



UNIVERSITI KUALA LUMPUR
MALAYSIA FRANCE INSTITUTE

FINAL EXAMINATION
SEPTEMBER 2014 SESSION

SUBJECT CODE : FRB30503
SUBJECT TITLE : TECHNOLOGY OF INDUSTRIAL REFRIGERATION
LEVEL : BACHELOR
TIME/DURATION : 9.00 AM – 12.00 PM
(3 HOURS)
DATE : 8 JANUARY 2015

INSTRUCTIONS TO CANDIDATES

1. All documents authorized (OPEN BOOK EXAMINATION)
 2. This question paper is printed on both sides of the paper.
 3. Answer should be written in blue or black ink except for sketching, graphic and illustration.
 4. This question paper consists only one section. Answer all questions.
 5. Answer all questions in English.
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THERE ARE 2 PRINTED PAGES OF QUESTIONS AND 4 PAGES OF APPENDICE, EXCLUDING THIS PAGE

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

A project consultant is designing a booster system for a freezer room at -25°C , with cooling capacity of 140kW and a cold room at -10°C , with cooling capacity of 280 kW.

The design completed with HP circuit with 2 single stage open type screw compressors and LP circuit which have 1 single stage open type screw compressor with a condenser which is cooling by a cooling tower and maximum water temperature is 28°C . Each evaporator supplied by thermal expansion valve Each compressor with its own oil separator and its own oil cooler is cooled by a cooling tower.

The design as the following conditions:

Refrigerant	:	R404A
Superheated in the piping of suction	:	5 °C
Superheated at exit of evaporator is	:	5 °C
Subcool of the liquid at exit condenser	:	3 °C

Question 1

Determine the range of temperature and pressure of the condensing and evaporating of HP circuit and evaporating of LP circuit.

(15 marks)

Question 2

From appendices 1 and 2, calculate the energy performances and the annual cost of the electric consumption of the compressors operate for 24 hours per day for 280kW of HP circuit and 140kW of LP circuit with a tariff of RM0.323 kWh.

From power consumption point of view, select the suitable compressor model for HP and LP circuit and justify your answer. The operating condition of cycle is $-30^{\circ}\text{C} / -15^{\circ}\text{C} / 33^{\circ}\text{C}$.

(20 marks)

Question 3

Draw the refrigeration schematics with expansion, bottle, condenser, compressors, and economiser if necessary and well placed pipes and valves between the components. Refer to appendix 1.

(15 marks)

Question 4

By using the attached diagram in Appendix 4, you are asked to draw the cycle and return the copy together with the answer booklet. Hence, state the values of discharge enthalpy and temperature of LP compressors. Assume that isentropic efficiency of compressor is 0.8 and the operating condition of cycle is $-30 / -15 / +33$ ° C

(15 marks)

Question 5

Calculate mass flow rate of the evaporators.

Hence, find the volume flow rate of R404A supply to and return from evaporators.

(15 marks)

Question 6

Calculate the diameter of the piping for supply to and return from evaporators.

Refer to appendix 1 and the velocity for entry evaporator is 1 m/s and for return from evaporator is 15 m/s.

(10 marks)


Question 7

Calculate the power rejected by condenser.

(10 marks)

END OF QUESTION

Appendix 1

	Appendix 1
BITZER Software v6.4.2 rev1276	10/12/2014 / All data subject to change. 4 / 11

