UNIVERSITY OF BORÅS

Process Design – Energy Carrier Production 15 ECTS

Ladokcode:42K17D
The exam is given to: KMREC16h, KMREC16h1

ExamCode: ______________________________

Date of exam: June 2, 2017
Time: 14.00-18.00

Means of assistance: Calculator, Steam table, Dictionary

Total amount of point on exam: 50 points
Requirements for grading:
Grade F: Less than 17 points
Grade FX: Minimum 17 points
Grade E: Minimum 20 points
Grade D: Minimum 25 points
Grade C: Minimum 30 points
Grade B: Minimum 35 points
Grade A: Minimum 40 points

Additional information:

Next re-exam date:

The marking period is, for the most part, 15 working days, plus up to 5 working days for administration, otherwise it's the following date:

Important! Do not forget to write the ExamCode on each paper you hand in.

Good Luck!

Examiner: Prof. Tobias Richards
Phone number: 073-2305964

1. When constructing a heat exchanger network, it is important to decide the minimum temperature difference
   a. What is the minimum temperature difference and can this occur on many places in the network or just in one place? (2p)
   b. Changing the minimum temperature will impact the cost of the network. What costs will dominate when the minimum temperature difference becomes very low? (1p)
   c. What costs for the whole network will dominate when the minimum temperature difference becomes very high? (1p)

2. In a process plant two streams are identified for a heat exchange. The hot stream has an inlet temperature of 110°C and a final temperature of 40°C, the mass flow is 2 kg/s and the heat capacity is 4 kJ/(kg·K). The corresponding values for the cold stream is: inlet temperature of 30°C, final temperature of 65°C, mass flow of 10 kg/s and a heat capacity of 3.1 kJ/(kg·K).
   a. How much energy can the heat exchanger transfer if this is maximized? (2p)
   b. What is the limit for the heat exchange? (1p)
   c. How much need is there for cooling and external heating? (1p)

3. Municipal solid waste is a difficult fuel due to several reasons and one of the problems is the low electricity production due to the corrosive environment for the superheater tubes. Explain how the introduction of a gasification unit could improve the situation (increase the electricity production) from a technical perspective. (3p)

4. The software Aspen Plus usually works according to a sequential modular approach.
   a. What does it mean? (1p)
   b. What implication will this have when loops are included in the flowsheet? Show how this problem can be solved. (2p)

5. To produce kraft paper pulp several process steps are used.
   a. The first is a reactor where reactions mainly should occur with the lignin structure and keep the cellulose intact. If the reaction order and the activation energy both are higher for the cellulose reaction with the hydroxyl-ion [OH^-] compared to the lignin reaction, how should the concentration of [OH^-] and the temperature be in order to maximize the selectivity? (3p)
   b. After the reactor, the two components need to be separated. How does this separation occur, what unit is used? (1p)
   c. After the first separation is a displacement washing. Explain what a displacement washing means. (2p)

6. A common reference for a thermal process is the Carnot cycle.
   a. Explain how a Carnot cycle works (include all 4 steps) (3p)
   b. Why is the Carnot cycle used as a reference? (1p)
   c. Is the Carnot cycle always a good reference? Explain your answer. (2p)

7. Turbines
   a. What parts are included in a gas turbine? (3p)
   b. Is a gas turbine a closed or an open process? (1p)
   c. Name and explain at least 3 different possibilities to increase the efficiency of a simple gas turbine. (3p)
   d. What are the two main types of turbines? Explain what the difference is between them. (2p)

8. Steam cycle
   a. Explain why the efficiency increases of a steam cycle when a feed water heat is introduced. (3p)
   b. What is the difference between a closed and an open feed water heater? (1p)
   c. What are the benefits of using a closed feed water heater instead of an open feed water heater? Are there any drawbacks? (2p)
   d. What limits the number of feed water heaters in a steam cycle? (1p)

9. A fixed tube heat exchanger is designed for the following operating conditions:

   Process fluid in tubes requires stainless steel MOC
   Shell side utility (cooling water) requires carbon steel MOC
   Heat transfer area = 60 m^2

   Operating pressure (both shell and tube) = 50 barg

   a. Determine the bare module cost of the pump in year 2001. (6p)
   b. Estimate the price of the pump in year 2015. (2p)

