

PART 4

Refrigerants, Brines, Oils





CONTENTS

PART **4** REFRIGERANTS, BRINES, OILS

SYSTEM DESIGN MANUAL

SUMMARY OF PART FOUR

This part of the System Design Manual presents data to guide the engineer in the application and selection of refrigerants, brines and oils when used with air conditioning system.

The text of this Manual is offered as a general guide for the use of industry and of consulting engineers in designing systems. Judgment is required for application to specific installation, and Carrier is not responsible for any uses made of this text.

refrigerants

1

brines

2

refrigeration oils

3

INDEX

CHAPTER 1. REFRIGERANTS

This chapter provides information concerning the refrigeration cycles and characteristics of the commonly used refrigerants and their selection for use in air conditioning applications.

To provide refrigeration, a refrigerant may be utilized either:

1. In conjunction with a compressor, condenser and evaporator in a compression cycle, or
2. With an absorbent in conjunction with an absorber, generator, evaporator, and condenser in an absorption cycle.

The refrigerant absorbs heat by evaporation generally at a low temperature and pressure level. Upon condensing at a higher level, it rejects this heat to any available medium, usually water or air.

In a compression system the refrigerant vapor is increased in pressure from evaporator to condenser pressure by the use of a compressor.

In an absorption system the increase in pressure is produced by heat supplied from steam or other suitable hot fluid which circulates thru a coil of pipe. The absorber-generator is analogous to a compressor in that the absorber constitutes the suction stroke and the generator the compression stroke. The evaporator spray header corresponds to the expansion valve. The evaporator and condenser are identical for both compression and absorption systems.

This chapter includes a discussion of the refrigeration cycle, refrigerant selection, and the commonly used refrigerants as well as tables indicating their characteristics and properties.

REFRIGERATION CYCLES

ABSORPTION CYCLE

The absorption refrigeration cycle utilizes two phenomena:

1. The absorption solution (absorbent plus refrigerant) can absorb refrigerant vapor.
2. The refrigerant boils (flash cools itself) when subjected to a lower pressure.

These two phenomena are used in the lithium bromide absorption machine to obtain refrigeration by using the bromide as an absorbent and water as a refrigerant.

Water is sprayed in an evaporator which is maintained at a high vacuum. A portion of the water flashes and cools that which remains. The water vapor is absorbed by a lithium bromide solution in the absorber. The resulting solution is then heated in the generator to drive off the water vapor which is condensed in the condenser. The water is returned to the evaporator, completing the cycle.

Figure 1 illustrates the absorption cycle. *Figure 2* illustrates the cycle plotted on the equilibrium diagram with numbered points representing pressures, temperatures, concentrations in the cycle.

On the lower left side of *Fig. 1* is the absorber partially filled with lithium bromide solution. On the lower right side is the evaporator containing water. A pipe connecting the shells is evacuated so that no air is present. The lithium bromide begins to absorb the water vapor; as the vapor is absorbed, the water boils, generating more vapor and causing the remainder of the water to be cooled.

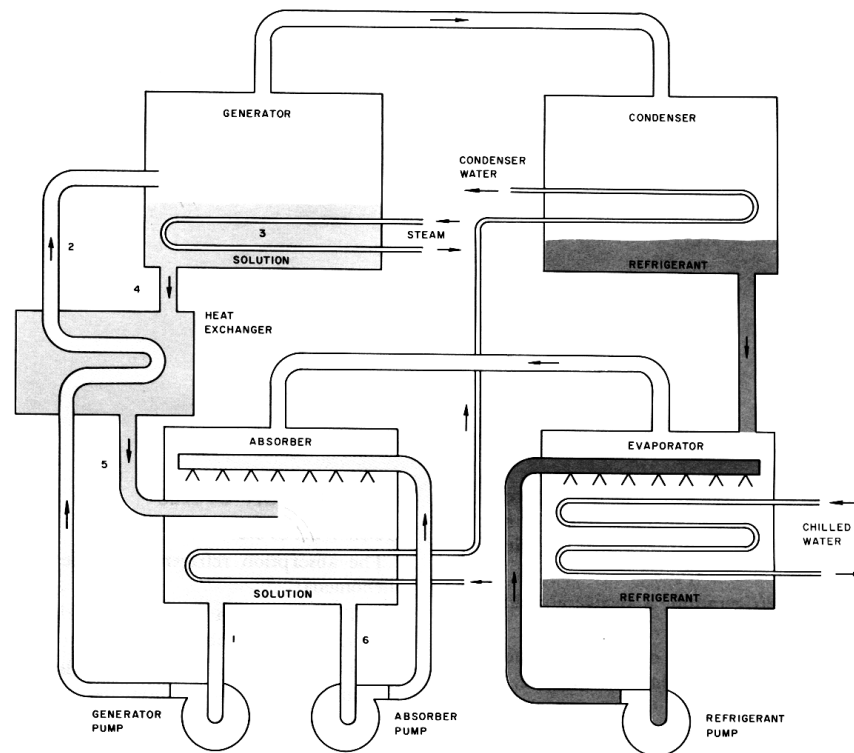


FIG. 1-ABSORPTION REFRIGERATION CYCLE

Since the water can vaporize more easily if it is being sprayed, a pump is used to circulate the water from the bottom of the evaporator to a spray header at the top. An evaporator tube bundle is located under the evaporator spray header; water inside the tubes, returning from the air conditioning coils or other load, is flash-cooled by the water on the outside of the evaporator tubes. The lithium bromide solution absorbs water vapor easier if it is sprayed; therefore, a pump is used to circulate the solution from the bottom of the absorber to a spray header at the top of absorber.

As the lithium bromide continues to absorb water vapor, it becomes diluted, and its ability to absorb additional water vapor decreases. The weak solution is

pumped to the generator where heat is applied by steam or other suitable hot fluid in the generator tube bundle to boil off the water vapor. The solution is concentrated and returned to the absorber. Since the weak solution going to the generator must be heated and the strong solution coming from the generator must be cooled, a heat exchanger is used in the solution circuit to conserve heat.

Water vapor boiled from the solution in the generator passes to the condenser to contact the relatively cold condenser tubes. The vapor condenses in the condenser and returns to the evaporator so that there is no loss of water in the cycle. Before the condenser water goes thru the condenser tubes, it passes thru a tube bundle located in the absorber. Here it picks up the heat of dilution and the heat of condensation which is generated as the solution absorbs water vapor.

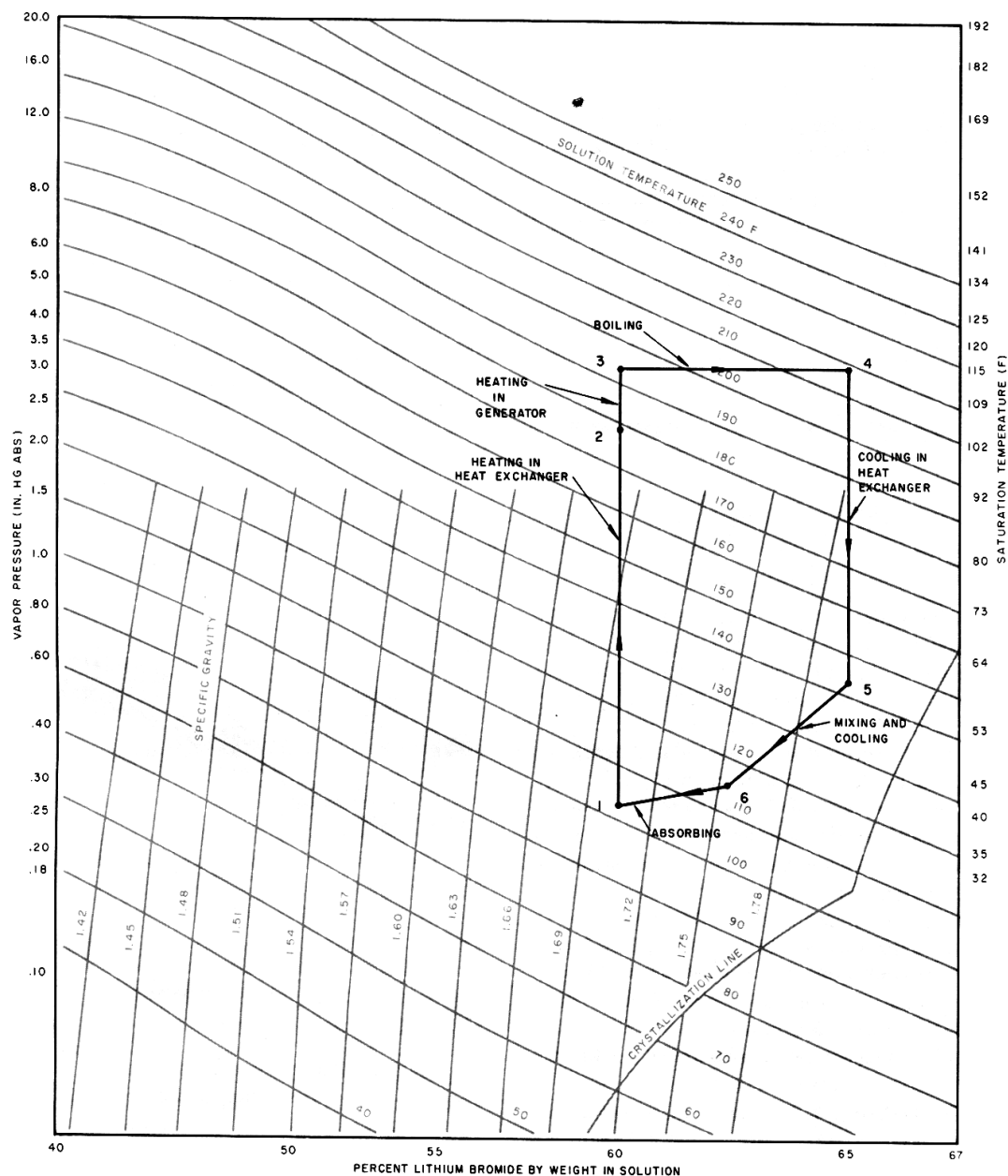


FIG. 2- EQUILIBRIUM DIAGRAM FOR LITHIUM BROMIDE

COMPRESSION CYCLE

The compression refrigeration cycle utilizes two phenomena:

1. The evaporation of a liquid refrigerant absorbs heat to lower the temperature of its surroundings.

2. The condensation of a refrigerant vapor rejects heat to raise the temperature of its surroundings.

The cycle may be traced from any point in the system. *Figure 3* is a schematic and *Fig. 4* is a pressure-enthalpy diagram of a compression cycle.

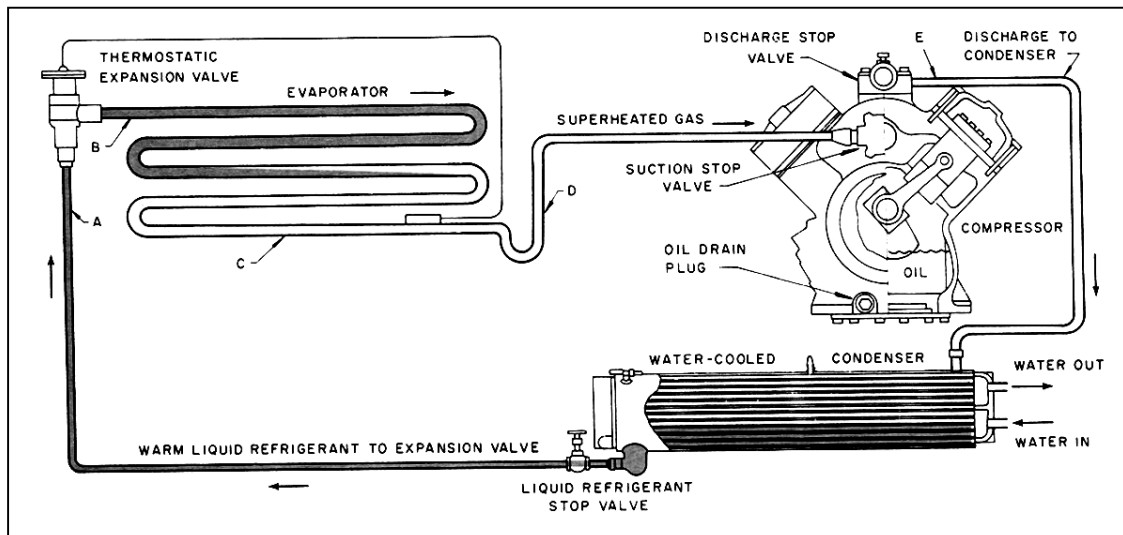


FIG. 3- RECIPROCATING COMPRESSION REFRIGERATION CYCLE

Starting with the liquid refrigerant ahead of the evaporator at point A in both Fig. 3 and 4, the admission of liquid to the evaporator is controlled by an automatic throttling device (expansion valve) which is actuated by temperature and pressure. The refrigerant pressure is reduced across the valve from condenser pressure, point A, to the evaporator pressure, point B. The valve acts as a boundary between the *high* and *low* sides of the system.

The pressure reduction allows the refrigerant to boil or vaporize. To support boiling, heat from the air or other medium to be cooled is transmitted to the evaporator surface and into the boiling liquid at a lower temperature. The refrigerant liquid and vapor passing thru the evaporator coil continues to absorb heat until it is completely evaporated, point C. Superheating of the gas, controlled by the expansion valve, occurs from C to D.

The superheated gas is drawn thru the suction line into the compressor cylinder. The downstroke of the piston pulls a cylinder of gas thru the suction valve and compresses it on the upstroke, raising its temperature and pressure to point E. The pressure produced causes the hot gas to flow to the condenser. The compressor discharge valve prevents re-entry of compressed gas into the cylinder and forms a boundary between the *high* and *low* sides.

In the condenser the condensing medium (air or water) absorbs heat to condense the hot gas. Liquid.

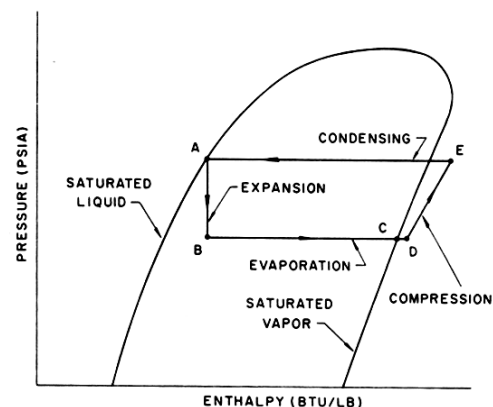


FIG. 4- PRESSURE-ENTHALPY DIAGRAM, COMPRESSION CYCLE

refrigerant is collected in receive which may be combined with or separate from condenser

The liquid is then forced thru the liquid line to the expansion valve A to repeat the cycle.

Liquid-Suction Interchangers

Compressor ratings for Refrigerants 12 and 500 are generally based on 65 F actual suction gas temperatures. When this suction gas temperature is not obtained at the compressor, its rating must be lowered by an appropriate multiplier. To develop the full rating, the required superheat which is over and above that available at the evaporator outlet may be obtained by a liquid-suction interchanger.

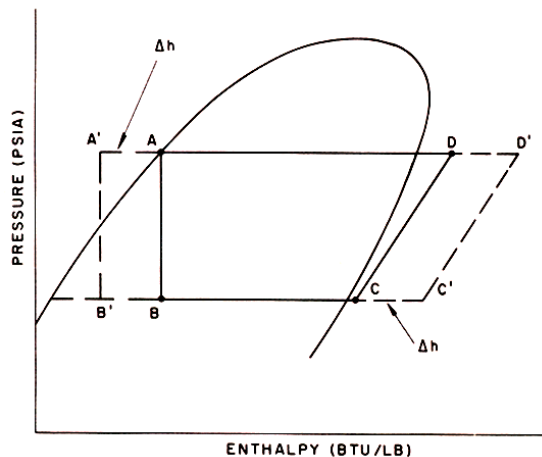


FIG. 5- EFFECT OF LIQUID-SUCTION INTERCHANGER ON COMPRESSION CYCLE

The effect of a liquid-suction interchanger on the refrigeration cycle is shown on the pressure-enthalpy diagram (Fig. 5).

The solid lines represent the basic cycle, while the dashed lines represent the same cycle with a liquid-suction interchanger. The useful refrigerating effect with an interchanger is B'C rather than BC as in the basic cycle.

Superheat increases the specific volume of the suction vapor to reduce the total weight of refrigerant circulated for a given displacement. It also increases the enthalpy of the vapor and may improve compressor volumetric efficiency. Provided the heat absorbed represents useful refrigeration such as liquid subcooling, the refrigerating effect per pound of refrigerant circulated is increased. With Refrigerants 22 and 717 volume increases faster than refrigerating effect; hence, superheating theoretically reduces capacity. With Refrigerants 12 and 500 the reverse is true, and superheating theoretically reduces both the cfm per ton and the power per ton. Figure 6 illustrates the loss due to superheating of the refrigerant vapor and the gain due to liquid subcooling. Net gain equals the gain minus the loss.

REFRIGERANT PROPERTIES

Refrigerant characteristics have a bearing on system design, application and operation. A refrigerant is selected after an analysis of the required characteristics

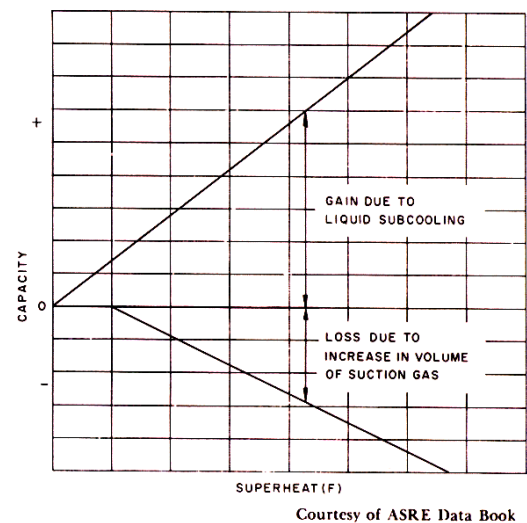


FIG. 6-EFFECT OF LIQUID-SUCTION INTERCHANGER ON CAPACITY

and a matching of these requirements with the specific properties of the available refrigerants.

Significant refrigerant characteristics are:

1. *Flammability and Toxicity* as they pertain to the safety of a refrigerant. The refrigerants treated in this chapter are classified in ASA B9.1 as Group 1, the least hazardous relative to flammability and explosiveness. The Underwriters' Laboratories classification with respect to toxicity puts these refrigerants in Groups 4 to 6. The higher numbered groups in this classification are the least toxic.

Figure 7 shows the structural formula of the refrigerant compounds treated in this chapter. The chlorine and fluorine elements in these refrigerants make them the least hazardous and least toxic respectively.

2. *Miscibility* of a refrigerant with compressor oil aids in the return of oil from the evaporator to the compressor crankcase in reciprocating machine applications. Centrifugal units have separate oil and refrigerant circuits.

Some refrigerants are highly miscible with compressor oil. Refrigerants 12 and 500 and lubricating oils are miscible in any proportion; Refrigerant 22 is less miscible. The effect of miscibility in a refrigeration system is illustrated in Fig. 8. If Refrigerant 12 is placed

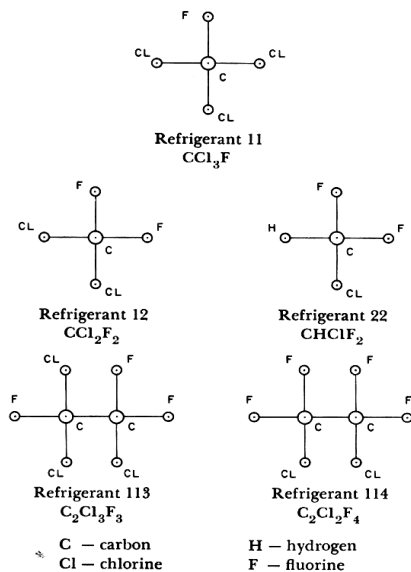


FIG. 7-STRUCTURAL FORMULAS FOR REFRIGERANTS

temperature, all of the refrigerant migrates to the vessel containing oil because of the absorption head of the oil. Raising the oil temperature limits this migration. For instance, if the oil is at an ambient temperature 20 degrees higher than the refrigerant or if the oil is heated by an immersion type heater to 20 degrees higher than the refrigerant temperature (Fig. 8b), only 67% of the oil weight of the refrigerant becomes dissolved in the oil.

3. Theoretical *Horsepower* Per Ton of refrigeration for most refrigerants at air conditioning temperature levels is approximately the same (Table 1).
4. *Rate of Leakage* of a refrigerant gas increases directly with pressure and inversely with molecular weight. The pressure of a refrigerant for a given saturated temperature increases in the following order: Refrigerant 113, 11, 114, 12, 500, 22. The molecular weight of a refrigerant decreases in the following order: Refrigerant 113, 114, 11, 12, 500, 22. Molecular weight is directly related to vapor specific volume; the higher

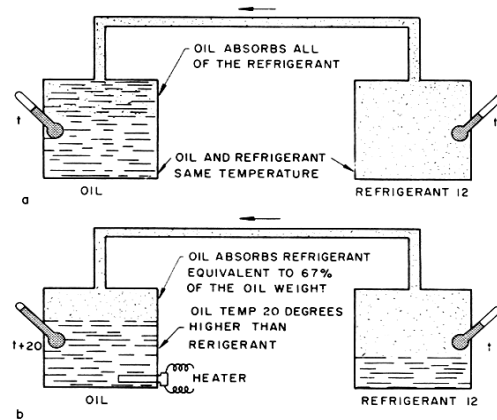


FIG. 8-MISCIBILITY OF REFRIGERANT 12 AND OIL.

The molecular weight, the higher the specific volume

5. *Leak Detection* of the refrigerant should be simple and positive for purposes of maintenance, cost and safety. The use of a halide torch makes it possible to detect and locate minute leaks of the halogen refrigerants.
6. *Vapor Density* influences the compressor displacement and pipe sizing. High vapor density accompanied by a reasonably high latent heat of vaporization (low cfm per ton) is desirable in a refrigerant. A low cfm per ton results in compact equipment and smaller refrigerant piping. Reciprocating refrigeration equipment requires a relatively high vapor density refrigerant for optimum performance. Centrifugal compressors require a low vapor density refrigerant for optimum efficiency at comparatively low tonnages. High vapor density refrigerants are used with centrifugals of large tonnage. The cfm per ton increases in the following order: Refrigerant 22, 500, 12, 114, 11, 113 (Fig. 9).

Cost which is usually a consideration in all selections should not influence the choice of a refrigerant since it generally has little economic bearing on the normal refrigeration system. Although Refrigerant 22 costs approximately twice as much as Refrigerant 12, the compressor required is smaller, tending to offset the additional cost of refrigerant.

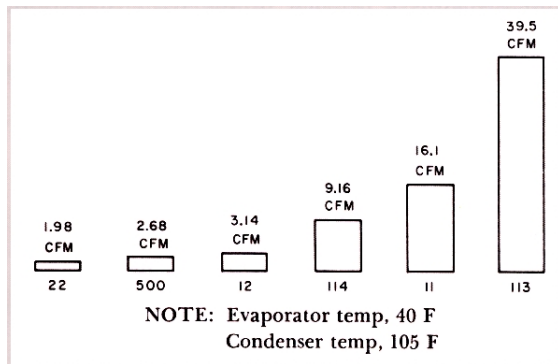


FIG. 9-SUCTION VOLUMES OF REFRIGERANTS
(CFM/TON)

HEAT TRANSFER COMPARISONS

The value of the evaporating and condensing film coefficient (Btu/sq ft/F) for Refrigerant 22 is greater than that for Refrigerants 12 and 500. However, it does not follow that cooling coils and condensers can, therefore, be rated for higher capacities with Refrigerant 22. The higher coefficient for Refrigerant 22 does not tell the complete story.

Various other factors should be considered:

1. Whether the heat exchanger is designed for either Refrigerant 22 or Refrigerants 12 and 500.
2. Whether heat transfer is between refrigerant and air or between refrigerant and water.
3. Whether tubes in a heat exchanger are prime surface or extended surface (including the amount of extended surface.)

The evaporating or condensing film coefficient is one of a number of factors which make up the total over-all transfer rate for the heat exchanger. Other factors involved are these:

1. Tube wall resistance (including extended surface, if any).
2. Air or water film coefficient.
3. Refrigerant pressure drop per circuit, which affects the mean effective temperature difference.
4. Surface ratio of tube outside surface to inside surface.
5. Fouling factors (water-cooled condensers).

COOLING COILS

Cooling coils using Refrigerant 22 normally provide a greater capacity than those using Refrigerant 12 or 500. A cooling coil, normally, has considerable extended surface on the air side of the tubes. The higher

evaporating film coefficient of Refrigerant 22 combined with the extended surface results in a significant increase in the overall heat transfer rate.

When cooling coil is designed to permit a normal pressure drop with Refrigerant 22, it may have a rather large pressure drop with Refrigerant 12 or 500. In such a case the decreased performance for Refrigerants 12 and 500 is due partially to the difference in their condensing film coefficients. In addition, it is affected by the pressure drop and the resulting lower mean effective temperature difference.

CONDENSERS

Water-cooled condensers using Refrigerant 22 normally provide a greater capacity than those using Refrigerant 12 or 500, depending on the fouling factor used in its selection. There are a number of reasons for this improvement other than the basically higher condensing film coefficient of the refrigerant.

1. The water film coefficient is relatively high as compared to air.
2. The extended surface or refrigerant side of the exchanger tubes assures maximum transfer rate and optimum balance between the inside and outside surfaces.

With Refrigerant 12 or 500 the performance of water-cooled condensers is otherwise not adversely affected since the pressure drop in the shell is not a consideration.

Air-cooled condensers using Refrigerant 22 normally provide a greater capacity than those using Refrigerant 12 or 500.

Air-cooled condensers have considerable extended surface on the air side of the tubes. The higher evaporating film coefficient of Refrigerant 22, combined with the extended surface results in a significant increase in the overall heat transfer rate.

When an air-cooled condenser is designed to allow for a normal pressure drop with Refrigerant 22, it may have a considerable pressure drop when used with Refrigerant 500 or 12. In such a case the decreased performance for Refrigerants 500 and 12 is not due entirely to the difference in their condensing film coefficients, but is affected also by pressure drop and the resulting lower mean effective temperature difference.

Normally, evaporative condensers use prime surface tubing (without extended surface on the outside of tubes). Where the unit is designed for Refrigerant 12 or 500, there is no significant increase in capacity when using Refrigerant 22.

If the unit is designed for Refrigerant 22 (smaller tubing or longer circuits), and is used with Refrigerant 12 or 500, the pressure drop is sufficient to reduce the rating. Such a design may create the impression that the increased rating for Refrigerant 22 is due to the condensing film, whereas actually the performance for Refrigerant 12 or 500 decreases due to coil design.

REFRIGERANT SELECTION

COMPRESSION CYCLE

The choice of a refrigerant for a compression system is limited by:

1. Economics,
2. Equipment type and size
3. Application

The manufacturer of the refrigeration compressor generally preselects the refrigerant to result in optimum owning cost. The specific refrigerant is determined by the type and size of the equipment.

To minimize the number of reciprocating compressor sizes required to fill out a line, the manufacturer rates each size for several refrigerants of relatively dense vapor such as Refrigerants 12, 500 and 22. In effect, this increases the number of units offered without adding sizes.

Centrifugal compressors at comparatively low tonnages require a high vapor volume refrigerant such as Refrigerant 113 or 11 to maintain optimum efficiency. For most sizes Refrigerant 114 or 12 can be used to obtain greater capacities. Refrigerants 500 and 22 are used with specially built centrifugals to obtain the highest capacities.

The refrigerant selected depends on the type of application. Air-cooled condensers may not use certain refrigerants because of the design condensing temperature required and corresponding limitations on compressor head pressure.

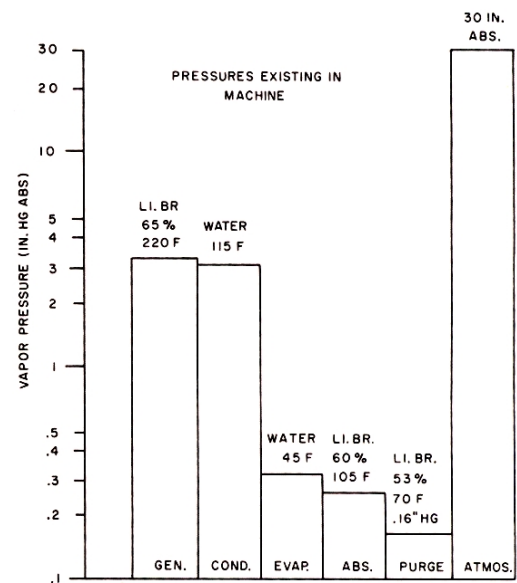
The temperature-pressure relationship of a refrigerant is of considerable importance in low temperature applications. If the evaporator pressure is comparatively low for the required evaporator temperature, the volume of vapor to be handled by the compressor is excessive. If the evaporator pressure is comparatively high for the required evaporator temperature, the system pressures are high.

The refrigerants that have been mentioned are the halogens (fluorinated hydrocarbon compounds), except for Refrigerant 500 which is an azeotropic mixture of two fluorinated hydrocarbons. The mixture does not separate into its component refrigerants with a change of

temperature or pressure. It has its own fixed thermodynamic properties which are unlike either of its components.

ABSORPTION CYCLE

Water as a refrigerant and lithium bromide as an absorbent are utilized in the basic absorption refrigeration cycle. The refrigerant should possess the same desirable qualities as those for a compression system. In addition, it should be suitable for use with an absorbent, so selected that:



NOTE: Absorption machine at full load, using lithium bromide as absorbent.

FIG. 10-PRESSURES AND TEMPERATURES OF A TYPICAL ABSORPTION MACHINE

1. The vapor pressures of the refrigerant and absorbent at the generator are different.
2. The temperature-pressure relations are consistent with practical absorber and generator temperatures and pressures. *Figure 10* shows absolute pressures and temperatures existing in a typical absorption machine at full load.
3. The refrigerant has a high solubility in the absorbent at absorber temperature and pressure and a low solubility at generator temperature and pressure.
4. The refrigerant and absorbent together are stable within the evaporator-generator range of temperatures. Normally, the absorbent must remain liquid at

absorber and generator temperatures and pressures. It should have a low specific heat, surface tension and viscosity and must be neutral to the materials used in the equipment.

REFRIGERANT TABLES

Table 1 is a tabulation of the various refrigerants and their characteristic. *Tables 2 to 7* list the properties of the refrigerants for various saturated temperatures.

TABLE 1—COMPARATIVE DATA OF REFRIGERANTS

REFRIGERANT NUMBER (ARI DESIGNATION)	11	12	22	113	114	500	502
Chemical Name	Trichloromono- fluoromethane	Dichlorodi- fluoromethane	Monochlorodi- fluoromethane	Trichlorotri- fluoroethane	Dichlorotetra- fluoroethane	Azeotrope of Dichlorodi- fluoromethane and Difluoroethane	Azeotrope of chlorodifluoro- thane and M- chloropent- fluoroethane
Chemical Formula	CCl ₃ F	CCl ₂ F ₂	CHClF ₂	CCl ₂ F-CClF ₂	C ₂ Cl ₂ F ₄	73.8% CCl ₂ F ₂ 26.2% CH ₃ CHF ₂	48.8% CHCl ₂ 51.2% CClF ₂
Molecular Wt	137.38	120.93	86.48	187.39	170.93	99.29	111.64
Gas Constant, R (ft-lb/lb-R)	11.25	12.78	17.87	8.25	9.04	15.57	13.87
Boiling Point at 1 atm (F)	74.7	-21.62	-41.4	117.6	38.4	-28.0	-50.1
Freezing Point at 1 atm (F)	-168	-252	-256	-31	-137	-254	*
Critical Temperature (F)	388.0	233.6	204.8	417.4	294.3	221.1	194.1
Critical Pressure (psia)	635.0	597.0	716.0	495.0	474.0	631.0	618.7
Specific Heat of Liquid, 86 F	.220	.235	.335	.218	.238	.300	.305
Specific Heat of Vapor, C _p 60 F at 1 atm	*	.146	.149	*	.156	.171	.164
Specific Heat of Vapor, C _v 60 F at 1 atm	*	.130	.127	*	.145	.151	.161
Ratio $\frac{C_p}{C_v} = K$ (86 F at 1 atm)	1.11	1.14	1.18	1.12	1.09	1.13	1.02
Ratio of Specific Heats Liquid, 105 F Vapor, C _p , 40 F sat. press.	2.04	1.55	2.14	1.47	1.59	1.77	1.97
Liquid Head (ft), psi at 105 F	1.61	1.84	2.04	1.51	1.65	2.10	1.98
Saturation Pressure (psia) at: -50 F	0.52	7.12	11.74	*	1.35	8.395	14.74
0 F	2.55	23.85	38.79	0.84	5.96	27.96	45.94
40 F	7.03	51.67	83.72	2.66	15.22	60.94	94.90
105 F	25.7	141.25	227.65	11.58	50.29	167.85	244.40
Net Refrigerating Effect (Btu/lb) 40 F-105 F (no subcooling)	67.56	49.13	66.44	54.54	43.46	59.82	43.72
Cycle Efficiency (% Carnot Cycle) 40 F-105 F	90.5	83.2	81.8	87.5	84.9	82.0	76.1
Solubility of Water in Refrigerant Miscibility with Oil Toxic Concentration (% by vol)	Negligible Miscible Above 10%	Negligible Miscible Above 20%	Negligible Limited Above 20%	Negligible Miscible Above 5%	Negligible Miscible Above 20%	Negligible Miscible Above 20%	560 ppm @ Limited Above 20
Odor	Ethereal, odorless when mixed with air	Same as R 11	Same as R 11	Same as R 11	Same as R 11	Same as R 11	Same as R
Warning Properties Explosive Range (% by vol) Safety Group, U.L. Safety Group, ASA B9.1 Toxic Decomposition Products	None None 5 1 Yes	None None 6 1 Yes	None None 5A 1 Yes	None None 4-5 1 Yes	None None 6 1 Yes	None None 5A 1 Yes	None None 5A when liq 1 Yes
Viscosity (centipoises) Saturated Liquid 95 F 105 F Vapor at 1 atm 30 F 40 F 50 F	.3893 .3723 .0101 .0103 .0105	.2463 .2395 .0118 .0119 .0121	.2253 .2207 .0120 .0122 .0124	.5845 .5472 .0097 .0098 .0100	.3420 .3272 .0108 .0109 .0111	.2150 .2100 .0117 .0119 .0122	.233 .225 .01175 .01202 .01225
Thermal Conductivity (k) Saturated Liquid 95 F 105 F Vapor at 1 atm 30 F 40 F 50 F	.0596 .0581 .0045 .0046 .0046	.0481 .0469 .0047 .0049 .0051	.0573 .0553 .0060 .0061 .0063	.0512 .0500 .0037 .0039 .0040	.0435 .0421 .0056 .0057 .0059	.044 .042 .0041 .0043 .0045	.03519 .03334 .00585 .00605 .00623
Liquid Circulated, 40 F-105 F (lb/min/ton)	2.96	4.07	3.02	3.66	4.62	3.35	4.58
Theoretical Displacement, 40 F-105 F (cu ft/min/ton)	16.1	3.14	1.98	39.5	9.16	2.69	2.04
Theoretical Horsepower Per Ton 40 F-105 F	0.676	0.736	0.75	0.70	0.722	0.747	.80
Coefficient at Performance 40 F-105 F (4.71/hp per ton)	6.95	6.39	6.29	6.74	6.52	6.31	5.86

