National Exams May 2019

09-MMP-B5, Mill Design and 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.

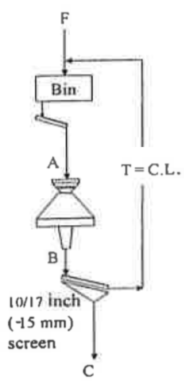
2. This is a CLOSED BOOK EXAM. However, some helpful comments and useful information are provided at the end. One of two calculators is permitted, any Casio or Sharp approved models.

3. ANSWER ONLY SIX (6) QUESTIONS OUT OF EIGHT (8) ASKED.

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

4. Each question is of equal value (16.7%).

1) **A** sample of ore from an industrial crushing plant (point C in the diagram) was received for testing in a lab. The sample indicated the following size distribution representing the material passing the screen (with 15 mm aperture size). The crusher in this circuit is a short head (SH) cone crusher, which can be operated at various closed side settings (css) depending on process requirements. Consider that screen efficiency is expressed as the amount of material recovered in the screen undersize relative to the amount feeding the screen. Estimated size distribution of the discharge at the operating css is tabulated below.



Circuit product

Size (mm)	% Cum. passing
0.5	31.3
2.0	46.3
4.0	59.0
6.0	67.1
7.5	74.2
9.0	85.3
12.0	92.9
15.0	99.2
20.0	100.0
24.4	100.0
30.0	100.0

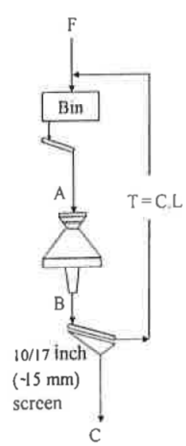
SH Cone Crusher discharge

Size (mm)	% Cum. Passing
0.5	0.0
2.0	0.0
4.0	0.0
6.0	10.5
7.5	18.2
9.0	25.5
12.0	39.0
15.0	51.0
20.0	68.1
24.4	80.1
30.0	91.3

a) Tabulate the size distribution of the circuit product according to logarithmic representation on both axes (i.e.,Gates-Gaudin-Schuhmann model) using the data at points; 2/46.3, 6/67.1, 9/85.3, 15/99.2 and plot the data on the graph paper provided indicating (qualitatively or quantitatively) the distribution modulus and size modulus as typical of this sample.

b) If the screening efficiency is 90%, what is the operating circulating load in percentage (stream T in the diagram above) in this circuit through the intermediate ore bin?

2) The ore processed in the circuit above is in the hard ore category corresponding to a crushability Bond Work index of 16.3 kWh/tonne. Assume in this case the circulating load to be 130% and refer to the related table below (2nd table following) showing unit power and capacity for various size of crushers. Estimated size distribution of the product from the cone crusher is given in the



SH Cone Crusher discharge

Size (mm)	% Cum. passing
0.5	0.0
2.0	0.0
4.0	0.0
6.0	10.5
7.5	18.2
9.0	25.5
12.0	39.0
15.0	51.0
20.0	68.1
24.4	80.1
30.0	91.3
34.5	97.2

table above. The ore tonnage processed is 9,000 tonne/day. The crushing circuit availability is 82%.

Typical unit power and capacity of various sizes of short head cone crushers

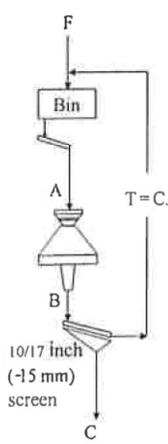
*D / G (cm/cm)	kW	T (Tonne/h)
120 / 6 -8	110	100
175 / 8 -11	150	150
210 / 9 -13	220	270

*D is cone diameter, G is the gape (mouth)

a) If the reduction ratio of the short head cone crusher(s) is 3.5, what would be the required crusher size and number of short head crusher(s) needed for this crushing circuit, both according to power and capacity criteria?

b) Assuming an M&S index of 1,800 as current, determine the preliminary cost of selected crusher(s), where D is equipment parameter X in (feet) in the generic cost equation with the following multiplier and exponents compiled based on an M&S index of 1,400. (a = 30010, b = 1.70)

3) Suppose that a single deck vibrating screen is required for the crushing circuit considered in Section 2. Suppose that the treatment tonnage per day and equipment availability are 9,000 tonne and 82%, respectively). The short head cone crusher discharge becomes the screen feed. The