   CEPCI = 397 for 2001
   CEPCI = 580 for 2015

   Equations you may need:

   $\log_{10} C_P^0 = K_1 + K_2\log_{10}(A) + K_3[\log_{10}(A)]^2$
   $\log_{10} F_P = C_1 + C_2\log_{10}(P) + C_3[\log_{10}(P)]^2$
   $C_{BM} = C_P^0 (B_1+B_2F_MF_P)$

Table A.1 Equipment Cost Data to Be Used with Equation (A.1) (*Continued*)

Equipment Type	Equipment Description	K_1	K_2	K_3	Capacity, Units	Min Size	Max Size
Heat exchangers	Scraped wall	3.7803	0.8569	0.0349	Area, m^2	2	20
	Teflon tube	3.8062	0.8924	−0.1671	Area, m^2	1	10
	Bayonet	4.2768	−0.0495	0.1431	Area, m^2	10	1000
	Floating head	4.8306	−0.8509	0.3187	Area, m^2	10	1000
	Fixed tube	4.3247	−0.3030	0.1634	Area, m^2	10	1000
	U-tube	4.1884	−0.2503	0.1974	Area, m^2	10	1000
	Kettle reboiler	4.4646	−0.5277	0.3955	Area, m^2	10	100
	Double pipe	3.3444	0.2745	−0.0472	Area, m^2	1	10
	Multiple pipe	2.7652	0.7282	0.0783	Area, m^2	10	100
	Flat plate	4.6656	−0.1557	0.1547	Area, m^2	10	1000
	Spiral plate	4.6561	−0.2947	0.2207	Area, m^2	1	100
	Air cooler	4.0336	0.2341	0.0497	Area, m^2	10	10,000
	Spiral tube	3.9912	0.0668	0.2430	Area, m^2	1	100
Heaters	Diphenyl heater	2.2628	0.8581	0.0003	Duty, kW	650	10,750
	Molten salt heater	1.1979	1.4782	−0.0958	Duty, kW	650	10,750

Table A.2 Pressure Factors for Process Equipment (Correlated from Data in Guthrie [1, 2], and Ulrich [3]) (*Continued*)

Equipment Type	Equipment Description	C_1	C_2	C_3	Pressure Range (barg)
Heat Exchanger	Bayonet, fixed tube sheet, floating head, kettle reboiler, and U-tube (both shell and tube)	0	0	0	P<5
		0.03881	−0.11272	0.08183	5<P<140
	Bayonet, fixed tube sheet, floating head, kettle reboiler, and U-tube (tube only)	0	0	0	P<5
		−0.00164	−0.00627	0.0123	5<P<140
	Double pipe and multiple pipe	0	0	0	P<40
		0.6072	−0.9120	0.3327	40<P<100
		13.1467	−12.6574	3.0705	100<P<300
	Flat plate and spiral plate	0	0	0	P<19
	Air cooler	0	0	0	P<10
		−0.1250	0.15361	−0.02861	10<P<100
	Spiral tube (both shell and tube)	0	0	0	P<150
		−0.4045	0.1859	0	150<P<400
	Spiral tube (tube only)	0	0	0	P<150
		−0.2115	0.09717	0	150<P<400
Heaters	Diphenyl heater, molten salt heater, and hot water heater	0	0	0	P<2
		−0.01633	0.056875	−0.00876	2<P<200

Table A.3 Identification Numbers for Material Factors for Heat Exchangers, Process Vessels, and Pumps to Be Used with Figure A.18

Identification Number	Equipment Type	Equipment Description	Material of Construction
1	Heat exchanger	Double pipe, multiple pipe,	CS-shell/CS-tube
2		fixed tube sheet, floating head,	CS-shell/Cu-tube
3		U-tube, bayonet, kettle reboiler, scraped	Cu-shell/Cu-tube
4		wall, and spiral tube	CS-shell/SS-tube
5			SS-shell/SS-tube
6			CS-shell/Ni alloy tube
7			Ni alloy, shell/Ni alloy-tube
8			CS-shell/Ti-tube
9			Ti-shell/Ti-tube
10		Air cooler	CS tube
11		Air cooler	Al tube
12		Air cooler	SS tube
13		Flat plate and spiral plate	CS (in contact with fluid)
14		Flat plate and spiral plate	Cu (in contact with fluid)
15		Flat plate and spiral plate	SS (in contact with fluid)
16		Flat plate and spiral plate	Ni alloy (in contact with fluid)
17		Flat plate and spiral plate	Ti (in contact with fluid)
18	Process vessels	Horizontal, vertical (including towers)	CS
19		Horizontal, vertical (including towers)	SS clad
20		Horizontal, vertical (including towers)	SS
21		Horizontal, vertical (including towers)	Ni alloy clad
22		Horizontal, vertical (including towers)	Ni alloy
23		Horizontal, vertical (including towers)	Ti clad
24		Horizontal, vertical (including towers)	Ti

