UNIVERSITY OF RUHUNA

Faculty of Engineering

Mid-Semester 5 Examination in Engineering: June 2014

Module Number: ME 5314 **Module Name: Refrigeration and Air Conditioning**

[Two Hours]

[Answer all questions. Each question carries **five** marks. Your drawings should be neat, clear and precise. R-134a property charts are provided.]

Q1. a) Show a refrigeration cycle with subcool and superheat on **p-h** axes. List the advantages of sub-cooling and superheating of refrigerant.

b) Compressor is the power consuming device in a refrigerator. What is the purpose of the compressor? Also briefly describe the on-off cycle of the compressor.

c) "Room air temperature is one factor that determines the COP of a refrigerator". Explain this statement.

d) What do you understand by the term '*global warming potential*' of a refrigerant?

e) List the health hazards a leaked refrigerant can cause to the user and neighbours?

[05 marks]

Q2. A vapor-compression refrigeration cycle operates between pressure levels of 0.12 MPa and 0.70 MPa. The cycle uses **R-134a** as the refrigerant at a mass flow rate of 0.04 kg/s. The refrigerant is superheated by 5 °C at the time of leaving the evaporator.

a) Draw the cycle on the given **p-h** chart.

b) Assuming isentropic compression, find

- the rate of power input to compressor.
- the rate of heat transfer out of the refrigerated space.
- the rate of heat transfer to the surroundings.
- the COP.

[05 marks]

Q3. a) Explain why air refrigeration systems are not as popular as vapour-compression systems.

b) Figure Q3 shows an ideal air refrigeration cycle. Temperature and pressure of air at the inlet of the compressor are 37 °C and 100 kPa, and the temperature of air at the outlet of turbine is at 17 °C. The compressor has a compression ratio of 15:1. The heat load on the system is 10 kW. Cp of air at room temperature is 1.005 kJ/kgK. Polytropic index for the compression and expansion processes may be taken as 1.4.

Show the processes on T-S plane and calculate:

- the required mass flow rate of air
- the required net-work input
- the COP.

Q4. Imagine you are asked to design and build a vapour compression refrigerator for households. The evaporating and condensing temperatures should be -23 °C and +37 °C respectively.

a) What other data you would need to start the design?

b) You have to choose the refrigerant from R-22 and R-134a. To help your decision, Table Q 4.1 and Table Q 4.2 are provided. What refrigerant will you choose? Explain your answer in technical, environmental and economic terms.

[05 marks]

