

NATIONAL EXAMS MAY 2013
09-MMP-85, Mill Design & Operations

3 hours duration

NOTES:

1. 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
2. This is a CLOSED BOOK EXAM.
One of two calculators is permitted, any Casio or Sharp approved models
3. ANSWER ONLY FIVE (5) QUESTIONS OUT OF SEVEN (7) asked.

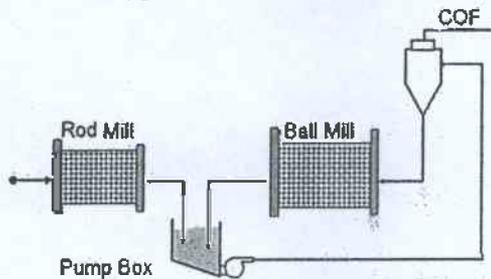
Five questions constitute a complete exam paper. You can start answering questions in the order you choose. Five best answers will be considered in your assessment

4. Each question is of equal value (20%)

- 1) The following section is intended to explore candidates' knowledge on design and operational aspects of mineral processing plants. Marking of correct choice with correct explanation provides full credit. Marking of correct choice merely with no explanation is worth only 50% of the full credit. Marking of correct choice with wrong explanation is worth only 25% of full credit. No attempt to answer or marking of wrong choice with wrong explanation is worth 0 (zero) % of full credit.
- i) The desired grizzly aperture opening for a primary crusher is equal to 80-85% of the gape of the crusher.
 - a. True
 - b. False
 - ii) For most applications on hard rock mining operations, a jaw crusher is a better selection for the design of crushing stations for an operating tonnage typically above 600 tonnes/hour.
 - a. True
 - b. False
 - iii) Autogenous mills are typically designed with large diameter : length ratio compared to conventional grinding mills.
 - a. True
 - b. False
 - iv) The ratio of length to diameter of a rod mill can exceed 1.4:1 and the length of rods can be as long as 30 feet.
 - a. True
 - b. False
 - v) Assuming other things being equal, design of a dry grinding circuit should consider 15% extra energy for application.
 - a. True
 - b. False
 - vi) Almost all wet gravity separation equipment is sensitive to the presence of slimes (i.e., minus 400 mesh). Slimes in excess of 10% cause serious separation problems.
 - a. True
 - b. False
 - vii) In general, gold processing plants (cyanidation) are designed to operate at slurry densities that are much greater than those used in flotation plants.
 - a. True
 - b. False

- viii) When designing the flotation circuit for a roughers stage, the scale-up factor for retention times obtained from bench tests is typically two.
 - a. True
 - b. False
- ix) Water addition to pump box of grinding circuits should be avoided since it increases the volumetric flowrate to hydrocyclone clusters, therefore necessitating use of greater number of units.
 - a. True
 - b. False
- x) Hydrophobicity is the most important parameter in operation of sink-float circuits for separation of minerals such as cassiterite (SnO_2).
 - a. True
 - b. False

2) A Rod Mill (RM) - Ball Mill (BM) grinding circuit was commissioned to process a blend of ores from the following zones with corresponding work index (W_i) values for each ore type:



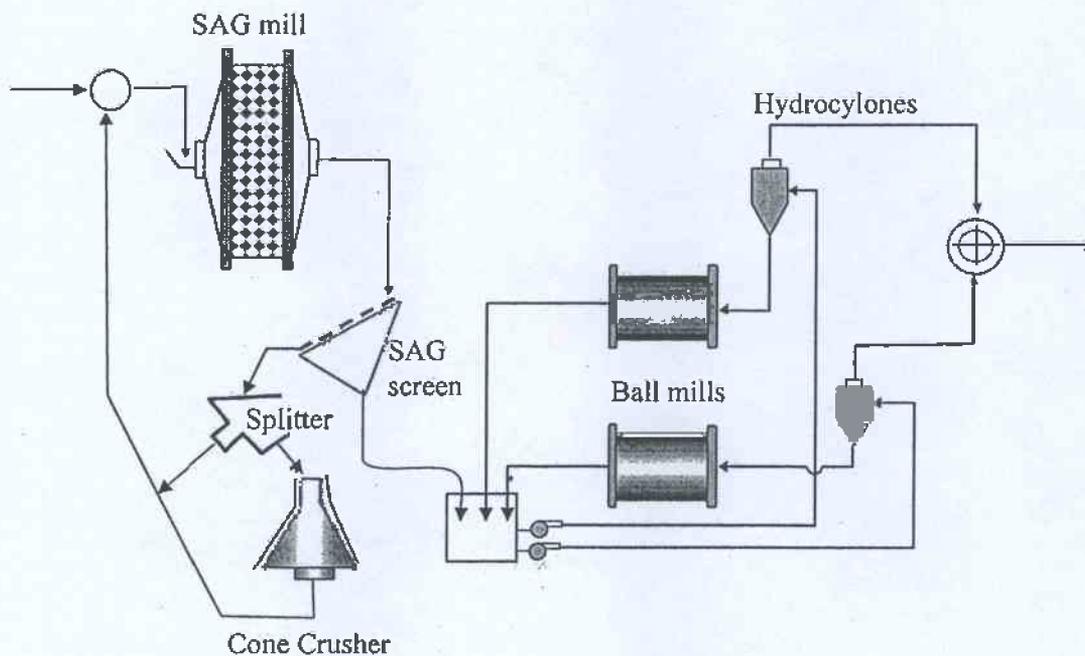
Ore type	% weight	W_i (kWh/tonne)	
		Rod Mill	Ball Mill
East Zone	25.0	16.0	15.0
West Zone	35.0	14.0	13.5
North Zone	40.0	11.0	10.0

