Chapter – 19 Brines and Brine Piping System

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Brine is the common name referring to all the secondary refrigerants or heat transfer fluids other then water. Water is the least expensive and it has best heat transfer properties among of all the secondary refrigerants. But, its freezing point is 32°F and therefore, cannot be used for low temperature refrigeration application.

It is the preference to use direct refrigerant to cool the product or process in industrial refrigeration application; heat transfer is penalized and power consumption is increased if secondary refrigerant is used instead of direct refrigerant. However, in some cases, use brine (secondary refrigerant) instead of direct refrigerant is more desirable and justifiable because of one or the combination of the following reasons:

1.0 Cost considerations; sometimes, the construction of brine piping system is less expensive than direct refrigerant piping due to the requirements of codes and regulations, particularly if the installation is with remote evaporator (more than 100 feet) or if the evaporator is located at high elevation. Cost comparison should be carefully exam to see if use of brine is justified; the brine system involves additional costs of brine cooler, brine pump, pumping HP, compressor power consumption, brine and refrigerant charges, maintenance and etc.

2.0 In the event of leakage, brine is more acceptable than refrigerant.

3.0 For multiple evaporator application, individual temperature control for each evaporator or space may be simpler, more accurate or more efficient with brine instead of refrigerant.

4.0 Some application requires sharp but short load peaks application, brine storage tank is able to provide the flywheel effect to average out the refrigeration load requirement.

5.0 The need of defrosting can be eliminated if brine is used for spray cooler application.

Inhibitor should be considered whenever brine is used to reduce the corrosion. The corrosion might be from the brine or might be caused by oxygen and/or carbon dioxide contaminations.

Corrosion inhibition is to form a surface of barrier that protects the metal from attack, some by reaction of the inhibitor and some by absorption. Environment Stabilizers and adjusters are also being used for corrosion inhibition; this is stabilizing or altering the overall environment to maintain in alkaline condition. It is best to use combination of the two types of additives, inhibitors and stabilizers. Do not use oxidants inhibitors such as sodium chromate as inhibitor for Ethylene Glycol. Both Methylene Chloride and Trichlorethylene do not require additives.

Figure 19-1 lists the common brines and the practical working brine temperature for the brine. The figure also shows the recommended tube material for the heat exchanger. The temperature limits shown are the approximate brine leaving temperature limit for flooded shell-and-tube heat exchanger. The temperature limitation is that heat exchanger selection would become unpractical and unviable if the leaving brine temperature is lower the temperature indicated. However, if the heat exchanger is DX, the leaving brine temperature limit for propylene glycol can be extended down to -25℉ and ethylene glycol down to -30℉ respectively at the proper brine concentration.

There are basically five groups of common brines:

(A) Salt brines such as calcium chloride and sodium chloride.

(B) Glycol brines such as propylene glycol and ethylene glycol.

(C) Alcohol brines such as methanol and ethanol.

(D) Chlorinated Hydrocarbon brines such as Methylene Chloride and Trichlorethylene.

(E) Floriated hydrocarbon brine such as R-11.

Sodium chloride and calcium chloride brine were very popular because low cost. Due to the corrosive nature of the brine, maintenance and initial cost are to be balanced and justified if sodium chloride or calcium chloride is to be selected. Other commonly used brines for refrigeration application are propylene glycol, ethylene glycol and methanol. Propylene glycol is the preferred brine for food, beverage and daily product application.

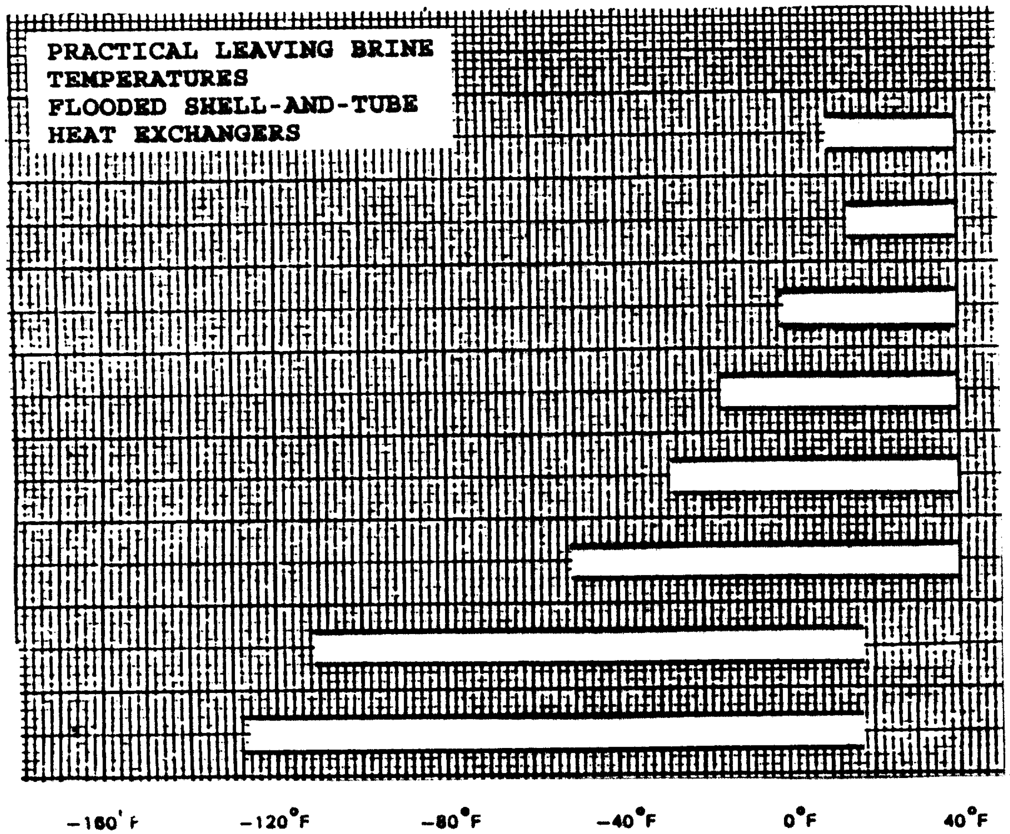
Ethylene Glycol is none corrosive brine. But, it becomes an acid end product when it is oxidized by air. Therefore, an inhibitor should be used for Ethylene Glycol brine. A ready mixed and specially engineered heat transfer fluids of propylene glycol and ethylene glycol are available in the market from suppliers such as Dow Chemical.

Ethanol and methanol are the derivative from alcohol and it is a flammable liquid. Ethanol is more expensive than methanol and the heat transfer properties are not as good as methanol brine. Therefore, methanol is better choice over ethanol.

Trichlorethylene and Methyl Chloride are halocarbons. It is only used as secondary refrigerant for very special low temperature application that well below -40℉.

R-11 is a very good secondary refrigerant; it can be used for very low temperature brine application down to -150℉. The only problem is that it is restricted due to CFC O-zone problem.

The safety and toxicity concerns for various common secondary refrigerants are listed as the following:



	TUBE MATERIALS	
	EXCELLENT	GOOD
SODIUM CHLORIDE	Cu. Ni.	Copper
PROPYLENE GLYCOL		Copper
ETHYLENE GLYCOL	Copper	Copper
CALCIUM CHLORIDE	Cu. Ni.	Steel *
METHANOL		Copper
ETHANOL		Copper
TRICHLORETHYLENE	Copper	Copper
METHYLENE CHLORIDE	Copper	Copper

Figure 19-1 Common Brine Working Temperatures

Table 19-01 **Brine Safety Ratings**

Brine	Safety Rating
Sodium Chloride	Non-flammable
Calcium Chloride	Non-flammable
Propylene Glycol	Flammable, moderate fire hazard. Flash point 210 ℉ to 225℉ undiluted.
Ethylene Glycol	Flammable, moderate fire hazard. Flash point 232 ℉ to 240℉ undiluted.
Methanol water	Flammable, fire hazard. Flash point 54℉ to 60℉ undiluted. Flash point 75℉ 30% solution.
Ethanol	Flammable, fire hazard. Flash point 55℉ undiluted.
Trichloroethylene	Non-flammable at ordinary ambient
Methylene Chloride	Non-flammable at ordinary ambient
R-11	Non-flammable

Table 19-02 **Brine Toxicity Data**

Brine	Safety Rating
Sodium Chloride	Non-toxic. Suitable for direct contact with food
Calcium Chloride	Non-toxic.
Propylene Glycol	Non-toxic. Suitable for food processing
Ethylene Glycol	Toxic.
Methanol water	Toxic.
Ethanol	Non-toxic
Trichloroethylene	Toxic. Threshold limit is about 100 ppm
Methylene Chloride	Slight toxicity, but generally considered Non-toxic, but threshold limit is about 500 ppm
R-11	Non-toxic, but threshold limit is about 1000 ppm

The data and the transportation properties of the brine required for heat transfer calculation or heat exchanger selection are as the following:

(1) Brine solution concentration, percent by weight.
(2) Brine inlet temperature and outlet temperature.
(3) Specific heat.
(4) Specific gravity.
(5) Viscosity.
(6) Thermal conductivity.

The transportation properties for the three typical brines of propylene glycol, ethylene glycol and methanol are shown in the figures from 19-2 to 19-16:

For Propylene Glycol Brine:

Figure 19-2 Propylene Glycol – Freeze Point.
Figure 19-3 Propylene Glycol – Specific Gravity.
Figure 19-4 Propylene Glycol – Thermal Conductivity.
Figure 19-5 Propylene Glycol – Specific Heat.
Figure 19-6 Propylene Glycol – Viscosity.

For Ethylene Glycol Brine:
Figure 19-7 Ethylene Glycol – Freeze Point.
Figure 19-8 Ehylenen Glycol – Specific Gravity.
Figure 19-9 Ethylene Glycol – Thermal Conductivity.
Figure 19-10 Ethylene Glycol – Specific Heat.
Figure 19-11 Ethylene Glycol – Viscosity.

