

NATIONAL PROFESSIONAL EXAMINATIONS

MAY 2012

09-MMP-A3 - 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 pages 5 and 6 with your examination booklet

(7) The mark distribution is as follows:

Problem 1 (a) 12, (b) 8, (c) 5, Total 25

Problem 2 (a) 2, (b) 10, (c) 3, (d) 5 Total 20 marks

Problem 3 (a) 4 (b) 2 Total 6 marks

Problem 4 (a) 3 (b) 3 Plot 3 Total 9 marks

Problem 5 Six 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 molybdenum 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)

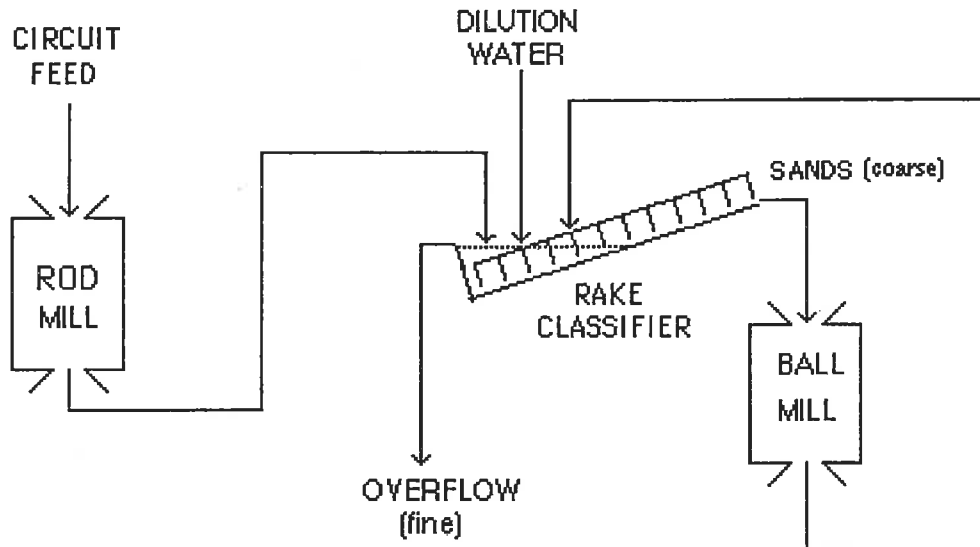


FIGURE 1. Layout of Grinding Circuit for Problem 2

A two-stage grinding circuit using a rod mill in open circuit with a ball mill in closed circuit with a rake classifier is used to grind 40 tonnes 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:

<u>Stream</u>	<u>%solids by wt</u>	<u>% - 100 microns</u>
Circuit (Rod Mill) Feed	80	5
Rod Mill Discharge	80	20
Classifier Sands (Ball Mill Feed)	75	20
Classifier Overflow	33.3	75
Ball Mill Discharge	75	47.5

Using the above data carry out a material balance and calculate the following:

- (a) the tonnes/hour of solids in the classifier overflow.
- (b) the tonnes/hour of solids in the classifier sands (coarse product).
- (c) the tonnes/hour of dilution water added to the rake classifier
- (d) the specific gravity of the ball mill discharge slurry.

Problem 3. (6 marks).

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

- (a) Using Stokes' equation (given above) calculate the diameter of gold particle (Specific gravity 19) which would settle in water at the same rate as a 40-micron diameter quartz (Specific gravity 2.65) particle settling in water.
- (b) Repeat the calculation in part (a) for both particles settling in air.

Problem 4. (9 marks). A sieve analysis was carried out on an ore and the results were as follows:

Size Microns	Weight g
+300	48
-300+150	43
-150+75	27
-75	42

Using the log-log graph paper provided on page six, plot the Cumulative Weight Percent Passing versus the Particle Size in microns. From the plot determine:

- (a) the mass median size (50% passing size) in microns
- (b) the estimated percentage of material in the -75+37 micron fraction

Problem 5. (30 marks).

Explain the similarities and differences between the following terms as they are related to mineral processing. Use sketches in your answers. **Only answer any five (5).**

- (i) Coagulation/flocculation
- (ii) Dense medium/classification cyclone
- (iii) Upstream/downstream tailings dam
- (iv) Frother/collector
- (v) Gyratory/cone crusher
- (vi) Ore/mineral
- (vii) Jig/shaking table
- (viii) Mechanical/column flotation cell
- (ix) d_{50}/d_{50c}
- (x) Rod/ball mill

Problem 6.

