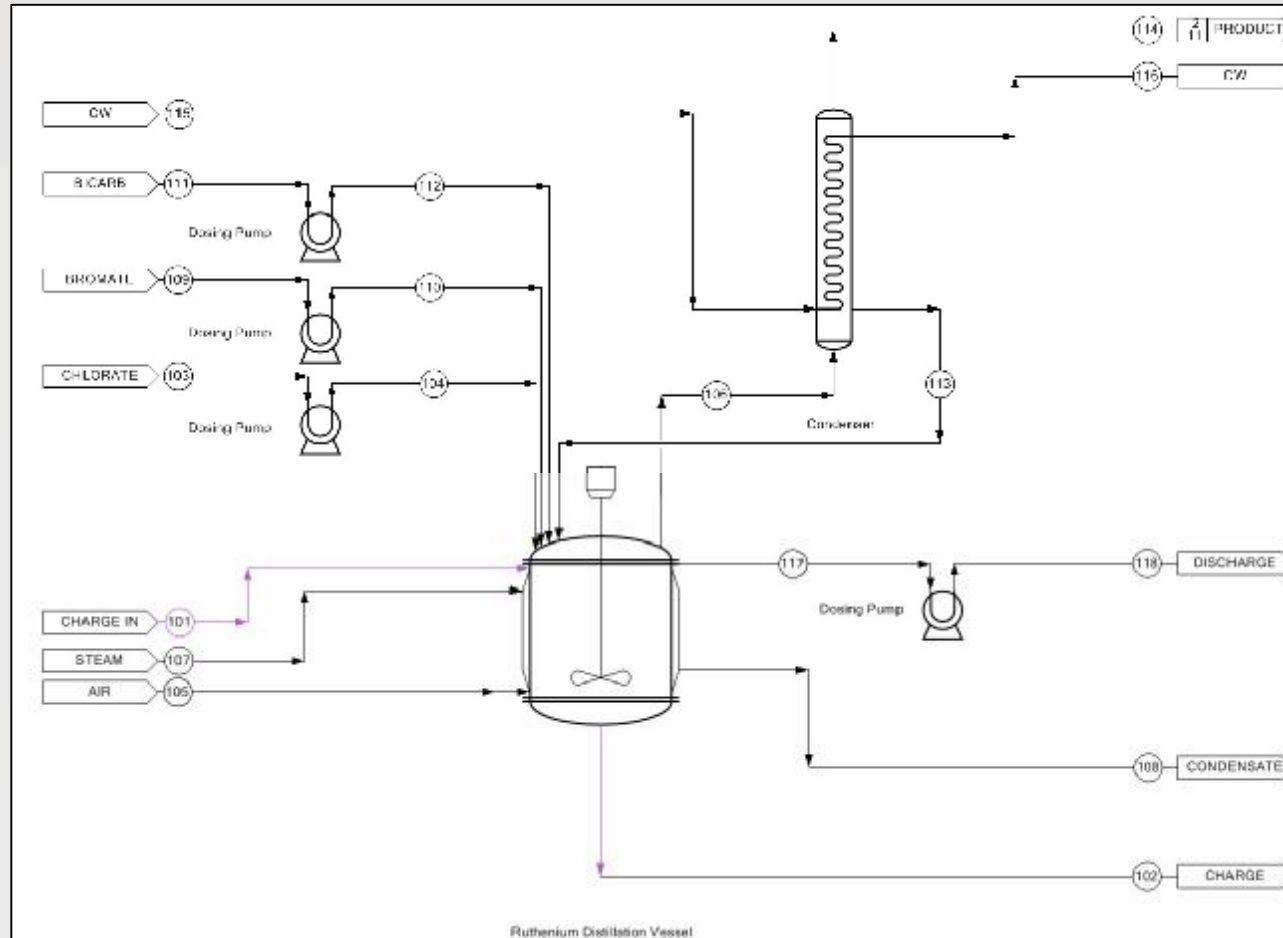


Particle Size Distributions and Population Balances



Dynamic Simulation

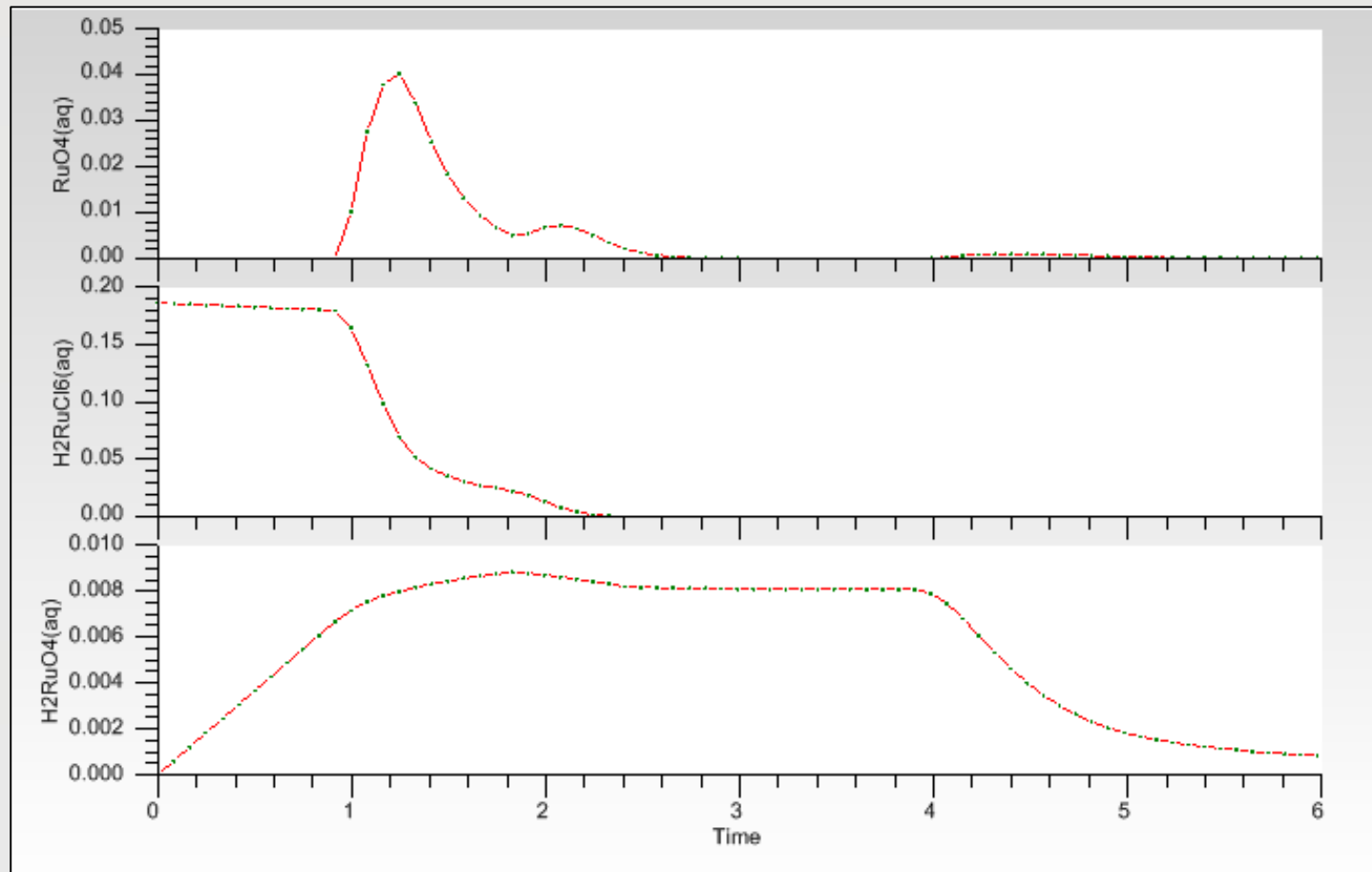
Consider the distillation of ruthenium, which occurs in batch with reagents dosed in at different times



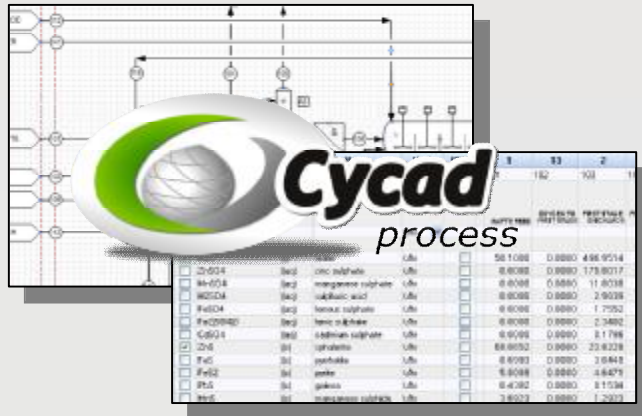
Rates of reaction are entered to model the batch operation

