ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2019 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

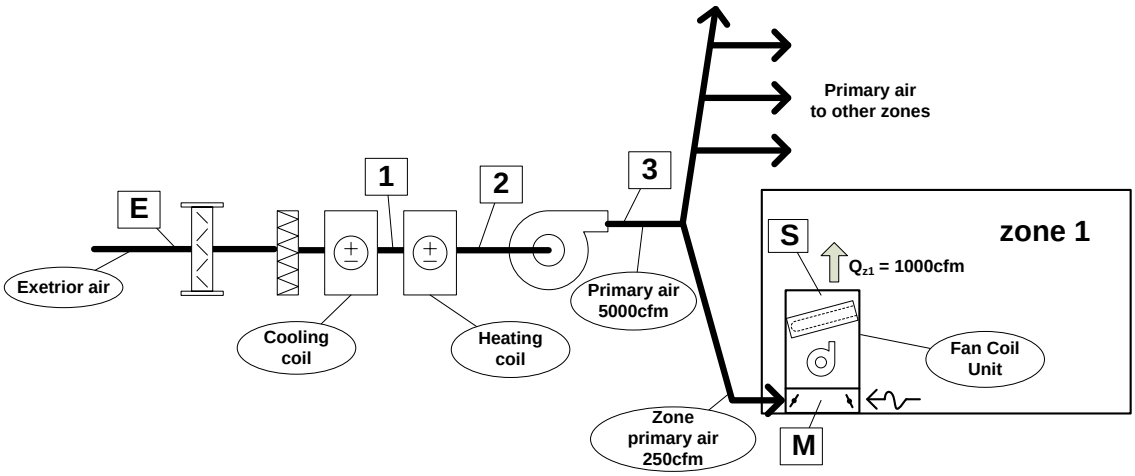
16-MC-B1
Environmental control in buildings

Problem # 1 (25 %)

The diagram shows an air-conditioning system serving 20 zones with Fan Coil Units.

The primary (exterior) airflow rate of the system fan is constant $\dot{Q}_{fan.} = 5000cfm$

The primary airflow rate of each zone is constant $\dot{Q}_{fan,coil,unit,primary} = 250cfm$



At a given moment (out of design operation), the data are as follows::

- **Zone 1** $t_{z,1} = 75°F$ $\phi = 50\%$ $\dot{Q}_{z1} = 1000cfm$
  sensible load $q_{sensible} = 16200$ Btu/hre
  latent load $q_{latent} = 1000$ Btu/hre
- Exterior air conditions (état E) dry bulb temperature $t_E = 90°F$
  wet bulb temperature $t_{wb} = 75°F$
- State of air leaving the system cooling coil (point 1) dry bulb temperature $t_1 = 50°F$
  relative humidity $\phi = 95\ \%$
- Temperature rise across the system fan $\Delta t_v = 2°F$

- Temperature rise across the fan of Fan Coil Unit — negligible
- Cooling coil dew point temperature of Fan Coil Unit — $t_{dp} = 52°F$

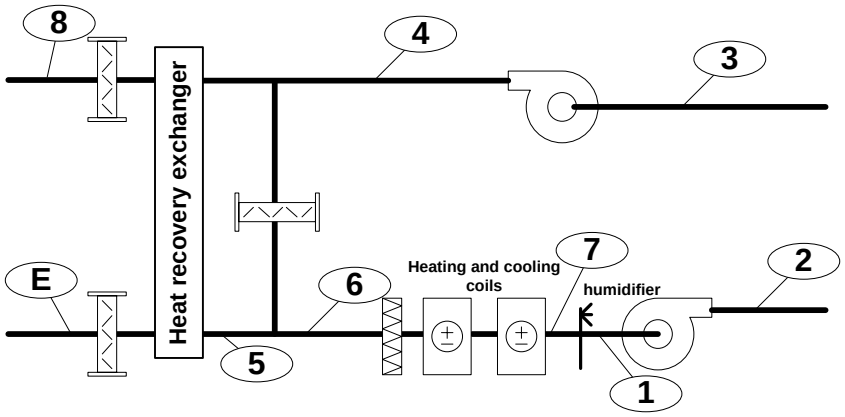
Locate the key air states of the process (*points E, 1, 2, 3, S and M*) on the psychrometric chart *(10 %) and determine*:

a) the system cooling coil capacity *(5 %)*;
b) the cooling coil capacity of Fan Coil Unit of the zone 1 *(5 %)*;
c) shown in the table the dry bulb temperature and humidity ratio of each point (*1, 2, 3, S and M*) *(5 %)*.

Use the conditions of the standard air.

Problem # 2 (20%)

The figure shows an air conditioning system with heat recovery exchanger. At a given moment (out of design operation), the data are as follows:



- Air temperature and humidity at state 3 — $t_3 = 23°C$ $\phi = 40\ \%$
- Air temperature and humidity ratio at state 2 (supply) — $t_2 = 30°C$ $w_2 = w_3$
- Exterior air — $t_{db} = t_E = -10°C$ $w_E = 0.001\ kg/kg_{dry\ air}$
- Fan air flow rate — $Q = 10\ m^3/s$
- Exterior air flow rate — 20% of fan air flow rate
- Temperature rise across the supply fan — $\Delta t_{Va} = 2°C$
- Temperature rise across the return fan — negligible

Consider two cases presented below:

A. Heat recovery exchange is a rotary **sensible** wheel with effectiveness $\varepsilon = 0.7$
B. Heat recovery exchange is a rotary **enthalpy** wheel with effectiveness $\varepsilon = 0.85$

Shown the air states **on the psychrometric chart** (*8%*) and shown **in the table** *(2%)* the temperature, humidity ratio and enthalpy of each point. Determine for cases A nd B :

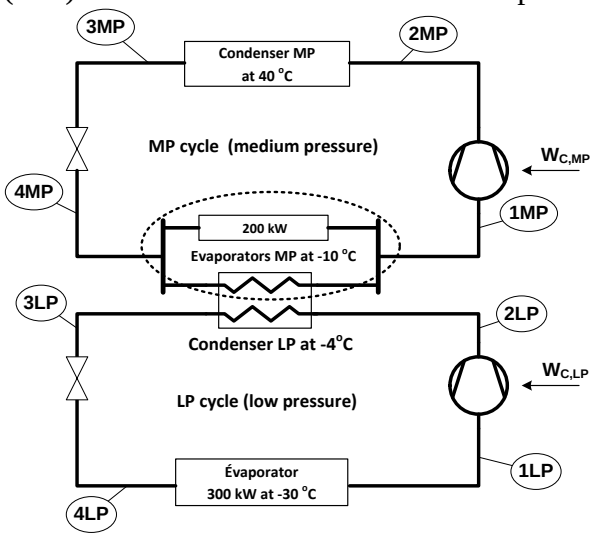
- Heating coil power and, if required, preheat coil power of exterior air to avoid the condensation *(5%)*;

- Steam rate injected by humidifier *(5%)*.