For Methanol Brine:
Figure 19-12 Methanol – Freeze Point.
Figure 19-13 Methanol – Specific Gravity.
Figure 19-14 Methanol – Thermal Conductivity.
Figure 19-15 Methanol – Specific Heat.
Figure 19-16 Methanol – Viscosity.

Most heat exchanger selection software programs include the transportation properties of the commonly used brine. Refer to brine software program for more accurate brine data and all other brines.

Sometime, the refrigeration system is required to be designed to cool the process fluid. The process fluid is not common brine and therefore, the specific heat, specific gravity, thermal conductivity and viscosity information are to be furnished by the user in order to make heat exchanger selection.

Brine concentration is usually expressed by percent by weight, not percent by volume. Percent by Weight and Percent by Volume conversion curve is shown in the Figure 19-2 for propylene glycol, Figure 19-7 for ethylene glycol and Figure 19-12 for methanol.

The viscosity of a brine effects heat transfer greatly. The viscosity is higher when the brine temperature is lower. Also, the viscosity is higher when the brine concentration is higher except the ethanol and methanol (see viscosity curve in Figure 19-16 for methanol. Ethanol has similar characteristic as methanol).

In heat exchanger selection and heat transfer calculation, the Reynolds number is a very important indicator if the heat exchanger for brine cooling is viable.

REYNOLDS NUMBER (Re):

