Table 45 . . . . Refrigerant 740 (Argon) Properties of Saturated Liquid and Saturated Vapor*

Temp K	Pressure atm	Density (g/cm³) Sat Liquid	Density (g/cm³) Sat Vapor	Enthalpy (j/g) Sat Liquid	Enthalpy (j/g) Sat Vapor	Entropy (j/g°K) Sat Liquid	Entropy (j/g°K) Sat Vapor	Temp K	Pressure atm	Density (g/cm³) Sat Liquid	Density (g/cm³) Sat Vapor	Enthalpy (j/g) Sat Liquid	Enthalpy (j/g) Sat Vapor	Entropy (j/g°K) Sat Liquid	Entropy (j/g°K) Sat Vapor
83.8[a]	.678	1.415	.004038	70.9	235.7	1.309	2.286	120	11.99	1.160	.06018	115.4	241.8	1.751	2.804
85	.778	1.408	.004581	71.5	236.3	1.327	2.284	125	15.63	1.115	.07919	122.1	240.7	1.802	2.752
90	1.322	1.377	.007448	77.8	235.0	1.399	2.179	130	20.00	1.065	.1035	129.2	238.7	1.855	2.698
95	2.114	1.345	.01148	84.1	239.6	1.465	2.103	133	22.20	1.008	.1254	137.0	235.6	1.910	2.641
100	3.213	1.312	.01693	90.3	240.9	1.529	3.034	140	31.31	.9413	.1790	146.0	230.8	1.971	2.577
105	4.684	1.277	.02411	96.5	241.8	1.588	2.972	145	38.45	.8339	.2447	156.7	223.2	2.041	2.499
110	6.592	1.240	.03338	102.7	242.3	1.644	2.914	150	46.75	.7013	.3795	173.4	207.4	2.147	2.373
115	9.004	1.202	.04520	109.0	242.3	1.698	2.858	150.86[b]	48.34	.5356	.5356				

* Unpublished data from Cryogenic Data Center, National Bureau of Standards, Boulder, Colorado.
[a] Triple point.
[b] Critical point.

Table 46 . . . . Refrigerant 740 (Argon) Properties of Liquid and Vapor*

Temp K	P = 0.1 atm			P = 1 atm (Sat temp = 87.28 K)			P = 4 atm (Sat temp = 102.84 K)			P = 7 atm (Sat temp = 110.93°K)			P = 10 atm (Sat temp = 116.78 K)		
T,	ρ g/cm³	h l/g	s l/g°K	ρ g/cm³	h l/g	s l/g°K	ρ g/cm³	h l/g	s l/g°K	ρ g/cm³	h l/g	s l/g°K	ρ g/cm³	h l/g	s l/g°K
Sat Liq				1.394	74.4	1.360	1.292	93.8	1.563	1.233	103.9	1.655	1.187	111.3	1.717
Sat Vapor				.005763	237.1	3.224	.02077	241.5	2.999	.03537	242.4	2.903	.05014	242.3	2.839
90	.0005433	239.9	3.729	.005574	238.5	3.241	1.378	77.9	1.398	1.379	78.1	1.397	1.380	78.2	1.396
100	.0004877	245.1	3.785	.004978	244.0	3.298	1.312	90.3	1.528	1.314	90.4	1.527	1.315	90.5	1.526
110	.0004431	250.3	3.834	.004501	249.4	3.349	.01908	245.8	3.039	1.241	102.7	1.644	1.242	102.8	1.643
120	.0004064	255.5	3.880	.004110	254.7	3.396	.01718	251.7	3.091	.03161	248.4	2.955	.04791	244.7	2.880
130	.0003747	260.8	3.921	.003784	260.0	3.438	.01566	257.5	3.137	.02846	254.7	3.006	.04340	251.7	2.916
140	.0003479	266.0	3.960	.003506	265.3	3.478	.01441	263.1	3.178	.02596	260.7	3.050	.03828	258.2	2.964
150	.0003247	271.2	3.996	.003267	270.6	3.514	.01336	268.6	3.217	.02393	266.6	3.091	.03503	264.4	3.007
160	.0003043	276.4	4.030	.003059	275.9	3.548	.01246	274.1	3.253	.02221	272.3	3.128	.03236	270.4	3.046
170	.0002864	281.6	4.061	.002876	281.1	3.580	.00168	279.6	3.285	.02078	277.9	3.162	.03012	276.3	3.081
180	.0002709	286.8	4.091	.002715	286.4	3.610	.01099	285.0	3.315	.01948	283.5	3.194	.02820	282.0	3.114
190	.0002562	292.0	4.119	.002570	291.6	3.638	.01039	290.4	3.345	.01837	289.0	3.224	.02653	287.7	3.145
200	.0002434	297.2	4.146	.002440	296.9	3.665	.009848	295.7	3.373	.01739	294.5	3.252	.02507	293.3	3.173
220	.0002212	307.7	4.196	.002217	307.4	3.715	.008924	306.4	3.423	.01572	305.4	3.304	.02280	304.4	3.226
240	.0002028	318.1	4.241	.002031	317.8	3.761	.008162	317.0	3.470	.01435	316.1	3.350	.02060	315.3	3.274
260	.0001872	328.6	4.283	.001874	328.3	3.803	.007522	327.5	3.512	.01321	326.8	3.393	.01894	326.1	3.317
280	.0001735	339.2	4.321	.001749	338.7	3.841	.006976	338.1	3.551	.01224	337.5	3.433	.01753	336.8	3.357
300	.0001622	349.8	4.357	.001623	349.1	3.877	.006505	348.6	3.587	.01141	348.1	3.469	.01633	347.6	3.394

