Equations and Diagrams

Summary: Open energy and entropy balance equations (Δ = out - in)

General Equations of Balance	Balance Equations for Steady-Flow Processes	Balance Equations for Single-Stream Steady-Flow Processes
$\frac{dm_{cv}}{dt} + \Delta(\dot{m})_{fs} = 0$ (2.25)	$\Delta(\dot{m})_{fs} = 0$ (7.1)	$\dot{m}_1 = \dot{m}_2 = \dot{m}$ (7.2)
$\frac{d(mU)_{cv}}{dt} + \Delta\left[\left(H + \frac{1}{2}u^2 + zg\right)\dot{m}\right]_{fs} = \dot{Q} + \dot{W}$ (2.27)	$\Delta\left[\left(H + \frac{1}{2}u^2 + zg\right)\dot{m}\right]_{fs} = \dot{Q} + \dot{W}$ (2.29)	$\Delta H + \frac{\Delta u^2}{2} + g\Delta z = Q + W_s$ (2.31)
$\frac{d(mS)_{cv}}{dt} + \Delta(S\dot{m})_{fs} - \sum_j \frac{\dot{Q}_j}{T_{\sigma,j}} = \dot{S}_G \geq 0$ (5.16)	$\Delta(S\dot{m})_{fs} - \sum_j \frac{\dot{Q}_j}{T_{\sigma,j}} = \dot{S}_G \geq 0$ (5.17)	$\Delta S - \sum_j \frac{Q_j}{T_{\sigma,j}} = S_G \geq 0$ (5.18)

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TABLE 1
HFC–134a Saturation Properties—Temperature Table

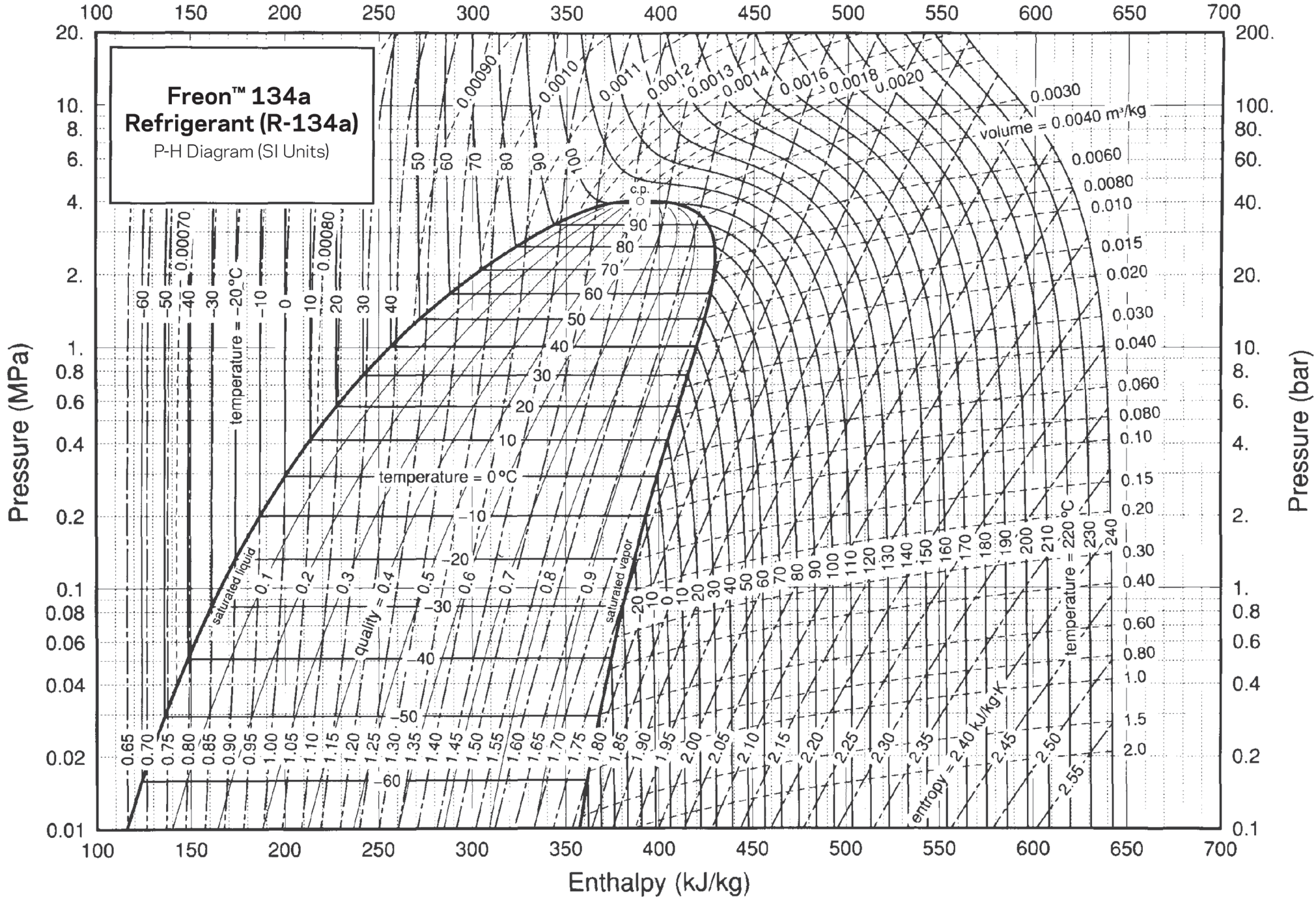
TEMP.	PRESSURE	VOLUME m^3/kg		DENSITY kg/m^3		ENTHALPY kJ/kg			ENTROPY kJ/(kg)(K)		TEMP.
°C	kPa (abs)	LIQUID v_f	VAPOR v_g	LIQUID $1/v_f$	VAPOR $1/v_g$	LIQUID h_f	LATENT h_{fg}	VAPOR h_g	LIQUID s_f	VAPOR s_g	°C
–100	0.57	0.0006	25.0000	1580.5	0.040	77.3	259.9	337.2	0.4448	1.9460	–100
–99	0.63	0.0006	22.7273	1577.8	0.044	78.4	259.4	337.8	0.4514	1.9407	–99
–98	0.70	0.0006	20.4082	1575.0	0.049	79.6	258.8	338.4	0.4581	1.9356	–98
–97	0.77	0.0006	18.5185	1572.3	0.054	80.7	258.2	339.0	0.4646	1.9306	–97
–96	0.86	0.0006	16.9492	1569.5	0.059	81.9	257.7	339.6	0.4711	1.9257	–96
–95	0.95	0.0006	15.3846	1566.8	0.065	83.0	257.1	340.1	0.4776	1.9209	–95
–94	1.04	0.0006	13.8889	1564.1	0.072	84.2	256.6	340.7	0.4841	1.9161	–94
–93	1.15	0.0006	12.6582	1561.3	0.079	85.3	256.0	341.3	0.4905	1.9115	–93
–92	1.27	0.0006	11.6279	1558.6	0.086	86.5	255.4	341.9	0.4968	1.9070	–92
–91	1.40	0.0006	10.6383	1555.8	0.094	87.6	254.9	342.5	0.5032	1.9025	–91
–90	1.53	0.0006	9.7087	1553.1	0.103	88.8	254.3	343.1	0.5095	1.8982	–90