The circuit receives 250 tonnes of blended ore per hour with an F_{80} value of 1.2 cm. Steady state operating work index (W_{io}) values for the rod mill and ball mill were found to be 12.0 and 9.61 kWh/tonne, when their power draws were 500 kW and 1250 kW, respectively.

- a) What is the work index efficiency of the RM and BM (as defined by Rowland, i.e., $W_i \cdot 100 / W_{io}$) and reduction ratio of the rod mill?
- b) If this circuit treats ore only from the North zone for a period of time what would be the new tonnage to be ground in the RM at an F_{80} value of 1.0 cm under same operating conditions of the work index efficiency (i.e., the same power draw producing the same P_{80} value)?

3) A concentrator processes 25,000 tonne per day (tpd) of ore in its SABC circuit shown below. The function of cone crusher is to reduce the amount of pebbles fraction that tends to build-up in the circulating load. When the operator notices the SAG mill power draw increasing beyond a certain limit, he diverts the circulating load to the cone-crusher. The frequency of its use averages 60%. Considering the design criteria listed and options of cone crushers below:

- a) Select the size and number of cone crusher(s) that can be recommended for this SABC circuit, according to capacity and power requirements.



Operating and design parameters:

Ore Tonnage:	25,000 tpd
Circulating load (SAG circuit):	30 %
Availability (SAG mill & Crusher):	93 %
Cone Crusher discharge set, CSS (R):	1 cm
Cone Crusher feed, 80% passing:	6.5 cm
Frequency of cone crusher use:	60%
Work index, W_{ic} :	17 kwh/t (safety factor included)

Cone Crusher power data along with capacity (tonne/h) at various discharge settings (R, i.e., css, closed side setting)

Crusher Size (ft)	Power (Typical kW)	CSS Discharge setting, R given from 6-16 in mm			
		6	10	13	16
4	120	50	75	100	120
6	160	95	130	175	200
7	280	140	230	300	350

Particle size, cumulative % passing, x	Cone Crusher
	100(x/R)
25	65
50	105
75	150
80	162
85	175
90	205
95	240
100	340

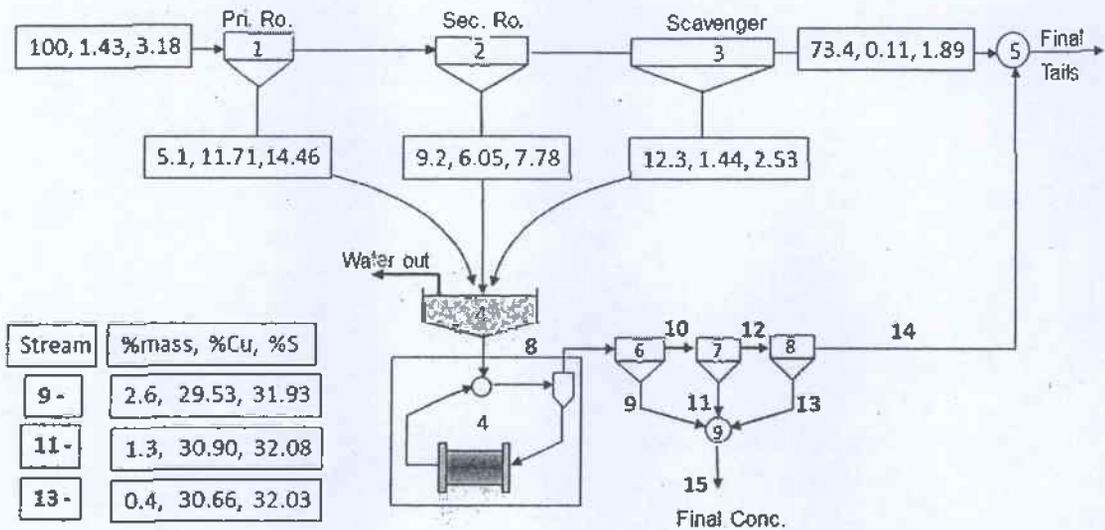
Hint: For a given size of crusher, R (crusher set size) affects both the capacity (as shown in the table above) as well as the product size granulometry given the table left by values of $100(x/R)$. Your selection should meet both the capacity requirement as well as the power requirement.