$$Re = \frac{M \times \text{TUBE ID}}{\mu \times 2.42}$$

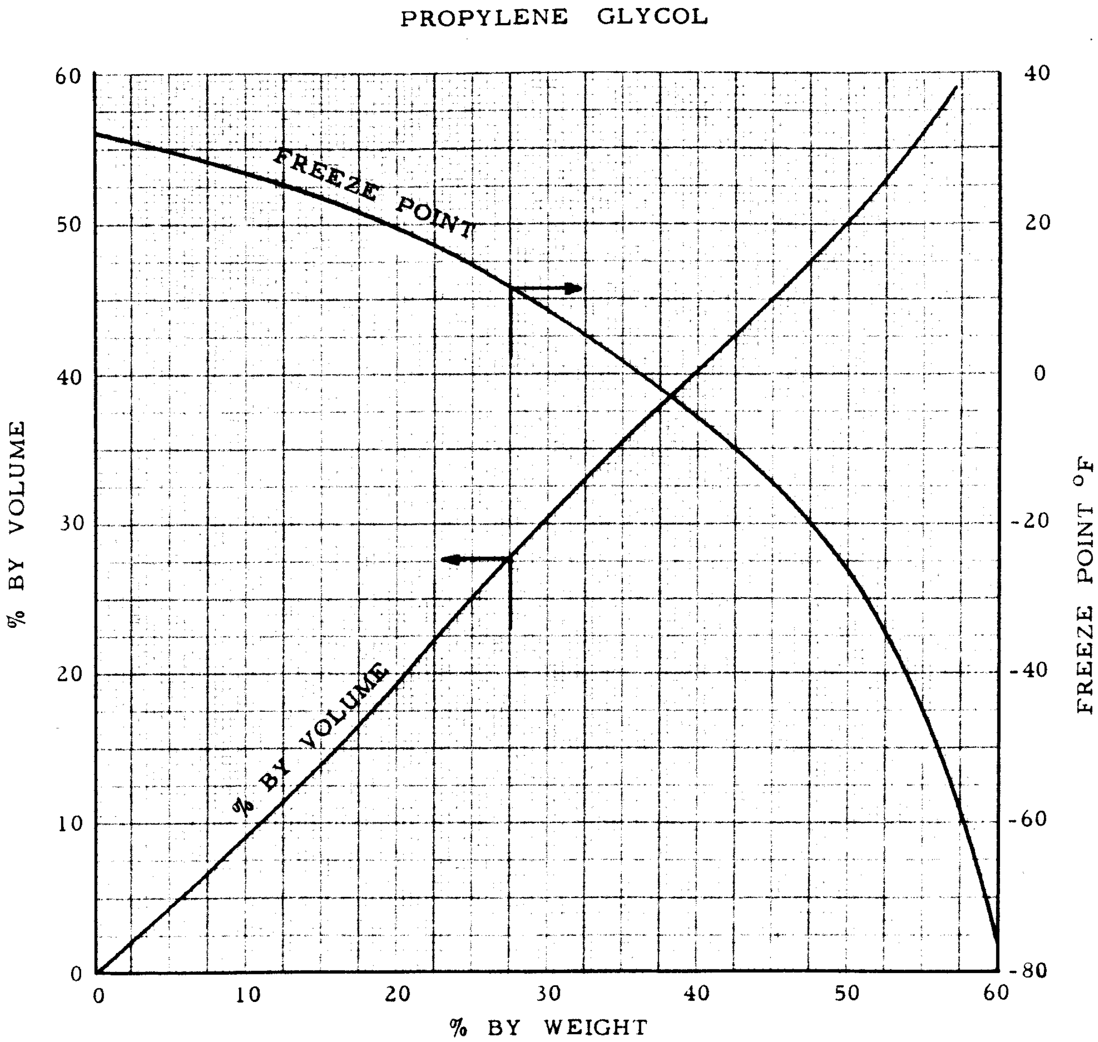


Figure 19-2 Propylene Glycol – Freeze Point

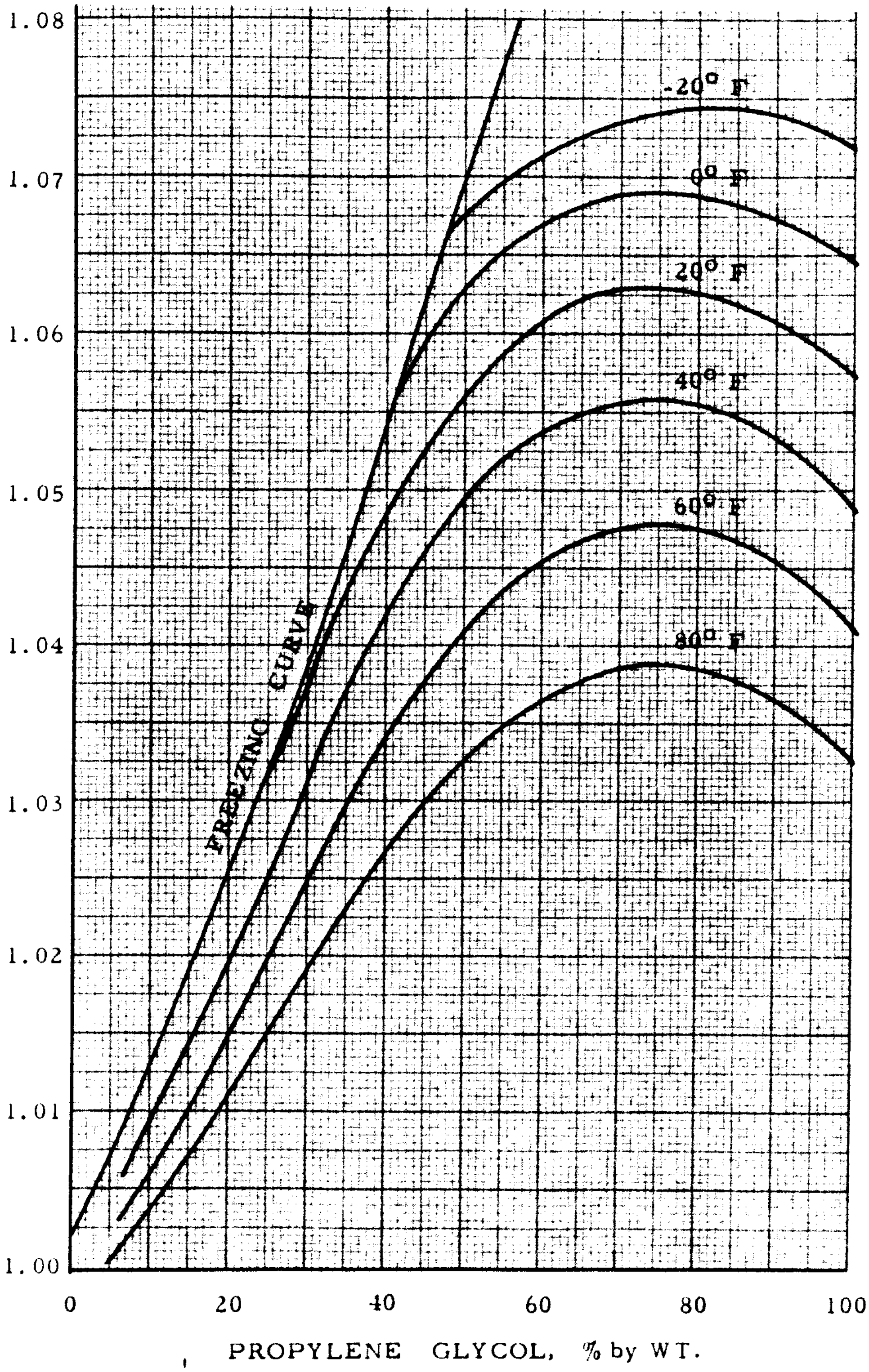


Figure 19-3 Propylene Glycol – Specific Gravity

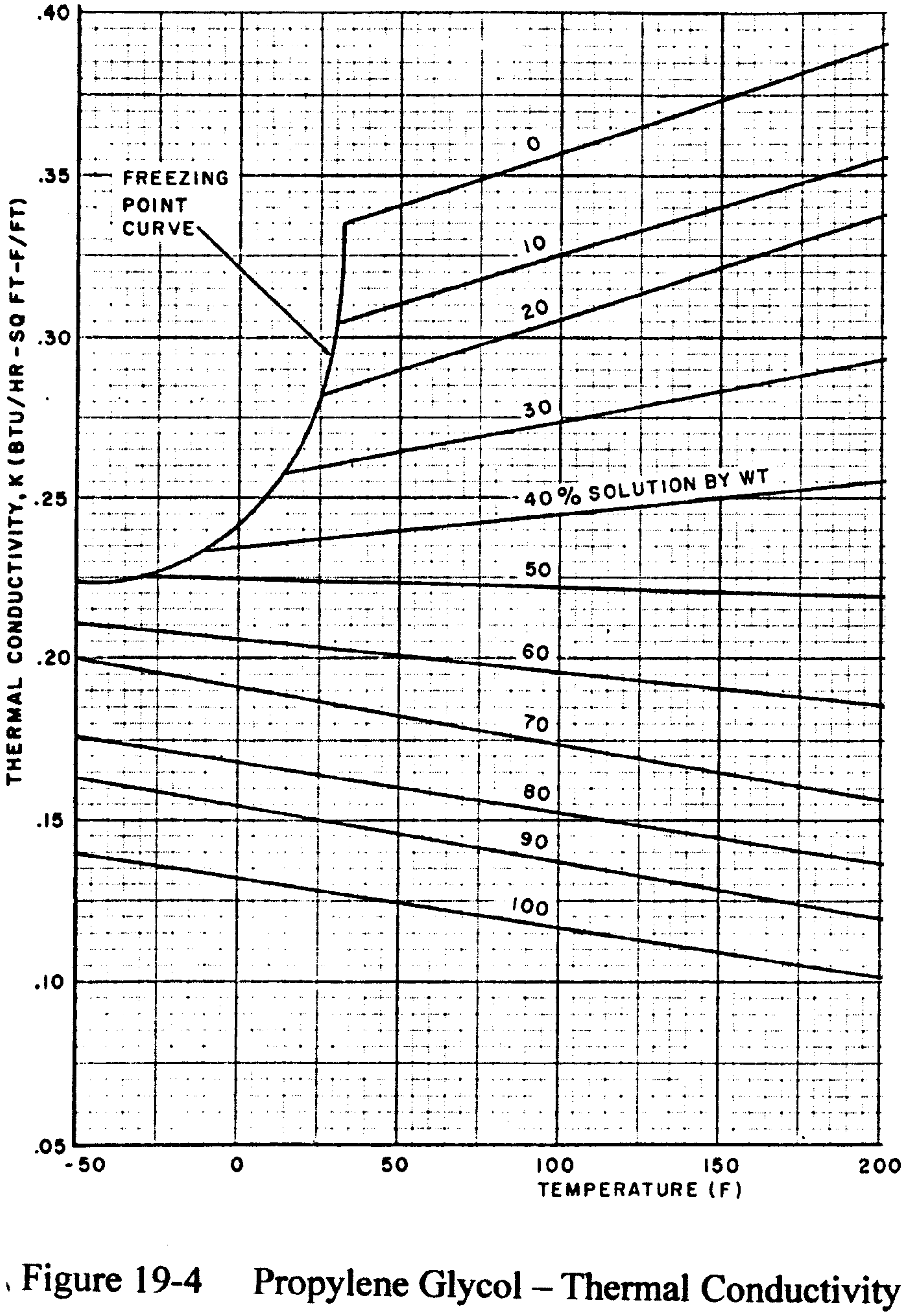


Figure 19-4 Propylene Glycol – Thermal Conductivity

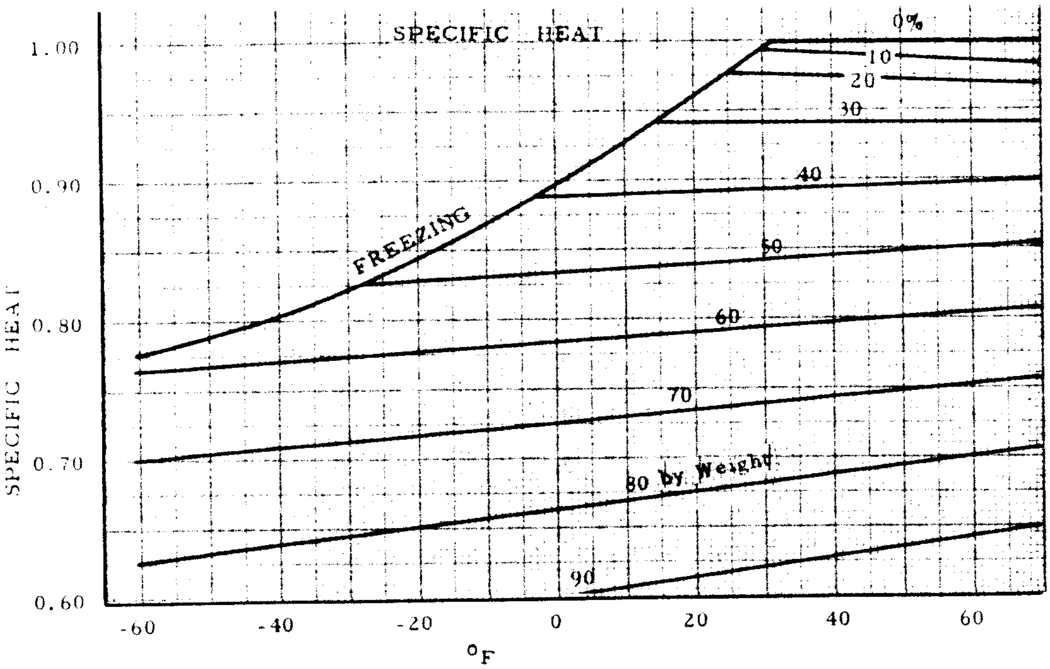


Figure 19-5 Propylene Glycol – Specific Heat

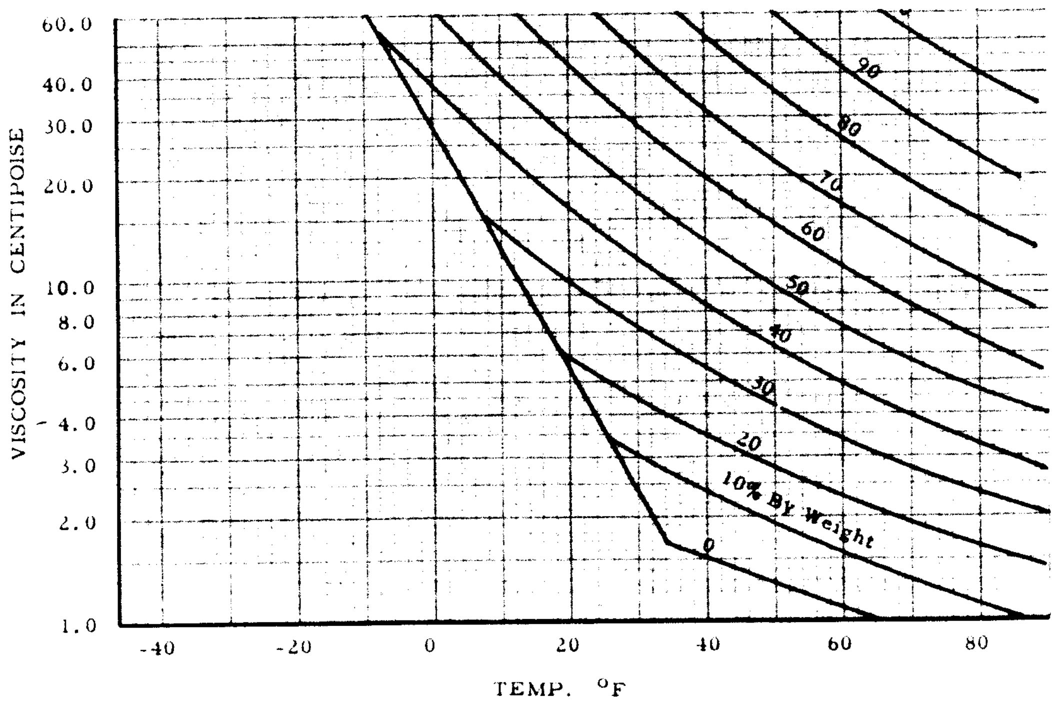


Figure 19-6 Propylene Glycol – Viscosity

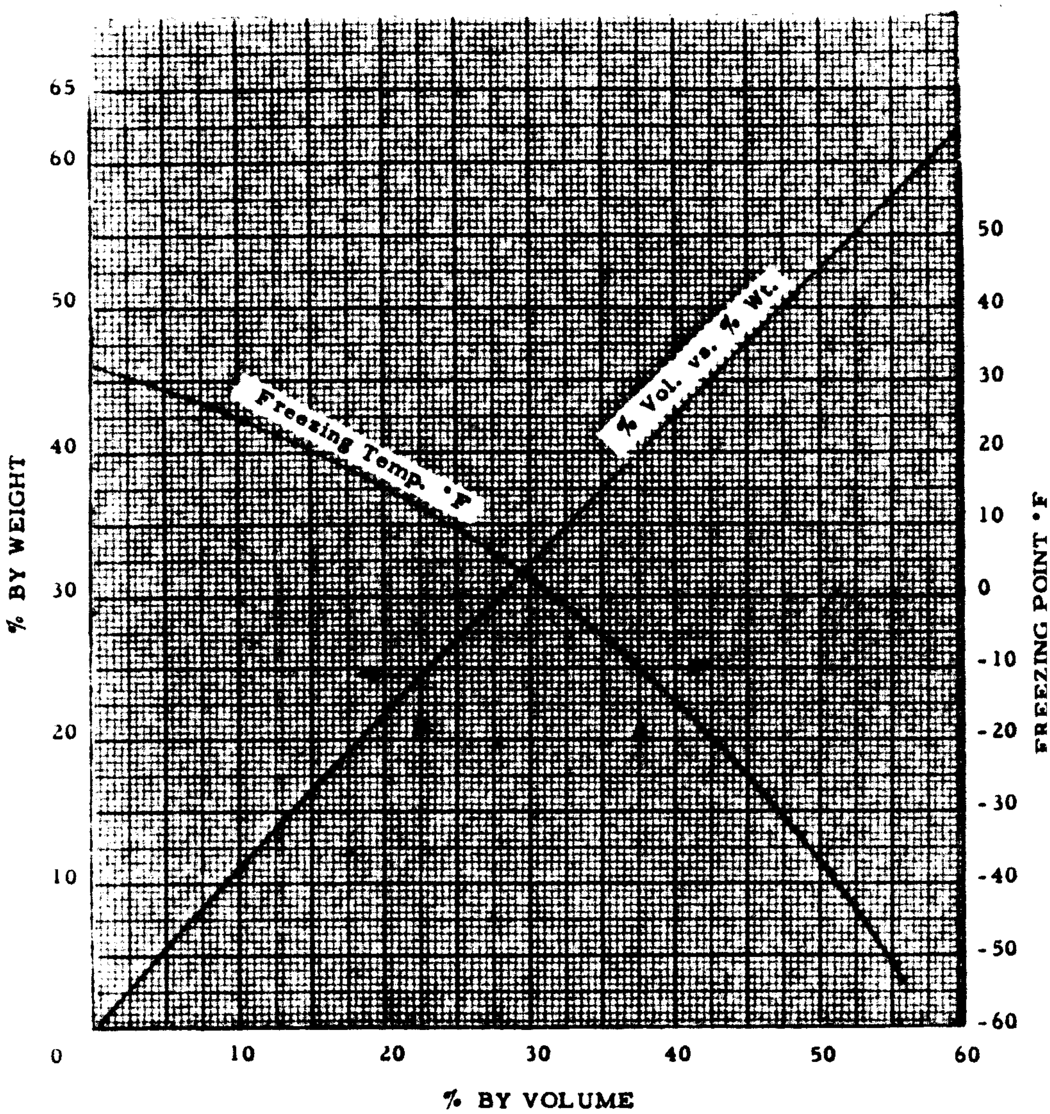


Figure 19-7 Ethylene Glycol – Freeze Point

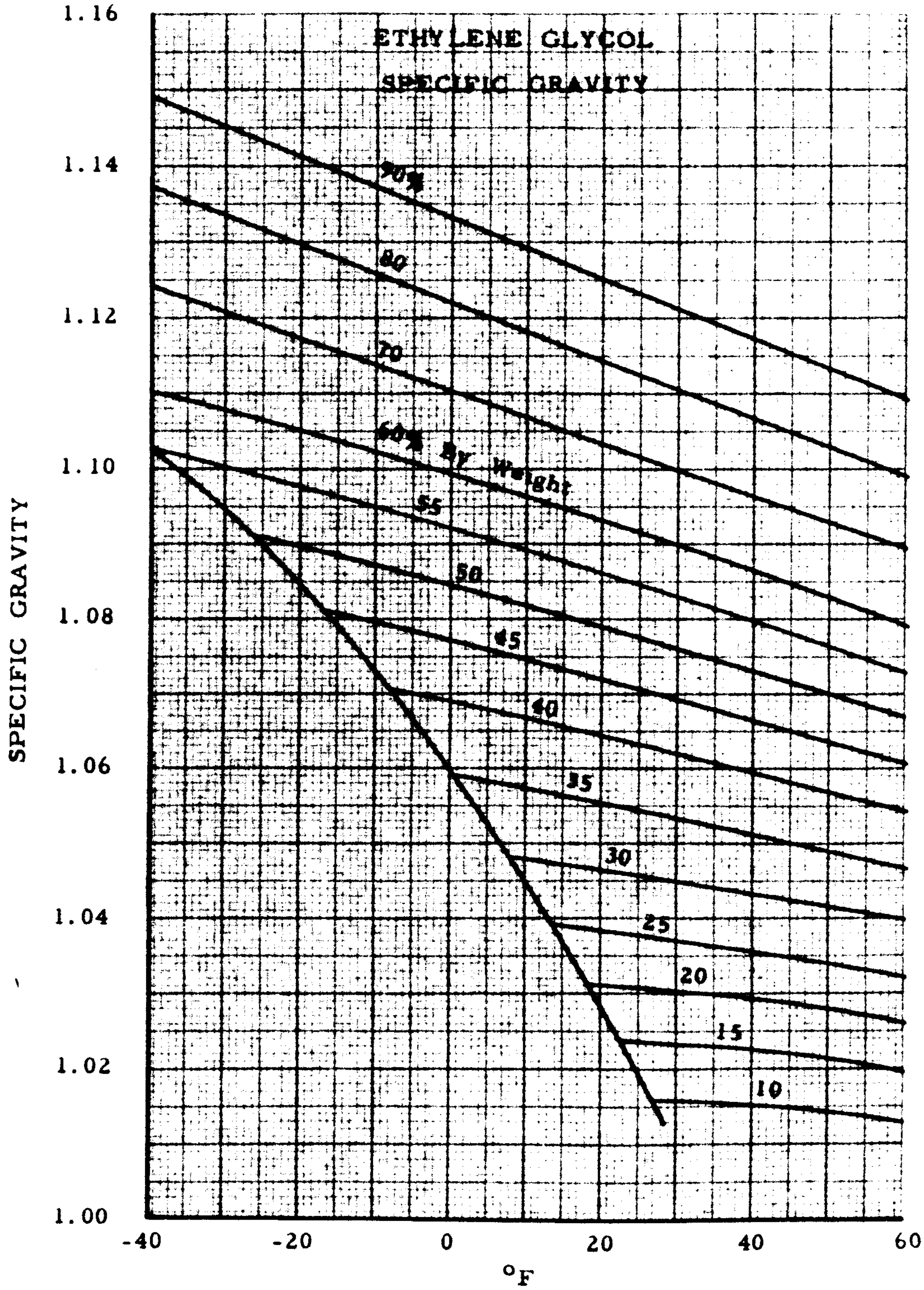


Figure 19-8 Ethylene Glycol – Specific Gravity

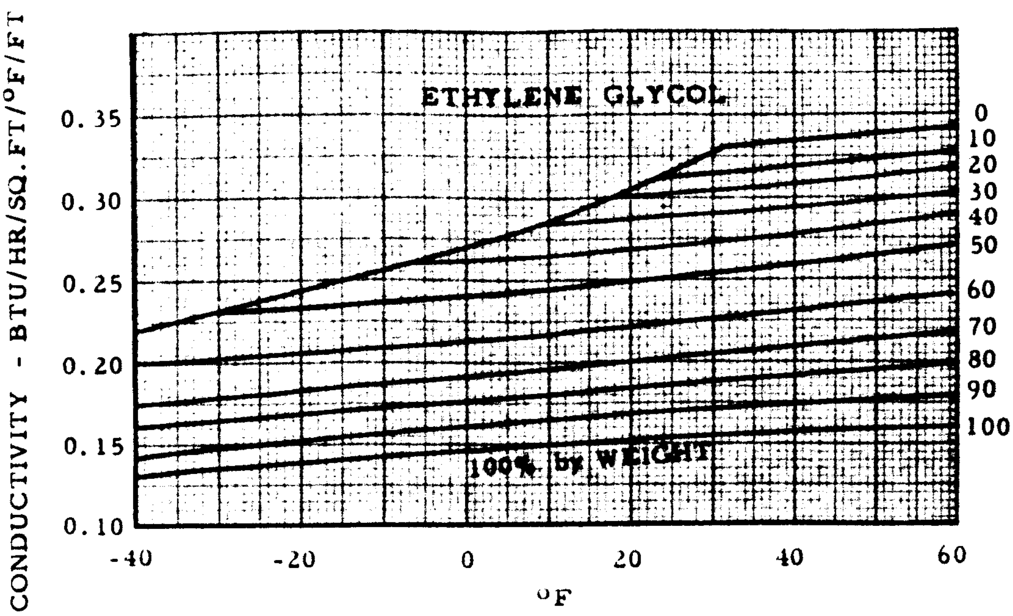


Figure 19-9 Ethylene Glycol – Thermal Conductivity

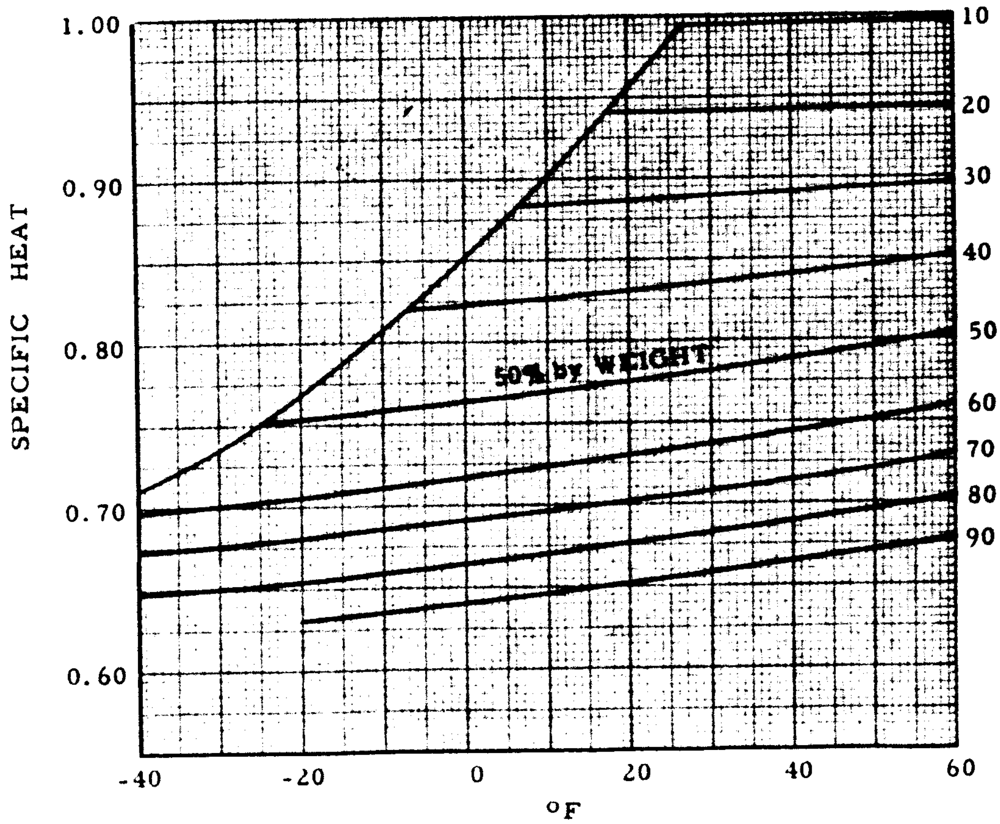


Figure 19-10 Ethylene Glycol – Specific Heat

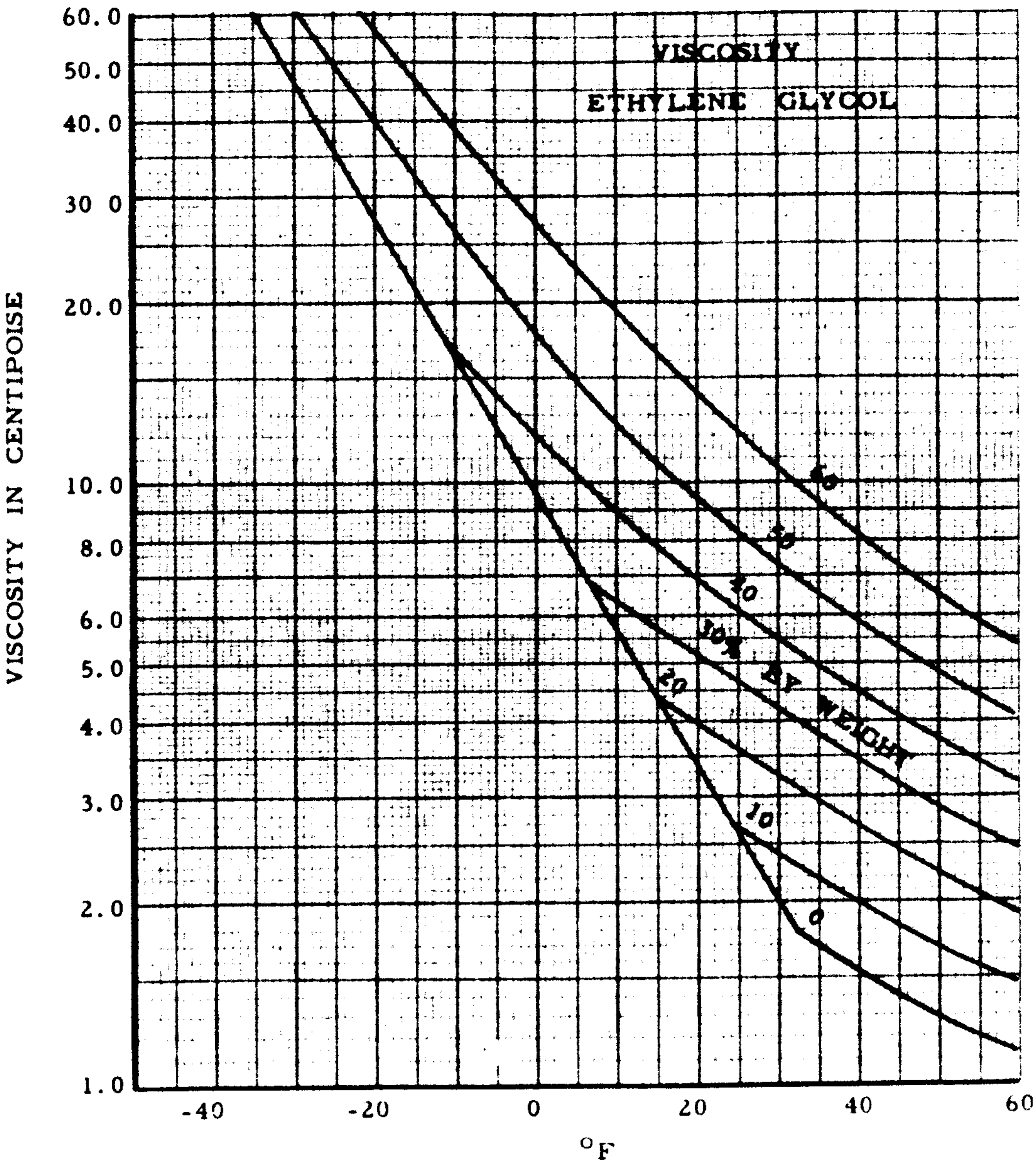


Figure 19-11 Ethylene Glycol – Viscosity

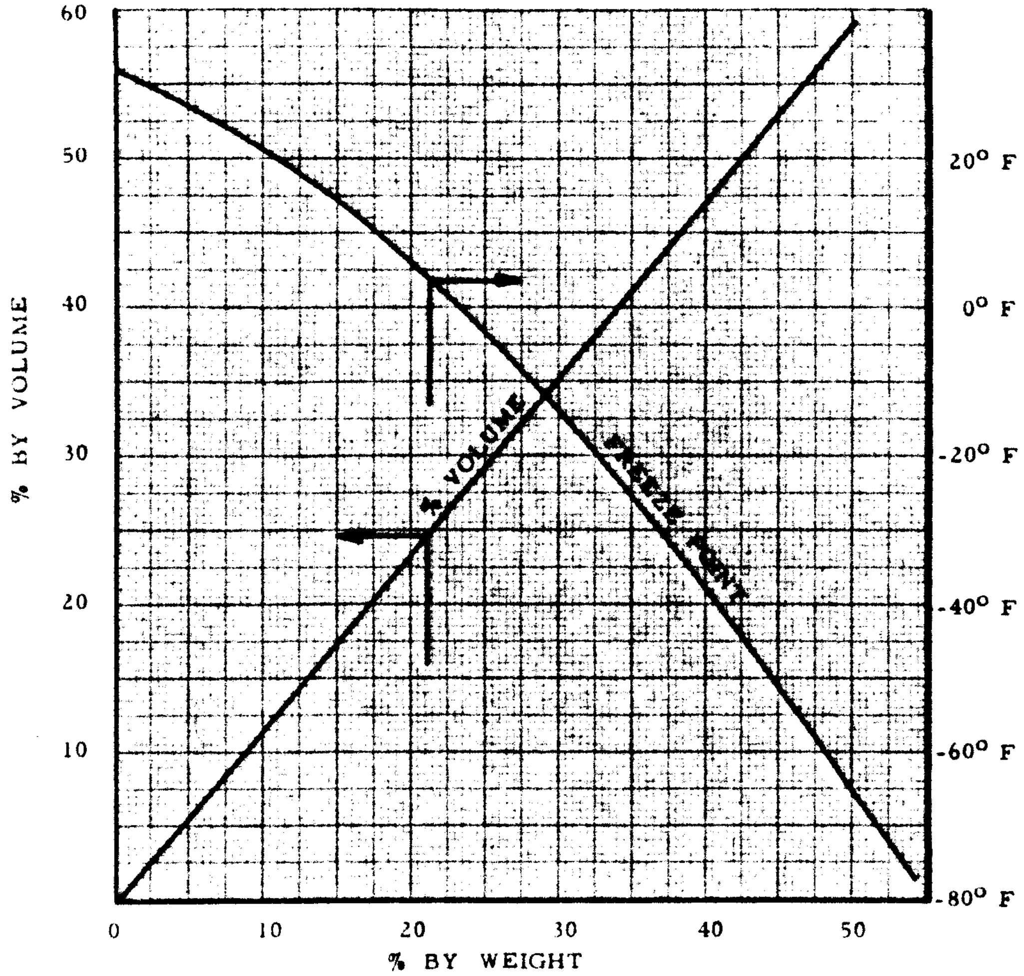


Figure 19-12 Methanol – Freeze Point

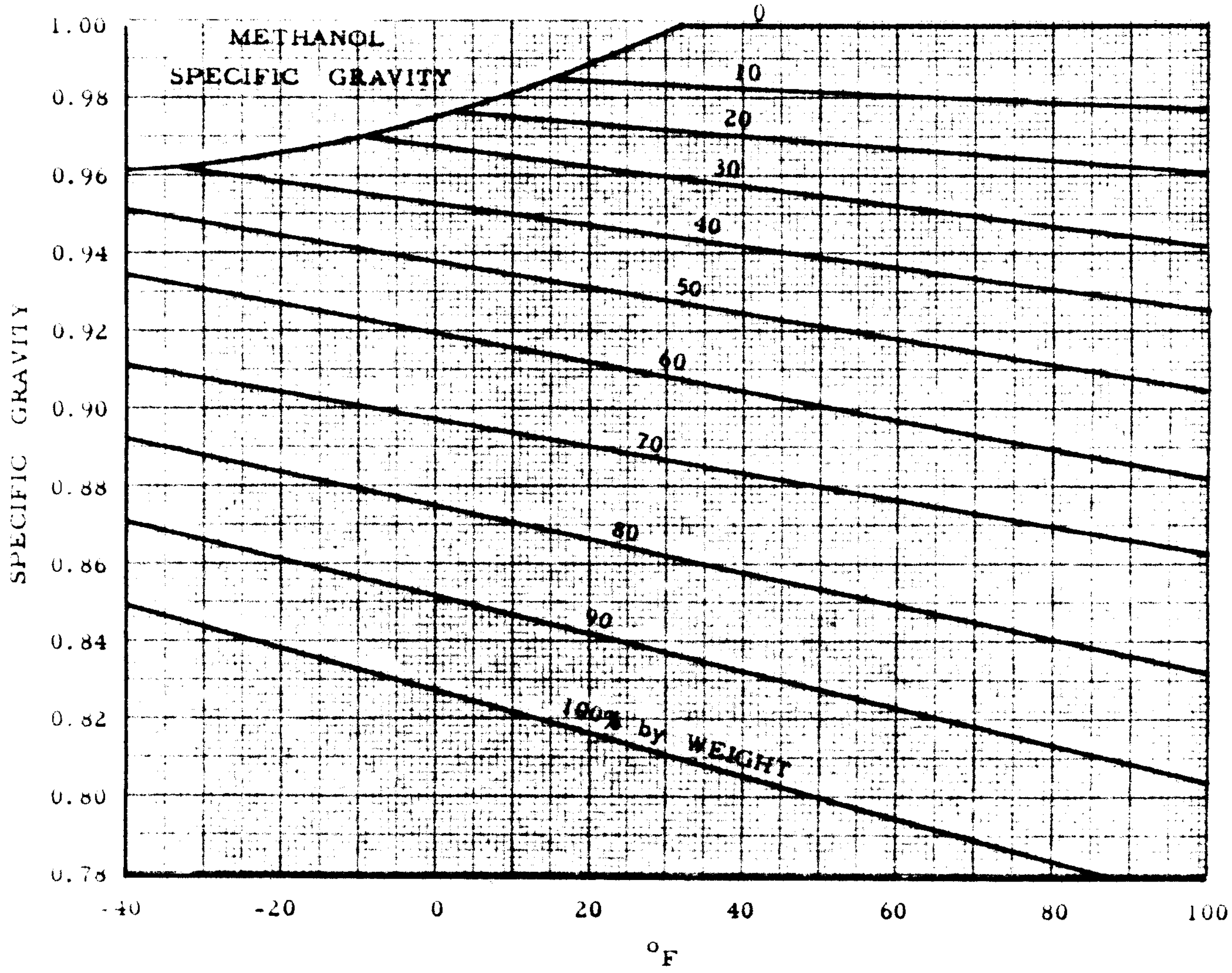


Figure 19-13 Methanol – Specific Gravity

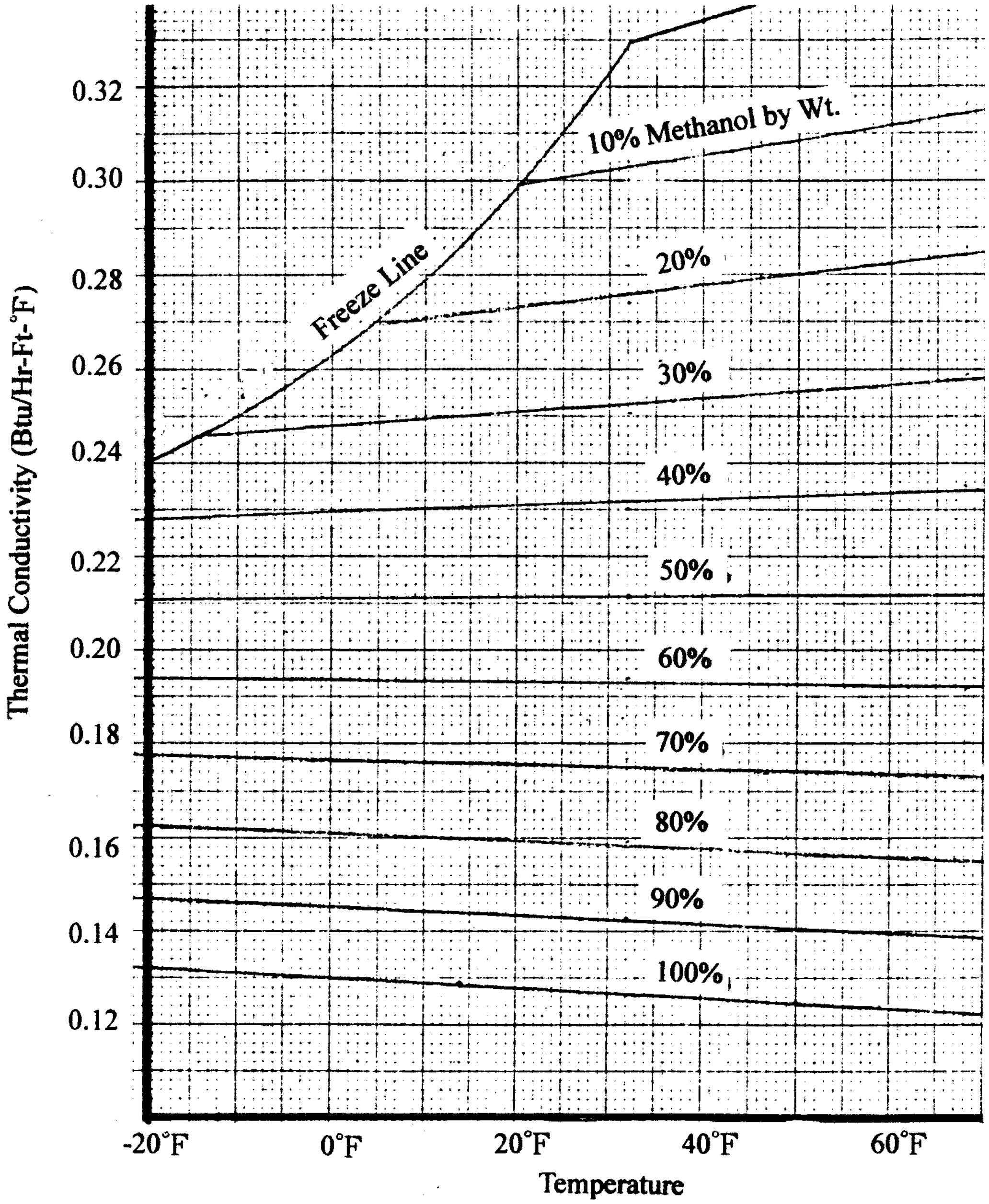


Figure 19-14 Methanol – Thermal Conductivity

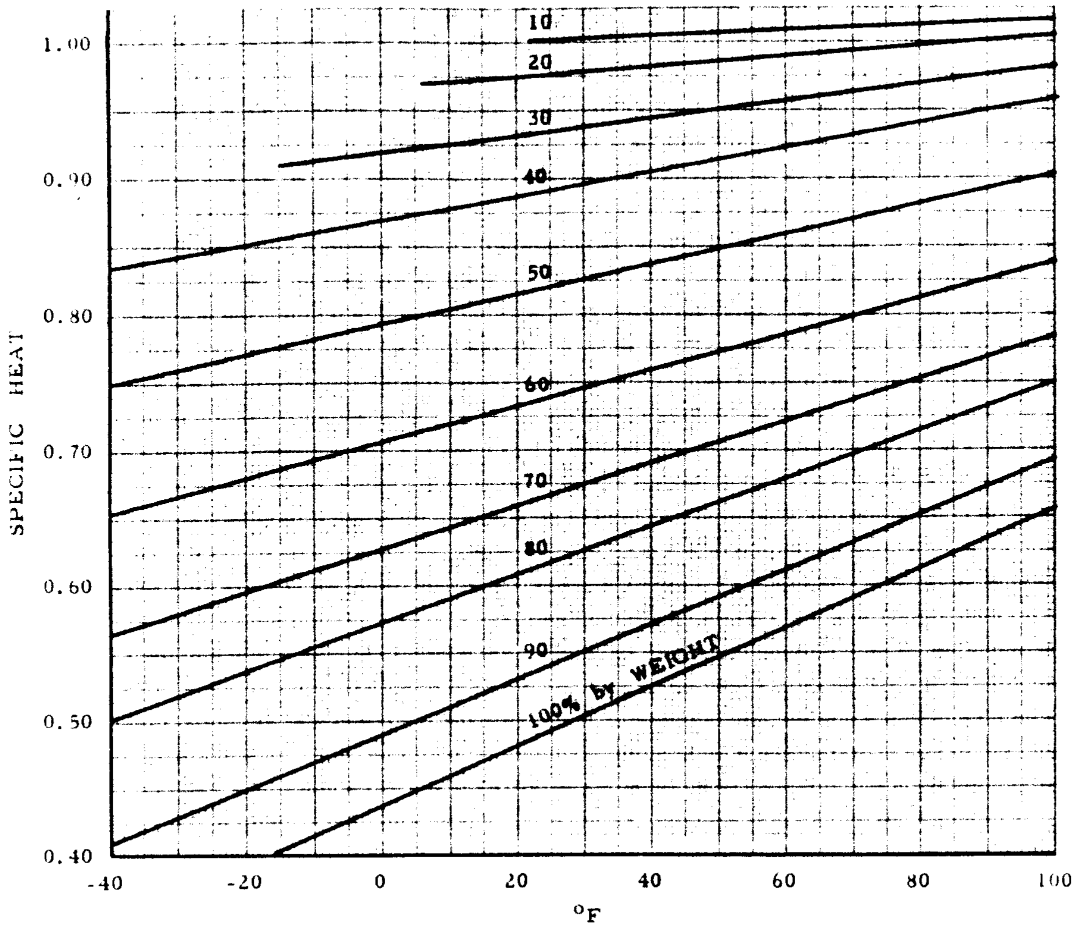


Figure 19-15 Methanol – Specific Heat

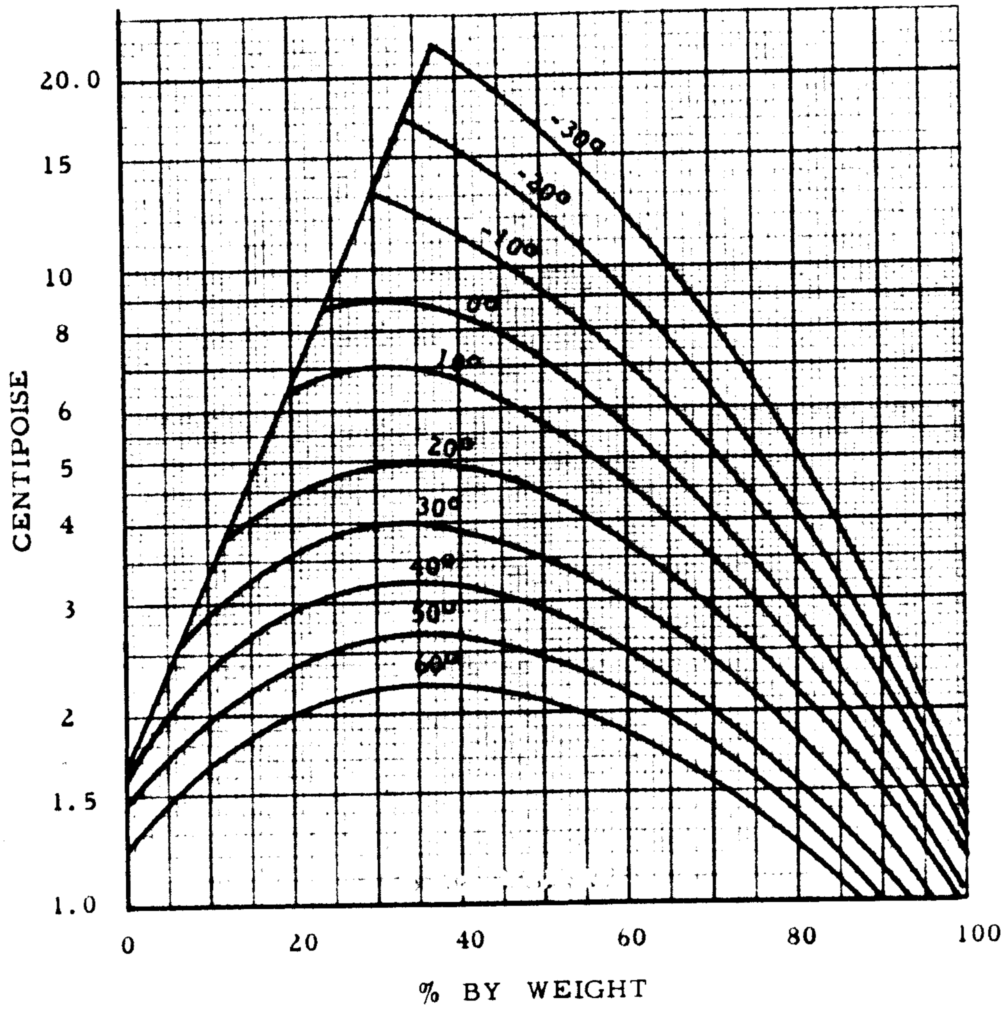


Figure 19-16 Methanol – Viscosity

$$M = \frac{\text{GPM x S.G. x 500 x NO.PASS}}{\text{NO.TUBES x TUBE FLOW AREA}}$$

$$Re = \frac{\text{V x 92,880 x S.G. x TUBE ID}}{\mu}$$

Where:

GPM	= Gallons per minute brine flow
S.G.	= Specific gravity of the brine
