

Section 2

REFRIGERANTS

Large quantities of heat can be absorbed by a substance through an increase in sensible heat involving either a big temperature difference or a large weight. In a change of state involving latent heat, however, a fraction of the weight will absorb an equivalent amount of heat.

In mechanical refrigeration a process is required that can transfer large quantities of heat economically and efficiently, and can be repeated continuously. The processes of evaporation and condensation of a liquid are, therefore, the logical steps in the refrigeration process.

Practically any liquid could be used for absorbing heat by evaporation. Water is ideal in many respects, but it boils at temperatures too high for ordinary cooling purposes, and freezes at temperatures too high for low temperature conditions. A refrigerant must satisfy two main requirements:

1. It must readily absorb heat at the temperature required by the product load.
2. For economy and continuous cooling, the system must use the same refrigerant over and over again.

There is no perfect refrigerant, and there are varying opinions as to which may be best for specific applications.

TYPES OF REFRIGERANT

There are many different types of refrigerant available, several of which are in common use. In early refrigeration applications, ammonia, sulfur dioxide, methyl chloride, propane, and ethane were widely used, and still are used in many applications. However, due to the fact that they are either toxic, dangerous, or have other undesirable characteristics, they have

been largely replaced in most applications by compounds developed especially for refrigeration use. Specialized refrigerants are used for ultra-low temperature work, or for large centrifugal compressors, but for the normal commercial refrigeration and air conditioning applications utilizing reciprocating compressors, refrigerants 12, 22, and 502 are now used almost exclusively. These are frequently referred

Table 3
COMPARATIVE PROPERTIES OF
R-12, R-22, and R-502

	R-12	R-22	R-502
Saturation Pressure, 70° F., psig	70.2	121.4	136.6
Boiling Point at 14.7 psia, °F. (Standard Atmospheric Pressure)	-21.6°	-41.4°	-50.1°
Liquid Density at 70° F., lb./cu. ft.	82.7	75.5	78.6
Solubility of Water at 78° F., ppm	93	1,300	560
Solubility of Water at -40° F., ppm	1.7	120	40

Comparative Refrigeration Effect

At operating conditions of
 -20° F. evaporating temperature
 110° F. condensing temperature
 0° F. liquid subcooling
 65° F. return gas temperature

	R-12	R-22	R-502
Evaporating pressure, psig	0.6	10.2	15.5
Condensing pressure, psig	136	226	246
Compression Ratio	9.9	9.7	8.6
Specific Volume of return gas, cu.ft./lb.	3.03	2.53	1.66
Refrigeration Effect BTU/lb.	53.7	73.03	48.72
Refrigeration Effect BTU/cu. ft.	17.8	28.9	29.3

to as R-12, R-22, and R-502, and although these were developed originally by Dupont as Freon refrigerants, the numerical designations are now standard with all manufacturers.

REFRIGERANT 12

Refrigerant 12 is widely used in household and commercial refrigeration and air conditioning. At temperatures below its boiling point it is a clear, almost colorless liquid. It is almost odorless, is not toxic or irritating, and is suitable for high, medium, and low temperature applications.

REFRIGERANT 22

Refrigerant 22 in most physical characteristics is similar to R-12. However, it has much higher saturation pressures than R-12 for equivalent temperatures, has a much larger latent heat of evaporation, and a lower specific volume, and as a result for a given volume of saturated refrigerant vapor, R-22 has a much greater refrigerating capacity. This allows the use of lower compressor displacement, sometimes resulting in smaller compressors, for performance comparable with R-12. Where size and economy are critical factors, such as package air conditioning units, R-22 is widely used.

Because of its characteristics at low evaporating temperatures and high compression ratios, the temperature of the compressed R-22 vapor becomes so high it frequently causes damage to the compressor. Copeland recommends R-22 in single stage systems for high and medium temperature applications only, although it is suitable for low temperature applications in multi-stage systems where the vapor temperature can be adequately controlled.

