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CONFIDENTIAL

SET A

UNIVERSITI KUALA LUMPUR

MALAYSIA FRANCE INSTITUTE

FINAL EXAMINATION

JANUARY 2010 SESSION

SUBJECT CODE	:	FRB30303
SUBJECT TITLE	:	PRODUCTION OF REFRIGERATION
LEVEL	:	BACHELOR
TIME/DURATION	:	9.00 am – 1:00 pm 4 HOURS
DATE	:	29 April 2010

INSTRUCTIONS TO CANDIDATES

1. All documents authorized (Open Book Examination)
2. Please read the instructions given in the question paper CAREFULLY.
3. This question paper is printed on both sides of the paper.
4. Please write your answers on the answer booklet provided.
5. Answer should be written in blue or black ink except for sketching, graphic and illustration.
6. This question paper consists only one section. Answer all questions.
7. Answer all questions in English.
8. The numerical result to be presented with 3 significant figures.

THERE ARE 13 PRINTED PAGES OF QUESTIONS.

INSTRUCTION: Answer ALL questions.

Please use the answer booklet provided.

An air-to-air refrigeration installation needs to be converted. The choices are R404A or R507A.

The technical file of this installation was spoil, but performance file of sizing remain as given in Appendix 1. The name plate cannot be read but the characteristics of the models of the range with R22 are given in Appendix 2.

We wish to estimate the performances of the refrigerating circuit with R507A or R404A to simplify calculations, assume as following:

The refrigerating circuit is sufficiently compact so that the pressure losses and the variations in temperature in the piping are neglected in this study.

PART A: Analyse existing fluid R22

The coordinates of the nominal cycle are given in Appendix 1

Question 1

To calculate the mass flow rate and volume flow rate of the air flowing through condenser and evaporator. The humidity of the air is neglected; the air is to be assumed dry and its thermal properties are given in Appendix 1.

(1 marks)

Question 2

To select a compressor model from the range suggested in Appendix 2.

(To follow the step of selection of a compressor)

(1.5 marks)

Question 3

To calculate the thermal losses of the compressor; express as percentage of absorptive power.

(1 marks)

Question 4

Fluid circulates counter flow in the two exchangers. Moreover, we assume the following:

For Evaporator: we neglect the zone of superheat and consider the total cooling power with the only evaporating zone

For condenser: we neglect the zone of subcooling and take desuperheating and condensing into account for the total of condensing power

To sketch the evolution of the profile of the temperatures by taking into account of the assumptions, then to calculate KS value of the evaporator and condenser.

(2.5 marks)

PART B: Replacemnt by R507A

The same temperatures of cycle are remaining. The percentage of thermal losses of the compressor to ambient is equivalent to that of R22.

Question 5

To fill in the thermodynamic properties table in Appendix 3 for user cycle.

(1.5 marks)

Question 6

To calculate the volumetric and effective efficiency of the compressor

(1 marks)

Question 7

To calculate the refrigerating power and absorptive power of the compressor

(1 marks)

Question 8

To determine the coordinates of the real point of discharge and the power rejected to the condenser.

(1 marks)

Question 9

To calculate the temperatures of air at exit of the exchangers (the volume flow rate remains same as Question 1

(1 marks)

Question 10

By considering the same assumptions as for R22, to calculate the value of KS product evaporator and condenser this should be installed for the proposed cycle.

(1 marks)

PART C: Determining new operation point with R507A

The value of KS products calculated in Question 10 and those installed (calculated in Question 4) are probably different; if, for an exchanger, this difference is lower than 10%, we neglect the corresponding temperature changes.

Question 11

For the evaporator and condenser, to compare the two values of KS product and to deduce the possible variation in the associated temperature.

(1 marks)

Question 12

To calculate the new temperatures of condensation and evaporation corresponding to the coupling between the compressor and the exchangers installed (calculated in Question 4).

As an example, the new operating point of the refrigerating unit with of R404A is given in Appendix 5.

(1 marks)

PART D: Comparison of the three fluids R22, R507A and R404A

The powers of the operating point with R507A and R404A are given in Appendix 5.

The refrigerant charge is same for the three cases is equal to 25 kg.

Rate of recovery at the end of the lifetime is 100%.

Annual leakage rate is 5%

We consider for the three fluids as following conditions:

Lifespan is 20 years.

