

TABLE 3. PROPERTIES OF TRICHLOROMONOFUOROMETHANE (CCl₃F)^a

SAT. TEMP. F	ABS. PRESS. LB PER SQ IN.	VOLUME		ENTHALPY AND ENTROPY TAKEN FROM -40 F							
		Liquid	Vapor	Enthalpy		Entropy		25 F Superheat		50 F Superheat	
				Liquid	Vapor	Liquid	Vapor	Enthalpy	Entropy	Enthalpy	Entropy
0	2.59	0.01020	13.700	7.81	90.4	0.0178	0.1975	93.9	0.2049	97.4	0.2120
5	2.96	0.01024	12.100	8.81	91.2	0.0200	0.1974	94.7	0.2047	97.2	0.2117
10	3.38	0.01028	10.700	9.82	92.0	0.0222	0.1973	95.5	0.2045	99.0	0.2114
15	3.85	0.01032	9.530	10.80	92.8	0.0243	0.1971	96.3	0.2043	99.8	0.2111
20	4.36	0.01036	8.490	11.90	93.7	0.0264	0.1970	97.2	0.2041	100.7	0.2109
25	4.94	0.01040	7.580	12.90	94.5	0.0286	0.1969	98.0	0.2039	101.5	0.2107
30	5.57	0.01045	6.770	13.90	95.3	0.0307	0.1969	98.8	0.2038	102.3	0.2105
35	6.27	0.01049	6.080	14.90	96.1	0.0328	0.1968	99.6	0.2037	103.1	0.2103
40	7.03	0.01053	5.460	16.00	96.8	0.0349	0.1968	100.3	0.2036	103.8	0.2101
45	7.88	0.01057	4.920	17.00	97.6	0.0370	0.1967	101.1	0.2035	104.6	0.2099
50	8.79	0.01062	4.440	18.10	98.4	0.0391	0.1967	101.9	0.2034	105.4	0.2098
55	9.80	0.01066	4.020	19.10	99.2	0.0412	0.1967	102.7	0.2033	106.2	0.2097
60	10.90	0.01071	3.640	20.20	100.0	0.0432	0.1967	103.5	0.2033	107.0	0.2096
65	12.10	0.01076	3.300	21.30	100.8	0.0453	0.1967	104.3	0.2032	107.8	0.2094
70	13.40	0.01081	3.000	22.40	101.5	0.0473	0.1967	105.0	0.2032	108.5	0.2093
75	14.80	0.01086	2.740	23.50	102.2	0.0493	0.1967	105.7	0.2031	109.2	0.2092
80	16.30	0.01091	2.500	24.50	102.9	0.0513	0.1966	106.4	0.2030	109.9	0.2090
85	17.90	0.01096	2.280	25.60	103.6	0.0533	0.1966	107.1	0.2029	110.6	0.2089
90	19.70	0.01101	2.090	26.70	104.4	0.0553	0.1966	107.9	0.2028	111.4	0.2088
95	21.60	0.01106	1.918	27.80	105.1	0.0573	0.1966	108.6	0.2028	112.1	0.2087
100	23.60	0.01111	1.761	28.90	105.7	0.0593	0.1965	109.2	0.2027	112.7	0.2085
105	25.90	0.01116	1.620	30.10	106.4	0.0613	0.1965	109.9	0.2026	113.4	0.2084

^a ASRE designation—Refrigerant 11.TABLE 4. PROPERTIES OF TRICHLOROTRIFLUOROETHANE (C₂Cl₃F₃)^a

