National Exams December 2010

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 (See pages 7 & 8). A Casio or Sharp approved calculator is permitted.

3. ANSWER ONLY FIVE (5) QUESTIONS OUT OF SEVEN (7) ASKED.

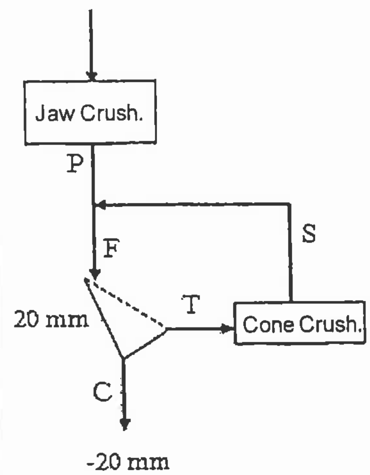
   Five questions constitute a complete exam paper. You can start answering questions in the order you choose. Five best answers will be considered in your assessment

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

Answer three (3) out of the following four (4) questions:

1) Suppose that the following table shows results of a simulation on a jaw crusher/cone crusher circuit based on some pilot plant work. On this basis, the flowsheet shown below is to be designed to produce 250 tonnes minus 20 mm material per hour.

Screen size	Feed, f	U/S, c	O/S, t
(mm)	Cum pass.	Cum pass.	Cum pass.
87.2	99.88	100	99.77
83.1	99.24	100	98.51
77.0	97.81	100	95.64
70.8	95.71	100	91.64
64.7	93.10	100	86.29
58.5	90.09	100	80.36
49.0	86.62	100	73.56
44.1	81.28	100	64.80
36.2	74.09	100	50.78
30.0	65.06	100	33.08
27.2	59.75	100	22.62
24.0	54.03	98.8	12.52
20.0	47.97	90.23	8.92
17.0	41.85	79.73	7.02
13.6	35.34	67.40	6.32
10.5	29.48	54.76	5.62
7.3	22.83	41.96	4.92
4.5	16.22	29.24	4.22



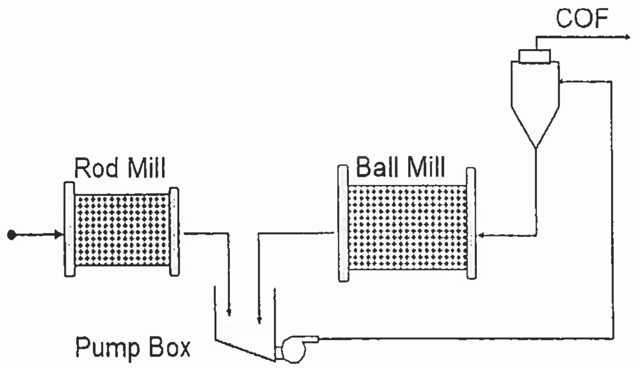
The small case letters in the table show percentage of cumulative passing size, while the capital letters on the flowsheet denote corresponding tonnage. Using the average of 30 mm, 24 mm, and 17 mm cumulative screen data, calculate

a) The tonnage of screen oversize (i.e., circulating load) as feed to the cone-crusher.

b) Assume that at the desirable closed side setting, the cone-crusher can reduce the screen oversize to a level where 80% size (P_{80}) is 19 mm. The work index for crushing is 16.3 kWh/tonne (which includes the safety factor). Which one of the cone-crusher sizes listed below satisfies both power and capacity requirement? (State your assumptions, if any).

	Size (D, cm/G, cm)	Unit Power (kW)	Unit Capacity (Tonne/h)
(1)	130 / 20	100	130
(2)	175 / 22	140	190
(3)	210 / 30	200	300

2) Estimate the power required to grind 100 Tonne/h ore in a ball mill operating in closed circuit with hydrocyclones at a circulating load of 300%. Rod mill discharge has a P_{80} of 0.25". Flotation feed size required corresponds to 80% -65 mesh (212 microns). The Bond work index, $W_{BM}i$ is determined to be 14.7 kWh/Tonne. For simplicity, consider the product of all efficiency/inefficiency factors (EF) for power estimation to be equal to 1 and add 10% extra for drive efficiency.