Operating time is 10 hours per day for R22 and 350 days per year.

Conversion factor for electricity is 0.1 kg of CO_2 / kWh.

The values of GWP100 are as follow:

R22 is 1700 kg of CO_2 /kg

R404A is 3800 kg of CO_2 /kg

R507A is 3800 kg of CO_2 /kg

Question 13

To calculate the cooling energy produced daily by the installation functioning in R22. This constant energy remaining with the other fluids, to deduce the operating time from the installation charged with R404A or R507A.

(1 marks)

Question 14

To calculate the power consumption during the lifespan of the installation for the three fluids,

(1 marks)

Question 15

To deduce the value for indirect TEWI

(0.5 marks)

Question 16

To calculate the direct TEWI for each fluid

(0.5 marks)

Question 17

To deduce the value for the total TEWI

(0.5 marks)

PART E : Conclusion

Question 18

To compare the two possible substitutes according to environmental and economic criteria (the two fluids are the same cost of kWh is 0.12 euros)

(1 marks)

Question 19

According to you, apart from the simplifying assumptions (intended to facilitate calculations), what is the advantage of the step adopted for the choice of the fluid?

(1 marks)

END OF QUESTION

Appendix 1: Sizing table of R22 for points of nominal cycle

External mode		Condenser Entry	Condenser Exit	Evaporator Entry	Evaporator Exit	
CP air	1,006 kJ.kg $^{-1}$;K $^{-1}$				-18	-24
Density (kg/m3)			1,184	0	1,383	

	1	2	2 R	2 B	3	4	5
	Suction	Discharge and entry of condenser	HP gas line	HP liquid line	exit of Condenser and entry of TXV	entry of evaporator	exit of evaporator
p	1.78	13.5	13.5	13.5	13.5	1.78	1.78
Tsat	-28	35	35	35	35	-28	-28
T	-23	98.4	35	35	32	-28	-23
H	242	315	260.5	88.2	84.3	84.3	242
S	0.988	1.02	0.882	0.323	0.310		0.988
v	0.1290	0.02290	0.01726	0.00087	0.00086		0.129

T in °C; P_{sat} in bar; T_{sat} in °C; h in kJ.kg $^{-1}$; s in kJ.kg $^{-1}$ K $^{-1}$; v in m ^{3} kg $^{-1}$

Qo	41.00kW
Wabs	22.20kW
Qcd	60.0kW

Appendix 2: Characteristics of series compressor and point of manufacturer cycle

Fluid: R-22

Suction Superheat : 15°C

Subcooling : 0°C

Temperature of condensation: 35°C

	V_{swept} (m^3/h)	Te (°C)	-35	-30	-28	-25	-20	-15	-10
CP1	127	$P_{refrigerator}$ (kW)	16.6	23	26.1	30.5	39.4	49.7	61.7
		P_{abs} (kW)	11.7	13.9	14.7	16	17.9	19.7	21.3
CP2	151	$P_{refrigerator}$ (kW)	20.4	28.2	32	37.5	48.4	61	75.7
		P_{abs} (kW)	14.4	17.1	18	19.6	22	24.2	26.1
CP3	181	$P_{refrigerator}$ (kW)	25.2	34.9	39.5	46.3	59.8	75.4	93.5
		P_{abs} (kW)	17.8	21.1	22.3	24.2	27.2	29.9	32.3
CP4	210	$P_{refrigerator}$ (kW)	28.7	39.7	44.9	52.6	68	85.7	106.3
		P_{abs} (kW)	20.2	24	25.4	27.5	30.9	34	36.7

	Suction	Isentropic discharge	Inlet of expansion
p	1.78	13.5	13.5
Tsat	-28	35	35
T	-13	85.6	35
H	248	304	88.2
v	0.1350		

T in °C; p_{sat} in bar; T_{sat} in °C; H in $kJ.kg^{-1}$; S in $kJ.kg^{-1}K^{-1}$; v in $m^3 kg^{-1}$

Appendix 3: Tables of the thermodynamic properties for R507A (to be returned with the answer sheet)

TABLE I: Nominal cycle considered

	1	2is	2R	2B	3	4	5
	Suction		HP gas line	HP liquid line	exit of condenser	entry of evaporator	exit of evaporator
p							
Tsat					35		-28
T							
h							
s							
v							