TEMP F	PRESSURE		VOLUME		DENSITY		ENTHALPY FROM -40°F			ENTROPY FROM -40°F	
	psia	psig	Liquid cu ft/lb	Vapor cu ft/lb	Liquid lb/cu ft	Vapor lb/cu ft	Liquid Btu/lb	Latent Btu/lb	Vapor Btu/lb	Liquid Btu/lb/ F deg	Vapor Btu/lb/ F deg
0	0.8377	28.21*	0.00966	31.31	103.56	0.03194	7.98	70.92	78.89	0.0182	0.1725
4	0.9503	27.99*	0.00968	27.84	103.27	0.03592	8.78	70.68	79.46	0.0199	0.1724
8	1.075	27.73*	0.00971	24.81	102.98	0.04031	9.59	70.44	80.03	0.0216	0.1723
12	1.213	27.45*	0.00974	22.17	102.69	0.04511	10.41	70.20	80.61	0.0234	0.1722
16	1.366	27.14*	0.00977	19.84	102.40	0.05040	11.22	69.96	81.18	0.0251	0.1722
20	1.534	26.80*	0.00979	17.81	102.10	0.05616	12.03	69.72	81.75	0.0268	0.1722
24	1.719	26.42*	0.00982	16.02	101.81	0.06243	12.85	69.48	82.33	0.0285	0.1721
28	1.922	26.01*	0.00985	14.43	101.51	0.06929	13.67	69.24	82.91	0.0302	0.1722
32	2.145	25.55*	0.00988	13.03	101.21	0.07675	14.49	69.00	83.49	0.0318	0.1722
36	2.388	25.06*	0.00991	11.79	100.91	0.08483	15.32	68.75	84.07	0.0335	0.1722
40	2.655	24.52*	0.00994	10.68	100.60	0.09361	16.16	68.50	84.65	0.0352	0.1723
44	2.944	23.93*	0.00997	9.703	100.30	0.1031	16.99	68.25	85.24	0.0368	0.1723
48	3.258	23.29*	0.01000	8.830	99.99	0.1133	17.82	68.00	85.82	0.0385	0.1724
52	3.602	22.59*	0.01003	8.044	99.68	0.1243	18.66	67.74	86.40	0.0401	0.1726
56	3.973	21.83*	0.01006	7.342	99.37	0.1362	19.50	67.48	86.98	0.0418	0.1727
60	4.374	21.02*	0.01010	6.713	99.05	0.1490	20.35	67.22	87.57	0.0434	0.1728
64	4.807	20.14*	0.01013	6.149	98.73	0.1626	21.19	66.96	88.15	0.0450	0.1729
68	5.275	19.18*	0.01016	5.640	98.42	0.1773	22.05	66.69	88.74	0.0467	0.1731
72	5.780	18.16*	0.01019	5.180	98.10	0.1931	22.90	66.43	89.33	0.0483	0.1732
76	6.320	17.06*	0.01023	4.769	97.77	0.2097	23.76	66.16	89.92	0.0499	0.1734
80	6.902	15.87*	0.01026	4.392	97.45	0.2277	24.63	65.88	90.51	0.0515	0.1736
84	7.527	14.60*	0.01030	4.051	97.12	0.2468	25.49	65.60	91.09	0.0531	0.1738
88	8.194	13.24*	0.01033	3.742	96.79	0.2672	26.36	65.32	91.68	0.0547	0.1740
92	8.908	11.79*	0.01037	3.463	96.46	0.2888	27.24	65.04	92.28	0.0563	0.1743
96	9.668	10.24*	0.01040	3.208	96.13	0.3117	28.11	64.75	92.86	0.0578	0.1744
100	10.48	8.59*	0.01044	2.976	95.79	0.3360	28.99	64.46	93.45	0.0594	0.1746
104	11.35	6.82*	0.01048	2.762	95.46	0.3620	29.89	64.16	94.05	0.0610	0.1748
108	12.28	4.93*	0.01051	2.567	95.12	0.3896	30.78	63.86	94.64	0.0626	0.1751
110	12.76	3.95*	0.01053	2.477	94.95	0.4038	31.22	63.71	94.93	0.0634	0.1752

* Inches of mercury below one atmosphere.

† Standard cycle temperatures.

^a ASRE designation—Refrigerant 113.

Values of v_s and v_d for use in Equation 4 can be obtained directly or by calculation from the tables of properties of refrigerants.

By a reversal of this same procedure the tabular data can be used to determine the state of a mixture leaving an expansion valve. Consider a valve to which saturated liquid at pressure p_s is admitted, and a mixture of saturated liquid and vapor at pressure p_d is discharged. The quality of the material at discharge is then determined by making use of the fact that the expansion process is completely irreversible, is a throttling process, and hence, occurs without change in enthalpy. Thus, the enthalpy of the mixture, h_m , is equal to the enthalpy of the saturated liquid at the entrance state, h_{ls} , and can therefore be read from the table.

Thus,

$$h_{ls} = h_m = h_{vd} - (1 - x)(h_{vd} - h_{ld}) \quad (5)$$

or,

$$x = (h_m - h_{ld}) \div (h_{vd} - h_{ld}) \quad (6)$$

where

h_{ls} = enthalpy of saturated liquid at entrance to expansion valve.

h_m = enthalpy of mixture.

h_{vd} = enthalpy of saturated vapor at discharge.

h_{ld} = enthalpy of liquid at discharge.

x = proportion of liquid in the mixture, decimal.

Vapor Compression Refrigeration Cycle

Simple Cycle. The refrigerant cycle is the series of state changes (which occur in the conditioning processes) needed to restore the refrigerant to a condition in which it will possess the ability to extract heat from the space to be cooled. For all compression-type systems the cycle consists of four processes: heat gain in the evaporator; pressure rise in the compressor; heat loss in the condenser; pressure loss in the expansion valve. The compression process is accomplished at the expense of energy added to the compressor in the form of shaft work, and the expansion process could be carried out, if the economics of the system would permit, in an expanding engine with consequent release of energy as shaft work. In ordinary systems, however, the additional first cost and maintenance costs of an expanding engine so greatly exceed the advantage resulting from the work realized, that such engines are not used, and the pressure reduction is allowed to occur irreversibly in an expansion valve. Basically, then, a refrigeration cycle consists of two heat transfer processes and two pressure change processes, no work entering into the heat transfer processes and—in the simple cycle—no heat transfer occurring during the pressure-change processes.

The most common and least complicated type of refrigeration cycle is called the simple saturation cycle, and is shown diagrammatically in Fig. 3 and plotted upon pressure-enthalpy coordinates in Fig. 4. For this system, saturated vapor flows without gain or loss of heat from the evaporator to the suction of the compressor. During passage through the compressor the energy added as shaft work goes entirely to increase the enthalpy of the refrigerant, and the compression process, which is assumed to occur irreversibly and without external heat transfer, is characterized by constant entropy. Thus, the state of the superheated vapor leaving the compressor can be determined from the tables of thermodynamic properties by noting the discharge pressure and fixing, also, the entropy of the saturated vapor at entrance to the compressor.

Superheated vapor from the compressor flows to the condenser where