NO.PASS	= Pass arrangement of the heat exchanger
NO.TUBES	= Number of tubes in the heat exchanger.
TUBE AREA	= Squire feet area of tube surface.
ID	= Tube ID, Feet
V	= Brine velocity, ft/sec.
TUBE ID	= Inside diameter of the tube, Ft.
μ	= Viscosity, Centipoice

From the above formula, it is obvious that the viscosity of the fluid is the most important factor to determine the Reynolds number; the Reynolds number is larger if the viscosity is lower. For a viable heat exchanger selection, the Re value must be greater than 2,100 for turbulent flow. If the Re number is below 2,100, it represents the laminar flow and the heat exchanger selection is not viable.

Viscosity will greatly impact on the size of the heat exchanger. Higher viscosity of the brine requires bigger heat exchanger and larger heat transfer surface. From experience, in case of R-22 application, the general guide for the tube external surface requirements is as the following:

For R-22	Viscosity	Sq.Ft./TR Tube Surface
	2 to 3 CP	8 Sq.Ft./TR
	3 to 5 CP	10 Sq.Ft./TR
	5 to 8 CP	14 Sq.Ft./TR
	12 CP	18 Sq.Ft./TR

Brine Flow Calculation:

Brine flow is determined by:

(1) Heat Load.
(2) Brine Transportation Properties:
    Specific Gravity
    Specific Heat
(3) Brine Temperature Difference or Range

Formula for Brine Flow & Refrigeration Capacity:

$$TR = \frac{GPM \text{ x } S.G. \text{ x } C_p \text{ x } \quad T}{24}$$

$$Btu/Min = GPM \text{ x } 8.33 \text{ x } S.G. \text{ x } C_p \text{ x } \quad T$$

$$Btu/Hr = 499.8 \text{ x } GPM \text{ x } S.G. \text{ x } C_p \text{ x } \quad T$$

TR	=	Tons of Refrigeration
