

**ROLE OF SIMULATION SOFTWARE IN DESIGN AND OPERATION OF
METALLURGICAL PLANTS: A CASE STUDY**

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ABSTRACT

This paper outlines the role of simulation software in design and operation of a typical metallurgical plant with mineral processing and hydrometallurgical units, to produce concentrate and pure metal. It addresses the role of simulation and mass balance software in the conceptual, feasibility and detailed design stages. It discusses the use of JKSimMet for sizing of mineral processing units, and METSIM and IDEAS for development of energy and mass balances.

In detailed design of a plant, the complex interaction and variation in performance of various units makes it difficult to predict overall system performance and availability. Simulation is used to:

- assess operating strategies that affect surge capacities at various stages
- compare different ore types and mining strategies that affect concentrate product quality.
- optimize transportation logistics for raw materials, concentrate and metal products.

INTRODUCTION

To maximize the efficiency and cost-effectiveness of mines, mineral processing plants and metallurgical plants, the design team has to consider many operating parameters and design criteria. Without computer tools that make metallurgical calculations simple and fast, this is almost impossible to do in a timely manner. These tools can evaluate performance for a variety of process concepts, design criteria such as ore grades, and throughput tonnages.

No single simulation tool can be applied to all stages of a project and areas of plant operation. Different packages have been developed to address different metallurgical projects, and a number have been commercialized with varying degrees of success. This paper discusses the benefits of using these tools for design and operation of a typical process plant that exhibits all the hallmarks of design and operation complexity experienced in the industry.

It is important to choose a simulation tool that provides maximum usefulness for design optimization, equipment selection and sizing, surge capacities, piping, reagent utilization rates, maintenance and transportation scheduling, etc. This choice is dependent on the stage of design and the type of operations involved.

At the scoping study level, preliminary testwork and information gained from similar operations may be sufficient to develop a conceptual heat and mass balance. At the prefeasibility level, a more definitive heat and mass balance table should be prepared on spreadsheets. For sizing equipment at the detailed feasibility and basic engineering levels, a totally accurate heat and mass balance is required, based on reliable testwork and firm design criteria.

Although an accurate heat and mass balance is the cornerstone of plant design and future operation, at best it provides only a static picture of a hypothetical steady-state operation. A tool such as IDEAS can simulate both steady and dynamic states, allowing the user to create a dynamic representation of the process with equipment such as pumps, valves, pipes and tanks. Scheduled and random stoppages, which influence availability and overall production performance, can be included to obtain a more realistic picture. Although other packages such as ARENA can simulate a process based on discrete events (useful in tracking surge capacities and production), they cannot incorporate process details such as chemistry, particle-size distributions and detailed unit operations.

This paper discusses several design tools used at different levels of project design and operation:

- HSC and STABCAL, for understanding system chemistry
- JKSimMet and USIM PAC, for design and optimization of mineral processing circuits
- METSIM, for heat and mass balances
- IDEAS, for heat and mass balances using dynamic simulation.

Appendix I lists the referenced simulation tools and identifies sources of further information.

PROCESS SIMULATION AT VARIOUS STAGES OF A PROJECT

Scoping Study: Typically, a project starts with a scoping study covering geology and resource estimation, mining, processing and environmental issues. Its goal is to collect initial information that demonstrates the project's economic attractiveness.

Based on preliminary testwork available, one or more process options are chosen, and an approximate mass and energy balance is performed to size equipment, estimate reagent usage and costs. A spreadsheet can be used to eliminate uneconomical options at this early stage.

From this early stage and throughout the design period, tools such as HSC and STABCAL can help clarify the chemical theory associated with the process concept. HSC performs several chemical and equilibrium calculations. STABCAL calculates stability equilibrium for aqueous systems, and can be used for speciation as well as free-energy databases.

Since neither HSC nor STABCAL can account for rates of chemical reactions and non-ideality of solutions, they cannot replace testwork and pilot-plant studies. However, they do provide preliminary information on the behavior of aqueous /solid systems in the form of Eh-pH diagrams.

Prefeasibility Study: A prefeasibility study warrants the initial use of standard mass and energy balance tools. Using preliminary testwork and design criteria, a standard package such as METSIM can be used to develop a preliminary heat and mass balance, with equipment sizing based on the mass balance.

