National Exams May 2011
04–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 an OPEN 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 5 marks each. All 3 parts are to be answered.

(a) A Bleach Plant uses the sequence XDEopDnD for kraft pulp bleaching. What does each of the letters refer to, in this sequence. What are the typical conditions of the first (X), fourth (Dn) and last stage (D_2) of this sequence, including temperature, consistency, pH, chemical dose and residence time?

(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 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 10 marks each. Only 2 parts of the following 3 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:

$$3\ NaClO_3 + 2\ H_2SO_4 + 0.80\ CH_3OH \rightarrow 3\ ClO_2 + Na_3H(SO_4)_2 + 2.3\ H_2O + 0.8\ HCOOH$$

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

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

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

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

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

6) Using the reaction to produce ClO_2 shown above, if a 45 metric ton per day ClO_2 Plant (93.5% efficient) produces 2250 L/min of ClO_2 solution by absorbing ClO_2 in 5°C water, what is the concentration of ClO_2 produced? What flowrate (kg/min) of 20% methanol solution is required? What flowrate of 6.4M sodium chlorate is required? (Cl – 35.45; O – 16.0; H – 1.008; Na – 23.0)

(e) A pulp mill produces 1250 metric tons per day of softwood bleached kraft pulp. In this mill, oxygen delignification is used prior to the bleach plant. Assuming a 46% yield from the digester producing pulp at 29 Kappa Number and a 40% 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 11.5 g/L, incoming Kappa Number of 29.0 prior to oxygen delignification and a D_0 Kappa Factor of 0.215. (Cl – 35.45; O – 16.0; H – 1.008)

2) Using the information above, calculate the wood supply required assuming a chip moisture of 42%, a reject rate of 3.5 ADMT/day and a yield loss from the bleaching process of 6%

3) Describe the purpose of washing of the pulp prior to and after oxygen delignification. What equipment can be used for washing? What component is removed from the pulp during this washing stage? How is it used in a pulp mill?

(f) 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? 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 48°C in an heat exchanger that uses E_1 stage filtrate at 82°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 = 850 ADMT/d
   iv) D_1 Stage operating consistency = 12% AD
   v) ClO_2 Solution Strength = 11.5 g/L
   vi) Assume prefect heat transfer in the heat exchanger

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

Question 2

Parts (a) – (d) are worth 5 marks each. Part (e) is worth 15 marks.

(a) Give a broad classification for the chemical constituents of wood, giving approximate proportions for each component in a typical softwood. How are these chemical constituents different in hardwood?

(b) The Kappa number of the pulp leaving a batch digester is high. What operating variables can the operator of the digester use to decrease the Kappa Number to the desired target range? Sketch a batch digester and indicate how and where changes to these variables are made.

(c) Sketch a block diagram of the recausticizing section of a kraft mill, from the recovery furnace to white liquor storage. Clearly label all parts and write any chemical reactions which occur.

(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) A pulp mill uses 8 batch digesters to cook wood chips. Each of the 8 digesters has a volume of 130 cubic meters. During a cook, the digester is filled to 80% of its rated volume with softwood chips at a bulk density of 138 kg/m^3. The wood moisture is 42% on total wood mass. The pulp yield on oven dry (O.D.) wood is 45%.

1) Calculate the required application of white liquor on wood in L/batch for an application rate of 16.0 % E.A. (effective alkali) on O.D. Wood. The white liquor has an effective alkali concentration of 92 g/L and its density is 1.1 g/mL.

2) Calculate the volume of black liquor in L/batch, required to maintain an L/W (Liquor / Wood) ratio of 4:1. 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 92 g/L, a sulphidity of 27.5%, a causticizing efficiency of 80%, and a reduction of 92%. Calculate the flow of white liquor in L/min that the recausticizing plant must make. 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 5 marks each. Part (f) is worth 10 marks.

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

(b) 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?

(c) Describe the construction of a pulp stone for the manufacture of groundwood pulp and the types of abrasive materials used. How is the stone prepared for service?