Problem # 3 (25%)

The figure shows a cascade refrigeration system with R-507 as refrigerant. The cooling capacity of evaporators and evaporation temperatures are indicated on the attached figure. The compressors used in the cycle are isentropic.

The evaporation and condensation temperatures of R-507 are also indicated on the figure. The R-507 leaves the evaporators as a saturated vapor (1LP and 1MP) and the condenser LP as a saturated liquid (3LP). It leaves the condenser MP as a supercooled liquid at 34°C (3MP).



Show the cycles on the attached R-507 diagram (*5%*) and determine:

a) Heat rejected by the LP condenser (*4%*);
b) The R-507 flow rates of MP and LP cycles (*7%*);
c) COPs (coefficients of performance) of LP and MP cycles and COP of cascade refrigeration cycle (*9%*).

Problem # 4 (10%)

The building cooling load ($\dot{Q}_{actuel}$) varies with the exterior air temperature as follow :

- It is of 875 tonns (3080 kW) at 95 °F (35 °C)
- It is of 0 tonne (0 kW) at 55 °F (13 °C)

Two scenarios are proposed to provide the air conditioning of the building.

Scenario A – the centrifugal chiller used has a colling nominal capacity ($\dot{Q}_{nom}$) of 925 tonns (3250 kW) ;

Scénario B – three (3) centrifugal chillers are used to provide air conditioning of the building. Each chiller has a colling nominal capacity ($\dot{Q}_{nom}$) of 300 tonns (1055 kW). The chiller operation strategy prioritizes the operation at full chiller load.

The chiller power input ($\dot{W}_{in}$) is expressed in terms of PLR as follows:

$$\dot{W}_{in} = \dot{W}_{in,nom} * \dot{Q}_{nom} * [A + B*(PLR) + C*(PLR)^2]$$

where PLR is a Part Load Ratio and the chiller-specific part-load coefficients A, B, C, are given in the table below.

	The chiller nominal power input $(\dot{W}_{in,nom})$	A	B	C
Scenario A	0.692 kW/tonne	0.201	0.555	0.221
Scenario B	0.673 kW/tonne	0.201	0.602	0.185

For the **both scenarios (A and B)**, determine:

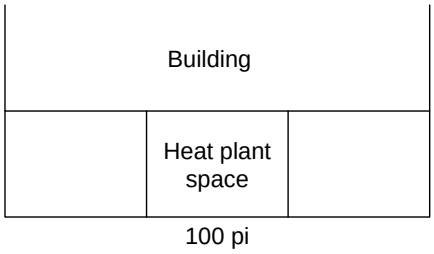
a) The chiller electric energy consumption for the exterior (BIN) temperature of **75 and 90 ^{o}F** if the numbers of hours (N_{BIN}) for these temperatures are respectively of **500 and 20** *(7%);*

Determine, for the **scenario A** :

b) The chiller COP coefficient for each BIN temperature *(3%).*

Problem # 5 (20%)

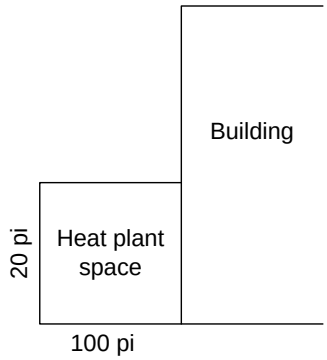
During a heating plant energy audit, when the outdoor air temperature was -3 ^{o}F, it was noted that the combustion air to gas boiler is taken from inferior part of heating plant space at 45 ^{o}F. It was measured also that temperature of the superior part of heating plant space is 90 ^{o}F. To increase the boiler efficiency it is then proposed to take the combustion air from the superior part of heating plant space.



Boiler capacity at ***design*** (full load) condition 200 BHP
Gas heating value 35300Btu/m^3_{gas}(37.2 MJ/m^3_{gas})
Boiler efficiency at ***design*** (full load) condition 80%

1 BHP = 33480 Btu/h

Assume the combustion air to boiler of 0.30 m^3_{air} / MJ of gas heating value. To determine the gas consumption ($CC_{part\ load}$) serving to determine the rate of combustion air to boiler in the part load operation, the following model could be used:



$$CC_{part,load} = CC_{design} * FHeatPLC\left(Q_{part,load}, Q_{design}\right)$$

$$FHeatPLC = \left(a + b * \frac{Q_{part,load}}{Q_{design}} + c * \left| \frac{Q_{part,load}}{Q_{design}} \right|^2 \right)$$

a = 0.082597 b = 0.99676 c = -0.079361

CC gas consumption (m^3_{gas}/h)
Q_{design} boiler capacity at design (full load) condition in Btu/h
$Q_{part,load}$ boiler capacity (demand) at part load condition (Btu/h)

Consider bin temperature of -3 ^{o}F with the heat load ($Q_{part,load}$) of 120 BHP (4 017 600 Btu/h)