10 marks

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From the list provided, choose the term 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 feed to the weight of the concentrate _____
- (d) The energy consumed in size reduction is proportional to the area of the new surface produced _____
- (e) Jaw crusher pivoted at the top _____
- (f) A separation process that uses the difference in electrical conductivity between the minerals in the ore feed _____
- (g) $\frac{d_{75} - d_{25}}{2d_{50}}$ _____
- (h) Flotation reagent that alters the chemical nature of mineral surfaces so that they become hydrophobic due to the action of the collector _____
- (i) Common flotation depressant for sulphide minerals _____
- (j) The pipe extending down from the overflow of a hydrocyclone _____

Aperture
 Universal
 Plumbite
 Magnetic
 Cutpoint
 Ratio of concentration
 Contact angle
 Apex
 MIBC
 von Rittinger
 Spiral
 Imperfection
 Ratio of enrichment
 Probable error
 Degree of liberation
 Collector
 Frother
 Leadite

Activator
 Amine
 Vortex finder
 Middlings
 Bond
 Copper sulphate
 Galena
 Hutch
 Blake
 Kick
 Tromp
 Sphalerite
 Dodge
 Separation efficiency
 Ratio of reduction
 Cyanide
 High tension
 Spigot

Bonus Question (2 marks):

May 2012

In 2011 the top 10 non-petroleum mineral commodities produced in Canada in terms of value of production (in alphabetical order) were:

Cement, Copper, Coal, Diamonds, Gold, Iron Ore, Nickel, Potash, Uranium, & Zinc.

Which two of these commodities is Canada the world's leading producer?

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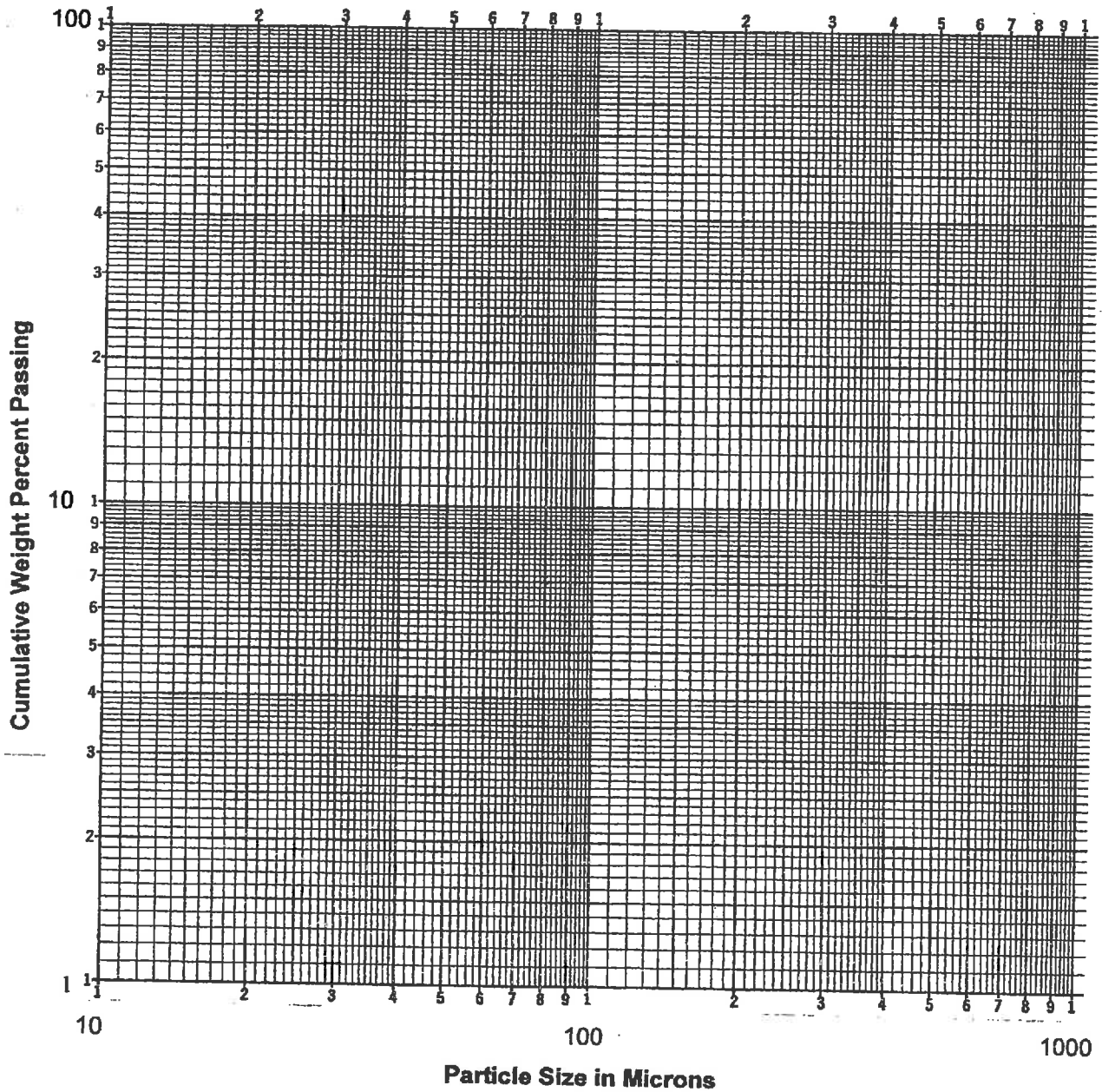


Figure 2. Size Analysis Graph for Problem 4