REFRIGERANT 502

Refrigerant 502 is an azeotropic mixture of R-22 and R-115. An azeotrope is the scientific name given to a specific mixture of different compounds in which the resulting mixture has different characteristics than either of its components, and which can evaporate and condense without a change in composition. In most physical characteristics, R-502 is similar to R-12 and R-22. While its latent heat of evaporation is not as high as either R-12 or R-22, its vapor is much heavier, or to describe it differently, its specific volume is much less. Therefore for a given compressor displacement, its refrigerating capacity is comparable to that of R-22, and at low temperatures usually will be greater. As with R-22, a compressor with lower compressor displacement may be used for performance equivalent to R-12. Because of its excellent low temperature characteristics, R-502 is well suited for low temperature refrigeration applications, and is recommended for all single stage applications where the evaporating temperature is 0° F. or below. It also is very satisfactory for use in two stage systems for extra low temperature applications, and is becoming popular for use in the medium temperature range.

REFRIGERANT SATURATION TEMPERATURE

At normal room temperatures, all three refrigerants can exist only as a gas unless under pressure, since their boiling points at atmospheric pressure are far below 0° F. Therefore refrigerants are always stored and transported in special pressure resistant drums. So long as both liquid and vapor are present in a closed system, with no external pressure influence, the refrigerant will either evaporate or condense depending on the outside temperature until the saturation pressure and temperature corresponding to the outside temperature is reached and heat transfer can no longer take place. A decrease in outside temperature will allow heat to flow out of the refrigerant, cause condensation, and lower the pressure; and an increase in outside temperature will cause heat to flow into the refrigerant, cause evaporation, and raise the pressure.

REFRIGERANT EVAPORATION

Now, presume the refrigerant is enclosed in a refrigeration system, with its temperature equalized with the outside temperature. Instead of changing the outside temperature, the pressure in the refrigeration system is lowered. Since this lowers the saturation point, the temperature of the liquid refrigerant is now above its boiling point. It will immediately start boiling violently, absorbing heat in the process and thus reducing the temperature of the remaining liquid and changing into gas as the change of state takes place. Heat will now flow into the system from the outside due to the decreased temperature of the refrigerant, and boiling will continue until the outside temperature is reduced to the saturation temperature of the refrigerant, or until the pressure in the system again rises to the equivalent saturation pressure of the outside temperature. If a means is provided, such as a compressor, to remove the refrigerant vapor so the pressure does not increase, while at the same time liquid refrigerant is fed back into the system, continuous refrigeration will be taking place. This is basically the process taking place in a refrigeration system evaporator.

REFRIGERANT CONDENSATION

Again, presume the refrigerant is enclosed in a refrigeration system, with its temperature equalized with the outside temperature. If hot refrigerant vapor is pumped into the system the pressure in the refrigeration system is increased, raising the saturation point.

As heat is transferred from the incoming hot vapor to the refrigerant liquid and the walls of the system, the temperature of the refrigerant vapor falls to its condensing temperature, and condensation starts. Heat from the latent heat of condensation flows from the system to the outside until the pressure in the system is lowered to the equivalent of the saturation pressure at the outside temperature. If a means is provided, such as a compressor, to maintain a supply of hot, high pressure refrigerant gas, while at the same time liquid refrigerant is drawn off, continuous condensation will take

place. This is basically the process taking place in a refrigeration system condenser.

REFRIGERANT-OIL RELATIONSHIPS

In reciprocating compressors, oil and refrigerant mix continuously. Refrigeration oils are soluble in liquid refrigerant, and at normal room temperatures they will mix completely. The ability of a liquid refrigerant to mix with oil is termed miscibility, and the refrigerant is described as being miscible with oil.

Oil circulating in a refrigeration system may be exposed to both very high and very low temperatures. Because of the critical nature of lubrication under these conditions, and the damage that can be done to the system by wax or other impurities in the oil, only highly refined oils specifically prepared for refrigeration usage can be used.

In general naphthenic oils are more soluble in refrigerants than paraffinic oils. Separation of the oil and refrigerant into separate layers can take place with both types of oil, although at somewhat lower temperatures with naphthenic oils. Separation does not necessarily affect the lubricating ability of the oil but it may create problems in properly supplying oil to the working parts.