–89	1.68	0.0006	8.9286	1550.4	0.112	89.9	253.8	343.7	0.5158	1.8939	–89
–88	1.84	0.0006	8.1967	1547.6	0.122	91.1	253.2	344.3	0.5220	1.8898	–88
–87	2.02	0.0006	7.5188	1544.9	0.133	92.3	252.7	344.9	0.5282	1.8857	–87
–86	2.20	0.0006	6.8966	1542.1	0.145	93.4	252.1	345.5	0.5344	1.8817	–86
–85	2.41	0.0006	6.3291	1539.4	0.158	94.6	251.6	346.2	0.5406	1.8778	–85
–84	2.63	0.0007	5.8480	1536.7	0.171	95.7	251.0	346.8	0.5467	1.8739	–84
–83	2.86	0.0007	5.4054	1533.9	0.185	96.9	250.5	347.4	0.5528	1.8702	–83
–82	3.11	0.0007	4.9751	1531.2	0.201	98.0	249.9	348.0	0.5589	1.8665	–82
–81	3.39	0.0007	4.6083	1528.5	0.217	99.2	249.4	348.6	0.5650	1.8629	–81
–80	3.68	0.0007	4.2553	1525.7	0.235	100.4	248.8	349.2	0.5710	1.8594	–80
–79	3.99	0.0007	3.9526	1523.0	0.253	101.5	248.3	349.8	0.5770	1.8559	–79
–78	4.33	0.0007	3.6630	1520.2	0.273	102.7	247.7	350.4	0.5830	1.8525	–78
–77	4.69	0.0007	3.3898	1517.5	0.295	103.9	247.2	351.1	0.5890	1.8492	–77
–76	5.07	0.0007	3.1546	1514.8	0.317	105.0	246.6	351.7	0.5949	1.846	–76
–75	5.48	0.0007	2.9326	1512.0	0.341	106.2	246.1	352.3	0.6009	1.8428	–75
–74	5.92	0.0007	2.7248	1509.3	0.367	107.4	245.5	352.9	0.6068	1.8397	–74
–73	6.39	0.0007	2.5381	1506.5	0.394	108.6	245.0	353.5	0.6126	1.8366	–73
–72	6.89	0.0007	2.3641	1503.8	0.423	109.7	244.4	354.2	0.6185	1.8336	–72
–71	7.42	0.0007	2.2075	1501.0	0.453	110.9	243.9	354.8	0.6243	1.8307	–71
–70	7.98	0.0007	2.0576	1498.3	0.486	112.1	243.3	355.4	0.6302	1.8279	–70
–69	8.58	0.0007	1.9231	1495.5	0.520	113.3	242.8	356.0	0.6360	1.8251	–69
–68	9.22	0.0007	1.7986	1492.8	0.556	114.5	242.2	356.6	0.6417	1.8223	–68
–67	9.89	0.0007	1.6835	1490.0	0.594	115.6	241.6	357.3	0.6475	1.8196	–67
–66	10.61	0.0007	1.5773	1487.3	0.634	116.8	241.1	357.9	0.6532	1.817	–66
–65	11.37	0.0007	1.4771	1484.5	0.677	118.0	240.5	358.5	0.6590	1.8144	–65
–64	12.18	0.0007	1.3850	1481.8	0.722	119.2	239.9	359.2	0.6647	1.8119	–64
–63	13.03	0.0007	1.3004	1479.0	0.769	120.4	239.4	359.8	0.6704	1.8095	–63
–62	13.93	0.0007	1.2210	1476.3	0.819	121.6	238.8	360.4	0.6760	1.8071	–62
–61	14.88	0.0007	1.1481	1473.5	0.871	122.8	238.2	361.0	0.6817	1.8047	–61