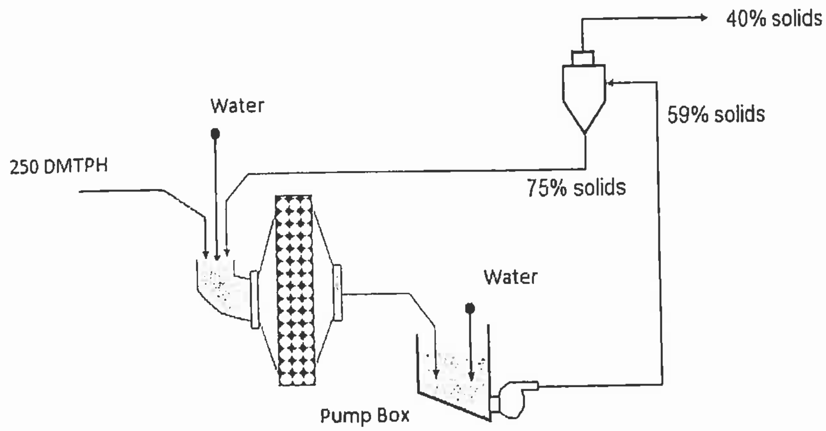


What size ball mill is necessary based on the use of the following table?

Your selection should specify the HP requirement as well as the diameter and length of the ball mill that should conform to industry standard on the length to diameter (L/D) ratio, typically of 1.3-1.4. Also consider that the selected mill is to be operated as an overflow type of discharge with a volumetric charge loading of 40% (state your assumptions, if any). For your selection, refer to the following table, where Mill Power is given in HP (1 kW = 1.34 HP).

				Mill Power							
				Overflow Disch.			Grate Disch.			Dia (D) Inside New Liners	
Ball Mill Diameter		Ball Mill Length		% Volumetric Loading			% Volumetric Loading				
M	FT	M	FT	35	40	45	35	40	45	M	FT
3.35	11.0	3.35	11.0	610	649	676	708	753	784	3.17	10.4
3.51	11.5	3.35	11.0	674	718	747	782	832	867	3.32	10.9
3.66	12.0	3.66	12.0	812	864	900	942	1003	1044	3.47	11.4
3.81	12.5	3.66	12.0	896	954	993	1040	1106	1152	3.63	11.9
3.96	13.0	3.96	13.0	1063	1130	1177	1233	1311	1365	3.78	12.4
4.12	13.5	3.96	13.0	1189	1266	1321	1379	1469	1532	3.93	12.9
4.27	14.0	4.27	14.0	1375	1464	1527	1595	1699	1771	4.08	13.4
4.42	14.5	4.27	14.0	1492	1588	1656	1730	1842	1921	4.24	13.9
4.57	15.0	4.57	15.0	1707	1817	1893	1980	2107	2196	4.39	14.4

3) An ore is found amenable for grinding in a SAG mill operated in closed circuit with hydrocyclones. The mass flow (dry metric tonnes per hour, DMTPH) and densities (% solids by weight) are marked on the flowsheet below.

