

มหาวิทยาลัยสงขลานครินทร์

คณะวิศวกรรมศาสตร์

การสอบปลายภาค ประจำภาคการศึกษาที่ 1

ปีการศึกษา 2547

วันที่ 2 ตุลาคม 2547

เวลา 13.30 - 16.00 ชม.

วิชา 216-433 การทำความเย็นและการปรับอากาศ

ห้อง 2200

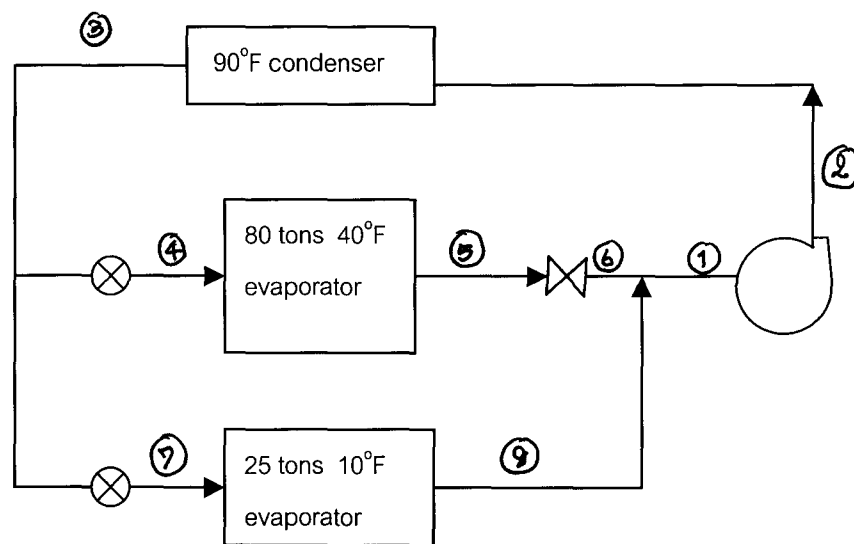
คำสั่ง

1. ข้อสอบมีทั้งหมด 7 ข้อ คะแนนรวม 120 คะแนน ให้เลือกทำครบ 100 คะแนน
2. ไม่อนุญาตให้นำ Lecture note และเอกสารต่างๆ เข้าห้องสอบ
3. นำเครื่องคิดเลขเข้าห้องสอบได้
4. ให้เขียนคำตอบและวิธีทำลงในสมุดคำตอบที่แจกให้

รศ.กำพล ประทีปชัยกุล

ผู้ออกข้อสอบ

- 1) An industrial plant uses a R-12 system with one compressor to serve both an air conditioning evaporator and a low temperature evaporator for process refrigeration. The air conditioning evaporator is a liquid chiller operating with a capacity of 80 tons and maintained at a temperature of 40°F by a pressure regulating valve at the outlet of the evaporator. The low temperature evaporator has a capacity of 25 tons and operates at a temperature of 10°F. The compressor suction pressure is the same as the pressure in the low temperature evaporator and the condensing temperature is 90°F. Calculate the power required by the compressor. Draw the P-h diagram. (20 marks)



- 2) Consider a reciprocating compressor operating with R-12. Refrigerant enters the cylinder at 20 psia and 20°F, but leave the evaporator saturated at 0.5°F. The vapor is discharged from the cylinder at 180 psia. Compute the volumetric efficiency for
- a clearance factor of 0.03
 - a clearance factor of 0.15
 - compare the mass flow rate for parts a and b

$$\text{Given } \eta_v = \left[1 + C - C \left(\frac{P_c}{P_b} \right)^{\frac{1}{n}} \right] \frac{V_3}{V_b}, \quad n = 1.13$$

(20 marks)

- 3) Moist air at 80°FDB and 67°FWB is cooled to 58°FDB and 80%RH. The volume flow rate is 2,000 cfm and the condensate leaves at 60°F. Find the heat transfer rate.