Since oil must pass through the compressor cylinders to provide lubrication, a small amount of oil is always circulating with the refrigerant. Oil and refrigerant gas do not mix readily, and the oil can be properly circulated through the system only if gas velocities are high enough to sweep the oil along. If velocities are not sufficiently high, oil will tend to lie on the bottom of refrigeration tubing, decreasing heat transfer and possibly causing a shortage of oil in the compressor. As evaporating temperatures are lowered, this problem becomes more critical since the viscosity of the oil increases with a decrease in temperature. For these reasons, proper design of piping is essential for satisfactory oil return.

One of the basic characteristics of a refrigerant and oil mixture in a sealed system is the fact that refrigerant is attracted by oil and will vaporize and migrate through the system to the compressor crankcase even though no pressure difference exists to cause the movement. On reaching the crankcase the refrigerant will condense into liquid, and this migration will continue until the oil is saturated with liquid refrigerant.

Excess refrigerant in the compressor crankcase can result in violent foaming and boiling action, driving all of the oil from the crankcase and causing lubrication problems. Therefore, provisions must be made to prevent the accumulation of excess liquid refrigerant in the compressor.

R-22 and R-502 are much less soluble in oil than R-12, and for that reason proper piping and system design for these two refrigerants is more critical with regard to oil return.

REFRIGERANT TABLES

To accurately determine the operating performance of a refrigeration system, very precise and accurate information is required on the various properties of refrigerants at any temperature and pressure to be considered. The refrigerant manufacturers have calculated and compiled this data in the form of tables of thermodynamic properties, and these tables are made available to design and application engineers and others who have a need for this information.

Figure 1 is an excerpt from an R-12 saturation table, which lists five major saturation properties of R-12, both liquid and vapor, at various temperatures. Pressure, volume, and density have been discussed previously.

Enthalpy is a term used in thermodynamics to describe the heat content of a substance. In refrigeration practice, enthalpy is expressed in terms of BTU per pound, and an arbitrary base of saturated liquid at -40° F. has been accepted as the standard zero value. In other

words, the enthalpy of any refrigerant is zero for liquid at -40° F. Liquid at temperatures below -40° F. is considered to have a negative enthalpy, while at all temperatures above -40° F. the refrigerant has a positive enthalpy value.

The difference in enthalpy values at different parts of the system are commonly used to determine the performance of a refrigeration unit. If the heat content per pound of the refrigerant entering and leaving a cooling coil can be determined, then the cooling ability of that coil can be calculated if the refrigerant flow rate is known.

Entropy can best be described as a mathematical ratio used in thermodynamics which is of use in solving complex refrigeration engineering problems. It is not easily defined or explained, is seldom used in commercial refrigeration applications and a discussion of it is beyond the scope of this manual.

Figure 2 is an excerpt from a R-502 superheat table. Superheat tables list saturation evaporating temperature and pressure in increments of 1 psi, and tabulate changes in specific volume, enthalpy, and entropy for various increases in temperature of the refrigerant vapor or superheat. Since superheat tables are quite lengthy and are available separately in bound volumes, complete superheat tables have not been included in this manual.

POCKET TEMPERATURE-PRESSURE CHARTS

Small pocket sized folders listing the saturation temperatures and pressures of common refrigerants are readily available from expansion valve and refrigerant manufacturers. Figure 3 is a typical example of a pocket sized chart.

A saturation chart for ready reference is an invaluable tool for the refrigeration serviceman or for anyone checking the performance of a refrigeration system. Suction and discharge pressures can be readily checked by means of gauges, and from these pressures the evaporating and condensing temperatures can be determined.