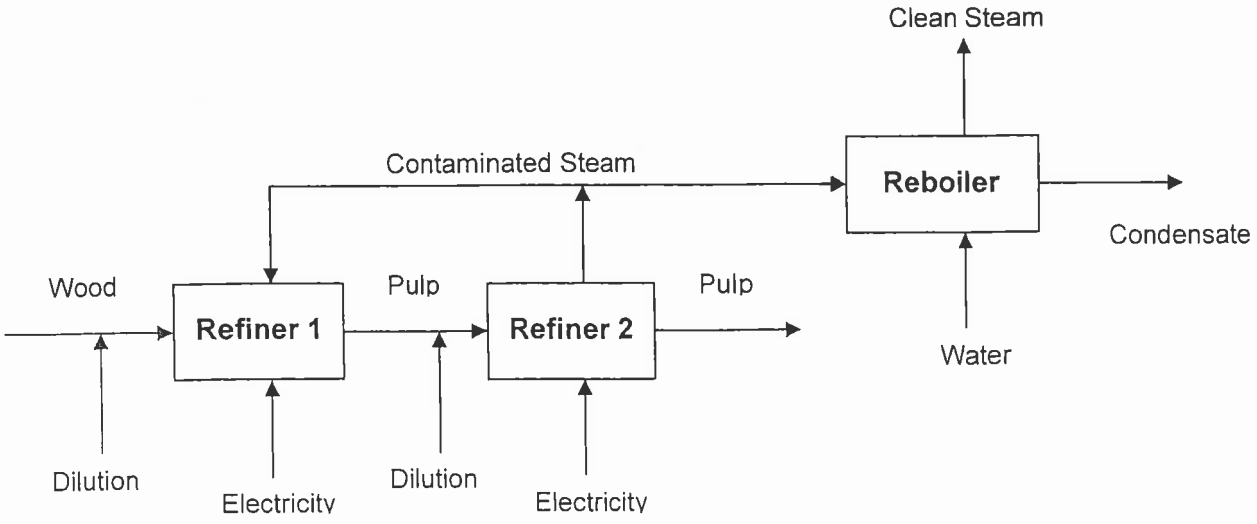
(d) With the aid of a sketch show a typical configuration of primary and secondary screening in a TMP mill. Also sketch a diagram depicting a typical pressure screen.

(e) How is heat recovery practiced in a TMP mill? Support your answer with a clearly labelled sketch of an energy balance for TMP steam recovery for paper drying.

(f) Below is a block diagram of TMP refining and heat recovery. The TMP refiners produce 350 oven dry (OD) metric tons per day of pulp at close to 100% yield. The electrical energy used is 8.2 GJ/OD metric ton, distributed equally between the two refiners. The wood enters the first refiner at 10°C and 42% moisture (on total wood). Dilution water at 75°C is added at each refiner to keep the discharge consistency at 45%. The pressurized steam and pulp streams leaving each refiner are at 124°C. Assume the enthalpy of steam is 2720 kJ/kg (0°C datum) and the heat capacity of water, wood and pulp are 4.18 kJ/kg°C.

1) Overall, how much contaminated steam is generated by the two streams?

2) How much clean steam at 115°C (enthalpy of 2680 kJ/kg) can be generated in the reboiler from 75°C water, from the contaminated steam condensing at 124°C?



Question 4

Parts (a) – (e) are worth 5 marks each. Part (f) is worth 10 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?

