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CONFIDENTIAL

SET A

UNIVERSITI KUALA LUMPUR

MALAYSIA FRANCE INSTITUTE

FINAL EXAMINATION

JANUARY 2010 SESSION

SUBJECT CODE	:	FRB40103
SUBJECT TITLE	:	TECHNOLOGY OF INDUSTRIAL REFRIGERATION
LEVEL	:	BACHELOR
TIME/DURATION	:	9.00 am – 1:00 pm 4 HOURS
DATE	:	5 May 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.

THERE ARE 10 PRINTED PAGES OF QUESTIONS.

INSTRUCTION: Answer ALL questions.

Please use the answer booklet provided.

PART A

A factory daily receive 100 000 litres of milk in the morning (08 00) and 100 000 litres of milk in the evening (20 00). Milk is received with 6°C and need to be cooled to 4°C in 2 hours.

Question 1

a) Calculate the required refrigerating power for this cooling.

[Take CP of milk as 4.18kJ / kg. K]

(1 marks)

b) Calculate the cooling energy.

(0.5 marks)

Milk is then processed using the following equipment:

	Power (kW)	Schedules of operation	
		ON	OFF
Separator	120	10h00	14h00
Pasteurizer	250	10h00	14h00
Maturator	50	12h00	16h00
Tunnel of cooling	300	14h00	18h00
Cold room	80	0h00	24h00

Table 1.1 Schedule of operation of equipment

c) To establish the histogram of the needs for the factory (in the form of table only)

(1 marks)

For this application, a designer proposes to install a refrigerating power of 920kW

d) What do you think about this choice? What power would you propose to install? (Justify your choice by the concept of thermal energy storage)

(0.5 marks)

Question 2

What advice would you give to your client regarding the operation time of the refrigeration system, without modifying the schedule of operation of varies equipment stated in the table 1.1 above.

(Note: Your objective is to limit the maximum demand of electricity consumption)

(1 marks)

Question 3

Between a solution of direct expansion and a system with secondary fluid and between a halogenous refrigerant (HCFC, HFC) and ammonia, what solution proposes to be adopted? (Justify your choice by having the advantages and disadvantages of each solution).

(2 marks)

PART B

The solution finally retained is to install a capacity of 800 kW by using an installation of ammonia produce glycol water at -8ºC by 2 flood plate exchangers supplied by LP bottle. The cycle is single stage operate in a mode -12ºC / +35ºC with screw compressors, each with its own oil separator. The condenser is common to the compressors. The cooling of oil is carried out by water cooled exchanger.

Question 4

Base on appendices 1 to 4; propose a selection of compressor by justifying your choice of power consumption.

(2 marks)

Question 5

Calculate the mass flow rate and the volume flow rate of vapour passing LP bottle.

(2 marks)

Question 6

To size the LP bottle by considering return or returns pipe at least 0.5 meters of the wall of the bottle, as shown figure below. We will take k = 0.045 for the calculation of velocity of separation and base on sizing of vapour section equal to 90% of the cross section of the bottle. Maximum mass of ammonia maintenance in the bottle is evaluated as 650 kg.

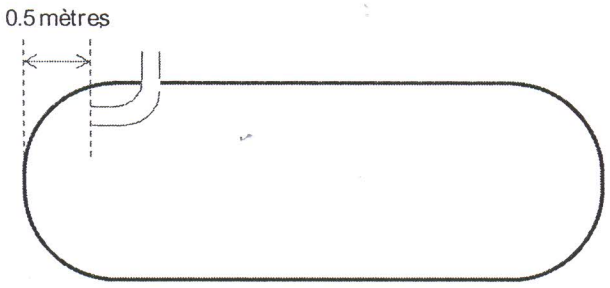


Figure 6.1 Return pipe at least 0.5 meters of the wall of the bottle

(4 marks)

PART C

Question 7

Calculate the discharge temperature which we obtain without oil cooling (we take an isentropic efficiency of 0.7)

(0.5 marks)

Question 8

Explain the role of oil in this application

(0.5 marks)

Question 9

Which place would you position (them) the temperature measurement for controlling oil cooling?

(0.5 marks)

Question 10

Is a system of reheating of oil, necessary? Why?