R-12

SATURATION PROPERTIES—TEMPERATURE TABLE

TEMP. °F	PRESSURE		VOLUME cu ft/lb		DENSITY lb/cu ft		ENTHALPY Btu/lb			ENTROPY Btu/(lb)(°R)		TEMP. °F
	PSIA	PSIG	LIQUID v_f	VAPOR v_g	LIQUID l/v_f	VAPOR l/v_g	LIQUID h_f	LATENT h_{fg}	VAPOR h_g	LIQUID s_f	VAPOR s_g	
—40	9.3076	10.9709*	0.010564	3.8750	94.661	0.25806	0	72.913	72.913	0	0.17373	—40
—39	9.5530	10.4712*	0.010575	3.7823	94.565	0.26439	0.2107	72.812	73.023	0.000500	0.17357	—39
—38	9.8035	9.9611*	0.010586	3.6922	94.469	0.27084	0.4215	72.712	73.134	0.001000	0.17343	—38
—37	10.059	9.441*	0.010596	3.6047	94.372	0.27741	0.6324	72.611	73.243	0.001498	0.17328	—37
—36	10.320	8.909*	0.010607	3.5198	94.275	0.28411	0.8434	72.511	73.354	0.001995	0.17313	—36
—35	10.586	8.367*	0.010618	3.4373	94.178	0.29093	1.0546	72.409	73.464	0.002492	0.17299	—35
—34	10.858	7.814*	0.010629	3.3571	94.081	0.29788	1.2659	72.309	73.575	0.002988	0.17285	—34
—33	11.135	7.250*	0.010640	3.2792	93.983	0.30495	1.4772	72.208	73.685	0.003482	0.17271	
—32	11.417	6.675*	0.010651	3.2035	93.886	0.31216	1.6887	72.106	73.795	0.003976	0.17271	
—31	11.706	6.088*	0.010662	3.1300	93.788	0.31949	1.9003	72.004	73.904	0.004470	0.17271	
—30	11.999	5.490*	0.010674	3.0585	93.690							95
	12.299	4.880*	0.010685	2.9890						0.004964	0.16330	96
						3.1566	30.619	56.242	86.861	0.062381	0.16326	97
					3.0923	3.2017	30.859	56.086	86.945	0.062804	0.16323	98
											0.16319	99
100	131.86	117.16	0.012693	0.30794	78.785	3.2474	31.100	55.929	87.029	0.063227	0.16315	100
101	133.70	119.00	0.012715	0.30362	78.647	3.2936	31.341	55.772	87.113	0.063649	0.16312	101
102	135.56	120.86	0.012738	0.29937	78.508	3.3404	31.583	55.613	87.196	0.064072	0.16308	102
103	137.44	122.74	0.012760	0.29518	78.368	3.3877	31.824	55.454	87.278	0.064494	0.16304	103
104	139.33	124.63	0.012783	0.29106	78.228	3.4357	32.067	55.293	87.360	0.064916	0.16301	104
