



SET A

UNIVERSITI KUALA LUMPUR
MALAYSIA FRANCE INSTITUTE

FINAL EXAMINATION
JULY 2010 SESSION

SUBJECT CODE : FRB 40103
SUBJECT TITLE : TECHNOLOGY OF INDUSTRIAL REFRIGERATION
LEVEL : BACHELOR
TIME/DURATION : 9.00 AM – 1.00 PM
(4 HOURS)
DATE : 21 NOVEMBER 2010

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 (1) section. Answer all questions.
 5. Answer all questions in English.
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THERE ARE 10 PRINTED PAGES OF QUESTIONS, EXCLUDING THIS PAGE.

INSTRUCTION: Answer ALL questions.

Please use the answer booklet provided.

A chemical process requires a secondary fluid at -20°C and at a power of 250kW.

By considering the possibility of air cooled condenser (temperature of condensation $+42^{\circ}\text{C}$) and/or on a plate type condenser supplied by an open cooling tower with return water temperature $+26^{\circ}\text{C}$ (thus condensation at $+35^{\circ}\text{C}$).

From the attached data:

Solution 1: Three (3) screw semi hermetic screw compressors of R507 at $-25/+42^{\circ}\text{C}$ with economizer (*appendix 1 compressor data*)

Solution 2: Two (2) open standard screw compressors of NH3 at $-25/+35^{\circ}\text{C}$ (*appendix 2 compressor data*)

Solution 3: Two (2) open reciprocating compressors of R507 at $-25/+35^{\circ}\text{C}$ (*appendix 3 compressor data*)

Solution 4: Two (2) open screw compressors of NH3 at $-25/+42^{\circ}\text{C}$ with economizer (*appendix 4 compressor data*)

and by considering an operating time of 5000h per annum at 100% of loads, a cost of kWh electricity of RM 0.328/ kWh and a cost of city water make up at the cooling tower of RM 0.85/ m^3 .

PART A

Question 1

Calculate the costs of energy of compression and city water consumption for the various solutions.

(4 marks)

Question 2

What other points can influence the choice for one of the 4 solutions by considering that the evaporator is of the type flooded plates.

(3 marks)

Question 3

Draw the general diagram of solution 4 with 2 compressors, each one having an oil separator and an oil cooler,

(3 marks)

PART B

A choice will be made on solution 3.

Two (2) piston compressors, each one with an oil separator having oil a capacity of 120 PPM and using polyolester oils for which one will have defined a limit of miscibility of 2%.

Question 4

Draw a detailed schematic diagram of the installation except manometers and safety devices

(2 marks)

Question 5

Calculate all the mass flow rates, volume flow rates and diameters of the pipes

(4 marks)

Question 6

Calculate the volume flow rate and the capacity of the oil rectifier

(2 marks)

PART C

Question 7

Sketch the schematic with the oil return and oil balancing of the compressors by using solution 1.

(2 marks)

END OF QUESTION

Appendix 1: semi hermetic screw of R507 at -25/+42 ° C with ECO

Appendix 2 open standard screw of NH3 -25/+35 ° C.