(0.5 marks)

Question 11

By retaining a manual system of oil recovery, draw the refrigerating diagram of the installation with device of separation of oil cooling and recovery, system of expansion, bottle, condenser, compressor, piping of connections, non-returns valve and oil flow controller positioning in the diagram.

(4 marks)

END OF QUESTION

Appendix 1 *Open type screw compressor with R717*

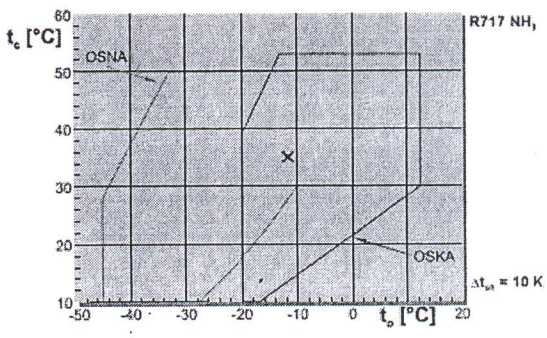
Bitzer SOFTWARE Version 5.1.2	*Appendix 1 Open type screw compressor with R717* 4/26/2010 / All data subject to change.

Compressor Selection: Open Screw Compressors

Input Values

Cooling capacity	**95kW**
Refrigerant	R717 [NH3]
Reference temperature	Dew point temp.
Evaporating SST	-12°C
Condensing SDT	35°C
Operating mode	Standard
Liquid subcooling	0K
Discharge gas temp.	80°C
Suct. gas superheat	5K
Useful superheat	100%
Speed	2900 /min
Capacity Control	100%

Application Limits (Standard)



Output

Compressor model	OSKA7441-K	OSKA7451-K
Cooling capacity	92.7 kW	110.6 kW
Cooling capacity *	92.7 kW	110.6 kW
Evaporator capacity	92.7 kW	110.6 kW
Power input	32.2 kW	33.0 kW
Condensing capacity	106.0 kW	126.5 kW
COP/EER	2.88	3.35
COP/EER *	2.88	3.35
Mass flow LP	305 kg/h	364 kg/h
Mass flow HP	305 kg/h	364 kg/h
Operating mode	Standard	Standard
Liquid temp.	35.0 °C	35.0 °C
Oil volume flow	1.58 m³/h	1.58 m³/h
Oil cooler outlet	55.3 °C	57.7 °C
Oil cooler load	18.90 kW	17.13 kW
Necces. driving motor	37.0 kW	45.0 kW
DG w/o cooling	167.0 °C	145.7 °C

Starting point for motor selection see T. Data/ Notes

Additional cooling/ Limitations (see Limits + T. Data)!

*According to EN12900 (5K suction gas superheat, 0K liquid subcooling)

Appendix 2 *Open type screw compressor with R717*

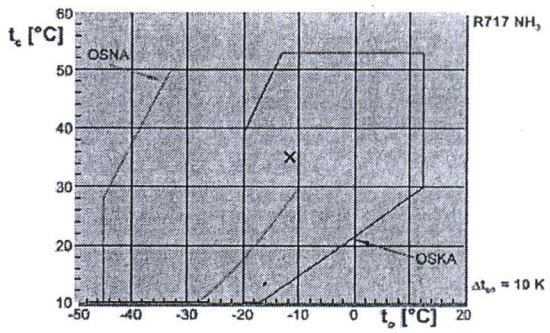
Bitzer SOFTWARE Version 5.1.2	*Appendix 2 Open type screw compressor with R717* 4/26/2010 / All data subject to change.

Compressor Selection: Open Screw Compressors

Input Values

Cooling capacity	**225kW**
Refrigerant	R717 [NH3]
Reference temperature	Dew point temp.
Evaporating SST	-12°C
Condensing SDT	35°C
Operating mode	Standard
Liquid subcooling	0K
Discharge gas temp.	80°C
Suct. gas superheat	5K
Useful superheat	100%
Speed	2900 /min
Capacity Control	100%

Application Limits (Standard)



Output

Compressor model	OSKA8561-K	OSKA8571-K
Cooling capacity	201 kW	244 kW
Cooling capacity *	201 kW	244 kW
Evaporator capacity	201 kW	244 kW
Power input	65.9 kW	73.8 kW
Condensing capacity	230 kW	279 kW
COP/EER	3.05	3.30
COP/EER *	3.05	3.30
Mass flow LP	662 kg/h	801 kg/h
Mass flow HP	662 kg/h	801 kg/h
Operating mode	Standard	Standard
Liquid temp.	35.0 °C	35.0 °C
Oil volume flow	2.65 m³/h	2.57 m³/h
Oil cooler outlet	51.1 °C	48.7 °C
Oil cooler load	37.0 kW	38.8 kW
Necces. driving motor	90.0 kW	90.0 kW
DG w/o cooling	158.3 °C	147.6 °C

Starting point for motor selection see T. Data/ Notes

Additional cooling/ Limitations (see Limits + T. Data)!