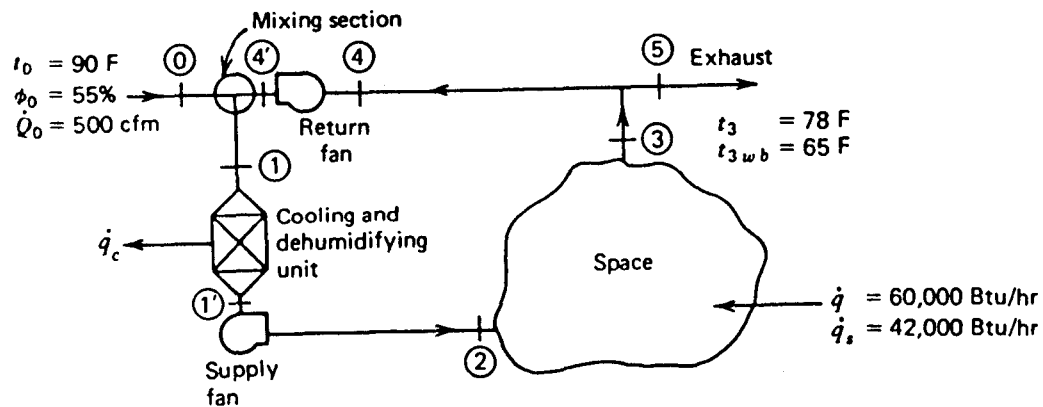
(20 marks)

- 4) Conditioned air is supplied to a space at 15°CDB and 14°CWB at the rate of $0.5 \text{ m}^3/\text{s}$. The sensible heat factor for the space is 0.7 and the space is to be maintained at 24°CDB . Determine the sensible and latent cooling loads for the space. Plot the process on the psychrometric chart.

(20 marks)

- 5) A given space is to be maintained at 78°FDB and 65°FWB . The total heat gain to the space has been determined to be 60,000 Btu/hr of which 42,000 Btu/hr is sensible heat transfer. The outdoor air requirement of the occupants is 500 cfm. The outdoor air has a temperature and relative humidity of 90°F and 55 %, respectively. Determine the quantity and the state of the air supplied to the space and the required capacity of the cooling and dehumidifying equipment. Assume $t_2 = 58^{\circ}\text{FDB}$.

(20 marks)

