National Exams December 2012

09-MMP-B5, 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 with some helpful comments and useful information. 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%).
5. Candidates are allowed to bring ONE aid sheet 8.5" x 11" hand-written on both sides containing notes and formulae.

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 95% 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 below 500 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 should not exceed 1.4:1 and the maximum length of a rod is typically 20 feet.

   a. True
   b. False

v) Assuming other things being equal, design of a dry grinding circuit should consider 10% 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 scavenger stage, the scale-up factor for flotation retention times obtained from bench tests is typically greater than 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) When designing the thickeners required for a concentrator, the scale-up factor from bench testing is approximately 1.1.

a. True
b. False

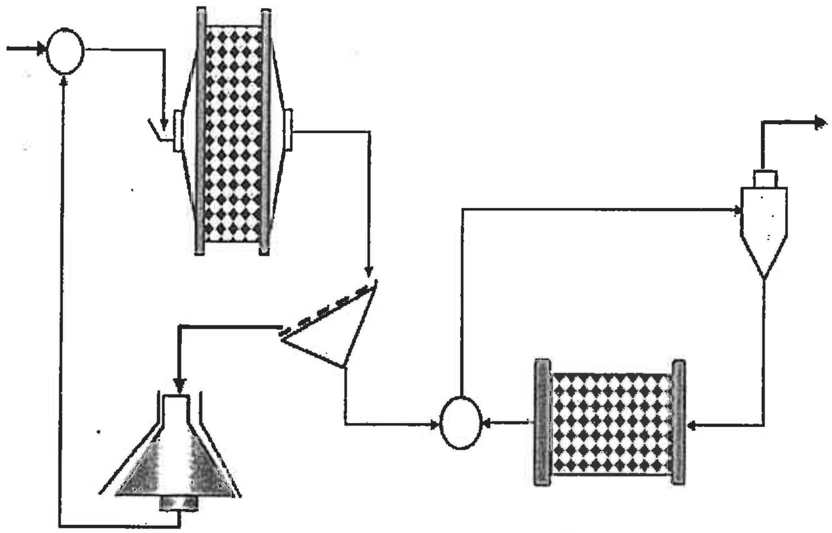
2) A base metal sulphide ore is ground using a rod mill-ball mil combination at an overall tonnage of 900 tonne/h (feeding three parallel lines) from a feed size (F_{80}) of 1 cm to a product size (P_{80}) of 100 mesh (150 microns). Under such conditions, this circuit has a specific power consumption of 8.60 kWh/tonne of ore ground. However, later on, ore changes as it is mined from deeper levels. This change in ore causes the recovery levels to decrease. Because of the changing nature of the ore with increased depth of mining, the metallurgical recovery can only be maintained by finer grinding. Test work has indicated that by crushing the feed to an F_{80} of 0.5 cm for the Rod mill-Ball mill circuit and grinding it further in this circuit to a product size (P_{80}) of 270 mesh (54 microns), recoveries will be satisfactory.

a) Calculate the Bond work index value for this circuit under operating conditions specified and estimate the overall installed power required for 300 tonne/h ore processed at each operating line (assume a safety factor of 1.2 to cover for all inefficiencies).

b) What would be the new tonnage to maintain recoveries when the ore is ground to 54 microns, assuming that operating work index determined in the previous step is applicable to new conditions?

3) A concentrator processes 14,000 mtpd of ore in its grinding facility consisting of a SAG/Ball mill combination. Because of a recent increase in hardness of the ore processed, the amount of critical size particles (pebbles) in the circulating load of the SAG mill has indicated a significant increase. In order to avoid a possibility of overloading conditions, the management decides to introduce cone crusher unit(s) to treat this stream. The critical size particles consisted of relatively hard fraction of the ore with an average work index, Wi, of 22 kWh per tonne. Out of the three options shown below:

a) Select the size and number of short head cone crusher(s) that can be recommended for this SAG circuit. What would be the appropriate discharge opening (i.e., set size, see hint below) acceptable for this selection (you may specify it as a range too)?



Operating and design parameters:

Ore Tonnage:	14,000 mtpd
Circulating load (SAG circuit):	30 %
Availability (SAG mill & Crusher):	95 %
Crusher product size, 80% passing:	1.85 cm
Crusher feed, 80% passing:	4.75 cm
Work index, W_{iC}:	22 kwh/t (safety factor included)

Short Head Symons crusher power data along with capacity (tonne/h) at various discharge settings (s, or R meaning the same thing, i.e., css, closed side setting)

Crusher Size	Power	Discharge setting, s = R given from 6-16 in mm			
D (cm)/G (cm)	Typical kW	6	10	13	16
120 / 7	110	45	70	90	110
175 / 9	150	90	125	160	190
210 / 11	220	135	225	270	330

Particle size, cumulative % passing, x	Short Head Cone Crusher	
	100(x/R)	
	Hard	Medium Hard
25	84	47
50	125	93
75	170	136
80	185	146
85	200	156
90	235	183
95	270	210
100	380	290

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., cost = aX^b, where X is the equipment parameter (use Marshall & Swift Equipment Cost Index: 1675 as current)

$a = 110.3$
$b = 1.079$ [both given according to M & S index of 1400 in Mular & Poulin]