Compressor Selection: Open Screw Compressors OS

Model OSN8591-K
Refrigerant R404A
Operating mode Standard

Tc[°C]		Te	-15°C	-20°C	-25°C	-30°C	-35°C	-40°C	-45°C
25	Q	[W]	321927	262211	211506	168714	132836	102966	78281
	P	[kW]	91.5	85.7	80.2	75.1	70.7	67.1	64.5
	I	[A]	-	-	-	-	-	-	-
	COP	-	3.52	3.06	2.64	2.25	1.88	1.54	1.21
	mLP	[kg/h]	8850	7378	6096	4986	4029	3209	2508
	mHP	[kg/h]	8850	7378	6096	4986	4029	3209	2508
	Qac	[kW]	-	-	-	-	-	-	-
	tcu	[°C]	24.6	24.6	24.6	24.6	24.6	24.6	24.6
	pm	[bar(a)]	-	-	-	-	-	-	-
Qsc	[kW]	-	-	-	-	-	-	-	
30	Q	[W]	303351	246088	197534	156620	122375	93922	70460
	P	[kW]	99	92.8	87	81.8	77.3	73.7	71.2
	I	[A]	-	-	-	-	-	-	-
	COP	-	3.07	2.65	2.27	1.92	1.58	1.28	0.99
	mLP	[kg/h]	8863	7369	6069	4942	3971	3137	2425
	mHP	[kg/h]	8863	7369	6069	4942	3971	3137	2425
	Qac	[kW]	-	-	-	-	-	-	-
	tcu	[°C]	29.6	29.6	29.6	29.6	29.6	29.6	29.6
	pm	[bar(a)]	-	-	-	-	-	-	-
Qsc	[kW]	-	-	-	-	-	-	-	
35	Q	[W]	282540	228098	182024	143284	110940	84145	62127
	P	[kW]	106.8	100.3	94.2	88.8	84.2	80.7	78.3
	I	[A]	-	-	-	-	-	-	-
	COP	-	2.65	2.27	1.93	1.61	1.32	1.04	0.79
	mLP	[kg/h]	8824	7314	5999	4860	3877	3034	2314
	mHP	[kg/h]	8824	7314	5999	4860	3877	3034	2314
	Qac	[kW]	-	-	-	-	-	-	-
	tcu	[°C]	34.6	34.6	34.6	34.6	34.6	34.6	34.6
	pm	[bar(a)]	-	-	-	-	-	-	-
Qsc	[kW]	-	-	-	-	-	-	-	


Q [W]
 P [kW]
 I [A]
 COP [-]
 mLP [kg/h]

Cooling capacity
 Power input
 Current
 COP/EER
 Mass flow LP

mHP [kg/h]
 Qac [kW]
 tcu [°C]
 pm [bar(a)]
 Qsc [kW]

Mass flow HP
 Additional cooling
 Liquid temp.
 ECO pressure
 sub cooler capacity (ECO)

Appendix 2

	Appendix 2
BITZER Software v6.4.2 rev1276	10/12/2014 / All data subject to change.
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Compressor Selection: Open Screw Compressors OS

Model OSK7451-K
Refrigerant R404A
Operating mode Economizer

Tc[°C]		Te	-15°C	-20°C	-25°C	-30°C	-35°C	-40°C	-45°C
25	Q	[W]	276013	232151	193861	160584	131788	106979	85711
	P	[kW]	82.3	77.3	72.4	67.9	63.9	60.6	58.2
	I	[A]	-	-	-	-	-	-	-
	COP	-	3.35	3.01	2.68	2.37	2.06	1.77	1.47
	mLP	[kg/h]	6821	5672	4677	3820	3086	2462	1935
	mHP	[kg/h]	7527	6456	5499	4647	3893	3227	2642
	Qac	[kW]	-	-	-	-	-	-	-
	tcu	[°C]	14.67	11.46	8.02	4.33	0.36	-3.9	-8.46
	pm	[bar(a)]	6.99	6.33	5.67	5.03	4.4	3.79	3.21
	Qsc	[kW]	27.9	30.6	31.6	31.3	30.1	28	25.3
30	Q	[W]	266440	223884	186779	154543	126636	102570	81907
	P	[kW]	88.4	83.3	78.4	74	70.1	66.9	64.4
	I	[A]	-	-	-	-	-	-	-
	COP	-	3.01	2.69	2.38	2.09	1.81	1.53	1.27
	mLP	[kg/h]	6779	5627	4630	3771	3036	2411	1885
	mHP	[kg/h]	7690	6592	5612	4740	3967	3284	2682
	Qac	[kW]	-	-	-	-	-	-	3.03
	tcu	[°C]	17.52	14.29	10.8	7.02	2.93	-1.47	-6.22
	pm	[bar(a)]	7.62	6.91	6.2	5.49	4.8	4.13	3.49
	Qsc	[kW]	34.4	36	36.1	35	33.1	30.4	27.1
35	Q	[W]	255540	214.521	178778	147719	120806	97560	77557
	P	[kW]	95.3	90	85.2	80.9	77.1	73.9	71.2
	I	[A]	-	-	-	-	-	-	-
	COP	-	2.68	2.38	2.1	1.83	1.57	1.32	1.09
	mLP	[kg/h]	6717	5563	4565	3705	2971	2347	1821
	mHP	[kg/h]	7840	6718	5716	4824	4032	3330	2711
	Qac	[kW]	-	-	-	-	-	2.81	11.42
	tcu	[°C]	20.6	17.3	13.73	9.84	5.62	1.03	-3.94
	pm	[bar(a)]	8.34	7.57	6.79	6.01	5.25	4.5	3.78
	Qsc	[kW]	40.5	41	40.3	38.5	35.8	32.5	28.7