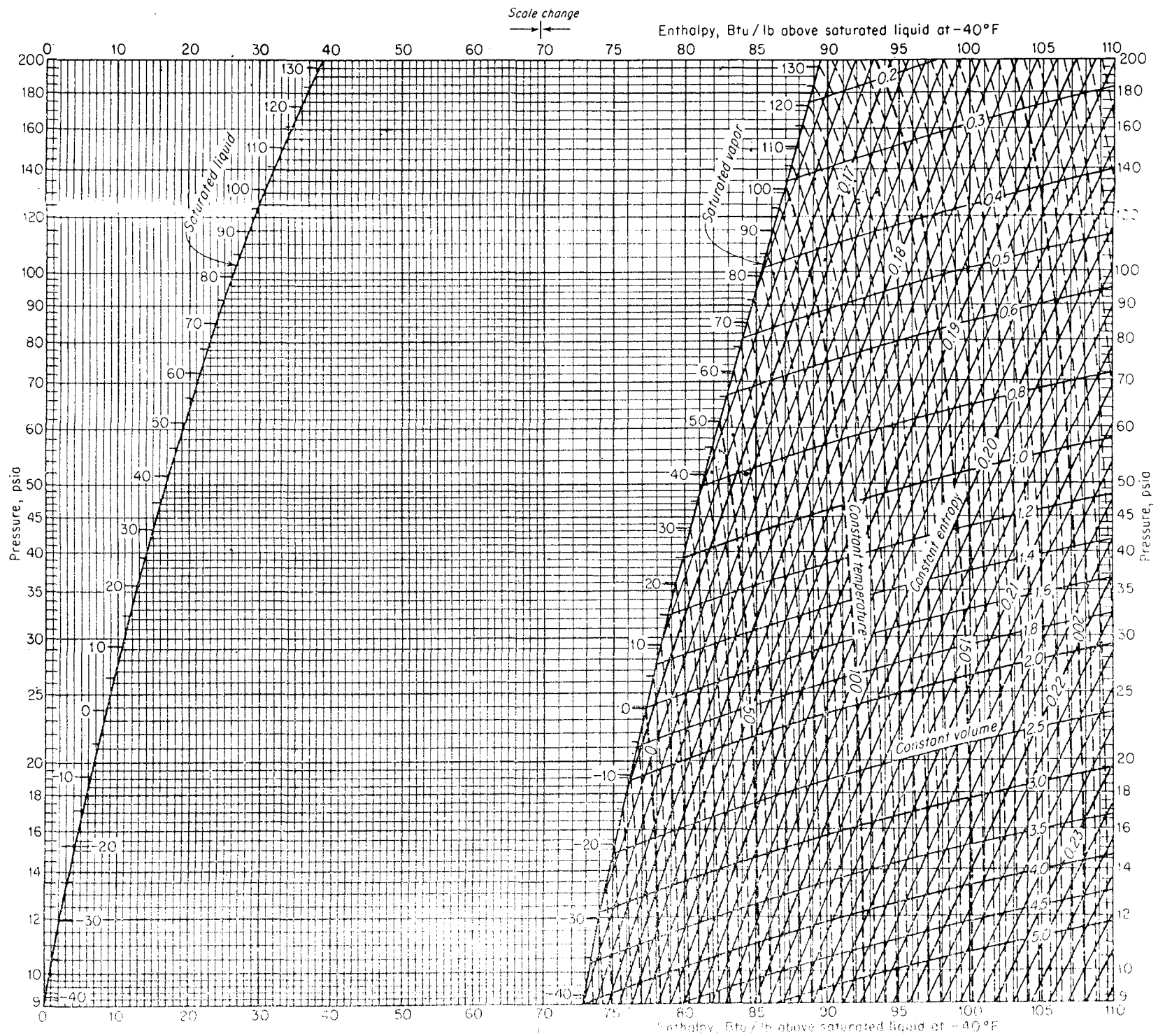


- 6) Determine the cooling load in a room at 3.00 pm. due to incandescent lights, turned on at 10.00 a.m. And turned off at 6.00 pm. The total wattage is 2,000. The room can be classified as ordinary furniture and no carpet room with medium air circulation rate and the lights are recessed and are not vented. The room floor is 3" concrete floor with tile.

(10 marks)

- 7) Determine the cooling load from 5 people in a bank doing light work at 4 pm. Two of them come into the bank at 12.00 am and leave the bank at 4.00 pm. while the rest come to the bank at 2.00 p.m. and leave the bank at 4 pm.

(10 marks)



