

## **POLITECNICO DI TORINO**

### **ESAMI DI STATO PER L'ABILITAZIONE ALLA PROFESSIONE DI INGEGNERE I SESSIONE – ANNO 2008**

Ramo Ing. Meccanica

TEMA N. 3

Una portata di 1200 kg/h di refrigerante R-407C si trova a 14 bar e 120 °C e deve essere condensata e sottoraffreddata a 30 °C. A tale scopo si prevede di utilizzare acqua, che è disponibile a 18 °C. Il fluido frigorifero viene quindi accumulato in un serbatoio pressurizzato e adiabatico.

Viene richiesto di:

1. Effettuare il dimensionamento di massima, termico e meccanico, del condensatore prestando attenzione a far sì che la differenza di temperatura tra i due fluidi non scenda sotto 3 °C;
2. Calcolare il volume di liquido contenuto nel serbatoio di accumulo affinché, nel caso in cui si verifichi un incremento a gradino di 5 °C della temperatura di ingresso del fluido frigorifero, la velocità di incremento della temperatura in uscita dal serbatoio sia inferiore a 0,5 °C/min.

Si allegano:

- Proprietà termofisiche e il diagramma Log (p) – h del fluido frigorifero R-407C;
- Caratteristiche di condotti che possono essere utilizzati per questa applicazione.

