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UNIVERSITI KUALA LUMPUR
Malaysia France Institute

FINAL EXAMINATION

SEPTEMBER 2014 SESSION

SUBJECT CODE	:	**FRB30403**
SUBJECT TITLE	:	**HEAT EXCHANGER**
LEVEL	:	**BACHELOR**
TIME / DURATION	:	**9.00 AM – 12.00 PM (3 HOURS)**
DATE	:	**5 JANUARY 2015**

INSTRUCTIONS TO CANDIDATES

1. **Please read the instructions given in the question paper CAREFULLY.**
2. **This question paper is printed on both sides of the paper.**
3. **Please write your answers on the answer booklet provided.**
4. **Answer should be written in blue or black ink except for sketching, graphic and illustration.**
5. **Answer all questions in English.**
6. **This is an open book examination. Documents, notes and calculator are allowed.**

THERE ARE 4 PAGES OF QUESTIONS, EXCLUDING THIS PAGE AND APPENDIX

INSTRUCTION: Answer ALL questions.
Please use the answer booklet provided.

Question 1

Answer the following questions. Your answers should be concise.

a) This question is on the evaporation of a refrigerant in a tube:
   i. Describe the different modes of evaporation in this type of evaporator
   (1 mark)
   ii. Specify briefly the possible impact of lubricating oil on heat transfer
   (1 mark)

b) Explain the design steps of a heat exchanger using the effectiveness-NTU method. Discuss TWO (2) assumptions and ONE (1) limitations of this method.
(2 marks)

c) Sketch and label schematic of a shell and tube evaporators. Explain THREE (3) methods to increase the overall heat transfer coefficient in these evaporators
(2 marks)

Question 2

A cascade cycle CO_2/R404a equipped with a condenser through evaporation is considered: carbon dioxide (CO_2) vapor is condensed at a temperature of 2 °C while R404a is evaporated by direct expansion at -3 ° C. The pressures of CO_2 and R404a are 37 bar and 5.5 bar respectively. The thermal power of the heat exchanger is 165 kW.

Answer the following questions:
Identify the technologies available for plate heat exchanger. Then, evaluate the advantages and disadvantages of those various alternatives that commercially available for this application.
(3 marks)

Question 3

Consider a dry expansion tubular evaporator R404a (the average saturation temperature of -3 °C) of 165 tubes of inner diameter 7.3 mm and length of 2 m. Properties of R404a are available in Table Q3.

Refrigerant 404A [R-125/143a/134a (44/52/4)] Properties of Liquid on Bubble Line and Vapor on Dew Line

Pressure, MPa	Temperature,* °C		Density, kg/m^3	Volume, m^3/kg	Enthalpy, kJ/kg		Entropy, kJ/(kg·K)		Specific Heat c_p, kJ/(kg·K)		c_p/c_v	Velocity of Sound, m/s		Viscosity, μPa·s		Thermal Cond., mW/(m·K)		Surface Tension, mN/m	Pressure, MPa
	Bubble	Dew	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor		
0.5	–6.15	–5.61	1173.0	0.03940	191.53	362.96	0.9690	1.6105	1.363	0.967	1.223	527	142.8	191.6	10.65	79.9	12.41	8.28	0.5
0.55	–3.24	–2.72	1162.3	0.03584	195.51	364.45	0.9837	1.6091	1.374	0.984	1.231	513	142.4	184.6	10.77	78.7	12.66	7.93	0.55
0.6	–0.53	–0.02	1152.0	0.03284	199.26	365.81	0.9973	1.6078	1.386	1.001	1.239	500	141.9	178.2	10.88	77.5	12.91	7.61	0.6
0.65	2.02	2.52	1142.3	0.03029	202.81	367.06	1.0101	1.6066	1.397	1.018	1.247	488	141.3	172.5	10.99	76.5	13.16	7.30	0.65
0.7	4.42	4.91	1132.9	0.02809	206.18	368.21	1.0222	1.6055	1.409	1.034	1.256	476	140.8	167.2	11.10	75.5	13.41	7.01	0.7