Appendix A

Thermodynamic Properties of Steam and Moist Air

TABLE A-1*

Saturated steam: temperature

Temp. Fah. t	Specific Volume		Internal Energy				Enthalpy			Entropy		
	.Press. Lbf. Sq. In. p	Sat. Liquid v _f	Sat. Vapor v _g	Sat. Liquid u _f	Evap. u _{fg}	Sat. Vapor u _g	Sat. Liquid h _f	Evap. h _{fg}	Sat. Vapor h _g	Sat. Liquid s _f	Evap. s _{fg}	Sat. Vapor s _g
32	0.8859	0.16022	3305.	.01	1021.2	1021.2	.01	1075.4	1075.4	0.00003	2.1870	2.1870
32.018	0.8866	0.16022	3302.	.00	1021.2	1021.2	.01	1075.4	1075.4	0.00000	2.1869	2.1869
35	0.9992	0.16021	2948.	2.99	1019.2	1022.2	3.00	1073.7	1076.7	0.0607	2.1704	2.1764
40	1.2166	0.16020	2445.	8.02	1015.8	1023.9	8.02	1070.9	1078.9	0.1617	2.1430	2.1592
45	1.4748	0.16021	203.7	13.04	1012.5	1025.5	13.04	1068.1	1081.1	0.2618	2.1162	2.1423
50	1.7803	0.16024	1704.2	18.06	1009.1	1027.2	18.06	1065.2	1083.3	0.3607	2.0899	2.1259
60	2.563	0.16035	1206.9	28.08	1002.4	1030.4	28.08	1059.6	1087.7	0.5555	2.0388	2.0943
70	3.632	0.16051	867.7	38.09	995.6	1033.7	38.09	1054.0	1092.0	0.7463	1.9896	2.0642
80	5.073	0.16073	632.8	48.08	988.9	1037.0	48.09	1048.3	1096.4	0.9332	1.9423	2.0356
90	6.988	0.16099	467.7	58.07	982.2	1040.2	58.07	1042.7	1100.7	1.1165	1.8966	2.0083
100	9.503	0.16130	350.0	68.04	975.4	1043.5	68.05	1037.0	1105.0	1.2963	1.8526	1.9822
110	1.2763	0.16166	265.1	78.02	968.7	1046.7	78.02	1031.3	1109.3	1.4730	1.8101	1.9574
120	1.6945	0.16205	203.0	87.99	961.9	1049.9	88.00	1025.5	1113.5	1.6465	1.7690	1.9336
130	2.225	0.16247	157.17	97.97	955.1	1053.0	97.98	1019.8	1117.8	1.8172	1.7292	1.9109
140	2.892	0.16293	122.88	107.95	948.2	1056.2	107.96	1014.0	1121.9	1.9851	1.6907	1.8892
150	3.722	0.16343	96.99	117.95	941.3	1059.3	117.96	1008.1	1126.1	2.1503	1.6533	1.8684
160	4.745	0.16395	77.23	127.94	934.4	1062.3	127.96	1002.2	1130.1	2.3130	1.6171	1.8484
170	5.996	0.16450	62.02	137.95	927.4	1065.4	137.97	996.2	1134.2	2.4732	1.5819	1.8293
180	7.515	0.16509	50.20	147.97	920.4	1068.3	147.99	990.2	1138.2	2.6311	1.5478	1.8109
190	9.343	0.16570	40.95	158.0	913.3	1071.3	158.03	984.1	1142.1	2.7866	1.5146	1.7932
200	11.529	0.16634	33.63	168.04	906.2	1074.2	168.07	977.9	1145.9	2.9400	1.4822	1.7762
210	14.125	0.16702	27.82	178.10	899.9	1077.0	178.14	971.6	1149.7	3.0913	1.4508	1.7599
220	17.188	0.16772	23.15	188.17	891.7	1079.8	188.22	965.3	1153.5	3.2406	1.4201	1.7441
230	20.78	0.16845	19.386	198.26	884.3	1082.6	198.32	958.8	1157.1	3.3880	1.3901	1.7289
240	24.97	0.16922	16.327	208.36	876.9	1085.3	208.44	952.3	1160.7	3.5335	1.3609	1.7143
250	29.82	0.17001	13.826	218.49	869.4	1087.9	218.59	945.6	1164.2	3.6772	1.3324	1.7001
260	35.42	0.17084	11.768	228.64	861.8	1090.5	228.76	938.8	1167.6	3.8193	1.3044	1.6864
270	41.85	0.17170	10.066	238.82	854.1	1093.0	238.95	932.0	1170.9	3.9597	1.2771	1.6731
280	49.18	0.17259	8.650	249.02	846.3	1095.4	249.18	924.9	1174.1	4.0986	1.2504	1.6602
290	57.53	0.17352	7.467	259.25	838.5	1097.7	259.44	917.8	1177.2	4.2360	1.2241	1.6477
300	66.98	0.17448	6.472	269.52	830.5	1100.0	269.73	910.4	1180.2	4.3720	1.1984	1.6356
310	77.64	0.17548	5.632	279.81	822.3	1102.1	280.06	903.0	1183.0	4.5067	1.1731	1.6238
320	89.60	0.17652	4.919	290.14	814.1	1104.2	290.43	895.3	1185.8	4.6400	1.1483	1.6123
330	103.00	0.17760	4.312	300.51	805.7	1106.2	300.84	887.5	1188.4	4.7722	1.1238	1.6010
340	117.93	0.17872	3.792	310.91	797.1	1108.0	311.30	879.5	1190.8	4.9031	1.0997	1.5901
350	134.53	0.17988	3.346	321.35	788.4	1109.8	321.80	871.3	1193.1	5.0329	1.0760	1.5793
360	152.92	0.18108	2.961	331.84	779.6	1111.4	332.35	862.9	1195.2	5.1617	1.0526	1.5688
370	173.23	0.18233	2.628	342.37	770.6	1112.9	342.96	854.2	1197.2	5.2894	1.0295	1.5585
380	195.60	0.18363	2.339	352.95	761.4	1114.3	353.62	845.4	1199.0	5.4163	1.0067	1.5483
390	220.2	0.18498	2.087	363.58	752.0	1115.6	364.34	836.2	1200.6	5.5422	9841	1.5383
400	247.1	0.18638	1.8661	374.27	742.4	1116.6	375.12	826.8	1202.0	5.6672	9617	1.5284
425	325.6	0.19014	1.4249	401.24	717.4	1118.6	402.38	802.1	1204.5	5.9767	9066	1.5043
450	422.1	0.19433	1.1011	428.6	690.9	1119.5	430.2	775.4	1205.6	6.282	8523	1.4806
475	539.3	0.19901	.8594	456.6	662.6	1119.2	458.5	746.4	1204.9	6.586	7985	1.4571
500	680.0	0.20443	.6761	485.1	632.3	1117.4	487.7	714.8	1202.5	6.888	7448	1.4335
525	847.1	0.21104	.5350	514.5	599.5	1113.9	517.8	680.0	1197.8	7.191	6906	1.4007
550	1044.0	0.21775	.4249	544.9	563.7	1108.6	549.1	641.6	1190.6	7.497	6354	1.3851
575	1274.0	0.22259	.3378	576.5	524.3	1100.8	581.9	598.6	1180.4	7.808	5785	1.3593
600	1541.0	0.22363	.2677	609.9	480.1	1090.0	616.7	549.7	1166.4	8.130	5187	1.3317
625	1849.7	0.22494	.2103	645.7	429.4	1075.1	654.2	492.9	1147.0	8.467	4544	1.3010
650	2205.	0.22673	.16206	685.0	368.7	1053.7	695.9	423.9	1119.8	8.831	3820	1.2651
675	2616.	0.22951	.11952	731.0	289.3	1020.3	745.3	332.9	1078.2	9.252	2934	1.2186
700	3090.	0.23666	.07438	801.7	145.9	947.7	822.7	167.5	990.2	9.902	1444	1.1346
708.44	3204.	0.25053	0.05053	872.6	0	872.6	902.5	0	902.5	1.0580	0	1.0580