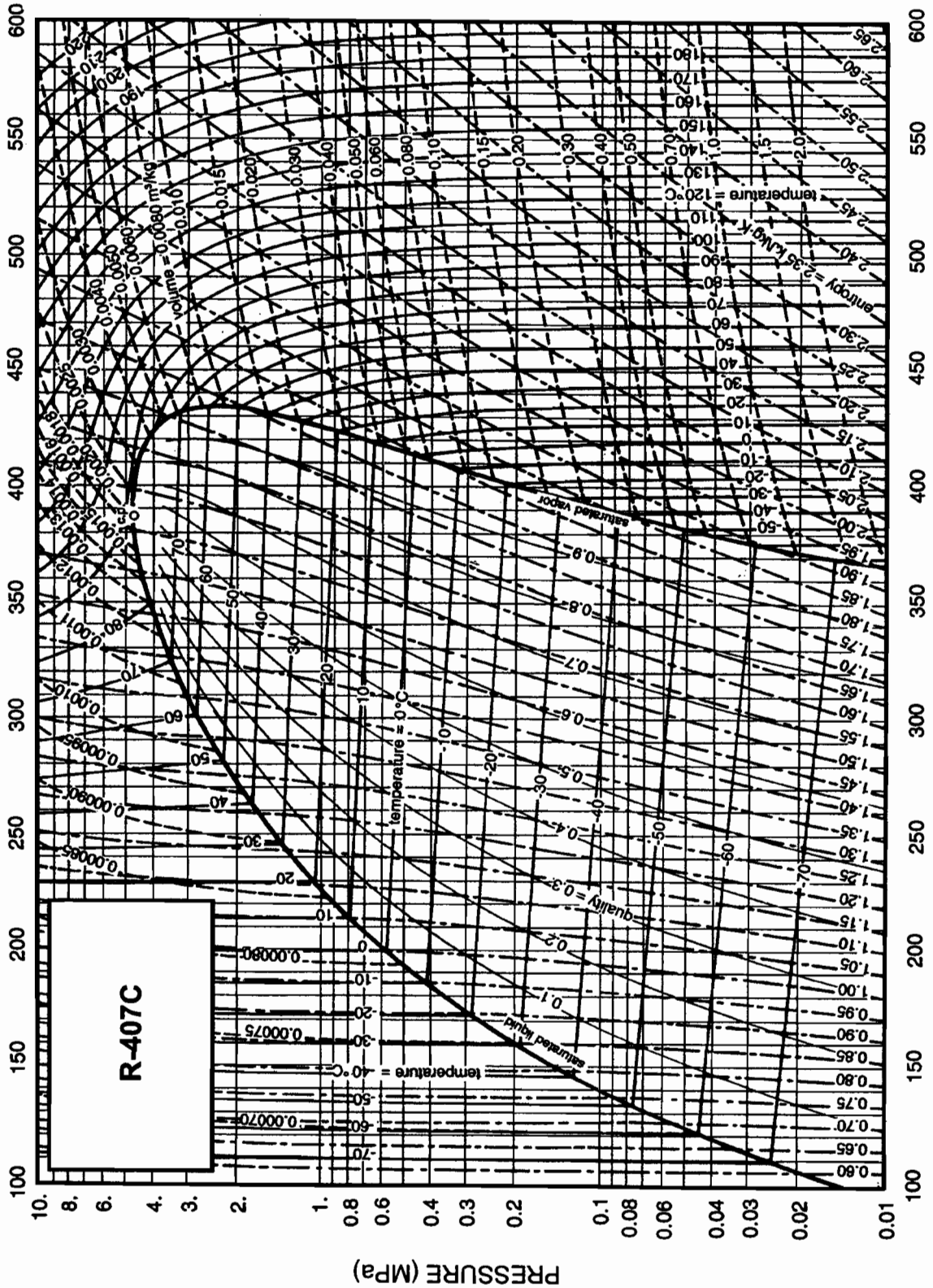


Fig. 11 Pressure-Enthalpy Diagram for Refrigerant 407C  
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Refrigerant 407C [R-32/125/134a (23/25/52)] Properties of Liquid on the Bubble Line and Vapor on the Dew Line