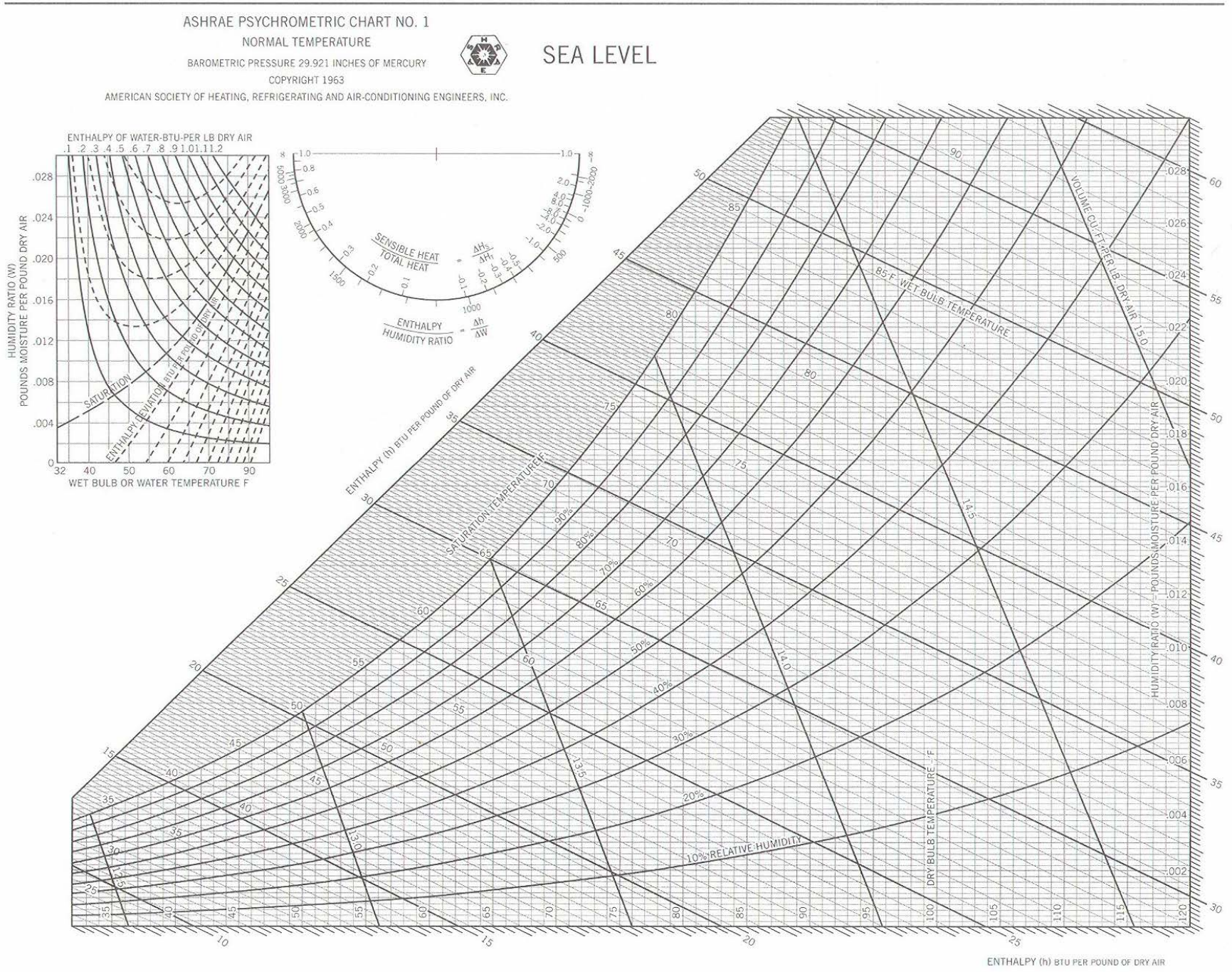
To make the energy balance of the heat plant space, it is assumed that:

- the boiler and equipment heat losses (heat plant space gains) are estimated at 180 000 Btu/h
- the flow rate of the infiltrating air is equal to the flow rate of combustion air to boiler
- the conductive heat transmission coefficient of heat plant space ($K_{cond} = \sum U_k A_k$) is determine as 1410 Btu/h^{o}F.

Determine :

a) new temperature of the combustion air to boiler (*15%*);
b) energy saving (in m^3 of gas) by this energy efficiency measure, considering the bin hours (for -3^{o}F) of 180 (*5%*).

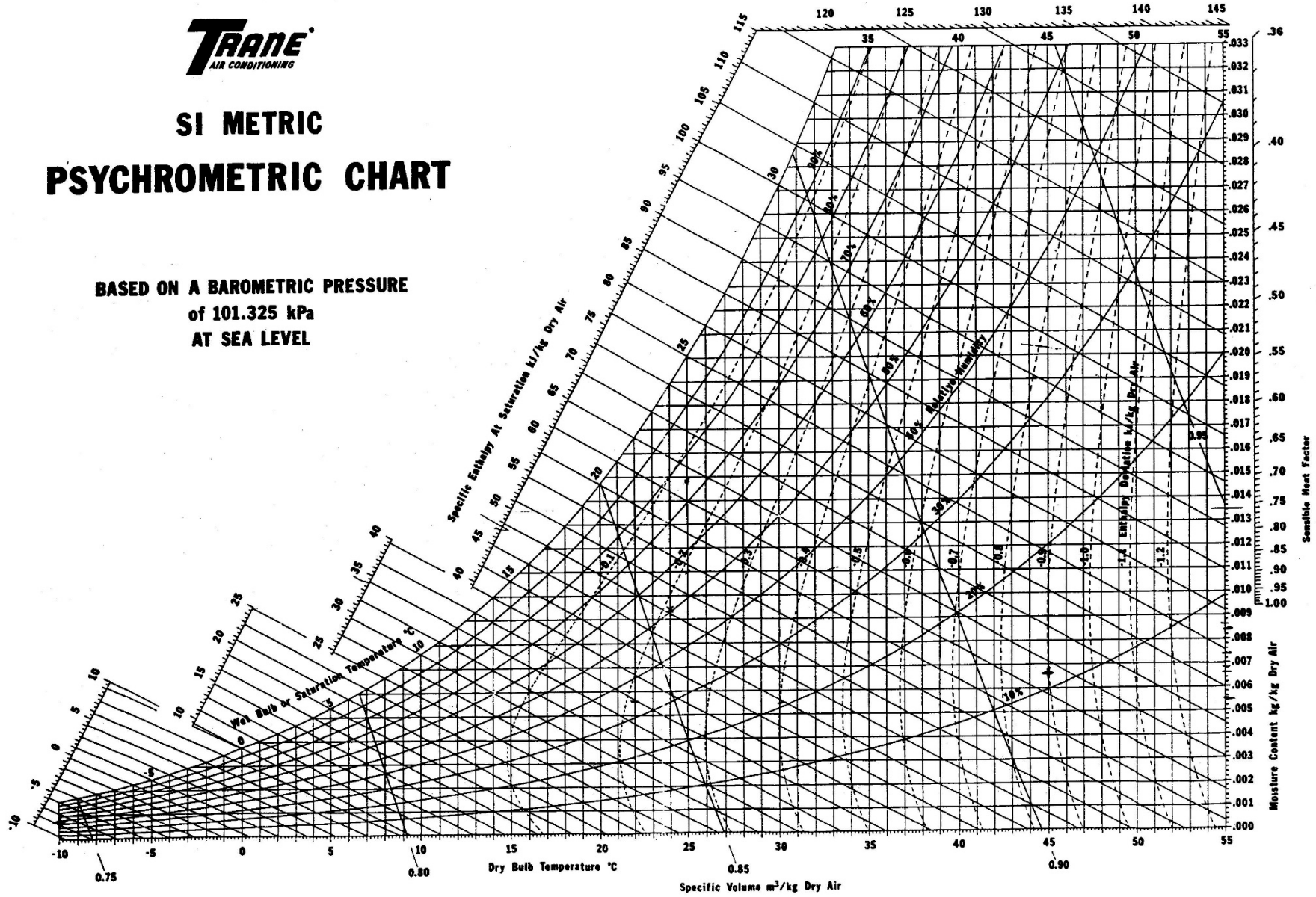
Chart 1*a* ASHRAE Psychrometric Chart No. 1 (IP) (Reprinted by permission of ASHRAE.)



