

NATIONAL PROFESSIONAL EXAMINATIONS

DECEMBER 2014

10-Met-B1 - Mineral Processing

DURATION: 3 hours

NOTES:

- (1) This is a CLOSED BOOK EXAM. No notes or textbooks permitted.**
- (2) Candidates may use one of the approved Casio or Sharp calculators.**
- (3) Answer all questions except where otherwise noted i.e. Problem 5.**
- (4) Show all calculations.**
- (5) If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.**
- (6) Hand in page 5 with your examination booklet**
- (7) The mark distribution is as follows:**
 - Problem 1 (a) 15, (b) 6 (c) 4 Total 25**
 - Problem 2 (a) 9 (b) 6 (c) 3 (d) 2 Total 20 marks**
 - Problem 3 (a) 6 marks (b) 4 Total 10 marks**
 - Problem 4 (a) 3 (b) 2 Total 5 marks**
 - Problem 5 Five marks each Total 30 marks**
 - Problem 6 One mark each total 10 marks**
 - Bonus Question 2 marks**

Unit conversions:

1 tonne (mt) = 1000kg = 2202.6 lb
1 ton (T) = 2000 lb
1 inch = 2.54 cm = 25,400 microns (μm)

Problem 1. (25 marks)

The Highland Valley mine in South Central British Columbia is Canada's largest copper mine. Their mill treats 130,000 mtpd of ore to produce both copper and molybdenum concentrates. The average ore grade is 0.388 % Cu and 0.0089% Mo. The following description of the mill was extracted from the publication *Canadian Milling Practice*.

The pit ore is trucked to two in-pit 60 in. by 89 in. gyratory crushers. The crusher reduced the ore to -7 in. in a single pass. Crushed ore is conveyed to the mill coarse ore stockpile. The ore is reclaimed by five grinding lines. Each line is composed of a 32 ft. diameter by 15.5 ft long primary semi-autogenous mill and two 16.5 diameter and 23 ft. long secondary ball mills. The SAG mill discharge is fed to a 0.5 inch slotted screen with the oversize recycled to the SAG mill. The undersize is fed to ball mills which are operated in closed circuit with a cluster of 30-in. hydrocyclones for classification. The cyclone overflow averages 80% passing 200 microns and the ore work index is 15 kw-hr/mt

Fuel oil, potassium amyl xanthate (PAX), Dowfroth 250 and pine oil are the collectors and frothers used to produce a bulk copper-molybdenum concentrate. Lime is added to the circuit to maintain a pH of 9.2. The bulk cleaning circuit pH is maintained at 10.5.

The cyclone overflow from each grinding circuit feeds four flotation banks each with 22 Denver 600 flotation cells. Each bank is arranged as eight rougher and 14 scavenger cells. Scavenger concentrates are pumped to the head of the flotation circuit. The tailings discharge by gravity to the tailings impoundment pump house. The bulk flotation concentrates are thickened in a 125-ft diameter thickener. The underflow from the thickener is pumped to the stock tank at 60% solids. The slurry is pumped from the stock tank to a conditioner and then to the copper/molybdenum separation flotation circuit. Sodium hydrosulphide (NaHS) is used in the conditioner to depress the copper minerals. Fuel oil is added as the molybdenite collector. The circuit consists of five Denver 30 rougher cells and 13 Denver 30 scavenger cells. The scavenger concentrate is recycled and the scavenger tail is the final copper concentrate.

The molybdenum rougher concentrate is reground in a 5 ft diameter by 10-ft long ball mill. The mill is in closed circuit with five 6-in. cyclones and the overflow is upgraded in a 3 ft diameter cleaner column. The column tails are recirculated to the 125-ft thickener.

The copper concentrate is thickened to 65% solids and then to three disc filters. The filter cake is dried in a natural gas fired dryer to 7% moisture and then sent to copper concentrate storage. The copper concentrate contains 41.4 % Cu.

The molybdenum concentrate still contains 2.5 to 4% copper. To remove most of the copper the copper from the concentrate is selectively leached using ferric chloride. The leached molybdenum concentrate is then filtered and dried.

(a) Sketch the flow sheet of the Highland Valley milling circuit described above.

(b) If the tailings contain 0.033% Cu, neglecting the copper in the molybdenum concentrate calculate the tpd of copper concentrate produced.

(c) Making reasonable assumptions use Bond's equation to calculate the net power in kilowatts required for grinding the ore. List the assumptions made.

