**UNIVERSITY OF GHANA**



FACULTY OF ENGINEERING SCIENCES

**DEPARTMENT OF FOOD PROCESS ENGINEERING**

B.Sc SECOND SEMESTER FINAL EXAMINATION, 2013/2014

**FPEN 202: FOOD PROCESS ENGINEERING CALCULATIONS**

**ANSWER FOUR (4) QUESTIONS** **TIME: 2 HRS**

1. For each of the following cases below, define the system and simplify the open-system energy balance equation. State when possible whether nonzero heat and shaft work terms are positive or negative.
   i. Steam enters a rotary turbine and turns a shaft connected to a generator. The inlet and outlet ports are at the same height. Some energy is transferred to the surroundings as heat.
   ii. A liquid stream in a heat exchanger is heated from 25°C to 80°C. The inlet and outlet pipes have the same diameter, and there is no change in elevation between these points.
   iii. Water passes through the sluice gate of a dam and falls on a turbine rotor, which turns a shaft connected to a generator. The fluid velocity on both sides of the dam is negligible, and the water undergoes insignificant pressure and temperature changes between the inlet and outlet.
   iv. Crude oil is pumped through a cross-country pipeline. The pipe inlet is 200m higher than the outlet, the pipe diameter is constant, and the pump is located near the midpoint of the pipeline. Energy dissipated by friction in the line is transferred as heat through the wall
   v. A chemical reaction takes place in a continuous reactor that contains no moving parts. Kinetic and potential energy changes from inlet to outlet are negligible.

2. (a) Five hundred kilograms per hour of steam drives a turbine. The steam enters at 44 atmosphere and 450°C at a linear velocity of 60m/s and leaves at a point 5m below the turbine inlet at atmospheric pressure and velocity of 360m/s. The turbine delivers shaft work at a rate of 70kW and heat loss from the turbine is estimated to be

$10^4$kCal/h. Calculate the specific enthalpy change associated with the process. **Take 1 Joule to be equal to $0.23\times10^{-3}$kCal.**

(b) A turbine discharges 200kg/h of saturated steam at 10.0bar absolute (having specific enthalpy of 2776.2kJ/kg). It is desired to generate steam at 250°C, 10.0bar and have specific enthalpy of 2943kJ/kg by mixing the turbine discharge with a second stream of superheated steam at 300°C, 10.0bar having specific enthalpy of 3052 kJ/kg.

i. If 300kg/h of the product steam is to be generated, how much heat must be added to the mixer?
ii. If instead the mixing is carried out adiabatically, at what rate is the product steam generated?

3. (a) Two streams of water are mixed to form the feed to a boiler. The process data are as follows:

Feed stream 1: 120kg/min @34°C and specific enthalpy of 142.4kJ/kg
Feed stream 2: 175kg/min @76°C and specific enthalpy of 318.2kJ/kg
Boiler pressure 20 bar (absolute)
The exiting stream emerges from the boiler through a 6cm internal diameter pipe. Calculate the require heat input to the boiler in kilojoules per minutes if the emerging stream is saturated at the boiler pressure and has specific volume and enthalpy of $0.0995m^3$/kg and ~~318.2~~ kJ/kg respectively. Neglect the kinetic energies of the liquid inlet streams. 2797.2

(b) A dilute solution is subjected to flash distillation. The solution is heated in a heat exchanger and then flashes in a vacuum vessel. If heat at a rate of 270000kJ/h is transferred to the solution in the heat exchanger, calculate

i. the temperature of the solution at the exit of the heat exchanger
ii. the amount of overhead vapor leaving the vacuum vessel.

The following data are given: Flow rate and temperature of the solution at the inlet of the heat exchanger is 1000 kg/h and 50°C, heat capacity of the solution is 3.8kJ/kg°C, and absolute pressure in the vacuum vessel is 70.14 kPa. The saturation temperature and the enthalpy of saturated vapor at 70.14 kPa from the steam tables are 90°C and 2660 kJ/kg respectively.

4. (a) A liquid fermentation medium at 30°C is pumped at a rate of 2000kg/h through a heater, where it is heated to 70°C under pressure. The waste hot water used to heat this medium enters at 95°C and leaves at 85°C. The average heat capacity of the fermentation medium is 4.06kJ/kgK and that of water is 4.21kJ/kgK. The fermentation stream and the waste water stream are separated by a metal surface through which heat is transferred and do not physically mix with each other. Make a