Detailed Feasibility Study: At this stage, steady-state heat and mass balance software is used to generate flows between unit operations. Greater care and accuracy are required to firm up the selected process options and corresponding equipment. Sizing software such as JKSimMet can be used for modeling and sizing.

Basic Engineering and Detailed Design: The mass balance produced at the feasibility stage depicts a static picture of flow of material and energy, but does not address the complexities of process start-up, ramp-up to full production, the interaction of unit operations, or the effect of stoppages on surge capacities and the ability to reach full capacity. At this stage, a model such as IDEAS is required to:

- verify that the process plant can achieve planned production levels
- identify possible bottlenecks
- analyze surge capacities and their effect on overall availability.

This model can be used to optimize surge capacities to reduce bottleneck effects, and to evaluate sensitivity to various process parameters and design criteria.

Model inputs include mass and energy flows obtained from the steady-state process mass balance, and scheduled and random stoppages. Outputs typically include plant availability, annual production for individual areas, overall annual production, and surge levels throughout the plant. The model can also predict stoppages in individual plant areas resulting from surge capacities being exceeded downstream, drops in throughput upstream, random

breakdowns, scheduled maintenance, and the unavailability of process reagents or utilities.

Operator Training: As process design advances, simulation tools such as IDEAS can transfer the steady-state mass and energy balance to a dynamic environment to model non-steady-state operations. Valves, pipes, tanks, pumps (with pump curves and other specifications) can be configured and sized, and operating logic and control strategies developed. IDEAS can provide operators with virtual hands-on training on a desktop, facilitating commissioning and start-up.

Control System Verification: IDEAS can verify thousands of signals from a control system, to create a virtual test panel that interfaces with PLCs and DCSs well before the operating plant is built. In one case, it was used to test controls logic for all motor start/stop circuits, valve on/off operations, analog signals and related sequence process start-up actions. This avoided start-up delays by enabling the client to correct the control logic prior to field implementation. The same model was later used to train staff in DCS operations.

CASE STUDY – PLANT DESCRIPTION

A representative metallurgical plant^{1,2}, shown in Figure 1, has been selected from the literature to showcase the different advantages and applications of process simulation in areas such as comminution, concentrate storage and transport by pipeline, hydrometallurgical treatment and shipping of both concentrate and cathode. This plant has the following features:

The resource is a porphyry copper orebody at an elevation of about 3,000 meters.

The mine is a conventional open-pit operation using electric shovels, trucks and an in-pit primary crusher. Crushed ore is transferred out of the pit by conveyors to several coarse ore stockpiles. Waste, oxides and low-grade sulfides are trucked to other stockpiles. Other low-grade materials are trucked close to the mill, in anticipation of possible future treatment.

The concentrator is designed to treat 40,000 metric tons per day of ore to produce 400,000 metric tons per year of copper in concentrate product. It includes two 28' x 14' SAG mills and four 18' x 24' ball mills in closed circuit, and a flotation circuit with 90 rougher cells, 30 scavenger cells and 10 column cells for cleaning. Final concentrate consists of 40 wt% copper, thickened to about 60 wt% solids and transported by two 6" and 7" pipelines to a filter near the port, 150 km away. Positive displacement

pumps provide the initial drive, and then slurry flow is by gravity at a rate of up to 300 metric tons per hour.

The hydrometallurgical plant is designed to treat about 40% of the concentrates to produce 80,000 tonnes of copper cathode per year. The concentrate is thickened to about 60% solids in a 50m diameter thickener, and pumped to continuously agitated storage tanks, 12 m in diameter x 12m high, that provide surge capacity between the filter plant and the hydrometallurgical plant.

Two belt filters filter the concentrate and wash out impurities. Filter cake is repulped with a recycle stream, and pumped to the leach section at a considerably lower solid wt%.

Leaching takes place with ammonia ammonium sulfate liquor in a series of tanks where air is sparged. The leaching reaction is very fast, and controlled by the rate of oxygen transfer. Ammonia gas is recovered from the off-gas and collected as an aqueous solution.

The PLS contains about 30 g/L copper as $\text{Cu}(\text{NH}_3)_4^{++}$. This is pumped to the SX unit, which consists of a two-stage extraction step, one wash stage and one strip stage. The EW circuit has 260 cells, each with 60 cathodes.