TABLE 2-PROPERTIES OF REFRIGERANT 12, LIQUID AND SATURATED VAPOR

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage P	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	
-100	1.4280	27.0138*	0.009985	22.164	100.15	0.045119	-12.466	78.714	66.248	-0.032005	0.18683	-100
-98	1.5381	26.7896*	.010002	20.682	99.978	.048352	-12.055	78.524	66.469	-.030866	.18623	-98
-96	1.6551	26.5514*	.010020	19.316	99.803	.051769	-11.644	78.334	66.690	-.029733	.18565	-96
-94	1.7794	26.2984*	.010037	18.057	99.627	.055379	-11.233	78.144	66.911	-.028606	.18508	-94
-92	1.9112	26.0301*	.010055	16.895	99.451	.059189	-10.821	77.954	67.133	-.027484	.18452	-92
-90	2.0509	25.7456*	0.010073	15.821	99.274	0.063207	-10.409	77.764	67.355	-0.026367	0.18398	-90
-88	2.1988	25.4443*	.010091	14.828	99.097	.067441	-9.9971	77.574	67.577	-.025256	.18345	-88
-86	2.3554	25.1255*	.010109	13.908	98.919	.071900	-9.5845	77.384	67.799	-.024150	.18293	-86
-84	2.5210	24.7884*	.010128	13.056	98.740	.076591	-9.1717	77.194	68.022	-.023049	.18242	-84
-82	2.6960	24.4321*	.010146	12.226	98.561	.081525	-8.7586	77.003	68.244	-.021953	.18192	-82
-80	2.8807	24.0560*	0.010164	11.533	98.382	0.086708	-8.3451	76.812	68.467	-0.020862	0.18143	-80
-78	3.0756	23.6592*	.010183	10.852	98.201	.092151	-7.9314	76.620	68.689	-.019776	.18096	-78
-76	3.2811	23.2409*	.010202	10.218	98.021	.097863	-7.5173	76.429	68.912	-.018695	.18050	-76
-74	3.4975	22.8002*	.010221	9.6290	97.839	.10385	-7.1029	76.238	69.135	-.017619	.18004	-74
-72	3.7254	22.3362*	.010240	9.0802	97.657	.11013	-6.6881	76.046	69.358	-.016547	.17960	-72
-70	3.9651	21.8482*	0.010259	8.5687	97.475	0.11670	-6.2730	75.853	69.580	-0.015481	0.17916	-70
-68	4.2172	21.3350*	.010278	8.0916	97.292	.12359	-5.8574	75.660	69.803	-.014418	.17874	-68
-66	4.4819	20.7959*	.010298	7.6462	97.108	.13078	-5.4416	75.467	70.025	-.013361	.17833	-66
-64	4.7599	20.2299*	.010317	7.2302	96.924	.13831	-5.0254	75.273	70.248	-.012308	.17792	-64
-62	5.0516	19.6360*	.010337	6.8412	96.739	.14617	-4.6088	75.080	70.471	-.011259	.17753	-62
-60	5.3575	19.0133*	0.010357	6.4774	96.553	0.15438	-4.1919	74.885	70.693	-0.010214	0.17714	-60
-58	5.6780	18.3607*	.010377	6.1367	96.367	.16295	-3.7745	74.691	70.916	-.009174	.17676	-58
-56	6.0137	17.6773*	.010397	5.8176	96.180	.17189	-3.3567	74.495	71.138	-.008139	.17639	-56
-54	6.3650	16.9619*	.010417	5.5184	95.993	.18121	-2.9386	74.299	71.360	-.007107	.17603	-54
-52	6.7326	16.2136*	.010438	5.2377	95.804	.19092	-2.5200	74.103	71.583	-.006080	.17568	-52
-50	7.1168	15.4313*	0.010459	4.9742	95.616	0.20104	-2.1011	73.906	71.805	-0.005056	0.17533	-50
-48	7.5183	14.6139*	.010479	4.7267	95.426	.21157	-1.6817	73.709	72.027	-.004037	.17500	-48
-46	7.9375	13.7603*	.010500	4.4940	95.236	.22252	-1.2619	73.511	72.249	-.003022	.17467	-46
-44	8.3751	12.8693*	.010521	4.2751	95.045	.23391	-0.8417	73.312	72.470	-.002011	.17435	-44
-42	8.8316	11.9399*	.010543	4.0691	94.854	.24576	-0.4211	73.112	72.691	-.001003	.17403	-42
-40	9.3076	10.9709*	0.010564	3.8750	94.661	0.25806	0.0000	72.913	72.913	0.000000	0.17373	-40
-38	9.8035	9.9611*	.010586	3.6922	94.469	.27084	0.4215	72.712	73.134	.001000	.17343	-38
-36	10.320	8.909*	.010607	3.5198	94.275	.28411	0.8434	72.511	73.354	.001995	.17313	-36
-34	10.858	7.814*	.010629	3.3571	94.081	.29788	1.2659	72.309	73.575	.002988	.17285	-34
-32	11.417	6.675*	.010651	3.2035	93.886	.31216	1.6887	72.106	73.795	.003976	.17257	-32
-30	11.999	5.490*	0.010674	3.0585	93.690	0.32696	2.1120	71.903	74.015	0.004961	0.17229	-30
-28	12.604	4.259*	.010696	2.9214	93.493	.34231	2.5358	71.698	74.234	.005942	.17203	-28
-26	13.233	2.979*	.010719	2.7917	93.296	.35820	2.9601	71.494	74.454	.006919	.17177	-26
-24	13.886	1.649*	.010741	2.6691	93.098	.37466	3.3848	71.288	74.673	.007894	.17151	-24
-22	14.564	0.270*	.010764	2.5529	92.899	.39171	3.8100	71.081	74.891	.008864	.17126	-22
-20	15.267	0.571	0.010788	2.4429	92.699	0.40934	4.2357	70.874	75.110	0.009831	0.17102	-20
-18	15.996	1.300	.010811	2.3387	92.499	.42758	4.6618	70.666	75.328	.010795	.17078	-18
-16	16.753	2.057	.010834	2.2399	92.298	.44645	5.0885	70.456	75.545	.011755	.17055	-16
-14	17.536	2.840	.010858	2.1461	92.096	.46595	5.5157	70.246	75.762	.012712	.17032	-14
-12	18.348	3.652	.010882	2.0572	91.893	.48611	5.9434	70.036	75.979	.013666	.17010	-12
-10	19.189	4.493	0.010906	1.9727	91.689	0.50693	6.3716	69.824	76.196	0.014617	0.16989	-10
-8	20.059	5.363	.010931	1.8924	91.485	.52843	6.8003	69.611	76.411	.015564	.16967	-8
-6	20.960	6.264	.010955	1.8161	91.280	.55063	7.2296	69.397	76.627	.016508	.16947	-6
-4	21.891	7.195	.010980	1.7436	91.074	.57354	7.6594	69.183	76.842	.017449	.16927	-4
-2	22.854	8.158	.011005	1.6745	90.867	.59718	8.0898	68.967	77.057	.018388	.16907	-2
0	23.849	9.153	0.011030	1.6089	90.659	0.62156	8.5207	68.750	77.271	0.019323	0.16888	0
2	24.878	10.182	.011056	1.5463	90.450	.64670	8.9522	68.533	77.485	.020255	.16869	2
4	25.939	11.243	.011082	1.4867	90.240	.67263	9.3843	68.314	77.698	.021184	.16851	4
6	27.036	12.340	.011107	1.4299	90.030	.69934	9.8169	68.094	77.911	.022110	.16833	6
8	28.167	13.471	.011134	1.3758	89.818	.72687	10.250	67.873	78.123	.023033	.16815	8
10	29.335	14.639	0.011160	1.3241	89.606	0.75523	10.684	67.651	78.335	0.023954	0.16798	10
12	30.539	15.843	.011187	1.2748	89.392	.78443	11.118	67.428	78.546	.024871	.16782	12
14	31.780	17.084	.011214	1.2278	89.178	.81449	11.554	67.203	78.757	.025786	.16765	14
16	33.060	18.364	.011241	1.1828	88.962	.84544	11.989	66.977	78.966	.026699	.16750	16
18	34.378	19.682	.011268	1.1399	88.746	.87729	12.426	66.750	79.176	.027608	.16734	18
20	35.736	21.040	0.011296	1.0988	88.529	0.91006	12.863	66.522	79.385	0.028515	0.16719	20
22	37.135	22.439	.011324	1.0596	88.310	.94377	13.300	66.293	79.593	.029420	.16704	22
24	38.574	23.878	.011352	1.0220	88.091	.97843	13.739	66.061	79.800	.030322	.16690	24
26	40.056	25.360	.011380	0.98612	87.870	1.0141	14.178	65.829	80.007	.031221	.16676	26
28	41.580	26.884	.011409	0.95173	87.649	1.0507	14.618	65.596	80.214	.032118	.16662	28

*Inches of mercury below one atmosphere.

Courtesy of E. I. du Pont de Nemours & Co.

TABLE 2-PROPERTIES OF REFRIGERANT 12, LIQUID AND SATURATED VAPOR (Contd)

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage p	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	
30	43.148	28.452	0.011438	0.91880	87.426	1.0884	15.058	65.361	80.419	0.033013	0.16648	30
32	44.760	30.064	.011468	.88725	87.202	1.1271	15.500	65.124	80.624	.033905	.16635	32
34	46.417	31.721	.011497	.85702	86.977	1.1668	15.942	64.886	80.828	.034796	.16622	34
36	48.120	33.424	.011527	.82803	86.751	1.2077	16.384	64.647	81.031	.035683	.16610	36
38	49.870	35.174	.011557	.80023	86.524	1.2496	16.828	64.406	81.234	.036569	.16598	38
40	51.667	36.971	0.011588	0.77357	86.296	1.2927	17.273	64.163	81.436	0.037453	0.16586	40
42	53.513	38.817	.011619	.74798	86.066	1.3369	17.718	63.919	81.637	.038334	.16574	42
44	55.407	40.711	.011650	.72341	85.836	1.3823	18.164	63.673	81.837	.039213	.16562	44
46	57.352	42.656	.011682	.69982	85.604	1.4289	18.611	63.426	82.037	.040091	.16551	46
48	59.347	44.651	.011714	.67715	85.371	1.4768	19.059	63.177	82.236	.040966	.16540	48
50	61.394	46.698	0.011746	0.65537	85.136	1.5258	19.507	62.926	82.433	0.041839	0.16530	50
52	63.494	48.798	.011779	.63444	84.900	1.5762	19.957	62.673	82.630	.042711	.16519	52
54	65.646	50.950	.011811	.61431	84.663	1.6278	20.408	62.418	82.826	.043581	.16509	54
56	67.853	53.157	.011845	.59495	84.425	1.6808	20.859	62.162	83.021	.044449	.16499	56
58	70.115	55.419	.011879	.57632	84.185	1.7352	21.312	61.903	83.215	.045316	.16489	58
60	72.433	57.737	0.011913	0.55839	83.944	1.7909	21.766	61.643	83.409	0.046180	0.16479	60
62	74.807	60.111	.011947	.54112	83.701	1.8480	22.221	61.380	83.601	.047044	.16470	62
64	77.239	62.543	0.011982	.52450	83.457	1.9066	22.676	61.116	83.792	.047905	.16460	64
66	79.729	65.033	.012017	.50848	83.212	1.9666	23.133	60.849	83.982	.048765	.16451	66
68	82.279	67.583	.012053	.49305	82.965	2.0282	23.591	60.580	84.171	.049624	.16442	68
70	84.888	70.192	0.012089	0.47818	82.717	2.0913	24.050	60.309	84.359	0.050482	0.16434	70
72	87.559	72.863	.012126	.46383	82.467	2.1559	24.511	60.035	84.546	.051338	.16425	72
74	90.292	75.596	.012163	.45000	82.215	2.2222	24.973	59.759	84.732	.052193	.16417	74
76	93.087	78.391	.012201	.43666	81.962	2.2901	25.435	59.481	84.916	.053047	.16408	76
78	95.946	81.250	.012239	.42378	81.707	2.3597	25.899	59.201	85.100	.053900	.16400	78
80	98.870	84.174	0.012277	0.41135	81.450	2.4310	26.365	58.917	85.282	0.054751	0.16392	80
82	101.86	87.16	.012316	.39935	81.192	2.5041	26.832	58.631	85.463	.055602	.16384	82
84	104.92	90.22	.012356	.38776	80.932	2.5789	27.300	58.343	85.643	.056452	.16376	84
86	108.04	93.34	0.012396	.37657	80.671	2.6556	27.769	58.052	85.821	.057301	.16368	86
88	111.23	96.53	0.012437	.36575	80.407	2.7341	28.241	57.757	85.998	.058149	.16360	88
90	114.49	99.79	0.012478	0.35529	80.142	2.8146	28.713	57.461	86.174	0.058997	0.16353	90
92	117.82	103.12	.012520	.34518	79.874	2.8970	29.187	57.161	86.348	.059844	.16345	92
94	121.22	106.52	.012562	.33540	79.605	2.9815	29.663	56.858	86.521	.060690	.16338	94
96	124.70	110.00	.012605	.32594	79.334	3.0680	30.140	56.551	86.691	.061536	.16330	96
98	128.24	113.54	.012649	.31679	79.061	3.1566	30.619	56.242	86.861	.062381	.16323	98
100	131.86	117.16	0.012693	0.30794	78.785	3.2474	31.100	55.929	87.029	0.063227	0.16315	100
102	135.56	120.86	.012738	.29937	78.508	3.3404	31.583	55.613	87.196	.064072	.16308	102
104	139.33	124.63	.012783	.29106	78.228	3.4357	32.067	55.293	87.360	.064916	.16301	104
106	143.18	128.48	.012829	.28303	77.946	3.5333	32.553	54.970	87.523	.065761	.16293	106
108	147.11	132.41	.012876	.27524	77.662	3.6332	33.041	54.643	87.684	.066606	.16286	108
110	151.11	136.41	0.012924	0.26769	77.376	3.7357	33.531	54.313	87.844	0.067451	0.16279	110
112	155.19	140.49	.012972	.26037	77.087	3.8406	34.023	53.978	88.001	.068296	.16271	112
114	159.36	144.66	.013022	.25328	76.795	3.9482	34.517	53.639	88.156	.069141	.16264	114
116	163.61	148.91	.013072	.24641	76.501	4.0584	35.014	53.296	88.310	.069987	.16256	116
118	167.94	153.24	.013123	.23974	76.205	4.1713	35.512	52.949	88.461	.070833	.16249	118
120	172.35	157.65	0.013174	0.23326	75.906	4.2870	36.013	52.597	88.610	0.071680	0.16241	120
122	176.85	162.15	.013227	.22698	75.604	4.4056	36.516	52.241	88.757	.072528	.16234	122
124	181.43	166.73	.013280	.22089	75.299	4.5272	37.021	51.881	88.902	.073376	.16226	124
126	186.10	171.40	.013335	.21497	74.991	4.6518	37.529	51.515	89.044	.074225	.16218	126
128	190.86	176.16	.013390	.20922	74.680	4.7796	38.040	51.144	89.184	.075075	.16210	128
130	195.71	181.01	0.013447	0.20364	74.367	4.9107	38.553	50.768	89.321	0.075927	0.16202	130
132	200.64	185.94	.013504	.19821	74.050	5.0451	39.069	50.387	89.456	.076779	.16194	132
134	205.67	190.97	.013563	.19294	73.729	5.1829	39.588	50.000	89.588	.077623	.16185	134
136	210.79	196.09	.013623	.18782	73.406	5.3244	40.110	49.608	89.718	.078489	.16177	136
138	216.01	201.31	.013684	.18283	73.079	5.4695	40.634	49.210	89.844	.079346	.16168	138
140	221.32	206.62	0.013746	0.17799	72.748	5.6184	41.162	48.805	89.967	0.080205	0.16159	140
142	226.72	212.02	.013810	.17327	72.413	5.7713	41.693	48.394	90.087	.081065	.16150	142
144	232.22	217.52	.013874	.16868	72.075	5.9283	42.227	47.977	90.204	.081928	.16140	144
146	237.82	223.12	.013941	.16422	71.732	6.0895	42.765	47.553	90.318	.082794	.16130	146
148	243.51	228.81	.014008	.15987	71.386	6.2551	43.306	47.122	90.428	.083661	.16120	148
150	249.31	234.61	0.014078	0.15564	71.035	6.4252	43.850	46.684	90.534	0.084531	0.16110	150
152	255.20	240.50	.014148	.15151	70.679	6.6001	44.399	46.238	90.637	.085404	.16099	152
154	261.20	246.50	.014221	.14750	70.319	6.7799	44.951	45.784	90.735	.086280	.16088	154
156	267.30	252.60	.014295	.14358	69.954	6.9648	45.508	45.322	90.830	.087159	.16077	156
158	273.51	258.81	.014371	.13976	69.584	7.1551	46.068	44.852	90.920	.088041	.16065	158
160	279.82	265.12	0.014449	0.13604	69.209	7.3509	46.633	44.373	91.006	0.088927	0.16053	160

TABLE 3-PROPERTIES OF REFRIGERANT 500, LIQUID AND SATURATED VAPOR

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage p	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	
-40	10.84	7.86*	0.0119	4.0757	84.37	0.2454	0.00	89.91	89.91	0.00000	0.21421	-40
-38	11.42	6.68*	.0119	3.8829	84.19	.2575	0.51	89.68	90.19	.00122	.21387	-38
-36	12.03	5.44*	.0119	3.6992	84.00	.2703	1.02	89.45	90.47	.00243	.21352	-36
-34	12.66	4.15*	.0119	3.5276	83.82	.2835	1.54	89.21	90.75	.00365	.21318	-34
-32	13.31	2.83*	.0120	3.3671	83.63	.2970	2.05	88.97	91.02	.00485	.21286	-32
-30	14.00	1.40*	0.0120	3.2121	83.45	0.3113	2.57	88.73	91.30	0.00606	0.21252	-30
-28	14.71	0.01	.0120	3.0674	83.26	.3260	3.09	88.49	91.58	.00725	.21221	-28
-26	15.45	0.75	.0120	2.9302	83.07	.3413	3.60	88.25	91.85	.00845	.21189	-26
-24	16.21	1.51	.0121	2.8020	82.89	.3569	4.13	88.00	92.13	.00963	.21160	-24
-22	17.01	2.31	.0121	2.6788	82.70	.3733	4.65	87.75	92.40	.01083	.21130	-22
-20	17.84	3.14	0.0121	2.5622	82.51	0.3903	5.17	87.50	92.67	0.01202	0.21101	-20
-18	18.70	4.00	.0121	2.4520	82.32	.4078	5.70	87.25	92.95	.01322	.21072	-18
-16	19.59	4.89	.0122	2.3477	82.13	.4260	6.22	87.00	93.22	.01438	.21044	-16
-14	20.51	5.81	.0122	2.2491	81.94	.4446	6.75	86.74	93.49	.01557	.21017	-14
-12	21.47	6.77	.0122	2.1548	81.75	.4641	7.27	86.49	93.76	.01674	.20991	-12
-10	22.46	7.76	0.0123	2.0657	81.56	0.4841	7.80	86.23	94.03	0.01793	0.20965	-10
-8	23.49	8.79	.0123	1.9807	81.37	.5049	8.33	85.97	94.30	.01909	.20939	-8
-6	24.55	9.85	.0123	1.9004	81.17	.5262	8.87	85.70	94.57	.02027	.20914	-6
-4	25.65	10.95	.0123	1.8238	80.98	.5483	9.40	85.44	94.84	.02144	.20890	-4
-2	26.79	12.09	.0124	1.7507	80.78	.5712	9.94	85.17	95.11	.02259	.20866	-2
0	27.96	13.26	0.0124	1.6818	80.59	0.5946	10.47	84.90	95.37	0.02376	0.20843	0
2	29.18	14.48	.0124	1.6155	80.39	.6190	11.01	84.63	95.64	.02491	.20819	2
4	30.43	15.73	.0125	1.5530	80.20	.6439	11.55	84.35	95.90	.02608	.20797	4
6	31.73	17.03	.0125	1.4929	80.00	.6698	12.09	84.08	96.17	.02722	.20775	6
8	33.06	18.36	.0125	1.4362	79.80	.6963	12.63	83.80	96.43	.02839	.20754	8
10	34.45	19.75	0.0126	1.3813	79.60	0.7239	13.17	83.52	96.69	0.02954	0.20732	10
12	35.88	21.18	.0126	1.3292	79.40	.7523	13.71	83.24	96.95	.03067	.20711	12
14	37.35	22.65	.0126	1.2796	79.20	.7815	14.26	82.95	97.21	.03182	.20691	14
16	38.86	24.16	.0127	1.2325	79.00	.8114	14.81	82.66	97.47	.03296	.20672	16
18	40.42	25.72	.0127	1.1873	78.80	.8422	15.35	82.37	97.72	.03411	.20652	18
20	42.03	27.33	0.0127	1.1440	78.59	0.8741	15.91	82.07	97.98	0.03526	0.20633	20
22	43.69	28.99	.0128	1.1027	78.39	0.9069	16.45	81.78	98.23	.03638	.20614	22
24	45.40	30.70	.0128	1.0631	78.18	0.9407	17.01	81.48	98.49	.03752	.20595	24
26	47.15	32.45	.0128	1.0254	77.98	0.9752	17.56	81.18	98.74	.03865	.20578	26
28	48.96	34.26	.0129	0.9892	77.77	1.0109	18.12	80.87	98.99	.03978	.20560	28
30	50.82	36.12	0.0129	0.9545	77.56	1.0476	18.67	80.57	99.24	0.04092	0.20542	30
32	52.74	38.04	.0129	.9212	77.35	1.0855	19.22	80.26	99.48	.04203	.20525	32
34	54.71	40.01	.0130	.8894	77.14	1.1244	19.79	79.94	99.73	.04316	.20508	34
36	56.72	42.02	.0130	.8591	76.93	1.1640	20.34	79.63	99.97	.04430	.20491	36
38	58.80	44.10	.0130	.8298	76.72	1.2051	20.91	79.31	100.22	.04542	.20475	38
40	60.94	46.24	0.0131	0.8017	76.50	1.2473	21.47	78.99	100.46	0.04654	0.20458	40
42	63.14	48.44	.0131	.7747	76.29	1.2908	22.03	78.67	100.70	.04764	.20442	42
44	65.39	50.69	.0131	.7490	76.07	1.3352	22.60	78.34	100.94	.04875	.20426	44
46	67.71	53.01	.0132	.7241	75.86	1.3811	23.16	78.01	101.17	.04986	.20410	46
48	70.09	55.39	.0132	.7002	75.64	1.4282	23.75	77.66	101.41	.05099	.20395	48
50	72.52	57.82	0.0133	0.6774	75.42	1.4763	24.31	77.33	101.64	0.05212	0.20380	50
52	75.02	60.32	.0133	.6554	75.20	1.5258	24.88	76.99	101.87	.05321	.20365	52
54	77.57	62.87	.0133	.6343	74.97	1.5764	25.46	76.64	102.10	.05431	.20350	54
56	80.22	65.52	.0134	.6138	74.75	1.6291	26.04	76.29	102.33	.05543	.20335	56
58	82.91	68.21	.0134	.5943	74.52	1.6826	26.59	75.96	102.55	.05649	.20320	58
60	85.66	70.96	0.0135	0.5756	74.30	1.7374	27.19	75.59	102.78	0.05763	0.20306	60
62	88.49	73.79	.0135	.5575	74.07	1.7939	27.76	75.24	103.00	.05872	.20291	62
64	91.39	76.69	.0135	.5400	73.84	1.8518	28.33	74.89	103.22	.05979	.20277	64
66	94.37	79.67	.0136	.5231	73.61	1.9116	28.92	74.51	103.43	.06091	.20262	66
68	97.41	82.71	.0136	.5069	73.38	1.9727	29.52	74.13	103.65	.06203	.20248	68
70	100.51	85.81	0.0137	0.4914	73.14	2.0350	30.10	73.76	103.86	0.06311	0.20234	70
72	103.71	89.01	.0137	.4763	72.91	2.0996	30.68	73.39	104.07	.06419	.20220	72
74	106.97	92.27	.0138	.4618	72.67	2.1655	31.27	73.01	104.28	.06527	.20206	74
76	110.29	95.59	.0138	.4479	72.43	2.2328	31.87	72.62	104.49	.06637	.20192	76
78	113.70	99.00	.0139	.4344	72.19	2.3021	32.47	72.22	104.69	.06749	.20178	78
80	117.20	102.5	0.0139	0.4213	71.95	2.3735	33.06	71.83	104.89	0.06855	0.20164	80
82	120.78	106.1	.0139	.4087	71.70	2.4469	33.63	71.46	105.09	.06959	.20149	82
84	124.40	109.7	.0140	.3967	71.46	2.5210	34.24	71.04	105.28	.07071	.20136	84
86	128.14	113.4	.0140	.3849	71.21	2.5981	34.84	70.63	105.47	.07179	.20121	86
88	131.96	117.3	.0141	.3735	70.96	2.6772	35.44	70.22	105.66	.07288	.20107	88

*Inches of mercury below one atmosphere.

TABLE 3-PROPERTIES OF REFRIGERANT 500, LIQUID AND SATURATED VAPOR (Contd)

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage p	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	
90	135.86	121.2	0.0141	0.3626	70.70	2.7581	36.04	69.81	105.85	0.07395	0.20092	90
92	139.83	125.1	.0142	.3520	70.45	2.8409	36.66	69.37	106.03	.07505	.20078	92
94	143.90	129.2	.0142	.3418	70.19	2.9261	37.26	68.96	106.22	.07611	.20064	94
96	148.03	133.3	.0143	.3319	69.93	3.0128	37.88	68.51	106.39	.07722	.20049	96
98	152.27	137.6	.0144	.3223	69.67	3.1024	38.47	68.10	106.57	.07826	.20035	98
100	156.61	141.9	0.0144	0.3130	69.41	3.1947	39.09	67.65	106.74	0.07935	0.20019	100
102	161.02	146.3	.0145	.3041	69.14	3.2889	39.71	67.20	106.91	.08042	.20004	102
104	165.55	150.9	.0145	.2953	68.87	3.3860	40.33	66.74	107.07	.08151	.19989	104
106	170.14	155.4	.0146	.2869	68.60	3.4850	40.96	66.27	107.23	.08261	.19974	106
108	174.84	160.1	.0146	.2788	68.33	3.5871	41.59	65.80	107.39	.08367	.19958	108
110	179.62	164.9	0.0147	0.2709	68.05	3.6914	42.22	65.32	107.54	0.08479	0.19942	110
112	184.51	169.8	.0148	.2632	67.78	3.7990	42.82	64.87	107.69	.08482	.19926	112
114	189.47	174.8	.0148	.2558	67.49	3.9086	43.47	64.37	107.84	.08691	.19910	114
116	194.55	179.9	.0149	.2486	67.21	4.0218	44.11	63.87	107.98	.08800	.19893	116
118	199.71	185.0	.0149	.2417	66.92	4.1376	44.72	63.40	108.12	.08905	.19876	118
120	204.99	190.3	0.0150	0.2349	66.63	4.2566	45.35	62.90	108.25	0.09012	0.19859	120
122	210.40	195.7	.0151	.2283	66.34	4.3807	46.02	62.35	108.37	.09124	.19841	122
124	215.88	201.2	.0151	.2219	66.04	4.5068	46.69	61.81	108.50	.09236	.19823	124
126	221.44	206.7	.0152	.2157	65.74	4.6357	47.33	61.29	108.62	.09342	.19805	126
128	227.13	212.4	.0153	.2097	65.43	4.7690	47.98	60.75	108.73	.09451	.19786	128
130	232.89	218.2	0.0154	0.2039	65.13	4.9050	48.65	60.19	108.84	0.09560	0.19767	130
132	238.80	224.1	.0154	.1982	64.81	5.0463	49.28	59.66	108.94	.09666	.19747	132
134	244.84	230.1	.0155	.1926	64.49	5.1924	49.91	59.13	109.04	.09771	.19726	134
136	250.96	236.3	.0156	.1872	64.17	5.3420	50.59	58.54	109.13	.09883	.19705	136
138	257.17	242.5	.0157	.1820	63.85	5.4951	51.30	57.91	109.21	.09996	.19684	138
140	263.52	248.8	0.0157	0.1769	63.52	5.6528	52.02	57.27	109.29	0.10114	0.19663	140
142	269.99	255.3	.0158	.1719	63.18	5.8170	52.73	56.63	109.36	.10228	.19639	142
144	276.55	261.9	.0159	.1670	62.84	5.9878	53.45	55.97	109.42	.10344	.19615	144
146	283.24	268.5	.0160	.1623	62.49	6.1626	54.15	55.33	109.48	.10456	.19591	146
148	290.04	275.3	.0161	.1577	62.14	6.3431	54.86	54.67	109.53	.10569	.19565	148
150	296.97	282.3	0.0162	0.1531	61.78	6.5304	55.62	53.95	109.57	0.10691	0.19539	150
152	304.01	289.3	.0163	.1487	61.42	6.7241	56.34	53.25	109.59	.10806	.19511	152
154	311.18	296.5	.0164	.1444	61.05	6.9253	57.07	52.54	109.61	.10922	.19483	154
156	318.47	303.8	.0165	.1402	60.66	7.1342	57.82	51.80	109.62	.11040	.19453	156
158	325.87	311.2	.0166	.1360	60.28	7.3510	58.61	51.01	109.62	.11163	.19421	158
160	333.40	318.7	0.0167	0.1320	59.88	7.5772	59.35	50.25	109.60	0.11280	0.19389	160

TABLE 4-PROPERTIES OF REFRIGERANT 22, LIQUID AND SATURATED VAPOR

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage P	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	
-155	0.2088	29.50*	0.01014	180.8	98.67	0.005531	-27.10	114.04	86.95	-0.07512	0.2292	-155
-150	0.2716	29.37*	.01018	141.2	98.24	0.007081	-25.97	113.50	87.52	-.07147	.2950	-150
-145	0.3500	29.21*	.01023	111.3	97.80	0.008982	-24.85	112.95	88.10	-.06787	.2911	-145
-140	0.4470	29.01*	.01027	88.53	97.36	0.01130	-23.73	112.41	88.68	-.06432	.2873	-140
-135	0.5658	28.77*	.01032	70.98	96.92	0.01409	-22.60	111.86	89.26	-.06082	.2837	-135
-130	0.7106	28.47*	0.01037	57.36	96.48	0.01744	-21.46	111.31	89.85	-0.05736	0.2803	-130
-125	0.8855	28.19*	.01041	46.69	96.04	0.02142	-20.33	110.76	90.43	-.05394	.2770	-125
-120	1.095	27.69*	.01046	38.28	95.59	0.02612	-19.19	110.21	91.02	-.05055	.2739	-120
-115	1.346	27.18*	.01051	31.59	95.14	0.03165	-18.04	109.65	91.61	-.04720	.2709	-115
-110	1.642	26.58*	.01056	26.24	94.68	0.03811	-16.89	109.08	92.20	-.04389	.2681	-110
-105	1.990	25.87*	0.01061	21.93	94.23	0.04560	-15.73	108.51	92.78	-0.04060	0.2653	-105
-100	2.398	25.04*	.01066	18.43	93.77	0.05425	-14.56	107.94	93.37	-.03734	.2627	-100
-95	2.873	24.07*	.01072	15.58	93.31	0.06419	-13.39	107.35	93.96	-.03411	.2603	-95
-90	3.423	22.95*	.01077	13.24	92.84	0.07556	-12.22	106.76	94.54	-.03091	.2579	-90
-85	4.056	21.66*	.01083	11.30	92.38	0.08849	-11.03	106.16	95.13	-.02773	.2556	-85
-80	4.782	20.19*	0.01088	9.695	91.91	0.1032	-9.838	105.55	95.71	-0.02457	0.2534	-80
-78	5.101	19.54*	.01090	9.130	91.72	0.1095	-9.359	105.30	95.94	-.02331	.2526	-78
-76	5.436	18.85*	.01093	8.604	91.53	0.1162	-8.878	105.05	96.18	-.02206	.2517	-76
-74	5.790	18.13*	.01095	8.115	91.34	0.1232	-8.397	104.80	96.41	-.02081	.2509	-74
-72	6.161	17.38*	.01097	7.658	91.14	0.1306	-7.914	104.55	96.64	-.01956	.2501	-72
-70	6.552	16.58*	0.01096	7.232	90.95	0.1383	-7.429	104.30	96.87	-0.01832	0.2493	-70
-68	6.962	15.75*	.01102	6.834	90.76	0.1463	-6.944	104.04	97.10	-.01708	.2486	-68
-66	7.393	14.87*	.01104	6.463	90.57	0.1548	-6.457	103.79	97.33	-.01584	.2478	-66
-64	7.846	13.95*	.01107	6.114	90.37	0.1636	-5.968	103.53	97.56	-.01460	.2470	-64
-62	8.321	12.98*	.01109	5.789	90.18	0.1727	-5.479	103.26	97.79	-.01337	.2463	-62
-60	8.818	11.97*	0.01113	5.484	89.99	0.1823	-4.987	103.00	98.01	-0.01214	0.2456	-60
-58	9.339	10.91*	.01114	5.199	89.79	0.1924	-4.495	102.74	98.24	-.01092	.2448	-58
-56	9.884	9.798*	.01116	4.931	89.60	0.2028	-4.001	102.47	98.47	-.00969	.2441	-56
-54	10.45	8.636*	.01119	4.680	89.40	0.2137	-3.506	102.20	98.69	-.00847	.2435	-54
-52	11.05	7.422*	.01121	4.444	89.20	0.2250	-3.009	101.93	98.92	-.00725	.2428	-52
-50	11.67	6.154*	0.01124	4.222	89.00	0.2368	-2.511	101.66	99.14	-0.00604	0.2421	-50
-48	12.34	4.829*	.01126	4.014	88.81	0.2491	-2.012	101.38	99.37	-.00483	.2414	-48
-46	13.06	3.445*	.01129	3.818	88.61	0.2619	-1.511	101.10	99.59	-.00361	.2408	-46
-44	13.71	2.002*	.01131	3.633	88.41	0.2752	-1.009	100.82	99.81	-.00241	.2401	-44
-42	14.45	0.498*	.01134	3.460	88.21	0.2891	-0.505	100.54	100.04	-.00120	.2395	-42
-40	15.22	0.526	0.01136	3.296	88.01	0.3034	0.000	100.26	100.36	0.00000	0.2389	-40
-38	16.02	1.328	.01139	3.141	87.81	0.3184	0.506	99.97	100.48	.00120	.2383	-38
-36	16.86	2.163	.01142	2.995	87.60	0.3338	1.014	99.68	100.70	.00240	.2377	-36
-34	17.73	3.032	.01144	2.858	87.40	0.3499	1.524	99.39	100.91	.00359	.2371	-34
-32	18.63	3.937	.01147	2.728	87.20	0.3666	2.035	99.10	101.13	.00479	.2365	-32
-30	19.57	4.877	0.01150	2.605	86.99	0.3839	2.547	98.80	101.35	0.00598	0.2359	-30
-28	20.55	5.853	.01152	2.488	86.79	0.4018	3.061	98.50	101.56	.00716	.2353	-28
-26	21.56	6.868	.01155	2.379	86.58	0.4204	3.576	98.20	101.78	.00835	.2348	-26
-24	22.62	7.921	.01158	2.275	86.37	0.4396	4.093	97.90	101.99	.00953	.2342	-24
-22	23.71	9.015	.01161	2.176	86.17	0.4596	4.611	97.59	102.20	.01072	.2337	-22
-20	24.85	10.15	0.01163	2.083	85.96	0.4802	5.131	97.29	102.42	0.01189	0.2332	-20
-18	26.02	11.32	.01166	1.994	85.75	0.5015	5.652	96.97	102.63	.01307	.2326	-18
-16	27.24	12.54	.01169	1.910	85.54	0.5236	6.175	96.66	102.84	.01425	.2321	-16
-14	28.50	13.81	.01172	1.830	85.33	0.5464	6.699	96.34	103.04	.01542	.2316	-14
-12	29.81	15.11	.01175	1.754	85.11	0.5700	7.224	96.03	103.25	.01659	.2311	-12
-10	31.16	16.47	0.01178	1.683	84.90	0.5944	7.751	95.70	103.46	0.01776	0.2306	-10
-8	32.56	17.87	.01181	1.614	84.69	0.6195	8.280	95.38	103.66	.01892	.2301	-8
-6	34.01	19.32	.01184	1.549	84.47	0.6456	8.810	95.05	103.86	.02009	.2296	-6
-4	35.51	20.81	.01187	1.487	84.26	0.6724	9.341	94.72	104.07	.02125	.2291	-4
-2	37.06	22.36	.01190	1.428	84.04	0.7001	9.874	94.39	104.27	.02241	.2286	-2
0	38.66	23.96	0.01193	1.372	83.83	0.7287	10.41	94.06	104.47	0.02357	0.2282	0
2	40.31	25.61	.01196	1.319	83.61	0.7582	10.95	93.72	104.66	.02472	.2277	2
4	42.01	27.32	.01199	1.268	83.39	0.7887	11.48	93.38	104.86	.02587	.2273	4
6	43.78	29.08	.01202	1.220	83.17	0.8200	12.02	93.03	105.06	.02703	.2268	6
8	45.59	30.90	.01206	1.173	82.95	0.8524	12.56	92.69	105.25	.02818	.2264	8
10	47.46	32.77	0.01209	1.129	82.72	0.8857	13.10	92.34	105.44	0.02932	0.2259	10
12	49.40	34.70	.01212	1.087	82.50	0.9201	13.65	91.99	105.63	.03047	.2255	12
14	51.39	36.69	.01215	1.047	82.28	0.9554	14.19	91.63	105.82	.03161	.2251	14
16	53.44	38.74	.01219	1.008	82.05	0.9919	14.74	91.27	106.01	.03275	.2246	16
18	55.55	40.86	.01222	0.9714	81.83	1.029	15.29	90.91	106.20	.03389	.2242	18
20	57.73	43.03	0.01226	0.9363	81.60	1.068	15.84	90.55	106.38	0.03503	0.2238	20
22	59.97	45.27	.01229	0.9027	81.37	1.108	16.39	90.18	106.57	.03617	.2234	22
24	62.27	47.58	.01233	0.8706	81.14	1.149	16.94	89.81	106.75	.03730	.2230	24
26	64.64	49.95	.01236	0.8398	80.91	1.191	17.50	89.43	106.93	.03844	.2226	26
28	67.08	52.39	.01240	0.8103	80.68	1.234	18.05	89.06	107.11	.03958	.2222	28

*Inches of mercury below one atmosphere.