105	141.25	126.55	0.012806	0.28701	78.088	3.4842	32.310	55.132	87.442	0.065339	0.16297	105
106	143.18	128.48	0.012829	0.28303	77.946	3.5333	32.553	54.970	87.523	0.065761	0.16293	106
107	145.13	130.43	0.012853	0.27910	77.804	3.5829	32.797	54.807	87.604	0.066184	0.16290	107
108	147.11	132.41	0.012876	0.27524	77.662	3.6332	33.041	54.643	87.684	0.066606	0.16286	108
109	149.10	134.40	0.012900	0.27143	77.519	3.6841	33.286	54.478	87.764	0.067028	0.16282	109
110	151.11	136.41	0.012924	0.26769	77.376	3.7357	33.531	54.313	87.844	0.067451	0.16279	110
111	153.14	138.44	0.012948	0.26400	77.231	3.7878	33.777	54.146	87.923	0.067873	0.16275	111
112	155.19	140.49	0.012972	0.26037	77.087	3.8406	34.023	53.978	88.001	0.068296	0.16271	112
113	157.27	142.57	0.012997	0.25680	76.941	3.8941	34.270	53.809	88.079	0.068719	0.16268	113
114	159.36	144.66	0.013022	0.25328	76.795	3.9482	34.517	53.639	88.156	0.069141	0.16264	114
115	161.47	146.77	0.013047	0.24982	76.649	4.0029	34.765	53.468	88.233	0.069564	0.16260	115
116	163.61	148.91	0.013072	0.24641	76.501	4.0584	35.014	53.296	88.310	0.069987	0.16256	116
117	165.76	151.06	0.013097	0.24304	76.353	4.1145	35.263	53.123	88.386	0.070410	0.16253	117
118	167.94	153.24	0.013123	0.23974	76.205	4.1713	35.512	52.949	88.461	0.070833	0.16249	118
119	170.13	155.43	0.013148	0.23647	76.056	4.2288	35.762	52.774	88.536	0.071257	0.16245	119
120	172.35	157.65	0.013174	0.23326	75.906	4.2870	36.013	52.597	88.610	0.071680	0.16241	120
121	174.59	159.89	0.013200	0.23010	75.755	4.3459	36.264	52.420	88.684	0.072104	0.16237	121
122	176.85	162.15	0.013227	0.22698	75.604	4.4056	36.516	52.241	88.757	0.072528	0.16234	122
123	179.13	164.43	0.013254	0.22391	75.452	4.4660	36.768	52.062	88.830	0.072952	0.16230	123
124	181.43	166.73	0.013280	0.22089	75.299	4.5272	37.021	51.881	88.902	0.073376	0.16226	124
125	183.76	169.06	0.013308	0.21791	75.145	4.5891	37.275	51.698	88.973	0.073800	0.16222	125

