Title: FLOTATION FUNDAMENTALS AND APPLICATIONS

Lead Instructor: Dr. Janusz S. Laskowski, Professor Emeritus, University of British Columbia
Course length: Two days (total: 14 hours)
Dates: Sunday, January 15 and Monday, January 16th

Objectives:
The aim of this two-day short course is to review flotation fundamentals and flotation technology. The course is geared towards practicing engineers and graduate students.
The material will be presented in an easily understandable manner without going into a lot of mathematical derivations, and without straying too far from topics directly relevant to the fine particle technology. We have been continuously overwhelmed by computerization and availability of better equipment, but flotation is still a surface chemistry based process in which what is frequently needed is the use of better reagents, better use of the existing reagents or optimization of the conditions under which these reagents are applied. The course is structured to discuss physico-chemical fundamentals and to show how better understanding of the fundamentals can be utilized to improve industrial results.

Course Outline

1. Separation methods in mineral processing. Fine particles in mineral processing. Flotation.

2. Flotation Reagents - Collectors: their properties, applications. Modifiers: activators, depressants, dispersants, pH regulators. Frothers: foams, bubble coalescence and foam stability, flotation froths, effect of frothers on flotation performance, application of frothers in flotation processes.

3. Flotation classification of minerals

4. Flotation technology - Flotation kinetics. Effect of particle size on flotation. Flotation machines. Classification of flotation machines. Mechanical cells, flotation columns. Flocculants in flotation circuits. Polymers in mineral processing. Effect of flocculants on surface properties of minerals and on flotation.

5. Flotation Plant Flowsheets.

(a) Flotation of inherently hydrophobic solids.
Coal flotation. Coal surface properties. Effect of rank on coal flotation. Floatability of coal macerals. Coal flotation reagents: collectors, promoters, frothers. Mode of action. Fine coal cleaning circuits. Flotation technology. Application of flotation columns.
Graphite and talc flotation.

(b) Sulphide ores
Theory of sulphide flotation. Classification of sulphide ores:
Cu ores, Cu-Mo ores, Cu-Pb-Zn ores, Cu-Ni ores.
Cu-Mo ores: bulk flotation, Cu-Mo selective
separation methods. Chilean Cu-Mo processing plants. Processing of Cu-

Ni ores in Canada (Inco Flotation Process). Flotation of Platinum Group Minerals (South Africa), Flotation of native gold and auriferous ores (South Africa, Australia).

(c) Flotation of oxidized ores of base metals
Oxidized and mixed oxide-sulphide ores of non-ferrous metals.
Processing of Cu oxidized ores. Reagents. Leaching-precipitation-flotation technology.
Processing of lead oxidized ores. Processing of Zn oxidized ores. Recent improvements in technology of cationic flotation of oxidized zinc ores.

(d) Oxides
Flotation of quartz and silicates. Flotation of iron ores, pelletization in the iron ore processing technology. Selective flocculation/reverse flotation (Tilden Mine flowsheet).
Flotation – concentrate pelletization (LKAB, Sweden).

(e) Flotation of industrial minerals.
Problems in separation of these minerals. Flotation of phosphate ores.
Florida “Cargo” double float process. Flotation of lanthanum (Bastnasite) ores.

(f) Flotation of soluble salts. Potash ores.
Separation of sylvite from halite in processing of Canadian sylvinite ores.
Use of insoluble long-chain primary amines as a collector. Blinders.
Typical flowsheets of Canadian plants.

(f) Processing of the Athabasca tar sands (oil sands). Oil sands deposits. Hot water flotation.
Flowsheets of oil sands processing plants.

Course notes will be provided

Title: STATE OF THE ART METALLURGICAL ACCOUNTING

Lead Instructor: Frederic Flament, Algosys
Course length: One day
Date: Monday, January 16th

Objectives

- Learn the best practices of metallurgical accounting
- Benchmark your current metallurgical accounting against best practices
- Get familiar with state-of-the art metallurgical accounting technology that can readily be implemented at your plant.

The importance of coherent material balance results has long been recognized by mining and metallurgical companies. Although this is still true nowadays, various stakeholders are increasingly concerned about the origin and the accuracy of the reported numbers.