TRANE
AIR CONDITIONING

SI METRIC
PSYCHROMETRIC CHART

BASED ON A BAROMETRIC PRESSURE
of 101.325 kPa
AT SEA LEVEL



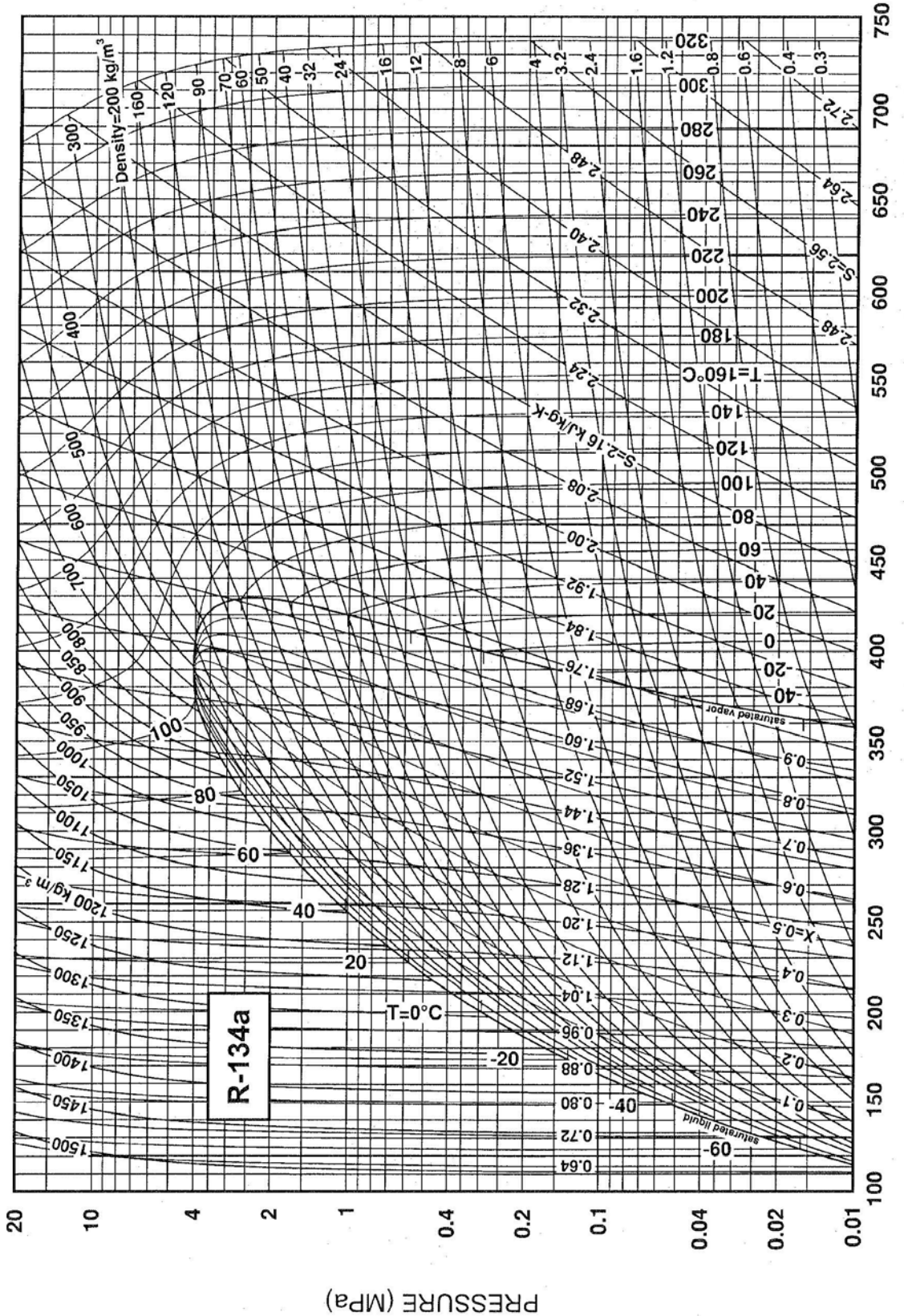


Fig. 8 Pressure-Enthalpy Diagram for Refrigerant 134a

Refrigerant 134a (1,1,1,2-Tetrafluoroethane) Properties of Saturated Liquid and Saturated Vapor