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EXCERPT FROM TYPICAL MANUFACTURER'S R-12 SATURATION PROPERTIES TABLE

Figure 1

"FREON - 502" — SUPERHEATED VAPOR

V=volume in cu ft/lb; H=enthalpy in Btu/lb; S=entropy in Btu/(lb) (°R) (saturation properties in parentheses)

TEMP. °F	ABSOLUTE PRESSURE, lb/sq in												TEMP. °F
	25			26			27			28			
	10.30 psig			11.30 psig			12.30 psig			13.30 psig			
	(-28.41° F)			(-26.70° F)			(-25.04° F)			(-23.43° F)			
	V	H	S	V	H	S	V	H	S	V	H	S	
	(1.612)	(76.64)	(0.1777)	(1.554)	(76.86)	(0.1776)	(1.499)	(77.06)	(0.1774)	(1.449)	(77.26)	(0.1772)	
-25	1.627	77.15	0.1789	1.561	77.11	0.1782	1.500	77.07	0.1774	—	—	—	-25
-20	1.648	77.91	0.1807	1.581	77.87	0.1799	1.519	77.83	0.1792	1.462	77.79	0.1784	-20
-15	1.669	78.67	0.1824	1.602	78.63	0.1816	1.539	78.59	0.1809	1.481	78.55	0.1802	-15
-10	1.690	79.44	0.1841	1.622	79.40	0.1834	1.559	79.36	0.1826	1.500	79.32	0.1819	-10
-5	1.711	80.21	0.1858	1.643	80.17	0.1851	1.579	80.13	0.1843	1.519	80.09	0.1836	-5
0	1.732	80.98	0.1875	1.663	80.95	0.1868	1.598	80.91	0.1860	1.539	80.87	0.1853	0
5	1.754	81.76	0.1892	1.683	81.72	0.1884	1.618	81.69	0.1877	1.558	81.65	0.1870	5
10	1.775	82.54	0.1909	1.703	82.51	0.1901	1.638	82.47	0.1894	1.576	82.43	0.1887	10
15	1.796	83.33	0.1925	1.724	83.29	0.1918	1.657	83.26	0.1910	1.595	83.22	0.1903	15
20	1.817	84.12	0.1942	1.744	84.08	0.1934	1.677	84.05	0.1927	1.614	84.01	0.1920	20
25	1.838	84.91	0.1958	1.764	84.88	0.1951	1.696	84.84	0.1943	1.633	84.81	0.1936	25
30	1.858	85.71	0.1975	1.784	85.68	0.1967	1.716	85.64	0.1960	1.652	85.61	0.1953	30
35	1.879	86.51	0.1991	1.804	86.48	0.1983	1.735	86.44	0.1976	1.671	86.41	0.1969	35
40	1.900	87.32	0.2007	1.825	87.28	0.2000	1.755	87.25	0.1992	1.689	87.21	0.1985	40
45	1.921	88.13	0.2023	1.845	88.09	0.2016	1.774	88.06	0.2008	1.708	88.03	0.2001	45
50	1.942	88.94	0.2039	1.865	88.91	0.2032	1.793	88.87	0.2025	1.727	88.84	0.2017	50
55	1.963	89.75	0.2055	1.885	89.72	0.2048	1.813	89.69	0.2040	1.746	89.66	0.2033	55
60	1.983	90.58	0.2071	1.905	90.54	0.2064	1.832	90.51	0.2056	1.764	90.48	0.2049	60
65	2.004	91.40	0.2087	1.925	91.37	0.2079	1.851	91.34	0.2072	1.783	91.30	0.2065	65
70	2.025	92.23	0.2103	1.945	92.20	0.2095	1.870	92.16	0.2088	1.802	92.13	0.2081	70
75	2.045	93.06	0.2118	1.965	93.03	0.2111	1.890	93.00	0.2104	1.820	92.97	0.2097	75
80	2.066	93.89	0.2134	1.984	93.86	0.2126	1.909	93.83	0.2119	1.839	93.80	0.2112	80
85	2.087	94.73	0.2149	2.004	94.70	0.2142	1.928	94.67	0.2135	1.857	94.64	0.2128	85
90	2.107	95.58	0.2165	2.024	95.55	0.2157	1.947	95.52	0.2150	1.876	95.49	0.2143	90
95	2.128	96.42	0.2180	2.044	96.39	0.2173	1.966	96.36	0.2165	1.894	96.34	0.2158	95
100	2.149	97.27	0.2195	2.064	97.24	0.2188	1.986	97.22	0.2181	1.913	97.19	0.2174	100
105	2.169	98.13	0.2210	2.084	98.10	0.2203	2.005	98.07	0.2196	1.931	98.04	0.2189	105
110	2.190	98.98	0.2226	2.104	98.96	0.2218	2.024	98.93	0.2211	1.950	98.90	0.2204	110
115	2.210	99.85	0.2241	2.123	99.82	0.2233	2.043	99.79	0.2226	1.968	99.76	0.2219	115
120	2.231	100.71	0.2256	2.143	100.68	0.2248	2.062	100.66	0.2241	1.987	100.63	0.2234	120
125	2.251	101.58	0.2271	2.163	101.55	0.2263	2.081	101.52	0.2256	2.005	101.50	0.2249	125
130	—	—	—	—	—	—	—	—	—	2.023	102.37	0.2264	130