	Reaction	Expression
1	$3 \text{H}_2\text{RuCl}_6 (\text{aq}) + 4 \text{H}_2\text{O} (\text{l}) + 4 \text{NaClO}_2 (\text{aq}) \rightarrow 3 \text{RuO}_4 (\text{aq}) + 12 \text{HCl} (\text{aq})$	$\text{rate} = 1\text{e}1 * [\text{H}_2\text{RuCl}_6 (\text{aq})] * [\text{NaClO}_2 (\text{aq})]$
2	$\text{NaClO}_3 (\text{aq}) + 6 \text{HCl} (\text{aq}) \rightarrow 3 \text{Cl}_2 (\text{aq}) + 3 \text{H}_2\text{O} (\text{l}) + \text{NaCl} (\text{aq})$	$\text{rate} = 1.3\text{e}1 * [\text{NaClO}_3 (\text{aq})] * [\text{HCl} (\text{aq})]$
3	$\text{RuO}_4 (\text{aq}) \rightarrow \text{RuO}_4 (\text{g})$	$\text{rate} = 7.5$
4	$\text{H}_2\text{RuCl}_6 (\text{aq}) \rightarrow \text{H}_2\text{RuO}_4 (\text{aq})$	$\text{rate} = 0.4\text{e}-1 * [\text{H}_2\text{RuCl}_6 (\text{aq})] - 0. * [\text{H}_2\text{RuO}_4 (\text{aq})]$
5	$3 \text{NaClO}_3 (\text{aq}) + \text{Cl}_2 (\text{aq}) + \text{H}_2\text{O} (\text{l}) + 2 \text{NaCl} (\text{aq}) \rightarrow 5 \text{NaClO}_2 (\text{aq}) + 2 \text{HCl} (\text{aq})$	$\text{rate} = 1.1\text{e}1 * [\text{Cl}_2 (\text{aq})] * [\text{NaClO}_3 (\text{aq})] * [\text{NaCl} (\text{aq})]$
6	$5 \text{H}_2\text{RuCl}_6 (\text{aq}) + 8 \text{H}_2\text{O} (\text{l}) + 4 \text{NaClO}_3 (\text{aq}) \rightarrow 5 \text{RuO}_4 (\text{aq}) + 26 \text{HCl} (\text{aq})$	$\text{rate} = 3\text{e}1 * [\text{H}_2\text{RuCl}_6 (\text{aq})] * [\text{NaClO}_3 (\text{aq})]$
7	$5 \text{H}_2\text{RuO}_4 (\text{aq}) + 8 \text{H}_2\text{O} (\text{l}) + 4 \text{NaBrO}_3 (\text{aq}) \rightarrow 5 \text{RuO}_4 (\text{aq}) + 26 \text{HCl} (\text{aq})$	$\text{rate} = 1\text{e}4 * [\text{H}_2\text{RuO}_4 (\text{aq})]^2 * [\text{NaBrO}_3 (\text{aq})]$
8	$\text{H}_2\text{O} (\text{l}) \rightarrow \text{H}_2\text{O} (\text{g})$	$\text{rate} = 1\text{e}-4$
9	$\text{Cl}_2 (\text{aq}) \rightarrow \text{Cl}_2 (\text{g})$	$\text{rate} = 1\text{e}-2$
10	$\text{NaClO}_3 (\text{aq}) + 6 \text{HCl} (\text{aq}) \rightarrow 3 \text{Cl}_2 (\text{g}) + 3 \text{H}_2\text{O} (\text{l}) + \text{NaCl} (\text{aq})$	$\text{rate} = 1\text{e}-3 * [\text{NaClO}_3 (\text{aq})] * [\text{HCl} (\text{aq})]$
11	$2 \text{NaClO}_3 (\text{aq}) + 4 \text{HCl} (\text{aq}) \rightarrow 2 \text{ClO}_2 (\text{g}) + \text{Cl}_2 (\text{aq}) + 2 \text{H}_2\text{O} (\text{l}) + 2 \text{NaCl} (\text{aq})$	$\text{rate} = 1\text{e}-3 * [\text{NaClO}_3 (\text{aq})] * [\text{HCl}]$

The model of this complex batch process using Cycad Process agrees with lab and plant data



Conclusions



Cycad Process is intuitive and easy to use

Outputs are directly matched with metallurgical requirements

Calculations based on well-known methods

Population balance methods are integrated with equipment models

Simulate batch lab and plant results

Cycad Process is a powerful tool for the design and simulation of process engineering plants

Questions?