*According to EN12900 (5K suction gas superheat, 0K liquid subcooling)

Appendix 3

GEA
Refrigeration Division

Grasso
Products b.v.

Parallelweg 27
5223 AL 's-Hertogenbosch
P.O. Box 343
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The Netherlands
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E-mail: products@grasso.nl
Website: www.grasso-global.com

Comsel - Grasso Sélection de Compresseur

Impression date/heure 09-01-2010 / 16:06
Version programme 3.8.02 Valide jusqu'au 31/12/2009

PROPRIÉTÉS TECHNIQUES (Package standard)

Screw compressor	1 x TR-T2240S-28	
Swept volume	1460,0	(m³/h)
Refrigerant	NH3	
Speed	2940	(/min)
Frequency	50	(Hz)
Evaporating temperature	-12,0	(°C)
Evaporating pressure	268,4	(kPa)
Superheat	5,0	(K)
Useful superheat	0,0	(K)
Condensing temperature	35,0	(°C)
Condensing pressure	1351,3	(kPa)
Liquid subcooling	0,0	(K)
Pressure ratio	5,03	(-)
Cooling capacity	861,4	(kW)
Power input	246,7	(kW)
COP =Qo / Pe	3,49	(-)

Charge partielle [%]	Pe [kW]	Qo [kW]
100	246,7	861,4
90	227,0	775,3
80	207,2	689,1
70	190,0	603,0
60	172,7	516,8
50	155,4	430,7
40	143,1	344,6
30	128,3	258,4
20	118,4	172,3
10	108,5	86,1

Partload perc. is not equal to position of control slide perc.

Partload values are approximate

Mass flow rate	2863,0	(kg/h)
Oil cooler load	120,5	(kW)
Temperature of entering of oil	50,0	(°C)
Operational flow rate	49,0	(l/min)
Total flow rate	128,9	(l/min)
Discharge temperature	80,0	(°C)
Condensing capacity	987.6	(kW)

Appendix 4

GEA
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Comsel - Grasso Sélection de Compresseur

Impression date/heure 09-01-2010 / 00:20
Version programme 3.8.02 Valide jusqu'au 31/12/2009

PROPRIÉTÉS TECHNIQUES (Package standard)

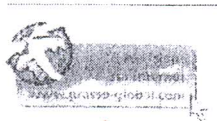
Screw compressor	1 x HR-H2655S-28	
Swept volume	471,0	(m³/h)
Refrigerant	NH3	
Speed	2940	(/min)
Frequency	50	(Hz)
Evaporating temperature	-12,0	(°C)
Evaporating pressure	268,4	(kPa)
Superheat	5,0	(K)
Useful superheat	0,0	(K)
Condensing temperature	35,0	(°C)
Condensing pressure	1351,3	(kPa)
Liquid subcooling	0,0	(K)
Pressure ratio	5,03	(-)
Cooling capacity	264,9	(kW)
Power input	79,5	(kW)
COP =Qo / Pe	3,33	(-)

Charge partielle [%]	Pe [kW]	Qo [kW]
100	79,5	264,9
90	73,1	238,4
80	66,8	211,9
70	61,2	185,4
60	55,7	158,9
50	50,1	132,5
40	46,1	106,0
30	41,3	79,5
20	38,2	53,0
10	35,0	26,5