T in °C; P_{sat} in bar; T_{sat} in °C; h in $kJ.kg^{-1}$; s in $kJ.kg^{-1}K^{-1}$; v in $m^3 kg^{-1}$

Appendix 4: Characteristics of R404A / R507A series compressor

$T_{suction}$ = 20°C and no subcooling

Powers in kW

		Tevap (°C)	-35	-30	-28	-25	-20	-15	-10
CP1	30	Pfrigo	23.4	31.1	34.8	40.2	50.9	63.3	77.2
		Pabs	13.2	15.3	16.2	17.4	19.5	21.3	23.1
	35	Pfrigo	21.2	28.4	31.8	36.9	46.8	58.3	71.2
		Pabs	13.5	15.8	16.7	18.1	20.3	22.4	24.5
	40	Pfrigo	18.9	25.6	28.8	33.4	42.7	53.3	65.6
		Pabs	13.6	16.1	17.1	18.7	21.1	23.5	25.8
CP2	30	Pfrigo	28.7	38.2	42.6	49.4	62.5	77.6	94.7
		Pabs	16.2	18.8	19.8	21.4	23.9	26.1	28.3
	35	Pfrigo	26	34.8	39	45.2	57.4	71.5	87.4
		Pabs	16.5	19.3	20.5	22.2	24.9	27.5	30
	40	Pfrigo	23.2	31.4	35.3	41	52.4	65.4	80.5
		Pabs	16.7	19.7	21	22.9	25.9	28.8	31.6
CP3	30	Pfrigo	35.5	47.2	52.7	61	77.2	95.9	117
		Pabs	20	23.2	24.5	26.4	29.5	32.3	35
	35	Pfrigo	32.1	43	48.2	55.9	70.9	88.4	108
		Pabs	20.4	23.9	25.3	27.4	30.8	34	37.1
	40	Pfrigo	28.7	38.8	43.6	50.7	64.7	80.8	99.5
		Pabs	20.6	24.4	26	28.3	32	35.6	39.1
CP4	30	Pfrigo	40.4	53.7	59.9	69.4	87.8	109	133
		Pabs	22.7	26.4	27.9	30	33.5	36.7	39.8
	35	Pfrigo	36.5	48.9	54.8	63.6	80.6	100.5	122.8
		Pabs	23.2	27.2	28.8	31.2	35	38.7	42.2
	40	Pfrigo	32.6	44.1	49.6	57.6	73.6	91.9	113.1
		Pabs	23.4	27.7	29.6	32.2	36.4	40.5	44.5

Appendix 5: Operating point of the circuit with of R-404A

Mode –28°C/+35°C:

Refrigerating Power : 45 kW
Absorptive Power : 24.9 kW
Power condenser : 66.2 kW

Exchangers necessary:
Condenser : KS = 8.44 kW/K (mode of air: +25°C/+30.5°C)
Evaporator : KS = 6.82 kW/K (for 6.26 kW/K installed: the temperature of evaporation does not change);AIR: -18°c/-24.6°c.

Point of real coupling:

MODE: -28°c/+37,1°c
Refrigerating Power : 43 kW
Absorptive Power : 25.2 kW
Power condenser : 64.4 kW

Exchanging modes (with the KS calculated with question 4):
Condenser : mode of air: +25°C/+30.4°C
Evaporator : mode of air: -18°c/-24.3°c

Appendix 6: Saturation table of R-507a

	liquid				vapor		
T	P	h	s	v	P	h	s
40	18.7	112	0.405	1.03	228	776	9.33
38	17.9	109	0.394	1.02	228	778	9.90
36	17.0	105	0.384	1.01	228	779	10.5
35	16.6	104	0.379	1.00	227	780	10.8
34	16.2	102	0.374	1.00	227	780	11.1
32	15.4	99.0	0.364	0.987	227	782	11.8
30	14.7	95.9	0.354	0.977	226	783	12.5

	liquid				vapor		
T	P	h	s	v	P	h	s
-25	2.63	18.9	0.0783	0.802	200	809	72.4
-26	2.53	17.7	0.0732	0.799	200	810	75.2
-27	2.43	16.4	0.0680	0.797	199	810	78.0
-28	2.34	15.1	0.0629	0.795	199	811	81.1
-29	2.25	13.8	0.0577	0.793	198	812	84.2
-30	2.16	12.6	0.0525	0.791	197	813	87.6