Q [W]
 P [kW]
 I [A]
 COP [-]
 mLP [kg/h]

Cooling capacity
 Power input
 Current
 COP/EER
 Mass flow LP

mHP [kg/h]
 Qac [kW]
 tcu [°C]
 pm [bar(a)]
 Qsc [kW]

Mass flow HP
 Additional cooling
 Liquid temp.
 ECO pressure
 sub cooler capacity (ECO)

Appendix 3

Table of R404A saturated

T (C)	Liquid with saturated				Vapour with saturated			
	P (bar)	h (kJ/kg)	s (J/kg K)	v (dm ³ /kg)	P (bar)	h (kJ/kg)	s (J/kg K)	v (dm ³ /kg)
-45	1.077	141.26	767.09	0.7670	1.039	339.88	1639.9	176.34
-40	1.354	147.45	794.21	0.7762	1.310	342.91	1634.1	141.69
-35	1.684	153.73	821.00	0.7858	1.634	345.91	1629.0	114.94
-30	2.074	160.10	847.45	0.7959	2.017	348.86	1624.6	94.06
-25	2.531	166.56	873.57	0.8064	2.466	351.77	1620.6	77.59
-20	3.060	173.10	899.37	0.8176	2.989	354.63	1617.0	64.47
-15	3.671	179.74	924.88	0.8293	3.592	357.42	1613.8	53.93
-10	4.371	186.46	950.12	0.8417	4.284	360.13	1611.0	45.38
-5	5.166	193.25	975.15	0.8548	5.072	362.77	1608.3	38.40
0	6.066	200.00	1000.00	0.8688	5.965	365.31	1605.9	32.65
5	7.079	207.10	1024.73	0.8838	6.970	367.75	1603.6	27.88
10	8.212	214.16	1049.41	0.8999	8.097	370.07	1601.4	23.90
15	9.476	221.34	1074.09	0.9174	9.354	372.25	1599.2	20.55
20	10.880	228.64	1098.87	0.9363	10.751	374.28	1596.9	17.71
25	12.432	236.11	1123.84	0.9571	12.297	376.13	1594.4	15.30
30	14.145	243.77	1149.07	0.9801	14.004	377.77	1591.7	13.23
35	16.028	251.67	1174.68	1.0059	15.883	379.15	1588.6	11.44
40	18.094	259.87	1200.78	1.0353	17.945	380.20	1584.9	9.88
45	20.356	268.45	1227.49	1.0692	20.204	380.82	1580.3	8.51
50	22.830	277.47	1254.92	1.1096	22.677	380.88	1574.3	7.29
55	25.531	287.05	1283.22	1.1595	25.381	380.12	1566.5	6.20
60	28.481	297.28	1312.53	1.2251	28.339	378.15	1555.5	5.20

Appendix 4