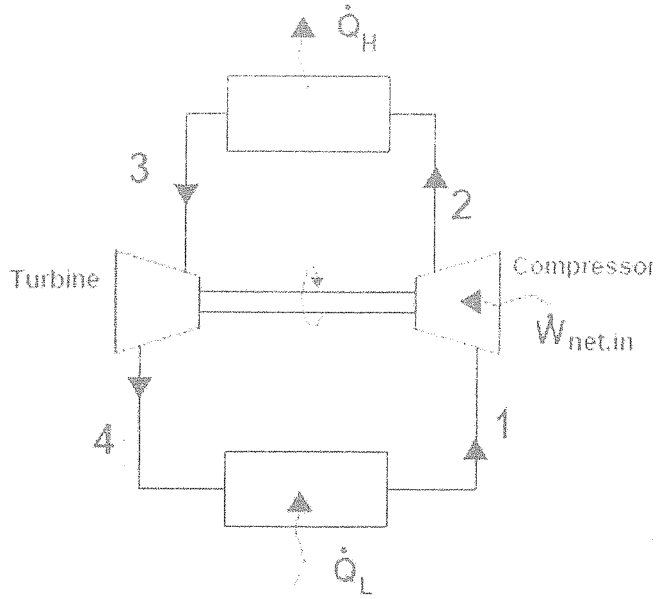


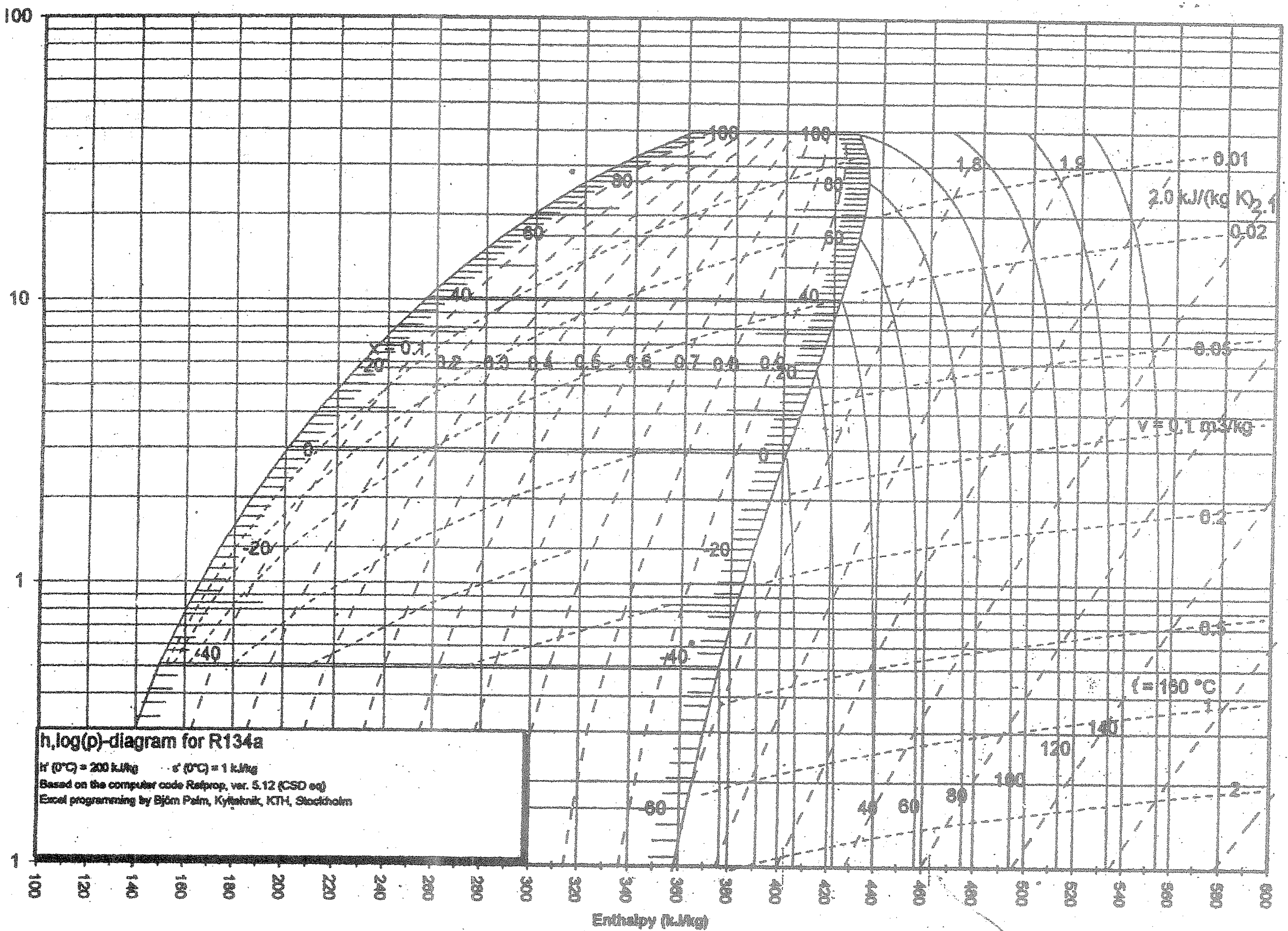
Figure Q3

Table Q 4.1: Comparative Refrigeration Performance of Different Refrigerants at – 23^{0}C Evaporating Temperature and +37^{0}C Condensing Temperature

Refrigerant Number	Refrigerant Name	Evaporator pressure (MPa)	Condenser pressure (MPa)	Net Refrigerating Effect (kJ/kg)	Refrigerant Circulated (kg/h)	Compressor Displacement (L/s)	Power Input (kW)
11	Trichlorofluoromethane	0.013	0.159	145.8	24.7	7.65	0.297
12	Dichlorodifluoromethane	0.134	0.891	105.8	34.0	1.15	0.330
22	Chlorodifluoromethane	0.218	1.390	150.1	24.0	0.69	0.326
123	Dichlorotrifluoroethane	0.010	0.139	130.4	27.6	10.16	0.306
125	Pentafluoroethane	0.301	1.867	73.7	48.9	0.71	0.444
134a	Tetrafluoroethane	0.116	0.933	135.5	26.6	1.25	0.345
502	r-22 / R – 115 azeotrope	0.260	1.563	91.9	39.2	0.72	0.391
717	Ammonia	0.166	1.426	1057.4	3.42	0.67	0.310

Table Q 4.2: Ozone depletion potential and Halocarbon global warming potential of popular refrigerants and mixtures

Refrigerant Number	Chemical Formula	Ozone depletion potential (ODP)	100-yr Global warming potential (GWP)
Chlorofluorocarbons			
11	CCl_3F	1.0	4,600
12	CCl_2F_2	1.0	10,600
113	CCl_2FCClF_2	0.80	14,000
114	$CClF_2CClF_2$	1.0	9,800
115	$CClF_2CF_3$	0.6	7,200
Hydrochlorofluorocarbons			
22	$CHClF_2$	0.055	1,700
123	$CHCl_2CF_3$	0.020	120
124	$CHClFCF_3$	0.020	620
141b	CH_3CCl_2F	0.11	700
142b	CH_3CClF_2	0.065	2,400
Hydrofluorocarbons			
32	CH_2F_2	0	550
125	CHF_2CF_3	0	3,400
134a	CH_2FCF_3	0	1,100
143a	CH_3CF_3	0	750
152a	CH_3CHF_2	0	43
Hydrocarbons			
50	CH_4	0	0
290	$CH_3CH_2CH_3$	0	0
Zoetropes			
407C	R-32/125/134A (23/25/52%wt)	0	1,700
410A	R-32/125 (50/50%wt)	0	2,000
Azeotropes			
500	R-12/152a (73.8/26.2 wt%)	0.74	6,310
502	R-22/115 (48.8/51.2 wt%)	0.31	5,494


h,log(p)-diagram for R134a
h' (0°C) = 200 kJ/kg · s' (0°C) = 1 kJ/kg
Based on the computer code Refprop, ver. 5.12 (CSD eq)
Excel programming by Björn Palm, Kylteknik, KTH, Stockholm
Enthalpy (kJ/kg)
2.0 kJ/(kg K)
v = 0.1 m3/kg
t = 160 °C
x = 0.1