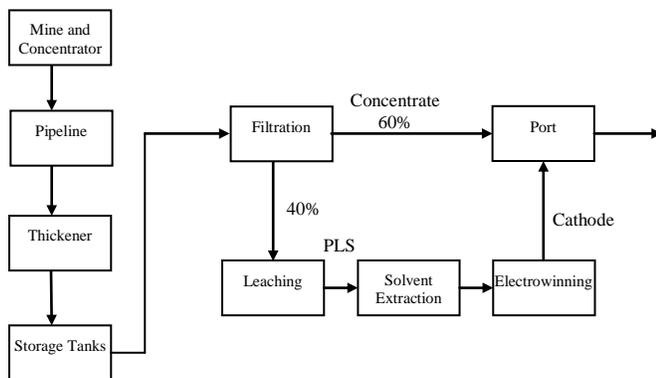


Figure 1. Case Study Schematic ^{1,2}

USE OF SIMULATION SOFTWARE FOR DESIGN OF VARIOUS PLANT AREAS

Mineral Processing: Communitation represents a large portion of a mineral processing plant's capital and operating costs. Cohen³ estimates the electrical power consumption of communitation circuits to be 30% to 70% of total plant power requirements, with power consumption varying with ore hardness. According to Weiss⁴, power consumption in mineral processing accounts for half of operating costs. For process plants that include both mineral processing and downstream

processes, the capital cost of communitation represents between 20% and 50%.

These figures underscore the value of simulation in process optimization, and in selecting and sizing equipment to achieve increased throughput, improve particle size and reduce costs

JKSimMet or USIM PAC can be used to size the SAG mills and optimize the process circuit of the case-study plant. These tools employ the following steps:

- characterization of the feed material in small-scale tests
- specifying equipment using known plant information and test results
- testing to size equipment and to optimize flowsheets and operating conditions.

JKSimMet and USIM PAC have built-in models of the following units:

- cone, jaw, gyratory and roll crushers
- autogenous, SAG, rod and ball mills
- screens
- hydrocyclones.

To achieve valid results, the user must test the model against available plant data. Once the model has been tested and has been found satisfactory, it can be used to optimize a particular design or operation.

JKSimMet has been in wide commercial use for 15 years. It has the following functions:

- compilation of a simple flowsheet
- specification of simulation and process data
- process plant modeling
- report printing.

Simulation is limited to prediction of steady-state performance of the equipment in terms of mass flow, solids concentration and size distribution. The model can be used to optimize equipment specifications and operating conditions, and to compare process designs to arrive at the best plant configuration in terms of throughput and/or particle size.

JKSimMet's SAG model⁵ is based on the work of Leung⁶, and its general structure is shown in Figure 2. The model has two components, one corresponding to breakage impact based on a drop-test determined by a weight falling from a fixed height, and the other corresponding to abrasion using tumbling tests. In the case study, JKSimMet can be used to size the SAG mills

by extrapolating the results of drop tests that determine the resistance to breakage of representative ore samples. The model can be used to scale up, based on volume, from pilot-plant data to commercial-size mills.

The relationship between the quantity of breakage and the input energy in JKSimMet SAG model is given as:

$$t_{10} = A (1 - e^{-bEcs}) \quad (1)$$

where t_{10} is the percentage of the ground particles that will pass through a screen one-tenth the size of the original particle, Ecs is the energy absorbed per unit mass during breakage measured in kWh/tonne, and A and b are parameters that characterize the equation for a particular ore. A is usually 50, and b is derived from a drop-test of similarly sized ore particles. Required sample size varies according to ore variability; generally, about 50 kg of 50 mm material is needed. This approach has been proven to be successful for scaling up from pilot mills of up to 2 m to commercial-scale mills of up to 8-9 m⁵.