–60	15.89	0.0007	1.0799	1470.7	0.926	124.0	237.7	361.7	0.6873	1.8024	–60
–59	16.95	0.0007	1.0163	1468.0	0.984	125.2	237.1	362.3	0.6929	1.8001	–59
–58	18.07	0.0007	0.9579	1465.2	1.044	126.4	236.5	362.9	0.6985	1.7979	–58
–57	19.25	0.0007	0.9025	1462.4	1.108	127.6	236.0	363.6	0.7041	1.7958	–57
–56	20.49	0.0007	0.8511	1459.6	1.175	128.8	235.4	364.2	0.7097	1.7937	–56
–55	21.80	0.0007	0.8032	1456.9	1.245	130.0	234.8	364.8	0.7152	1.7916	–55
–54	23.17	0.0007	0.7587	1454.1	1.318	131.2	234.2	365.4	0.7208	1.7896	–54
–53	24.62	0.0007	0.7168	1451.3	1.395	132.4	233.6	366.1	0.7263	1.7876	–53
–52	26.14	0.0007	0.6775	1448.5	1.476	133.7	233.1	366.7	0.7318	1.7857	–52
–51	27.73	0.0007	0.6410	1445.7	1.560	134.9	232.5	367.3	0.7373	1.7838	–51
–50	29.41	0.0007	0.6068	1442.9	1.648	136.1	231.9	368.0	0.7428	1.7819	–50
–49	31.16	0.0007	0.5747	1440.1	1.740	137.3	231.3	368.6	0.7482	1.7801	–49
–48	33.00	0.0007	0.5447	1437.3	1.836	138.5	230.7	369.2	0.7537	1.7783	–48
–47	34.93	0.0007	0.5165	1434.5	1.936	139.8	230.1	369.9	0.7591	1.7766	–47
–46	36.95	0.0007	0.4902	1431.6	2.040	141.0	229.5	370.5	0.7645	1.7749	–46
–45	39.06	0.0007	0.4653	1428.8	2.149	142.2	228.9	371.1	0.7699	1.7732	–45
–44	41.27	0.0007	0.4419	1426.0	2.263	143.5	228.3	371.8	0.7753	1.7716	–44
–43	43.58	0.0007	0.4198	1423.2	2.382	144.7	227.7	372.4	0.7806	1.77	–43
–42	45.99	0.0007	0.3992	1420.3	2.505	145.9	227.1	373.0	0.7860	1.7685	–42
–41	48.51	0.0007	0.3798	1417.5	2.633	147.2	226.5	373.7	0.7913	1.767	–41

TABLE 2 (continued)
HFC-134a Superheated Vapor—Constant Pressure Tables

V = Volume in m^3/kg H = Enthalpy in kJ/kg S = Entropy in kJ/(kg)(K) v_s = Velocity of Sound in m/sec
Cp = Heat Capacity at Constant Pressure in kJ/(kg)(°C) Cp/Cv = Heat Capacity Ratio (Dimensionless)

TEMP	PRESSURE = 1900.00 kPa (abs)							PRESSURE = 2000.00 kPa (abs)						TEMP
°C	V	H	S	Cp	Cp/Cv	v_s		V	H	S	Cp	Cp/Cv	v_s	°C
65.22	0.00098	296.6	1.3113	1.7353	1.7594	314.0	SAT LIQ	0.00099	300.4	1.3223	1.7690	1.7844	302.2	67.47
65.22	0.00991	428.3	1.7007	1.4544	1.5098	128.6	SAT VAP	0.00931	428.8	1.6991	1.5055	1.5484	127.2	67.47
