Mansoura University
Faculty of Engineering
Mech. Power Engineering Dept.

4th Year Candidates
Final Exam., May, 2013
Time: 3 Hours

Refrigeration and A/C systems Control (MPE 4424)

Answer the following questions: (60 marks)

Question No. 1 (12 marks):

a) Define the following terms:

- The controller – corrective action – time lag - control agent- droop- cycling and the throttling range with a diagram showing the relation between the controlled variable with valve position in both cooling and heating processes. (7 marks)

b) Discuss the different types of control loops that are normally used in Ref. & AC applications. Sketch an air conditioning system using a closed loop showing its main components and the function of each component. (5 marks)

Question No. 2 (12 marks):

a) Discuss the various moisture sensing elements that sense the relative humidity of air. Sketch the Nylon humidity sensor and how to avoid error in sensor reading due to wide temperature variations . (4 marks)

b) What is actuator? Mention its main types according to energy source and discuss with simple sketch how the pneumatic one is controlling a valve? (3marks)

c) Mention the different types of control systems with respect to the energy source. Discuss with simple sketches the theory of operation of bridge circuit in case of increasing air temperature (increasing load in cooling applications). (5 marks)

Question No. 3 (12 marks):

a) Mention the different modes of control. Discuss the proportional control modes, describe them mathematically and illustrate the variation of control point for each against time and how PI control respond to load changes. (4 marks)

b)A straight-charged Thermostatic Expansion Valve (TEV) is designed to operate at an evaporator temperature of -4 ^{0}C with a degree of superheat of 8 K . R134a is the refrigerant used in the refrigeration system as well as the bulb. Find

- The required spring pressure at the design condition;

- Assuming the spring pressure to remain constant, find the degree of superheat, if the same TEV operates at an evaporator temperature of -24 °C. Comment on results. (4 marks)

c) Classify the temperature sensors for electronic temperature controllers. Sketch each type & theory of operation and their advantages and disadvantages. (4 marks)

Question No. 4 (12 marks):

a) Name some of expansion devices that are used in refrigeration and air conditioning systems . Explain how the capillary tube works and represent the variation of refrigerant mass rate through compressor and capillary tube with evaporator temperature on a figure (balance point). (5 marks)

b) Refrigeration system has the following data:

Evaporator capacity: 82 kW, Used refrigerant R-22 Sub-cooling:15°C
Evaporating temperature: -20°C, Condensing temperature: 46°C,

P.T.O

Pressure drop in liquid line (filter drier, sight glass, manual shut-off valve, pipe bends and solenoid valve): 0.5 bars and the evaporator is placed in the same level as the receiver. Pressure drop in liquid distributor and its pipes: 0.4 bar. Pressure drop in the evaporating coil and suction line: 0.4 bars.

Select from the provided catalogue the proper TEV with MOP, rated capacity and code number of its thermostatic element and its orifice assembly. Check if the given amount of sub-cooling is enough to avoid flash gas in liquid line before entering to that expansion valve. (7 marks)

Question No. 5 (14 marks):

a) Explain the function of each of the following:

Evaporating pressure regulator - capacity regulator - condensing pressure regulator - NRV- sight glass - filter & dryer, and solenoid valves on liquid line. Draw a diagram for the plant fed with all of the aforementioned items and their location. (5 marks)

b)

1. Which of the following statements are true?

a. The refrigerant mass flow rate through a capillary tube increases as condenser pressure decreases and evaporator pressure increases
b. The refrigerant mass flow rate through a capillary tube increases as condenser pressure increases and evaporator pressure decreases
c. A capillary tube tends to supply more mass flow rate as refrigeration load increases
d. A capillary tube tends to supply more mass flow rate as refrigeration load decreases

2. Which of the following statements are true?

a. An automatic expansion valve maintains a constant pressure in the condenser
b. An automatic expansion valve maintains a constant pressure in the evaporator
c. In an automatic expansion valve, the mass flow rate of refrigerant increases as the refrigeration load increases
d. Automatic expansion valve based systems are critically charged

3. A thermostatic expansion valve:

a. Maintains constant evaporator temperature
b. Maintains a constant degree of superheat
c. Increases the mass flow rate of refrigerant as the refrigeration load increases
d. Prevents slugging of compressor

4. Which of the following statements are true?

a. A float valve maintains a constant level of liquid in the float chamber
b. A float valve maintains a constant pressure in the float chamber
c. Low-side float valves are used with direct expansion type evaporators
d. High-side float valves are used in flooded type evaporators