Temp.,* °C	Pressure, MPa	Density, kg/m³ Liquid	Volume, m³/kg Vapor	Enthalpy, kJ/kg Liquid	Enthalpy, kJ/kg Vapor	Entropy, kJ/(kg·K) Liquid	Entropy, kJ/(kg·K) Vapor	Specific Heat c_p, kJ/(kg·K) Liquid	Specific Heat c_p, kJ/(kg·K) Vapor	c_p/c_v Vapor	Velocity of Sound, m/s Liquid	Velocity of Sound, m/s Vapor	Viscosity, μPa·s Liquid	Viscosity, μPa·s Vapor	Thermal Cond., mW/(m·K) Liquid	Thermal Cond., mW/(m·K) Vapor	Surface Tension, mN/m	Temp., °C
−103.30a	0.00039	1591.1	35.496	71.46	334.94	0.4126	1.9639	1.184	0.585	1.164	1120.	126.8	2175.	6.46	145.2	3.08	28.07	−103.30
−100.00	0.00056	1582.4	25.193	75.36	336.85	0.4354	1.9456	1.184	0.593	1.162	1103.	127.9	1893.	6.60	143.2	3.34	27.50	−100.00
−90.00	0.00152	1555.8	9.7698	87.23	342.76	0.5020	1.8972	1.189	0.617	1.156	1052.	131.0	1339.	7.03	137.3	4.15	25.79	−90.00
−80.00	0.00367	1529.0	4.2682	99.16	348.83	0.5654	1.8580	1.198	0.642	1.151	1002.	134.0	1018.	7.46	131.5	4.95	24.10	−80.00
−70.00	0.00798	1501.9	2.0590	111.20	355.02	0.6262	1.8264	1.210	0.667	1.148	952.	136.8	809.2	7.89	126.0	5.75	22.44	−70.00
−60.00	0.01591	1474.3	1.0790	123.36	361.31	0.6846	1.8010	1.223	0.692	1.146	903.	139.4	663.1	8.30	120.7	6.56	20.80	−60.00
−50.00	0.02945	1446.3	0.60620	135.67	367.65	0.7410	1.7806	1.238	0.720	1.146	855.	141.7	555.1	8.72	115.6	7.36	19.18	−50.00
−40.00	0.05121	1417.7	0.36108	148.14	374.00	0.7956	1.7643	1.255	0.749	1.148	807.	143.6	472.2	9.12	110.6	8.17	17.60	−40.00
−30.00	0.08438	1388.4	0.22594	160.79	380.32	0.8486	1.7515	1.273	0.781	1.152	760.	145.2	406.4	9.52	105.8	8.99	16.04	−30.00
−28.00	0.09270	1382.4	0.20680	163.34	381.57	0.8591	1.7492	1.277	0.788	1.153	751.	145.4	394.9	9.60	104.8	9.15	15.73	−28.00
−26.07b	0.10133	1376.7	0.19018	165.81	382.78	0.8690	1.7472	1.281	0.794	1.154	742.	145.7	384.2	9.68	103.9	9.31	15.44	−26.07
−26.00	0.10167	1376.5	0.18958	165.90	382.82	0.8694	1.7471	1.281	0.794	1.154	742.	145.7	383.8	9.68	103.9	9.32	15.43	−26.00
−24.00	0.11130	1370.4	0.17407	168.47	384.07	0.8798	1.7451	1.285	0.801	1.155	732.	145.9	373.1	9.77	102.9	9.48	15.12	−24.00
−22.00	0.12165	1364.4	0.16006	171.05	385.32	0.8900	1.7432	1.289	0.809	1.156	723.	146.1	362.9	9.85	102.0	9.65	14.82	−22.00
−20.00	0.13273	1358.3	0.14739	173.64	386.55	0.9002	1.7413	1.293	0.816	1.158	714.	146.3	353.0	9.92	101.1	9.82	14.51	−20.00
−18.00	0.14460	1352.1	0.13592	176.23	387.79	0.9104	1.7396	1.297	0.823	1.159	705.	146.4	343.5	10.01	100.1	9.98	14.21	−18.00
−16.00	0.15728	1345.9	0.12551	178.83	389.02	0.9205	1.7379	1.302	0.831	1.161	695.	146.6	334.3	10.09	99.2	10.15	13.91	−16.00
−14.00	0.17082	1339.7	0.11605	181.44	390.24	0.9306	1.7363	1.306	0.838	1.163	686.	146.7	325.4	10.17	98.3	10.32	13.61	−14.00
−12.00	0.18524	1333.4	0.10744	184.07	391.46	0.9407	1.7348	1.311	0.846	1.165	677.	146.8	316.9	10.25	97.4	10.49	13.32	−12.00
−10.00	0.20060	1327.1	0.09959	186.70	392.66	0.9506	1.7334	1.316	0.854	1.167	668.	146.9	308.6	10.33	96.5	10.66	13.02	−10.00
−8.00	0.21693	1320.8	0.09242	189.34	393.87	0.9606	1.7320	1.320	0.863	1.169	658.	146.9	300.6	10.41	95.6	10.83	12.72	−8.00
−6.00	0.23428	1314.3	0.08587	191.99	395.06	0.9705	1.7307	1.325	0.871	1.171	649.	147.0	292.9	10.49	94.7	11.00	12.43	−6.00
−4.00	0.25268	1307.9	0.07987	194.65	396.25	0.9804	1.7294	1.330	0.880	1.174	640.	147.0	285.4	10.57	93.8	11.17	12.14	−4.00
−2.00	0.27217	1301.4	0.07436	197.32	397.43	0.9902	1.7282	1.336	0.888	1.176	631.	147.0	278.1	10.65	92.9	11.34	11.85	−2.00
0.00	0.29280	1294.8	0.06931	200.00	398.60	1.0000	1.7271	1.341	0.897	1.179	622.	146.9	271.1	10.73	92.0	11.51	11.56	0.00
2.00	0.31462	1288.1	0.06466	202.69	399.77	1.0098	1.7260	1.347	0.906	1.182	612.	146.9	264.3	10.81	91.1	11.69	11.27	2.00
4.00	0.33766	1281.4	0.06039	205.40	400.92	1.0195	1.7250	1.352	0.916	1.185	603.	146.8	257.6	10.90	90.2	11.86	10.99	4.00
6.00	0.36198	1274.7	0.05644	208.11	402.06	1.0292	1.7240	1.358	0.925	1.189	594.	146.7	251.2	10.98	89.4	12.04	10.70	6.00
8.00	0.38761	1267.9	0.05280	210.84	403.20	1.0388	1.7230	1.364	0.935	1.192	585.	146.5	244.9	11.06	88.5	12.22	10.42	8.00
10.00	0.41461	1261.0	0.04944	213.58	404.32	1.0485	1.7221	1.370	0.945	1.196	576.	146.4	238.8	11.15	87.6	12.40	10.14	10.00
12.00	0.44301	1254.0	0.04633	216.33	405.43	1.0581	1.7212	1.377	0.956	1.200	566.	146.2	232.9	11.23	86.7	12.58	9.86	12.00
14.00	0.47288	1246.9	0.04345	219.09	406.53	1.0677	1.7204	1.383	0.967	1.204	557.	146.0	227.1	11.32	85.9	12.77	9.58	14.00
16.00	0.50425	1239.8	0.04078	221.87	407.61	1.0772	1.7196	1.390	0.978	1.209	548.	145.7	221.5	11.40	85.0	12.95	9.30	16.00