Temp K	P = 40 atm (Sat temp = 145.99 K)			P = 70 atm			P = 100 atm			P = 200 atm			P = 400 atm		
Sat Liq	.8320	159.3	2.057												
Sat Vapor	.2835	321.1	2.481												
90	1.390	79.5	1.386	1.398	80.9	1.377	1.407	82.2	1.368	1.433	85.9	1.341			
100	1.327	91.7	1.314	1.338	92.9	1.303	1.349	94.1	1.293	1.380	98.4	1.262	1.429	107.8	1.211
110	1.259	103.6	1.228	1.274	104.8	1.218	1.287	105.9	1.207	1.325	109.5	1.167	1.383	118.3	1.112
120	1.183	115.7	1.133	1.203	116.8	1.118	1.220	116.9	1.101	1.268	120.1	1.060	1.338	128.3	1.008
130	1.091	128.6	1.036	1.122	129.3	1.013	1.147	129.5	1.794	1.209	130.6	1.744	1.290	137.9	1.675
140	.9673	144.6	1.905	1.026	142.1	1.915	1.063	141.3	1.883	1.147	141.7	1.828	1.243	147.9	1.750
150	.3158	231.8	2.553	.9328	158.9	2.031	.9654	155.3	1.994	1.081	152.9	1.904	1.195	157.6	1.817
160	.1704	248.3	2.647	.6191	190.0	2.231	.8387	173.6	2.097	1.011	165.1	1.982	1.148	168.0	1.894
170	.1471	256.3	2.709	.3814	228.9	2.430	.8632	194.9	2.232	.9372	177.6	2.058	1.101	178.2	1.946
180	.1315	265.3	2.759	.3336	243.4	2.550	.5001	218.3	2.368	.8596	190.6	2.133	1.053	188.5	2.004
190	.1198	273.1	2.801	.2429	255.7	2.618	.4021	236.4	2.453	.7810	204.0	2.205	1.007	198.4	2.058
200	.1106	280.4	2.839	.2161	265.8	2.668	.3433	250.2	2.515	.7056	217.4	2.274	.9604	208.6	2.110
220	.09656	293.9	2.903	.1810	282.9	2.750	.2750	271.6	2.637	.5787	242.7	2.394	.8718	228.8	2.207
240	.08637	306.6	2.959	.1581	297.8	2.814	.2347	289.0	2.712	.4879	264.9	2.491	.7908	248.6	2.293
260	.07835	318.8	3.007	.1414	311.4	2.869	.2071	304.3	2.774	.4238	284.2	2.568	.7194	267.6	2.369
280	.07153	330.6	3.051	.1284	324.4	2.917	.1865	318.4	2.826	.3768	301.5	2.633	.6579	285.8	2.438
300	.06645	342.1	3.091	.1180	336.8	2.960	.1703	331.7	2.872	.3409	317.4	2.687	.6056	303.0	2.496

* Unpublished data from Cryogenic Data Center, National Bureau of Standards, Boulder, Colorado.
Bold horizontal line indicates phase change (liquid above, vapor below the line).