Courtesy of E. I. du Pont de Nemours & Co. 1964

TABLE 4-PROPERTIES OF REFRIGERANT 22, LIQUID AND SATURATED VAPOR (Contd)

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage P	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	
30	69.59	54.90	0.01243	0.7821	80.44	1.279	18.61	88.67	107.28	0.04070	0.2218	30
32	72.17	57.47	.01247	0.7550	80.21	1.324	19.17	88.29	107.46	.04182	.2214	32
34	74.82	60.12	.01251	0.7291	79.97	1.372	19.73	87.90	107.63	.04295	.2210	34
36	77.54	62.84	.01254	0.7043	79.73	1.420	20.29	87.51	107.80	.04407	.2206	36
38	80.34	65.64	.01258	0.6804	79.50	1.470	20.86	87.12	107.97	.04520	.2202	38
40	83.21	68.51	0.01262	0.6575	79.26	1.521	21.42	86.72	108.14	0.04632	0.2199	40
42	86.15	71.46	.01266	0.6356	79.01	1.573	21.99	86.32	108.31	.04744	.2195	42
44	89.18	74.48	.01270	0.6149	78.77	1.627	22.56	85.91	108.47	.04855	.2191	44
46	92.28	77.58	.01274	0.5942	78.53	1.683	23.13	85.51	108.63	.04967	.2188	46
48	95.46	80.77	.01278	0.5748	78.28	1.740	23.70	85.09	108.80	.05079	.2184	48
50	98.73	84.03	0.01282	0.5561	78.03	1.798	24.28	84.68	108.95	0.05190	0.2180	50
52	102.07	87.38	.01286	0.5381	77.78	1.859	24.85	84.26	109.11	.05301	.2177	52
54	105.50	90.81	.01290	0.5208	77.53	1.920	25.43	83.83	109.26	.05412	.2173	54
56	109.02	94.32	.01294	0.5041	77.28	1.984	26.01	83.41	109.42	.05523	.2170	56
58	112.62	97.93	.01298	0.4881	77.03	2.049	26.59	82.98	109.56	.05634	.2166	58
60	116.31	101.62	0.01303	0.4727	76.77	2.115	27.17	82.54	109.71	0.05745	0.2163	60
62	120.09	105.39	.01307	0.4579	76.52	2.184	27.76	82.10	109.86	.05855	.2159	62
64	123.96	109.26	.01311	0.4436	76.26	2.254	28.34	81.66	110.00	.05966	.2156	64
66	127.92	113.22	.01316	0.4298	76.00	2.327	28.93	81.21	110.14	.06076	.2152	66
68	131.97	117.28	.01320	0.4165	75.73	2.401	29.52	80.76	110.28	.06186	.2149	68
70	136.12	121.43	0.01325	0.4037	75.47	2.477	30.12	80.30	110.41	0.06296	0.2146	70
72	140.37	125.67	.01330	0.3914	75.20	2.555	30.71	79.84	110.55	.06406	.2142	72
74	144.71	130.01	.01335	0.3795	74.93	2.635	31.31	79.37	110.68	.06516	.2139	74
76	149.15	134.45	.01339	0.3680	74.66	2.717	31.91	78.90	110.81	.06626	.2136	76
78	153.69	138.99	.01344	0.3569	74.39	2.802	32.51	78.42	110.93	.06736	.2132	78
80	158.33	143.63	0.01349	0.3462	74.12	2.889	33.11	77.94	111.05	0.06846	0.2129	80
82	163.07	148.37	.01354	0.3359	73.84	2.977	33.71	77.46	111.17	.06956	.2126	82
84	167.92	153.22	.01359	0.3259	73.56	3.069	34.32	76.97	111.29	.07065	.2122	84
86	172.87	158.17	.01365	0.3162	73.28	3.162	34.93	76.47	111.40	.07175	.2119	86
88	177.93	163.23	.01370	0.3069	72.99	3.258	35.54	75.97	111.51	.07285	.2116	88
90	183.09	168.40	0.01375	0.2979	72.71	3.357	36.16	75.46	111.62	0.07394	0.2112	90
92	188.37	173.67	.01381	0.2892	72.41	3.458	36.77	74.95	111.72	.07504	.2109	92
94	193.76	179.06	.01386	0.2807	72.13	3.562	37.39	74.43	111.82	.07613	.2106	94
96	199.26	184.56	.01392	0.2726	71.83	3.669	38.02	73.91	111.92	.07723	.2102	96
98	204.87	190.18	.01398	0.2647	71.54	3.778	38.64	73.38	112.02	.07832	.2099	98
100	210.60	195.91	0.01404	0.2570	71.24	3.891	39.27	72.84	112.11	0.07942	0.2096	100
102	216.45	201.76	.01410	0.2496	70.93	4.006	39.90	72.29	112.19	.08052	.2092	102
104	222.42	207.72	.01416	0.2424	70.63	4.125	40.53	71.74	112.27	.08161	.2089	104
106	228.50	213.81	.01422	0.2355	70.32	4.247	41.17	71.19	112.35	.08271	.2086	106
108	234.71	220.02	.01429	0.2288	70.01	4.372	41.80	70.62	112.43	.08381	.2082	108
110	241.04	226.35	0.01435	0.2222	69.69	4.500	42.45	70.05	112.50	0.08491	0.2079	110
112	247.50	232.80	.01442	0.2159	69.40	4.632	43.09	69.47	112.56	.08601	.2075	112
114	254.08	239.38	.01448	0.2097	69.05	4.768	43.74	68.89	112.63	.08711	.2072	114
116	260.79	246.10	.01455	0.2038	68.72	4.907	44.39	68.29	112.68	.08821	.2068	116
118	267.63	252.94	.01462	0.1980	68.39	5.051	45.05	67.69	112.74	.08932	.2065	118
120	274.60	259.91	0.01469	0.1924	68.05	5.198	45.71	67.08	112.78	0.09042	0.2061	120
122	281.71	267.01	.01477	0.1869	67.71	5.350	46.37	66.46	112.82	.09153	.2058	122
124	288.95	274.25	.01484	0.1816	67.37	5.506	47.03	65.83	112.86	.09264	.2054	124
126	296.33	281.63	.01492	0.1765	67.02	5.667	47.71	65.19	112.89	.09375	.2051	126
128	303.84	289.14	.01500	0.1715	66.67	5.832	48.38	64.54	112.92	.09487	.2047	128
130	311.50	296.80	0.01508	0.1666	66.31	6.002	49.06	63.88	112.94	0.09598	0.2043	130
132	319.29	304.60	.01516	0.1619	65.95	6.178	49.74	63.21	112.95	.09711	.2039	132
134	327.23	312.54	.01525	0.1573	65.58	6.359	50.43	62.52	112.96	.09823	.2035	134
136	335.32	320.63	.01534	0.1528	65.21	6.545	51.13	61.83	112.95	.09936	.2032	136
138	343.56	328.86	.01543	0.1484	64.83	6.737	51.82	61.12	112.95	.1005	.2028	138
140	351.94	337.25	0.01552	0.1442	64.44	6.936	52.53	60.40	112.93	0.1016	0.2024	140
142	360.48	345.79	.01561	0.1400	64.05	7.141	53.24	59.67	112.91	.1028	.2019	142
144	369.17	354.48	.01571	0.1360	63.65	7.353	53.96	58.92	112.88	.1039	.2015	144
146	378.02	363.32	.01581	0.1321	63.24	7.572	54.68	58.16	112.84	.1051	.2011	146
148	387.03	372.33	.01592	0.1282	62.83	7.799	55.41	57.38	112.79	.1062	.2007	148
150	396.19	381.50	0.01603	0.1245	62.40	8.033	56.14	56.59	112.73	0.1074	0.2002	150
152	405.52	390.83	.01614	0.1208	61.97	8.276	56.89	55.77	112.66	.1086	.1997	152
154	415.02	400.32	.01625	0.1173	61.53	8.528	57.64	54.94	112.58	.1097	.1993	154
156	424.68	409.99	.01637	0.1138	61.08	8.790	58.40	54.09	112.49	.1109	.1988	156
158	434.52	419.82	.01650	0.1104	60.62	9.062	59.17	53.21	112.38	.1121	.1983	158
160	444.53	429.83	0.01663	0.1070	60.15	9.345	59.95	52.32	112.26	0.1133	0.1978	160

TABLE 5-PROPERTIES OF REFRIGERANT 11, LIQUID AND SATURATED VAPOR

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage P	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	
— 40	0.7432	28.41*	.009873	43.92	101.28	0.02277	0.000	87.19	87.19	0.000000	0.2078	— 40
— 38	0.7958	28.30*	.009888	41.20	101.14	0.02427	0.404	87.03	87.43	.000960	.2073	— 38
— 36	0.8515	28.19*	.009902	38.68	100.99	0.02586	0.808	86.86	87.67	.001915	.2069	— 36
— 34	0.9105	28.07*	.009917	36.33	100.84	0.02752	1.212	86.69	87.90	.002867	.2065	— 34
— 32	0.9728	27.94*	.009932	34.16	100.69	0.02928	1.616	86.52	88.14	.003814	.2061	— 32
— 30	1.039	27.81*	.009946	32.13	100.54	0.03112	2.020	86.36	88.38	.004756	.2057	— 30
— 28	1.108	27.67*	.009961	30.25	100.39	0.03306	2.425	86.19	88.62	.005695	.2054	— 28
— 26	1.181	27.52*	.009976	28.50	100.24	0.03509	2.829	86.03	88.85	.006629	.2050	— 26
— 24	1.259	27.36*	.009991	26.86	100.09	0.03723	3.233	85.86	89.09	.007559	.2046	— 24
— 22	1.340	27.19*	.01001	25.34	99.94	0.03947	3.638	85.69	89.33	.008485	.2043	— 22
— 20	1.426	27.02*	.01002	23.91	99.79	0.04182	4.043	85.53	89.57	.009408	.2039	— 20
— 18	1.516	26.83*	.01004	22.59	99.64	0.04428	4.448	85.36	89.81	.01033	.2036	— 18
— 16	1.611	26.64*	.01005	21.34	99.49	0.04685	4.852	85.20	90.05	.01124	.2033	— 16
— 14	1.711	26.44*	.01007	20.18	99.33	0.04955	5.258	85.03	90.29	.01215	.2029	— 14
— 12	1.815	26.23*	.01008	19.10	99.18	0.05237	5.663	84.87	90.53	.01306	.2026	— 12
— 10	1.925	26.00*	.01010	18.08	99.03	0.05531	6.068	84.70	90.77	.01396	.2023	— 10
— 8	2.041	25.77*	.01011	17.13	98.88	0.05839	6.474	84.54	91.01	.01486	.2020	— 8
— 6	2.162	25.52*	.01013	16.23	98.73	0.06161	6.879	84.37	91.25	.01576	.2017	— 6
— 4	2.289	25.26*	.01015	15.39	98.57	0.06497	7.285	84.20	91.49	.01665	.2014	— 4
— 2	2.422	24.99*	.01016	14.61	98.42	0.06847	7.691	84.04	91.73	.01754	.2012	— 2
0	2.561	24.71*	.01018	13.87	98.27	0.07212	8.098	83.87	91.97	.01842	.2009	0
2	2.706	24.41*	.01019	13.17	98.12	0.07593	8.504	83.71	92.21	.01930	.2006	2
4	2.859	24.10*	.01021	12.52	97.96	0.07989	8.910	83.54	92.45	.02018	.2004	4
6	3.018	23.78*	.01022	11.90	97.81	0.08402	9.317	83.38	92.69	.02106	.2001	6
8	3.184	23.44*	.01024	11.32	97.65	0.08832	9.724	83.21	92.93	.02193	.1999	8
10	3.358	23.08*	.01026	10.78	97.50	0.09279	10.13	83.04	93.18	.02280	.1996	10
12	3.539	22.72*	.01027	10.26	97.34	0.09743	10.54	82.88	93.42	.02366	.1994	12
14	3.728	22.33*	.01029	9.779	97.19	0.1023	10.95	82.71	93.66	.02452	.1991	14
16	3.926	21.93*	.01031	9.321	97.03	0.1073	11.35	82.55	93.90	.02538	.1989	16
18	4.131	21.51*	.01032	8.889	96.88	0.1125	11.76	82.38	94.14	.02623	.1987	18
20	4.346	21.07*	.01034	8.481	96.72	0.1179	12.17	82.21	94.38	.02709	.1985	20
22	4.569	20.62*	.01036	8.095	96.57	0.1235	12.58	82.05	94.62	.02794	.1983	22
24	4.801	20.15*	.01037	7.731	96.41	0.1294	12.99	81.88	94.86	.02878	.1981	24
26	5.043	19.65*	.01039	7.386	96.25	0.1354	13.40	81.71	95.11	.02962	.1979	26
28	5.294	19.14*	.01041	7.060	96.10	0.1417	13.81	81.54	95.35	.03046	.1977	28
30	5.556	18.61*	.01042	6.750	95.94	0.1481	14.21	81.37	95.59	.03130	.1975	30
32	5.827	18.06*	.01044	6.457	95.78	0.1549	14.62	81.21	95.83	.03213	.1973	32
34	6.109	17.48*	.01046	6.180	95.62	0.1618	15.03	81.04	96.07	.03296	.1971	34
36	6.403	16.89*	.01048	5.917	95.46	0.1690	15.44	80.87	96.31	.03379	.1969	36
38	6.707	16.27*	.01049	5.667	95.31	0.1765	15.85	80.70	96.55	.03462	.1968	38
40	7.022	15.62*	.01051	5.430	95.15	0.1842	16.26	80.53	96.79	.03544	.1966	40
42	7.350	14.96*	.01053	5.205	94.99	0.1921	16.68	80.36	97.04	.03626	.1964	42
44	7.689	14.27*	.01055	4.991	94.83	0.2004	17.09	80.19	97.28	.03707	.1963	44
46	8.041	13.55*	.01056	4.788	94.67	0.2089	17.50	80.02	97.52	.03789	.1961	46
48	8.405	12.81*	.01058	4.594	94.51	0.2177	17.91	79.85	97.76	.03870	.1960	48
50	8.783	12.04*	.01060	4.411	94.35	0.2267	18.32	79.68	98.00	.03951	.1958	50
52	9.173	11.24*	.01062	4.236	94.19	0.2361	18.73	79.51	98.24	.04031	.1957	52
54	9.578	10.42*	.01064	4.069	94.03	0.2458	19.14	79.33	98.48	.04111	.1956	54
56	9.996	9.569*	.01065	3.910	93.86	0.2557	19.56	79.16	98.72	.04191	.1954	56
58	10.43	8.688*	.01067	3.759	93.70	0.2660	19.97	78.99	98.96	.04271	.1953	58
60	10.88	7.778*	.01069	3.615	93.54	0.2766	20.38	78.82	99.20	.04350	.1952	60
62	11.34	6.836*	.01071	3.478	93.38	0.2875	20.80	78.64	99.44	.04430	.1951	62
64	11.82	5.864*	.01073	3.347	93.21	0.2988	21.21	78.47	99.68	.04509	.1949	64
66	12.31	4.859*	.01075	3.222	93.05	0.3104	21.62	78.29	99.92	.04587	.1948	66
68	12.82	3.822*	.01077	3.102	92.89	0.3224	22.04	78.12	100.15	.04666	.1947	68
70	13.35	2.752*	.01079	2.988	92.72	0.3347	22.45	77.94	100.39	.04744	.1946	70
72	13.89	1.647*	.01080	2.879	92.56	0.3473	22.87	77.77	100.63	.04822	.1945	72
74	14.45	0.507*	.01082	2.775	92.39	0.3603	23.28	77.59	100.87	.04899	.1944	74
76	15.02	0.328	.01084	2.676	92.23	0.3738	23.70	77.41	101.11	.04977	.1943	76
78	15.62	0.923	.01086	2.580	92.06	0.3875	24.11	77.23	101.35	.05054	.1942	78
80	16.23	1.537	.01088	2.489	91.90	0.4017	24.53	77.06	101.58	.05131	.1941	80
82	16.87	2.169	.01090	2.402	91.73	0.4163	24.94	76.88	101.82	.05208	.1940	82
84	17.52	2.820	.01092	2.319	91.56	0.4313	25.36	76.70	102.06	.05284	.1939	84
86	18.19	3.490	.01094	2.239	91.39	0.4467	25.78	76.52	102.29	.05360	.1938	86
88	18.88	4.180	.01096	2.162	91.23	0.4625	26.19	76.34	102.53	.05436	.1938	88
90	19.59	4.891	.01098	2.089	91.06	0.4787	26.61	76.16	102.77	.05512	.1937	90
92	20.32	5.622	.01100	2.018	90.89	0.4954	27.03	75.97	103.00	.05588	.1936	92
94	21.07	6.374	.01102	1.951	90.72	0.5126	27.45	75.79	103.24	.05663	.1935	94
96	21.84	7.147	.01104	1.886	90.55	0.5302	27.86	75.61	103.47	.05738	.1935	96
98	22.64	7.942	.01106	1.824	90.38	0.5482	28.81	75.42	103.71	.05813	.1934	98

*Inches of mercury below one atmosphere.

Courtesy of

Carrier Airconditioning Company



TABLE 5-PROPERTIES OF REFRIGERANT 11, LIQUID AND SATURATED VAPOR (Contd)

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage P	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	
100	23.46	8.760	0.01109	1.765	90.21	0.5667	28.70	75.24	103.94	0.05888	0.1933	100
102	24.30	9.600	.01111	1.707	90.04	0.5857	29.12	75.06	104.17	.05962	.1933	102
104	25.16	10.46	.01113	1.652	89.87	0.6052	29.54	74.87	104.41	.06036	.1932	104
106	26.05	11.35	.01115	1.600	89.69	0.6252	29.96	74.68	104.64	.06110	.1931	106
108	26.96	12.26	.01117	1.549	89.52	0.6457	30.38	74.50	104.87	.06184	.1931	108
110	27.89	13.19	0.01119	1.500	89.35	0.6667	30.80	74.31	105.11	0.06258	0.1930	110
112	28.85	14.15	.01121	1.453	89.18	0.6882	31.22	74.12	105.38	.06331	.1930	112
114	29.83	15.14	.01124	1.408	89.00	0.7103	31.64	73.93	105.57	.06404	.1929	114
116	30.84	16.15	.01125	1.365	88.83	0.7329	30.06	73.74	105.80	.06477	.1929	116
118	31.88	17.18	.01128	1.323	88.65	0.7561	32.48	73.55	106.03	.06550	.1928	118
120	32.94	18.25	0.01130	1.282	88.48	0.7798	32.91	73.36	106.26	0.06622	0.1928	120
122	34.03	19.34	.01133	1.244	88.30	0.8041	33.33	73.16	106.49	.06695	.1927	122
124	35.15	20.45	.01135	1.206	88.12	0.8289	33.75	72.97	106.72	.06767	.1927	124
126	36.29	21.60	.01137	1.170	87.95	0.8544	34.17	72.77	106.95	.06839	.1927	126
128	37.47	22.77	.01139	1.136	87.77	0.8805	34.60	72.58	107.18	.06911	.1926	128
130	38.67	23.97	0.01142	1.102	87.59	0.9071	35.02	72.38	107.40	0.06982	0.1926	130
132	39.90	25.20	.01140	1.070	87.41	0.9344	35.45	72.19	107.63	.07054	.1925	132
134	41.16	26.46	.01146	1.039	87.23	0.9624	35.87	71.99	107.86	.07125	.1925	134
136	42.45	27.75	.01149	1.009	87.05	0.9909	36.30	71.79	108.08	.07196	.1925	136
138	43.77	29.08	.01151	0.9802	86.87	1.020	36.72	71.59	108.31	.07267	.1925	138
140	45.12	30.43	0.01154	0.9523	86.69	1.050	37.15	71.39	108.54	0.07337	0.1924	140
142	46.51	31.81	.01156	0.9254	86.51	1.081	37.57	71.19	108.76	.07408	.1924	142
144	47.92	33.23	.01158	0.8994	86.32	1.112	38.00	70.98	108.98	.07478	.1924	144
146	49.37	34.67	.01161	0.8742	86.14	1.144	38.43	70.78	109.21	.07548	.1924	146
148	50.85	36.15	.01163	0.8500	85.96	1.177	38.86	70.57	109.43	.07618	.1923	148
150	52.36	37.67	0.01166	0.8265	85.77	1.210	39.28	70.37	109.65	0.07688	0.1923	150
152	53.91	39.22	.01168	0.8038	85.59	1.244	39.71	70.16	109.87	.07758	.1923	152
154	55.49	40.80	.01171	0.7819	85.40	1.279	40.14	69.95	110.10	.07828	.1923	154
156	57.11	42.42	.01174	0.7607	85.21	1.315	40.57	69.74	110.32	.07897	.1923	156
158	58.76	44.07	.01176	0.7402	85.03	1.351	41.00	69.53	110.54	.07966	.1922	158
160	60.45	45.76	.01179	0.7204	84.84	1.388	41.43	69.32	110.76	.08035	.1922	160

TABLE 6-PROPERTIES OF REFRIGERANT 113, LIQUID AND SATURATED VAPOR

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage p	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	
-30	0.2987	29.31*	0.00947	82.26	105.64	0.01216	1.97	72.68	74.65	0.0047	0.1738	-30
-28	0.3214	29.27*	.00948	76.81	105.50	.01302	2.36	72.57	74.93	.0056	.1737	-28
-26	0.3458	29.22*	.00949	71.71	105.37	.01395	2.76	72.45	75.21	.0065	.1736	-26
-24	0.3718	29.16*	.00950	66.99	105.23	.01493	3.16	72.33	75.49	.0074	.1735	-24
-22	0.3995	29.11*	.00952	62.63	105.09	.01597	3.56	72.21	75.77	.0083	.1733	-22
-20	0.4288	29.05*	0.00953	58.61	104.96	0.01706	3.96	72.09	76.05	0.0092	0.1732	-20
-18	0.4600	28.98*	.00954	54.88	104.82	.01822	4.36	71.98	76.34	.0101	.1731	-18
-16	0.4931	28.92*	.00955	51.42	104.68	.01945	4.76	71.86	76.62	.0110	.1730	-16
-14	0.5280	28.85*	.00957	48.23	104.54	.02074	5.16	71.74	76.90	.0119	.1729	-14
-12	0.5652	28.77*	.00958	45.25	104.40	.02210	5.56	71.62	77.18	.0128	.1729	-12
-10	0.6046	28.69*	0.00959	42.48	104.26	0.02354	5.96	71.51	77.47	0.0137	0.1728	-10
-8	0.6462	28.60*	.00960	39.92	104.12	.02505	6.36	71.39	77.75	.0146	.1727	-8
-6	0.6902	28.51*	.00962	37.54	103.98	.02664	6.76	71.27	78.03	.0155	.1726	-6
-4	0.7369	28.42*	.00963	35.31	103.84	.02832	7.17	71.15	78.32	.0164	.1726	-4
-2	0.7860	28.32*	.00964	33.24	103.70	.03009	7.57	71.03	78.60	.0173	.1725	-2
0	0.8377	28.21*	0.00966	31.31	103.56	0.03194	7.98	70.92	78.89	0.0182	0.1725	0
2	0.8924	28.10*	.00967	29.52	103.41	.03388	8.38	70.80	79.18	.0190	.1724	2
4	0.9503	27.99*	.00968	27.84	103.27	.03592	8.78	70.68	79.46	.0199	.1724	4
6	1.011	27.86*	.00970	26.27	103.13	.03806	9.19	70.56	79.75	.0208	.1723	6
8	1.075	27.73*	.00971	24.81	102.98	.04031	9.59	70.44	80.03	.0216	.1723	8
10	1.142	27.60*	0.00972	23.45	102.84	0.04265	10.00	70.32	80.32	0.0225	0.1723	10
12	1.213	27.45*	.00974	22.17	102.69	.04511	10.41	70.20	80.61	.0234	.1722	12
14	1.288	27.30*	.00975	20.97	102.55	.04769	10.81	70.08	80.89	.0242	.1722	14
16	1.366	27.14*	.00977	19.84	102.40	.05040	11.22	69.96	81.18	.0251	.1722	16
18	1.448	26.97*	.00978	18.79	102.25	.05322	11.62	69.84	81.46	.0259	.1722	18
20	1.534	26.80*	0.00979	17.81	102.10	0.05616	12.03	69.72	81.75	0.0268	0.1722	20
22	1.624	26.61*	.00981	16.89	101.96	.05922	12.44	69.60	82.04	.0276	.1721	22
24	1.719	26.42*	.00982	16.02	101.81	.06243	12.85	69.48	82.33	.0285	.1721	24
26	1.818	26.22*	.00984	15.20	101.66	.06579	13.26	69.36	82.62	.0293	.1722	26
28	1.922	26.01*	.00985	14.43	101.51	.06929	13.67	69.24	82.91	.0302	.1722	28
30	2.031	25.79*	0.00987	13.71	101.36	0.07294	14.08	69.12	83.20	0.0310	0.1722	30
32	2.145	25.55*	.00988	13.03	101.21	.07675	14.49	69.00	83.49	.0318	.1722	32
34	2.264	25.31*	.00990	12.39	101.06	.08071	14.91	68.87	83.78	.0327	.1722	34
36	2.388	25.06*	.00991	11.79	100.91	.08483	15.32	68.75	84.07	.0335	.1722	36
38	2.519	24.79*	.00993	11.22	100.76	.08913	15.74	68.62	84.36	.0343	.1722	38
40	2.655	24.52*	0.00994	10.68	100.60	.09361	16.16	68.50	84.65	0.0352	0.1723	40
42	2.797	24.23*	.00996	10.18	100.45	.09826	16.57	68.37	84.94	.0360	.1723	42
44	2.944	23.93*	.00997	9.703	100.30	.1031	16.99	68.25	85.24	.0368	.1723	44
46	3.098	23.61*	.00999	9.253	100.14	.1081	17.41	68.12	85.53	.0377	.1724	46
48	3.258	23.29*	.01000	8.830	99.99	.1133	17.82	68.00	85.82	.0385	.1724	48
50	3.427	22.94*	0.01002	8.426	99.83	0.1187	18.24	67.87	86.11	0.0393	0.1725	50
52	3.602	22.59*	.01003	8.044	99.68	.1243	18.66	67.74	86.40	.0401	.1726	52
54	3.784	22.22*	.01005	7.682	99.52	.1302	19.08	67.61	86.69	.0410	.1726	54
56	3.973	21.83*	.01006	7.342	99.37	.1362	19.50	67.48	86.98	.0418	.1727	56
58	4.170	21.43*	.01008	7.018	99.21	.1425	19.93	67.35	87.28	.0426	.1727	58
60	4.374	21.02*	0.01010	6.713	99.05	0.1490	20.35	67.22	87.57	0.0434	0.1728	60
62	4.586	20.59*	.01011	6.424	98.89	.1557	20.77	67.09	87.86	.0442	.1729	62
64	4.807	20.14*	.01013	6.149	98.73	.1626	21.19	66.96	88.15	.0450	.1729	64
66	5.036	19.67*	.01015	5.889	98.58	.1698	21.62	66.83	88.45	.0459	.1730	66
68	5.275	19.18*	.01016	5.640	98.42	.1773	22.05	66.69	88.74	.0467	.1731	68
70	5.523	18.68*	0.01018	5.404	98.26	0.1851	22.48	66.56	89.04	0.0475	0.1731	70
72	5.780	18.16*	.01019	5.180	98.10	.1931	22.90	66.43	89.33	.0483	.1732	72
74	6.042	17.62*	.01021	4.971	97.93	.2012	23.33	66.29	89.62	.0491	.1733	74
76	6.320	17.06*	.01023	4.769	97.77	.2097	23.76	66.16	89.92	.0499	.1734	76
78	6.607	16.47*	.01025	4.574	97.61	.2186	24.19	66.02	90.21	.0507	.1735	78
80	6.902	15.87*	0.01026	4.392	97.45	0.2277	24.63	65.88	90.51	0.0515	0.1736	80
82	7.208	15.25*	.01028	4.218	97.28	.2371	25.06	65.74	90.80	.0523	.1737	82
84	7.527	14.60*	.01030	4.051	97.12	.2468	25.49	65.60	91.09	.0531	.1738	84
86	7.856	13.93*	.01031	3.893	96.96	.2569	25.93	65.46	91.39	.0539	.1739	86
88	8.194	13.24*	.01033	3.742	96.79	.2672	26.36	65.32	91.68	.0547	.1740	88
90	8.545	12.53*	0.01035	3.600	96.63	0.2778	26.80	65.18	91.98	0.0555	0.1741	90
92	8.908	11.79*	.01037	3.463	96.46	.2888	27.24	65.04	92.28	.0563	.1742	92
94	9.281	11.03*	.01039	3.333	96.30	.3001	27.67	64.90	92.57	.0571	.1743	94
96	9.668	10.24*	.01040	3.208	96.13	.3117	28.11	64.75	92.86	.0578	.1744	96
98	10.07	9.42*	.01042	3.089	95.96	.3237	28.55	64.60	93.15	.0586	.1745	98
100	10.48	8.59*	0.01044	2.976	95.79	0.3360	28.99	64.46	93.45	0.0594	0.1746	100
102	10.91	7.71*	.01046	2.867	95.63	.3488	29.44	64.31	93.75	.0602	.1747	102
104	11.35	6.82*	.01048	2.762	95.46	.3620	29.89	64.16	94.05	.0610	.1748	104
106	11.81	5.88*	.01050	2.662	95.29	.3756	30.33	64.01	94.34	.0618	.1750	106
108	12.28	4.93*	.01051	2.567	95.12	.3896	30.78	63.86	94.64	.0626	.1751	108

*Inches of mercury below one atmosphere.

Courtesy of E. I. du Pont de Nemours & Co.

TABLE 6-PROPERTIES OF REFRIGERANT 113, LIQUID AND SATURATED VAPOR (Contd)

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage P	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	
110	12.76	3.95*	0.01053	2.477	94.95	0.4038	31.22	63.71	94.93	0.0634	0.1752	110
112	13.25	2.95*	.01055	2.391	94.78	.4182	31.67	63.56	95.23	.0641	.1753	112
114	13.76	1.91*	.01057	2.308	94.61	.4333	32.12	63.40	95.52	.0649	.1755	114
116	14.29	0.83*	.01059	2.228	94.43	.4489	32.57	63.25	95.82	.0657	.1756	116
118	14.84	0.14	.01061	2.151	94.26	.4649	33.03	63.09	96.12	.0665	.1757	118
120	15.40	0.70	0.01063	2.078	94.09	0.4813	33.48	62.93	96.41	0.0673	0.1758	120
122	15.97	1.27	.01065	2.008	93.92	.4981	33.93	62.78	96.71	.0680	.1760	122
124	16.56	1.86	.01067	1.941	93.74	.5153	34.38	62.62	97.00	.0688	.1761	124
126	17.17	2.47	.01069	1.876	93.57	.5330	34.83	62.46	97.29	.0696	.1763	126
128	17.80	3.10	.01071	1.814	93.39	.5514	35.29	62.30	97.59	.0704	.1764	128
130	18.45	3.74	0.01073	1.754	93.22	0.5702	35.75	62.14	97.89	0.0712	0.1765	130
132	19.11	4.41	.01075	1.697	93.04	.5894	36.21	61.97	98.18	.0719	.1767	132
134	19.79	5.09	.01077	1.642	92.86	.6091	36.67	61.80	98.47	.0727	.1768	134
136	20.48	5.78	.01079	1.590	92.69	.6290	37.13	61.64	98.77	.0735	.1770	136
138	21.19	6.49	.01081	1.540	92.51	.6494	37.59	61.48	99.06	.0742	.1771	138
140	21.93	7.23	0.01083	1.491	92.33	0.6707	38.05	61.31	99.36	0.0750	0.1773	140
142	22.69	7.99	.01085	1.444	92.15	.6926	38.52	61.13	99.65	.0758	.1774	142
144	23.47	8.77	.01087	1.399	91.98	.7150	38.98	60.96	99.94	.0765	.1775	144
146	24.27	9.57	.01089	1.355	91.80	.7379	39.45	60.79	100.24	.0773	.1777	146
148	25.09	10.39	.01092	1.313	91.62	.7615	39.92	60.61	100.53	.0781	.1778	148
150	25.93	11.23	0.01094	1.273	91.44	0.7856	40.38	60.44	100.82	0.0789	0.1780	150
152	26.79	12.09	.01096	1.234	91.25	.8102	40.85	60.27	101.11	.0796	.1782	152
154	27.67	12.97	.01098	1.197	91.07	.8353	41.32	60.09	101.41	.0804	.1783	154
156	28.56	13.86	.01100	1.162	90.89	.8608	41.79	59.91	101.70	.0812	.1785	156
158	29.48	14.78	.01102	1.128	90.71	.8869	42.26	59.73	101.99	.0819	.1786	158
160	30.44	15.74	0.01105	1.094	90.53	0.9141	42.74	59.55	102.29	0.0827	0.1788	160