Pressure, MPa	Temperature, °C		Density, kg/m <sup>3</sup>	Volume, m <sup>3</sup> /kg	Enthalpy, kJ/kg		Entropy, kJ/(kg·K)		Specific Heat c <sub>p</sub> , kJ/(kg·K)			Velocity of Sound, m/s		Viscosity, μPa·s		Thermal Cond., mW/(m·K)		Surface Tension, mN/m	Pressure, MPa
	Bubble	Dew			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Vapor	Liquid	Vapor	Liquid	Vapor		
0.01000	-82.82	-74.96	1496.6	1.89611	91.52	365.89	0.5302	1.9437	1.246	0.667	1.181	1000.	149.0	722.4	8.22	148.0	6.43	24.80	0.01000
0.02000	-72.81	-65.15	1468.1	0.98986	104.03	371.89	0.5942	1.9071	1.255	0.692	1.180	948.	151.8	593.0	8.63	142.1	7.06	22.98	0.02000
0.04000	-61.51	-54.07	1435.2	0.51699	118.30	378.64	0.6635	1.8730	1.268	0.725	1.181	891.	154.6	486.9	9.09	135.7	7.79	20.95	0.04000
0.06000	-54.18	-46.89	1413.5	0.35346	127.63	382.97	0.7068	1.8543	1.278	0.748	1.184	854.	156.1	433.2	9.39	131.5	8.28	19.65	0.06000
0.08000	-48.61	-41.44	1396.8	0.26976	134.78	386.21	0.7389	1.8416	1.287	0.767	1.186	827.	157.1	398.2	9.62	128.5	8.65	18.68	0.08000
0.10000	-44.06	-36.98	1382.9	0.21867	140.65	388.83	0.7648	1.8321	1.295	0.783	1.189	805.	157.8	372.6	9.81	126.0	8.96	17.89	0.10000
0.10132b	-43.79	-36.71	1382.1	0.21597	141.01	388.99	0.7663	1.8315	1.295	0.784	1.189	803.	157.8	371.1	9.82	125.9	8.98	17.84	0.10132
0.12000	-40.19	-33.19	1371.0	0.18413	145.69	391.04	0.7865	1.8245	1.302	0.798	1.192	786.	158.3	352.6	9.97	123.9	9.23	17.23	0.12000
0.14000	-36.80	-29.87	1360.4	0.15918	150.12	392.95	0.8053	1.8183	1.308	0.811	1.195	769.	158.7	336.3	10.11	122.1	9.47	16.65	0.14000
0.16000	-33.77	-26.90	1350.9	0.14027	154.10	394.64	0.8220	1.8130	1.314	0.823	1.198	755.	159.0	322.6	10.23	120.5	9.68	16.13	0.16000
0.18000	-31.02	-24.21	1342.2	0.12544	157.73	396.15	0.8370	1.8084	1.320	0.835	1.201	741.	159.2	310.9	10.34	119.0	9.88	15.67	0.18000
0.20000	-28.50	-21.74	1334.1	0.11348	161.07	397.52	0.8507	1.8043	1.326	0.845	1.203	729.	159.4	300.6	10.45	117.7	10.06	15.25	0.20000
0.22000	-26.17	-19.46	1326.6	0.10363	164.17	398.78	0.8632	1.8007	1.331	0.856	1.206	718.	159.6	291.5	10.55	116.5	10.23	14.86	0.22000
0.24000	-24.00	-17.34	1319.5	0.09537	167.07	399.94	0.8748	1.7974	1.336	0.865	1.209	708.	159.6	283.3	10.64	115.3	10.39	14.50	0.24000
0.26000	-21.96	-15.35	1312.8	0.08834	169.80	401.01	0.8857	1.7945	1.341	0.875	1.212	698.	159.7	275.9	10.72	114.3	10.54	14.17	0.26000
0.28000	-20.05	-13.47	1306.5	0.08228	172.38	402.01	0.8959	1.7918	1.346	0.884	1.215	689.	159.7	269.1	10.80	113.3	10.68	13.85	0.28000
0.30000	-18.23	-11.70	1300.4	0.07700	174.83	402.95	0.9055	1.7893	1.351	0.892	1.218	680.	159.8	262.9	10.88	112.3	10.82	13.56	0.30000
0.32000	-16.51	-10.01	1294.6	0.07236	177.17	403.83	0.9145	1.7869	1.355	0.901	1.221	672.	159.7	257.2	10.96	111.4	10.95	13.28	0.32000
0.34000	-14.86	-8.41	1289.0	0.06824	179.41	404.67	0.9232	1.7848	1.360	0.909	1.224	664.	159.7	251.9	11.03	110.6	11.08	13.01	0.34000
0.36000	-13.29	-6.87	1283.7	0.06457	181.55	405.45	0.9314	1.7827	1.364	0.917	1.226	656.	159.7	246.9	11.10	109.8	11.20	12.76	0.36000
0.38000	-11.79	-5.40	1278.5	0.06127	183.61	406.20	0.9392	1.7808	1.369	0.925	1.229	649.	159.6	242.3	11.16	109.0	11.32	12.51	0.38000
0.40000	-10.34	-3.99	1273.5	0.05829	185.60	406.91	0.9468	1.7790	1.373	0.932	1.232	642.	159.6	237.9	11.22	108.2	11.44	12.28	0.40000
0.42000	-8.95	-2.63	1268.7	0.05559	187.52	407.59	0.9540	1.7773	1.377	0.940	1.235	635.	159.5	233.8	11.29	107.5	11.55	12.06	0.42000
0.44000	-7.61	-1.32	1264.0	0.05312	189.37	408.24	0.9609	1.7757	1.382	0.947	1.238	629.	159.4	229.9	11.34	106.8	11.66	11.85	0.44000
0.46000	-6.31	-0.05	1259.4	0.05086	191.17	408.85	0.9676	1.7741	1.386	0.954	1.241	623.	159.3	226.2	11.40	106.2	11.76	11.64	0.46000
0.48000	-5.06	1.17	1255.0	0.04878	192.91	409.44	0.9741	1.7726	1.390	0.961	1.244	616.	159.2	222.7	11.46	105.5	11.87	11.44	0.48000