Table Q3 : Properties of R404a

Answer the following questions:

a) The superheated vapor zone is 20% of the active exchange surface of the heat exchanger. Calculate the mass of superheated vapor in the heat exchanger

(1 mark)

b) The “two-phase” of the evaporator area represents 80% of the active surface of the heat exchanger. Answer the following questions for the vapor fraction of 20% (at the inlet), 50%, 80%, 100%:

i. The void fraction

ii. The average density of the liquid and vapor mixture

(1 mark)

c) Given that the heat transfer zone for changing vapor fraction from 20% to 50% is 35% of the total heat transfer area, from 50% to 80% is 25%of the total heat transfer area, and finally from 80% to 100% is 20% of the total heat transfer area. Calculate the mass of refrigerant in the evaporation zone

(1 mark)

Question 4

We will use NTU method to re-size a counter current tubular heat exchanger using copper tubes with the thickness of 1 mm and thermal conductivity (k) of 380 W / m K.

The (hot fluid) primary fluid is water, enters the heat exchanger at 85 °C with a flow rate of 4 m^3/ hour under the following conditions:

Density (ρ): 968.8 kg/m^3
Specific heat (c_p): 4205 J / kg K
Dynamic viscosity (μ): 3.22×10^{-4} Pa.s
Kinematic viscosity (α): 3.33×10^{-7} m^2/s
Thermal conductivity (k): 0.656 W / m K

The (cold fluid) secondary fluid is water enters the heat exchanger at 10 ° C with a flow rate of 1 m^3 / h under the following conditions:

Density (ρ): 999.9 kg/m^3
Specific heat (c_p): 4195 J / kg K
Dynamic viscosity (μ): 1.40×10^{-3} Pa.s
Kinematic viscosity (α): 1.40×10^{-6} m^2/s
Thermal conductivity (k): 0.573 W / m K

The primary hydraulic diameter is 25 mm and the secondary hydraulic diameter is 13 mm.

a) We will take, as a first approach, a total area of 0.2 m² of heat exchange surface. Based on the information given above, calculate the following (for each side of the heat exchanger)

i. The mass flow rate in kg/s
ii. The heat capacity rate in W/K
iii. The average flow velocity in m/s
iv. The Reynolds number and the Prandtl number
v. The Nusselt number by the formula: $Nu = 0.023\ Re^{0.8}\ Pr^{0.4}$. Then, calculate the convection coefficient h in W / m² K
vi. The overall heat transfer coefficient, U
vii. The number of transfer unit(NTU)
viii. The capacity ratio of the heat flow(c)

ix. The effectiveness of this counter-current heat exchanger (You may use figure in the Appendix)

x. The actual power(heat transfer) of the heat exchanger, and the outlet temperatures of the fluids

(3 marks)

b) Repeat exactly the same calculations for a total heat exchange surface of 0.4 m², 0.8 m², 1.2 m² and 2 m², bearing in mind that the flow conditions are independent of the heat exchange surface area.

c) To tabulate the values into Table Q4(please copy this table on your answer script):

A :	Surface exchange area (m^2)	0.2	0.4	0.8	1.2	2.0
NTU :	Number of transfer units					
ε :	Effectiveness					
Φ :	Actual power interchange (W)					
Ts_1 :	Primary outlet temperature (°C)					
Ts_2 :	Temperature of secondary output(°C)					

Table Q4

(3 marks)

d) Represent the evolution of the actual heat exchanged (Φ) depending on the exchange surface area (A), what can you deduce? For any single argument can it be explained?

(1 mark)

e) Find (analytically or graphically) the exchange surface area necessary to satisfy these conditions: secondary outlet temp = 70 ° C and actual heat exchange (Φ) = 70000 Watts.

(1 mark)

END OF QUESTION

APPENDIX

Graph for counter flow heat exchanger