18.00	0.53718	1232.6	0.03830	224.66	408.69	1.0867	1.7188	1.397	0.989	1.214	539.	145.5	216.0	11.49	84.1	13.14	9.03	18.00
20.00	0.57171	1225.3	0.03600	227.47	409.75	1.0962	1.7180	1.405	1.001	1.219	530.	145.1	210.7	11.58	83.3	13.33	8.76	20.00
22.00	0.60789	1218.0	0.03385	230.29	410.79	1.1057	1.7173	1.413	1.013	1.224	520.	144.8	205.5	11.67	82.4	13.53	8.48	22.00
24.00	0.64578	1210.5	0.03186	233.12	411.82	1.1152	1.7166	1.421	1.025	1.230	511.	144.5	200.4	11.76	81.6	13.72	8.21	24.00
26.00	0.68543	1202.9	0.03000	235.97	412.84	1.1246	1.7159	1.429	1.038	1.236	502.	144.1	195.4	11.85	80.7	13.92	7.95	26.00
28.00	0.72688	1195.2	0.02826	238.84	413.84	1.1341	1.7152	1.437	1.052	1.243	493.	143.6	190.5	11.95	79.8	14.13	7.68	28.00
30.00	0.77020	1187.5	0.02664	241.72	414.82	1.1435	1.7145	1.446	1.065	1.249	483.	143.2	185.8	12.04	79.0	14.33	7.42	30.00
32.00	0.81543	1179.6	0.02513	244.62	415.78	1.1529	1.7138	1.456	1.080	1.257	474.	142.7	181.1	12.14	78.1	14.54	7.15	32.00
34.00	0.86263	1171.6	0.02371	247.54	416.72	1.1623	1.7131	1.466	1.095	1.265	465.	142.1	176.6	12.24	77.3	14.76	6.89	34.00
36.00	0.91185	1163.4	0.02238	250.48	417.65	1.1717	1.7124	1.476	1.111	1.273	455.	141.6	172.1	12.34	76.4	14.98	6.64	36.00
38.00	0.96315	1155.1	0.02113	253.43	418.55	1.1811	1.7118	1.487	1.127	1.282	446.	141.0	167.7	12.44	75.6	15.21	6.38	38.00
40.00	1.0166	1146.7	0.01997	256.41	419.43	1.1905	1.7111	1.498	1.145	1.292	436.	140.3	163.4	12.55	74.7	15.44	6.13	40.00
42.00	1.0722	1138.2	0.01887	259.41	420.28	1.1999	1.7103	1.510	1.163	1.303	427.	139.7	159.2	12.65	73.9	15.68	5.88	42.00
44.00	1.1301	1129.5	0.01784	262.43	421.11	1.2092	1.7096	1.523	1.182	1.314	418.	138.9	155.1	12.76	73.0	15.93	5.63	44.00
46.00	1.1903	1120.6	0.01687	265.47	421.92	1.2186	1.7089	1.537	1.202	1.326	408.	138.2	151.0	12.88	72.1	16.18	5.38	46.00
48.00	1.2529	1111.5	0.01595	268.53	422.69	1.2280	1.7081	1.551	1.223	1.339	399.	137.4	147.0	13.00	71.3	16.45	5.13	48.00
50.00	1.3179	1102.3	0.01509	271.62	423.44	1.2375	1.7072	1.566	1.246	1.354	389.	136.6	143.1	13.12	70.4	16.72	4.89	50.00
52.00	1.3854	1092.9	0.01428	274.74	424.15	1.2469	1.7064	1.582	1.270	1.369	379.	135.7	139.2	13.24	69.6	17.01	4.65	52.00
54.00	1.4555	1083.2	0.01351	277.89	424.83	1.2563	1.7055	1.600	1.296	1.386	370.	134.7	135.4	13.37	68.7	17.31	4.41	54.00
56.00	1.5282	1073.4	0.01278	281.06	425.47	1.2658	1.7045	1.618	1.324	1.405	360.	133.8	131.6	13.51	67.8	17.63	4.18	56.00
58.00	1.6036	1063.2	0.01209	284.27	426.07	1.2753	1.7035	1.638	1.354	1.425	350.	132.7	127.9	13.65	67.0	17.96	3.95	58.00
60.00	1.6818	1052.9	0.01144	287.50	426.63	1.2848	1.7024	1.660	1.387	1.448	340.	131.7	124.2	13.79	66.1	18.31	3.72	60.00
62.00	1.7628	1042.2	0.01083	290.78	427.14	1.2944	1.7013	1.684	1.422	1.473	331.	130.5	120.6	13.95	65.2	18.68	3.49	62.00
64.00	1.8467	1031.2	0.01024	294.09	427.61	1.3040	1.7000	1.710	1.461	1.501	321.	129.4	117.0	14.11	64.3	19.07	3.27	64.00
66.00	1.9337	1020.0	0.00969	297.44	428.02	1.3137	1.6987	1.738	1.504	1.532	311.	128.1	113.5	14.28	63.4	19.50	3.05	66.00
68.00	2.0237	1008.3	0.00916	300.84	428.36	1.3234	1.6972	1.769	1.552	1.567	301.	126.8	109.9	14.46	62.6	19.95	2.83	68.00
70.00	2.1168	996.2	0.00865	304.28	428.65	1.3332	1.6956	1.804	1.605	1.607	290.	125.5	106.4	14.65	61.7	20.45	2.61	70.00
72.00	2.2132	983.8	0.00817	307.78	428.86	1.3430	1.6939	1.843	1.665	1.653	280.	124.0	102.9	14.85	60.8	20.98	2.40	72.00
74.00	2.3130	970.8	0.00771	311.33	429.00	1.3530	1.6920	1.887	1.734	1.705	269.	122.6	99.5	15.07	59.9	21.56	2.20	74.00
76.00	2.4161	957.3	0.00727	314.94	429.04	1.3631	1.6899	1.938	1.812	1.766	259.	121.0	96.0	15.30	59.0	22.21	1.99	76.00
78.00	2.5228	943.1	0.00685	318.63	428.98	1.3733	1.6876	1.996	1.904	1.838	248.	119.4	92.5	15.56	58.1	22.92	1.80	78.00
80.00	2.6332	928.2	0.00645	322.39	428.81	1.3836	1.6850	2.065	2.012	1.924	237.	117.7	89.0	15.84	57.2	23.72	1.60	80.00
85.00	2.9258	887.2	0.00550	332.22	427.76	1.4104	1.6771	2.306	2.397	2.232	207.	113.1	80.2	16.67	54.9	26.22	1.14	85.00
90.00	3.2442	837.8	0.00461	342.93	425.42	1.4390	1.6662	2.756	3.121	2.820	176.	107.9	70.9	17.81	52.8	29.91	0.71	90.00
95.00	3.5912	772.7	0.00374	355.25	420.67	1.4715	1.6492	3.938	5.020	4.369	141.	101.9	60.4	19.61	51.7	36.40	0.33	95.00
100.00	3.9724	651.2	0.00268	373.30	407.68	1.5188	1.6109	17.59	25.35	20.81	101.	94.0	45.1	24.21	59.9	60.58	0.04	100.00
101.06c	4.0593	511.9	0.00195	389.64	389.64	1.5621	1.5621	∞	∞	∞	0.	0.0	—	—	∞	∞	0.00	101.06