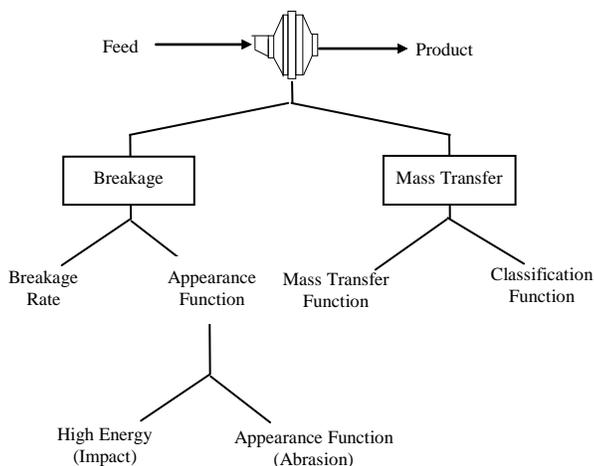


Figure 2. General Structure of JKSimMet SAG Model⁵

To determine abrasion resistance, 3-kg samples of 50-mm natural ore are tumbled for 10 minutes in a small dry mill at 70% of critical speed. The products of each run are sized, and t_{10} is measured for each run.

Based on results of several runs, the hardness category of ore samples is determined. JKSimMet has a database of several hundred ore samples. By performing several SAG circuit simulations, SAG mill size is verified (28' x 14'). The simulation outcome shows that SAG mills chosen would be able to achieve or exceed the target grind of 80% passing 75 μ m for all ores tested.

Plant-Wide Mass and Energy Balance: Although JKSimMet and USIM PAC can be used for mass balancing in the mill, it is important to use a single tool for plant-wide balancing. Practical choices available for modeling the mass and energy balance range from computer spreadsheets, to packages like IDEAS and METSIM, which offer a wide range of capabilities and features tailored to the mining and metals industry.

Software developed for the hydrocarbon industry, such as Aspen and HYSYS, have recently been applied to metallurgical process modeling. Although these can be used for some operations, they have a number of shortcomings for mining and metals. They do not include all the unit operations and the inorganic compounds database that are essential to mining and metals projects. Their comprehensive thermodynamic databases, while useful for the prediction of phase equilibrium and rates of reactions in hydrocarbon processing, cannot be applied in the mining and metals industry. This is because while ore or concentrate grade may be known, the results of extraction are unpredictable due to wide variations in feedstocks.

Moreover, equilibrium data are of limited use in inorganic chemistry without continuous laboratory and pilot-plant tests for each individual case.

Metallurgical process modeling cannot dispense with reliable testwork. Theoretical predictive tools should in the first instance be used for qualitative analysis and testwork verification.

Ore Feed: Ore feed is input to the simulation model based on testwork interpretation and the mining plan. In mineral processing models, it is possible to follow only the metals of interest, but hydrometallurgical models must include the chemical identities and quantities of all feed metal species, impurities and reagents at the start. Once the model has been developed with robust logic, the user may investigate the effects of changing feed grades on both concentrate and metal production.

Grinding Circuit: Modeling can be performed using steady-state methods that basically separate or mix various components of ore slurry and concentrate. Flotation cells are modeled using component separator objects that the user sets to control the mass pull and recovery of copper in the concentrate, based on the test data.

Concentrate Split: The split between concentrate for export and feed to the hydrometallurgical plant is based on the design capacities of the hydrometallurgical plant and the pipelines taking concentrate to the port, with special consideration given to the port's loading and

shipping schedule. Using the known steady-state flow for concentrate slurry, the pipeline capacity and the various scheduled and unplanned stoppages, a dynamic model can be developed to verify the project's export capacity and optimize concentrate storage facilities and stockpile sizes.

Pipeline: At the study stage, the steady-state flow in the concentrator and pipeline should be modeled, including scheduled and random stoppages. This enables the user to optimize concentrator and pipeline capacity, while ensuring that concentrate stored at site neither runs out nor accumulates to the point that operations must be interrupted.

Figure 3 is an IDEAS screen output that couples steady-state flow in the concentrator and pipeline with programmed and random stoppages. It shows surge capacities for a four-month period of operation, from the point at which only the concentrator is working, to the first batch of concentrate slurry piped to the port, to the start-up of the hydrometallurgical plant. At this point, the supply of concentrate drops, until production on both sides of the stockpile is stabilized at design capacities; but stockpile levels never jeopardize the required supply of concentrate to the port and the hydrometallurgical plant.

