National Exams May 2019

16–Chem–B5, Pulp and Paper Technology

3-hour 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. Candidates may use one of two calculators, the Casio or Sharp Approved models. This is a CLOSED BOOK exam.

3. Any 3 questions constitute a complete paper. Only the first three questions as they appear in your answer book will be marked.

4. All questions are of equal value. Marks for question parts are indicated under each question.

5. Most questions require an answer in essay format. Clarity and organization of the answer are important.

Question 1

Parts (a) – (c) are worth 10 marks each. All 3 parts are to be answered.

(a) A Conventional Bleach Plant uses the sequence DEopDnD for Kraft pulp bleaching. What does each of the letters refer to, in this sequence? What are the typical conditions of the first three stages (D_0, Eop and D_1 stages) of this sequence, including temperature, consistency, pH, chemical dose, chemical residual, Kappa Factor and residence time? Assume that the Bleach Plant is being fed with 25 Kappa Number pulp.

(b) How are BOD, AOX, Toxicity and TSS measured? How are these parameters affected by a Kraft mill bleach plant? How is bleach plant effluent treated to minimize its impact before it is discharged to the environment?

(c) Describe the two technologies for oxygen delignification in use today, giving typical delignification conditions. How does each of these technologies promote the mixing and diffusion of oxygen into the pulp? How much delignification can be reasonably accomplished by each oxygen delignification process and what limits the delignification?

Parts (d) – (f) are worth 20 marks each. Only 2 parts of the following 3 (d, e, f) are required to complete Question 1. Only the first two parts as they appear in your answer book will be marked.

(d) Chlorine dioxide can be made by the following net reaction: (R8 / SVP-Lite Processes):

$$3\ NaClO_3 + 2\ H_2SO_4 + 0.85\ CH_3OH \rightarrow 3\ ClO_2 + Na_3H(SO_4)_2 + 0.6\ CHOOH + 2\ H_2O + CH_2OH + 0.2\ CO_2$$

1) What is the reducing agent used in the above ClO_2 production process?

2) What role does the chloride ion (Cl^-) play in this reaction?

3) What are the typical concentrations of the sodium chlorate, sulphuric acid and sodium sulphate in the generator under normal operating conditions?

4) What are the typical feed strengths for the raw materials required for this generator?

5) How is the by-product sodium sesquisulphate separated from the generator liquor?

6) What are the typical uses for the by-product sodium sesquisulphate in a bleached Kraft pulp mill?

7) Using the reaction above, if a 45-metric ton per day ClO_2 Plant (96.0% efficient) produces 2,500 L/min of ClO_2 solution by absorbing ClO_2 in 6°C water, what is the concentration of ClO_2 produced? What flowrate (kg/min) of 10% Methanol solution is required? What flowrate of 6.2M sodium chlorate solution is required?
(Cl – 35.45; O – 16.0; H – 1.008; Na – 23.0)

(e) In an energy reduction project, a pulp mill is considering an installation of a chlorine dioxide heat exchanger to heat chlorine dioxide solution prior to mixing with the pulp in the D_1 and D_2 bleaching stages:

1) What sources of filtrate or water could a pulp mill use to heat the chlorine dioxide solution?
2) What design criteria, should the engineering department of the pulp mill use to design the heat exchanger?
3) What safety parameters should they be aware of in this design?
4) Will metallurgy be important? What metallurgy is required and why?

5) If the temperature of the stock from the preceding extraction stage is 60°C and the target operating temperature of the D_1 steam mixer is 75°C, what savings in steam consumption in the D_1 Stage can be achieved, by heating the incoming chlorine dioxide solution from 4°C to 49°C in a heat exchanger that uses E_1 stage filtrate at 76°C? What will be the resulting E_1 filtrate temperature? Use the following assumptions for the calculation:

   i) Incoming E_1 Kappa Number = 5.5
   ii) D_1 Stage Kappa Factor = 0.72
   iii) Bleach Plant production rate = 1000 ADMT/d
   iv) D_1 Stage operating consistency = 10% AD
   v) ClO_2 Solution Strength = 12.0 g/L