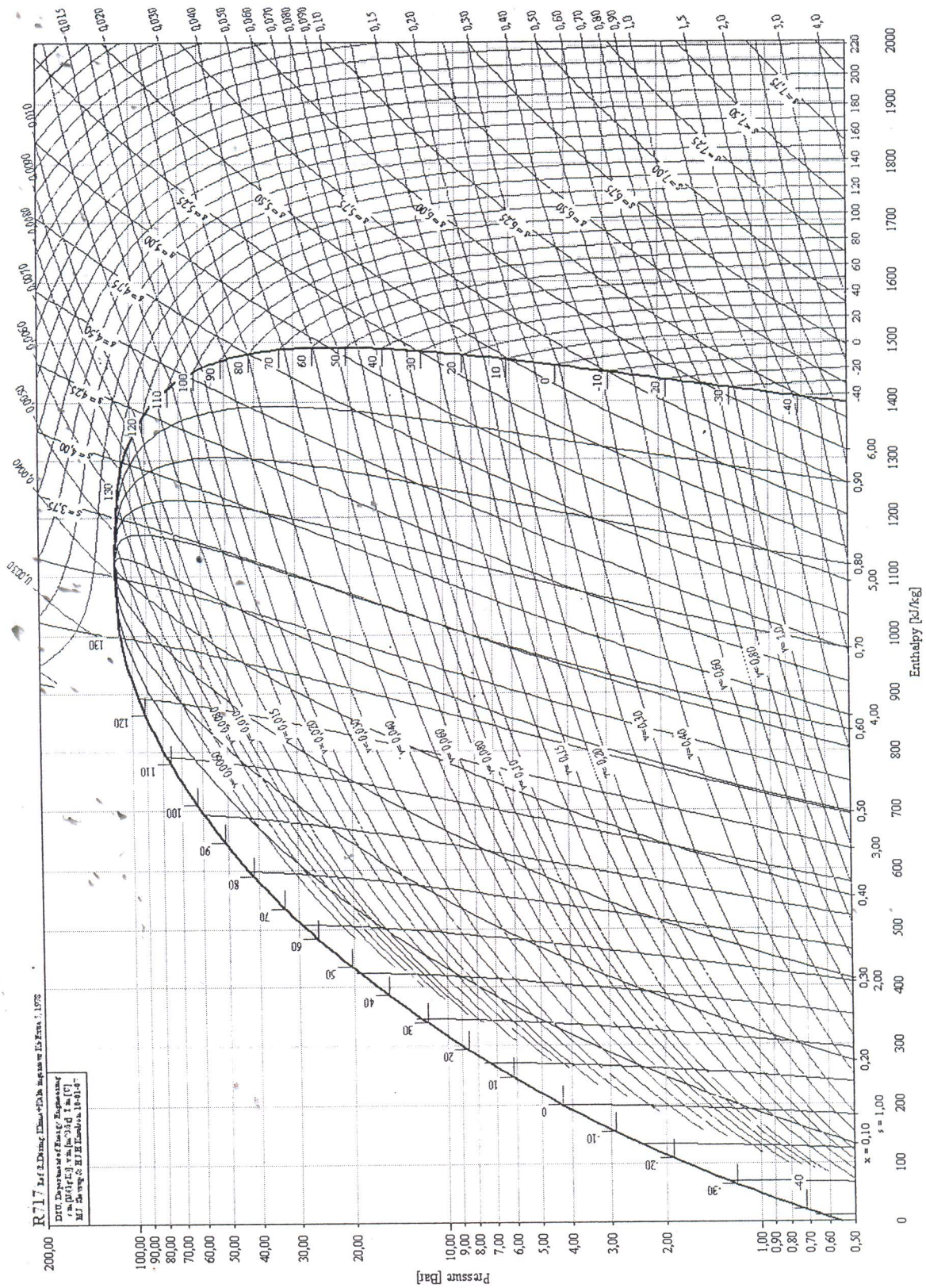
Partload perc. is not equal to position of control slide perc.

Partload values are approximate

Mass flow rate	880,0	(kg/h)
Oil cooler load	40,7	(kW)
Temperature of entering of oil	50,0	(°C)
Operational flow rate	19,6	(l/min)
Total flow rate	43,5	(l/min)
Discharge temperature	80,0	(°C)
Condensing capacity	303,7	(kW)



Appendix 5 PH diagram of R717



Appendix 6 Saturation table of R717

Refrigerant: R717, NH3, Ammonia, Saturation
Reference: R.Döring. Klima+Kälte ingenieur Ki-Extra 5, 1978