T in °C; P_{sat} in bar; T_{sat} in °C; h in $kJ.kg^{-1}$; s in $kJ.kg^{-1}K^{-1}$; v in $l.kg^{-1}$

Appendix 7: Superheated vapour table of the R507A

P_{sat} in bar; T_{sat} in °C; h in $kJ.kg^{-1}$; s in $kJ.kg^{-1}K^{-1}$; v in $m^3 kg^{-1}$

		overheat (K)							
tsat		12.1	21.1	25	30	35	40	45	52.7
40	h	245.0	256.0	260.0	266.0	272.0	278.0	283.0	292.0
	s	0.827	0.861	0.875	0.892	0.909	0.925	0.941	0.965
	v	0.0106	0.01142	0.01174	0.01213	0.01251	0.01288	0.01323	0.0138
38	h	244.0	255.0	259.0	265.0	271.0	277.0	282.0	291.0
	s	0.828	0.861	0.875	0.892	0.909	0.925	0.941	0.965
	v	0.0112	0.0120	0.0124	0.0128	0.0132	0.0135	0.0139	0.0144
36	h	243.0	254.0	258.0	264.0	270.0	275.0	281.0	289.0
	s	0.828	0.861	0.875	0.892	0.909	0.9250	0.9410	0.9640
	v	0.0118	0.0127	0.0130	0.0134	0.0138	0.0142	0.0146	0.0152
35	h	243.0	253.0	258.0	264.0	269.0	275.0	280.0	289.0
	s	0.828	0.862	0.875	0.892	0.909	0.925	0.941	0.964
	v	0.0121	0.0130	0.0133	0.0138	0.0142	0.0146	0.0150	0.0155
34	h	242.0	253.0	257.0	263.0	269.0	274.0	280.0	288.0
	s	0.829	0.862	0.875	0.892	0.909	0.925	0.941	0.964
	v	0.0125	0.0133	0.0137	0.0141	0.0145	0.0149	0.0153	0.0159
32	h	241.0	252.0	256.0	262.0	267.0	273.0	278.0	287.0
	s	0.830	0.862	0.875	0.892	0.909	0.925	0.941	0.964
	v	0.01318	0.01407	0.0144	0.0149	0.0153	0.0157	0.0161	0.0167
30	h	241.0	251.0	255.0	261.0	266.0	272.0	277.0	285.0
	s	0.830	0.862	0.876	0.892	0.909	0.925	0.940	0.964
	v	0.0139	0.0148	0.0152	0.0157	0.0161	0.0165	0.0170	0.0176

		overheat (K)							
tsat		5	10	20	30	40	45	48	50
-25	h	205.0	209.0	217.0	226.0	235.0	239.0	242.0	244.0
	s	0.826	0.843	0.875	0.907	0.938	0.953	0.962	0.968
	v	0.0744	0.0764	0.0802	0.0839	0.0876	0.0894	0.0905	0.0912
-26	h	204.0	208.0	217.0	225.0	234.0	239.0	241.0	243.0
	s	0.827	0.843	0.876	0.908	0.939	0.954	0.963	0.969
	v	0.0772	0.0793	0.0832	0.0871	0.0909	0.0928	0.094	0.095
-27	h	203.0	208.0	216.0	225.0	233.0	238.0	240.0	242.0
	s	0.827	0.844	0.877	0.908	0.939	0.955	0.964	0.970
	v	0.0802	0.0823	0.0864	0.0904	0.094	0.096	0.097	0.098
-28	h	203.0	207.0	215.0	224.0	233.0	237.0	240.0	241.0
	s	0.828	0.845	0.877	0.909	0.940	0.955	0.964	0.970
	v	0.0833	0.0855	0.090	0.094	0.098	0.100	0.101	0.102
-29	h	202.0	206.0	215.0	223.0	232.0	236.0	239.0	241.0
	s	0.829	0.846	0.878	0.910	0.941	0.956	0.965	0.971
	v	0.0865	0.089	0.093	0.098	0.102	0.104	0.105	0.106
-30	h	202.0	206.0	214.0	223.0	231.0	236.0	238.0	240.0
	s	0.830	0.846	0.879	0.911	0.942	0.957	0.966	0.972
	v	0.090	0.092	0.097	0.101	0.106	0.108	0.109	0.110