   Please calculate for the following:
   vi) Chlorine dioxide solution flowrate to D_1 Stage
   vii) E_1 Filtrate flowrate required
   viii) E_1 Filtrate Temperature out of heat exchanger
   ix) Steam savings achieved by using the ClO_2 Heat Exchanger

(f) A pulp mill produces 1500 metric tons per day of softwood bleached Kraft pulp. In this mill, oxygen delignification is used prior to the bleach plant. Assuming a 45% yield from the digester producing pulp at 28.0 Kappa Number and a 42% delignification in the oxygen delignification stage:

1) Calculate the flow of chlorine dioxide solution in L/min required in the delignification D_0 Stage, given a chlorine dioxide solution of 11.0 g/L, incoming Kappa Number of 28.0 prior to oxygen delignification and a D_0 Kappa Factor of 0.180. (Cl – 35.45; O – 16.0; H – 1.008)

2) Using the information above, calculate the wood supply required assuming a chip moisture of 44%, a reject rate of 3.25 ADMT/day and a yield loss from the bleaching process of 5%.

3) Describe the purpose of washing of the pulp prior to and after oxygen delignification. What equipment can be used for washing? How is it used in a pulp mill? What component is removed from the pulp mixture during this washing stage? What will be the impact later in bleaching if this component is not washed out of the pulp stock?

Question 2

Parts (a) – (e) are worth 10 marks each. Part (f) is worth 20 marks.

(a) Sketch and describe a typical multiple effect evaporation system used in the recovery of kraft mill black liquor. Define steam economy, and give a typical value that might be expected for a 6-stage evaporator system.

(b) Describe the steam generation technology of a kraft recovery boiler. Also describe how the recovery boiler serves in the recovery of pulping chemicals, explaining any chemical reactions that occur.

(c) What is Crude Tall Oil? What material is recovered in a kraft mill to produce Crude Tall Oil? How is it produced? Which wood species would you expect to achieve higher yields of Crude Tall Oil and why? How can this product be used in a Kraft pulp mill?

(d) Two processes are available to you to cook wood chips using the Kraft process – batch digesters and conventional Kamyr digester. Each process has its advantages and disadvantages over the other process. Describe these differences and how one process would be more advantageous than the other.

(e) The Kappa number of the pulp leaving a continuous digester is low. What operating variables can the operator of the digester house use to increase the Kappa Number to the desired target range? Sketch a continuous digester and indicate how and where changes to these variables are made.

Part (f) is worth 20 marks.

(f) A pulp mill uses 6 batch digesters to cook wood chips. Each of the 6 digesters has a volume of 175 cubic meters. During a cook, the digester is filled to 80% of its rated volume with hardwood chips at a bulk density of 285 kg/m^3. The wood moisture is 45% on total wood mass. The pulp yield on oven dry (O.D.) wood is 54%.

1) Calculate the required application of white liquor on wood in L/batch for an application rate of 15.0 % E.A. (effective alkali) on O.D. Wood. The white liquor has an effective alkali concentration of 93 g/L and its density is 1.09 g/mL.

2) Calculate the volume of black liquor in L/batch, required to maintain an L/W (Liquor / Wood) ratio of 4.1:1. What is the purpose of the addition of this black liquor?

3) Calculate the production rate of brown stock that will be produced from this digester house.

4) The white liquor from the recausticizing plant at this mill has an effective alkali concentration of 93 g/L, a sulphidity of 28%, a causticizing efficiency of 82%, and a reduction of 92%. Calculate the **amount** of white liquor **per digester cook** that the recausticizing plant must make to supply the digester house above. **What will be the equivalent white liquor production rate?** Also calculate the stoichiometric amount of lime to be applied in the slaker and the amount of lime mud produced. (Ca = 40.1, Na = 23.0; S = 32.0; O = 16.0; H = 1.01)

Question 3

Parts (a) – (e) are worth 10 marks each. Part (f) is worth 20 marks.