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EXCERPT FROM TYPICAL MANUFACTURER'S R-502 SUPERHEAT TABLE

Figure 2

Vapor Pressure, Psig

°F.	"Freon-113"	"Freon-114"	"Freon-13"	R-502**
-50		27.2*	57.0	
-48		27.0*	60.0	
-46		26.8*	63.0	
-44		26.6*	66.2	
-42		26.3*	69.4	
-40		26.1*	72.7	7.9*
-38		25.9*	76.2	6.7*
-36		25.6*	79.7	5.4*
-34		25.3*	83.3	4.2*
-32		25.0*	87.1	2.9*
-30	29.3*	24.7*	90.9	1.4*
-28	29.3*	24.4*	94.9	0.0
-26	29.2*	24.0*	98.9	0.8
-24	29.2*	23.7*	103.0	1.5
-22	29.1*	23.3*	107.3	2.3
-20	29.1*	22.9*	111.7	3.1
-18	29.0*	22.5*	116.2	4.0
-16	28.9*	22.1*	120.8	4.9
-14	28.9*	21.8*	125.7	5.8
-12	28.8*	21.1*	130.5	6.8
-10	28.7*	20.6*	135.4	7.8
-8	28.6*	20.1*	140.5	8.8
-6	28.5*	19.6*	145.7	9.9
-4	28.4*	19.0*	151.1	11.0
-2	28.3*	18.4*	156.5	12.1
0	28.2*	17.8*	162.2	13.3
2	28.1*	17.2*	167.9	14.5
4	28.0*	16.5*	173.7	15.7
6	27.9*	15.8*	179.8	17.0
8	27.7*	15.1*	185.9	18.4
10	27.6*	14.3*	192.2	19.8
12	27.5*	13.5*	198.6	21.2
14	27.3*	12.7*	205.2	22.7
16	27.1*	11.9*	211.9	24.2
18	27.0*	11.0*	218.8	25.7
20	26.8*	10.1*	225.8	27.3
22	26.6*	9.1*	233.0	29.0
24	26.4*	8.1*	240.3	30.7
26	26.2*	7.1*	247.8	32.5
28	26.0*	6.1*	255.5	34.3
30	25.8*	5.0*	263.3	36.1
32	25.6*	3.9*	271.3	38.0
34	25.3*	2.7*	279.5	40.0
36	25.1*	1.5*	287.8	42.0
38	24.8*	0.2*	296.3	44.1
40	24.5*	0.5	305.0	46.2
42	24.2*	1.2	313.9	48.4
44	23.9*	1.9	322.9	50.7
46	23.6*	2.6	332.2	53.0
48	23.3*	3.3	341.6	55.4
50	22.9*	4.0	351.2	57.8
52	22.6*	4.8	361.1	60.3
54	22.2*	5.6	371.1	62.9
56	21.8*	6.4	381.3	65.5
58	21.4*	7.3	391.7	68.2
60	21.0*	8.1	402.4	71.0
62	20.6*	9.0	413.3	73.8
64	20.1*	9.9	424.2	76.7
66	19.7*	10.9	435.6	79.7
68	19.2*	11.9	447.0	82.8
70	18.7*	12.9	458.8	85.8
72	18.2*	13.9	470.7	89.0
74	17.6*	15.0	482.9	92.3
76	17.1*	16.1	495.3	95.6
78	16.5*	17.2	508.1	99.0
80	15.9*	18.3	521.0	102.5
82	15.3*	19.5	534.1	106.1
84	14.6*	20.7	547.5	109.7
86	13.9*	22.0	561.3	113.4
88	13.2*	23.3	575.4	117.3
90	12.5*	24.6	590.0	121.2
92	11.8*	25.9	605.1	125.1
94	11.0*	27.3	620.8	129.2
96	10.2*	28.7	637.1	133.3
98	9.4*	30.2	654.0	137.6
100	8.6*	31.7	671.5	141.9
102	7.7*	33.2	689.6	146.3
104	6.8*	34.8	708.3	150.9
106	5.9*	36.4	727.6	155.4
108	4.9*	38.0	747.5	160.1
110	4.0*	39.7	768.0	164.9
112	3.0*	41.4	789.1	169.8
114	1.9*	43.2	810.8	174.8
116	0.8*	45.0	833.1	179.9
118	0.1*	46.9	856.0	185.0
120	0.7	48.7	880.3	190.3
122	1.3	50.7	905.1	195.7
124	1.9	52.7	930.4	201.2
126	2.5	54.7	956.1	206.7
128	3.1	56.7	982.3	212.4
130	3.7	58.8	1009.0	218.2
132	4.4	61.0	1036.1	224.1
134	5.1	63.2	1063.6	230.1
136	5.8	65.5	1091.5	236.3
138	6.5	67.7	1119.8	242.5
140	7.2	70.1	1148.5	248.8
142	8.0	72.5		
144	8.8	74.9		
146	9.6	77.4		
148	10.4	80.0		
150	11.2	82.6		
152	12.1	85.2		
154	13.0	87.9		
156	13.9	90.7		
158	14.8	93.5		
160	15.7	96.4		

ABOVE CRITICAL TEMPERATURE

*Inches mercury below one atmosphere.
**Patented by Carrier Corporation.