* Tables A-1 through A-3 are abridged from J. H. Keenan, P. G. Hill, and J. G. Moore, *Steam Tables—Thermodynamic Properties of Water Including Vapor and Liquid Phases*, John Wiley & Sons, Inc., New York, 1969, with permission. From Irving Granet, *Thermodynamics and Heat Power* (Reston, Va.: Reston Publishing Company, 1974).

TABLE 9-19

Rate of heat gain from occupants of conditioned spaces^a

Degree of Activity	Typical Application	Total Heat Adult, Male		Total Heat Adjusted ^b		Sensible Heat		Latent Heat	
		Watts	Btu/hr	Watts	Btu/hr	Watts	Btu/hr	Watts	Btu/hr
Seated at rest	theater, movie	115	400	100	350	60	210	40	140
Seated, very light work, writing	offices, hotels, apts.	140	480	120	420	65	230	55	190
Seated, eating	restaurant ^c	150	520	170	580 ^c	75	255	95	325
Seated, light work typing	offices, hotels, apts.	185	640	150	510	75	255	75	255
Standing, light work, or walking slowly	retail store, bank	235	800	185	640	90	315	95	325
Light bench work	factory	255	880	230	780	100	345	130	435
Walking, 3 mph, light machine work	factory	305	1040	305	1040	100	345	205	695
Bowling ^d	bowling alley	350	1200	280	960	100	345	180	615
Moderate dancing	dance hall	400	1360	375	1280	120	405	255	875
Heavy work, heavy machine work, lifting	factory	470	1600	470	1600	165	565	300	1035
Heavy work, athletics	gymnasium	585	2000	525	1800	185	635	340	1165

Source: Reprinted from *ASHRAE Handbook and Product Directory—1977 Fundamentals*, with permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Ga.

^aNote: Tabulated values are based on 78°F room dry-bulb temperature. For 80°F room dry bulb, the total heat remains the same, but the sensible heat value should be decreased by approximately 8 percent and the latent heat values increased accordingly.

^bAdjusted total heat gain is based on normal percentage of men, women, and children for the application listed, with the postulate that the gain from an adult female is 85 percent of that of an adult male, and that the gain from a child is 75 percent of that of an adult male.

^cAdjusted total heat value for eating in a restaurant, includes 60 Btu/hr for food per individual (30 Btu sensible, 30 Btu latent).

^dFor bowling figure one person per alley actually bowling, and all others are sitting (400 Btu/hr) or standing and walking slowly (790 Btu/hr).