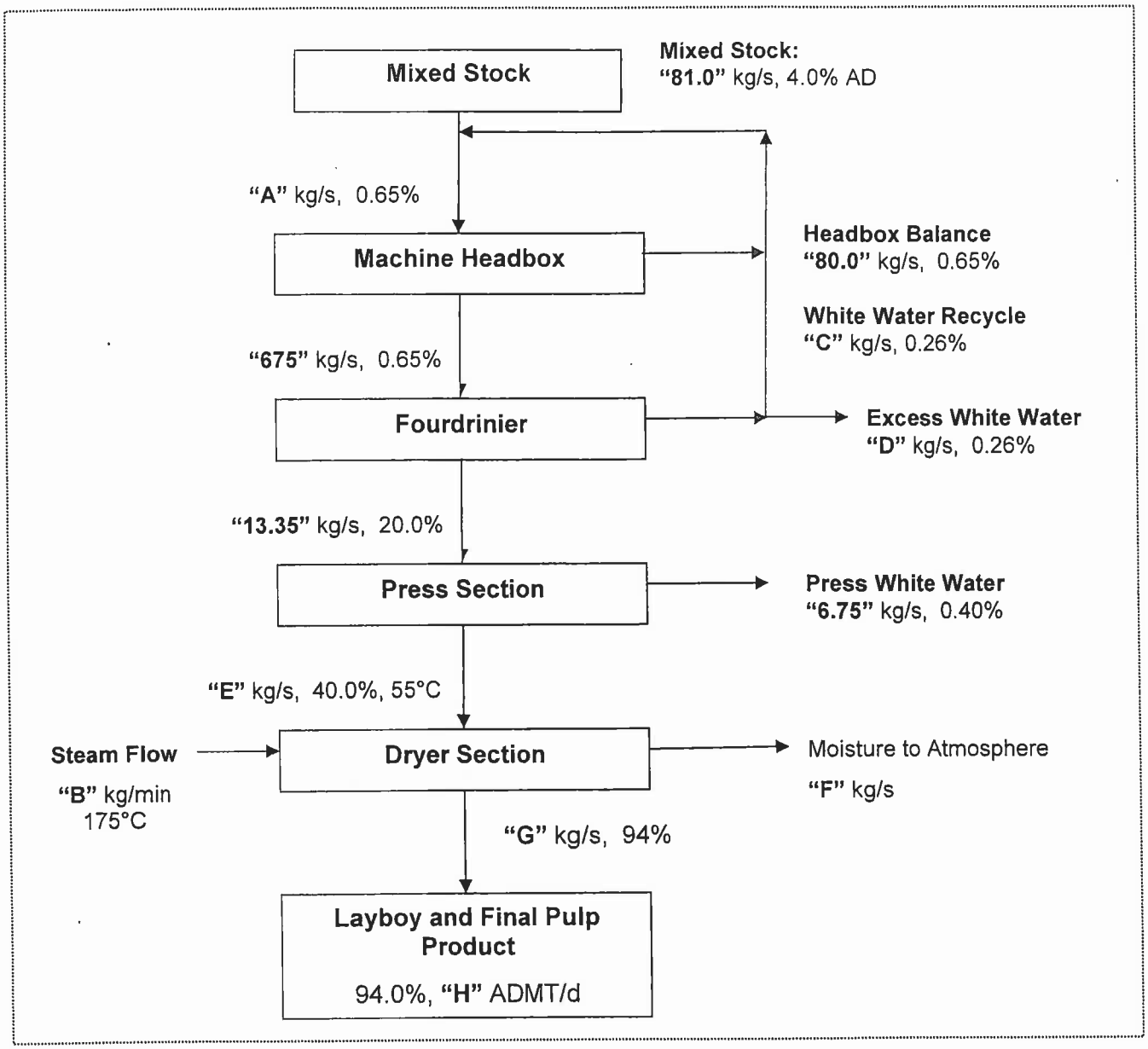
(b) Describe the paper strength tests and give typical values with units for tensile index, tear index and burst index for a kraft pulp. How do these properties vary as the pulp is refined in preparation for papermaking?

(c) 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.

(d) What is calendaring? What are its purposes? Describe and contrast a calendar stack and a supercalendar stack.

(e) 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.

(f) Complete the water and fibre balance in the following block diagram of a paper machine, by determining the values for A, B, C, D, F, G and H. 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:
"81.0" kg/s, 4.0% AD
"A" kg/s, 0.65%
Machine Headbox
Headbox Balance
"80.0" kg/s, 0.65%
White Water Recycle
"C" kg/s, 0.26%
"675" kg/s, 0.65%
Fourdrinier
Excess White Water
"D" kg/s, 0.26%
"13.35" kg/s, 20.0%
Press Section
Press White Water
"6.75" kg/s, 0.40%
"E" kg/s, 40.0%, 55°C
Steam Flow
"B" kg/min
175°C
Dryer Section
Moisture to Atmosphere
"F" kg/s
"G" kg/s, 94%
Layboy and Final Pulp Product
94.0%, "H" ADMT/d