SH Cone Crusher discharge

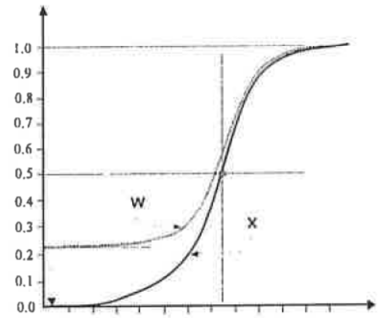
Size (mm)	% Cum. passing
0.5	0.0
2.0	0.0
4.0	0.0
6.0	10.5
7.5	18.2
9.0	25.5
12.0	39.0
15.0	51.0
20.0	68.1
24.4	80.1
30.0	91.3
34.5	97.2

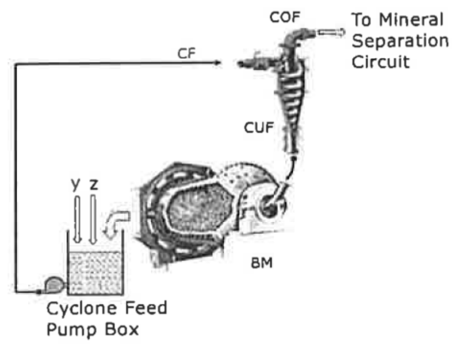
circulating load is 130%. Assume that ore related characteristics in terms of bulk density, moisture and particle shape factor all add up to a coefficient of 1.18. Using the charts and information given in the appendix:

a) Determine the net surface area (with a safety factor of 20%) and appropriate dimensions of the screen.

b) Determine a preliminary current cost for the screen(s) selected (based on 1:1 ratio with the short head cone crusher(s) for operating flexibility (a = 2033, b = 0.5172).

4) 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. The followings represent typical performance curve(s) based on a steady state operation and a grinding circuit, where hydrocyclones have the most common applications.





a) What are the three main characteristics that we learn from a hydrocyclone performance curve? Indicate what the vertical and horizontal axes are. Label w, x, y, and z in the diagrams above. What are the three types of flow pattern from a hydrocyclone underflow that an operator can observe?

b) Describe why and how particle size is controlled in a ball mill circuit in 4-5 sentences. If the slurry densities around a hydrocyclone (in % solids, wt.) are 40% (COF), 60% (CF) and 75% (CUF), what is the solids recovery to underflow and circulating load ratio?

5) A supplier of second hand mineral process equipment salvaged the following types of equipment from a concentrator which was operated 10 years before closing down 3 years ago due to depleting ore reserves and low metal prices at that time. The supplier paid 40% of the original price for each item listed and spent a total of 1,109,570 USD for dismantling, and repair/improvement program on these two types of equipment. He is expecting to make a profit by selling the equipment at a price corresponding to 60% of the current level.

i- Two 54" by 74" Gyratory crusher
ii- Four 7 ft Standard cone crushers

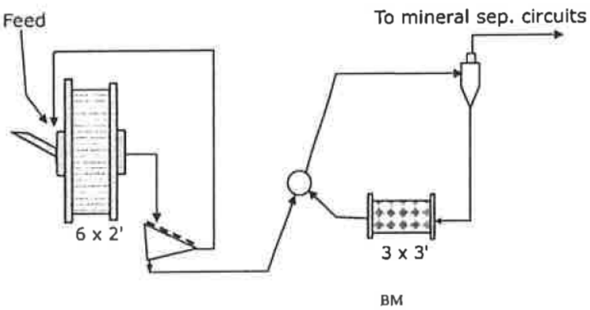
Assuming that the M & S index is now about 1800 compared to 1200 at the time of construction of the old plant,

a) Estimate the approximate original price of each item assuming that the M &S indices given are valid.
b) Estimate the overall profit that can potentially be made by the supplier

(Note: Cost parameters "a, b" given in the appendix are all for an M & S value of 1400)

6) Design of AG/SAG mill circuits often relies on pilot plant testwork. Suppose that a pilot plant campaign involving a circuit of a SAG/Ball mill combination shown below produced the following process characteristics on an ore tested.

SAG mill section:		Ball mill section:	
Feed rate:	2.2 tonnes/h	Power draw measured:	10.0 kW
Power draw measured:	10.56 kW	C.L.:	230%
C.L.:	70%	Feed size (F_{80}):	1.0 mm
Feed size (F_{80}):	10.0 cm	Product size (P_{80}, COF):	100 µm
Product Transfer size (P_{80}):	1.0 mm	Pilot-SAG/BM availability:	100%