GPM	=	Fluid Flow Rate, Gallons per Minute
S.G.	=	Specific Gravity of the Fluid
C_p	=	Specific Heat of the Fluid, BTU/LB-°F
T	=	Temperature Range of the Fluid, °F, ($T_2 - T_1$)

Or

$$GPM = \frac{TR \text{ x } 24}{S.G. \text{ x } C_p \text{ x } \quad T}$$

$$GPM = \frac{Btu/Min}{8.33 \text{ x } S.G. \text{ x } C_p \text{ x } \quad T}$$

$$GPM = \frac{Btu/Hr}{499.8 \text{ x } S.G. \text{ x } C_p \text{ x } \quad T}$$

Example for Brine Flow Calculation:

Capacity:	220 TR
Brine range:	27.5°F to 21°F
Fluid:	35% By weight ethylene glycol brine

$$\text{Brine average temperature} = \frac{27.5 + 21}{2} = 24.3°F$$

Brine properties at the mean temperature of 24.3°F:

Specific Gravity: 1.056
Specific Heat: 0.845 BTU/LB-°F

$$TR = \frac{GPM \times S.G. \times C_p \times \quad T}{24}$$

$$220 = \frac{GPM \times 1.056 \times 0.845 \times (27.5 - 21)}{24}$$

Brine Flow = 910 GPM

Formula for Brine Pumping HP:

$$BHP = \frac{W \times H}{33{,}000 \times EFFICIENCY}$$

BHP = Brake HP.
W = Weight of liquid. Lbs/Min.
H = Total head in feet (Corrected for brine flow)

Heat Exchanger Tube Material for Common Refrigerants and Secondary Refrigerants

	Excellent	Good
Sodium Chloride	Cu. Ni	Copper
Propylene Glycol		Copper
Ethylene Glycol	Copper	Copper
Calcium Chloride	Cu. Ni.	Steel*
Methanol		Copper
Trichlorethylene	Copper	Copper
Methyl Chloride	Copper	Copper
Sodium Nitrate	S.S.	Copper
Calcium Nitrate		Copper*
Acetone		Copper
Ethanol		Copper

Water	Copper	Copper
Sea Water		Cu. Ni.
Halocarbons		Copper
Hydrocarbons		Copper
Ammonia		Steel

Notes:
*Must be inhibited.
Ethylene Glycol and Sodium Chloride brine are also recommended to be inhibited.

