

Mass and Energy Balances in Biochemical Engineering (BBL133)

Major Test

Full Marks 40  
Venue: LH325

Time: 15:30 -17:30  
Date: 23.11.2015

1. Liquid from a brewery fermenter can be considered to contain 10% ethanol and 90% water. 50000 kg/h of this fermentation product are pumped to a distillation column on the factory site. Under current operating conditions a distillate of 45% ethanol and 55% water is produced from the top of the column at a rate one-tenth that of the feed.
- (a) What is the composition of the waste 'bottoms' from the still?
  - (b) What is the rate of alcohol loss in the bottoms?
- [8]
2. In downstream processing of gluconic acid, concentrated fermentation broth containing 20% (w/w) gluconic acid is cooled in a heat exchanger prior to crystallisation. 2000 kg/h liquid leaving an evaporator at 90°C must be cooled to 6°C. Cooling is achieved by heat exchange with 2700 kg/h water initially at 2°C. If the final temperature of the cooling water is 50°C what is the rate of heat loss from the gluconic acid solution to the surroundings? Assume the heat capacity of gluconic acid is 0.35 cal g<sup>-1</sup> °C<sup>-1</sup>.
- [8]
3. Water is being pumped from the bottom of a well 5 m deep at the rate of 1 m<sup>3</sup>/h into a vented storage tank to maintain a level of water in a tank 50 m above the ground. To prevent freezing in the winter a small heater puts 9 kW into the water during its transfer from the well to the storage tank. Heat is lost from the whole system at the constant rate of 7 kW. What is the temperature of the water as it enters the storage tank, assuming that the well water is at 2°C? A 2 HP pump is being used to pump the water. About 55% of the rated horsepower goes into the work of pumping and the rest is dissipated as heat to the atmosphere.
- [8]
4. A wet filter cake passes through a continuous hot air dryer, in which 10 kg of water per minute evaporate. A stream of hot air enters the dryer at a rate of 400 kg/min. the temperature of outlet gas is 50°C. The gas stream is then cooled to 20°C, causing a portion of water to condense. The pressure is more or less constant at 1 atm.
- a) Use the psychrometric chart to estimate the specific enthalpy, wet bulb temperature, relative humidity and dew point of the wet air at 50°C.
  - b) Determine the absolute humidity and specific enthalpy of wet air at 20°C.
  - c) Calculate the rate of condensation of water.
  - d) Estimate the heat removal rate to carry out the cooling and condensation process.
- [16]