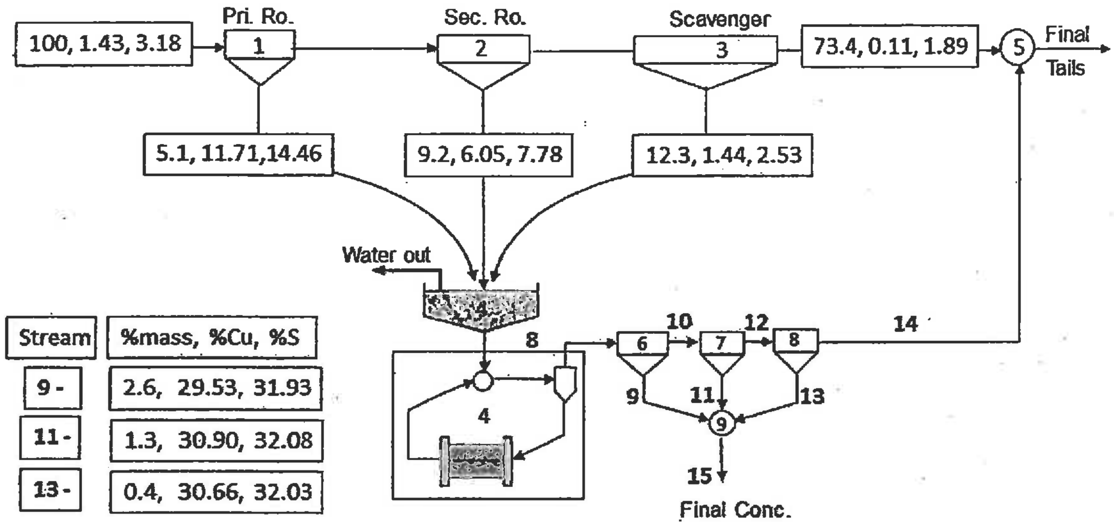
4) Column flotation is used throughout the mining industries with a broad range of applications in processing of ores. Write a short essay on column flotation, one that provides answers to the following specific questions.

a. How they are different from conventional flotation machines, what are the main design features
b. What are advantages and disadvantages for certain applications
c. Where are they typically used in mineral process flowsheets
d. What is meant by "bias", "gas hold-up", "superficial velocity"
e. Draw a 2-stage column-conventional cell circuit arrangement, state the function of the latter
f. What types of mechanisms are used for introduction of air
g. What is the typical froth depth used in columns
h. How process control is achieved in general terms. Name two process control aids (sensors or mechanisms) that can be utilized for froth depth control

(Note: qualitative description of the froth depth control will be considered as a bonus)

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).

a) Calculate & tabulate cumulative copper grade and recovery for the individual stages of roughers-scavengers and cleaning sections in the flowsheet.



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

	Primary Roughers	Cleaners as a whole
Slurry densities (% solids, wt.)	40	35
Solids (specific gravities)	2.7	3.4
Retention times (minutes)	8	15
Unit cell volumes (m^3)	25	10
Plant (circuit availability, %)	95	95

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

6) Find out classification requirements for the grinding circuit preparing feed to the cleaning stage given in question 5, considering the following design and operating criteria:

Feed to cleaners (cyclone overflow)	117 tonnes/h
Average dry S.G. (assume it to be equal for both overflow and underflow)	3.4
Circulating load ratio	2.45
Target particle size, K_{80}	40 μm
Hydrocyclone overflow density	35% solids (wt.)
Hydrocyclone underflow density	70% solids (wt.)
Operating pressure	75 kPa

a) What size hydrocyclone can you recommend for this circuit?

b) How many units are needed (assume 30 percent as stand-by) and what is the total cost?

Use the following data for cost estimation, where D is equipment parameter in inches.:

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

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

Note: This question is to be handled independent of question 6 as it does not require any other information.

7) i) A supplier of second hand mineral process equipment salvaged the following types of equipment from a concentrator which was operated 12 years before closing down 6 years ago due to depleting ore reserves and low metal prices at that time. The supplier paid 30% of the original price for each item listed and spent 600,000 USD for dismantling and maintenance program, which involved replacement of motors and liners in some cases. He is expecting to make a profit by selling the equipment at a price corresponding to 50% of the current level.

Cost of each item can be estimated using the following form of equation, Price = $a(X)^b$

Number of units	Equipment type and size designation	Equipment parameter, X	Cost equation parameters	
			a	b
1	Vibrating grizzly (W=36", L= 60")	W^2*L	2543	0.556
1	Jaw crusher (W = 48", L = 42")	W*L	110.3	1.079
2	Standard cone crusher (D = 5 ft)	D	25070	1.756
2	Short-head cone crusher (D = 7 ft)	D	30010	1.700

(Note: In the price equation above, cost parameters "a, b" given are all for an M & S value of 1400)

Assuming that the M & S index is now about 1675 compared to 1000 at the time of construction of the old plant, estimate the approximate original price of each item and estimate the overall profit that can potentially be made by the process equipment supplier.

ii) In 2001, a 40,000 tonne/day concentrator could be built for $5,300 / tonne/day. In recent years, cost indices indicated significant increases. Currently, M & S is estimated to be around 1675. Using the "six-tenths rule" and the M & S Equipment Cost Index data, estimate the current cost of a 60,000 tonne/day concentrator. M & S Index (2001):1131; M & S Index (Current): 1675.

Comments & Useful information:

Questions 2 & 3 require use of the Bond equation for power estimation which you are expected to know.

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.

$C_1 = [(53-V)/53]^{-1.43}$
$C_2 = 3.27 * \Delta P^{-0.28}$
$C_3 = [1.65/G_S - G_L]^{0.5}$

(You are expected to be familiar with meaning of symbols)

$D50_C$ (base) = $2.84 * D^{0.66}$, D (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 = l.25x149 = 186 microns for application.