Vapor Pressure, Psig

°F.	"Freon-11"	"Freon-12"	"Freon-502"	"Freon-22"
-50		15.4*	0.0	6.0*
-48		14.6*	0.8	4.7*
-46		13.8*	1.6	3.3*
-44		12.9*	2.5	1.8*
-42		11.9*	3.4	0.3*
-40	28.4*	11.0*	4.3	0.6
-38	28.3*	10.0*	5.2	1.4
-36	28.2*	9.9*	6.2	2.3
-34	28.1*	7.8*	7.2	3.2
-32	28.0*	6.7*	8.3	4.1
-30	27.8*	5.5*	9.4	5.0
-28	27.7*	4.3*	10.5	6.0
-26	27.5*	3.0*	11.7	7.0
-24	27.4*	1.6*	12.9	8.1
-22	27.2*	0.3*	14.2	9.2
-20	27.0*	0.6	15.5	10.3
-18	26.9*	1.3	16.9	11.5
-16	26.7*	2.1	18.3	12.7
-14	26.5*	2.8	19.7	13.9
-12	26.2*	3.7	20.2	15.2
-10	26.0*	4.5	22.8	16.6
-8	25.8*	5.4	24.4	18.0
-6	25.5*	6.3	26.0	19.4
-4	25.3*	7.2	27.7	20.9
-2	25.0*	8.2	29.4	22.5
0	24.7*	9.2	31.2	24.1
2	24.4*	10.2	33.1	25.7
4	24.1*	11.2	35.0	27.4
6	23.8*	12.3	37.0	29.2
8	23.5*	13.5	39.0	31.0
10	23.1*	14.6	41.1	32.9
12	22.7*	15.8	43.2	34.9
14	22.3*	17.1	45.4	36.9
16	21.9*	18.4	47.7	39.0
18	21.5*	19.7	50.1	41.1
20	21.1*	21.0	52.4	43.3
22	20.6*	22.4	54.9	45.5
24	20.2*	23.9	57.4	47.9
26	19.7*	25.4	60.0	50.2
28	19.1*	26.9	62.7	52.7
30	18.6*	28.5	65.4	55.4
32	18.1*	30.1	68.2	57.8
34	17.5*	31.7	71.1	60.5
36	16.9*	33.4	74.1	63.3
38	16.3*	35.2	77.1	66.1
40	15.6*	37.0	80.2	69.0
42	14.9*	38.8	83.4	72.0
44	14.2*	40.7	86.6	75.0
46	13.5*	42.7	90.0	78.2
48	12.8*	44.7	93.4	81.4
50	12.0*	46.7	96.9	84.7
52	11.2*	48.8	100.5	88.1
54	10.4*	51.0	104.1	91.5
56	9.5*	53.2	107.9	95.1
58	8.7*	55.4	111.7	98.8
60	7.7*	57.7	115.6	102.5
62	6.8*	60.1	119.6	106.3
64	5.8*	62.5	123.7	110.2
66	4.8*	65.0	127.9	114.2
68	3.7*	67.6	132.2	118.3
70	2.6*	70.2	136.6	122.5
72	1.5*	72.9	141.1	126.8
74	0.4*	75.6	145.6	131.2
76	0.4	78.4	150.3	135.7
78	1.0	81.3	155.1	140.3
80	1.6	84.2	159.9	145.0
82	2.2	87.2	164.9	149.8
84	2.9	90.2	170.0	154.7
86	3.6	93.3	175.1	159.8
88	4.3	96.5	180.4	164.9
90	5.0	99.8	185.8	170.1
92	5.7	103.1	191.3	175.4
94	6.5	106.5	196.9	180.9
96	7.3	110.0	202.6	186.5
98	8.1	113.5	208.4	192.1
100	8.9	117.2	214.4	197.9
102	9.8	120.9	220.4	203.8
104	10.6	124.6	226.6	209.9
106	11.5	128.5	232.9	216.0
108	12.5	132.4	239.3	222.3
110	13.4	136.4	245.8	228.7
112	14.4	140.5	252.5	235.2
114	15.3	144.7	259.2	241.9
116	16.4	148.9	266.1	248.7
118	17.4	153.2	273.1	255.6
120	18.5	157.7	280.3	262.6
122	19.6	162.2	287.6	269.7
124	20.7	166.7	295.0	277.0
126	21.9	171.4	302.5	284.4
128	23.0	176.2	310.2	291.8
130	24.3	181.0	318.0	299.3
132	25.5	185.9	326.0	307.1
134	26.8	191.0	334.1	315.2
136	28.1	196.1	342.3	323.6
138	29.4	201.3	350.7	332.3
140	30.8	206.6	359.2	341.3
142	32.2	212.0	367.8	350.3
144	33.7	217.5	376.7	359.4
146	35.1	223.1	385.6	368.6
148	36.6	228.8	394.7	377.9
150	38.2	234.6	404.0	387.2
152	39.7	240.5	413.4	396.6
154	41.3	246.5	423.0	406.1
156	43.0	252.6	432.7	415.6
158	44.6	258.8	442.6	425.1
160	46.3	265.1	452.6	434.6

*Inches mercury below one atmosphere.

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CONDENSED PRESSURE - TEMPERATURE CHART

Figure 3