Table A.4 Constants for Bare Module Factor to Be Used in Equation (A.4) (Correlated from Data in Guthrie [1, 2] and Ulrich [3])

Equipment Type	Equipment Description	B_1	B_2
Heat exchangers	Double pipe, multiple pipe, scraped wall, and spiral tube	1.74	1.55
	Fixed tube sheet, floating head, U-tube, bayonet, kettle reboiler, and Teflon tube	1.63	1.66
	Air cooler, spiral plate, and flat plate	0.96	1.21
Process vessels	Horizontal	1.49	1.52
	Vertical (including towers)	2.25	1.82
Pumps	Reciprocating	1.89	1.35
	Positive displacement	1.89	1.35
	Centrifugal	1.89	1.35

A.3.1 Bare Module and Material Factors for Heat Exchangers, Process Vessels, and Pumps

The material factors, F_M, for heat exchangers, process vessels, and pumps are given in Figure A.18, with the appropriate identification number listed in Table A.3. The bare module factors for this equipment are given by the following equation:

$$C_{BM} = C_p^o F_{BM} = C_p^o(B_1 + B_2 F_M F_P) \tag{A.4}$$

The values of the constants B_1 and B_2 are given in Table A.4. The bare module cost for ambient pressure and carbon steel construction, C_{BM}^o, and the bare module factor for the equipment at these conditions, F_{BM}^o, are found by setting F_M and F_P equal to unity. The data given in Tables A.3 and A.4 and Figure A.18 are average values from the following references: Guthrie [1, 2], Ulrich [3], Navarrete [6], Perry et al. [7], and Peters and Timmerhaus [8].

(*text continues on p. 977*)

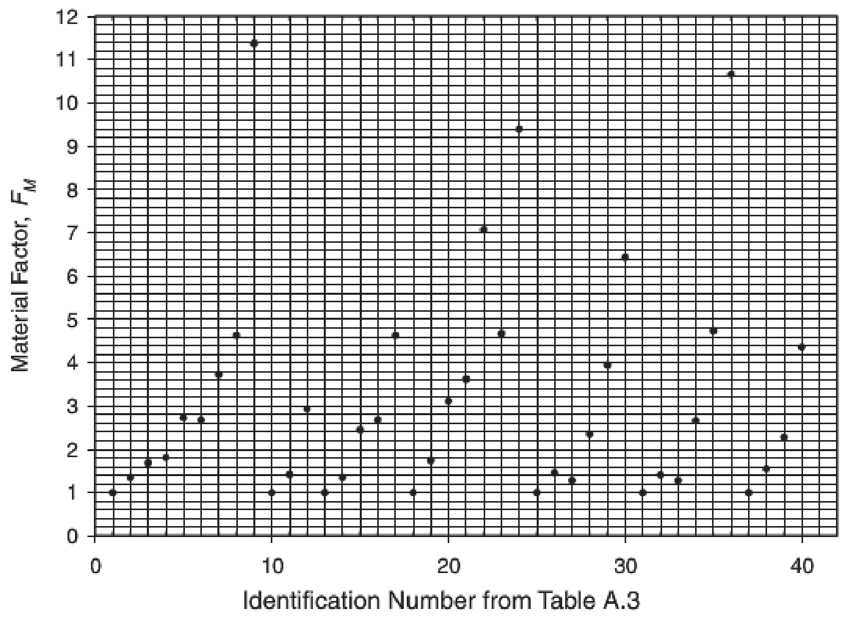

Figure A.18 Material Factors for Equipment in Table A.3 (Averaged Data from References [1, 2, 3, 6, 7, and 8])