5. Which of the following statements are true?

a. An electronic expansion valve is bi-directional.
b. In an electronic expansion valve, the refrigerant mass flow rate increases as the amount of liquid at evaporator exit increases.
c. In an electronic expansion valve, the refrigerant mass flow rate increases as the temperature of refrigerant at evaporator exit increases.
d. Electronic expansion valves are used in all-year air conditioning systems. (7 marks)

Good Luck

Prof. E. Elshafei

R 22

Capacity in KW for Range B –60°C to–25°C

Valve type	Orifice no.	Pressure drop across valve Δp bar								Pressure drop across valve Δp bar							
		2	4	6	8	10	12	14	16	2	4	6	8	10	12	14	16
		Evaporating temperature –25°C								**Evaporating temperature –30°C**							
TEX 5-3	01	8.1	10.2	11.6	12.5	13.3	13.8	14.2	14.4	7.2	9.0	10.2	11.1	11.7	12.2	12.5	12.7
TEX 5-4.5	02	11.3	14.2	16.1	17.4	18.5	19.2	19.7	20.0	10.1	12.6	14.3	15.4	16.4	17.0	17.5	17.8
TEX 5-7.5	03	16.4	20.7	23.5	25.6	27.3	28.6	29.5	30.0	14.6	18.3	20.8	22.7	24.2	25.4	26.2	26.8
TEX 5-12	04	23.5	29.6	33.6	36.6	39.0	40.8	42.1	42.8	20.9	26.3	29.8	32.5	34.6	36.3	37.5	38.2
TEX 12-4.5	01	11.3	14.5	16.4	17.8	18.8	19.6	20.0	20.3	10.2	13.1	14.8	16.0	16.9	17.6	18.0	18.3
TEX 12-7.5	02	18.5	23.6	26.8	29.0	30.7	31.9	32.7	33.2	16.8	21.4	24.2	26.2	27.7	28.8	29.5	29.9
TEX 12-12	03	26.8	34.2	38.9	42.3	45.0	46.9	48.3	49.1	24.3	30.9	35.1	38.1	40.5	42.4	43.7	44.5
TEX 12-18	04	35.4	45.3	51.7	56.6	60.4	63.4	65.6	67.0	32.0	40.8	46.6	51.0	54.6	57.4	59.6	61.0
TEX 20-20	01	46.0	58.0	66.0	72.0	76.0	80.0	82.0	83.0	41.0	52.0	59.0	65.0	69.0	72.0	74.0	76.0
TEX 55-35	01	100	127	143	155	163	169	173	174	91.0	115	129	139	146	151	155	156
TEX 55-60	02	154	194	218	236	249	258	264	267	140	175	197	212	224	232	237	240
		Evaporating temperature –40°C								**Evaporating temperature –50°C**							
TEX 5-3	01	5.6	7.0	7.9	8.5	9.0	9.4	9.7	9.8		5.5	6.1	6.6	7.0	7.3	7.5	7.7
TEX 5-4.5	02	7.9	9.9	11.1	12.0	12.7	13.3	13.7	13.9		7.7	8.7	9.4	9.9	10.4	10.7	10.9
TEX 5-7.5	03	11.4	14.3	16.2	17.7	19.0	19.9	20.7	21.2		11.2	12.7	13.9	14.9	15.8	16.4	16.9
TEX 5-12	04	16.3	20.5	23.2	25.3	27.1	28.5	29.5	30.2		16.0	18.2	19.9	21.3	22.5	23.4	24.1
TEX 12-4.5	01	8.3	10.5	11.9	12.8	13.5	14.0	14.4	14.6		8.5	9.5	10.2	10.8	11.2	11.5	11.7
TEX 12-7.5	02	13.7	17.2	19.4	21.0	22.2	23.1	23.7	24.1		13.9	15.5	16.8	17.7	18.5	19.0	19.4
TEX 12-12	03	19.6	24.8	28.1	30.6	32.6	34.1	35.3	36.1		19.8	22.5	24.5	26.2	27.6	28.6	29.4
TEX 12-18	04	25.5	32.6	37.4	41.1	44.2	46.8	48.8	50.3		25.9	29.9	33.1	35.9	38.2	40.2	41.6
TEX 20-20	01	33.0	42.0	47.0	52.0	55.0	58.0	60.0	62.0		33.0	38.0	42.0	45.0	47.0	49.0	51.0
TEX 55-35	01	73.0	92.0	102	110	116	120	122	123		73.0	81.0	87.0	91.0	94.0	96.0	97.0
TEX 55-60	02	114	141	158	170	178	185	189	191		113	126	135	142	147	150	151
		Evaporating temperature –55°C								**Evaporating temperature –60°C**							
TEX 5-3	01										4.4	4.9	5.3	5.6	5.9	6.1	6.2
TEX 5-4.5	02										6.2	7.0	7.6	8.0	8.4	8.6	8.8
TEX 5-7.5	03										9.0	10.3	11.3	12.1	12.9	13.5	13.9
TEX 5-12	04										12.9	14.7	16.1	17.3	18.3	19.2	19.8
TEX 12-4.5	01		7.6	8.5	9.2	9.7	10.1	10.4	10.5								
TEX 12-7.5	02		12.5	14.0	15.1	16.0	16.7	17.2	17.5								
TEX 12-12	03		17.8	20.3	22.1	23.7	25.0	26.0	26.7								
TEX 12-18	04		23.3	27.0	30.0	32.6	34.8	36.7	38.2								
TEX 20-20	01		30.0	34.0	37.0	40.0	43.0	45.0	46.0								
TEX 55-35	01		66.0	73.0	78.0	82.0	84.0	86.0	87.0								
TEX 55-60	02		102	113	121	127	131	134	135								