Brine Concentration Determination:

In general speaking, the brine concentration should be optimized that the freezing point of the brine should be more than 5°F below the lowest possible evaporative temperature for the refrigeration system. For example: In the case of ethylene glycol brine system, the lowest evaporative temperature is 14°F, the freezing temperature of the brine should be at least 14°F - 5°F = 9°F, therefore, the concentration of the ethylene glycol brine should be 24% by weight. General speaking, too much of conservative by increase the percent of brine concentration has no advantage to the operation and it is harmful to energy consumption, because the heat transfer is penalized and the power consumption is increased due to higher viscosity.

Brine Piping:

The brine piping system construction shall generally follow the water piping system practices.

Figure 19-17 is the equivalent length of valves and fittings for the carbon steel piping in addition to the regular piping run. Figure 19-18 is the pressure drop through pipe for water flow.

Figure 19-19 is the pressure drop correction factor for brine flow. The flow must be turbulent flow; that is the Turbulent Flow Factor (β) must be greater 0.1.

EQUIVALENT LENGTH IN FEET TO BE ADDED TO RUN OWING TO VALVES AND FITTINGS

Type of Fitting	Nominal Pipe Sizes—Inches ½	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	11	12
Gate Valve—Open	.3	.5	.6	.8	.9	1.2	1.4	1.7	2.0	2.5	2.7	3.0	3.5	4.0	4.5	5.0	6.0	6.5	7.0
Globe Valve—Open	16	21	26	35	43	54	65	80	95	110	120	140	160	180	210	250	280	305	330