TABLE 7-PROPERTIES OF REFRIGERANT 114, LIQUID AND SATURATED VAPOR

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
t	Absolute P	Gage P	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	t
-80	0.464	28.97*	0.009469	51.26	105.603	0.01951	- 8.73	69.17	60.44	- 0.0227	0.1595	-80
-78	0.50	28.90*	.009484	49.83	105.398	.02007	- 8.30	69.01	60.71	- .0215	.1593	-78
-76	0.535	28.85*	.009506	44.87	105.193	.02229	- 7.87	68.85	60.98	- .0203	.1592	-76
-74	0.58	28.73*	.009513	41.69	105.058	.0240	- 7.44	68.69	61.25	- .0191	.1590	-74
-72	0.62	28.66*	.009528	38.92	104.924	.0257	- 7.01	68.53	61.52	- .0179	.1589	-72
-70	0.670	28.59*	0.009543	36.40	104.790	0.02747	- 6.57	68.36	61.79	- 0.0167	0.1587	-70
-68	0.72	28.46*	.009558	34.20	104.624	.02925	- 6.14	68.20	62.06	- .0155	.1586	-68
-66	0.775	28.33*	.009573	31.74	104.458	.0315	- 5.71	68.04	62.33	- .0143	.1585	-66
-64	0.833	28.23*	.009589	29.77	104.292	.0336	- 5.28	67.88	62.60	- .0132	.1583	-64
-62	0.895	28.10*	.009604	27.79	104.126	.0360	- 4.84	67.72	62.88	- .0121	.1582	-62
-60	0.959	27.99*	0.009619	26.06	103.960	0.03838	- 4.40	67.56	63.16	- 0.0110	0.1580	-60
-58	1.028	27.83*	.009635	24.55	103.792	.04075	- 3.96	67.39	63.43	- .0098	.1579	-58
-56	1.10	27.68*	.009651	22.94	103.622	.0436	- 3.52	67.22	63.70	- .0087	.1578	-56
-54	1.175	27.52*	.009666	21.50	103.452	.0465	- 3.08	67.05	63.97	- .0075	.1577	-54
-52	1.26	27.35*	.009682	20.16	103.282	.0496	- 2.64	66.89	64.25	- .0064	.1576	-52
-50	1.349	27.20*	0.009698	18.96	103.113	0.05274	- 2.20	66.73	64.53	- 0.0054	0.1575	-50
-48	1.438	27.0 *	.009714	17.85	102.938	.0560	- 1.76	66.56	64.80	- .0043	.1574	-48
-46	1.535	26.8 *	.009731	16.80	102.766	.0595	- 1.32	66.39	65.07	- .0032	.1573	-46
-44	1.635	26.6 *	.009747	15.75	102.594	.0635	- 0.88	66.23	65.35	- .0021	.1572	-44
-42	1.745	26.4 *	.009764	14.87	102.422	.06725	- 0.44	66.07	65.63	- .0010	.1571	-42
-40	1.866	26.12*	0.00978	14.02	102.25	0.07132	0.00	65.91	65.91	0.0000	0.1571	-40
-38	1.990	25.87*	.00980	13.20	102.08	.07574	0.45	65.74	66.19	.0011	.1570	-38
-36	2.121	25.60*	.00981	12.44	101.90	.08038	0.91	65.56	66.47	.0021	.1569	-36
-34	2.259	25.32*	.00983	11.73	101.72	.08524	1.36	65.38	66.74	.0032	.1568	-34
-32	2.404	25.03*	.00985	11.07	101.55	.09034	1.81	65.21	67.02	.0042	.1567	-32
-30	2.557	24.72*	0.00987	10.45	101.37	0.09568	2.27	65.03	67.30	0.0053	0.1567	-30
-28	2.718	24.39*	.00988	9.877	101.19	.1013	2.72	64.86	67.58	.0063	.1567	-28
-26	2.887	24.04*	.00990	9.338	101.01	.1071	3.17	64.68	67.86	.0074	.1566	-26
-24	3.064	23.68*	.00992	8.833	100.83	.1132	3.63	64.51	68.14	.0084	.1565	-24
-22	3.249	23.31*	.00994	8.362	100.65	.1196	4.08	64.34	68.42	.0095	.1565	-22
-20	3.444	22.91*	0.00995	7.921	100.47	0.1263	4.54	64.16	68.70	0.0105	0.1565	-20
-18	3.648	22.49*	.00997	7.508	100.29	.1332	4.99	63.99	68.98	.0116	.1565	-18
-16	3.862	22.06*	.00999	7.121	100.11	.1404	5.44	63.81	69.26	.0126	.1564	-16
-14	4.085	21.61*	.01001	6.757	99.92	.1480	5.90	63.64	69.54	.0136	.1564	-14
-12	4.319	21.13*	.01003	6.416	99.74	.1559	6.35	63.46	69.82	.0146	.1564	-12
-10	4.564	20.63*	0.01005	6.095	99.56	0.1641	6.81	63.29	70.10	0.0157	0.1564	-10
-8	4.819	20.11*	.01006	5.794	99.37	.1726	7.26	63.11	70.38	.0167	.1564	-8
-6	5.086	19.57*	.01008	5.510	99.19	.1815	7.72	62.94	70.66	.0177	.1564	-6
-4	5.365	19.00*	.01010	5.244	99.00	.1907	8.18	62.77	70.94	.0187	.1564	-4
-2	5.655	18.41*	.01012	4.992	98.81	.2003	8.63	62.59	71.22	.0197	.1565	-2
0	5.958	17.79*	0.01014	4.756	98.62	0.2103	9.09	62.42	71.50	0.0207	0.1565	0
2	6.274	17.15*	.01016	4.533	98.44	.2206	9.54	62.24	71.78	.0217	.1565	2
4	6.603	16.48*	.01018	4.322	98.25	.2314	10.00	62.07	72.07	.0227	.1565	4
6	6.945	15.78*	.01020	4.123	98.06	.2425	10.46	61.89	72.35	.0236	.1566	6
8	7.301	15.06*	.01022	3.935	97.87	.2541	10.91	61.71	72.63	.0246	.1566	8
10	7.671	14.31*	0.01024	3.758	97.68	0.2661	11.37	61.54	72.91	0.0256	0.1566	10
12	8.057	13.52*	.01026	3.591	97.48	.2785	11.83	61.36	73.19	.0266	.1567	12
14	8.457	12.71*	.01028	3.432	97.29	.2914	12.29	61.19	73.47	.0275	.1567	14
16	8.873	11.86*	.01030	3.282	97.10	.3047	12.75	61.01	73.75	.0285	.1568	16
18	9.305	10.98*	.01032	3.140	96.90	.3185	13.20	60.83	74.04	.0295	.1568	18
20	9.753	10.07*	0.01034	3.005	96.71	0.3328	13.66	60.65	74.32	0.0304	0.1569	20
22	10.22	9.12*	.01036	2.877	96.51	.3476	14.12	60.48	74.60	.0314	.1569	22
24	10.70	8.14*	.01038	2.756	96.32	.3629	14.58	60.30	74.88	.0323	.1570	24
26	11.20	7.12*	.01040	2.641	96.12	.3786	15.05	60.12	75.17	.0333	.1571	26
28	11.72	6.07*	.01043	2.532	95.92	.3949	15.51	59.94	75.45	.0342	.1571	28
30	12.25	4.99*	0.01045	2.429	95.73	0.4118	15.97	59.76	75.73	0.0352	0.1572	30
32	12.81	3.85*	.01047	2.330	95.53	.4292	16.43	59.58	76.01	.0361	.1573	32
34	13.38	2.69*	.01049	2.236	95.33	.4472	16.89	59.40	76.29	.0370	.1574	34
36	13.98	1.47*	.01051	2.147	95.13	.4658	17.36	59.22	76.58	.0380	.1575	36
38	14.59	0.22*	.01053	2.062	94.93	.4849	17.82	59.04	76.86	.0389	.1575	38
40	15.22	0.52	0.01056	1.982	94.73	0.5047	18.28	58.86	77.14	0.0398	0.1576	40
42	15.88	1.18	.01058	1.905	94.52	.5250	18.75	58.67	77.42	.0408	.1577	42
44	16.56	1.86	.01060	1.832	94.32	.5460	19.21	58.49	77.70	.0417	.1578	44
46	17.26	2.56	.01063	1.762	94.12	.5676	19.68	58.31	77.99	.0426	.1579	46
48	17.98	3.28	.01065	1.695	93.91	.5899	20.14	58.12	78.27	.0435	.1580	48
50	18.73	4.03	0.01067	1.632	93.71	0.6129	20.61	57.94	78.55	0.0444	0.1581	50
52	19.50	4.80	.01070	1.571	93.50	.6365	21.08	57.75	78.83	.0453	.1582	52
54	20.29	5.59	.01072	1.513	93.30	.6609	21.54	57.56	79.11	.0463	.1583	54
56	21.11	6.41	.01074	1.458	93.09	.6859	22.01	57.38	79.39	.0472	.1584	56
58	21.96	7.26	.01077	1.405	92.88	.7117	22.48	57.19	79.67	.0481	.1585	58

*Inches of mercury below one atmosphere.

Courtesy of E. I. du Pont de Nemours & Co.

TABLE 7—PROPERTIES OF REFRIGERANT 114, LIQUID AND SATURATED VAPOR (Contd)

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage P	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	
60	22.83	8.13	0.01079	1.354	92.68	0.7383	22.95	57.00	79.95	0.0490	0.1587	60
62	23.72	9.02	.01082	1.306	92.47	.7655	23.42	56.81	80.23	.0499	.1588	62
64	24.64	9.94	.01084	1.260	92.26	.7936	23.89	56.62	80.51	.0508	.1589	64
66	25.59	10.89	.01086	1.216	92.05	.8225	24.36	56.43	80.79	.0517	.1590	66
68	26.57	11.87	.01089	1.174	91.84	.8521	24.83	56.24	81.07	.0526	.1591	68
70	27.57	12.87	0.01091	1.133	91.63	0.8826	25.30	56.04	81.35	0.0534	0.1593	70
72	28.61	13.91	.01094	1.094	91.41	0.9140	25.78	55.85	81.62	.0543	.1594	72
74	29.67	14.97	.01097	1.057	91.20	0.9462	26.25	55.65	81.90	.0552	.1595	74
76	30.76	16.06	.01099	1.021	90.99	0.9793	26.73	55.45	82.18	.0561	.1596	76
78	31.88	17.18	.01102	0.9869	90.77	1.013	27.20	55.26	82.46	.0570	.1597	78
80	33.04	18.34	0.01104	0.9541	90.56	1.048	27.68	55.06	82.73	0.0579	0.1599	80
82	34.22	19.52	.01107	.9226	90.34	1.084	28.15	54.86	83.01	.0587	.1600	82
84	35.44	20.74	.01110	.8923	90.13	1.121	28.63	54.66	83.29	.0596	.1601	84
86	36.69	21.99	.01112	.8632	89.91	1.159	29.11	54.46	83.56	.0605	.1603	86
88	37.97	23.27	.01115	.8353	89.69	1.197	29.58	54.25	83.84	.0613	.1604	88
90	39.29	24.59	0.01118	0.8084	89.47	1.237	30.06	54.05	84.11	0.0622	0.1605	90
92	40.64	25.94	.01120	.7827	89.25	1.278	30.54	53.84	84.39	.0631	.1607	92
94	42.02	27.32	.01123	.7579	89.03	1.320	31.02	53.64	84.66	.0639	.1608	94
96	43.44	28.74	.01126	.7340	88.81	1.362	31.50	53.43	84.93	.0648	.1609	96
98	44.89	30.19	.01129	.7111	88.59	1.406	31.99	53.22	85.21	.0656	.1611	98
100	46.39	31.69	0.01132	0.6890	88.37	1.452	32.47	53.01	85.48	0.0665	0.1612	100
102	47.92	33.22	.01135	.6677	88.15	1.498	32.95	52.80	85.75	.0674	.1614	102
104	49.48	34.78	.01137	.6472	87.93	1.545	33.43	52.59	86.02	.0682	.1615	104
106	51.09	36.39	.01140	.6274	87.70	1.594	33.92	52.37	86.29	.0691	.1617	106
108	52.73	38.03	.01143	.6084	87.48	1.644	34.40	52.16	86.56	.0699	.1618	108
110	54.41	39.71	0.01146	0.5901	87.25	1.695	34.89	51.94	86.83	0.0708	0.1619	110
112	56.14	41.44	.01149	.5724	87.01	1.747	35.38	51.72	87.09	.0716	.1621	112
114	57.90	43.20	.01152	.5554	86.77	1.801	35.87	51.50	87.36	.0725	.1622	114
116	59.70	45.00	.01156	.5389	86.54	1.856	36.35	51.28	87.63	.0733	.1624	116
118	61.55	46.85	.01159	.5230	86.31	1.912	36.84	51.05	87.89	.0741	.1625	118
120	63.44	48.74	0.01162	0.5077	86.08	1.970	37.33	50.83	88.16	0.0750	0.1627	120
122	65.37	50.67	.01165	.4929	85.85	2.029	37.83	50.60	88.42	.0758	.1628	122
124	67.35	52.65	.01168	.4787	85.61	2.089	38.32	50.37	88.69	.0767	.1630	124
126	69.37	54.67	.01171	.4649	85.37	2.151	38.81	50.14	88.95	.0775	.1631	126
128	71.43	56.73	.01175	.4515	85.13	2.215	39.31	49.91	89.21	.0783	.1633	128
130	73.54	58.84	0.01178	0.4387	84.89	2.280	39.80	49.67	89.47	0.0792	0.1634	130
132	75.69	60.99	.01181	.4262	84.65	2.346	40.30	49.44	89.73	.0800	.1635	132
134	77.90	63.20	.01185	.4142	84.41	2.414	40.80	49.20	89.99	.0808	.1637	134
136	80.15	65.45	.01188	.4025	84.16	2.484	41.29	48.96	90.25	.0816	.1638	136
138	82.44	67.74	.01192	.3912	83.91	2.556	41.79	48.72	90.51	.0825	.1640	138
140	84.79	70.09	0.01195	0.3803	83.66	2.629	42.29	48.47	90.76	0.0833	0.1641	140

TABLE 8—PROPERTIES OF REFRIGERANT 502, LIQUID AND SATURATED VAPOR

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage P	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	
—100	3.230	23.34*	0.01015	10.84	98.49	0.09228	—15.15	82.52	67.37	—0.0388	0.1906	—100
—98	3.466	22.86*	.01017	10.15	98.30	0.09852	—14.65	82.28	67.63	—0.0375	.1900	—98
—96	3.716	22.36*	.01019	9.515	98.11	0.1051	—14.15	82.04	67.89	—0.0361	.1895	—96
—94	3.979	21.82*	.01021	8.928	97.92	0.1120	—13.66	81.81	68.15	—0.0347	.1890	—94
—92	4.258	21.25*	.01023	8.384	97.72	0.1193	—13.16	81.57	68.41	—0.0334	.1885	—92
—90	4.552	20.65*	0.01025	7.879	97.53	0.1269	—12.66	81.33	68.67	—0.0320	0.1880	—90
—88	4.862	20.02*	.01027	7.411	97.34	0.1349	—12.16	81.09	68.93	—0.0307	.1875	—88
—86	5.190	19.35*	.01029	6.976	97.14	0.1433	—11.66	80.85	69.19	—0.0294	.1870	—86
—84	5.534	18.65*	.01031	6.572	96.95	0.1522	—11.17	80.62	69.45	—0.0280	.1866	—84
—82	5.897	17.91*	.01034	6.196	96.75	0.1614	—10.67	80.38	69.71	—0.0267	.1861	—82
—80	6.278	17.14*	0.01036	5.845	96.55	0.1711	—10.17	80.14	69.97	—0.0254	0.1857	—80
—78	6.679	16.32*	.01038	5.519	96.35	0.1812	—9.66	79.90	70.24	—0.0241	.1853	—78
—76	7.100	15.47*	.01040	5.214	96.15	0.1918	—9.16	79.66	70.50	—0.0228	.1848	—76
—74	7.541	14.57*	.01042	4.930	95.95	0.2028	—8.65	79.41	70.76	—0.0215	.1844	—74
—72	8.004	13.62*	.01044	4.664	95.75	0.2144	—8.15	79.17	71.02	—0.0202	.1841	—72
—70	8.490	12.63*	0.01047	4.416	95.55	0.2265	—7.65	78.93	71.28	—0.0189	0.1837	—70
—68	8.999	11.60*	.01049	4.183	95.35	0.2390	—7.14	78.68	71.54	—0.0176	.1833	—68
—66	9.531	10.52*	.01051	3.966	95.14	0.2522	—6.64	78.44	71.80	—0.0163	.1829	—66
—64	10.09	9.38*	.01053	3.762	94.94	0.2658	—6.13	78.19	72.06	—0.0150	.1826	—64
—62	10.67	8.20*	.01056	3.571	94.73	0.2801	—5.63	77.95	72.32	—0.0137	.1823	—62
—60	11.28	6.96*	0.01058	3.391	94.52	0.2949	—5.12	77.70	72.58	—0.0125	0.1819	—60
—58	11.91	5.67*	.01060	3.222	94.32	0.3103	—4.61	77.45	72.84	—0.0112	.1816	—58
—56	12.58	4.32*	.01063	3.064	94.11	0.3264	—4.10	77.20	73.10	—0.0099	.1813	—56
—54	13.27	2.91*	.01065	2.915	93.90	0.3430	—3.59	76.95	73.36	—0.0087	.1810	—54
—52	13.99	1.44*	.01067	2.775	93.69	0.3604	—3.08	76.70	73.62	—0.0074	.1807	—52
—50	14.74	0.04	0.01070	2.643	93.47	0.3784	—2.57	76.44	73.87	—0.0062	0.1804	—50
—48	15.52	0.82	.01072	2.519	93.26	0.3971	—2.06	76.19	74.13	—0.0049	.1801	—48
—46	16.33	1.64	.01075	2.401	93.05	0.4165	—1.55	75.94	74.39	—0.0037	.1799	—46
—44	17.18	2.48	.01077	2.291	92.83	0.4366	—1.03	75.68	74.65	—0.0025	.1796	—44
—42	18.06	3.36	.01080	2.186	92.62	0.4574	—0.52	75.42	74.90	—0.0012	.1793	—42
—40	18.97	4.28	0.01082	2.087	92.40	0.4791	0	75.16	75.16	0	0.1791	—40
—38	19.92	5.23	.01085	1.994	92.18	0.5015	0.52	74.90	75.42	.0012	.1788	—38
—36	20.91	6.21	.01087	1.906	91.96	0.5247	1.03	74.64	75.67	.0024	.1786	—36
—34	21.93	7.24	.01090	1.823	91.74	0.5487	1.56	74.33	75.93	.0037	.1784	—34
—32	23.00	8.30	.01093	1.744	91.52	0.5735	2.07	74.11	76.18	.0049	.1781	—32
—30	24.10	9.40	0.01095	1.669	91.30	0.5993	2.60	73.84	76.44	0.0061	0.1779	—30
—28	25.24	10.54	.01098	1.598	91.08	0.6259	3.12	73.57	76.69	.0073	.1777	—28
—26	26.42	11.72	.01101	1.531	90.85	0.6534	3.64	73.30	76.94	.0085	.1775	—26
—24	27.64	12.95	.01103	1.467	90.63	0.6818	4.16	73.03	77.19	.0097	.1773	—24
—22	28.91	14.21	.01106	1.406	90.40	0.7112	4.69	72.75	77.44	.0109	.1771	—22
—20	30.22	15.52	0.01109	1.349	90.18	0.7415	5.21	72.48	77.69	0.0121	0.1769	—20
—18	31.57	16.88	.01112	1.294	89.95	0.7729	5.74	72.20	77.94	.0133	.1767	—18
—16	32.97	18.28	.01115	1.242	89.72	0.8052	6.27	71.92	78.19	.0145	.1766	—16
—14	34.42	19.72	.01117	1.193	89.49	0.8386	6.80	71.64	78.44	.0156	.1764	—14
—12	35.91	21.22	.01120	1.145	89.26	0.8731	7.33	71.36	78.69	.0168	.1762	—12
—10	37.46	22.76	0.01123	1.101	89.02	0.9086	7.86	71.07	78.93	0.0180	0.1760	—10
—8	39.05	24.35	.01126	1.058	88.79	0.9453	8.40	70.78	79.18	.0192	.1759	—8
—6	40.69	26.00	.01129	1.017	88.55	0.9831	8.93	70.49	79.42	.0204	.1757	—6
—4	42.39	27.69	.01132	0.9784	88.32	1.022	9.47	70.20	79.67	.0215	.1756	—4
—2	44.14	29.44	.01135	0.9414	88.08	1.062	10.00	69.91	79.91	.0227	.1754	—2
0	45.94	31.24	0.01138	0.9061	87.84	1.104	10.54	69.61	80.15	0.0239	0.1753	0
2	47.79	33.10	.01142	0.8724	87.60	1.146	11.08	69.31	80.39	.0250	.1751	2
4	49.71	35.01	.01145	0.8402	87.36	1.190	11.62	69.01	80.63	.0262	.1750	4
6	51.68	36.98	.01148	0.8094	87.12	1.235	12.16	68.70	80.86	.0273	.1749	6
8	53.70	39.01	.01151	0.7800	86.88	1.282	12.70	68.40	81.10	.0285	.1747	8
10	55.79	41.09	0.01154	0.7519	86.63	1.330	13.25	68.08	81.33	0.0296	0.1746	10
12	57.94	43.24	.01158	0.7250	86.39	1.379	13.80	67.77	81.57	.0308	.1745	12
14	60.14	45.45	.01161	0.6992	86.14	1.430	14.34	67.46	81.80	.0319	.1743	14
16	62.41	47.72	.01164	0.6746	85.89	1.482	14.89	67.14	82.03	.0331	.1742	16
18	64.75	50.05	.01168	0.6510	85.64	1.536	15.44	66.82	82.26	.0342	.1741	18
20	67.14	52.45	0.01171	0.6283	85.39	1.592	15.99	66.50	82.49	0.0354	0.1740	20
22	69.61	54.91	.01175	0.6066	85.14	1.649	16.54	66.17	82.71	.0365	.1739	22
24	72.13	57.44	.01178	0.5858	84.88	1.707	17.10	65.84	82.94	.0376	.1738	24
26	74.73	60.04	.01182	0.5659	84.63	1.767	17.65	65.51	83.16	.0388	.1736	26
28	77.40	62.70	.01185	0.5467	84.37	1.829	18.21	65.17	83.38	.0399	.1735	28
30	80.13	65.44	0.01189	0.5283	84.11	1.893	18.76	64.84	83.60	0.0410	0.1734	30
32	82.94	68.24	.01193	0.5106	83.85	1.958	19.32	64.49	83.81	.0422	.1733	32
34	85.82	71.12	.01196	0.4937	83.59	2.026	19.88	65.15	84.03	.0433	.1732	34
36	88.77	74.07	.01200	0.4774	83.33	2.095	20.44	65.80	84.24	.0444	.1731	36
38	91.80	77.10	.01204	0.4617	83.07	2.166	21.01	66.44	84.45	.0455	.1730	38

*Inches of mercury below one atmosphere.

Courtesy of E. I. du Pont de Nemours & Co. 1963

TABLE 8—PROPERTIES OF REFRIGERANT 502, LIQUID AND SATURATED VAPOR (Contd)

TEMP (F)	PRESSURE (lb/sq in.)		VOLUME (cu ft/lb)		DENSITY (lb/cu ft)		ENTHALPY (Btu/lb)			ENTROPY (Btu/lb-R)		TEMP (F)
	Absolute P	Gage P	Liquid v _l	Vapor v _g	Liquid 1/v _l	Vapor 1/v _g	Liquid h _l	Latent h _{fg}	Vapor h _g	Liquid s _l	Vapor s _g	
40	94.90	80.20	0.01208	0.4466	82.80	2.239	21.57	63.09	84.06	0.0466	0.1729	40
42	98.08	83.38	.01212	0.4321	82.53	2.314	22.14	62.73	84.87	.0478	.1728	42
44	101.3	86.64	.01216	0.4182	82.26	2.391	22.71	62.36	85.07	.0489	.1727	44
46	104.7	89.97	.01220	0.4047	81.99	2.471	23.28	61.99	85.27	.0500	.1726	46
48	108.1	93.39	.01224	0.3918	81.72	2.552	23.85	61.62	85.47	.0511	.1725	48
50	111.6	96.89	0.01228	0.3793	81.44	2.636	24.42	61.25	85.67	0.0522	0.1724	50
52	115.2	100.5	.01232	0.3673	81.17	2.722	25.00	60.87	85.87	.0533	.1723	52
54	118.8	104.1	.01236	0.3557	80.89	2.811	25.58	60.48	86.06	.0544	.1722	54
56	122.6	107.9	.01241	0.3446	80.61	2.902	26.16	60.09	86.25	.0555	.1721	56
58	126.4	111.7	.01245	0.3338	80.33	2.996	26.73	59.70	86.43	.0566	.1720	58
60	130.3	115.6	0.01249	0.3234	80.04	3.092	27.32	59.30	86.62	0.0578	0.1719	60
62	134.3	119.6	.01254	0.3134	79.76	3.191	27.91	58.89	86.80	.0589	.1717	62
64	138.4	123.7	.01258	0.3037	79.47	3.292	28.48	58.49	86.97	.0600	.1716	64
66	142.6	127.9	.01253	0.2944	79.18	3.397	29.08	58.07	87.15	.0611	.1715	66
68	146.9	132.2	.01268	0.2854	78.88	3.504	29.67	57.65	87.32	.0622	.1714	68
70	151.3	136.6	0.01272	0.2766	78.59	3.615	30.25	57.23	87.48	0.0633	0.1713	70
72	155.8	141.1	.01277	0.2682	78.29	3.728	30.85	56.80	87.65	.0644	.1712	72
74	160.3	145.6	.01282	0.2601	77.99	3.845	31.45	56.36	87.81	.0655	.1711	74
76	165.0	150.3	.01287	0.2522	77.68	3.965	32.04	55.92	87.96	.0665	.1709	76
78	169.8	155.1	.01292	0.2446	77.38	4.089	32.64	55.47	88.11	.0676	.1708	78
80	174.6	159.9	0.01298	0.2372	77.07	4.216	33.24	55.02	88.26	0.0687	0.1707	80
82	179.6	164.9	.01303	0.2300	76.76	4.347	33.84	54.56	88.40	.0698	.1706	82
84	184.7	170.0	.01308	0.2231	76.44	4.482	34.45	54.09	88.54	.0709	.1704	84
86	189.8	175.1	.01314	0.2164	76.13	4.621	35.06	53.62	88.68	.0720	.1703	86
88	195.1	180.4	.01319	0.2099	75.80	4.763	35.67	53.14	88.81	.0731	.1701	88
90	200.5	185.8	0.01325	0.2036	75.48	4.911	36.28	52.65	88.93	0.0742	0.1700	90
92	206.0	191.3	.01331	0.1976	75.15	5.062	36.89	52.16	89.05	.0753	.1698	92
94	211.6	196.9	.01337	0.1916	74.82	5.218	37.51	51.65	89.16	.0764	.1697	94
96	217.3	202.6	.01343	0.1859	74.48	5.379	38.13	51.14	89.27	.0775	.1695	96
98	223.1	208.4	.01349	0.1804	74.15	5.545	38.75	50.62	89.37	.0786	.1693	98
100	229.1	214.4	0.01355	0.1750	73.80	5.716	39.37	50.10	89.47	0.0796	0.1692	100
102	235.1	220.4	.01361	0.1697	73.45	5.892	40.00	49.56	89.56	.0807	.1690	102
104	241.3	226.6	.01368	0.1646	73.10	6.074	40.62	49.02	89.64	.0818	.1688	104
106	247.6	232.9	.01375	0.1597	72.74	6.262	41.25	48.47	89.72	.0829	.1686	106
108	254.0	239.3	.01382	0.1549	72.38	6.456	41.88	47.90	89.78	.0840	.1684	108
110	260.5	245.8	0.01389	0.1502	72.01	6.656	42.52	47.33	89.85	0.0851	0.1682	110
112	267.1	252.4	.01396	0.1457	71.64	6.863	43.15	46.75	89.90	.0862	.1679	112
114	273.9	259.2	.01403	0.1413	71.26	7.078	43.79	46.15	89.94	.0872	.1677	114
116	280.8	266.1	.01411	0.1370	70.87	7.299	44.43	45.55	89.98	.0883	.1674	116
118	287.8	273.1	.01419	0.1328	70.48	7.528	45.07	44.93	90.00	.0894	.1672	118
120	295.0	280.3	0.01427	0.1288	70.08	7.765	45.71	44.31	90.02	0.0905	0.1669	120
122	302.2	287.5	.01435	0.1248	69.68	8.011	46.36	43.67	90.03	.0916	.1666	122
124	309.7	295.0	.01444	0.1210	69.26	8.265	47.00	43.02	90.02	.0926	.1663	124
126	317.2	302.5	.01453	0.1173	68.84	8.529	47.65	42.36	90.01	.0937	.1660	126
128	324.9	310.2	.01462	0.1136	68.41	8.802	48.29	41.69	89.98	.0948	.1657	128
130	332.7	318.0	0.01471	0.1101	67.96	9.086	48.95	41.00	89.95	0.0958	0.1654	130
132	340.6	325.9	.01481	0.1066	67.51	9.380	49.59	40.30	89.98	.0969	.1650	132
134	348.7	334.0	.01491	0.1032	67.05	9.685	50.24	39.59	89.83	.0979	.1646	134
136	357.0	342.3	.01502	0.09997	66.58	10.00	50.88	38.87	89.75	.0990	.1642	136
138	365.3	350.6	.01513	0.09679	66.09	10.33	51.53	38.13	89.66	.1000	.1638	138
140	373.8	359.1	0.01525	0.09368	65.59	10.67	52.17	37.38	89.55	0.1011	0.1634	140
142	382.5	367.8	.01537	0.09067	65.07	11.03	52.81	36.62	89.43	.1021	.1630	142
144	391.3	376.6	.01549	0.08773	64.54	11.40	53.45	35.84	89.29	.1031	.1625	144
146	400.3	385.6	.01563	0.08489	63.99	11.78	54.08	35.06	89.14	.1041	.1620	146
148	409.4	394.7	.01577	0.08213	63.42	12.18	54.70	34.27	88.97	.1051	.1615	148
150	418.6	403.9	0.01591	0.07946	62.84	12.59	55.32	33.47	88.79	0.1061	0.1610	150
152	428.1	413.4	.01607	0.07688	62.22	13.01	55.92	32.68	88.60	.1070	.1604	152
154	437.6	422.9	.01624	0.07441	61.59	13.44	56.51	31.88	88.39	.1079	.1599	154
156	447.4	432.7	.01641	0.07204	60.92	13.88	57.10	31.08	88.18	.1088	.1593	156
158	457.2	442.5	.01661	0.06978	60.22	14.33	57.66	30.30	87.96	.1097	.1587	158
160	467.3	452.6	0.01681	0.06764	59.49	14.78	58.21	29.53	87.74	0.1105	0.1582	160

CHAPTER 2. BRINES

This chapter provides information to guide the engineer in the selection of brines, and includes the properties of the commonly used brines.

At temperatures above 32 F, water is the most commonly used heat transfer medium for conveying a refrigeration load to an evaporator. At temperatures below 32 F, brines are used. They may be:

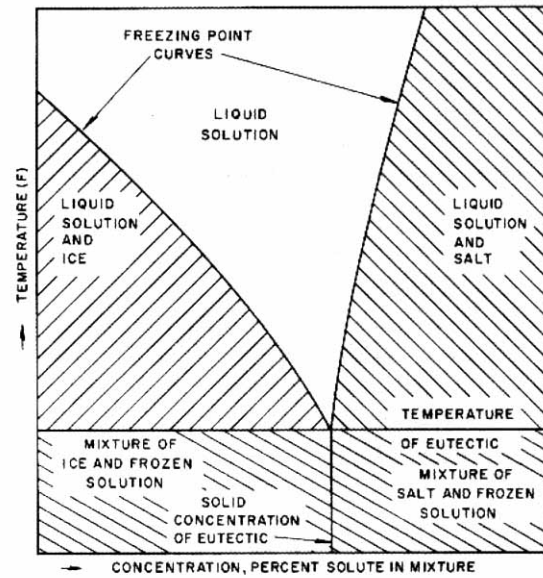
1. An aqueous solution of inorganic salts, i.e. sodium chloride or calcium chloride. For low temperatures, a eutectic mixture may be used.
2. An aqueous solution of organic compounds, i.e. alcohols or glycols. Ethanol water, methanol water, ethylene glycol and propylene glycol are examples.
3. Chlorinated or fluorinated hydrocarbons and halocarbons.

A solution of any salt in water, or in general any solution, has a certain concentration at which the freezing point is at a minimum. A solution of such a concentration is called a eutectic mixture. The temperature at which it freezes is the eutectic temperature. A solution at any other concentration starts to freeze at a higher temperature. *Figure 11* illustrates the relationship between the freezing point (temperature) of a brine mixture and the percent of solute in the mixture (concentration). *Chart 18* covers a range of temperatures wide enough to reveal the two freezing point curves.

When the temperature of a brine with a concentration below the eutectic falls below the freezing point, ice crystals form and the concentration of the residual solution increases until at the eutectic temperature the remaining solution reaches a eutectic concentration. Below this temperature the mixture solidifies to form a mechanical mixture of ice and frozen eutectic solution.

When the temperature of a brine with a concentration above the eutectic falls below the freezing point, salt crystallizes out and the concentration of the residual solution decreases until at the eutectic temperature the remaining solution reaches a eutectic concentration. Below this temperature the mixture solidifies to form a mechanical mixture of salt and frozen eutectic solution.

This chapter includes a discussion of these brines, also tables and charts indicating properties.



Courtesy of ASHRAE Guide and Data Book 1963

FIG. 11-BRINE MIXTURE

BRINE SELECTION

The selection of a brine is based upon a consideration of the following factors:

1. *Freezing Point* -Brine must be suitable for the lowest operating temperature.
2. *Application* -When using an open piping system, the possibility of product contamination by the brine should be checked.
3. *Cost* -The initial charge and quantity of make-up required are factors in the determination of costs.
4. *Safety* -Toxicity and flammability of brine.
5. *Thermal Performance* -Viscosity, specific gravity, specific heat and thermal conductivity are utilized to determine thermal performance.
6. *Suitability* -Piping and system equipment material require a stable and relatively corrosive-free brine.
7. *Codes* -Brine must be acceptable by codes, ordinances, regulatory agencies and insurer.

TABLE 9-TYPICAL BRINE APPLICATIONS

	Sodium Chloride	Calcium Chloride	Ethylene Glycol	Propylene Glycol	Methanol Water	Ethanol Water	Chlorinated or Fluorinated Hydrocarbons
Breweries				X			
Chemical Plants	X	X	X		X	X	X
Dairies	X	X		X			
Food Freezing	X	X		X		X	
Heat Pumps		X	X				X
Meat Packing	X	X					
Preheat Coils (Air Conditioning Systems)			X				
Skating Rinks		X	X		X		
Snow Melting	X	X	X				
Low Temperature (Specine)		X	X				X
Ice Cream		X		X			

The most common brines are aqueous solutions of calcium chloride or sodium chloride. Although both of these brines have the advantage of low cost, they have the disadvantage of being corrosive. To overcome corrosion, an inhibitor may be added to the brine. Sodium dichromate is a satisfactory and economical inhibitor. Sodium hydroxide is added to keep the brine slightly alkaline.

Sodium chloride is cheaper than calcium chloride brine; however, it cannot be used below its eutectic point of -6 F. It is preferred where contact with calcium chloride brine cannot be tolerated, for example, with unsealed foodstuffs. The use of calcium chloride of commercial grade is not satisfactory below -40 F.

Systems using aqueous solutions of alcohol or glycol are more susceptible to leakage than those using salts. A disadvantage of alcohol is its flammability. It is utilized mainly in industrial processes where similar hazards already exist, and in the same temperature range as the salts (down to -40 F). The toxicity of methanol water (wood alcohol) is a disadvantage. Conversely, the non-toxicity of ethanol water (denatured grain alcohol) is an advantage.

Corrosion inhibitors should be used with alcohol type brines as recommended by the manufacturer of the alcohol.

Aqueous solutions of glycol are utilized mainly in commercial applications as opposed to industrial processes. Ethylene and propylene glycol possess equal corrosiveness which an inhibitor can neutralize. Galvanized surfaces are particularly prone to attack by the glycols and should be avoided.

An inhibitor and potable water are recommended for making up glycol brines. The glycol manufacturer should be consulted for inhibitor recommendations. Some manufacturers have a brine sample analysis service to assist in maintaining a satisfactory brine condition in the system. Heat transfer glycols are available with nonoily inhibitors which do not penalize heat transfer qualities (sodium nitrite or borox).

Glycols can be used as heat transfer media at relatively high temperatures. With stabilizers, glycol oxidation in air at high temperatures is eliminated for all practical purposes.

Ethylene glycol is more toxic than propylene glycol, but less toxic than methanol water. Propylene glycol is preferred to ethylene glycol in food freezing for example.

Chlorinated and fluorinated hydrocarbons are expensive and are used in very low temperature work (below -40 F).

Table 8 presents typical application for the various brines.

Load, brine quantity and temperature rise are all related to each other so that, when any two are known, the third may be found by the formula:

$$\text{Load (tons)} = \frac{\text{gpm} \times \text{temp rise (F)} \times \text{sp gr} \times C_p}{24}$$

where:

sp gr = specific gravity of brine

C_p = specific heat of brine (Btu/lb-F)

PIPING

All materials in the piping system including flange gaskets, valve seats and packing, pump seals and other specialties must be compatible with the brine. Copper tubing (except for the salt brines) and standard steel pipe are suitable for general use.

The pump rating and motor horsepower should be based on the particular brine used and the actual operating temperature.

FRICTION LOSS

To determine the friction loss in a brine piping system, the engineer should first calculate the loss as if water were being used. A multiplier is then used to convert the calculated loss to the actual loss for the brine system. The multiplier is calculated as follows:

$$\text{Multiplier} = \text{sp gr} \times \frac{f_b}{f_w}$$

where:

sp gr = specific gravity of brine

f_b = friction factor for the brine

f_w = friction factor for water at the brine velocity

Friction factor is determined from the Reynolds number. The Reynolds number is:

$$\text{Re} = \frac{7740 \times d \times v \times \text{sp gr}}{\mu'}$$

where:

d = inside pipe diameter (in.)

v = brine velocity (ft/sec)

sp gr = specific gravity of brine = $\frac{1\text{b/cu ft}}{62.5}$

$$\mu' = \text{viscosity (centipoises)} = \frac{\text{absolute viscosity, 1b/(hr) (ft)}}{2.42}$$

Example 1 illustrates the use of the multiplier to determine the brine friction loss thru a heat transfer coil.