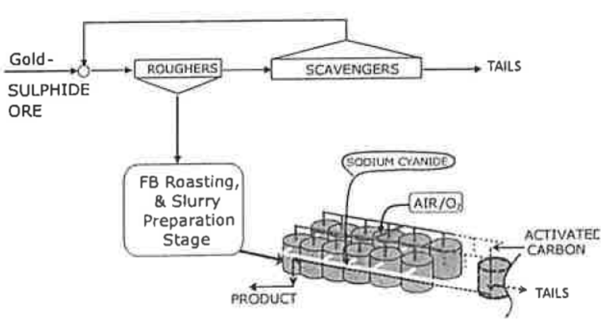


Ignoring the Ball mill portion of the pilot circuit, determine:

a) The specific power requirement for the SAG mill (kWh/tonne), its operating work index (kWh/tonne) and the motor size (in Megawatts, MWs) for a commercial size SAG mill to process 40,000 tonnes per day with 95% circuit availability. Consider a combined mechanical efficiency of 89% for motor & pinion/gear assembly to estimate to total MWs needed.

b) **Diameter** (ft) and the length (**Effective Grinding Length**, ft) of the commercial SAG mill (to be operated at 15% steel ball charge addition), considering the correlation between MW and **$D^{2.5}$•EGL** values of installed facilities (provided in the appendix).

7) A gold processing company had a flowsheet tested on a pilot scale. Pilot tests indicate that it is possible to produce a bulk flotation concentrate consisting of sulphide minerals carrying 98.5% of the gold that is locked mostly within pyrite and pyrrhotite. The sulphide-gold concentrate is then



Plant feed (% wt.)	100%
Circulating load from scavenger	25%
Roughers Slurry density	40%
Overall flotation mass recovery:	30.0%
Mass lost during roasting	25.0%
Feed to cyanidation (% wt.)	22.5%
Cyanidation slurry density	50%
Flotation Cell Size, m^3	100
Cyanidation Tank Size, m*m (Ø*H)	14 x 12

calcined in a fluidized bed roaster to be treated in a cyanidation process using atmospheric leaching. The flowsheet used is shown below in its simplified form. For a 40,000 tonne/day operation, retention time decided for the roughers is 12 minutes. It is 25 hours for the cyanidation for an overall gold extraction of 95%. Specific gravities of the ore and calcine are 3.1 and 2.93. Additional features of the process are tabulated as follows.

a) Determine the number of flotation cells needed for the roughers (ignoring the scavenger section) if the agitator plus aeration occupies 20% of each cell (100 m^3).

b) Determine the number of cyanidation tanks needed if the agitator plus aeration occupies 20% of each tank (with 14 m diameter by 12 m height) operated at 85% of the full volume.

8) Thickeners are an important part of mineral processing flowsheets and vehicles of sustainability of processes with emphasis on efficient use of water. Explain what goes on in process by providing specific attention to the following:

   a) Main types of equipment (provide a simplified sketch for conventional case and label main components). Nature of feed(s) and product. Reagents commonly involved in this process

   b) Explain design features and mechanisms of a high capacity thickener.

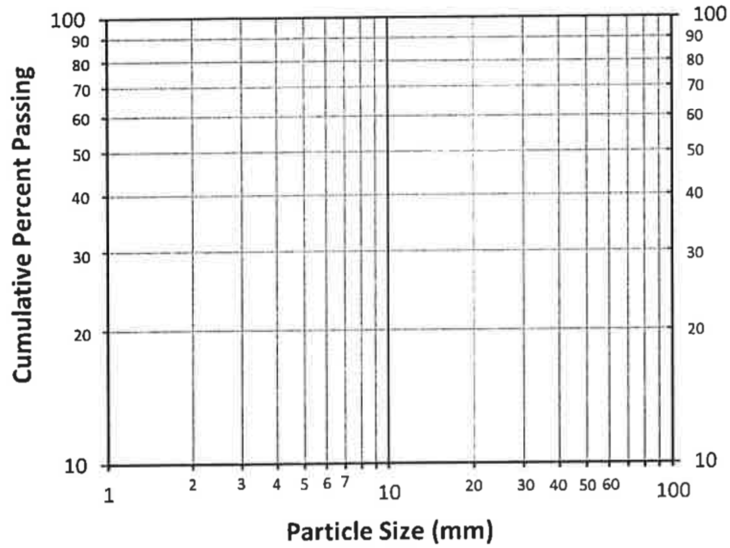
   c) Operating and process control features

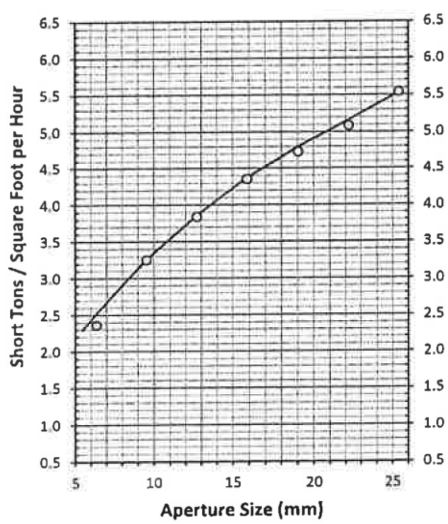
Comments & Useful information:

- Questions 2 & 6 require use of the Bond equation for power estimation, which you are expected to know.
- Generic cost equation is: Cost = aX^b

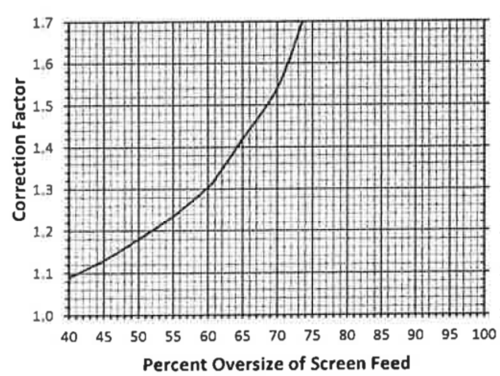
  For cone crushers, X is the cone diameter in feet. "a" and "b" values for each type of equipment are specified as part of problem statement.

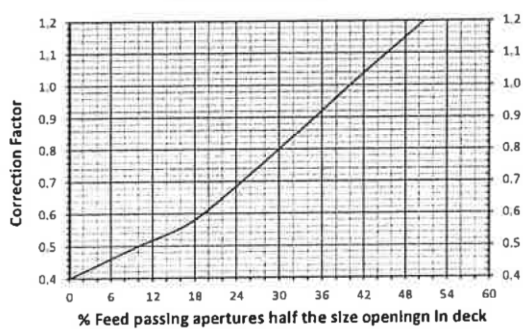
  For screens, X is $W^2 * L$ (both dimensions are in ft for screens).





A = Feed rate / [C * M * K * Q]





Screen Dimensions and Net Effective Screening Area (sq. ft.)

Screen Size	Top Deck	2nd Deck	3rd Deck	Screen Size	Top Deck	2nd Deck	3rd Deck
5' x 10'	45.0	40.5	36.5	6' x 16'	88.0	79.2	71.3
5' x 12'	54.0	48.6	43.7	6' x 20'	110.0	99.0	89.1
5' x 14'	63.0	56.7	51.0	7' x 12'	78.0	70.2	63.2
5' x 16'	72.0	64.8	58.3	7' x 14'	91.0	81.9	73.7
5' x 20'	90.0	81.0	72.9	7' x 16'	104.0	93.6	84.2
6' x 6'	33.0	29.7	26.7	7' x 20'	130.0	117.0	105.3
6' x 8'	44.0	39.6	35.6	8' x 12'	90.0	81.0	72.9
6' x 10'	55.0	49.5	44.6	8' x 14'	115.0	103.5	93.2
6' x 12'	66.0	59.4	53.5	8' x 16'	120.0	108.0	97.2
6' x 14'	77.0	69.3	62.4	8' x 20'	150.0	135.0	121.5

- Separation methods yielding two products can be quantified using a number of equations. One such equation in common use is as follows:

$$R = \frac{c(f-t)}{f(c-t)}$$

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

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

CAPCOSTS Page 121
Crushers/Pulverizers

GYRATORY CRUSHERS

Price = aX^b, US dollars

where **X is the feed opening (gape = G) by mantle diameter (D) in square inches** Cost includes drive and lubrication system; excludes motor

Primary Crusher Range, in.^{2} 1780 to 8200 a = 71.25 b = 1.199

Type	G by D, in. x in	G x D, sq. in.	Range, Discharge Opening (set), in.
Primary	30 x 55	1650	2.5 to 5.5
	42 x 65	2730	4.5 to 7
	54 x 74	3996	5.5 to 8
	60 x 89	5340	6 to 9
	60 x 109	6540	8.5 to 12

CAPCOSTS Page 123
Crushers/Pulverizers

CONE CRUSHERS

Price = aX^b, US dollars

where **X is the diameter of the mantle at the discharge annulus in feet.** Cost includes drive and lubrication system, excludes motor. Usual diameters are 2, 3, 3.75, 4, 4.25, 5, 5.5, and 7.

Standard Cone Range in X, ft.: 3 to 7 a = 25070 b = 1.756

Shorthead Cone Range in X, ft: 3 to 7 a = 30010 b = 1.700

Crusher Diameter at Annulus, ft	Range of Discharge Sizes (closed sets), inch
3	1.25 to 1.5
4	0.375 to 1.5
5	0.625 to 2
7	0.75 to 2.5