TABLE 9-20

Sensible cooling-load factors (CLFs) for people

Total Hours in Space	Hours after Each Entry Into Space																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
2	0.49	0.58	0.17	0.13	0.10	0.08	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4	0.49	0.59	0.66	0.71	0.27	0.21	0.16	0.14	0.11	0.10	0.08	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01
6	0.50	0.60	0.67	0.72	0.76	0.79	0.34	0.26	0.21	0.18	0.15	0.13	0.11	0.10	0.08	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.03
8	0.51	0.61	0.67	0.72	0.76	0.80	0.82	0.84	0.38	0.30	0.25	0.21	0.18	0.15	0.13	0.12	0.10	0.09	0.08	0.07	0.06	0.05	0.05	0.04	0.04
10	0.53	0.62	0.69	0.74	0.77	0.80	0.83	0.85	0.87	0.89	0.42	0.34	0.28	0.23	0.20	0.17	0.15	0.13	0.11	0.10	0.09	0.08	0.07	0.06	0.06
12	0.55	0.64	0.70	0.75	0.79	0.81	0.84	0.86	0.88	0.89	0.91	0.92	0.45	0.36	0.30	0.25	0.21	0.19	0.16	0.14	0.12	0.11	0.09	0.08	0.08
14	0.58	0.66	0.72	0.77	0.80	0.83	0.85	0.87	0.89	0.90	0.91	0.92	0.93	0.94	0.47	0.38	0.31	0.26	0.23	0.20	0.17	0.15	0.13	0.11	0.11
16	0.62	0.70	0.75	0.79	0.82	0.85	0.87	0.88	0.90	0.91	0.92	0.93	0.94	0.95	0.95	0.96	0.49	0.39	0.33	0.28	0.24	0.20	0.18	0.16	0.16
18	0.66	0.74	0.79	0.82	0.85	0.87	0.89	0.90	0.92	0.93	0.94	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.50	0.40	0.33	0.28	0.24	0.21

Source: Reprinted from *ASHRAE Handbook—1985 Fundamentals*, with permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Ga.

TABLE 9-21

Cooling-load factors (CLFs) when lights are on for 10 hours

"a" Coef- ficients	"b" Class- ification	Number of Hours after Lights Are Turned On																							
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0.45	A	0.03	0.47	0.58	0.66	0.73	0.78	0.82	0.86	0.88	0.91	0.93	0.49	0.39	0.32	0.26	0.21	0.17	0.13	0.11	0.09	0.07	0.06	0.05	0.04
	B	0.10	0.54	0.59	0.63	0.66	0.70	0.73	0.76	0.78	0.80	0.82	0.39	0.35	0.32	0.28	0.26	0.23	0.21	0.19	0.17	0.15	0.14	0.12	0.11
	C	0.15	0.59	0.61	0.64	0.66	0.68	0.70	0.72	0.73	0.75	0.76	0.33	0.31	0.29	0.27	0.26	0.24	0.23	0.21	0.20	0.19	0.18	0.17	0.16
	D	0.18	0.62	0.63	0.64	0.66	0.67	0.68	0.69	0.69	0.70	0.71	0.27	0.26	0.26	0.25	0.24	0.23	0.23	0.22	0.21	0.21	0.20	0.19	0.19
0.55	A	0.02	0.57	0.65	0.72	0.78	0.82	0.85	0.88	0.91	0.92	0.94	0.40	0.32	0.26	0.21	0.17	0.14	0.11	0.09	0.07	0.06	0.05	0.04	0.03
	B	0.08	0.62	0.66	0.69	0.73	0.75	0.78	0.80	0.82	0.84	0.85	0.32	0.29	0.26	0.23	0.21	0.19	0.17	0.15	0.14	0.12	0.11	0.10	0.09
	C	0.12	0.66	0.68	0.70	0.72	0.74	0.75	0.77	0.78	0.79	0.81	0.27	0.25	0.24	0.22	0.21	0.20	0.19	0.17	0.16	0.15	0.14	0.14	0.13
	D	0.15	0.69	0.70	0.71	0.72	0.73	0.73	0.74	0.75	0.76	0.76	0.22	0.22	0.21	0.20	0.20	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15
0.65	A	0.02	0.66	0.73	0.78	0.83	0.86	0.89	0.91	0.93	0.94	0.95	0.31	0.25	0.20	0.16	0.13	0.11	0.08	0.07	0.05	0.04	0.04	0.03	0.02
	B	0.06	0.71	0.74	0.76	0.79	0.81	0.83	0.84	0.86	0.87	0.89	0.25	0.22	0.20	0.18	0.16	0.15	0.13	0.12	0.11	0.10	0.09	0.08	0.07
	C	0.09	0.74	0.75	0.77	0.78	0.80	0.81	0.82	0.83	0.84	0.85	0.21	0.20	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.11	0.11	0.10
	D	0.11	0.76	0.77	0.77	0.78	0.79	0.79	0.80	0.81	0.81	0.82	0.17	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.12	0.12
0.75	A	0.01	0.76	0.81	0.84	0.88	0.90	0.92	0.93	0.95	0.96	0.97	0.22	0.18	0.14	0.12	0.09	0.08	0.06	0.05	0.04	0.03	0.03	0.02	0.02
	B	0.04	0.79	0.81	0.83	0.85	0.86	0.88	0.89	0.90	0.91	0.92	0.18	0.16	0.14	0.13	0.12	0.10	0.09	0.08	0.08	0.07	0.06	0.06	0.05
	C	0.07	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.89	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07
	D	0.08	0.83	0.83	0.84	0.84	0.85	0.85	0.86	0.86	0.87	0.87	0.12	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.09	0.09