70	0.01043	435.1	1.7205	1.3658	1.4297	133.3		0.00959	432.5	1.7101	1.4452	1.4943	129.9	70
75	0.01092	441.7	1.7398	1.3032	1.3722	137.7		0.01009	439.5	1.7303	1.3600	1.4173	134.7	75
80	0.01137	448.1	1.7580	1.2587	1.3301	141.5		0.01055	446.1	1.7493	1.3019	1.3638	138.9	80
85	0.01179	454.3	1.7755	1.2259	1.2980	145.0		0.01097	452.5	1.7673	1.2601	1.3242	142.7	85
90	0.01219	460.4	1.7923	1.2011	1.2725	148.3		0.01137	458.8	1.7845	1.2291	1.2936	146.2	90
95	0.01257	466.4	1.8086	1.1821	1.2518	151.3		0.01175	464.8	1.8011	1.2055	1.2692	149.3	95
100	0.01294	472.2	1.8244	1.1674	1.2346	154.1		0.01211	470.8	1.8173	1.1874	1.2493	152.3	100
105	0.01329	478.0	1.8399	1.1561	1.2202	156.7		0.01246	476.7	1.8330	1.1733	1.2327	155.1	105
110	0.01364	483.8	1.8550	1.1475	1.2078	159.3		0.01279	482.6	1.8483	1.1625	1.2186	157.7	110
115	0.01397	489.5	1.8698	1.1409	1.1971	161.7		0.01312	488.4	1.8633	1.1542	1.2066	160.2	115
120	0.01429	495.2	1.8844	1.1361	1.1877	164.0		0.01344	494.1	1.8781	1.1479	1.1961	162.6	120
125	0.01461	500.9	1.8987	1.1327	1.1795	166.2		0.01374	499.8	1.8925	1.1433	1.1869	164.9	125
130	0.01492	506.5	1.9129	1.1305	1.1721	168.3		0.01405	505.5	1.9068	1.1401	1.1789	167.1	130
135	0.01523	512.2	1.9268	1.1293	1.1656	170.4		0.01434	511.2	1.9208	1.1380	1.1717	169.2	135
140	0.01553	517.8	1.9405	1.1290	1.1597	172.4		0.01463	516.9	1.9347	1.1369	1.1652	171.3	140
145	0.01582	523.5	1.9541	1.1293	1.1543	174.3		0.01492	522.6	1.9483	1.1366	1.1594	173.3	145
150	0.01611	529.1	1.9676	1.1303	1.1495	176.2		0.01520	528.3	1.9619	1.1370	1.1541	175.2	150
155	0.01640	534.8	1.9808	1.1319	1.1450	178.0		0.01547	534.0	1.9752	1.1380	1.1493	177.1	155
160	0.01668	540.5	1.9940	1.1338	1.1410	179.8		0.01575	539.7	1.9884	1.1395	1.1449	178.9	160
165	0.01696	546.1	2.0070	1.1362	1.1372	181.5		0.01602	545.4	2.0015	1.1415	1.1409	180.7	165
170	0.01724	551.8	2.0199	1.1389	1.1337	183.2		0.01629	551.1	2.0145	1.1439	1.1372	182.4	170
175	0.01752	557.5	2.0327	1.1419	1.1305	184.8		0.01655	556.8	2.0274	1.1466	1.1337	184.1	175
180	0.01779	563.2	2.0454	1.1452	1.1275	186.5		0.01681	562.6	2.0401	1.1496	1.1305	185.7	180
