TABLE 6. PROPERTIES OF MONOFLUOROTRICHLOROMETHANE (F-11)

| Sat. Temp. F | Abs. Press. Lb per Sq In. | Volume | | Specific Enthalpy and Entropy Taken From −40 F | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Specific Enthalpy | | Entropy | | 25 F Superheat | | 50 F Superheat | |
| | | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Sp. En. | Entropy | Sp. En. | 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 | 98.2 | 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 |

NOTE: Sp. En. = Specific Enthalpy.

TABLE 7. PROPERTIES OF WATER

| Sat. Temp. F | Abs. Press. Lb per Sq In. | Volume | | Specific Enthalpy and Entropy Taken From +32 F | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Specific Enthalpy | | Entropy | | 50 F Superheat | | 100 F Superheat | |
| | | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Sp. En. | Entropy | Sp. En. | Entropy |
| 32 | 0.0887 | 0.01602 | 3296.0 | 0.00 | 1073.0 | 0.0000 | 2.1826 | 1096.9 | 2.2277 | 1120.8 | 2.2688 |
| 35 | 0.1000 | 0.01602 | 2941.0 | 3.02 | 1074.4 | 0.0062 | 2.1724 | 1098.3 | 2.2172 | 1122.2 | 2.2581 |
| 40 | 0.1217 | 0.01602 | 2441.0 | 8.05 | 1076.8 | 0.0163 | 2.1555 | 1100.6 | 2.2000 | 1124.5 | 2.2406 |
| 45 | 0.1475 | 0.01602 | 2034.0 | 13.07 | 1079.2 | 0.0262 | 2.1390 | 1102.9 | 2.1832 | 1126.7 | 2.2234 |
| 50 | 0.1780 | 0.01602 | 1702.0 | 18.08 | 1081.5 | 0.0361 | 2.1230 | 1105.2 | 2.1667 | 1129.0 | 2.2066 |
| 55 | 0.2140 | 0.01603 | 1430.0 | 23.08 | 1083.9 | 0.0459 | 2.1073 | 1107.5 | 2.1506 | 1131.3 | 2.1902 |
| 60 | 0.2561 | 0.01603 | 1206.0 | 28.08 | 1086.2 | 0.0556 | 2.0920 | 1109.8 | 2.1349 | 1133.5 | 2.1742 |
| 65 | 0.3054 | 0.01604 | 1021.0 | 33.08 | 1088.6 | 0.0652 | 2.0771 | 1112.2 | 2.1196 | 1135.8 | 2.1585 |
| 70 | 0.3628 | 0.01605 | 868.0 | 38.07 | 1090.9 | 0.0746 | 2.0625 | 1114.5 | 2.1046 | 1138.1 | 2.1432 |
| 75 | 0.4295 | 0.01606 | 740.0 | 43.06 | 1093.2 | 0.0840 | 2.0483 | 1116.7 | 2.0900 | 1140.3 | 2.1283 |
| 80 | 0.507 | 0.01607 | 632.9 | 48.05 | 1095.5 | 0.0933 | 2.0344 | 1119.0 | 2.0758 | 1142.5 | 2.1138 |
| 85 | 0.596 | 0.01609 | 543.3 | 53.04 | 1097.8 | 0.1025 | 2.0208 | 1121.2 | 2.0619 | 1144.7 | 2.0996 |
| 90 | 0.698 | 0.01610 | 467.9 | 58.03 | 1100.0 | 0.1116 | 2.0075 | 1123.4 | 2.0483 | 1146.8 | 2.0857 |
| 95 | 0.815 | 0.01612 | 404.2 | 63.01 | 1102.3 | 0.1206 | 1.9946 | 1125.6 | 2.0350 | 1148.9 | 2.0721 |
| 100 | 0.949 | 0.01613 | 350.3 | 68.00 | 1104.6 | 0.1296 | 1.9819 | 1127.9 | 2.0220 | 1151.1 | 2.0588 |
| 105 | 1.101 | 0.01615 | 304.4 | 72.98 | 1106.8 | 0.1384 | 1.9695 | 1130.2 | 2.0093 | 1153.2 | 2.0458 |

NOTE: Sp. En. = Specific Enthalpy.



Consider, for example, F-12 with a quality (the per cent in vapor form) of 30 per cent; the specific enthalpy of this material would be equal to:

$$h_m = h_l + 0.30\ (h_v - h_l) \qquad (2)$$

*where*

$h_m$ = specific enthalpy of the mixture.
$h_l$ = specific enthalpy of the liquid.
$h_v$ = specific enthalpy of the saturated vapor.

Values of $h_l$ and $h_v$ are obtained from Table 1 for the actual pressure of the mixture.

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 completly 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,

$$h_{ls} = h_m = h_{vd} - (1 - x)\ (h_{vd} - h_{ld}) \qquad (3)$$

or,

$$x = (h_m - h_{ld}) \div (h_{vd} - h_{ld}) \qquad (4)$$

*where*

$h_{ls}$ = specific enthalpy of saturated liquid at entrance to expansion valve.
$h_m$ = specific enthalpy of mixture.
$h_{vd}$ = specific enthalpy of saturated vapor at discharge.
$h_{ld}$ = specific enthalpy of liquid at discharge.
$x$ = proportion of liquid in the mixture.

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.

## Simple Refrigeration Cycles

The most common and least complicated type of refrigeration cycle is shown in Fig. 1 and is called the *simple saturation cycle*. For this system saturated vapor flows without gain or loss of heat from the