[186] CONCENTRATE SURGE CAPACITY

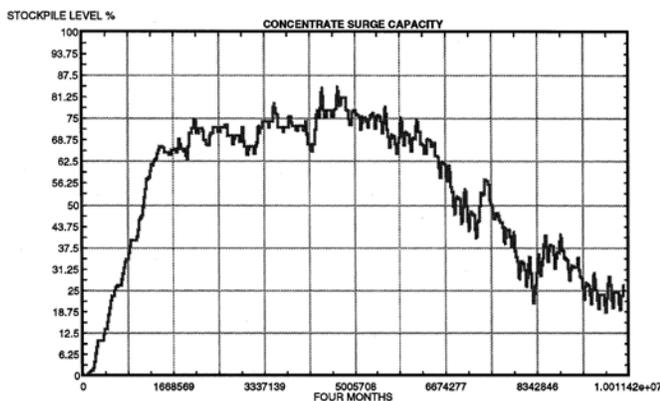


Figure 3. On-line Concentrate Storage Levels at the Concentrator over a Four-Month Period

At the detailed design stage, IDEAS can be used for the dynamic modeling of the flow of concentrate slurry through the pipeline, with accurate simulation of pipes, valves, pumps and gravity flow. This enables the designer to see his selected equipment in virtual action.

Hydrometallurgical Plant and Port Facilities: The IDEAS model can be extended to include the hydrometallurgical plant, and slurry storage and dewatering facilities at the port. This can be used to optimize storage capacities at

the hydrometallurgical plant and port, along with surge capacity at the concentrator.

Although software such as ARENA can be used to model discrete events at the port site, IDEAS can simulate these events on the same platform that was used for the production and flow of slurry and the chemistry-intensive operations of the hydrometallurgical plant. The user can specify a distribution and input probabilities for the shipping related events in a table. Items can be created with a random distribution or at constant rate of arrival.

The distributions available in IDEAS include beta, binomial, constant, empirical, Erlang, exponential, gamma, hyper-exponential, log normal, normal, Pearson type V, Pearson type VI, Poisson, triangular, uniform integer, uniform real and Weibull. Weibull, essentially an exponential distribution, is commonly used to describe product life cycles or the time to complete tasks, and is well-suited to mining and metals projects.

Shipping: IDEAS' discrete modeling capability can simulate concentrate loading and shipping based on a variety of parameters, eg:

- loading hours from 6 am to 6 pm
- 24-hour delay for ship preparation before loading can commence (berthing time, paperwork, etc)
- maximum loading rate of 2,000 tonnes per hour
- random and planned stoppages of loading equipment
- maximum ship capacity of 20,000 tonnes.

The model can be used to confirm the practicality of the shipping schedule. It can assess the impact of shipping interruptions on stockpiles, the hydrometallurgical plant and ultimately the concentrator upstream.

Hydrometallurgical Plant Energy and Mass Balance:

Energy and material balances are at the core of all hydrometallurgical designs, and are essential to the design and sizing of process equipment. An accurate balance can resolve design issues such as steam requirements for reaching a set temperature, wash ratio in a CCD system to achieve the desired recovery of metal values, and toxic impurity levels in discharge to tailings.

While METSIM and IDEAS create reliable heat and mass balances, IDEAS can be extended to detailed dynamic simulation of the process over extensive periods of operation.

Heat balance is not of interest in mineral process models, but it is as important as material balance in hydrometallurgical processes. Its development is based

on system component data and standard relationships such as:

- ΔH° , standard enthalpy (kJ/mol)
- C_p° , heat capacity at constant pressure (J/mol/K)
- ΔH° (reaction) = ΔH° (products) - ΔH° (reactants).
- $$\Delta H_T = \Delta H_{298.15} + \int_{298.15}^T C_p dT \quad (2)$$

Model Material Properties Database: Both METSIM and IDEAS have a database of thermodynamic properties for the commonly used components in the mining industry. In IDEAS, these properties are in the form of individual text files that can be called up and loaded by the user. The user can also create additional components and add them to the database.

METSIM assembles compounds from elemental building blocks, and can track elements in terms of quantity and concentration. In IDEAS, components are chosen directly, and the user can monitor the flow and concentration of elements and sub-component species (e.g., sulfate or ammonia ion content of streams and their concentrations). The outline of the dialog box for the IDEAS Material Properties Object is shown in Figure 4.