Appendix 3 Open Pistons of R507 at -25/+35 ° C

Appendix 4 open Screw NH3 at -25/+42 ° C with ECO

Appendix 1

COMPRESSOR: hss3120/3.5 Economised (External cooling) REFRIG: R507

-----Fiche compresseur 1-----		min	<	actual	<	max	---	units	---	warning
DUTY				99.1				kW		
MOTOR INPUT POWER				49.8				kW		
COP	(based on Motor Input Power)			1.99						
DUTY				28.2				TonsRefr.		
Part load setting	25.0	<	100.0					%		
Suction Gauge	-42.5	<	-25.0	<			3.5	C		
Delivery Gauge	4.65	<	42.0	<			55.0	C		
Liq subcooling (rel.to del.gauge)			5.0					C		
Total suction vapour superheat			5.0					C		
Useful suction vapour superheat			0.0					C		
Superheat at economiser port			0.0					C		
Liquid cooled in HX/Flash ves.to within			0.0		C			of economiser gaug		
Compressor speed:supply freq			50					hz		
Suction Pressure	1.24	<	2.62	<			7.0	bar abs		
Delivery Pressure	7.25	<	19.7	<			26.7	bar abs		
Pressure Ratio	3.5	<	7.53	<			13.0			
Aprx.Optimum.Effic.PrRat	6.25	<	7.53	<			9.7			
Pressure Difference			17.1	<			23.1	bar		
Absorbed Power at this speed			49.8	<			84.0	kW		
Type of cooling used			External							
Temperature of injected oil			40.0	<			60.0	C		
Oil injection rate			1.72					m3/h		
Compressor cooling/Oilcooler duty			11.3					kW		
Discharge temperature (approx)			54.3	<			100.0	C		
Volumetric efficiency			0.8272							
Isentropic efficiency			0.5384							
Liquid enthalpy ex-receiver			253.0					kJ/kg		
Vapour enthalpy ex-evaporator			349.0					kJ/kg		
Vapour enthalpy at suction			354.0					kJ/kg		
Vapour enthalpy at discharge			396.0					kJ/kg		
Mass flow rate at machine suction			0.65					kg/s		
Suction vapour specific volume			0.075					m3/kg		
Discharge vapour specific volume			0.01					m3/kg		
Mass flowrate at machine discharge			0.98					kg/s		
Approximate condenser load			140.0					kW		
Type of machine			Economised							
Economiser gauge			-1.83					C		
Economiser mass flow rate	0.049	<	0.33					kg/s		
Economiser liquid subcooling load			36.0					kW		
Economiser subcooled liq.Enthalpy			198.0					kJ/kg		
Economiser vapour outlet Enthalpy			362.0					kJ/kg		

THESE COMMENTS RELATED TO YOUR MACHINE SELECTION SHOULD BE READ CAREFULLY

!!!!!!!!!!!!!!!!!!!! DANGER !!!!!!!!!!!!!!!!!!!!! INVALID SELECTION !!!!!!!!!!!!!!!!!!!!!
 One or more of the operating ranges for this machine are violated !
 output values are probably very OPTIMISTIC
 !!!! Do NOT run the machine at these conditions !!!
 !!!
 SEMI HERMETIC Hallscrew the quoted POWER is electrical motor input power
 ! DANGER ! Delivery superheat is less than 20.0 C Oil separator performance may be suspect. Take action to increase suction and hence delivery superheat (consider fitting a Suction/Liquid Heat Exchanger).

Appendix 2

Fiche compresseur 2

Date:- 26-02-03

HOWDEN XRV COMPRESSOR SELECTION

Program Ref. 0101/0058

For 125 kWR on NH3 at 2950 rpm

Compressor XRV 127R4-16542

INPUT DATA

Evap.temp -25 deg.C	Suct.temp -20 deg.C	Useful s'ht 0 deg.C
Evap.press 1.517 bar.a	Suct.press 1.517 bar.a	Suct.loss 0 bar
Cond.temp 35 deg.C		Subcooling 5 deg.C
Cond.press 13.5 bar.a	Disch.press 13.5 bar.a	Disch.loss 0 bar

FULL LOAD

Evap.Cap. (kWR)	143.1	Cond.Cap. (kWR)	172.4
Abs.Power (kW)	68.73	Abs.Torque (Nm)	222.4
Suct.Mass Flow (kg/h)	473.4	Total Oil Flow (l/s)	.66
Est.Pt.Load Power (kW)	63.92	Injection Oil Flow (l/s)	.25
Oil Temp (deg.C)	55	Disch.Temp.(deg.C)	92.67
Oil Cooler (kW)	41		

MINIMUM LOAD

Oil Temp (deg.C)	55	Disch.Temp.(deg.C)	91
Oil Cooler (kW)	39	Total Oil Flow (l/s)	.66

QIL PUMP ----- If the pull-down time from pre-start pressure conditions to a gas differential pressure of 4 bar across the compressor may exceed 2 mins then a start-up oil pump will be required. This pump should have a min. flow of 0.5 l/s when producing an oil pressure at the compressor 2 bar above the compressor discharge pressure. See XRV Manual for recommendations on oil circuits and the use of oil pumps, (start-up or continuous).