(a) Why is Jackpine not a very suitable species for making mechanical pulp for newsprint? Why is aspen not a suitable species for newsprint? Name a boreal forest species which is suited for newsprint and why it is more suitable.

(b) Two methods can be used to produce mechanical pulp for newsprint. What are they? Why is one process more favourable than the other? What are the disadvantages of one process over the other? What equipment is used for each process?

(c) What are two methods for bleaching groundwood pulp? What are the typical conditions and type of equipment needed for each method of bleaching? What brightness improvement gains may be expected? Which is the most common method and why?

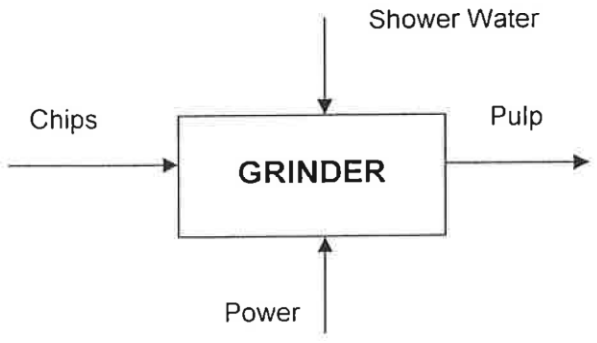
(d) Differentiate between the groundwood, TMP, CTMP and Kraft pulping processes. What are the typical advantages and disadvantages of each process? Which processes are not typically used for high quality, high brightness, high strength papers and why? Where do groundwood, TMP and CTMP pulps have an advantage over Kraft pulps?

(e) With the aid of a sketch show a typical configuration of primary and secondary screening in a TMP mill. Also sketch a diagram depicting a typical pressure screen.

Part (f) is worth 20 marks.

(f) A 40 ADMT/day grinder consumes 1,500 kWh/ADMT. The wood enters the grinder at 25°C and 42% moisture (total mass basis). For simplicity, you may assume that both wood and water have the same heat capacity of 4.18 kJ/kg°C. Also assume 99% yield.

1) How much shower water (kg/s) supplied at 40°C, is required to keep the vat temperature at 70°C?



Question 4

Parts (a) – (e) are worth 10 marks each. Part (f) is worth 20 marks.

(a) Describe the test for Canadian Standard Freeness (CSF). What does it measure? As pulp is refined in preparation for papermaking, what happens to the Canadian Standard Freeness?

(b) Describe the paper strength tests and give typical values with units for tensile index, tear index and burst index for a kraft pulp. How do these properties vary as the pulp is refined in preparation for papermaking? What is the purpose of a PFI Mill for the purpose of determining pulp strength?