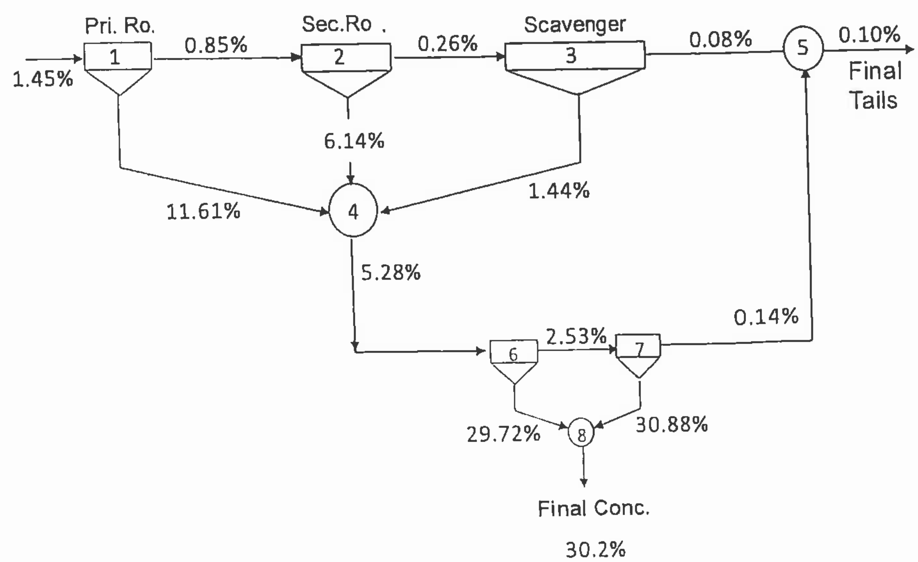


a) Operators maintain a ratio of 5 between water addition to pump box and that to the mill. How much water addition (m^3/h) is needed at each addition point to operate this circuit to maintain the densities at their indicated optimum levels.

b) Calculate the circulating load ratio of dry solids.

c) Select the proper size and numbers of hydrocyclones for this circuit considering the following additional design criteria: Specific gravity (S.G.) = 2.9, the operating pressure (ΔP) = 50 kPa and D_{50} of 154 μm provides adequate liberation for the separation stage.

4) Treatment of a relatively high grade porphyry copper ore has been piloted according to the flowsheet shown below. Copper assays obtained under steady state conditions are as marked.



a) Estimate the <u>cumulative grade-recovery performance</u> for this flowsheet (Show data for both Roughers-Scavenger and cleaners). You may sketch a graph showing relative positions of 5 data points needed.

b) Estimate the volumetric flow into the scavenger section and determine how many units of 17 m^3 cells are required for this stage considering the following criteria (state your assumptions, if any).

Plant Feed:	10,000 Tonne/day
Availability:	90%
Specific gravity:	2.80
Scav. Feed Density:	36.0% Solids by weight
Gas hold-up:	15% (vol.)
Volume occupied by agitator shaft and impeller	5% (vol.)

Retention time for scavengers: 9 min.

<u>Answer two (2) out of the following three (3) questions</u>:

5) Particle size reduction is a crucial step in mineral processing as it is an energy demanding process making a major contribution to overall capital and operating costs. Therefore, the design and selection of grinding circuits is highly important.

a) Draw a simplified version of an ABC circuit and label all units involved. What do these letters specifically refer to? State the objective of having the unit 'C' in this circuit. Name an alternate method by which the same objective can be attained.

b) A new trend in mineral processing flowsheet design relates to use of HPGR technology. What is it? Describe how it works with a simplified diagram illustrating its essential elements. What are the proposed advantages in using it? What does it compete with? What can it potentially replace?

6) 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? Comment on its main components.

   b) Your answer to this second part should briefly cover the following points about feedback control method:

      i) Sketch of a block diagram showing its main elements.
      ii) Brief definition of the terminology used.
      iii) Main types of feedback control systems in use
      iv) Its main advantages
      v) Disadvantages

7) The cost of equipment for an old Cu-Ni sulphide ore processing plant treating 6,000 tonne/day indicated the following (in 2004 US dollars, M&S index: 1233).

	2004 USD
Crushers	1,971,800
Grinding Mills	4,107,918
Cu Flotation Conc.	1,780,098
Ni-Cu Flotation Conc.	3,012,473
Auxiliary equipment	1,861,132

   a) Another company wants to build a new plant in the same location to process a similar ore at 9,000 Tonnes/day. In a separate column above estimate the cost of each major item for the new plant for the current year (i.e., 2010, M & S index 1561) using the six-tenth rule.

   b) Assuming that the cost of possible other equipment items is absorbed in the total purchased equipment cost (i) according to above, prepare a table showing breakdown of the total capital cost into the following components. What is the total capital investment?

      ii) Process equipment installed cost (suggested multiplier, i.e., SM: 1.43)
      iii) Process piping/material & installation cost (SM: 0.10)
      iv) Instrumentation/control, material & installation (SM: 0.03)
      v) Buildings and Site Development (SM: 0.35)
      vi) Auxiliaries (e.g., water supply, tailing disposal etc.) (SM: 0.10)
      vii) Outside lines (SM: 0.08)
      viii) Total physical plant costs
      ix) Engineering and construction (SM: 0.25)
      x) Contingency (SM: 0.10)
      xi) Size factor (SM: 0.05)
      xii) Fixed capital costs
      xiii) Working capital (SM: 0.12)

Comments & Useful information:

Question 1a requires knowledge on mass split using particle size as the ingredient. If you don't remember the related formula for it, you can derive it on the basis of two-product mass balance considerations.