T	P	Vl	Vg	Hl	Hg	R	Sl	Sg
°C	Bar	dm^3/kg	m^3/kg	kJ/kg	kJ/kg	kJ/kg	kJ/(kgK)	kJ/(kgK)
-40	0,717	1,4491	1,55117	20,25	1407,25	1387	0,2909	6,2398
-38	0,797	1,4542	1,4048	29,1	1410,38	1381,27	0,3286	6,2026
-36	0,885	1,4594	1,27465	37,97	1413,46	1375,5	0,3661	6,1662
-34	0,98	1,4647	1,15868	46,84	1416,51	1369,66	0,4033	6,1305
-32	1,083	1,4701	1,05513	55,74	1419,5	1363,77	0,4403	6,0956
-30	1,195	1,4755	0,96249	64,64	1422,46	1357,81	0,477	6,0613
-28	1,315	1,481	0,87945	73,57	1425,36	1351,8	0,5135	6,0277
-26	1,446	1,4865	0,80488	82,5	1428,22	1345,72	0,5497	5,9947
-24	1,587	1,4921	0,73779	91,45	1431,04	1339,58	0,5857	5,9623
-22	1,738	1,4978	0,67733	100,42	1433,8	1333,38	0,6214	5,9305
-20	1,901	1,5036	0,62274	109,4	1436,51	1327,11	0,657	5,8994
-18	2,076	1,5094	0,57338	118,39	1439,17	1320,78	0,6923	5,8687
-16	2,263	1,5154	0,52866	127,4	1441,78	1314,38	0,7273	5,8386
-14	2,464	1,5214	0,4881	136,43	1444,34	1307,91	0,7622	5,8091
-12	2,679	1,5275	0,45123	145,46	1446,84	1301,38	0,7968	5,78
-10	2,908	1,5336	0,41769	154,52	1449,29	1294,77	0,8312	5,7514
-8	3,152	1,5399	0,38712	163,58	1451,68	1288,09	0,8653	5,7233
-6	3,412	1,5463	0,35921	172,66	1454,01	1281,35	0,8993	5,6957
-4	3,688	1,5527	0,33371	181,76	1456,29	1274,53	0,9331	5,6685
-2	3,982	1,5593	0,31037	190,87	1458,51	1267,63	0,9666	5,6417
0	4,294	1,5659	0,28898	200	1460,66	1260,66	1	5,6153
2	4,625	1,5727	0,26935	209,14	1462,76	1253,62	1,0332	5,5893
4	4,975	1,5795	0,25131	218,3	1464,8	1246,5	1,0661	5,5637
6	5,345	1,5865	0,23471	227,47	1466,77	1239,3	1,0989	5,5384
8	5,737	1,5936	0,21943	236,67	1468,68	1232,01	1,1315	5,5135
10	6,15	1,6008	0,20533	245,87	1470,52	1224,65	1,1639	5,489
12	6,586	1,6081	0,19232	255,1	1472,3	1217,21	1,1961	5,4647
14	7,046	1,6155	0,18029	264,34	1474,02	1209,67	1,2281	5,4408
16	7,53	1,6231	0,16916	273,6	1475,66	1202,06	1,26	5,4172
18	8,039	1,6308	0,15885	282,89	1477,24	1194,35	1,2917	5,3939
20	8,574	1,6386	0,14929	292,19	1478,74	1186,55	1,3232	5,3708
22	9,136	1,6466	0,14041	301,51	1480,17	1178,66	1,3546	5,3481
24	9,725	1,6547	0,13216	310,86	1481,53	1170,68	1,3859	5,3255
26	10,343	1,663	0,12449	320,23	1482,82	1162,59	1,4169	5,3033
28	10,991	1,6714	0,11734	329,62	1484,03	1154,41	1,4479	5,2812
30	11,669	1,68	0,11069	339,04	1485,16	1146,12	1,4787	5,2594
32	12,379	1,6888	0,10447	348,48	1486,21	1137,73	1,5093	5,2377
34	13,121	1,6978	0,09867	357,96	1487,19	1129,23	1,5398	5,2163
36	13,896	1,7069	0,09327	367,33	1488,09	1120,75	1,5699	5,1952
38	14,705	1,7162	0,0882	376,86	1488,89	1112,03	1,6002	5,1741
40	15,549	1,7257	0,08345	386,43	1489,61	1103,19	1,6303	5,1532