Example 1- Friction Loss Multiplier

Given:

A 5/8 in. copper tube coil with a circuit water velocity of 4.29 ft/sec and a pressure drop of 7.5 psi.

Mean water temperature = 55 F.

Find:

Friction loss multiplier and pressure drop when using ethylene glycol at a mean brine temperature of 92.5 F and 41% solution by weight at the same circuit liquid velocity.

Solution:

Refer to *Chart 1*.

$$\frac{\epsilon}{d} = \frac{.00006}{.575} = .000104$$

where:

ϵ = absolute roughness of drawn tubing

d = inside diameter of 5/8 in. copper tubing

Refer to *Chart 19*.

Specific gravity of ethylene glycol at a mean brine temperature of 92.5 F and 41% solution by weight is 1.05.

Refer to *Chart 18*.

Viscosity of ethylene glycol at the same condition equals 2.1 centipoises.

$$\text{Re} = \frac{7740 \times .575 \times 4.29 \times 1.05}{2.1} = 9520 = 9.52 \times 10^3$$

Refer to *Chart 1*.

For a Reynolds number of 9.52×10^3 and a relative roughness of .000104, the chart indicates friction factor $f_b = .031$.

Specific gravity of fresh water at a mean temperature of 55 F = 1.00

Refer to *Chart 28*.

Viscosity of fresh water at a mean temperature of 55 F = 1.2 centipoises.

$$\text{Re (water)} = \frac{7740 \times .575 \times 4.29 \times 1.00}{1.2} = 15,900 = 1.59 \times 10^4$$

Refer again to *Chart 1*.

For a Reynolds number of 1.59×10^4 and a relative roughness of .000104, the chart indicates a friction factor $f_w = .027$.

$$\begin{aligned} \text{Friction multiplier} &= \text{sp gr (brine)} \times \frac{f_b}{f_w} \\ &= 1.05 \times \frac{.031}{.027} = 1.21 \end{aligned}$$

Brine friction loss = 1.21×7.5 psi = 9.08 psi or

$$= \frac{9.08 \times 2.31}{1.05} = 20.0 \text{ ft brine}$$

PUMP BRAKE HORSEPOWER

To determine the horsepower required by a pump with brine, the following formula may be used:

$$\text{bhp} = \frac{\text{gpm} \times \text{total head (ft brine)} \times \text{sp gr}}{3960 \times \text{eff}}$$

where:

gpm = gallons/min. of brine

total head = total pump head (ft brine)

sp gr = specific gravity of brine

eff = pump efficiency

BRINE PROPERTIES

Specific gravity, viscosity, conductivity, specific heat, concentration, and freezing and boiling points are important factors in the consideration of liquids other than water suitable for cooling and heating purposes. High values of specific gravity, conductivity and specific heat, and low values of viscosity, promote a high rate of heat transfer. High values of specific gravity and viscosity result in high pumping head and consequently high

pumping costs. High specific heats are desirable in that they reduce the quantity of liquid required to be circulated or stored for a given duty. Low viscosities are desirable from a standpoint of both rate of heat transfer and low pumping costs. They are particularly desirable at the lower temperatures where the viscosity increases.

Table 9 is a tabulation of the various brines covered in this chapter, giving the properties of these brines at different temperatures and suitable concentrations. Charts 2 to 28 present the viscosity, specific gravity, specific heat and thermal conductivity of the brines for various mean brine temperatures and compositions.

TABLE 10-BRINE PROPERTIES

Temp. (F)	Brine	Solution (by wt) (%)	Density (lb/cu ft)	Specific Heat (Btu/lb-F)	Thermal Cond. (Btu/hr -sq ft-F/ft)	Viscosity (Centi- poises)	Freezing Point (F)	Boiling Point (F)	Gpm/ton /10 deg rise	h_b *	V_b †	Relative Cost per Gal. of Solution
30	Sodium Chloride	12	68.2	.86	.28	2.2	17.5	215.	2.55	941	1.61	1
	Calcium Chloride	12	69.2	.83	.32	2.4	19.0	213.	2.62	971	1.78	3
	Methanol Water	15	61.5	1.00	.28	3.2	13.5	187.	2.45	781	2.63	13
	Ethanol Water	20	61.0	1.04	.27	5.5	12.0	189.	2.37	621	4.60	20
	Ethylene Glycol	25	64.7	.92	.30	3.7	12.9	217.	2.52	775	2.92	42
	Propylene Glycol	30	64.5	.94	.26	8.0	13.0	216.	2.47	525	6.35	43
15	Sodium Chloride	21	72.8	.80	.25	4.2	1.0	216.	2.57	693	2.90	1
	Calcium Chloride	20	74.8	.72	.31	4.8	1.0	214.	2.77	730	3.28	5
	Methanol Water	22	60.4	.97	.26	5.3	4.5	182.	2.56	599	4.44	19
	Ethanol Water	25	61.0	1.02	.25	8.2	4.5	187.	2.41	504	6.85	25
	Ethylene Glycol	35	66.0	.86	.28	6.8	0.0	219.	2.65	576	5.25	60
	Propylene Glycol	40	65.3	.89	.24	20.0	-4.2	218.	2.58	103	‡	58
-5	Calcium Chloride	25	78.4	.67	.29	10.3	-21.0	215.	2.85	513	6.75	6
	Methanol Water	35	60.0	.89	.23	9.9	-22.0	176.	2.82	98	8.40	30
	Ethanol Water	36	60.6	.95	.22	13.5	-16.0	183.	2.62	97	‡	35
	Ethylene Glycol	45	67.4	.79	.25	17.2	-15.5	223.	2.82	103	‡	78
	Propylene Glycol	50	66.5	.83	.23	80.0	-29.0	222.	2.72	98	‡	75
-30	Calcium Chloride	30	82.1	.63	.28	27.8	-47.0	216.	2.90	110	‡	8
	Methanol Water	45	60.0	.80	.22	18.0	-45.0	171.	3.13	91	‡	39
	Ethanol Water	52	59.5	.81	.19	20.2	-50.0	179.	3.11	83	‡	50
	Ethylene Glycol	55	69.0	.73	.22	75.0	-43.0	227.	2.98	93	‡	97
	Propylene Glycol	60	67.2	.77	.21	700.0	-55.0	227.	2.90	91	‡	90

* h_b = coefficient of heat transfer between brine and surface (Btu/hr-sq ft.F), at 7 fps velocity for .554 in. ID tubing.

† V_b = minimum brine velocity (ft/sec), at Re=3500 for .554 in. ID tubing.

‡Above 10 ft/sec.

Note that specific gravity for propylene glycol (Chart 23) in the composition range of 50% to 100% (same mean brine temperature, F) is the same for two

compositions. Specific gravity alone, therefore, is not a reliable method of determining the solution composition of this brine.

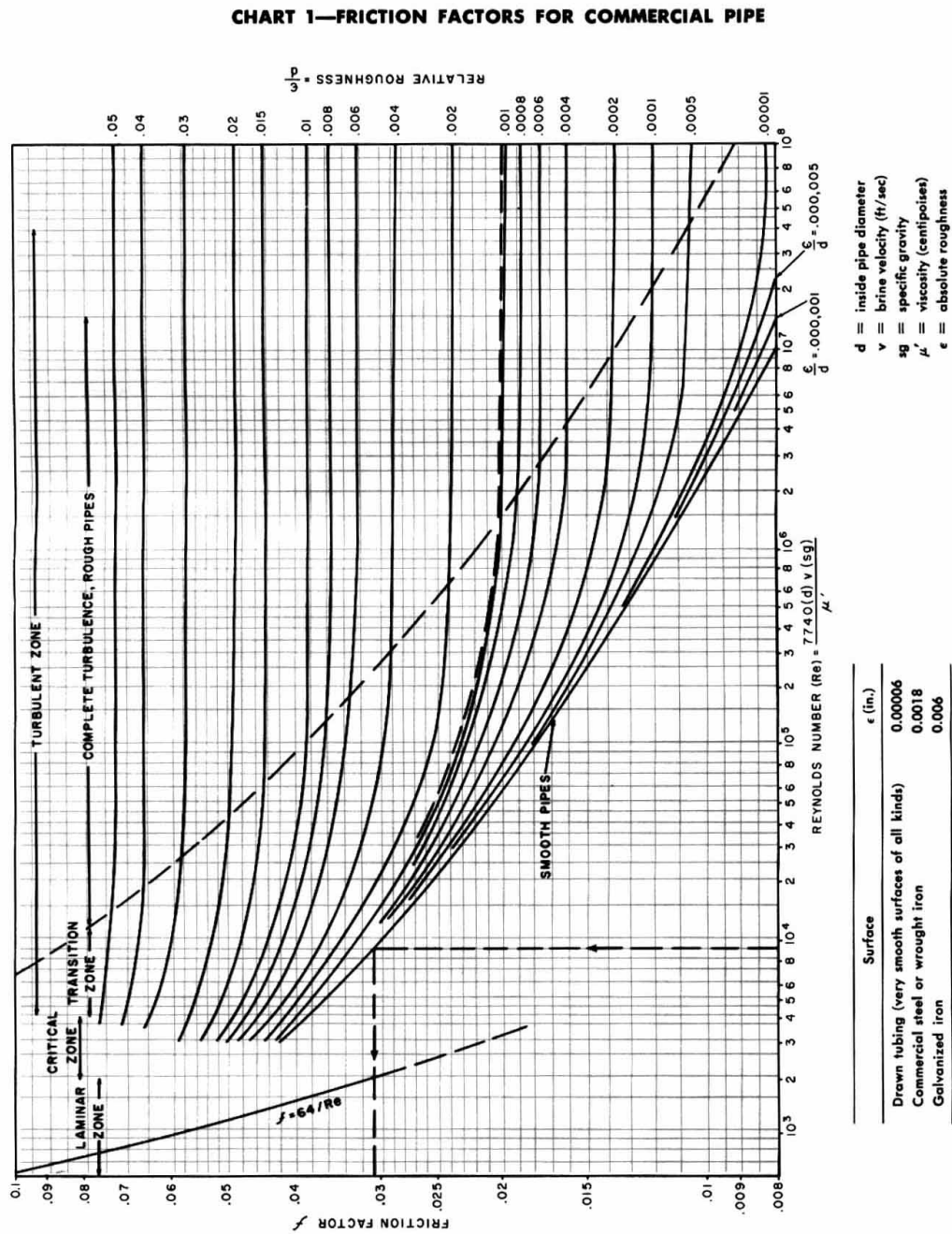


CHART 2-SODIUM CHLORIDE-VISCOSITY

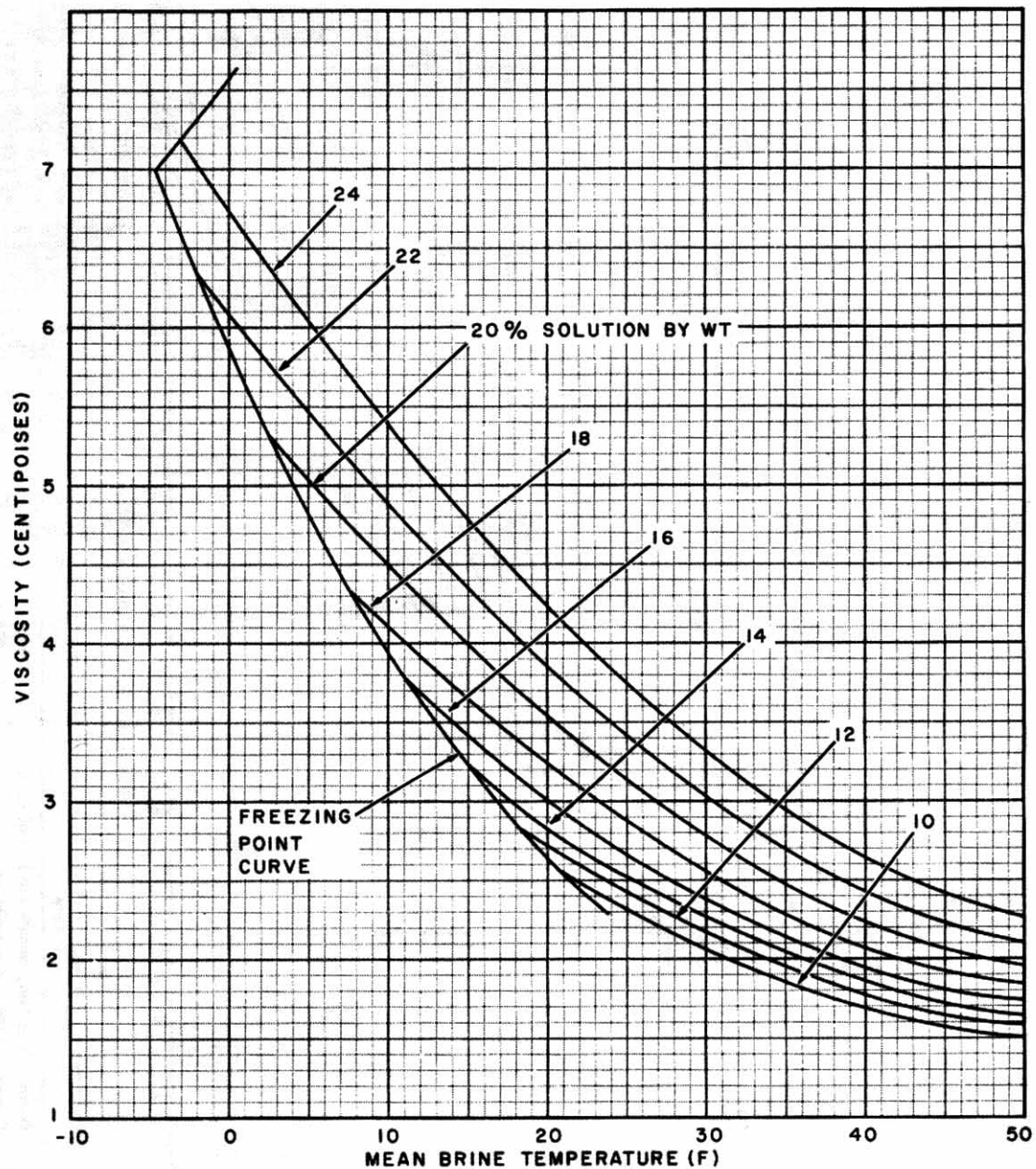
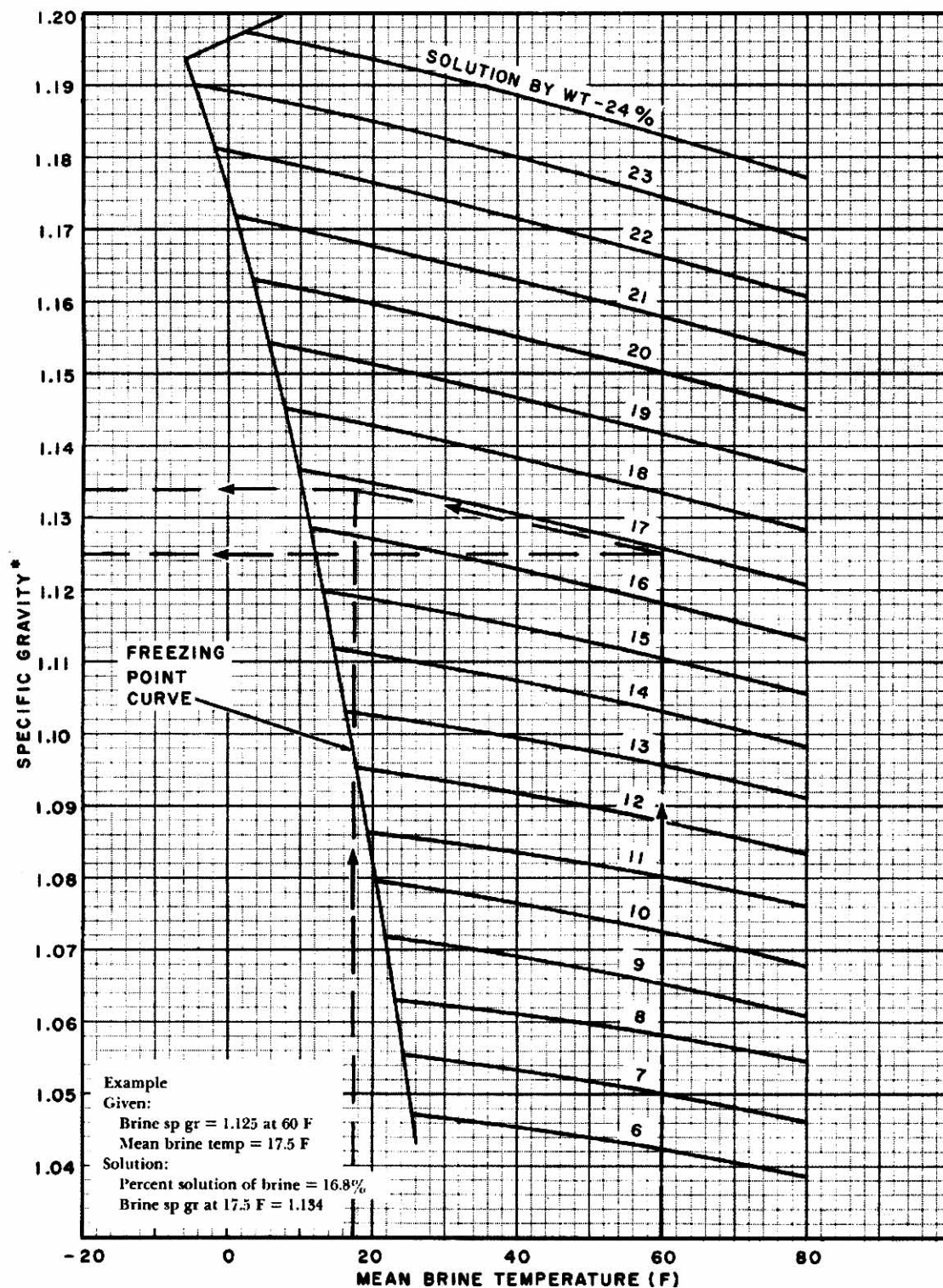


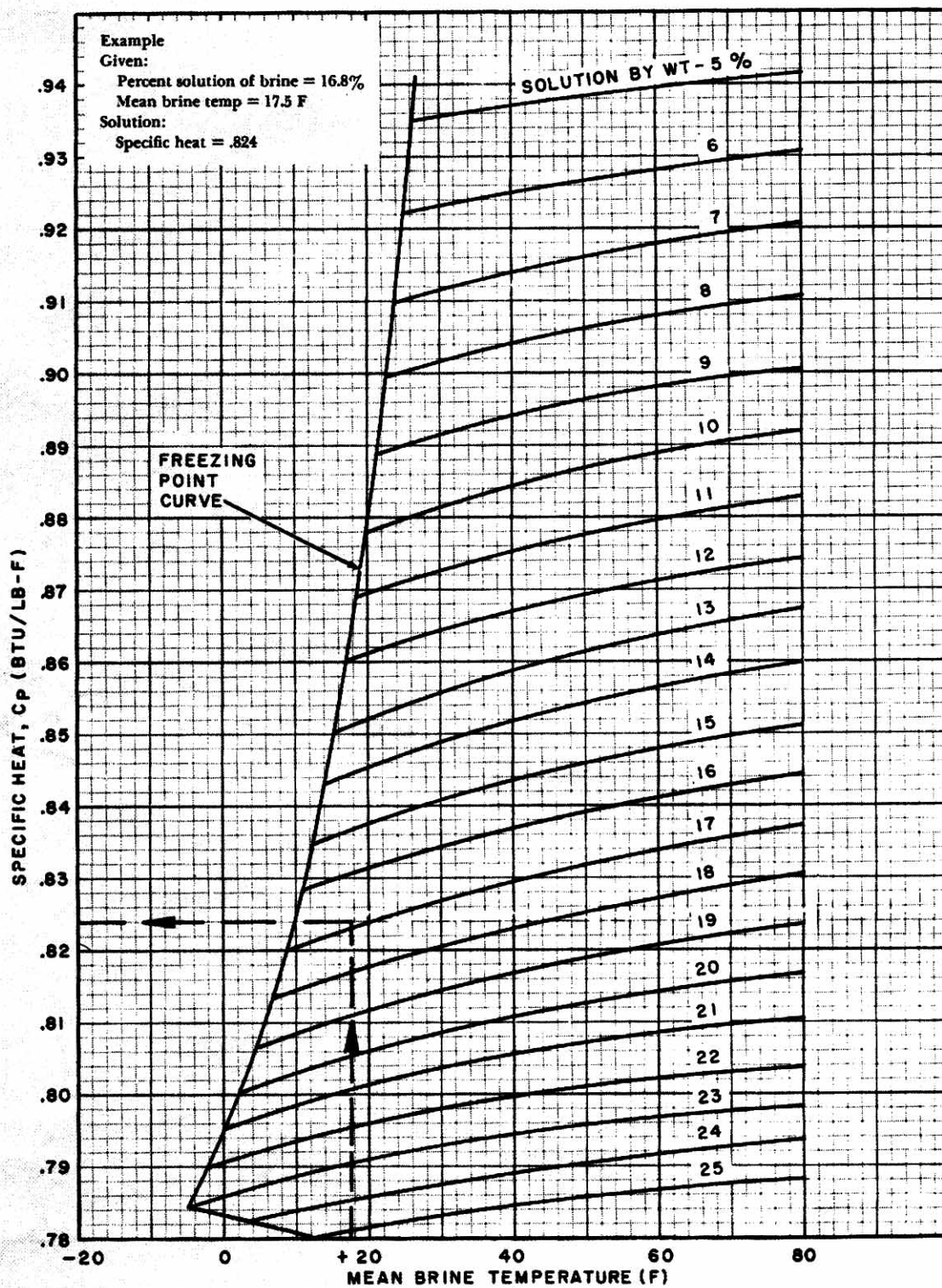
CHART 3-SODIUM CHLORIDE-SPECIFIC GRAVITY



*With reference to 60 F water.

Courtesy of Dow Chemical Co.

CHART 4-SODIUM CHLORIDE-SPECIFIC HEAT



Courtesy of Dow Chemical Co.

CHART 5-SODIUM CHLORIDE-THERMAL CONDUCTIVITY

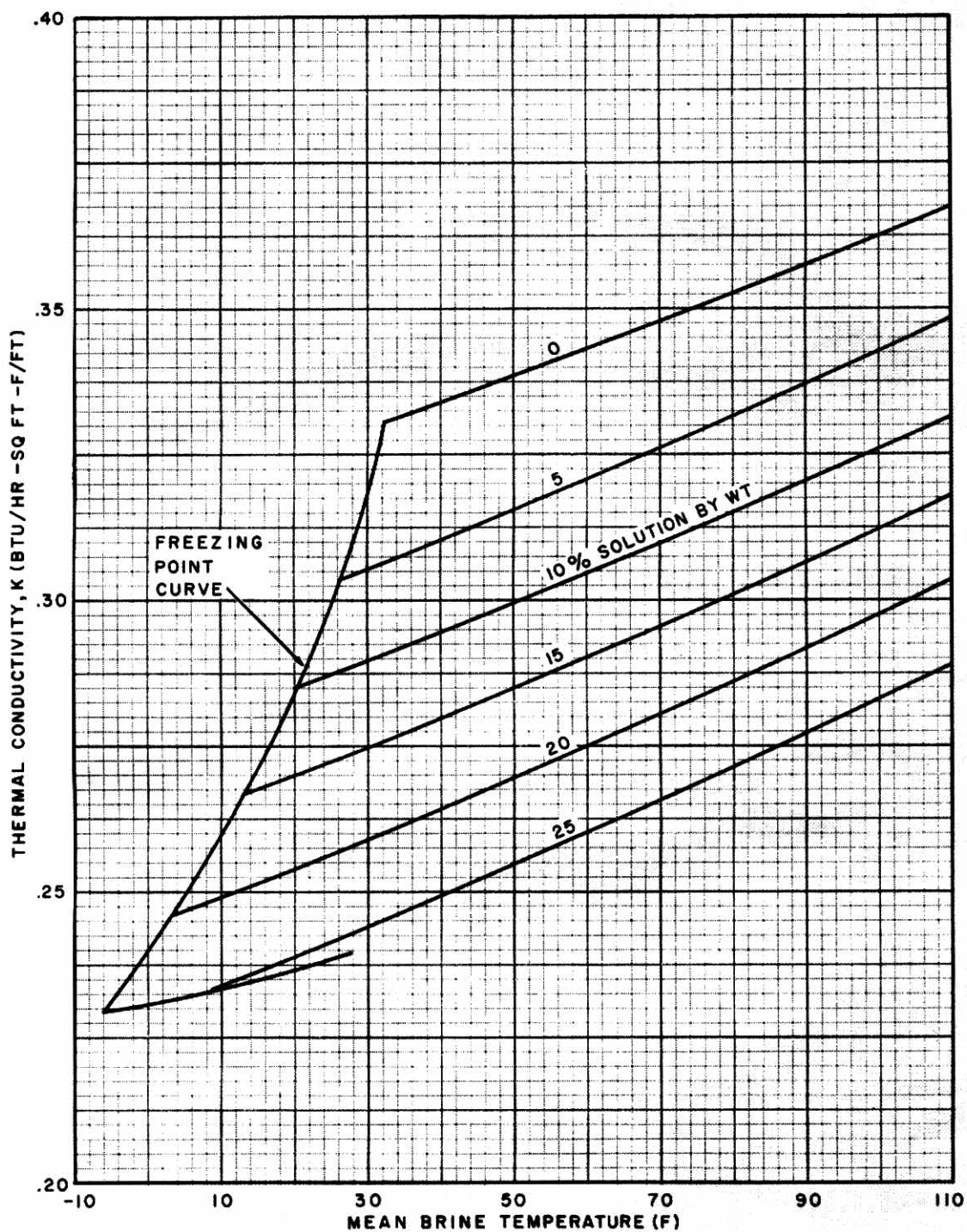


CHART 6-CALCIUM CHLORIDE-VISCOSITY

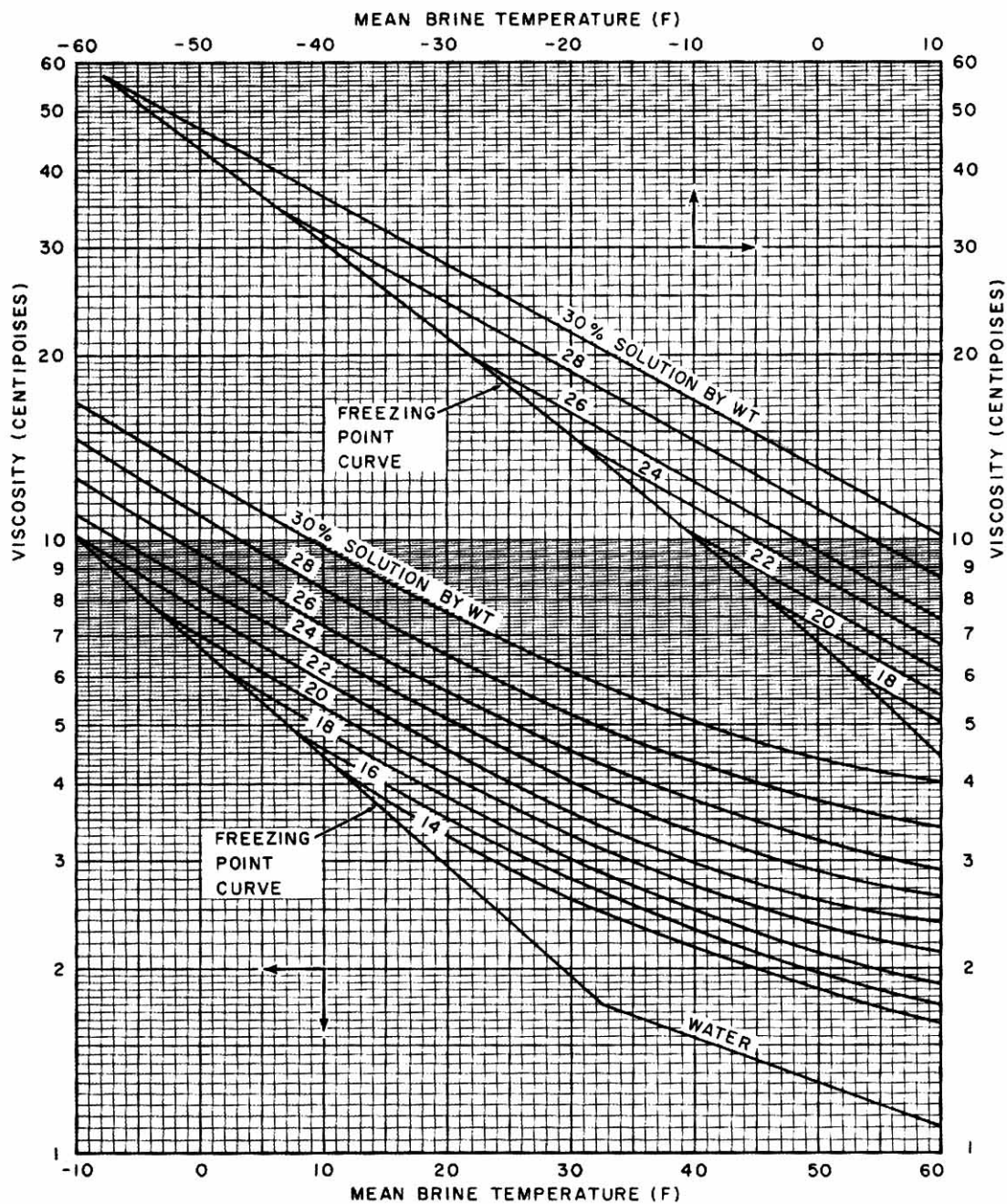
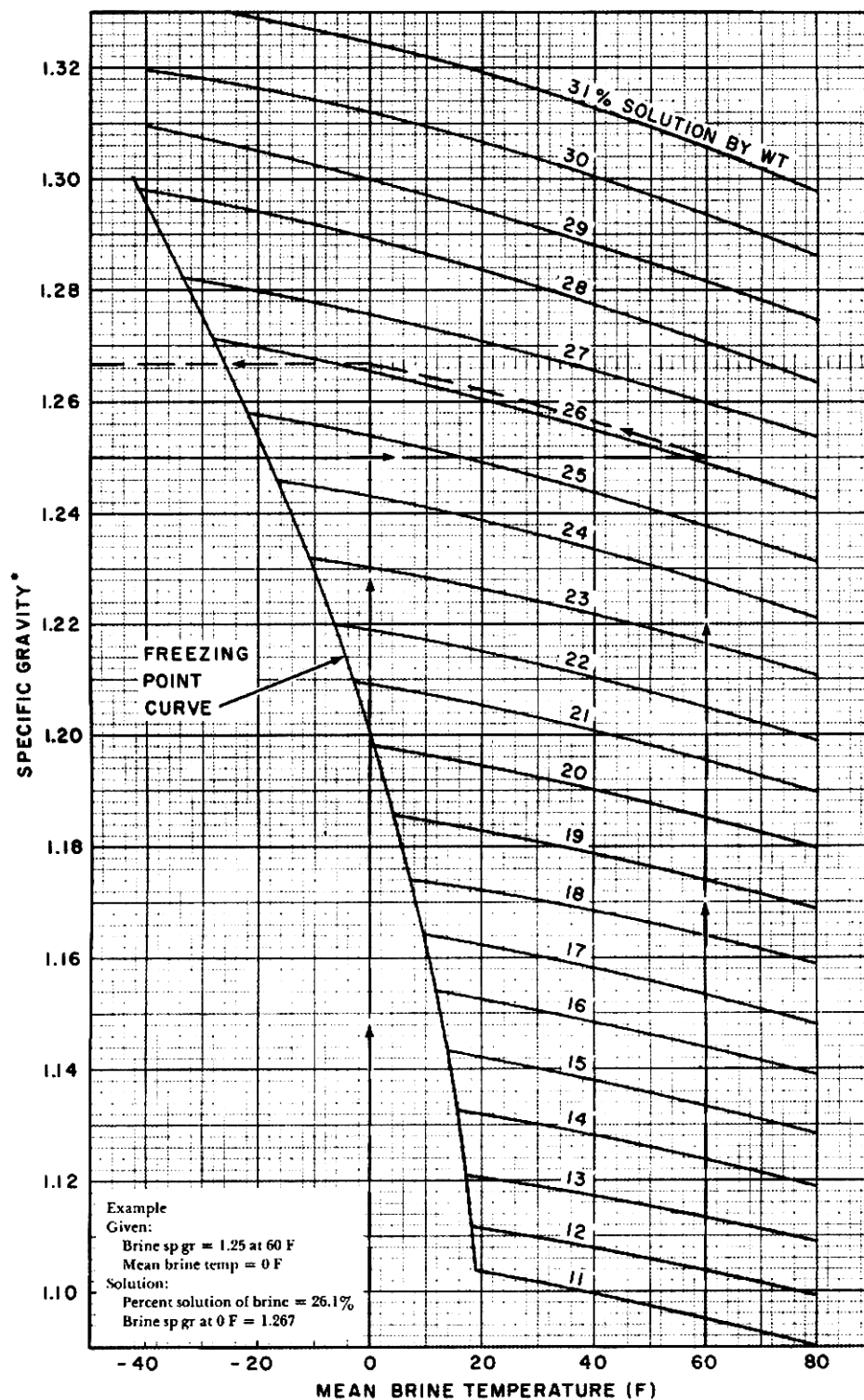


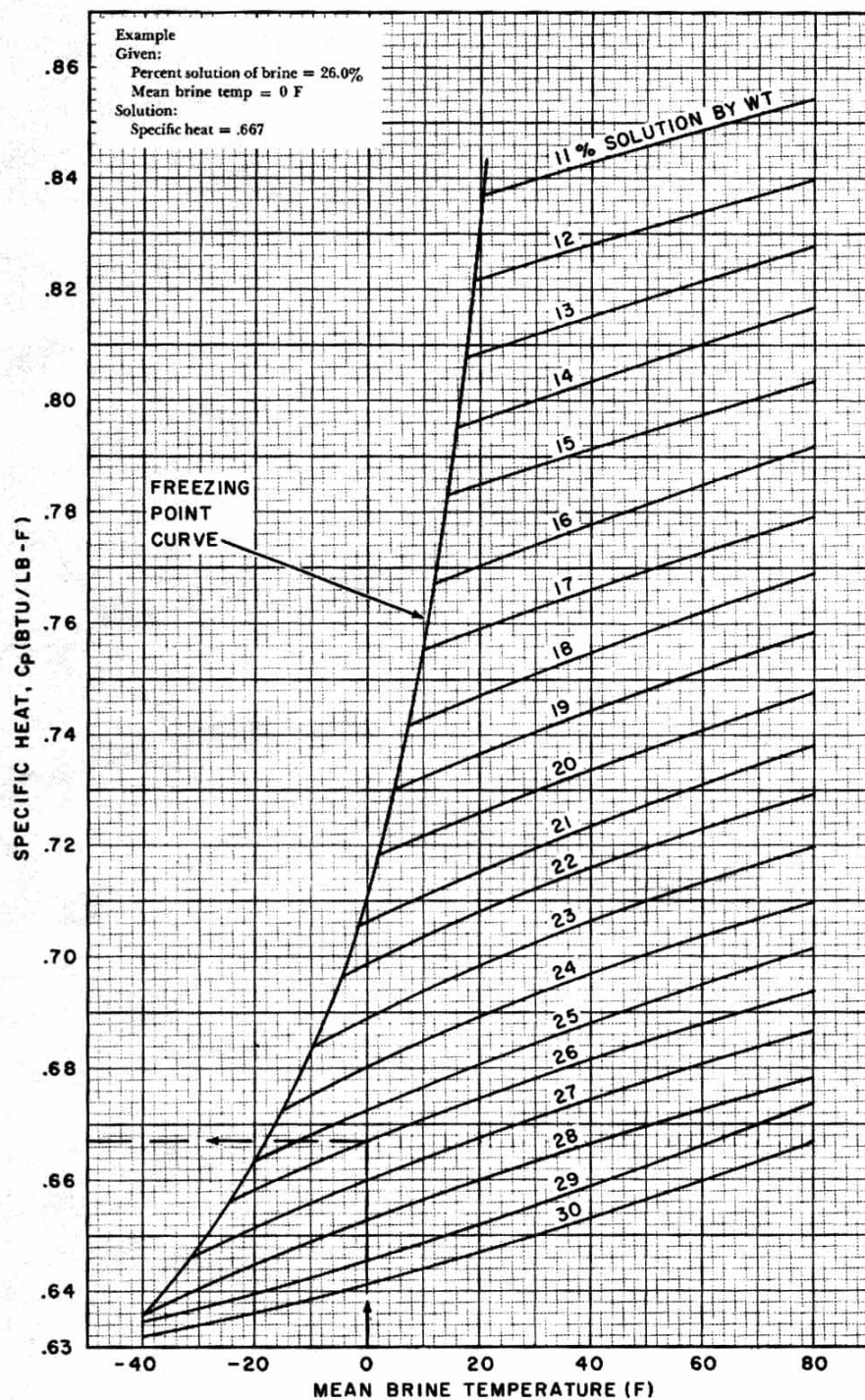
CHART 7-CALCIUM CHLORIDE-SPECIFIC GRAVITY



*With reference to 60 F water.