Angle Valve—Open	8	11	14	18	20	25	31	40	45	51	60	70	80	91	110	125	140	152	165
Standard 45 deg. Elbow	.8	1.0	1.3	1.6	2.0	2.5	3.0	3.8	4.5	5.0	5.8	6	8	8.5	10	11	13	14	15
Standard 90 deg. Elbow	1.5	2.0	2.5	3.5	4.5	5.0	6.5	8.0	10	11	13	14	16	18	20	23	26	28	30
Medium Sweep 90 deg. Elbow	1.4	1.8	2.3	3.0	3.5	4.5	5.2	6.8	8	9	10	11	14	15	17	19	21	23	25
Long Sweep 90 deg. Elbow	1.0	1.5	2.0	2.5	3.0	3.5	4	5	6	7	8	9	10	12	14	16	18	19	20
Square Elbow 90 deg.	3.0	4.5	5.5	7.5	9	12	14	17	20	22	24	26	33	38	44	50	53	55	57
Close Return Bend	3.5	5	6	8	10	13	15	18	20	24	26	30	35	42	49	54	61	66	72
Stand Tee—Full Size Branch*	3.0	4.5	5.5	7.5	9	12	14	17	20	22	24	26	33	38	44	50	53	55	57
Stand Tee—Through Run	1.0	1.5	2.0	2.5	3.0	3.5	4	5	6	7	8	9	10	12	14	16	18	19	20
Sudden Enlargement from d to D**																			
d/D = ¼	1.5	2.0	2.5	3.5	4.5	5.0	6.5	8.0	10	11	13	14	16	18	20	23	26	28	30
d/D = ½	1.0	1.3	1.6	2.2	2.6	3.3	3.8	4.9	5.6	6.4	7.0	8.1	10	11	13	15	16	17	18
d/D = ¾	.3	.5	.6	.8	.9	1.2	1.4	1.7	2.0	2.5	2.7	3.0	3.5	4.0	4.5	5.0	6.0	6.5	7.0
Sudden Contraction from D to d**																			
d/D = ¼	.8	1.0	1.3	1.6	2.0	2.5	3.0	3.8	4.5	5.0	5.8	6	8	8.5	10	11	13	14	15
d/D = ½	.6	.8	1.0	1.3	1.5	1.8	2.3	2.8	3.4	3.6	4.3	4.8	5.6	6.4	7.5	8.5	9.5	11	12
d/D = ¾	.3	.5	.6	.8	.9	1.3	1.4	1.7	2.0	2.5	2.7	3.0	3.5	4.0	4.5	5.0	6.0	6.5	7.0
Ordinary Pipe Entrance with upstream end of pipe flush with inside of tank	.9	1.3	1.5	2.0	2.4	3.0	3.6	4.5	5.1	6.0	6.6	7.5	9.0	11	12	14	15	17	18
Entrance with pipe projecting into tank beyond inside face (Borda Entrance)	1.5	2.0	2.5	3.5	4.0	5.0	6.0	7.8	9.0	10	12	13	15	17	19	21	24	27	30