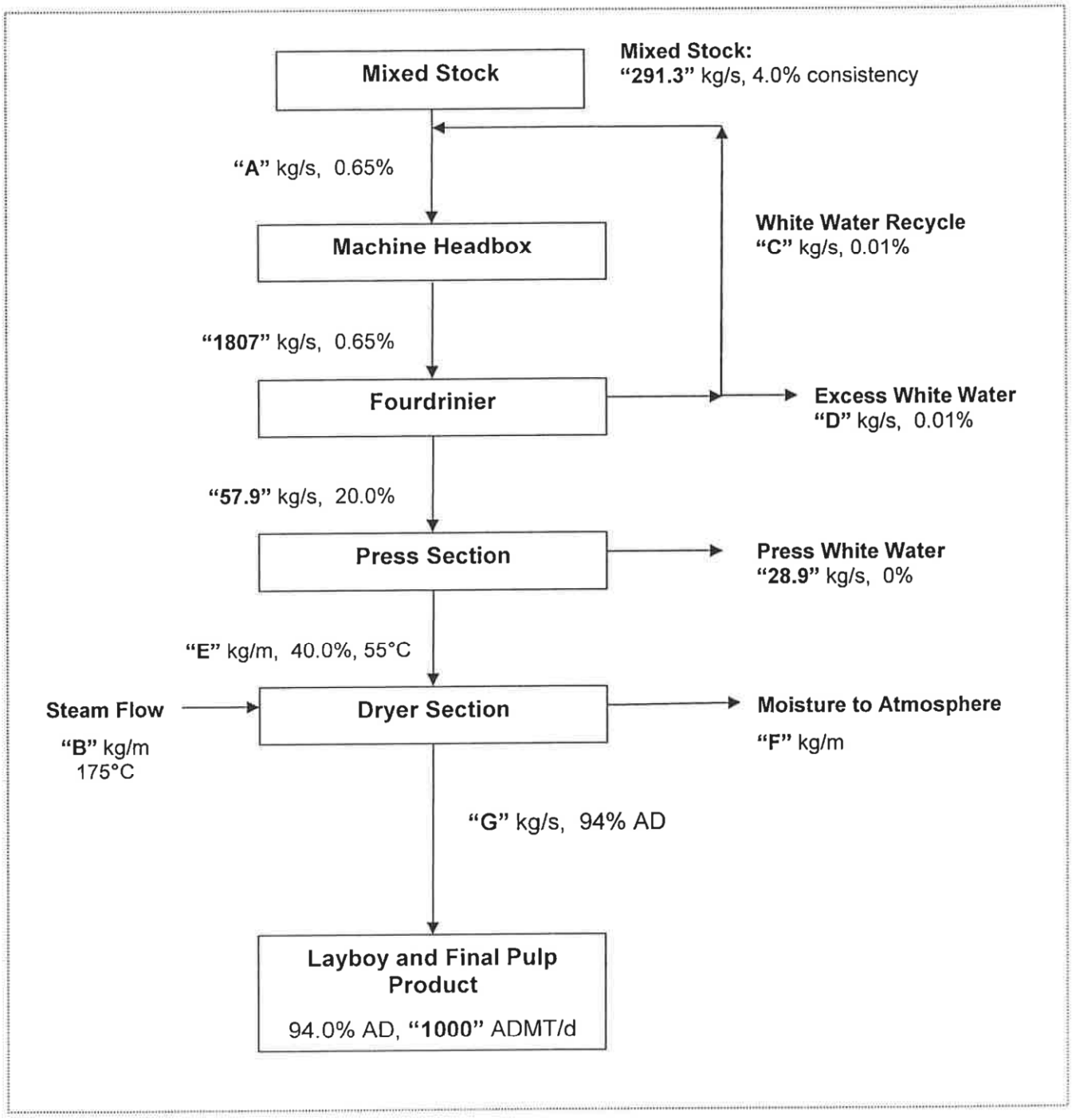
(c) Pulp cleaning systems – What is the purpose of pulp cleaning systems prior to the pulp or paper machines and what is the principle of operation? Describe a typical cleaning system. Sketch a system and label the components.

(d) Describe how paper is dried in the dryer section of a paper machine. Describe how condensate is removed from dryer cans and why this is important.

(e) Sketch a diagram of a fourdrinier wet end, showing and clearly labelling the drainage elements.

Part (f) is worth 20 marks.

(f) Complete the water and fibre balance in the following block diagram of a pulp machine, by determining the values for A, B, C, D, E, F and G. The stock flows in kg/s are total flows, including water and the stock consistencies are in mass percent. See the block diagram on the next page:


Mixed Stock
Mixed Stock:
"291.3" kg/s, 4.0% consistency
"A" kg/s, 0.65%
Machine Headbox
White Water Recycle
"C" kg/s, 0.01%
"1807" kg/s, 0.65%
Fourdrinier
Excess White Water
"D" kg/s, 0.01%
"57.9" kg/s, 20.0%
Press Section
Press White Water
"28.9" kg/s, 0%
"E" kg/m, 40.0%, 55°C
Steam Flow
"B" kg/m
175°C
Dryer Section
Moisture to Atmosphere
"F" kg/m
"G" kg/s, 94% AD
Layboy and Final Pulp Product
94.0% AD, "1000" ADMT/d