Conversions for Units, to Equivalent in British System of Units:
To convert temperature in degrees Kelvin (°K) to degrees Rankine (°R), multiply (°K) by 1.8
To convert pressure in atmospheres (atm) to (psia), multiply (atm) by 14.696
To convert density (ρ) in grams per cubic centimeter (g/cm³) to (lbs/cu ft), multiply (g/cm³) by 62.428
To convert enthalpy (h) in joules per gram (j/g) to (Btu/lb), multiply (j/g) by .42992
To convert entropy (s) in joules per gram °K (j/g°K) to (Btu/lb°R), multiply (j/g°K) by .23885

CHAPTER 21

SECONDARY COOLANTS (BRINES)

Brines: Properties, Corrosion; Glycols: Properties, Corrosion Inhibition, Service Considerations; Halocarbons

In many refrigeration applications, heat is transferred, not to the primary refrigerant used in the vapor compression cycle, but to a secondary coolant, which may be *any liquid cooled by the refrigerant and used for the transmission of heat without a change in its state.* These secondary coolants are sometimes known as heat transfer fluids, brines, or secondary refrigerants.

The physical properties of several different classes of secondary coolants are given in the following sections, with some information on their use and their requirements for corrosion protection. Corrosion problems are discussed in more detail in Chapter 79 of the 1964 GUIDE AND DATA BOOK.

Previous Guide And Data Books contained reference tables on endothermal mixtures and eutectic points of some aqueous salt solutions, which are omitted from this edition since they are not secondary coolants. Several literature references[1-4] are retained as suggested sources for this information.

BRINES

A solution of any salt in water has a certain concentration at which the freezing point is lowest. A solution of this concentration is called a eutectic mixture, or cryohydrate, and the temperature at which it freezes is the eutectic temperature. A solution at any other concentration will start to freeze at a higher temperature, and as the temperature is lowered, it will freeze out pure ice or salt. The remaining liquid will approach the eutectic concentration until it freezes at the eutectic point.

Referring to Fig. 1, if a solution of concentration x_1, less than the eutectic, at a temperature above 32 F, is cooled, it will not solidify when 32 F is reached (point *A*), but will continue to cool as a liquid until point *B* is reached. At this point, ice crystals of pure water will begin to form, accompanied by the removal of their latent heat. The removal of this water from the solution increases the concentration of the residual solution. As the temperature is lowered these crystals continue to form, and the mixture of ice crystals and brine solution forms a slush. When point *C* is reached, there is a mixture of ice crystals, C_s, and brine solution of concentration C_1, in the proportions of l_1 parts of brine to l_s parts of ice crystals in $(l_1 + l_s)$ parts of mixture. When the process has continued to point *D*, there is a mixture of m_1 parts of eutectic brine solution D_1, and m_s parts of ice, D_s, all at the eutectic temperature. As more heat is removed, the m_1 parts of eutectic brine freeze at uniform temperature until all of the latent heat is removed. The frozen eutectic mixture is a mechanical mixture of salt and frozen water, not a solution, and consequently the latent heat must be corrected for the heat of solution. If this is positive, it decreases the effective latent heat; if negative, it increases the effective latent heat.

If the initial solution is of greater concentration than the eutectic, salt instead of water freezes out as the temperature is lowered, and the concentration is decreased until, at the eutectic temperature, the eutectic concentration is reached. In brines used as a refrigerating fluid, salt sometimes freezes out because the concentration is too high.

The upper right branch of the curve in Fig. 1 gives the solubility—point *E* at 32 F, point *F* at a higher temperature.

When melting a eutectic brine, the water must redissolve the salt, which may require agitation, circulation, or other mixing aids.

BRINE PROPERTIES

Water solutions of calcium and sodium chloride are the most common refrigeration brines. The properties of pure calcium chloride brine and sodium chloride brine are given in Tables 1 and 2. For commercial grades use the formulas indicated in the footnotes to these tables. Figs. 2 and 6, which give the specific heats for liquid brines, may be used for computation of heat loads with ordinary brine.[1] Figs. 3 and 7 show the specific gravity, commonly used as the measure of

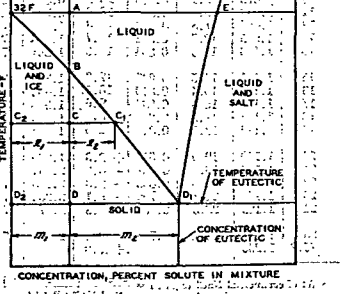


Fig. 1 . . . . Brine Mixture

The general responsibility for this chapter is assigned to TC 1.9, Refrigerants and Brines.