*Temperatures are on the ITS-90 scale a = triple point b = normal boiling point c = critical point

Refrigerant 134a Properties of Superheated Vapor

Pressure = 0.101325 MPa
Saturation temperature = −26.07°C

Temp.,* °C	Density, kg/m³	Enthalpy, kJ/kg	Entropy, kJ/(kg·K)	Vel. Sound, m/s
Saturated				
Liquid	1374.34	166.07	0.8701	747.1
Vapor	5.26	382.90	1.7476	145.7
−20.00	5.11	387.68	1.7667	147.8
−10.00	4.89	395.65	1.7976	151.0
0.00	4.69	403.74	1.8278	154.2
10.00	4.50	411.97	1.8574	157.2
20.00	4.34	420.34	1.8864	160.1
30.00	4.18	428.85	1.9150	162.9
40.00	4.04	437.52	1.9431	165.7
50.00	3.91	446.33	1.9708	168.4
60.00	3.78	455.30	1.9981	171.0
70.00	3.67	464.43	2.0251	173.6
80.00	3.56	473.70	2.0518	176.1
90.00	3.46	483.13	2.0781	178.6
100.00	3.36	492.71	2.1041	181.0
110.00	3.27	502.44	2.1298	183.4
120.00	3.19	512.32	2.1553	185.7
130.00	3.11	522.35	2.1805	188.1
140.00	3.03	532.52	2.2054	190.3
150.00	2.96	542.83	2.2301	192.6

Pressure = 0.200 MPa
Saturation temperature = −10.07°C

Temp.,* °C	Density, kg/m³	Enthalpy, kJ/kg	Entropy, kJ/(kg·K)	Vel. Sound, m/s
Saturated				
Liquid	1325.78	186.69	0.9506	672.8
Vapor	10.01	392.71	1.7337	146.9
−10.00	10.01	392.77	1.7339	147.0
0.00	9.54	401.21	1.7654	150.6
10.00	9.13	409.73	1.7961	154.0
20.00	8.76	418.35	1.8260	157.3
30.00	8.42	427.07	1.8552	160.4
40.00	8.12	435.90	1.8839	163.4
50.00	7.83	444.87	1.9121	166.3
60.00	7.57	453.97	1.9398	169.2
70.00	7.33	463.20	1.9671	171.9
80.00	7.11	472.57	1.9940	174.6
90.00	6.89	482.08	2.0206	177.2
100.00	6.70	491.74	2.0468	179.7
110.00	6.51	501.53	2.0727	182.2
120.00	6.34	511.47	2.0983	184.7
130.00	6.17	521.55	2.1236	187.1
140.00	6.01	531.76	2.1486	189.4
150.00	5.87	542.12	2.1734	191.7

Pressure = 0.400 MPa
Saturation temperature = 8.94°C

Temp.,* °C	Density, kg/m³	Enthalpy, kJ/kg	Entropy, kJ/(kg·K)	Vel. Sound, m/s
Saturated				
Liquid	1263.84	212.08	1.0432	583.8
Vapor	19.52	403.80	1.7229	146.6
10.00	19.41	404.78	1.7263	147.0
20.00	18.45	414.00	1.7583	151.2
30.00	17.61	423.21	1.7892	155.0
40.00	16.87	432.46	1.8192	158.6
50.00	16.20	441.76	1.8485	162.0
60.00	15.60	451.15	1.8771	165.3
70.00	15.05	460.63	1.9051	168.4
80.00	14.54	470.21	1.9326	171.4
90.00	14.08	479.91	1.9597	174.3
100.00	13.65	489.72	1.9864	177.1
110.00	13.24	499.65	2.0126	179.8
120.00	12.87	509.71	2.0386	182.4
130.00	12.51	519.90	2.0641	185.0
140.00	12.18	530.21	2.0894	187.5
150.00	11.87	540.66	2.1144	190.0

Pressure = 0.600 MPa
Saturation temperature = 21.58°C

Temp.,* °C	Density, kg/m³	Enthalpy, kJ/kg	Entropy, kJ/(kg·K)	Vel. Sound, m/s
Saturated				
Liquid	1219.08	229.62	1.1035	524.0
Vapor	29.13	410.67	1.7178	145.0
30.00	27.79	418.97	1.7455	149.0
40.00	26.41	428.72	1.7772	153.4
50.00	25.21	438.44	1.8077	157.4
60.00	24.16	448.16	1.8374	161.2
70.00	23.22	457.93	1.8662	164.7
80.00	22.37	467.75	1.8944	168.0
90.00	21.59	477.65	1.9221	171.2
100.00	20.88	487.64	1.9492	174.3
110.00	20.22	497.72	1.9759	177.3
120.00	19.61	507.92	2.0022	180.1
130.00	19.04	518.22	2.0280	182.9
140.00	18.51	528.63	2.0536	185.6
150.00	18.01	539.17	2.0787	188.2
160.00	17.54	549.82	2.1036	190.8
170.00	17.10	560.59	2.1282	193.3
180.00	16.68	571.48	2.1525	195.8
190.00	16.29	582.50	2.1766	198.2
200.00	15.91	593.63	2.2003	200.6