Name	No. of Components in Stream
0	Not Used
1	Water
2	Steam
3	Cu2S
4	CuFeS2
5	CuFeS4
6	CuCO3.Cu(OH)2
7	FeS2
8	CaCO3
9	MgCO3
10	Cu_s
11	Fe3O4
12	CaAl2Si2O8
13	SiO2
14	Si3
15	Si2
16	Si
17	SiO
18	SiO3
19	SiO4
20	SiO5
21	SiO6
22	SiO7
23	SiO8
24	SiO9
25	SiO10
26	SiO11
27	SiO12
28	SiO13
29	SiO14
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104	SiO89
105	SiO90
106	SiO91
107	SiO92
108	SiO93
109	SiO94
110	SiO95
111	SiO96
112	SiO97
113	SiO98
114	SiO99
115	SiO100

Figure 4. Components Tab of Dialog Box for the IDEAS Material Properties Object

Model General Features: Both METSIM and IDEAS distinguish material component phases such as liquid,

solid, organic and aqueous. Solution volumes are based on specific gravity, taking the effect of ionic species into account. This is very important for hydrometallurgical plants, as design criteria are usually based on concentration of aqueous species, which in turn affect and are affected by the specific gravity of solutions.

Both tools also enable the user to set the basis units for mass, time, volume and concentration throughout the model. If heat balance is not of interest, this part of the model can be turned off.

METSIM has been the tool of choice for performing heat and mass balances in the metals and mining industry for several years. The recent transition of METSIM to the Windows platform is continuously being improved, but it may still present considerable challenges to the users of the old MS DOS version. The flowsheet-based Windows version handles inputting of data differently, but many features are still similar to the MS DOS version. METSIM permits the user to design output files in spreadsheet form.

In IDEAS, dialog boxes can be used to enter process design criteria, introduce controllers to set performance set points, and access process information from display boxes and on-line graph outputs. The user can see the heat and mass balance grid as part of the model, or link the model to an Excel spreadsheet that displays the data as the model is running. Model flowsheets can be produced to resemble process flow diagrams with interactive icons.

CASE STUDY: MATERIAL AND ENERGY BALANCE RESULTS

The case study model includes mining (ore flow), concentrate production, transport to the stockpile, concentrate shipping, and repulping and leaching in the hydrometallurgy plant. Concentrate containing 40% copper by weight is piped from the concentrator to the port and hydrometallurgical plant at a rate of up to 300 metric tons per hour.

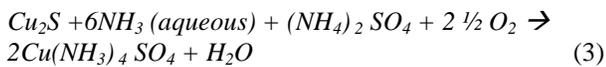
Both METSIM and IDEAS model the flow of mass from the mine to the concentrator and the hydrometallurgical plant. It is inside the hydrometallurgical plant where the following additional features of the modeling software become crucial:

- representation of chemical reactions
- efficient and robust control of flows, concentrations, reaction conversions and other design criteria
- modules (objects) that represent common hydrometallurgical unit operations.

Both tools offer these features, but with different approaches for inputting the data and simulating the process.

Filtration is modeled using the IDEAS filter object. The input criteria for the filter object are set to allow for a wash water ratio of one displacement, and a final cake moisture content of 14 wt%. METSIM has similar capability, and can also calculate some preliminary dimensions for the belt filter units.

Concentrate leaching is modeled using a reactor object that represents the chemistry of an ammonia-ammonium sulfate leach process, and the following reaction for oxidation of chalcocite:



The IDEAS reactor object can be used to ensure copper extraction at 40%, and to limit ammonia-ammonium sulfate addition, enabling the free ammonia in leach discharge to be set to a target level. Addition of air can be fixed at a level above stoichiometric.

The model shows a PLS stream of about 150 cu m / hr and a specific gravity of 1.1. The copper content of this stream is 30 g/L, and the free ammonia is 8.5 g/L. Solution pH is 9.

The IDEAS Solvent Extraction module calculates the mass and energy balance for the next stage of the hydrometallurgy plant. The organic extractant used for the ammoniacal PLS is LIX-54 at 30 wt% by volume. The diluent is kerosene at 70 wt% by volume. The SX object simulates the copper concentration in the raffinate at 0.15 g/L. The solvent extraction train model consists of two extraction, one strip and one organic wash stage. At any of these stages, the user can input the organic to aqueous volumetric flow ratio, and the model adjusts the recycle flows to achieve these conditions.