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TABLE 9-22

Design values of *a* coefficient: features of room furnishings, light fixtures, and ventilation arrangements

<i>a</i>	Furnishings	Air Supply and Return	Type of Light Fixture
0.45	Heavyweight, simple furnishings, no carpet	Low rate; supply and return below ceiling [$V \leq 2.5 (0.5)$]*	Recessed, not vented
0.55	Ordinary furniture, no carpet	Medium to high ventilation rate; supply and return below ceiling or through ceiling grill and space [$V \geq 2.5 (0.5)$]*	Recessed, not vented
0.65	Ordinary furniture, with or without carpet	Medium to high ventilation rate or fan coil or induction type air-conditioning terminal unit; supply through ceiling or wall diffuser; return around light fixtures and through ceiling space. [$V \geq 2.5 (0.5)$]*	Vented
0.75 or greater	Any type of furniture	Ducted returns through light fixtures	Vented or free-hanging in air stream with ducted returns

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* *V* is room air supply rate in L/s m² (CFM/ft²) of floor area

TABLE 9-23

The *b* classification values calculated for different envelope construction and room air circulation rates

Room Envelope Construction* [mass of floor area, (kg/m ² , lb/ft ²)]	Room Air Circulation and Type of Supply and Return**			
	Low	Medium	High	Very High
50.8-mm (2-in.) Wood Floor (48.8, 10)	B	A	A	A
76.2-mm (3-in.) Concrete Floor (195.3, 40)	B	B	B	A
152.4-mm (6-in.) Concrete Floor (366.2, 75)	C	C	C	B
203.2-mm (8-in.) Concrete Floor (585.8, 120)	D	D	C	C
304.8-mm (12-in.) Concrete Floor (781.1, 160)	D	D	D	D

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* Floor covered with carpet and rubber pad; for a floor covered only with floor tile take next classification to the right in the same row.

** *Low*: Low ventilation rate—minimum required to cope with cooling load due to lights and occupants in interior zone. Supply through floor, wall, or ceiling diffuser. Ceiling space not vented and $f = 2.27 \text{ W/m}^2 \text{ }^\circ\text{C}$ (0.4 Btu/hr ft² °F) (where f = inside surface convection coefficient used in calculation of *b* classification).

Medium: Medium ventilation rate, supply through floor, wall, or ceiling diffuser. Ceiling space not vented and $f = 3.41 \text{ W/m}^2 \text{ }^\circ\text{C}$ (0.60 Btu/hr ft² °F).

High: Room air circulation induced by primary air of induction unit or by fan coil unit. Return through ceiling space and $f = 4.54 \text{ W/m}^2 \text{ }^\circ\text{C}$ (0.80 Btu/hr ft² °F).

Very High: High room air circulation used to minimize temperature gradients in a room. Return-through ceiling space and $f = 6.81 \text{ W/m}^2 \text{ }^\circ\text{C}$ (1.2 Btu/hr ft² °F).