OIL INJECTION ----- A throttle valve should be installed in the oil INJECTION line (NOT the bearing feed) for oil flow rate adjustment to get the discharge temperatures shown above.

DRIVER ----- Driver power should be at least 10% above full load power.

TOLERANCE ----- Full load power and capacity have a tolerance of +/- 5% Part load powers are not guaranteed.

UPDATES ----- Selections made after update notification may be invalid. Non-registered users of this program cannot be notified of updates or modifications so selections by non-registered users will be considered invalid and will not be supported.

Appendix 3

MYCOM RECIPRO COMPRESSOR PERFORMANCE SINGLE STAGE

REFRIGERANT	AMMONIA
MODEL	N6WB
CAPACITY	130,7 [kW]
CAPACITY	37,2 [TR]
ABSORBED POWER	60,0 [kW]
SPEED	1100 [Rpm]
LOAD	100 [%]
CONDENSING TEMP.	35,0 [degC]
EVAPORATIVE TEMP.	-25,0 [degC]
SUCTION SUPERHEAT	0,00 [degC]
LIQUID SUBCOOLING	5,00 [degC]
SUCTION TEMP.	-25,0 [degC]
SUCTION PRES.	0,152 [MPaA]
DISCHARGE PRES.	1,35 [MPaA]
SUCTION PRES.LOSS	0,000 [MPaA]
DISCHARGE PRES.LOSS	0,000 [MPaA]
SWEPT VOLUME	526 [m3/h]
DISCHARGE TEMP.	138 [degC]
REFRIG. FLOW RATE(SUC.)	334 [m3/h]
REFRIG. FLOW RATE(DIS.)	63,5 [m3/h]
REFRIG. FLOW RATE(SUC.)	433 [Kg/h]
REFRIG. FLOW RATE(DIS.)	433 [Kg/h]
OIL HEAT REJECTION	3,02 [kW]
COP	2,18 [-]
--- SUPERHEAT in not counted in refrigeration capacity ---	
--- WITH WATERCOOLED OIL COOLER ---	
SELECTED OIL SEPARATOR	OSF-125 [-]

Appendix 4

Fiche compresseur 4

Date:- 26-02-03

HOWDEN XRV COMPRESSOR SELECTION

Program Ref. 0101/0058

For 125 kWR on NH3 at 2950 rpm

Compressor XRV 127R3-16550

With Open Flash Superfeed (SF)

INPUT DATA

Evap.temp -25 deg.C	Suct.temp -20 deg.C	Useful s'ht 0 deg.C
Evap.press 1.517 bar.a	Suct.press 1.517 bar.a	Suct.loss 0 bar
Cond.temp 42 deg.C		Subcooling 5 deg.C
Cond.press 16.43 bar.a	Disch.press 16.43 bar.a	Disch.loss 0 bar
SF loss 0 bar	SF s'ht 5 deg.C	

FULL LOAD

Evap.Cap. (kWR)	130.2	Cond.Cap. (kWR)	155.8
Abs.Power (kW)	66.63	Abs.Torque (Nm)	215.6
Suct.Mass Flow (kg/h)	357.3	Total Oil Flow (l/s)	.71
Est.Pt.Load Power (kW)	64.63	Injection Oil Flow (l/s)	.27
Oil Temp (deg.C)	55	Disch.Temp. (deg.C)	91.17
Oil Cooler (kW)	42		
SF Mass Flow (kg/h)	87.13001	SF Port Press (bar.a)	2.096

MINIMUM LOAD

Oil Temp (deg.C)	55	Disch.Temp. (deg.C)	88
Oil Cooler (kW)	39	Total Oil Flow (l/s)	.71

OIL PUMP ----- If the pull-down time from pre-start pressure conditions to a gas differential pressure of 4 bar across the compressor may exceed 2 mins then a start-up oil pump will be required. This pump should have a min. flow of 0.5 l/s when producing an oil pressure at the compressor 2 bar above the compressor discharge pressure. See XRV Manual for recommendations on oil circuits and the use of oil pumps, (start-up or continuous).

OIL INJECTION ----- A throttle valve should be installed in the oil INJECTION line (NOT the bearing feed) for oil flow rate adjustment to get the discharge temperatures shown above.