The electrowinning simulation is based on annual production of 80,000 tonnes per year of copper cathode. IDEAS' Electrowinning object models the process, with design criteria of current density at 280 amps /sq m, current efficiency at 92%, and 260 cells with 60 cathodes each. The model can perform the overall energy and material balance for the EW operation and estimate power consumption.

Table 1 summarizes typical simulation results for the hydrometallurgical plant. Flow rates and temperatures enable the user to quickly size equipment such as leach tanks, heat exchangers and SX-EW tankage.

Additional Data Gained from Simulation: Using various ore grades as the starting point for the model, it is possible to analyze the effect on concentrate grade and the hydrometallurgical plant operation over an extended time. This is done by assigning an appropriate copper grade to each campaign, and building changes in head grade into the model. IDEAS' logic capabilities enable the user to simulate changes in grade or mixing from several stockpiles to control the resultant ore grade. The downstream effect of these changes on concentrator and hydrometallurgical plant operation is concurrently displayed.

Historical data on scheduled and random stoppages from a similar operation can be applied to the case study's material and energy balance. In this way, IDEAS provides a semi-dynamic simulation of surge capacities and the effect of downtime on overall production.

CONCLUSIONS

Knowing when and where to use simulation technology is fundamental to the successful design and operation of a mining and metallurgical project. Correct application of simulation technology improves design accuracy, and saves time and money by clarifying many project details early in the design cycle.

Table 1: Material and Energy Balance Model Results and Criteria

1.Feed to concentrate thickener	
Total Flow,	250 metric tons per hour
Solids Density	55 wt %
Concentrate Copper	40 wt %
2. Concentrate thickener	
Underflow Solids	60 wt %
Thickener Overflow	220 cubic meters per hour
Overflow Solids	200 ppm
3. Thickener underflow split between leach plant and the concentrate storage at port	
Portion of flow to leach plant,	46.2%
Tonnage of contained copper to leach	25.4 metric tons per hour

Table 1: Material and Energy Balance Model Results and Criteria (Cont'd)

4. Concentrate Dewatering Belt Filters	
Wash water requirement per each belt filter	16 cubic meters per hour
Wash ratio	1.0
Wash Filtrate	18 cubic meters per hour
Filter cake flow per filter	36 metric tons per hour
Filter cake solids density	86 wt %
5. Concentrate Repulp	
Total raffinate for repulping	335 cubic meters per hour
Repulped concentrate solids density	15 wt%
Total repulp liquor	30 cubic meters per hour
Repulp liquor composition	
Copper	4 grams per liter
NH3 f	25 grams per liter
NH3 t	50 grams per liter
SO4	60 grams per liter
6. Ammonia-Ammonium Sulfate Leaching	
Chemical reaction:	$Cu_2S + 6NH_3 \text{ (aqueous)} + (NH_4)_2 SO_4 + 2 \frac{1}{2} O_2 \rightarrow 2Cu(NH_3)_4 SO_4 + H_2O$
Copper extraction	40 wt%
NH3 f in leach discharge	5 grams per liter
No. of tanks	4
Leach feed	410 metric tons per hour
Leach tanks air input	17 metric tons per hour
Leach tanks discharge solids density	13 wt%
Leach tanks discharge copper	33 grams per liter
Temperature	45° C
7. Residue and Wash Thickeners	
Residue thickener underflow solids density	55 wt%
Residue thickener overflow solids density	100 ppm
Residue thickener wash ratio	1.0
Overflow solution flow rate	375 metric tons per hour
Underflow slurry flow rate	94 metric tons per hour
Wash thickener underflow solids density	55 wt%
Wash thickener overflow solids density	100 ppm
Total raffinate addition rate	315 cubic meters per hour
Total wash thickener overflow to repulping	310 cubic meters per hour
Total wash thickener underflow to Filter	100 metric tons per hour
8. Leach Residue Filter	
Filter Cake Solids Density	86 wt%
Wash ratio	1.0
Total filter cake flow	60 metric tons per hour
Slurry to residual floatation	87 metric tons per hour

- II. METSIM
Proware, 4611 East Blue Mountain Drive
Tucson, Arizona, USA 85718
Tel: (520) 299-7834
Fax: (520) 299-8009
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