Correction for sub-cooling Δt_{sub}

Δt_{sub}	4K	10K	15K	20K	25K	30K	35K	40K	45K	50K
R22	1.0	1.06	1.11	1.15	1.20	1.25	1.30	1.35	1.39	1.44

Note: Insufficient sub-cooling can produce flash gas.

Thermostatic expansion valves, type TE 5 - TE 55

Capacity

R 22

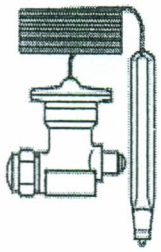
Capacity in KW for Range N: –40°C to +10°C

Valve type	Orifice no.	Pressure drop across valve Δp bar								Pressure drop across valve Δp bar							
		2	4	6	8	10	12	14	16	2	4	6	8	10	12	14	16
		Evaporating temperature +10°C								**Evaporating temperature 0°C**							
TEX 5-3	01	12.4	16.3	18.8	20.5	21.7	22.4	22.8	23.0	12.8	16.7	19.1	20.8	22.0	22.7	23.2	23.3
TEX 5-4.5	02	17.2	22.5	25.9	28.1	29.7	30.6	31.1	31.3	17.7	22.9	26.1	28.3	29.9	30.9	31.5	31.7
TEX 5-7.5	03	25.3	32.8	37.4	40.6	42.6	43.9	44.5	44.7	25.9	33.0	37.5	40.6	42.8	44.2	45.0	45.3
TEX 5-12	04	35.8	46.6	53.3	57.8	60.8	62.6	63.6	63.9	36.6	47.0	53.5	58.0	61.2	63.2	64.3	64.7
TEX 12-4.5	01	16.8	22.5	26.1	28.6	30.3	31.4	32.1	32.3	16.1	21.2	24.5	26.8	28.5	29.6	30.3	30.6
TEX 12-7.5	02	27.3	36.4	42.1	46.1	48.8	50.7	51.6	52.0	26.2	34.5	39.8	43.5	46.1	47.8	48.9	49.3
TEX 12-12	03	40.2	53.3	61.6	67.2	71.1	73.5	74.9	75.5	38.7	50.8	58.5	63.9	67.7	70.3	71.9	72.6
TEX 12-18	04	53.2	70.2	80.9	88.1	93.0	96.1	97.8	98.5	51.7	67.6	77.8	85.0	90.2	93.7	95.8	96.9
TEX 20-30	01	72.0	94.4	108	118	124	129	131	132	66.3	86.0	98.5	107	113	118	120	121
TEX 55-50	01	158	209	241	263	278	287	293	295	145	190	218	237	251	260	265	267
TEX 55-85	02	239	313	360	391	412	425	432	434	221	286	326	355	375	388	395	397
		Evaporating temperature -10°C								**Evaporating temperature -20°C**							
TEX 5-3	01	11.1	14.3	16.3	17.7	18.8	19.5	19.9	20.1		11.5	13.0	14.1	15.0	15.6	16.0	16.2
TEX 5-4.5	02	15.4	19.7	22.4	24.3	25.7	26.7	27.3	27.6		15.9	18.1	19.6	20.8	21.6	22.1	22.4
TEX 5-7.5	03	22.7	28.7	32.7	35.6	37.8	39.4	40.4	40.9		23.2	26.3	28.7	30.6	32.0	32.9	33.5
TEX 5-12	04	32.3	41.1	46.8	51.0	54.1	56.3	57.7	58.4		33.2	37.7	41.1	43.7	45.7	47.0	47.8
TEX 12-4.5	01		18.7	21.4	23.4	24.8	25.8	26.4	26.6		15.9	18.1	19.6	20.8	21.6	22.1	22.4
TEX 12-7.5	02		30.4	34.8	37.9	40.2	41.8	42.8	43.2		25.9	29.4	32.0	33.9	35.2	36.1	36.5
TEX 12-12	03		44.5	50.9	55.6	59.0	61.4	62.9	63.7		37.7	42.9	46.7	49.6	51.7	53.1	53.9
TEX 12-18	04		59.1	67.7	74.0	78.7	82.1	84.3	85.6		49.9	57.0	62.3	66.4	69.6	71.8	73.1
TEX 20-30	01		75.4	85.9	93.6	99.2	103	106	107		63.7	72.4	78.8	83.8	87.4	90.0	91.4
TEX 55-50	01		166	189	205	217	225	229	231		140	158	171	181	187	191	193
TEX 55-85	02		251	285	309	327	339	346	349		213	240	260	275	285	291	294
		Evaporating temperature -30°C								**Evaporating temperature -40°C**							
TEX 5-3	01		9.0	10.2	11.1	11.7	12.2	12.5	12.7			7.9	8.5	9.0	9.4	9.7	9.8
TEX 5-4.5	02		12.6	14.3	15.4	16.4	17.0	17.5	17.8			11.1	12.0	12.7	13.3	13.7	13.9
TEX 5-7.5	03		18.3	20.8	22.7	24.2	25.4	26.2	26.8			16.2	17.7	19.0	19.9	20.7	21.2
TEX 5-12	04		26.3	29.8	32.5	34.6	36.3	37.5	38.2			23.2	25.3	27.1	28.5	29.5	30.2
TEX 12-4.5	01			14.8	16.0	16.9	17.6	18.0	18.3			11.9	12.8	13.5	14.0	14.4	14.6
TEX 12-7.5	02			24.2	26.2	27.7	28.8	29.5	29.9			19.4	21.0	22.2	23.1	23.7	24.1
TEX 12-12	03			35.1	38.1	40.5	42.4	43.7	44.5			28.1	30.6	32.6	34.1	35.3	36.1
TEX 12-18	04			46.6	51.0	54.6	57.4	59.6	61.0			37.4	41.1	44.2	46.8	48.8	50.3
TEX 20-30	01			59.2	64.5	68.8	72.0	74.4	75.8			47.5	51.8	55.4	58.2	60.4	61.9
TEX 55-50	01			129	139	146	151	155	156			102	110	116	120	122	123
TEX 55-85	02			197	212	224	232	237	240			158	170	178	185	189	191