0.50000	-3.84	2.36	1250.6	0.04687	194.61	410.01	0.9803	1.7712	1.394	0.968	1.247	611.	159.1	219.3	11.51	104.9	11.97	11.25	0.50000
0.55000	-0.96	5.17	1240.2	0.04266	198.65	411.33	0.9951	1.7679	1.404	0.985	1.254	597.	158.8	211.6	11.65	103.4	12.22	10.80	0.55000
0.60000	1.73	7.79	1230.4	0.03913	202.45	412.54	1.0088	1.7649	1.414	1.002	1.262	584.	158.4	204.6	11.77	102.0	12.45	10.39	0.60000
0.65000	4.26	10.25	1221.0	0.03613	206.04	413.64	1.0217	1.7622	1.423	1.018	1.270	571.	158.1	198.3	11.89	100.7	12.68	10.00	0.65000
0.70000	6.65	12.58	1212.0	0.03355	209.45	414.64	1.0338	1.7596	1.433	1.034	1.277	560.	157.7	192.5	12.00	99.5	12.89	9.63	0.70000
0.75000	8.91	14.78	1203.3	0.03129	212.71	415.57	1.0452	1.7572	1.443	1.050	1.285	549.	157.3	187.2	12.11	98.4	13.11	9.29	0.75000
0.80000	11.06	16.87	1195.0	0.02931	215.82	416.43	1.0561	1.7549	1.452	1.066	1.293	538.	156.8	182.3	12.22	97.3	13.32	8.97	0.80000
0.85000	13.11	18.86	1186.9	0.02755	218.81	417.23	1.0664	1.7528	1.462	1.081	1.302	528.	156.4	177.6	12.33	96.2	13.52	8.66	0.85000
0.90000	15.07	20.77	1179.1	0.02598	221.69	417.97	1.0763	1.7507	1.471	1.097	1.310	519.	155.9	173.3	12.43	95.2	13.72	8.37	0.90000
0.95000	16.95	22.59	1171.5	0.02457	224.47	418.65	1.0857	1.7488	1.481	1.112	1.319	509.	155.5	169.3	12.53	94.2	13.92	8.09	0.95000
1.00000	18.76	24.35	1164.1	0.02330	227.15	419.29	1.0948	1.7469	1.490	1.127	1.327	501.	155.0	165.5	12.63	93.3	14.12	7.83	1.00000
1.10000	22.19	27.67	1149.8	0.02109	232.28	420.44	1.1120	1.7433	1.510	1.158	1.345	484.	154.0	158.4	12.82	91.5	14.51	7.33	1.10000
1.20000	25.39	30.77	1136.0	0.01923	237.13	421.44	1.1281	1.7400	1.530	1.190	1.365	468.	152.9	152.1	13.00	89.9	14.90	6.87	1.20000
1.30000	28.40	33.68	1122.8	0.01765	241.74	422.30	1.1431	1.7367	1.550	1.222	1.385	452.	151.9	146.3	13.18	88.3	15.29	6.45	1.30000
1.40000	31.24	36.42	1109.9	0.01629	246.15	423.04	1.1574	1.7337	1.571	1.255	1.406	438.	150.8	140.9	13.35	86.8	15.69	6.05	1.40000
1.50000	33.94	39.02	1097.4	0.01510	250.38	423.68	1.1709	1.7307	1.592	1.289	1.428	424.	149.7	136.0	13.53	85.4	16.09	5.68	1.50000
1.60000	36.50	41.49	1085.1	0.01405	254.44	424.21	1.1838	1.7277	1.615	1.324	1.452	411.	148.6	131.3	13.70	84.1	16.51	5.33	1.60000
1.70000	38.95	43.84	1073.1	0.01312	258.38	424.66	1.1961	1.7248	1.638	1.360	1.477	398.	147.5	127.0	13.87	82.8	16.93	5.00	1.70000
1.80000	41.29	46.09	1061.3	0.01229	262.18	425.02	1.2080	1.7220	1.662	1.398	1.504	386.	146.3	122.9	14.04	81.5	17.37	4.69	1.80000
1.90000	43.54	48.25	1049.6	0.01154	265.88	425.31	1.2194	1.7191	1.688	1.438	1.532	374.	145.2	119.1	14.21	80.3	17.83	4.40	1.90000
2.00000	45.70	50.31	1038.1	0.01087	269.48	425.51	1.2304	1.7163	1.715	1.481	1.563	363.	144.0	115.4	14.38	79.2	18.30	4.12	2.00000
2.10000	47.79	52.30	1026.7	0.01025	273.00	425.65	1.2411	1.7135	1.743	1.526	1.596	352.	142.8	111.9	14.56	78.0	18.80	3.86	2.10000
2.20000	49.80	54.22	1015.3	0.00969	276.43	425.71	1.2515	1.7106	1.774	1.573	1.632	341.	141.6	108.6	14.74	76.9	19.32	3.60	2.20000
2.30000	51.74	56.07	1004.0	0.00917	279.80	425.70	1.2616	1.7077	1.806	1.624	1.670	330.	140.4	105.4	14.92	75.9	19.87	3.36	2.30000
2.40000	53.63	57.86	992.7	0.00869	283.10	425.63	1.2714	1.7048	1.841	1.679	1.712	320.	139.2	102.4	15.10	74.8	20.45	3.13	2.40000
2.50000	55.45	59.58	981.4	0.00825	286.35	425.48	1.2810	1.7018	1.878	1.738	1.757	310.	138.0	99.4	15.29	73.8	21.06	2.91	2.50000
2.60000	57.22	61.26	970.0	0.00784	289.55	425.27	1.2904	1.6988	1.918	1.802	1.806	300.	136.7	96.6	15.48	72.8	21.71	2.70	2.60000
2.70000	58.94	62.88	958.6	0.00746	292.71	425.00	1.2996	1.6957	1.962	1.872	1.861	290.	135.5	93.8	15.68	71.8	22.39	2.50	2.70000
2.80000	60.62	64.45	947.1	0.00710	295.83	424.65	1.3087	1.6925	2.009	1.948	1.920	280.	134.2	91.1	15.89	70.9	23.13	2.31	2.80000
2.90000	62.25	65.98	935.5	0.00676	298.92	424.23	1.3176	1.6892	2.062	2.032	1.987	270.	133.0	88.5	16.11	70.0	23.91	2.13	2.90000
3.00000	63.84	67.47	923.																