*Pressure drop through side outlet, or from side outlet through run.
**Equivalent feet of the smaller diameter pipe, "d."

Figure 19-17 Water Main – Equivalent Length Valves & Fittings

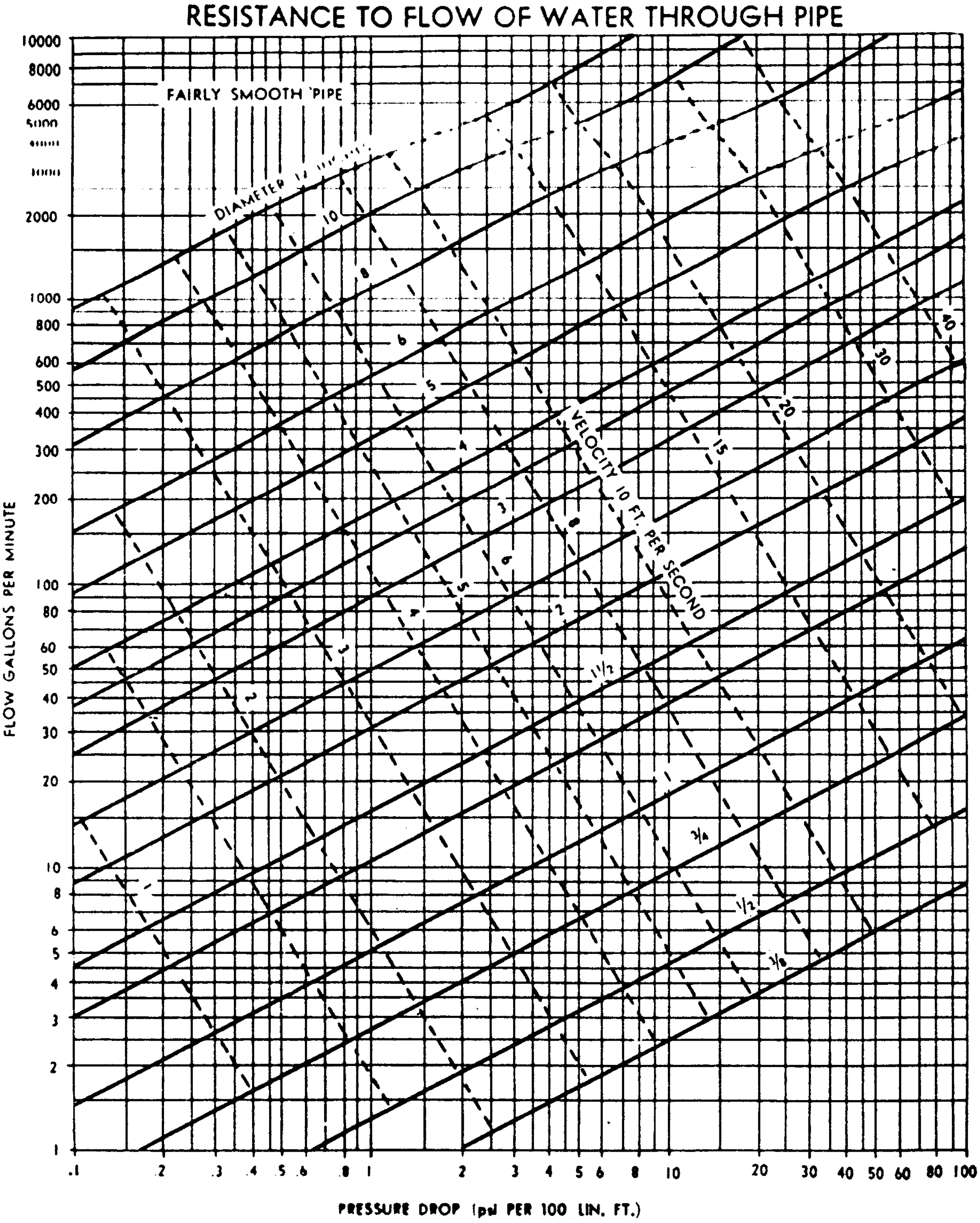
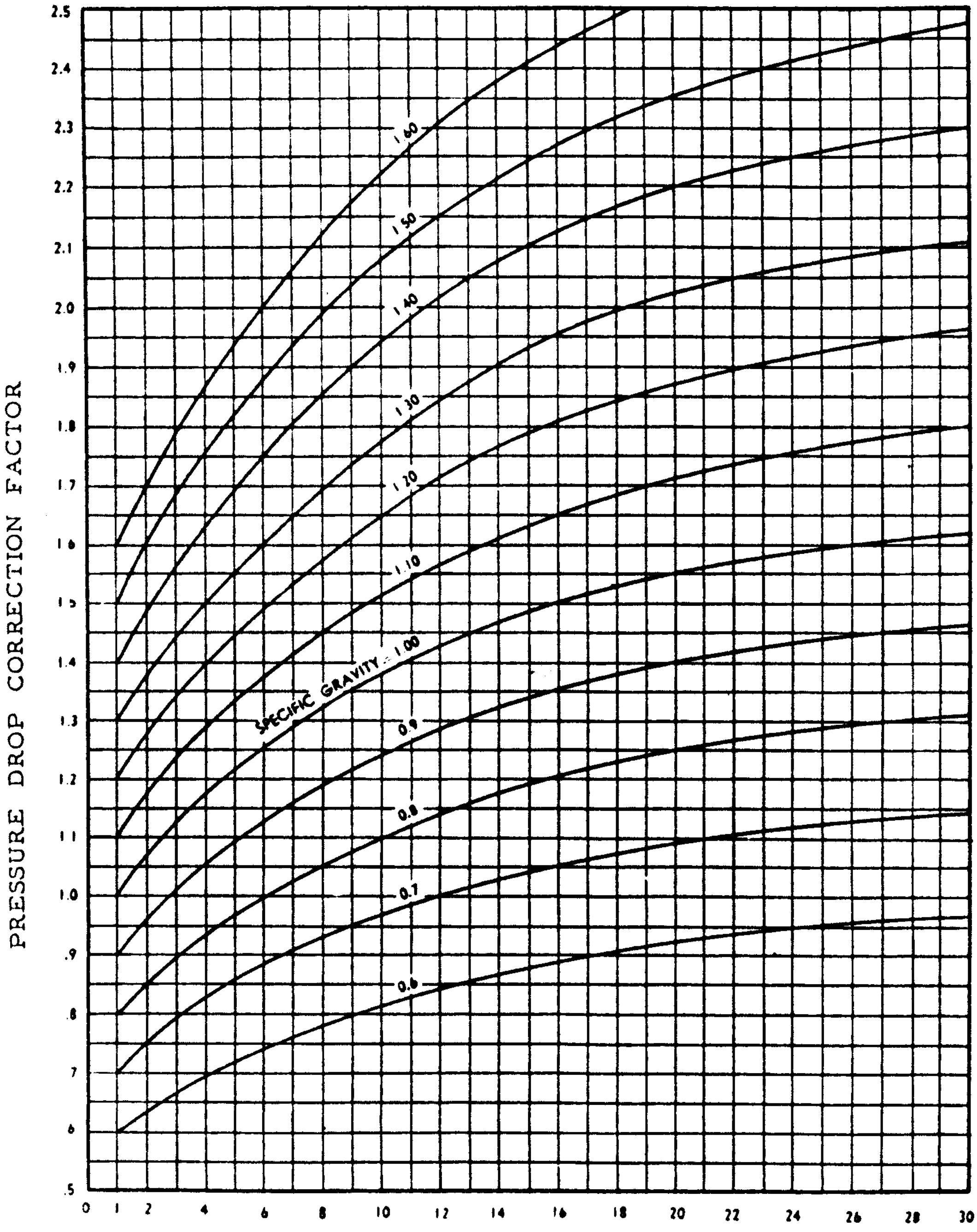


Figure 19-18 Water Resistance Pressure Drop through Pipe



*Kinematic Viscosity (Y) is Obtained From Formula $Y = \frac{U}{S}$
Where U Is Absolute Viscosity In Centipoise & S Is Specific Gravity

Figure 19-19 Pressure Drop Correction Factor for Brine Flow

$$\beta = \frac{D \times V \times S}{\mu} > 0.1$$

Where:

β = Turbulent Factor

D = Diameter of the pipe, inches.
V = Velocity brine flow, Ft/Sec.
S = Specific gravity.
μ = Absolute viscosity, centipoises.