Courtesy of Dow Chemical Co.

CHART 8-CALCIUM CHLORIDE-SPECIFIC HEAT



Courtesy of Dow Chemical Co.

CHART 9-CALCIUM CHLORIDE-THERMAL CONDUCTIVITY

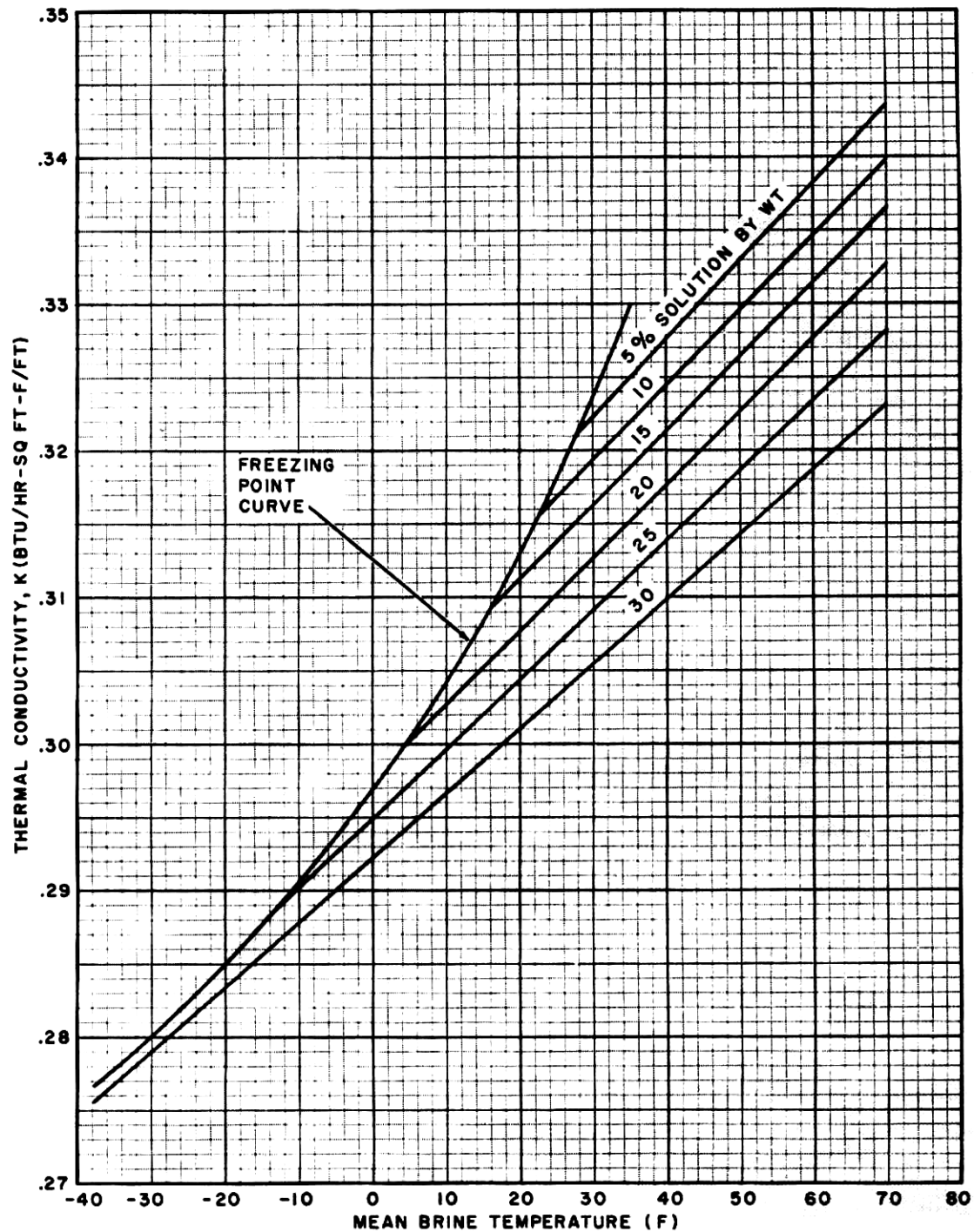
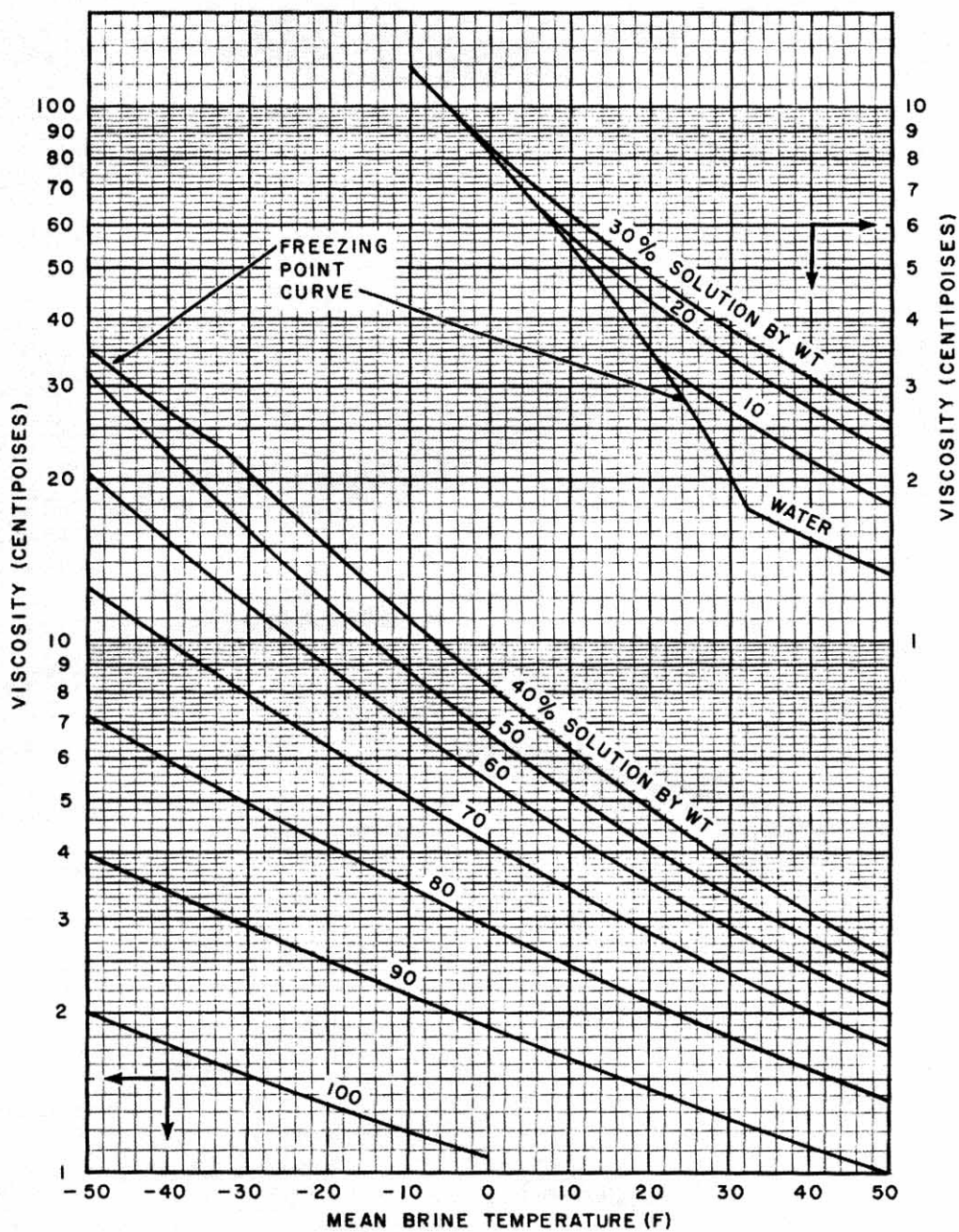
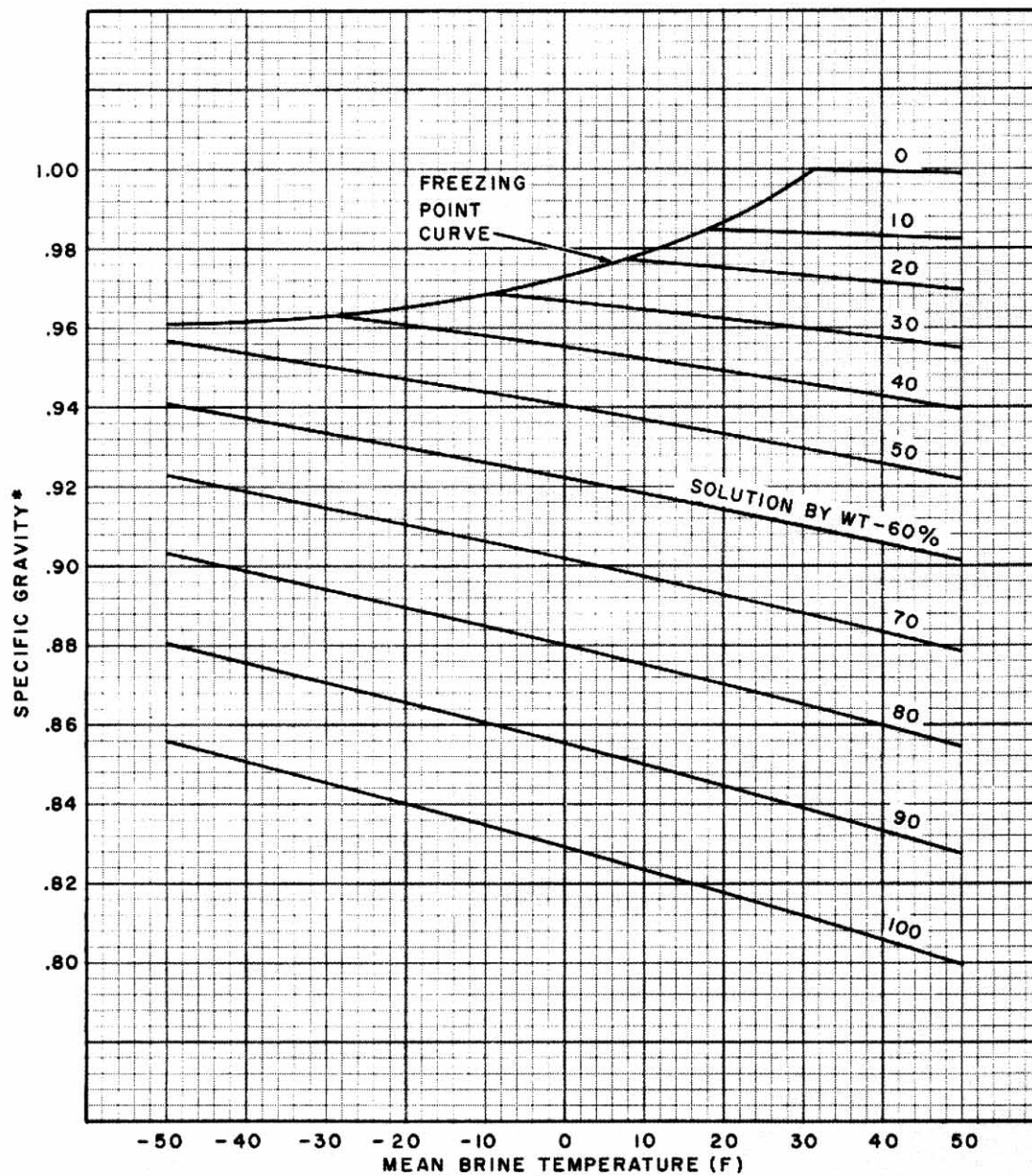


CHART 10-METHANOL BRINE-VISCOSITY



Courtesy of Carbide and Carbon Chemicals Corporation

CHART 11-METHANOL BRINE-SPECIFIC GRAVITY



*With reference to 60 F water.

Courtesy of Carbide and Carbon Chemicals Corporation

CHART 12-METHANOL BRINE-SPECIFIC HEAT

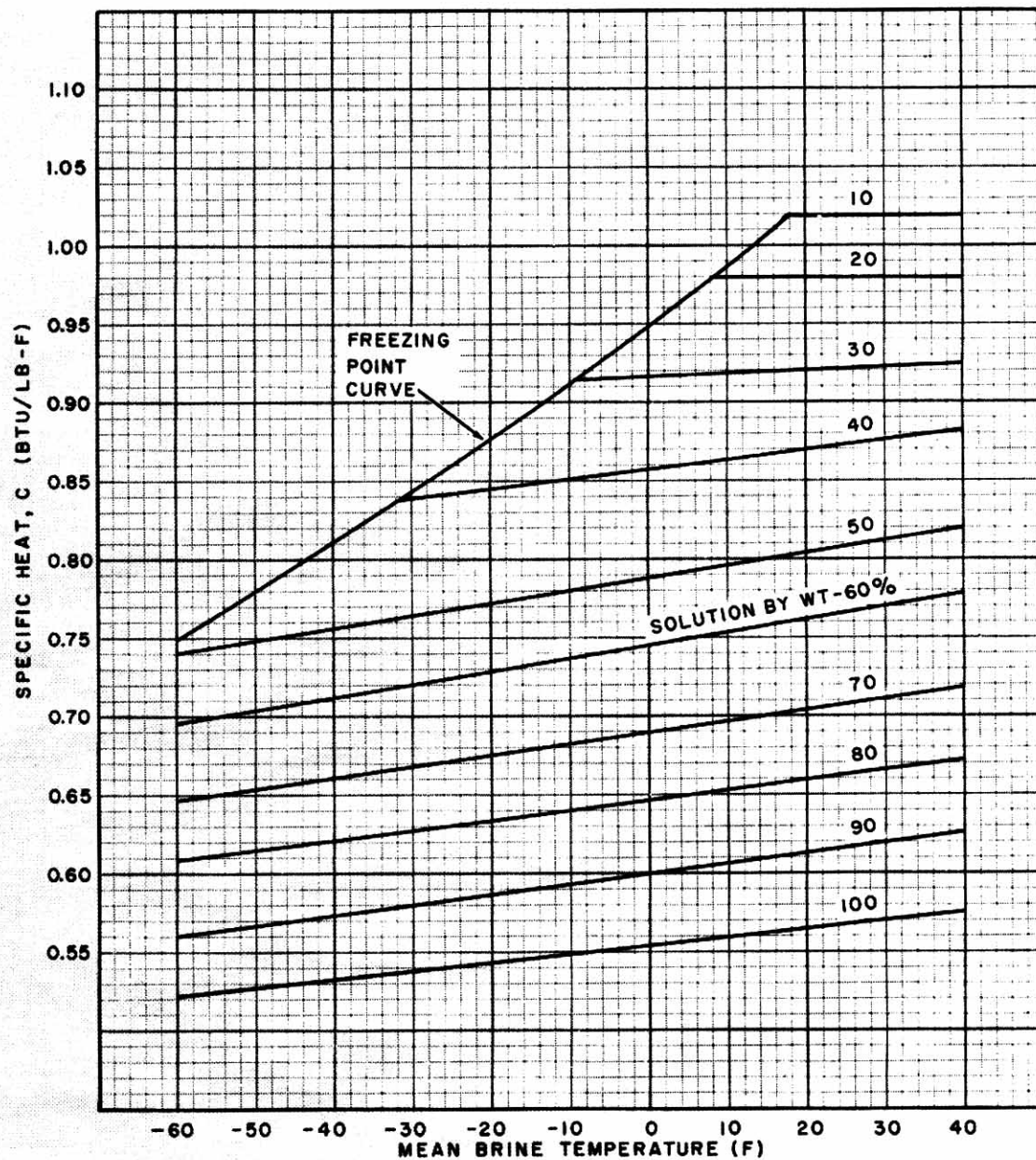


CHART 13-METHANOL BRINE-THERMAL CONDUCTIVITY

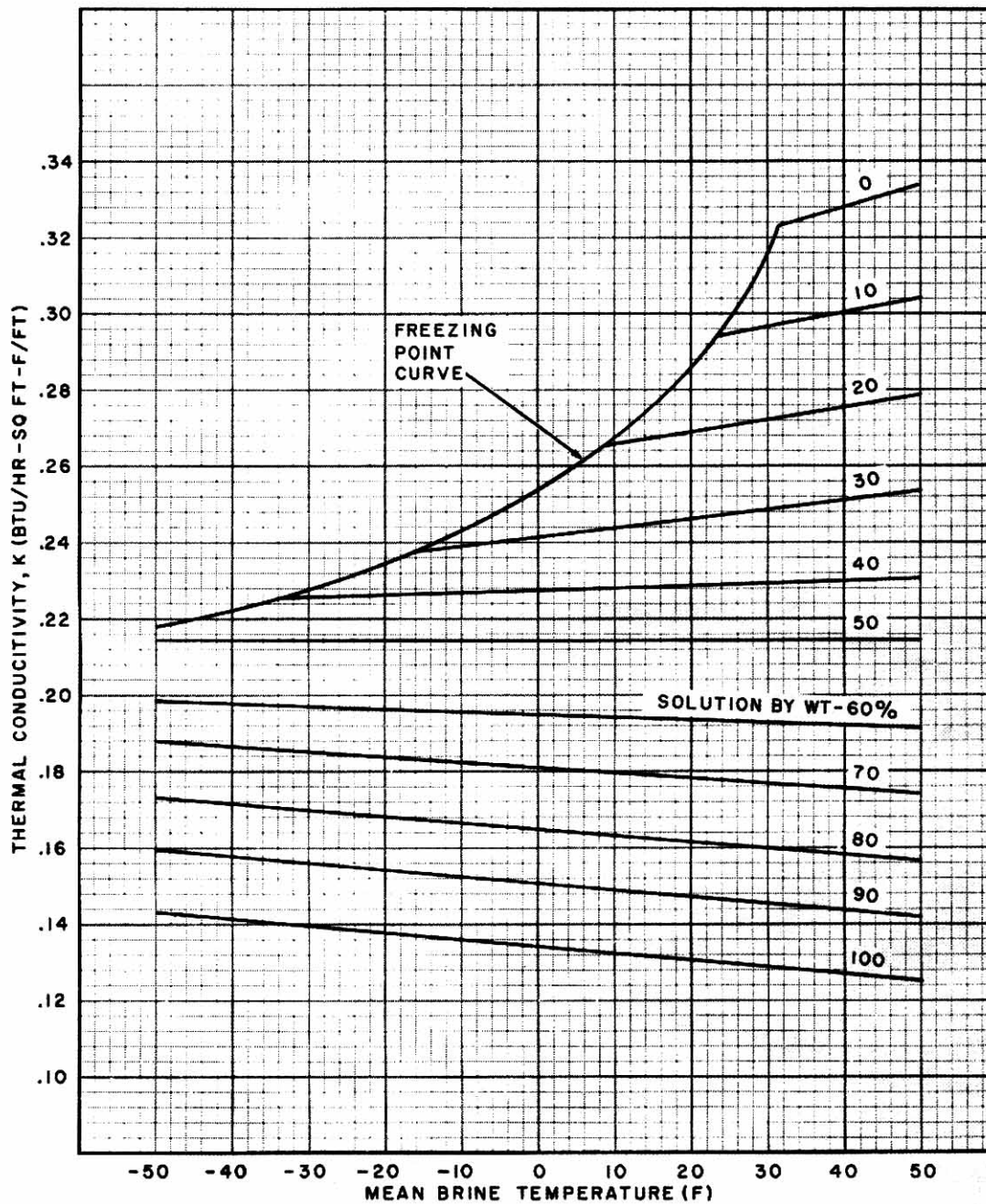


CHART 14-ETHANOL BRINE-VISCOSITY

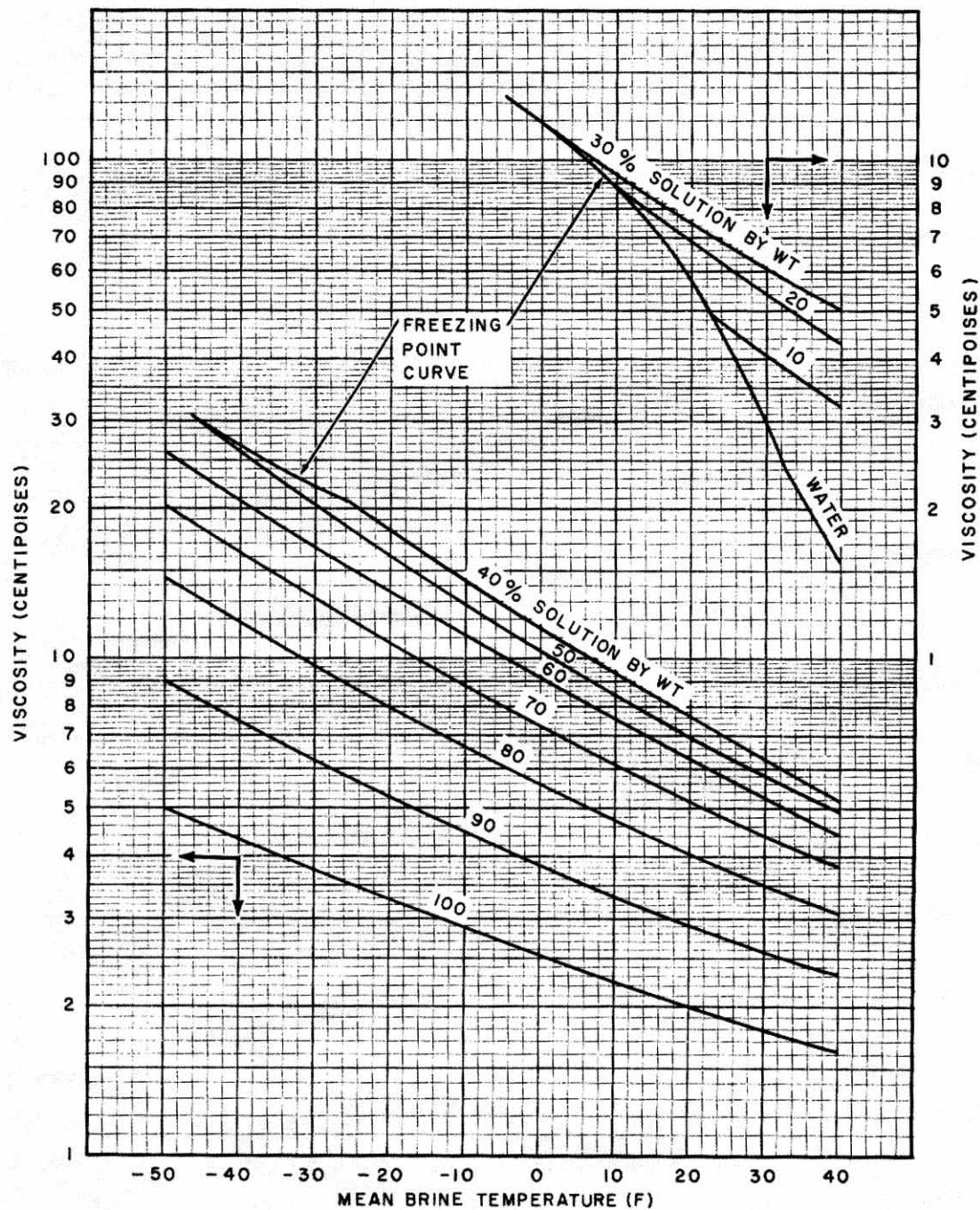
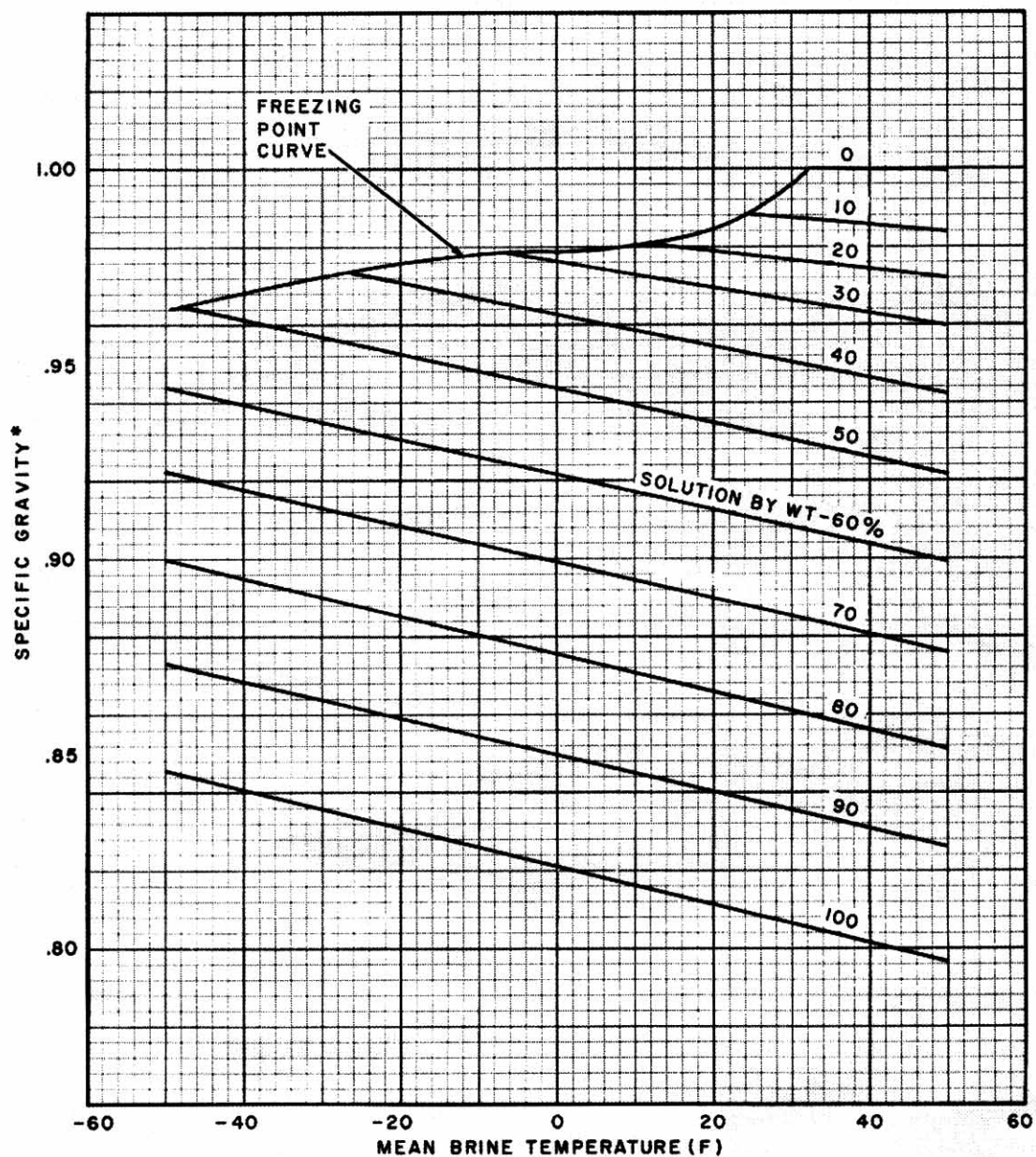


CHART 15-ETHANOL BRINE-SPECIFIC GRAVITY



*With reference to 60 F water.