Ordering

R 22

Thermostatic element

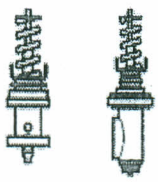


Valve type	Pressure equalization	Capillary tube	Code no.					
			Range N –40 to +10°C		Range NM –40 to –5°C	Range NL –40 to –15°C	Range B –60 to –25°C	
	¼ in. / 6 mm	m	Without MOP	MOP+15°C	MOP 0°C	MOP –10°C	Without MOP	MOP –20°C
TEX 5	Ext. [1]	3	067B3250	067B3267	067B3249	067B3253	067B3263	067B3251
TEX 12	Ext. [2]	3	067B3210	067B3227	067B3207	067B3213		067B3211
TEX 12	Ext. [2]	5	067B3209					067B3212
TEX 20	Ext. [2]	3	067B3274	067B3286	067B3273	067B3275		067B3276
TEX 20	Ext. [2]	5	067B3290					067B3287
TEX 55	Ext. [2]	3	067G3205	067G3220	067G3206			067G3207
TEX 55	Ext. [2]	5	067G3209					067G3217

[1]) Pressure equalization with solder connector can be supplied on contacting Danfoss.

[2]) Available as accessory: solder adapter for TE 12, TE 20 and TE 55. Code no. 068B0170.