185	0.01806	569.0	2.0580	1.1487	1.1248	188.1		0.01707	568.3	2.0527	1.1528	1.1276	187.4	185
190	0.01832	574.7	2.0705	1.1524	1.1221	189.6		0.01733	574.1	2.0653	1.1563	1.1248	189.0	190
195	0.01859	580.5	2.0829	1.1563	1.1197	191.2		0.01758	579.9	2.0777	1.1599	1.1222	190.5	195
200	0.01885	586.3	2.0952	1.1604	1.1174	192.7		0.01784	585.7	2.0900	1.1638	1.1198	192.1	200
205	0.01911	592.1	2.1074	1.1645	1.1152	194.1		0.01809	591.5	2.1023	1.1678	1.1175	193.6	205
210	0.01937	597.9	2.1195	1.1688	1.1132	195.6		0.01834	597.4	2.1145	1.1719	1.1153	195.0	210
215	0.01963	603.8	2.1316	1.1732	1.1113	197.0		0.01858	603.2	2.1265	1.1761	1.1133	196.5	215
220	0.01989	609.7	2.1436	1.1776	1.1095	198.4		0.01883	609.1	2.1386	1.1804	1.1114	197.9	220

TEMP	PRESSURE = 2200.00 kPa (abs)							PRESSURE = 2400.00 kPa (abs)						TEMP
°C	V	H	S	Cp	Cp/Cv	v_s		V	H	S	Cp	Cp/Cv	v_s	°C
71.72	0.00102	307.8	1.3433	1.8446	1.8417	279.5	SAT LIQ	0.00104	314.9	1.3632	1.9351	1.9120	257.6	75.69
71.72	0.00825	429.3	1.6956	1.6230	1.6389	124.2	SAT VAP	0.00735	429.5	1.6917	1.7675	1.7530	121.2	75.69
75	0.00860	434.5	1.7105	1.5190	1.5466	128.1		—	—	—	—	—	—	75
80	0.00909	441.8	1.7313	1.4143	1.4531	133.3		0.00782	436.7	1.7122	1.5873	1.5944	126.8	80
85	0.00953	448.7	1.7507	1.3450	1.3903	137.7		0.00829	444.3	1.7336	1.4637	1.4851	132.3	85
90	0.00993	455.3	1.7690	1.2961	1.3449	141.7		0.00870	451.4	1.7533	1.3841	1.4137	136.9	90
95	0.01031	461.6	1.7865	1.2601	1.3103	145.3		0.00909	458.2	1.7718	1.3286	1.3630	141.0	95
100	0.01067	467.9	1.8033	1.2329	1.2831	148.6		0.00945	464.7	1.7894	1.2882	1.3250	144.8	100
105	0.01100	474.0	1.8195	1.2121	1.2612	151.7		0.00978	471.1	1.8064	1.2579	1.2954	148.2	105
110	0.01133	480.0	1.8354	1.1959	1.2429	154.6		0.01010	477.3	1.8227	1.2346	1.2715	151.3	110
115	0.01164	485.9	1.8508	1.1834	1.2276	157.3		0.01041	483.4	1.8386	1.2166	1.2519	154.3	115
120	0.01195	491.8	1.8658	1.1737	1.2145	159.9		0.01070	489.5	1.8541	1.2026	1.2355	157.1	120
125	0.01224	497.7	1.8806	1.1662	1.2032	162.4		0.01098	495.5	1.8692	1.1917	1.2215	159.7	125
130	0.01253	503.5	1.8951	1.1606	1.1934	164.7		0.01126	501.4	1.8841	1.1832	1.2095	162.3	130