- b) What is the current cost of this crusher according to the approach by Mular & Poulin, i.e., $\text{cost} = aX^b$, where X is the equipment parameter (i.e., mantle diameter of the cone-crusher in ft). Use the Marshall & Swift Equipment Cost Index of 1675 as current.

$$a = 30010$$

$$b = 1.7 \text{ [both given according to M \& S index of 1400 in Mular \& Poulin]}$$

- 4) Column flotation is used throughout the mining industries with a broad range of applications in processing of ores. Write a short essay on column flotation, one that provides answers to the following specific questions.
- How they are different from conventional flotation machines, what are the main design features
 - What are advantages and disadvantages for certain applications
 - Where are they typically used in mineral process flowsheets
 - What is meant by "bias", "gas hold-up", "superficial velocity" in column operation flotation.
 - Draw a 2-stage column-conventional cell circuit arrangement, state the function of the latter
 - What types of mechanisms are used for introduction of air
 - What is the typical froth depth used in columns
- 5) A process flowsheet for a relatively high grade simple copper ore has been piloted according to the configuration below, which shows some output of a steady state mass balance. The numbers in each case denote % mass, % Cu and % S, respectively. A commercial plant will be designed to treat 10,000 tonne ore per day (TPD).
- Calculate & tabulate cumulative copper grade and recovery for the roughers-scavengers and cleaning sections in the flowsheet.



b) How many cells will be required for the cleaning stages as a whole, considering the following criteria for this 10,000 TPD plant.

	Cleaners as a whole
Slurry densities (% solids, wt.)	35
Solids (specific gravities)	3.4
Retention times (minutes)	15
Unit cell volumes (m ³)	10
Plant (circuit availability, %)	95

Use 1.2 as a multiplier for volumes to account for air and agitator.

6) Hydrocyclones are useful for a number of objectives in mineral processing operations. Examples include particle size control in grinding circuits, desliming of slime-sensitive process streams and preparation of tailings for backfill operations.

- Suppose that a concentrator typically processes a stream containing 60% (wt.) minus 200 mesh (74 μm) material to satisfy their liberation requirements. Determine the D_{50c} value (μm) of hydrocyclone to meet this objective.
- For a D_{50c} of 150 mesh (100 μm), estimate the particle size (in μm) in the cyclone overflow for 80% passing.
- It is desired to design to a hydrocyclone circuit to remove 98.8% of the minus 400 mesh (37 μm) particles from a clayey slurry of gravity-separation circuit feed flowing at 45 liters/s at a density of 20% solids (by vol.). The dry solids have an effective density of 2.82. A pressure drop of 140 kPa will be used. Determine the size and number of the hydrocyclones that will be needed make the desired size split.

Estimate the cost of the total number of hydrocyclones to be installed using the following data, where D is equipment parameter in inches.:

$$\left. \begin{array}{l} a = 3969 \\ b = 0.5782 \end{array} \right\} \text{ for D from } \\ \text{4 to 12 inches}$$

$$\left. \begin{array}{l} a = 103.5 \\ b = 1.684 \end{array} \right\} \text{ for D from } \\ \text{12 to 24 inches}$$

- 7) The following question on process control has two parts. The first part (a) explores your general knowledge on the topic.
- a) Write a short essay on process control objectives and strategies and their importance in mineral processing, specifically grinding circuit control. What are the most commonly used controlled variables and manipulated variables applicable here? What does the acronym DCS stand for in an operating plant? What does the acronym PID stand for?
 - b) Your answer to this second part should briefly cover the following points about pH control in a flotation process that is sensitive to pH by both alkali and acid addition:
 - i) Sketch of a block diagram showing its main elements.
 - ii) Brief definition of the terminology used.
 - iii) Main types of feedforward/feedback control systems in use
 - iv) Their main advantages
 - v) Disadvantages

Comments & Useful information:

Questions 2 & 3 require use of the Bond equation for power estimation, i.e.;

$$W = W_i * \left(\frac{10}{\sqrt{P_{80}}} - \frac{10}{\sqrt{F_{80}}} \right)$$

W_i estimated under operating circuit conditions becomes W_{io} .

Question 6 is about hydrocyclone sizing (Krebs approach), involving the use of the following equation; $D50_C$ (application) = $D50_C$ (base) * $C_1 * C_2 * C_3$. Consider the following correction factors, data etc.

$$C_1 = \left[\frac{(53-V)}{53} \right]^{1.43} \quad \text{(You are expected to be familiar with meaning of symbols)}$$

$$C_2 = 3.27 * \Delta P^{-0.28}$$

$$C_3 = [1.65/G_S - G_L]^{0.5}$$

$$D50_C \text{ (base)} = 2.84 * D^{0.66}, \quad D \text{ (in cm)}$$

1 inch = 2.54 cm

Relationship of $D50_C$ to overflow size distribution

Required Overflow Size Distribution (% passing) of specified Micron Size	Multiplier - To Be Multiplied (Times Micron Size)
98.8	0.54
95.0	0.73
90.0	0.91
80.0	1.25
70.0	1.67
60.0	2.08
50.0	2.78

Example: Produce an overflow of 80% passing 149 microns (100 mesh). Multiplier from the Table above at 80% passing = 1.25. Micron size for application = 149 microns (100 mesh). $D50_C$ required = $1.25 * 149 = 186$ microns for application.