Orifice assembly



Valve type	Rated capacity Range N: –40 to 10°C kW	Rated capacity Range B: –60 to –25°C kW	Orifice no.	Code no.
TEX 5-3	19.7	11.9	01	067B2089
TEX 5-4.5	26.9	16.7	02	067B2090
TEX 5-7.5	36.8	24.8	03	067B2091
TEX 5-12	55.3	35.4	04	067B2092
TEX 12-4.5	26.8	17.2	01	067B2005
TEX 12-7.5	43.4	28.2	02	067B2006
TEX 12-12	64.0	41.4	03	067B2007
TEX 12-18	84.4	55.9	04	067B2008
TEX 20-30	108.0	70.0	01	067B2172
TEX 55-50	239.0	148.0	01	067G2005
TEX 55-85	356.0	228.0	02	067G2006

The rated capacity is based on:
Evaporating temperature t_e = +5°C for range N and t_e = –30°C for range B
Condensing temperature t_c = +32°C
Refrigerant temperature ahead of valve t_l = +28°C

Refrigerant Pressure Temperature Table

°C Temp	R717 bar	R22 bar	R134a bar	R404a bar	R507 bar
-60	0.218	0.375	0.159	0.522	0.522
-58	0.249	0.420	0.180	0.544	0.582
-56	0.283	0.469	0.205	0.606	0.648
-54	0.320	0.522	0.232	0.674	0.719
-52	0.362	0.580	0.261	0.747	0.796
-50	0.408	0.644	0.294	0.827	0.880
-48	0.459	0.713	0.330	0.913	0.970
-46	0.515	0.787	0.370	1.006	1.068
-44	0.576	0.868	0.413	1.106	1.173
-42	0.644	0.955	0.460	1.214	1.286
-40	0.717	1.049	0.516	1.330	1.408
-38	0.797	1.151	0.572	1.454	1.523
-36	0.885	1.204	0.633	1.587	1.663
-34	0.98	1.259	0.699	1.730	1.813
-32	1.083	1.376	0.770	1.882	1.973
-30	1.195	1.501	0.847	2.045	2.144
-28	1.315	1.635	0.930	2.218	2.325
-26	1.446	1.930	1.020	2.402	2.518
-24	1.587	2.092	1.116	2.598	2.723
-22	1.738	2.265	1.219	2.806	2.940
-20	1.901	2.448	1.330	3.027	3.170
-18	2.076	2.643	1.448	3.260	3.414
-16	2.263	2.849	1.575	3.507	3.671
-14	2.464	3.068	1.710	3.767	3.942
-12	2.679	3.299	1.854	4.043	4.228
-10	2.908	3.543	2.007	4.333	4.529
-8	3.152	3.801	2.170	4.639	4.846
-6	3.412	4.072	2.344	4.961	5.179
-4	3.688	4.358	2.527	5.299	5.529
-2	3.982	4.659	2.722	5.655	5.896
0	4.294	4.976	2.928	6.028	6.282
2	4.625	5.308	3.146	6.420	6.686
4	4.975	5.657	3.376	6.830	7.108
6	5.345	6.023	3.619	7.260	7.551
8	5.737	6.406	3.876	7.710	8.014
10	6.150	6.807	4.145	8.180	8.498
12	6.586	7.226	4.429	8.672	9.004
14	7.046	7.665	4.728	9.186	9.532
16	7.530	8.123	5.042	9.722	10.084
18	8.039	8.601	5.371	10.281	10.659
20	8.574	9.099	5.716	10.864	11.258
22	9.136	9.619	6.078	11.472	11.883
24	9.725	10.160	6.457	12.104	12.534
26	10.343	10.723	6.853	12.763	13.212
28	10.991	11.309	7.267	13.448	13.919
30	11.669	11.919	7.701	14.160	14.653
32	12.379	12.552	8.153	14.900	15.418
34	13.121	12.210	8.625	15.669	16.213
36	13.896	13.892	9.117	16.468	17.041
38	14.705	14.601	9.630	17.297	17.901
40	15.549	15.335	10.164	18.157	18.795
42	16.429	16.097	10.720	19.049	19.724
44	17.347	16.885	11.299	19.974	20.689
46	18.302	17.702	11.901	20.932	21.692
48	19.297	18.548	12.526	21.925	22.734
50	20.331	19.423	13.176	22.953	23.816
52	21.407	20.328	13.851	24.018	24.94
54	22.525	21.265	14.552	25.120	26.107
56	23.686	22.232	15.278	26.260	27.319
58	24.892	23.232	16.032	27.440	28.578
60	26.143	24.266	16.813	28.660	29.884
62	27.440	25.333	17.623	29.921	31.241
64	28.785	26.435	18.462	31.225	32.649
66	30.179	27.573	19.331	32.572	34.112
68	31.622	28.747	20.231	33.964	35.63
70	33.117	29.959	21.162	35.402	37.207
72	34.664	31.210	22.126	36.887	-
74	36.264	32.500	23.123	-	-
76	37.919	33.832	24.154	-	-
78	39.629	35.205	25.221	-	-
80	41.397	36.623	26.324	-	-