135	0.01281	509.3	1.9094	1.1565	1.1847	167.0		0.01153	507.3	1.8986	1.1767	1.1990	164.7	135
140	0.01308	515.1	1.9235	1.1537	1.1770	169.1		0.01179	513.2	1.9129	1.1719	1.1898	167.0	140
145	0.01335	520.8	1.9374	1.1519	1.1701	171.2		0.01205	519.0	1.9270	1.1684	1.1817	169.2	145
150	0.01362	526.6	1.9510	1.1510	1.1639	173.3		0.01230	524.9	1.9408	1.1660	1.1744	171.3	150
155	0.01388	532.3	1.9646	1.1509	1.1583	175.2		0.01255	530.7	1.9545	1.1646	1.1679	173.4	155
160	0.01413	538.1	1.9779	1.1515	1.1532	177.1		0.01279	536.5	1.9680	1.1641	1.1620	175.4	160
165	0.01439	543.9	1.9912	1.1526	1.1485	179.0		0.01303	542.3	1.9814	1.1642	1.1567	177.3	165
170	0.01464	549.6	2.0042	1.1541	1.1443	180.8		0.01326	548.1	1.9946	1.1649	1.1518	179.2	170
175	0.01488	555.4	2.0172	1.1561	1.1404	182.6		0.01349	554.0	2.0077	1.1662	1.1473	181.1	175
180	0.01513	561.2	2.0300	1.1585	1.1367	184.3		0.01372	559.8	2.0206	1.1679	1.1432	182.9	180
185	0.01537	567.0	2.0428	1.1612	1.1334	186.0		0.01395	565.7	2.0335	1.1699	1.1394	184.6	185
190	0.01561	572.8	2.0554	1.1642	1.1302	187.6		0.01417	571.5	2.0462	1.1723	1.1359	186.3	190
195	0.01585	578.6	2.0679	1.1674	1.1273	189.3		0.01440	577.4	2.0588	1.1751	1.1327	188.0	195
200	0.01608	584.5	2.0803	1.1708	1.1246	190.8		0.01462	583.3	2.0713	1.1780	1.1296	189.6	200
205	0.01631	590.3	2.0927	1.1744	1.1221	192.4		0.01483	589.2	2.0837	1.1812	1.1268	191.2	205
210	0.01654	596.2	2.1049	1.1781	1.1197	193.9		0.01505	595.1	2.0960	1.1846	1.1241	192.8	210
215	0.01677	602.1	2.1170	1.1820	1.1174	195.4		0.01526	601.0	2.1082	1.1882	1.1216	194.4	215
220	0.01700	608.0	2.1291	1.1861	1.1153	196.9		0.01548	607.0	2.1203	1.1919	1.1193	195.9	220
225	0.01723	614.0	2.1411	1.1902	1.1133	198.4		0.01569	612.9	2.1324	1.1957	1.1171	197.4	225
230	—	—	—	—	—	—		0.01590	618.9	2.1443	1.1996	1.1150	198.9	230


Freon™ 134a
Refrigerant (R-134a)
P-H Diagram (SI Units)
Pressure (MPa)
Pressure (bar)
Enthalpy (kJ/kg)
c.p.
saturated liquid
saturated vapor
quality = 0.4
temperature = 0 °C
temperature = −20 °C
temperature = 220 °C
volume = 0.0040 m³/kg
entropy = 2.40 kJ/kg·K

Chemours™