Extrapolated values from International Critical Tables

CHART 16-ETHANOL BRINE-SPECIFIC HEAT

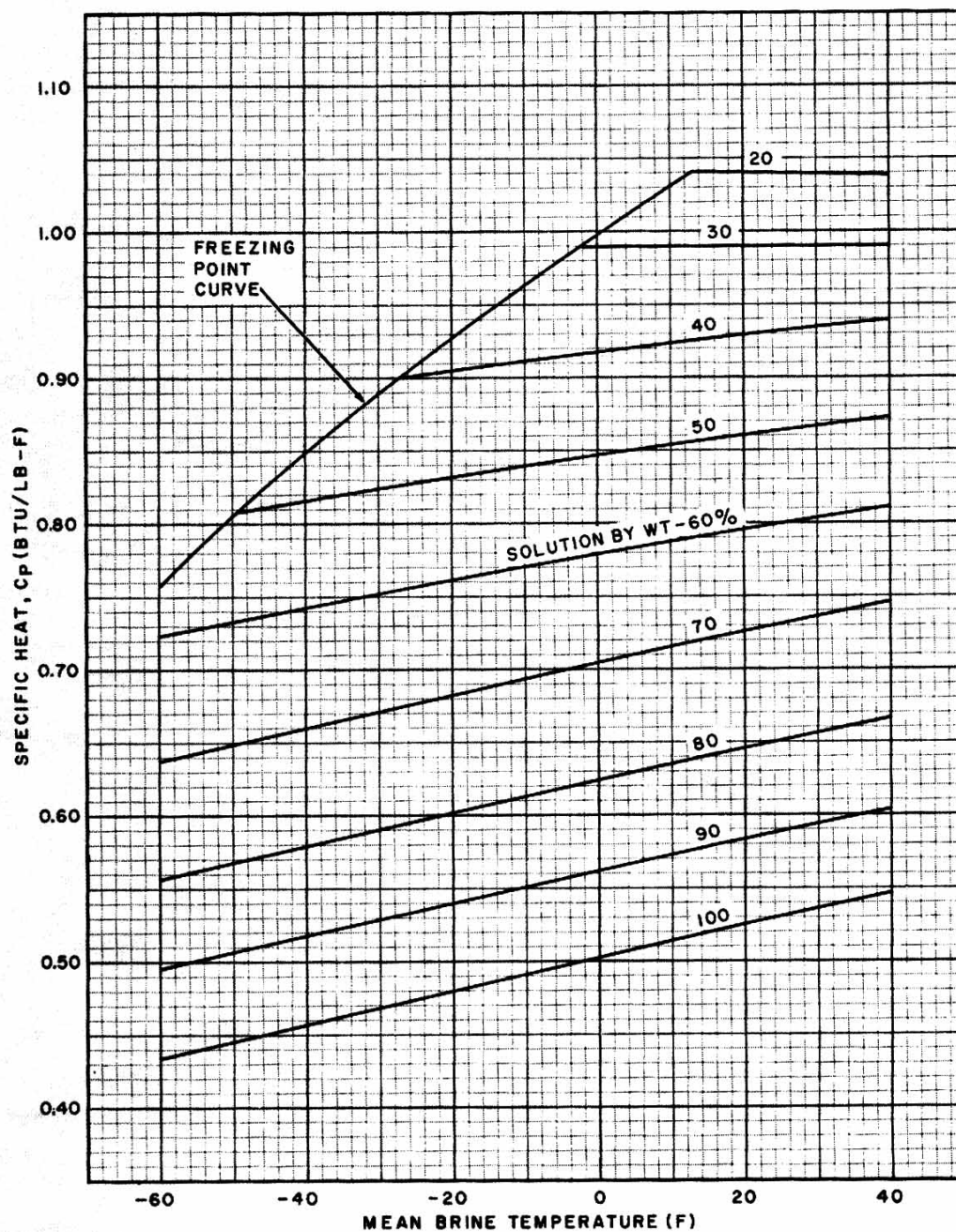


CHART 17-ETHANOL BRINE-THERMAL CONDUCTIVITY

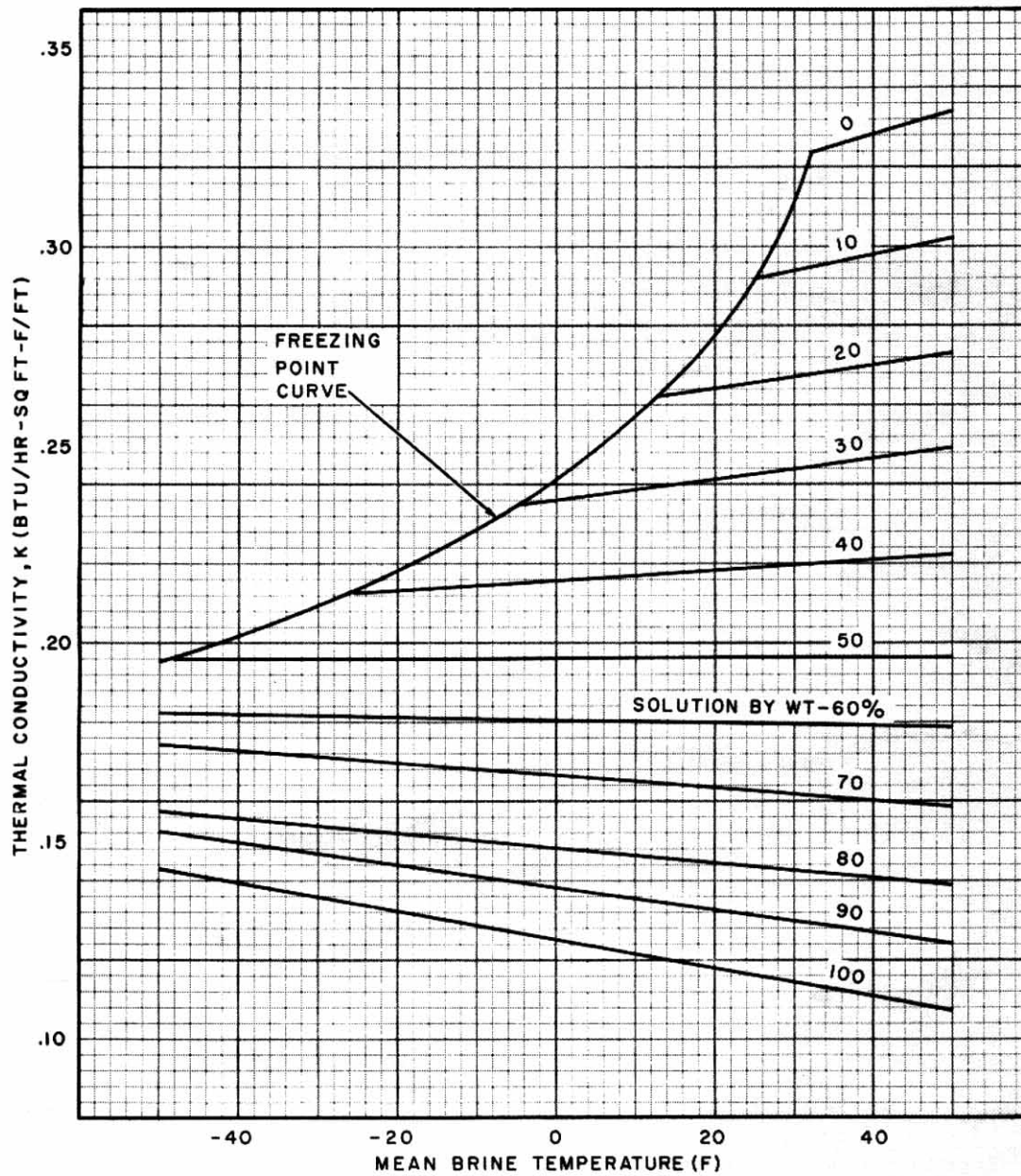
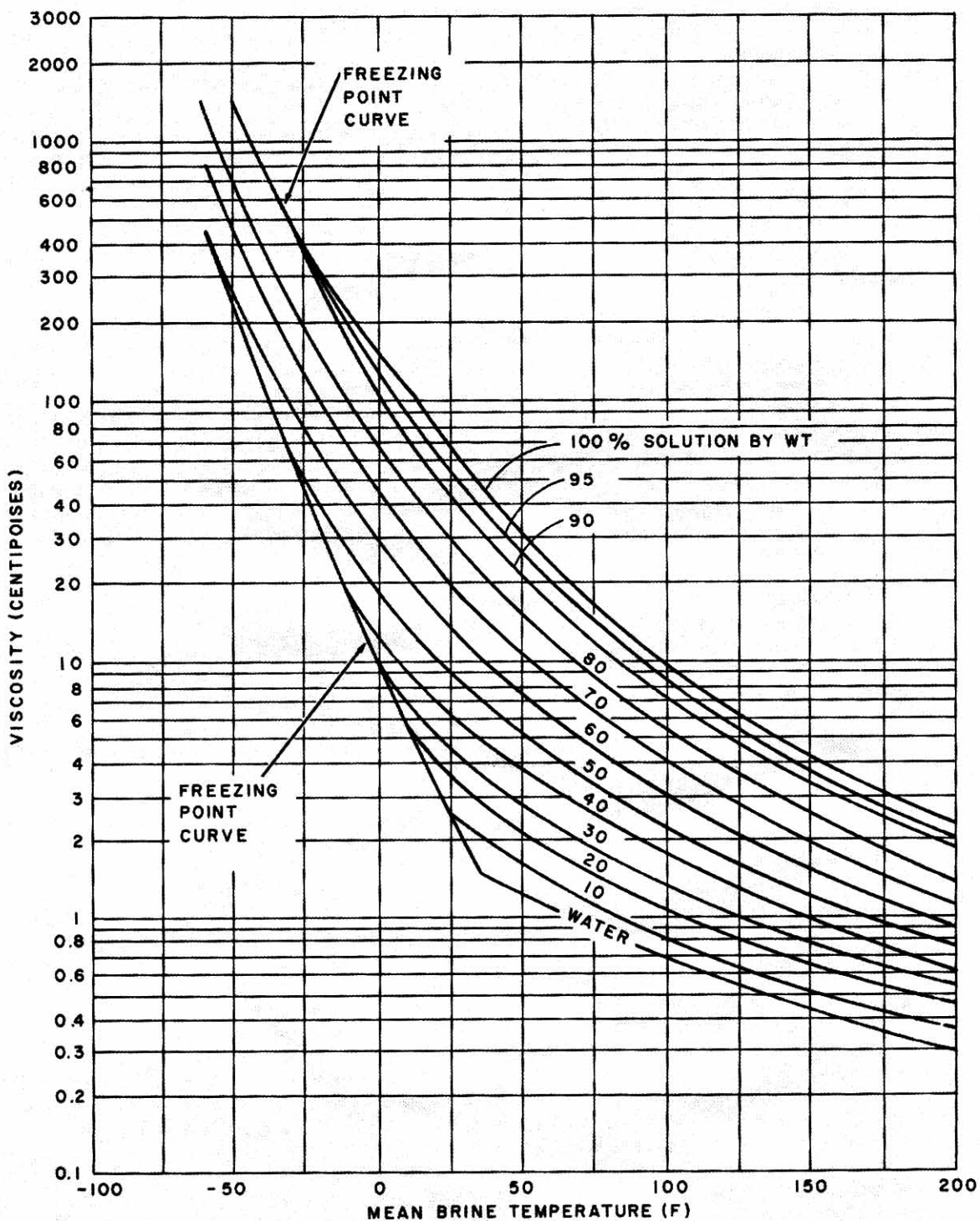
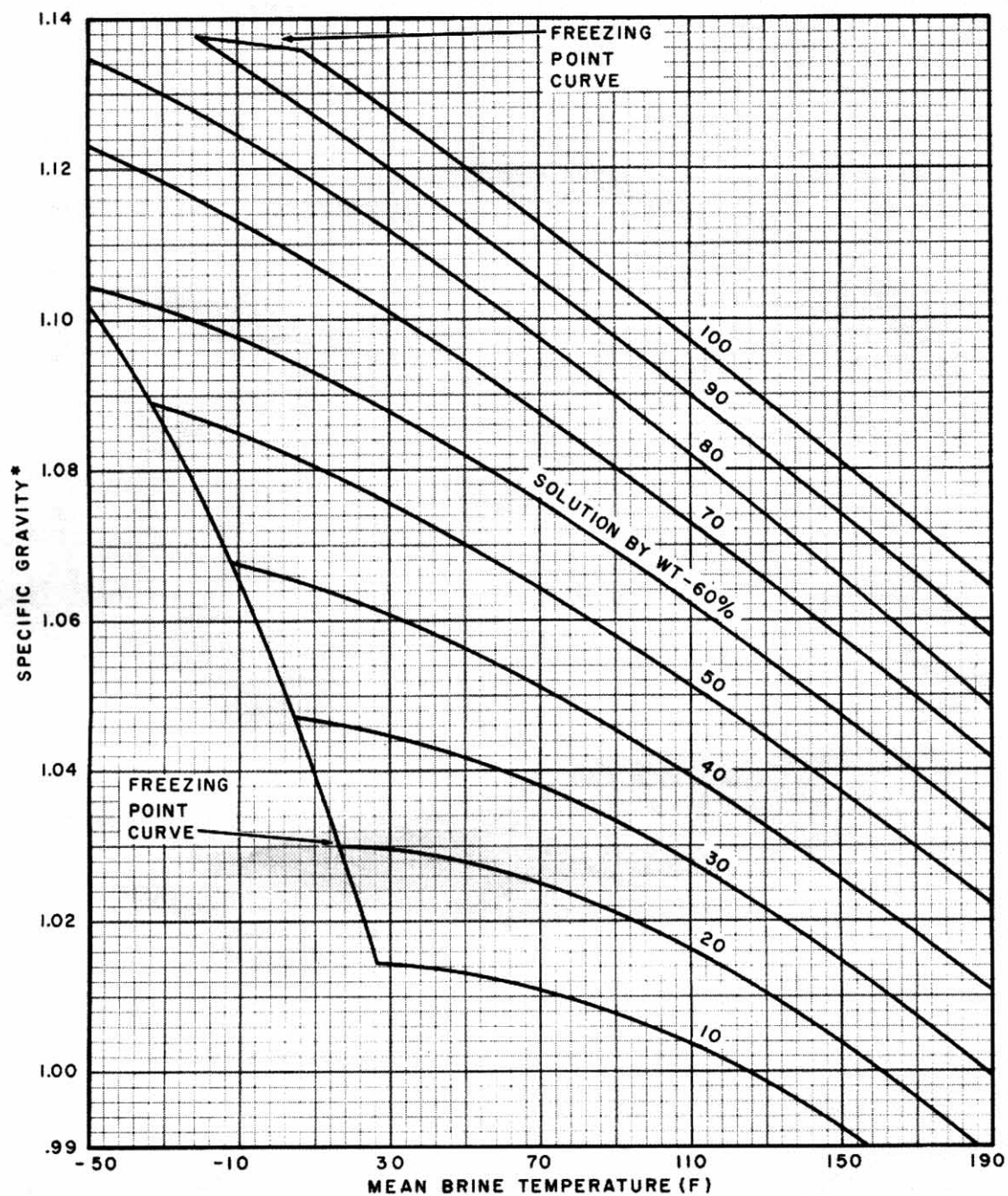


CHART 18-ETHYLENE GLYCOL-VISCOSITY



From *Glycols, Properties and Uses*, Dow Chemical Co. 1961

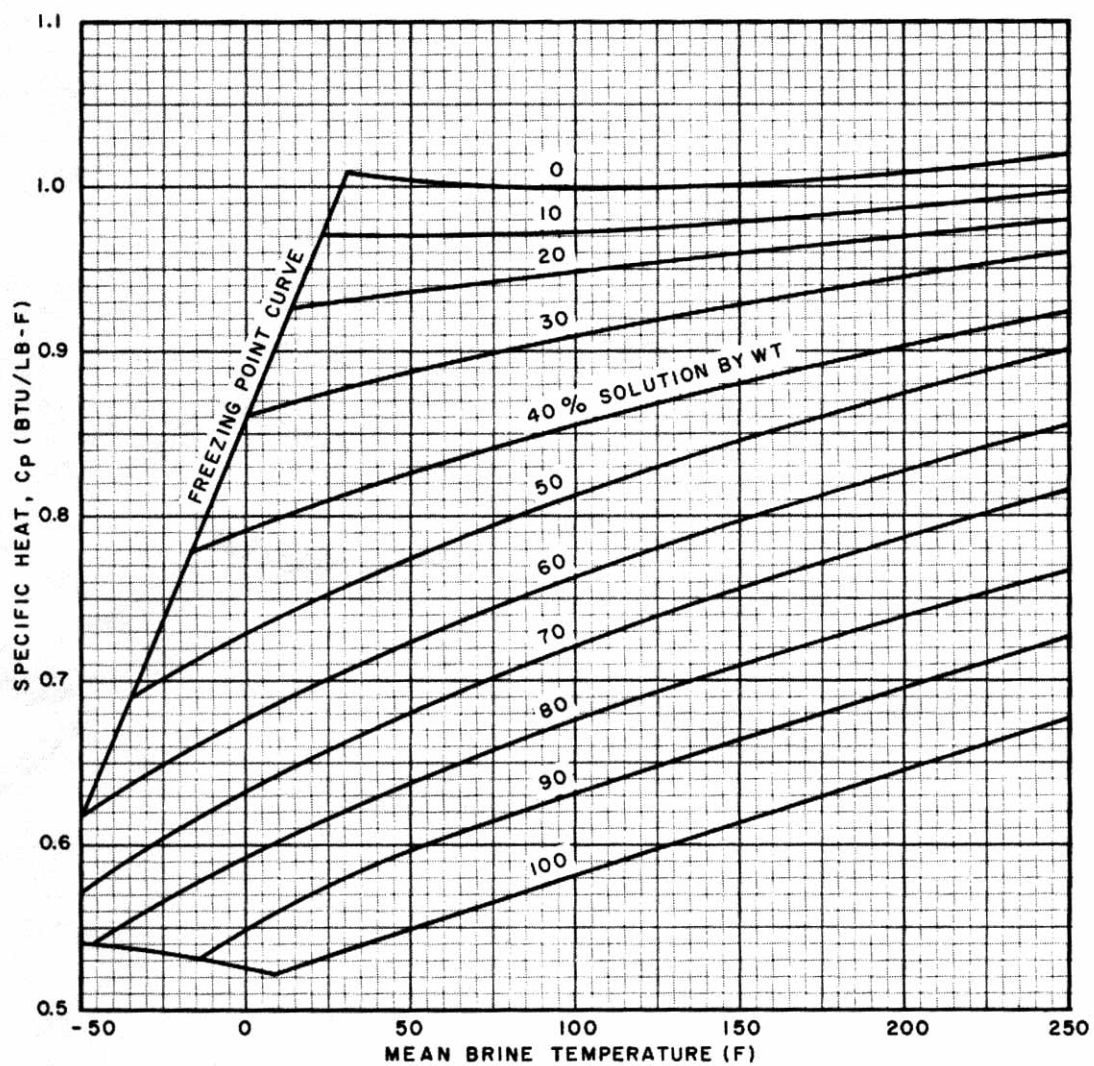
CHART 19-ETHYLENE GLYCOL-SPECIFIC GRAVITY



*With reference to 60 F water.

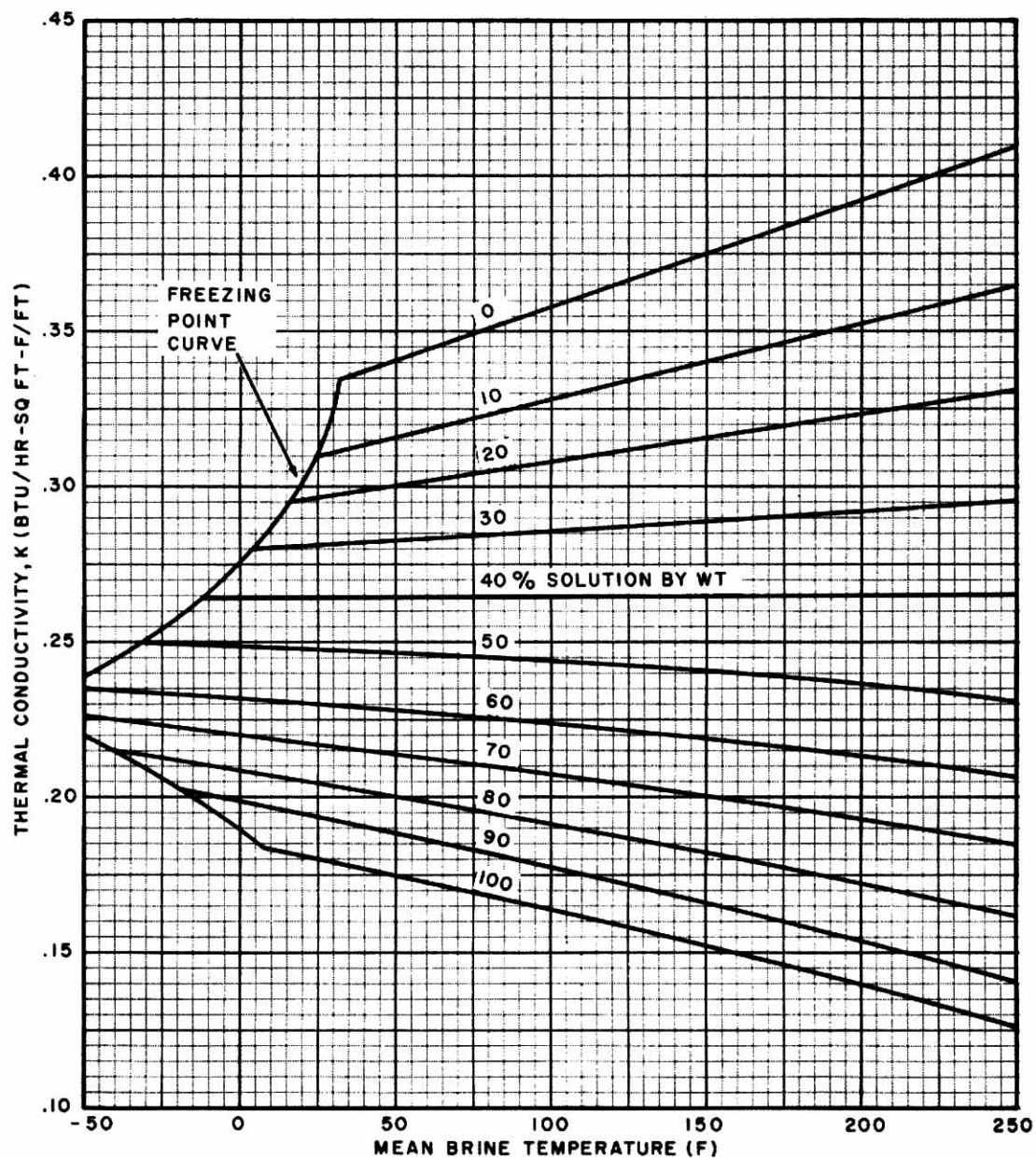
From *Glycols, Properties and Uses*, Dow Chemical Co. 1961

CHART 20-ETHYLENE GLYCOL-SPECIFIC HEAT



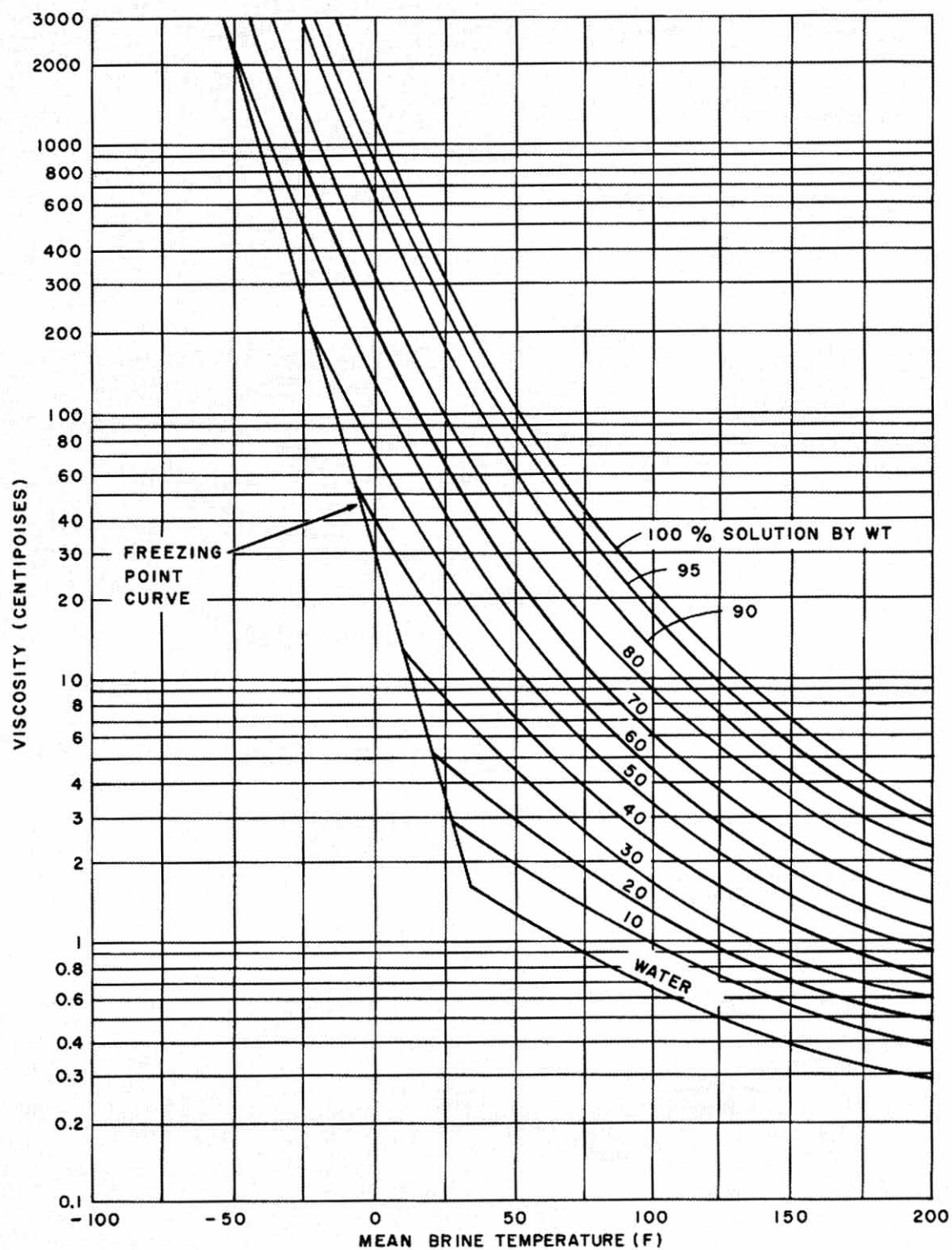
From *Glycols*, Union Carbide Chemicals Co. 1958

CHART 21-ETHYLENE GLYCOL-THERMAL CONDUCTIVITY



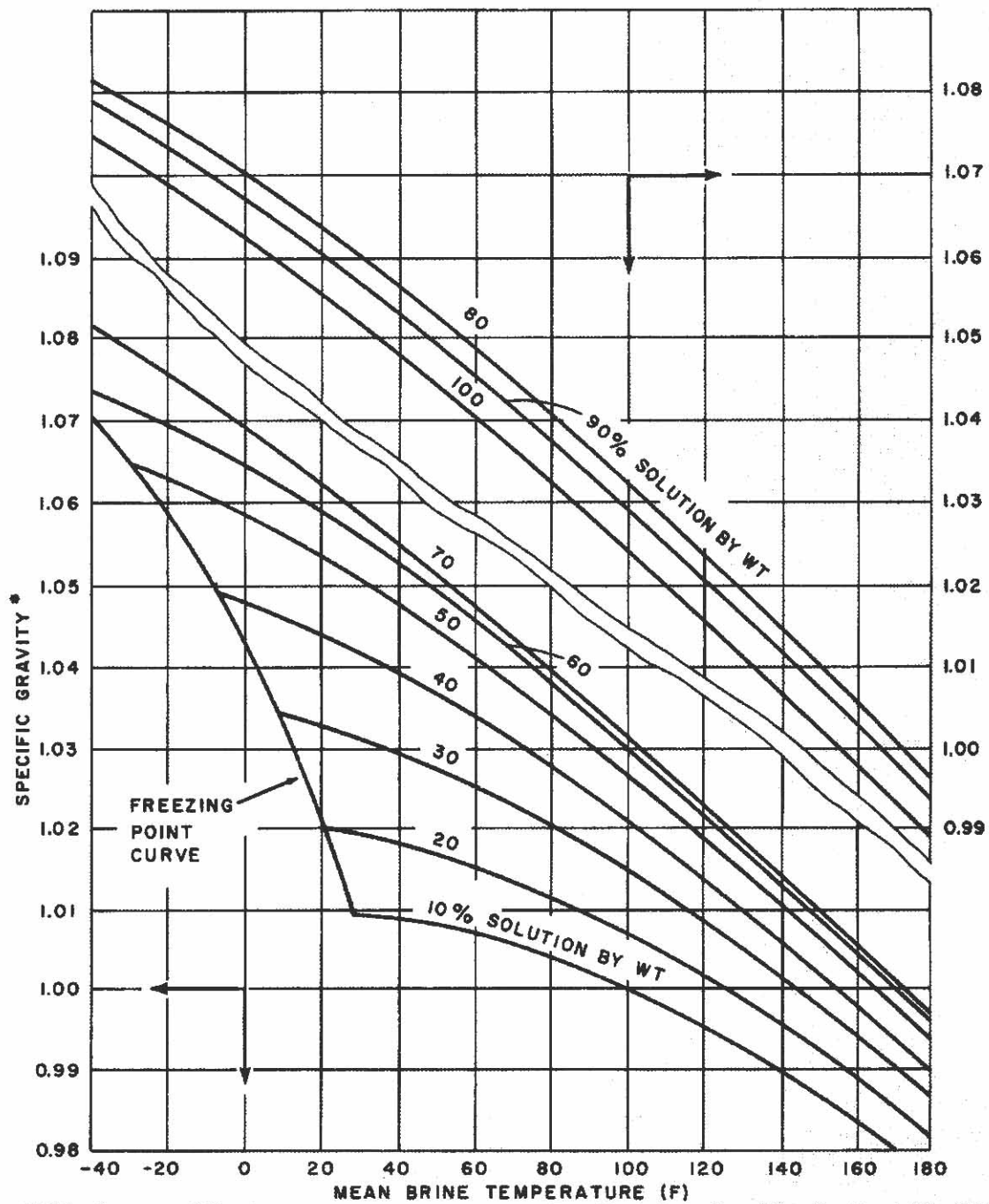
From Glycols, Union Carbide Chemicals Co. 1958

CHART 22-PROPYLENE GLYCOL-VISCOSITY



From Glycols, Properties and Uses, Dow Chemical Co. 1961

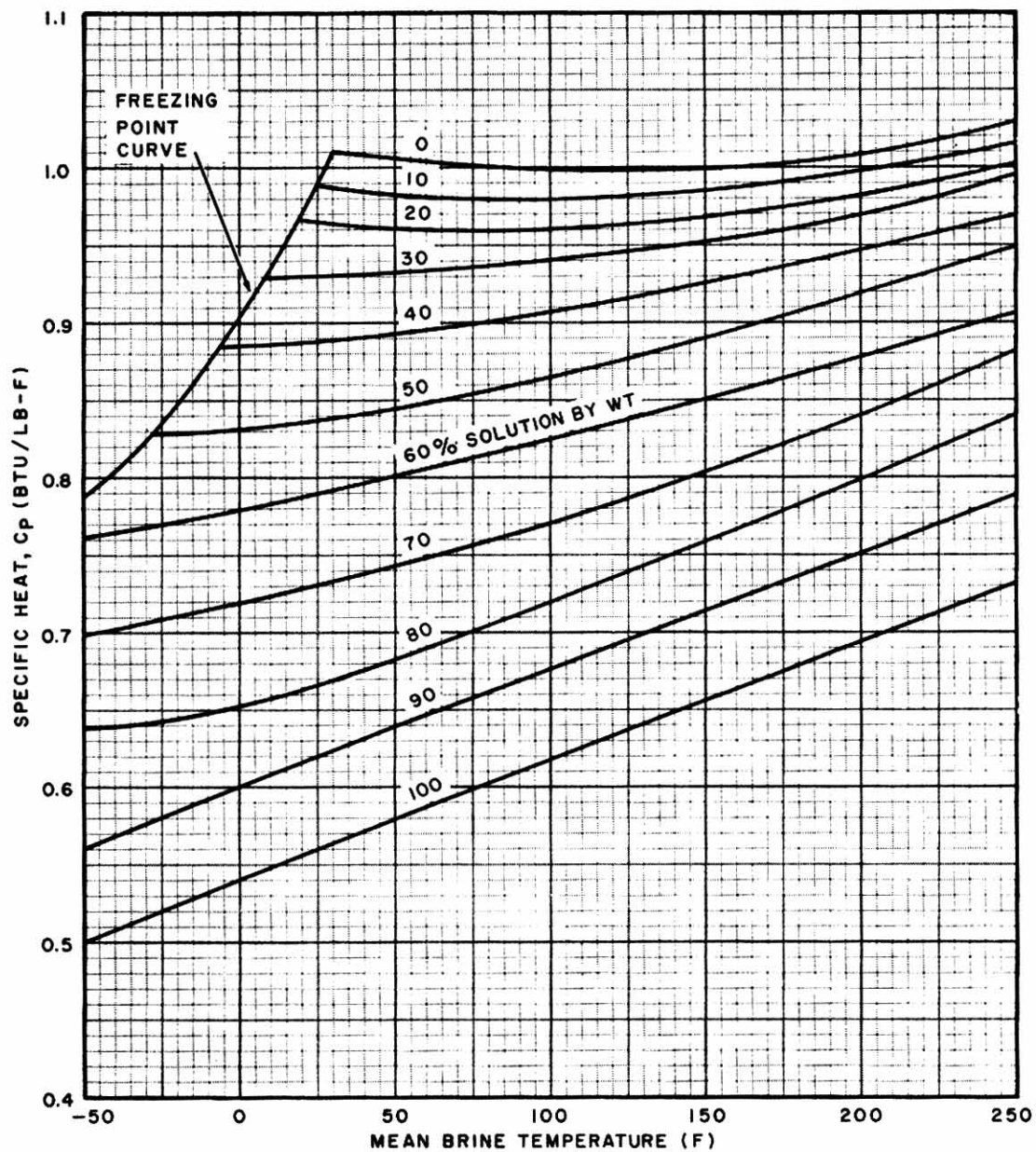
CHART 23-PROPYLENE GLYCOL-SPECIFIC GRAVITY



*With reference to 60 F water.

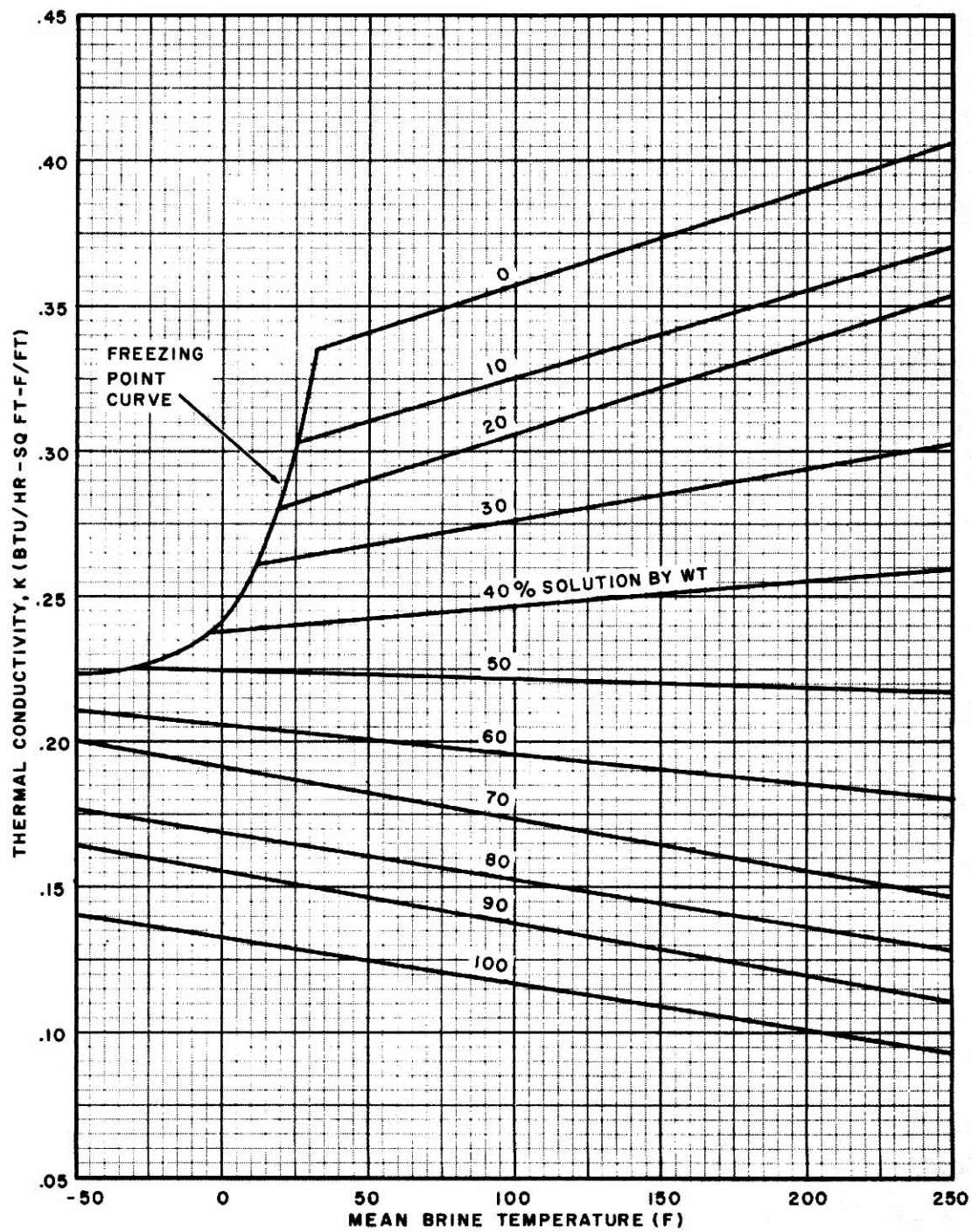
From Glycols, Properties and Uses, Dow Chemical Co. 1961

CHART 24-PROPYLENE GLYCOL-SPECIFIC HEAT



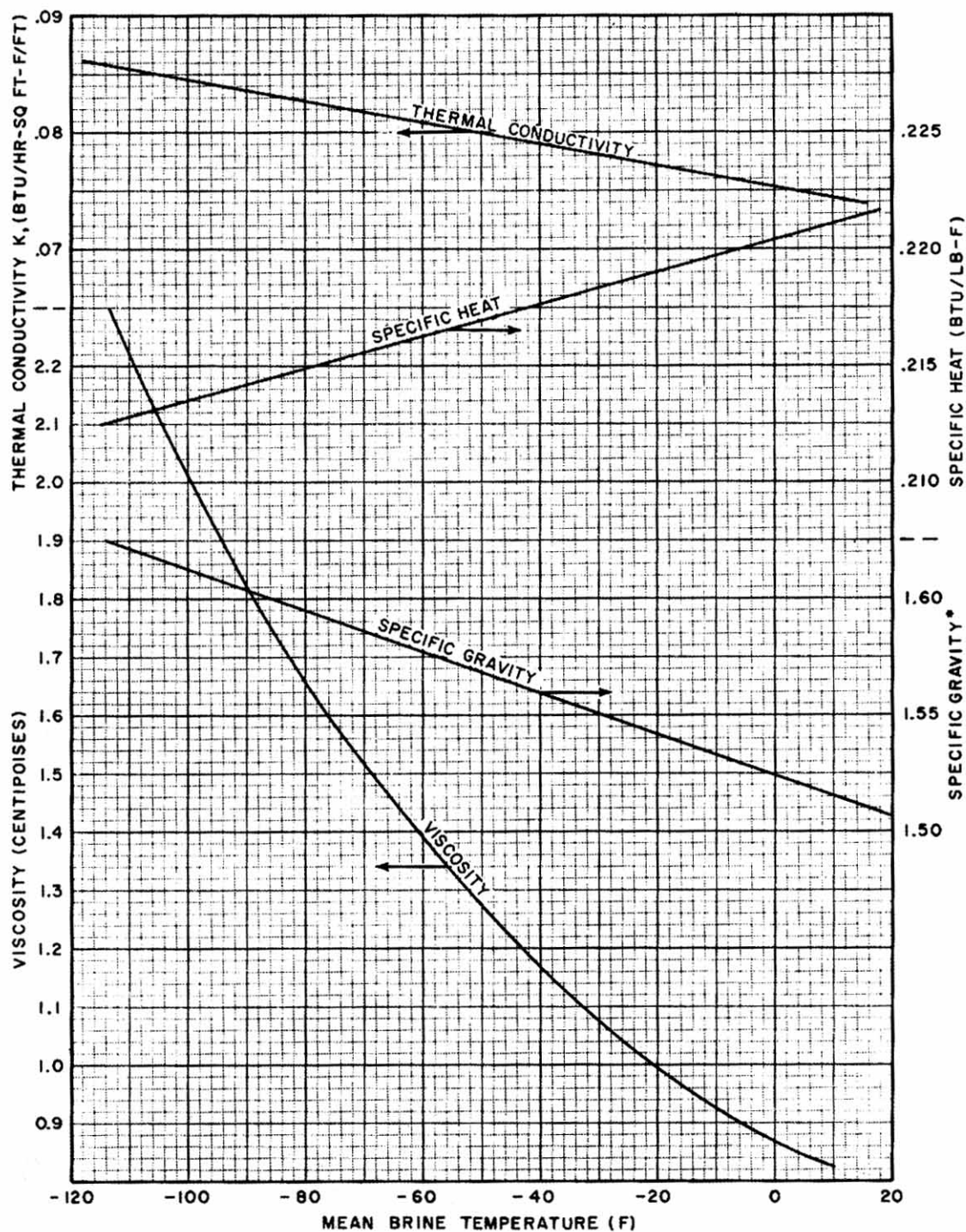
From *Glycols*, Union Carbide Chemicals Co. 1958

CHART 25-PROPYLENE GLYCOL-THERMAL CONDUCTIVITY



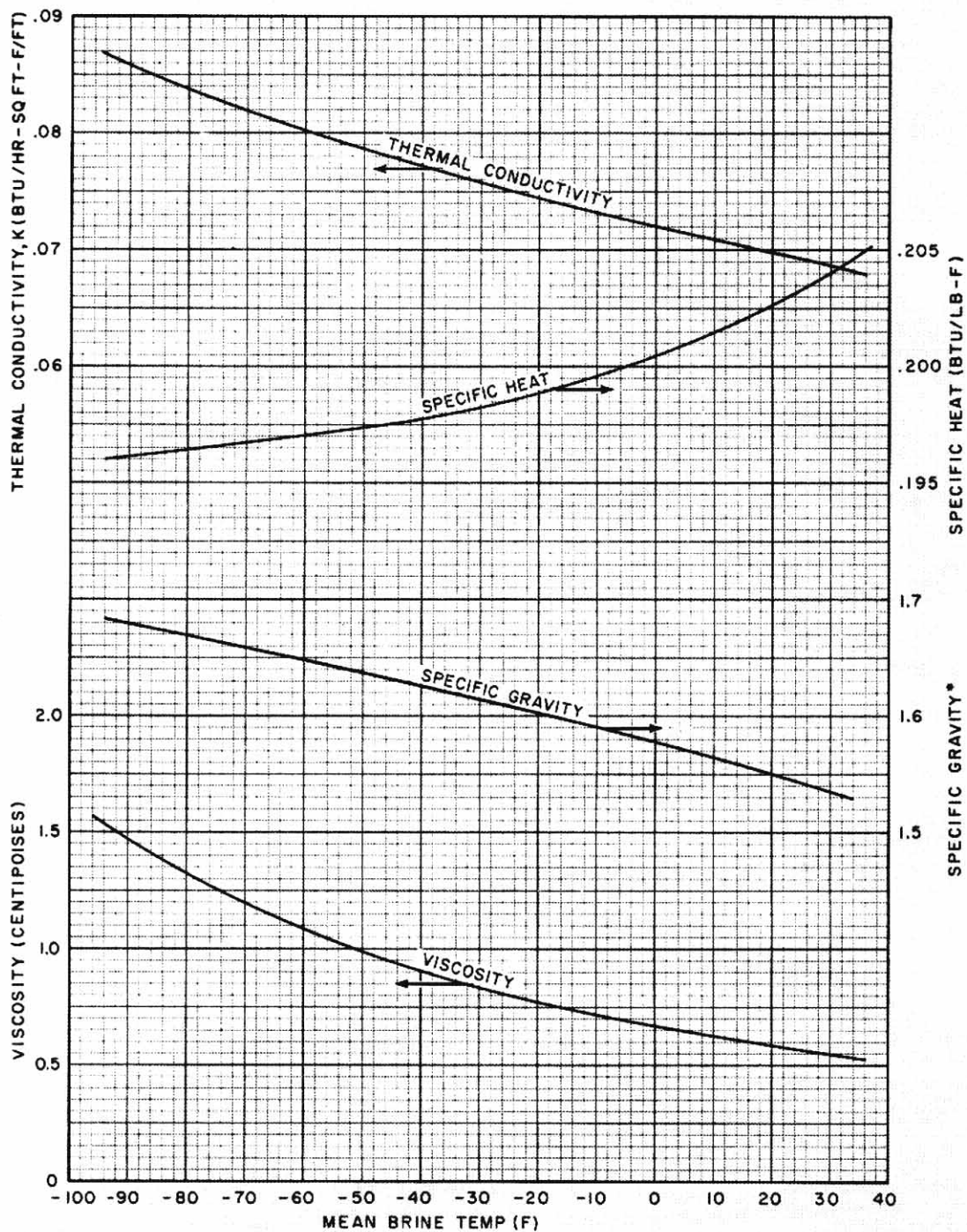
From *Glycols*, Union Carbide Chemicals Co. 1958

CHART 26-TRICHLOROETHYLENE-PROPERTIES



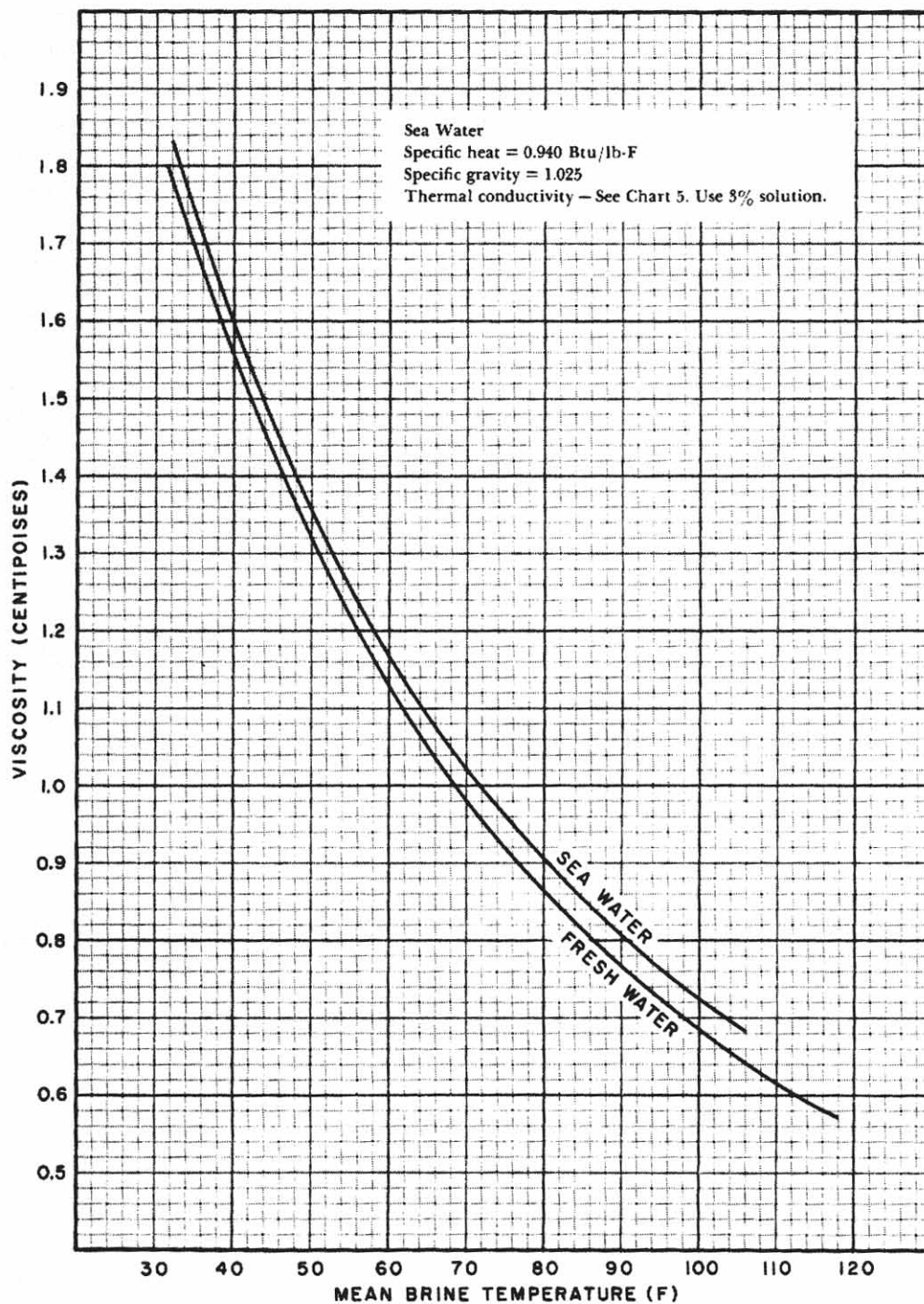
*With reference to 60 F water.