Tabella 10 - Tubi corrugati esternamente. 19 alette al pollice.



Spessore alette:  $a = 0,35 \pm 0,05$   
 Passo alette:  $p = 1,3 \pm 0,03$   
 Altezza alette:  $H = 1,45 \pm 0,1$



dimensioni	pesi indica- tivi in g/m	Ø est. Di	Ø sotto le alette d	spess. sotto le alette e	superf. esterna Ae m <sup>2</sup> /m	rappor- to delle superf. Ae/Ai	Ø est. D	spes- sore E
11 x 16 x 1	520	16	13	1	0,135	3,90	16,15	1,50
12 x 17 x 1	560	17	14	1	0,144	3,80	17,20	1,45
12,80 x 18,80 x 1,50	823	18,80	15,80	1,50	0,158	3,90	19,05	1,90
13,40 x 18,80 x 1,20	713	18,80	15,80	1,20	0,158	3,70	19,05	1,70
13,80 x 18,80 x 1	637	18,80	15,80	1	0,158	3,60	19,05	1,45
15 x 20,40 x 1,20	840	20,40	17,40	1,20	0,182	3,26	20,60	1,75
16 x 21,40 x 1,20	890	21,40	18,40	1,20	0,192	3,80	21,70	1,75
<i>Tubi corrugati esternamente. 26 alette al pollice</i>								
14 x 18,80 x 0,90	620	18,80	15,80	0,90	0,215	4,88	19,05	1,40