The last decade has shown that most metallurgical accounting concerns can be addressed by making two important changes to plant performance monitoring practices. First, the migration from spreadsheet-based to relational-database-based systems brings transparency, data integrity, traceability and auditability into the metallurgical accounting. Relational databases also facilitate the production of reports that metallurgical accountants must issue routinely. Second, introducing data redundancy into the metal balance procedure allows the estimation of measurements errors. It will be shown how measurement errors affect the calculation of performance indicators such as concentrate grades and recoveries. Data redundancy also allows the detection of otherwise hidden outliers and bias. The short course will show how data redundancy can be introduced into a metal balance and appropriately dealt with.

The course will provide students with sufficient knowledge for benchmarking their own metal accounting practices against different case studies of industrial implementations of state of the art metallurgical accounting.

Outline

1. **Introduction and overview (30 minutes)**
    - Evolution of metallurgical accounting
    - Tasks included in metallurgical accounting
    - What should be expected from a state of the art metallurgical accounting system?

2. **Measurement errors: first source of metallurgical accounting issues (30 minutes)**
    - Origin of the different kinds of measurement errors
    - Introduction of a statistical framework to deal with uncertainty/measurements errors
    - Impact of such errors on KPI/process monitoring and relations with SPC (six sigma for example)
    - How to cope with those errors

3. **Metal balancing with "just enough" measurements (30 minutes)**

- n-product formula to compute a metal balance
- Issues with such metal balance computations (sensitivity analysis)
- Examples

4. **Metal balancing with a redundant data set (60 minutes)**
   - What is the redundancy in metal balancing?
   - Which benefits does it bring?
   - How to access and achieve such data redundancy?
   - Data reconciliation through mass balancing
   - Examples

5. **Tracking in-process inventories (30 minutes)**
   - Review of different inventories: tanks, bins, stockpiles, heap, etc.
   - Review of three different estimation methods
   - Best practices for in-process inventories accounting

6. **Data handling and reporting (60 minutes)**
   - Issues with common spreadsheets: second source of metallurgical accounting issues
   - Needs for a relational database based system
   - How to deal with missing values
   - Provisory data versus approved/official numbers
   - Best practices in reporting

Part II: Case studies (180 minutes)

1. Flotation plants
2. Hydrometallurgical plants
3. Gold processing plants
4. Oil sands processing plants
5. Uranium ore processing plants
6. Custom milling operations
7. Smelters
8. Managing PGMs accounts
9. Managing Mine-to-Mill Reconciliation

Part III: Wrap-up and conclusions (60 minutes)

- Synthesis of main issues and their practical solutions
- Calls for actions

Hardcopy of slides along with pens will be provided for taking notes.

Title: STATISTICAL BENCHMARK SURVEYING

Lead Instructor: Norman Owen Lotter, Ph.D., P.Eng., Pr.Eng., C.Eng., FSAIMM,
Course Length: One Day
Date: Monday, January 16th

Objectives: This course will provide a structure for the production of a representative set of concentrator flowsheet samples taken for quantitative mineralogical measurement.

Modern quantitative mineralogical measurement by QEMSCAN or MLA of representative samples taken from the operating flowsheet of a concentrator leads to powerful diagnosis of the flowsheet limitations and identification of process opportunities. The key question, of course, is whether the samples taken are representative. If not, then all of the images and data files produced are meaningless. This short course sets out a structure of a surveying approach with quality control diagnostics to assure that the set of composite samples produced by this approach are representative at the 95% confidence level. This is achieved by recognizing and managing the residual lognormality that is present in mill feed and float feed; by performing appropriate minimum sample mass experiments; by performing a semivariogram on the rougher float feed to determine the appropriate spacing of the surveys; and by performing replicate surveys to contribute to a final set of composite samples.

Outline
1. Specific Objectives
2. Requirements of the Samples to Meet the Rules of Representativity
3. The Semivariogram
4. Gy's Minimum Sample Mass Model
5. Krige's Lognormal Distribution and the External Reference Distribution
6. The Two-Hour Survey Unit
7. Replicate Survey Units and the Central Limit Theorem
8. Sichel's t-Estimator and the Internal Reference Distribution
9. Final Composite Preparation
10. Gy's Safety Line and Subsampling

Written course notes, Tutorials on Excel (per flash card), Hard copies of Power Point presentation will be provided

Each candidate MUST bring their own computer with Excel installed. They must furthermore be prepared with an electrical cable to recharge their computers.