Question 2 (as well as part of Q1) requires the Bond equation for power estimation which you are expected to know.

Question 3 requires knowledge on water- solid balancing based on density data provided. In order to get circulating load, you can also consider a hydrocyclone as a device for concentrating solids to the underflow. You should make use of the following information for hydrocyclone sizing.

$D50_C$ (application) = $D50_C$ (base) $\cdot C_1 \cdot C_2 \cdot C_3$

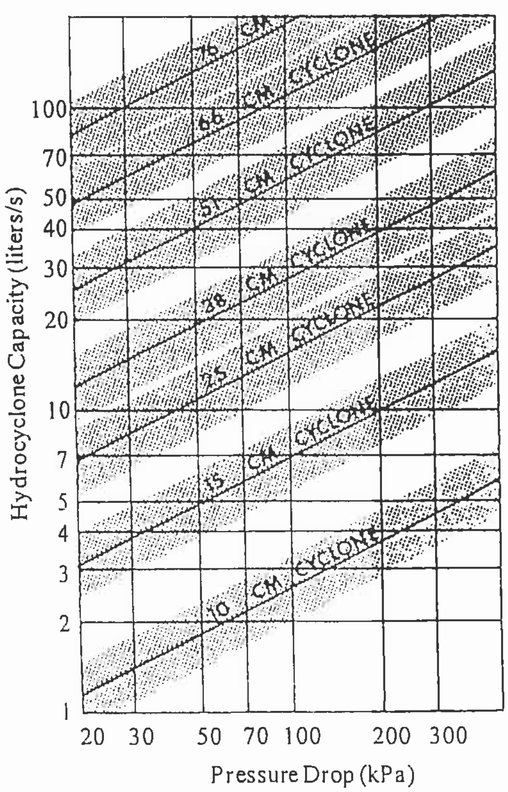
$C_1 = [(53-V)/53]^{-1.43}$

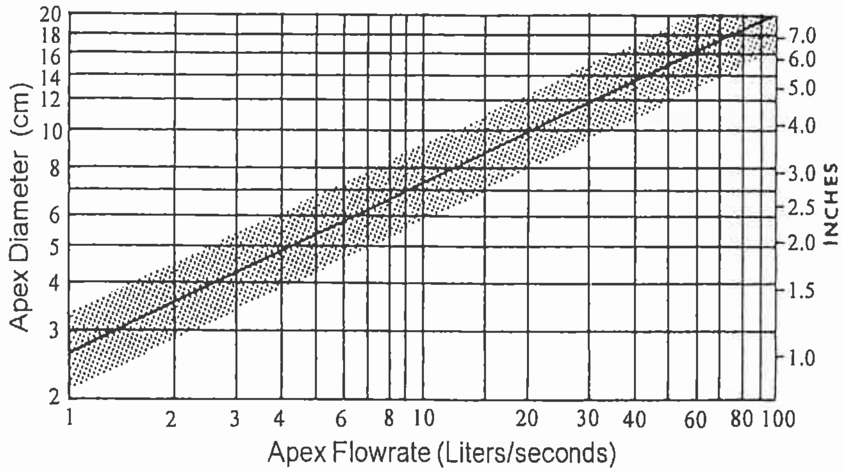
$C_2 = 3.27 \cdot \Delta P^{-0.28}$

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

$D50_C$ (base) $= 2.84 \cdot D^{0.66}$, D (in cm)   1 inch = 2.54 cm

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





Question 4 requires knowledge on mass balancing, specifically mass split using metal assays as the ingredient as well as recovery formulas which you are expected to know.

Question 7 requires basic knowledge on preliminary cost estimation methods and certain rules compiled by Mular & Poulin (1998, CIM Special Volume 47), e.g.,

$Cost_1/Cost_2 = (Capacity_1 / Capacity_2)^{0.6}$

In the question regarding cost breakdown, suggested multipliers (SM) are given in the brackets. However, you are expected to be familiar with basic definitions and concepts, e.g., as to where these multipliers are applicable and how to estimate an updated cost.