Pressure = 0.800 MPa
Saturation temperature = 31.33°C

Temp.,* °C	Density, kg/m³	Enthalpy, kJ/kg	Entropy, kJ/(kg·K)	Vel. Sound, m/s
Saturated				
Liquid	1181.92	243.58	1.1495	477.4
Vapor	38.99	415.58	1.7144	142.9
40.00	36.98	424.61	1.7437	147.6
50.00	35.03	434.85	1.7758	152.4
60.00	33.36	444.98	1.8067	156.8
70.00	31.90	455.08	1.8366	160.8
80.00	30.62	465.17	1.8656	164.6
90.00	29.46	475.30	1.8939	168.1
100.00	28.41	485.49	1.9215	171.5
110.00	27.46	495.74	1.9486	174.7
120.00	26.58	506.07	1.9753	177.8
130.00	25.77	516.50	2.0015	180.8
140.00	25.01	527.03	2.0272	183.7
150.00	24.31	537.66	2.0527	186.4
160.00	23.65	548.40	2.0777	189.2
170.00	23.03	559.24	2.1025	191.8
180.00	22.45	570.20	2.1270	194.4
190.00	21.89	581.28	2.1511	196.9
200.00	21.37	592.46	2.1750	199.4

Pressure = 1.000 MPa
Saturation temperature = 39.39°C

Temp.,* °C	Density, kg/m³	Enthalpy, kJ/kg	Entropy, kJ/(kg·K)	Vel. Sound, m/s
Saturated				
Liquid	1149.06	255.44	1.1874	438.6
Vapor	49.16	419.31	1.7117	140.6
40.00	48.95	419.99	1.7139	141.0
50.00	45.86	430.91	1.7482	146.9
60.00	43.34	441.56	1.7807	152.0
70.00	41.21	452.05	1.8117	156.7
80.00	39.36	462.47	1.8416	160.9
90.00	37.74	472.86	1.8706	164.9
100.00	36.29	483.26	1.8989	168.6
110.00	34.99	493.69	1.9265	172.1
120.00	33.80	504.19	1.9535	175.4
130.00	32.71	514.75	1.9800	178.6
140.00	31.70	525.39	2.0061	181.7
150.00	30.76	536.12	2.0318	184.6
160.00	29.90	546.95	2.0571	187.5
170.00	29.08	557.88	2.0820	190.3
180.00	28.32	568.91	2.1066	193.0
190.00	27.60	580.05	2.1309	195.6
200.00	26.92	591.29	2.1550	198.2

Pressure = 1.200 MPa
Saturation temperature = 46.32°C

Temp.,* °C	Density, kg/m³	Enthalpy, kJ/kg	Entropy, kJ/(kg·K)	Vel. Sound, m/s
Saturated				
Liquid	1118.89	265.91	1.2200	405.0
Vapor	59.73	422.22	1.7092	138.2
50.00	58.09	426.51	1.7226	140.7
60.00	54.32	437.83	1.7571	146.9
70.00	51.26	448.81	1.7896	152.3
80.00	48.69	459.61	1.8206	157.1
90.00	46.49	470.30	1.8504	161.5
100.00	44.55	480.94	1.8794	165.6
110.00	42.83	491.58	1.9075	169.4
120.00	41.28	502.25	1.9350	173.0
130.00	39.87	512.95	1.9619	176.4
140.00	38.58	523.72	1.9882	179.7
150.00	37.39	534.56	2.0142	182.8
160.00	36.29	545.48	2.0397	185.8
170.00	35.26	556.50	2.0648	188.8
180.00	34.31	567.60	2.0896	191.6
190.00	33.40	578.80	2.1141	194.4
200.00	32.56	590.11	2.1382	197.1
210.00	31.76	601.51	2.1621	199.7
220.00	31.01	613.02	2.1856	202.3
230.00	30.29	624.64	2.2090	204.8
240.00	29.61	636.36	2.2320	207.2
250.00	28.96	648.18	2.2548	209.7

Pressure = 1.400 MPa
Saturation temperature = 52.43°C

Temp.,* °C	Density, kg/m³	Enthalpy, kJ/kg	Entropy, kJ/(kg·K)	Vel. Sound, m/s
Saturated				
Liquid	1090.50	275.38	1.2488	375.1
Vapor	70.76	424.50	1.7068	135.6
60.00	66.61	433.69	1.7347	141.2
70.00	62.25	445.31	1.7691	147.5
80.00	58.74	456.56	1.8014	153.0
90.00	55.79	467.60	1.8322	158.0
100.00	53.24	478.53	1.8619	162.5
110.00	51.03	489.39	1.8906	166.6
120.00	49.05	500.25	1.9186	170.5
130.00	47.28	511.11	1.9459	174.2
140.00	45.67	522.02	1.9726	177.7
150.00	44.19	532.97	1.9988	181.0
160.00	42.83	544.00	2.0246	184.2
170.00	41.57	555.10	2.0499	187.2
180.00	40.41	566.28	2.0748	190.2
190.00	39.31	577.55	2.0994	193.1
200.00	38.28	588.92	2.1237	195.9
210.00	37.32	600.38	2.1477	198.6
220.00	36.41	611.94	2.1714	201.3
230.00	35.55	623.60	2.1948	203.9
240.00	34.73	635.35	2.2179	206.4
250.00	33.96	647.22	2.2408	208.9

Pressure = 1.600 MPa
Saturation temperature = 57.91°C

Temp.,* °C	Density, kg/m³	Enthalpy, kJ/kg	Entropy, kJ/(kg·K)	Vel. Sound, m/s
Saturated				
Liquid	1063.28	284.11	1.2748	348.1
Vapor	82.34	426.27	1.7042	132.9
60.00	80.74	428.99	1.7124	134.7
70.00	74.43	441.47	1.7493	142.3
80.00	69.61	453.30	1.7833	148.7
90.00	65.71	464.76	1.8153	154.2
100.00	62.43	476.01	1.8458	159.2
110.00	59.62	487.13	1.8753	163.8
120.00	57.14	498.19	1.9038	168.0
130.00	54.95	509.23	1.9315	171.9
140.00	52.98	520.28	1.9586	175.6
150.00	51.18	531.36	1.9851	179.1
160.00	49.54	542.49	2.0111	182.5
170.00	48.03	553.68	2.0366	185.7
180.00	46.63	564.94	2.0617	188.8
190.00	45.32	576.29	2.0865	191.8
200.00	44.10	587.71	2.1109	194.7
210.00	42.96	599.23	2.1350	197.6
220.00	41.88	610.84	2.1588	200.3
230.00	40.87	622.55	2.1823	203.0
240.00	39.91	634.35	2.2055	205.6
250.00	39.00	646.25	2.2285	208.2

*Temperatures are on the ITS-90 scale