Bond's Equation:

$$W = \frac{10 W_i}{\sqrt{P}} - \frac{10 W_i}{\sqrt{F}}$$

Problem 2. (20 marks)

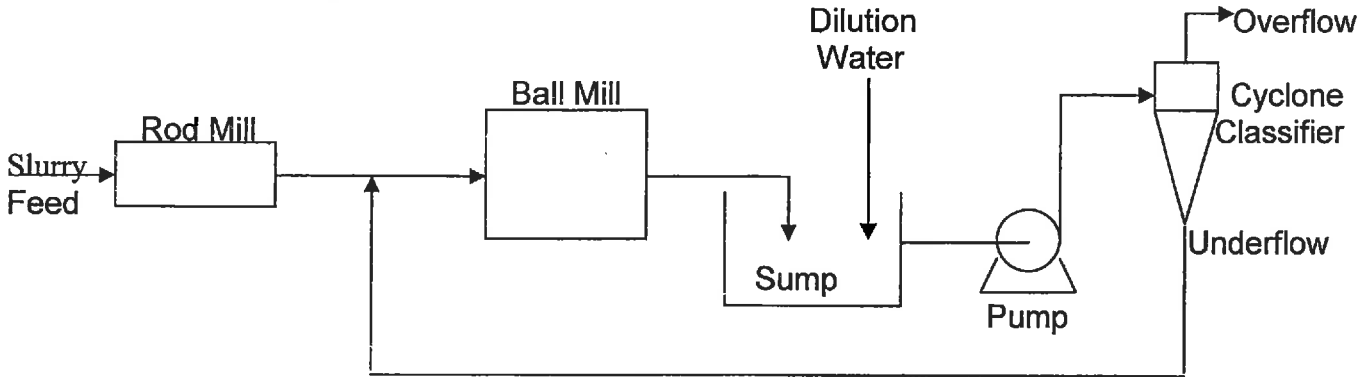


FIGURE 1. Layout of Grinding Circuit for Problem 2

A two-stage grinding circuit using a rod mill in open circuit with a ball mill in closed circuit with a cyclone classifier is used to grind 100 tons per hour of ore (SG 3.0). The circuit layout is illustrated in Figure 1 above.

Assume that the circuit was sampled and the results were as follows:

	Percent - 200 mesh	Percent solids by weight	80 % passing Size Microns
Rod Mill Discharge	5	75	3600
Ball Mill Discharge	20	75	529
Cyclone Overflow	30	40	289
Cyclone Underflow	15	75	784

- (a) Carry out a material balance and calculate the solids flowrate in
 (i) the cyclone overflow.
 (ii) the cyclone underflow. **(9 marks)**
- (b) Calculate the tons/hour of dilution water added to the sump. **(6 marks)**
- (c) Calculate the specific gravity of the cyclone underflow slurry. **(3 marks)**
- (d) List two actions a grinding circuit operator could take to product a finer product. **(2 marks)**

Problem 3. (10 marks)

$$v = \frac{g d^2 (D_s - D_f)}{18 \mu}$$

- (a) If a 100-micron diameter ore particle takes 1.5 seconds to settle one meter in water, using Stokes Equation (given above) calculate the time it would take a 10-micron diameter ore particle to settle one meter in water.
- (b) List two limitations of Stokes equation.

Problem 4. (5 marks).

A flotation kinetics test was carried out on an oil sands sample. The results were as follows:

<u>Flotation Time Minutes</u>	<u>Bitumen Recovery</u>
1	50%
12	90%
15	90%

Assuming that the flotation follows the following first order rate equation:

$$R = RI [1 - \exp(-kt)]$$

- (a) Using the available data determine the parameters RI and k.
 (b) Determine the flotation time required to achieve an 80% recovery.

Problem 5.**(30 marks).**

Using sketches describe the following terms as they apply to mineral processing. Answer any **SIX** of the following eleven topics:

Gyratory crusher	Lamella thickener
Hydrocyclone classifier	Flocculation
Jig	Frother
Zeta Potential	Xanthate
Flotation Column	Tailings dam
A size analysis technique other than sieving	

Problem 6.

10 marks

HAND IN THIS PAGE WITH YOUR EXAM BOOKLET

From the list provided, choose the word(s) which best describes the following statements:

- (a) The main lead-bearing ore mineral _____
- (b) The percentage of mineral occurring as free particles. _____
- (c) Ratio of concentrate grade to the feed grade _____
- (d) The energy consumed in size reduction is proportional to the reduction in volume of the particles concerned _____
- (e) Jaw crusher pivoted at the bottom _____
- (f) A contact angle of zero means the surface is _____
- (g) $\frac{d_{75} - d_{25}}{2}$ _____
- (h) The most abundant metal in the earth's crust _____
- (i) Common flotation activator for sphalerite _____
- (j) A concentration unit operation that uses the difference in electrical conductivity to separate minerals _____

Table	Activator	Sortex
Universal	Amine	Pulsator
Leadite	Hutch	Gaudin
Cutpoint	Bond	Zeta Potential
Ratio of concentration	Copper sulphate	Centrifuge
Flowing film concentrator	Galena	Hydrophobic
Middlings	Jig	von Rittinger
Magnetic separator	Blake	Frother
Gangue	Kick	Humphreys spiral
Hydrophilic	Tromp	Partition parameter
Imperfection	Sphalerite	SAG
Ratio of enrichment	Silica	Fatty acid
Probable error	Separation efficiency	Cyanide
Degree of liberation	Ratio of reduction	Collector
Pyrite	High tension	Floatable
Aluminum	Iron	Dodge

Bonus Question (2 marks) List two metals which currently sell for less than \$1.50/lb

_____ and _____