DRIVER ----- Driver power should be at least 10% above full load power.

TOLERANCE ----- Full load power and capacity have a tolerance of +/- 5% Part load powers are not guaranteed.

UPDATES ----- Selections made after update notification may be invalid. Non-registered users of this program cannot be notified of updates or modifications so selections by non-registered users will be considered invalid and will not be supported

Appendix 5

Saturated Table for R507

T (°C)	Saturated Liquid				Saturated Vapour			
	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	1.074	139.26	758.61	0.7555	1.074	337.10	1625.7	167.36
-40	1.356	146.14	788.35	0.7657	1.356	340.04	1620.0	134.30
-35	1.691	152.97	817.20	0.7761	1.691	342.95	1614.9	108.90
-30	2.086	159.75	845.24	0.7869	2.086	345.82	1610.5	89.15
-25	2.548	166.48	872.52	0.7981	2.548	348.64	1606.6	73.60
-20	3.084	173.19	899.11	0.8097	3.084	351.42	1603.1	61.24
-15	3.701	179.88	925.08	0.8218	3.701	354.14	1600.1	51.30
-10	4.406	186.57	950.50	0.8343	4.406	356.80	1597.4	43.24
-5	5.209	193.27	975.46	0.8475	5.209	359.39	1595.0	36.64
0	6.117	200.00	1000.00	0.8613	6.117	361.89	1592.7	31.20
5	7.140	206.78	1024.32	0.8760	7.140	364.30	1590.6	26.68
10	8.286	213.65	1048.42	0.8915	8.286	366.61	1588.6	22.89
15	9.567	220.62	1072.41	0.9081	9.567	368.78	1586.6	19.69
20	10.992	227.73	1096.43	0.9261	10.992	370.81	1584.5	16.98
25	12.572	235.02	1120.58	0.9457	12.572	372.65	1582.2	14.65
30	14.320	242.53	1144.99	0.9674	14.320	374.28	1579.6	12.65
35	16.247	250.31	1169.83	0.9916	16.247	375.64	1576.5	10.92
40	18.367	258.43	1195.26	1.0193	18.367	376.66	1572.8	9.41
45	20.694	266.97	1221.53	1.0518	20.694	377.25	1568.2	8.07
50	23.244	276.03	1248.94	1.0911	23.244	377.29	1562.3	6.89
55	26.034	285.79	1277.94	1.1411	26.034	376.54	1554.5	5.82
60	29.082	296.53	1309.31	1.2098	29.082	374.70	1543.9	4.85

Appendix 6 (Continue)

