Indian Institute of Technology Delhi

Semester: January 2015 – May 2015

Minor-II

Course No.: CHL 471 **Course Title: Process Equipment Design** **Max. Marks: 15**

Duration: 5:30 pm-6:30 pm **Date:** 19.03.2015

Note: Answer all 4 questions given in this question paper. The source of any data taken from the book(s) **MUST** be cited in the answer script. This is an "Open Book, Open Notes" exam. "Open Book" means you can keep with yourself the books of McCabe and Smith, DQ Kern, and Coulson and Richardson. No other books. Photocopies or print-outs of these books or parts of them is allowed. "Open Notes" means you can keep with yourself your own class/lecture notes, and worked out tutorial sheets. No other material. No photocopied notes. No material from past years. **Question no. 1 and 2 are split into small parts and thus the marks will be given to the right answers only.**

Q.1 An aqueous solution is to be concentrated from 10wt% to 40wt% at a rate of 2000 kg/h in a single effect evaporator. The feed enters at 30°C into the evaporator where the vapour head is maintained at 0.2713 bar. The solution boils at 70°C. The thermal energy to the solution is supplied by condensing a saturated steam in the steam chest at 1.7 bar. The specific heat of the solution is 0.946 kcal/kg·°C and the overall heat transfer coefficient based on inside area of the tube is 2000 kcal/h·m^2·°C. Evaluate the following:

i. elevation in boiling point,
ii. rate of steam supply,
iii. number of tubes if the height of the tube in the evaporator is 1.5 m.

5 (1 + 1 + 3)

Q.2 A process industry has to expand his operations by setting up a similar plant in some other location. In one of the processes, an oil is being cooled from 150°C to 85°C with a flow rate of 75 kg/h using water at 35°C in a double pipe heat exchanger in counter current mode. The specific heat capacity of the oil is 2 kJ/kg·°C and the water comes out from the heat exchanger at 80°C. It is suggested that in the new plant, two small counter current double pipe heat exchanges may be installed, which can be connected in series on the water side and in parallel on the oil side. The oil flow rate is split equally between the two exchangers. It is to be assumed that the overall heat transfer coefficient of the single large exchanger as well as each small exchanger is same (850 W/m^2·°C).

i. Draw block diagram for the small exchangers network.
ii. Evaluate temperatures of all the streams in the heat exchanger network.
iii. Heat exchange areas of the single large and connected small exchangers.
iv. Based on the above calculation(s), comment on the most economical arrangement, considering smaller exchangers cost 10% more per unit surface area, and pumping cost is same in both the cases.

7 (1+3+2+1)

Q.3 In a distillation tray tower, for a given bottom and distillate composition under what condition do we need minimum number of trays? Why is it not practical to work at this condition?

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Q.4 Please calculate the amount of time it will take for a single pure CO_2 bubble to completely dissolve in a large pool of water. The mass transfer coefficient for CO_2 in the continuous phase is 10^{-2} m/s. The diameter of the bubble is 10 mm. The molar density, ρ of CO_2, in the bubble is 5 mol/litre. The concentration of CO_2 far from the bubble is 0 and the concentration at the interface can be assumed to be 10^{-2} mol/litre. Assume the molar density, mass transfer coefficient, and the interfacial concentration to be constant.

One potential option for CO_2 sequestration is deep oceans. Here the concentration of CO_2 in the continuous aqueous phase is low and convective effects are also negligible to prevent the carbon dioxide to come to the surface. Hence, it could work as a large sink for injected CO_2 from the atmosphere. Calculations similar to above can be useful in understanding the dissolution of the injected CO_2 in oceans.

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