CHART 27-REFRIGERANT 11-PROPERTIES



*With reference to 60 F water.

CHART 28-WATER-VISCOSITY



CHAPTER 3. REFRIGERATION OILS

This chapter covers general classification and quality of lubricating oils that are important in refrigeration. The recommendation of oils to be used in a refrigeration system is primarily the responsibility of the refrigeration system manufacturer. However, it is important for an engineer to understand the basis of the selection of these oils in order to properly apply them in the field.

CLASSIFICATION

Oils classified by source fall in three main groups: animal, vegetable and mineral. Animal and vegetable oils are called fixed oils because they cannot be refined without decomposing. They are unstable and tend to form acids and gums that make them unsuitable for refrigeration purposes.

There are three major classifications of mineral oil: naphthene base, paraffin base, and mixed base. When distilled, a naphthene base oil yields a residue of heavy pitch or asphalt. California oils, some Gulf Coast and heavy Mexican oils are in this class. A paraffin base oil yields a paraffin base oils are Pennsylvania, Northern Louisiana, and parts of Oklahoma and Kansas. The mixed oils contain both naphthene and paraffin bases. Illinois and some mid-continent oils are in this class.

Experience has shown that the naphthene base oils are more suited for refrigeration work for three main reason:

1. They flow better at low temperatures.
2. Carbon deposits from these oils are of a soft nature and can easily be removed.
3. They deposit less wax at low temperatures.

When obtained from selected crudes and properly refined and treated, all three classes of mineral oil can be considered satisfactory for refrigeration use.

PROPERTIES

To meet the requirements of a refrigeration system, a good refrigeration oil should:

1. Maintain sufficient body to lubricate at high temperature and yet be fluid enough to flow at low temperature.
2. Have a pour point low enough to allow flow at any point in the system.
3. Leave no carbon deposits when in contact with hot surfaces encountered in the system during normal operation.
4. Deposit no wax when exposed to the lowest temperatures normally encountered in the system.
5. Contain little or no corrosive acid.
6. Have a high resistance to the flow of electricity.
7. Have a high flash and fire point to indicate proper blending.
8. Be stable in the presence of oxygen.
9. Contain no sulfur compounds.
10. Contain no moisture.
11. Be light in color, to indicate proper refining.

As lubricating oils for refrigeration compressors are a specialty product, they require consideration apart from normal lubricants. The emphasis in this chapter is on oil used in refrigeration. Do not consider the emphasis as applicable to lubricants in general.

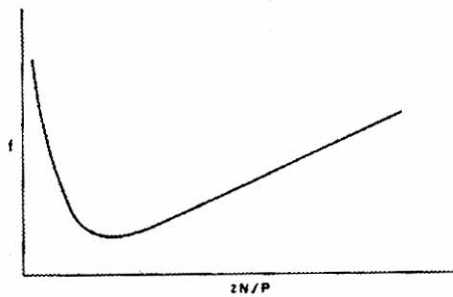


FIG. 12-LUBRICATION CHARACTERISTICS

The characteristics of oil for refrigeration (not necessarily in order of importance) are these:

1. Viscosity
2. Pour point
3. Carbonization
4. Floc point
5. Neutralization
6. Dielectric strength
7. Flash point
8. Fire point
9. Oxidation stability
10. Corrosion tendency
11. Moisture content
12. Color

VISCOSITY

Viscosity or coefficient of internal friction is that property of a liquid responsible for resistance to flow; it indicates how thick or thin an oil is.

The purpose of an oil is to lubricate bearing or rubbing surfaces. If the oil is too thin, it does not stay between the rubbing surfaces but is forced out, leaving no protective film. If the oil is too thick, it causes drag and loss of power, and may not be able to flow between the bearing or rubbing surfaces.

Friction loss f is illustrated in *Fig. 12* as a function of viscosity z , speed N in revolutions per unit time, and load P per unit area.

Viscosity is usually measured in terms of Saybolt Seconds Universal (SSU). Under standard temperature conditions, oil is allowed to flow thru a carefully calibrated orifice until a standard volume has passed. The number of seconds necessary for the given volume of oil to flow thru the orifice is the viscosity of the oil in Saybolt Seconds Universal. The higher the viscosity, the more

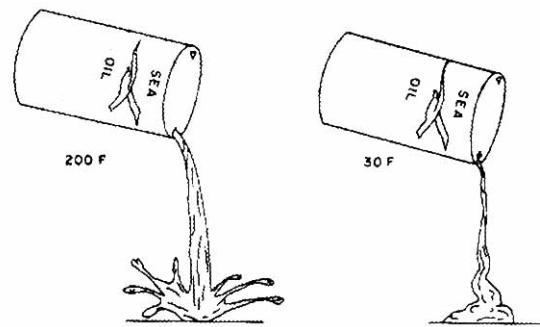


FIG. 13-EFFECT OF TEMPERATURE ON VISCOSITY

seconds it takes to pass thru the hole, or the higher the viscosity, the thicker the oil.

Viscosity is affected by temperature (*Fig. 13*), thus making it an important characteristic of refrigeration oils. The viscosity increases as the temperature decreases, or the lower the temperature the thicker the oil. In low temperature applications, this thickening of oil with its increasing resistance to flow is a major problem. As low temperatures occur in the evaporator, an oil that is too viscous thickens and may stay in the evaporator, thus decreasing the heat transfer and possibly creating a serious lack of lubrication in the compressor.

Oil may thin out or become less viscous at high temperatures. Too warm a crankcase may conceivably thin the oil to a point where it can no longer lubricate properly. A refrigeration oil must maintain sufficient body to lubricate at high temperatures and yet to be fluid enough to flow at low temperatures. Oil should be selected which has the lowest viscosity possible to do the assigned job.

Viscosity is also affected by the miscibility of the oil and the refrigerant. The miscibility of oil and refrigerants varies from almost no mixing (with Refrigerant 717, ammonia) to complete mixing (with some halogenated hydrocarbons such as Refrigerant 12).

Refrigerant 717 has almost no effect on the viscosity of a properly refined refrigeration oil. As it is not miscible, there is no dilution of oil and therefore no change in viscosity.

In the case of miscible refrigerants such as Refrigerant 12, the refrigerant mixes with and dilutes the oil, and lubrication must be performed by this mixture. This mixing reduces the viscosity of the oil.

CHART 29-OIL-REFRIGERANT VISCOSITY

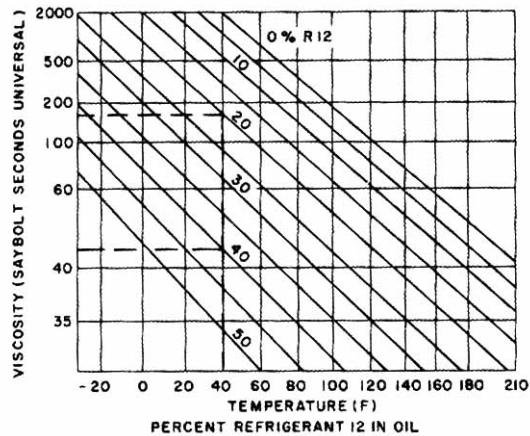


Chart 29 shows viscosity change for mixtures of oil and Refrigerant 12. For example, oil at 40 F containing 20% Refrigerant 12 by weight has a viscosity of approximately 150 SSU.

When the amount of Refrigerant 12 is increased to 40%, the SSU is reduced to 45.

When oil and refrigerants are miscible, the oil is carried thru the system by the refrigerant. It is imperative that the oil be returned to the compressor. Keeping low side gas velocity up assures this proper oil return. With a completely miscible refrigerant, the oil is diluted sufficiently even at low temperatures to keep the viscosity low and to allow the oil to return easily with the refrigerant to the compressor.

There is a third group of refrigerants whose miscibility with oil varies. For example, Refrigerant 22 is completely miscible with oil at high temperatures, but at low temperatures it separates into two layers with the oil on top. When designing or selecting equipment for this group of refrigerants, great care must be taken to allow for low temperature separation of oil and refrigerant.

Oil separation in a flooded cooler necessitates the use of an oil bleed line from the bottom of the cooler to the suction loop. Because the oil is lighter than Refrigerant 22 and floats on top of the liquid refrigerant, an auxiliary oil bleed line from the side of the cooler is required.

POUR POINT

The pour point of an oil is that temperature at which it ceases to flow.



FIG. 14-POUR POINT TUBE

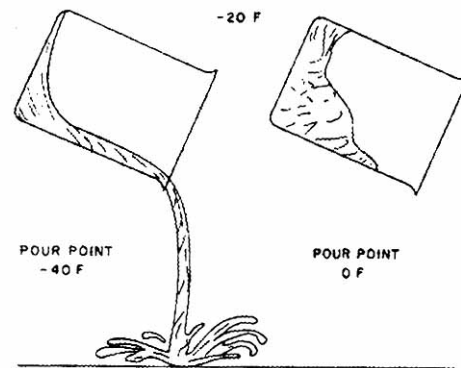


FIG. 15-POUR POINT

Pour point is simple to determine. Using the apparatus shown in the Fig. 14, the selected batch of oil is slowly cooled under test condition until the oil no longer flows. This temperature is the pour point.

Figure 15 shows two oils with different pour points which have been cooled to the same temperature (-20 F). On the left the oil with a -40 F pour point flows freely. On the right the oil with the 0 F pour point does not flow.

Pour point depends on the wax content and/or viscosity.

With all refrigerants some oil is passed to the evaporator. Regardless of how small an amount, this oil must be returned to the compressor. In order that it may be returned, it must be able to flow thruout the system.

Oil pour point is very important with nonmiscible and partly miscible refrigerants; with the miscible refrigerants the viscosity of the oil refrigerant mixture assumes greater importance as shown in Chart 29, Oil-Refrigerant Viscosity.

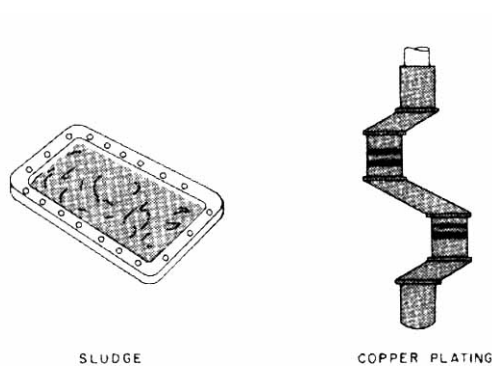


FIG. 16-CARBON DEPOSIT

CARBONIZATION

All refrigeration oils can be decomposed by heat. When such action takes place, a carbon deposit remains.

Carbonization properties of an oil are measured by the Conradson Carbon Value. This value is found by heating and decomposing an oil until only the carbon deposit remains. The ratio of the weight of the carbon deposit to the weight of the original oil sample is the Conradson Carbon Value.

Hot surfaces within the refrigeration system sometimes decompose the oil. The carbon remaining is hard and adhesive in paraffin base oils, and forms sludge.

Naphthene base oils form a light fluffy carbon which, though a contaminant, is not as damaging as the hard carbon. However, neither type of carbon deposit is desirable as there is some indication that a relationship exists between oil breakdown, carbonization and copper plating (Fig. 16).

A good oil should not carbonize when in contact with hot surfaces encountered in the system during normal operation. A refrigeration oil should have as low a Conradson Carbon Value as practical.

FLOC POINT

All refrigeration oils contain some wax though the amount varies considerably. As the temperature of the oil decreases, the solubility of the wax also decreases. When there is more wax present than the oil can hold, some separates and precipitates.

The method used to determine the waxing tendencies of a refrigeration oil is the floc test (Fig. 17). A mixture of 10% oil and 90% Refrigerant 12 in a clear container is cooled until the wax starts to separate, turning the mixture cloudy. As cooling continues, small

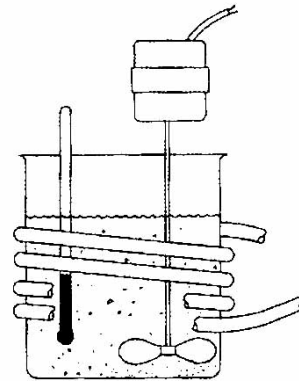


FIG. 17 – FLOC TEST

clusters of wax form. The temperature at which these clusters are first noticeable to the unaided eye is the floc point.

The free wax that is formed when a refrigeration oil is cooled can clog metering devices and restrict flow.

Wax normally deposits out in the colder parts of the system such as in the evaporator and its metering device (Fig. 18). Wax in the evaporator causes some loss of heat transfer; wax in the metering device can cause restriction or sticking.

A good refrigeration oil should not deposit wax when exposed to the lowest temperatures normally encountered in the refrigeration system.

NEUTRALIZATION

Almost all refrigeration oils have some acid tendencies. Nearly all oil contains material of uncertain composition referred to as organic acids. These are

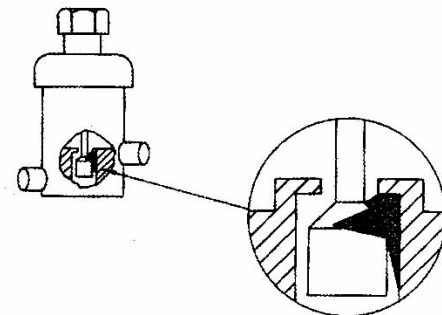


FIG. 18-WAX DEPOSITS

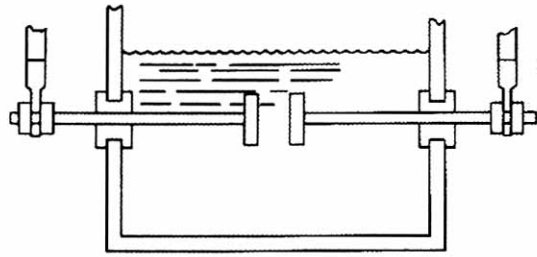


FIG. 19-DIELECTRIC TESTING

usually harmless and should not be confused with mineral acids which are harmful.

The neutralization number is a measure of the amount of mineral acid, and is determined by measuring the amount of test fluid that must be added to the oil to bring it to a neutral condition. A low neutralization number means that few acids are contained in the oil.

Improper refining may leave a large proportion of corrosive acid present in an oil. A low neutralization number indicates a low acid content. Acids may corrode interior parts of the system; they react with motor insulation and other materials to form sludge which can eventually cause a complete system breakdown. A low neutralization number is highly desirable in refrigeration oils.

DIELECTRIC STRENGTH

Dielectric strength is a measure of the resistance of an oil to the passage of electric current. It is measured in kilovolts on a test cell as shown in *Fig. 19*. The poles in the cell are a predetermined distance apart. They are immersed in the oil so that current must pass thru the oil to flow from one pole to the other. The kilovolts necessary to cause a spark to jump this gap is known as the dielectric rating. Good refrigeration oils normally have a rating of over 25 kilovolts.

A dielectric rating is important because it is a measure of impurities in the oil. If the oil is free of foreign matter, it has a high resistance to current flow. If the oil contains impurities, its resistance to current flow is low.

The presence of foreign matter in a refrigeration system is sufficient reason for considering this test valuable. Hermetic motors make a high kilovolt rating necessary for refrigeration oils since a low kilovolt rating may be a contributing factor to shorted windings.

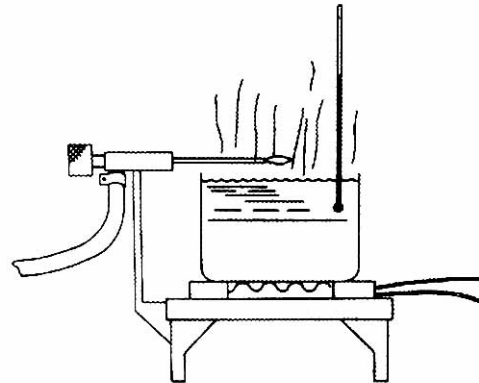


FIG. 20-FLASH AND FIRE POINT TESTS

FLASH POINT AND FIRE POINT

The flash point of an oil is that temperature at which oil vapor flashes when exposed to a flame. The fire point is that temperature at which it continues to burn.

The apparatus shown in *Fig. 20* heats the oil while a small gas flame is passed closely over the surface of the oil. When a flash of fire is noted at some point on the surface, the flash point has been reached. The apparatus continues to heat the oil until it ignites and continues to burn. This is the fire point.

The flash point of a good refrigeration oil is well over 300 F. Temperatures obtained in the normal refrigeration system rarely reach this point. The test for flash and fire points is important as it is a means of detecting inferior blends.

It is possible to get an acceptable viscosity reading for a refrigerant oil by mixing a small amount of high viscosity oil with a large amount of low viscosity oil. The viscosity of the mixture indicates a satisfactory oil when actually the low viscosity oil is inferior and breaks down under normal use. Fortunately, this can be detected using the flash and fire point test which indicates the inferiority of the low viscosity oil.

OXIDATION STABILITY

Oxidation stability is the ability of refrigeration oil to remain stable in the presence of oxygen. The Sligh Oxidation Test is used to determine this stability (*Fig. 21*).

While exposed to oxygen in the flask, the oil is heated to a high temperature for an extended period of time. The solid sludge that is formed in the flask is weighed and

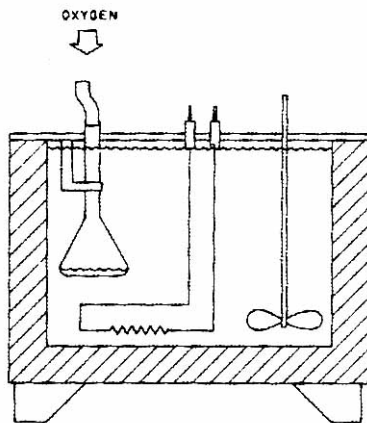


FIG. 21-SLIGH OXIDATION TEST

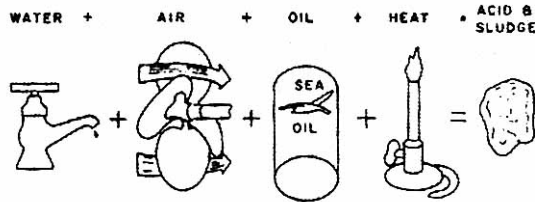


FIG. 22-OIL BREAKDOWN

reported as the Sligh Oxidation Number.

When air enters a system, some moisture generally accompanies it. The combination of moisture, air, refrigeration oil and discharge temperatures produces acid which creates sludge (Fig. 22). If oil has a low Sligh Oxidation Number, the oil breakdown to acid and sludge is quite slow.

CORROSION TENDENCY

The corrosion tendency of a refrigeration oil is measured by the copper strip corrosion test (Fig. 23). This test is intended to indicate the presence of undesirable sulfur compounds in the refrigeration oil.

A strip of polished copper is immersed in an oil sample in a test tube. This is subjected to temperatures around 200 F. After about 3 hours, the copper is removed from the oil, cleaned with a solvent, and examined for discoloration. If the copper is tarnished or pitted, then sulfur is present in the oil. Well refined oils

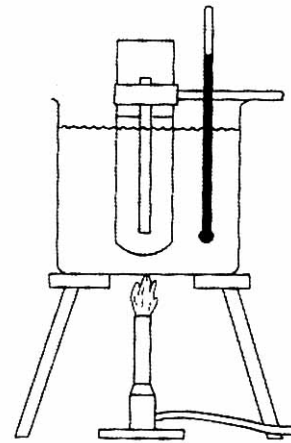


FIG. 23-CORROSION TEST

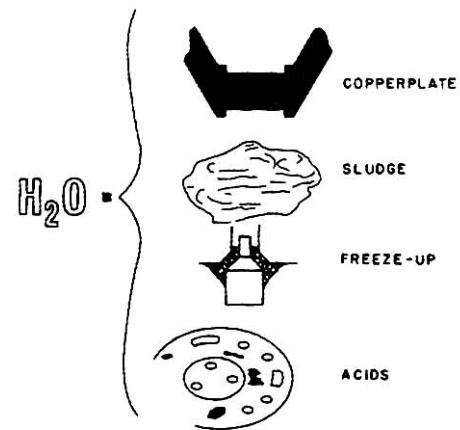
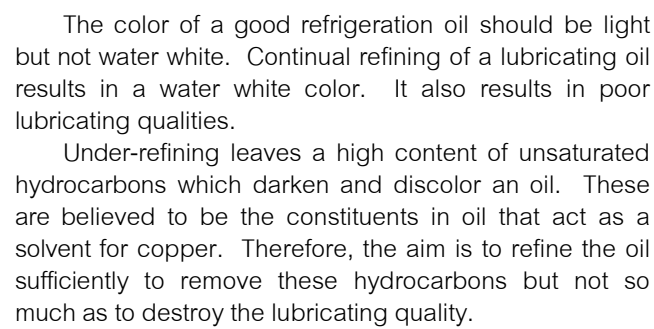


FIG. 24-MOISTURE AND AIR IN THE SYSTEM

rarely cause more than a slight tarnishing of copper in this test.

A good refrigeration oil should score negative in the copper strip corrosion test. If it does not, it contains sulfur in a corrosive form.

Sulfur alone is a deadly enemy of the refrigeration system but, in the presence of moisture, sulfurous acid is formed, one of the most corrosive compounds in existence. Though the sulfurous acid converts immediately to sludge, this sludge is certain to create serious mechanical problems.



SPECIFICATIONS

1. For open and hermetic reciprocating compressors at standard air conditioning levels, the following oil characteristics are typical:
Viscosity, 150 ± 10 SSU at 100 F
40 to 45 SSU at 210 F
Dielectric (min.), 25 kv
Pour Point (max.), -35 F
Flash Point (min.), 330 F
Neutralization Number (max.), .05
Floc Point (max.), -70 F
2. For centrifugal compressors used for water cooling at air conditioning levels, the following are typical properties:
Viscosity, 300 ± 25 SSU at 100 F
50 to 55 SSU at 210 F
Dielectric (min.), 25 kv
Pour Point (max.), 20 F
Flash Point (min.), 400 F
Neutralization Number (max.), 0.1
3. For special applications, consult the equipment manufacturer.

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INDEX

PART 4 REFRIGERANTS, BRINES, OILS

A

Absorption cycle
Absorption system
Alcohols
 Applications
 table 9
 properties
 table 10
 uses

B

Brine
 applications
 table 9
 piping
 properties
 selection

C

Calcium chloride
 applications
 table 9
 properties
 table 10
 specific gravity
 chart, 7
 specific heat
 chart 8
 thermal conductivity
 chart 9
 uses
 viscosity
 chart 6
Classification of oils
Compression cycle
 fig. 3
 fig. 4
Compression system
Condensers

Cooling coils

E

Equilibrium diagram
 fig. 2
Ethanol brine
 specific gravity
 chart 15
 specific heat
 chart 16
 thermal conductivity
 chart 17
 viscosity
 chart 14
Ethylene glycol
 specific heat
 chart 20
 thermal conductivity
 chart 21
 viscosity
 chart 18

Eutectic mixture
Eutectic temperature

F

Flammability
Friction factors
 chart 1
Friction loss

G

Glycols
 applications
 table 9
 properties
 table 10
 uses

H

Heat transfer comparisons
 cooling coils
 condensers
Horsepower per ton, 4-6

I

Inhibitors

L

Leak detection, 4-6
Leakage rate, 4-6
Liquid-suction interchanger

M

Methanol brine
 specific gravity
 chart 11
 specific heat
 chart 12
 thermal conductivity
 chart 13
 viscosity
 chart 10
Miscibility

O

Oil specifications

P

Piping
Properties of oils

carbonization
color
corrosion tendency
dielectric strength
fire point
flash point
floc point
moisture content
neutralization
oxidation stability
pour point
viscosity

Properties of refrigerants

R 11
R 12
R 22
R 113
R 114
R 500
R 502

Propylene glycol

specific gravity
chart 23
specific heat
chart 24
thermal conductivity
chart 25
viscosity
chart 22

Pump brake horsepower

R

Rate of leakage

Refrigerant properties

flammability
horsepower per ton
leak detection
miscibility
rate of leakage
toxicity
vapor density

Refrigerant selection

absorption cycle
compression cycle

Refrigerant tables

R 11
R 12
R 22
R 113
R 114
R 500
R 502

Refrigerant 11

properties
chart 27

Refrigerants

comparative data
table 1
use

Refrigerant cycles

absorption cycle
compression cycle

Refrigeration oils

classification
properties
carbonization
color
corrosion tendency
dielectric strength
fire point
flash point
floc point
moisture content
neutralization
oxidation stability
pour point
viscosity
specifications

S

Sodium chloride

applications
table 9
properties
table 10
specific gravity
chart 3
specific heat
chart 4
thermal conductivity
chart 5
uses
viscosity
chart 2

Specific gravity

calcium chloride
chart 7
ethanol brine
chart 15

Specific gravity (contd)

ethylene glycol
chart 19
methanol brine
chart 11

propylene glycol
chart 23
refrigerant I I
chart 27
sea water
chart 28
sodium chloride
chart 3
trichloroethylene
chart 26

Specific heat

calcium chloride
chart,8
ethanol brine
chart 16,
ethylene glycol
chart 20
methanol brine
chart 12
propylene glycol
chart 24
refrigerant I I
chart 27
sea water
chart 28
sodium chloride
chart 4
trichloroethylene
chart 26

Specifications of oils

T

Thermal conductivity

calcium chloride
chart 9
ethanol brine
chart 17
ethylene glycol
chart 21
methanol brine
chart 13
propylene glycol
chart 25
refrigerant
chart 27
sea water
chart 28
sodium chloride
chart 5
trichloroethylene
chart 26

Toxicity

Trichloroethylene
properties
chart 26

V

Vapor density

Viscosity

calcium chloride
chart 6
ethanol brine

chart 14
ethylene glycol
chart 18
methanol brine
chart 10,
propylene glycol
chart 22,
refrigerant 11chart 27
sodium chloride
chart 2

trichloroethylene
chart 26
water
chart 28

W

Water

viscosity
chart 28



FIGURE

PART 4 REFRIGERANTS, BRINES, OILS

- Fig. 1 – Absorption Refrigeration Cycle
- Fig. 2 – Equilibrium Diagram for Lithium Bromide
- Fig. 3 – Reciprocating Compression Refrigeration Cycle
- Fig. 4 – Pressure-Enthalpy Diagram, Compression Cycle
- Fig. 5 – Effect of Liquid-Suction Interchanger on Compression
- Fig. 6 – Effect of Liquid-Suction Interchanger on Capacity
- Fig. 7 – Structural Formulas For Refrigerants
- Fig. 8 – Miscibility of Refrigerant 12 and Oil
- Fig. 9 – Suction Volumes of Refrigerants (CFM/TON)
- Fig. 10 – Pressures and Temperatures of a Typical Absorption Machine
- Fig. 11 – Brine Mixture
- Fig. 12 – Lubrication Characteristics
- Fig. 13 – Effect of Temperature on Viscosity
- Fig. 14 – Pour Point Tube
- Fig. 15 – Pour Point
- Fig. 16 – Carbon Deposit
- Fig. 17 – Flog Test
- Fig. 18 – Wax Deposits
- Fig. 19 – Dielectric Testing
- Fig. 20 – Flash and Fire Point Tests
- Fig. 21 – Sligh Oxidation Test
- Fig. 22 – Oil Breakdown
- Fig. 23 – Corrosion Test
- Fig. 24 – Moisture and Air in the System
- Fig. 25 – Color Testing



TABLE PART 4 REFRIGERANTS, BRINES, OILS

TABLE 1 – COMPARATIVE DATA OF REFRIGERANTS

TABLE 2 – PROPERTIES OF REFRIGERANT 12, LIQUID AND SATURATED VAPOR

TABLE 2 – PROPERTIES OF REFRIGERANT 12, LIQUID AND SATURATED VAPOR (Contd)

TABLE 3 – PROPERTIES OF REFRIGERANT 12, LIQUID AND SATURATED VAPOR

TABLE 3 – PROPERTIES OF REFRIGERANT 500, LIQUID AND SATURATED VAPOR (Contd)

TABLE 4 – PROPERTIES OF REFRIGERANT 22, LIQUID AND SATURATED VAPOR

TABLE 4 – PROPERTIES OF REFRIGERANT 22, LIQUID AND SATURATED VAPOR (Contd)

TABLE 5 – PROPERTIES OF REFRIGERANT 11, LIQUID AND SATURATED VAPOR

TABLE 5 – PROPERTIES OF REFRIGERANT 11, LIQUID AND SATURATED VAPOR (Contd)

TABLE 6 – PROPERTIES OF REFRIGERANT 113, LIQUID AND SATURATED VAPOR

TABLE 6 – PROPERTIES OF REFRIGERANT 113, LIQUID AND SATURATED VAPOR (Contd)

TABLE 7 – PROPERTIES OF REFRIGERANT 114, LIQUID AND SATURATED VAPOR

TABLE 7 – PROPERTIES OF REFRIGERANT 114, LIQUID AND SATURATED VAPOR (Contd)

TABLE 8 – PROPERTIES OF REFRIGERANT 502, LIQUID AND SATURATED VAPOR

TABLE 8 – PROPERTIES OF REFRIGERANT 114, LIQUID AND SATURATED VAPOR (Contd)

TABLE 9 – TYPICAL BRINE APPLICATIONS

TABLE 10 – BRINE PROPERTIES



CHART

PART 4 REFRIGERANTS, BRINES, OILS

CHART 1 – FRICTION FACTORS FOR COMMERCIAL PIPE

CHART 2 – SODIUM CHLORIDE – VISCOSITY

CHART 3 – SODIUM CHLORIDE – SPECIFIC GRAVITY

CHART 4 – SODIUM CHLORIDE – SPECIFIC HEAT

CHART 5 – SODIUM CHLORIDE – THERMAL CONDUCTIVITY

CHART 6 – CALCIUM CHLORIDE– VISCOSITY

CHART 7 – CALCIUM CHLORIDE– SPECIFIC GRAVITY

CHART 8 – CALCIUM CHLORIDE– SPECIFIC HEAT

CHART 9 – CALCIUM CHLORIDE– THERMAL CONDUCTIVITY

CHART 10 – METHANOL BRINE - VISCOSITY

CHART 11 – METHANOL BRINE - SPECIFIC GRAVITY

CHART 12 – METHANOL BRINE - SPECIFIC HEAT

CHART 13 – METHANOL BRINE - THERMAL CONDUCTIVITY

CHART 14 – ETHANOL BRINE - VISCOSITY

CHART 15 – ETHANOL BRINE - SPECIFIC GRAVITY

CHART 16 – ETHANOL BRINE - SPECIFIC HEAT

CHART 17 – ETHANOL BRINE - THERMAL CONDUCTIVITY

CHART 18 – ETHYLENE GLYCOL- VISCOSITY

CHART 19 – ETHYLENE GLYCOL- SPECIFIC GRAVITY

CHART 20 – ETHYLENE GLYCOL- SPECIFIC HEAT

CHART 21 – ETHYLENE GLYCOL- THERMAL CONDUCTIVITY

CHART 22 – PROPYLENE GLYCOL- VISCOSITY

CHART 23 – PROPYLENE GLYCOL- SPECIFIC GRAVITY

CHART 24 – PROPYLENE GLYCOL- SPECIFIC HEAT

CHART 25 – PROPYLENE GLYCOL- THERMAL CONDUCTIVITY

CHART 26 – TRICHLOROETHYLENE - PROPERTIES

CHART 27 – REFRIGERANT- PROPERTIES

CHART 28 – WATER – VISCOSITY

CHART 29 – OIL-REFRIGERANT VISCOSITY (4-59)