R.507

T (°C)	P _{sat} (Bar)	h (kJ/kg)	s (J/kg.K)	v (m ³ /kg)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	
20		376.61	382.28	387.84	393.32	398.75	404.13	409.47	414.80	420.10	425.40	430.70	436.00	441.30	446.61	451.94	457.27	462.63				
	10.9918	1604.13	1622.98	1641.18	1658.83	1676.01	1692.79	1709.21	1725.31	1741.12	1756.68	1772	1787.11	1802.02	1816.75	1831.31	1845.71	1859.96				
	0.01768	0.01835	0.01899	0.0196	0.02019	0.02076	0.02132	0.02186	0.02238	0.02288	0.02331	0.02371	0.02414	0.02451	0.02488	0.02526	0.02563					
25		378.71	384.59	390.34	395.99	401.56	407.08	412.55	417.99	423.41	428.81	434.21	439.60	444.99	450.38	455.79	461.20	466.63				
	12.5721	1602.36	1621.6	1640.11	1658.01	1675.39	1692.33	1708.88	1725.09	1740.99	1756.62	1772	1787.16	1802.1	1816.86	1831.44	1845.85	1860.11				
	0.01531	0.01593	0.01652	0.01708	0.01762	0.01814	0.01864	0.01913	0.0196	0.02007	0.02052	0.02097	0.02141	0.02184	0.02227	0.02269	0.02311					
30		380.63	386.76	392.72	398.55	404.28	409.95	415.55	421.12	426.65	432.16	437.65	443.14	448.62	454.10	459.59	465.09	470.59				
	14.3196	1600.39	1620.11	1638.99	1657.17	1674.78	1691.91	1708.61	1724.94	1740.95	1756.67	1772.12	1787.33	1802.32	1817.11	1831.72	1846.15	1860.43				
	0.01328	0.01386	0.0144	0.01492	0.01541	0.01588	0.01634	0.01679	0.01722	0.01764	0.01805	0.01846	0.01885	0.01924	0.01963	0.02	0.02038					
35		382.35	388.76	394.95	400.98	406.89	412.71	418.46	424.15	429.81	435.43	441.03	446.62	452.20	457.77	463.34	468.92	474.50				
	16.2468	1598.14	1618.44	1637.75	1656.27	1674.15	1691.49	1708.37	1724.84	1740.97	1756.78	1772.31	1787.59	1802.64	1817.47	1832.11	1846.57	1860.87				
	0.01152	0.01206	0.01257	0.01305	0.01351	0.01395	0.01437	0.01477	0.01517	0.01555	0.01593	0.01629	0.01665	0.01701	0.01735	0.01769	0.01803					
40		383.81	390.55	397.01	403.26	409.37	415.36	421.26	427.10	432.88	438.63	444.34	450.03	455.71	461.37	467.04	472.70	478.36				
	18.3669	1595.46	1616.48	1636.32	1655.24	1673.43	1691.02	1708.1	1724.75	1741.01	1756.93	1772.56	1787.91	1803.02	1817.91	1832.59	1847.09	1861.41				
	0.00999	0.01051	0.01099	0.01144	0.01187	0.01227	0.01266	0.01303	0.01339	0.01375	0.01409	0.01442	0.01475	0.01507	0.01539	0.0157	0.016					
45		384.96	392.10	398.87	405.38	411.70	417.88	423.95	429.94	435.86	441.73	447.56	453.36	459.14	464.91	470.66	476.42	482.17				
	20.6942	1592.22	1614.15	1634.62	1654.02	1672.59	1690.47	1707.78	1724.61	1741.03	1757.08	1772.82	1788.26	1803.45	1818.39	1833.13	1847.66	1862.02				
	0.00865	0.00915	0.00961	0.01004	0.01044	0.01081	0.01118	0.01152	0.01186	0.01218	0.01249	0.0128	0.0131	0.01339	0.01368	0.01396	0.01424					
50		385.74	393.37	400.51	407.31	413.88	420.26	426.52	432.67	438.73	444.74	450.70	456.61	462.50	468.37	474.22	480.07	485.91				
	23.2441	1588.23	1611.32	1632.58	1652.56	1671.55	1689.77	1707.36	1724.41	1741	1757.21	1773.06	1788.61	1803.88	1818.9	1833.69	1848.28	1862.67				
	0.00747	0.00797	0.00841	0.00881	0.00919	0.00955	0.00988	0.01021	0.01052	0.01082	0.01111	0.01139	0.01166	0.01193	0.0122	0.01246	0.01271					
55		386.05	394.31	401.89	409.03	415.87	422.49	428.94	435.27	441.49	447.64	453.73	459.77	465.78	471.75	477.71	483.65	489.58				
	26.0336	1583.25	1607.86	1630.11	1650.77	1670.28	1688.89	1706.79	1724.09	1740.89	1757.26	1773.26	1788.92	1804.29	1819.4	1834.26	1848.9	1863.34				
	0.00643	0.00692	0.00735	0.00774	0.0081	0.00844	0.00875	0.00905	0.00934	0.00962	0.00989	0.01015	0.01041	0.01066	0.0109	0.01114	0.01137					
60		385.79	394.86	402.97	410.51	417.66	424.54	431.21	437.73	444.13	450.43	456.66	462.83	468.96	475.05	481.11	487.15	493.18				
	29.0817	1588.23	1611.32	1632.58	1652.56	1671.55	1689.77	1707.36	1724.41	1741	1757.21	1773.06	1788.61	1803.88	1818.9	1833.69	1848.28	1862.67				
	0.00747	0.00797	0.00841	0.00881	0.00919	0.00955	0.00988	0.01021	0.01052	0.01082	0.01111	0.01139	0.01166	0.01193	0.0122	0.01246	0.01271					