

AMMONIA

Foreword

Anhydrous ammonia and ammonium hydroxide (commonly referred to as "aqua ammonia") are very useful chemicals in today's modern world. Their wide range of uses for air pollution control, refrigeration, heat treating, potable water treatment, waste treatment and a multitude of chemical process industry applications make them valuable and essential chemicals.

The increasing use of these products and the rising safety consciousness of industry has prompted LaRoche Industries Inc. (LaRoche) to prepare this booklet of information for its employees, customers and other interested personnel.

THE INFORMATION CONTAINED HEREIN IS NOT INTENDED TO BE COMPREHENSIVE.

Individuals seeking information not covered in this booklet are urged to contact LaRoche directly.

Contents

- Thermodynamic Properties of Saturated Ammonia (Table I & II)3, 4
- Freezing Point of Aqueous Ammonia (Table III & Figure 4)5, 19
- Density of Aqueous Ammonia Solutions at 20/4° C (Table IV & Figure 5)5, 20
- Solubility of Ammonia in Alcohols (Table V)5
- Thermodynamic Properties of Ammonia Superheated Vapor (Table VI)6, 7
- Thermodynamic Properties of Aqueous Ammonia (Table VII)8, 9
- Solubility of Ammonia in Aqueous Salt Solutions at 25°C (Table VIII)10
- Ionization of Aqueous Ammonia at 25°C (Table IX)11
- Corrosive Behavior of Materials in Ammonia (Table X)12, 13
- Physical and Thermodynamic Properties of Ammonia (Table XI, Part 1)14
- Viscosity of Saturated Ammonia Liquid and
Ammonia Vapor of Various Temperatures (Table XI, Part 2)14
- Relative Neutralizing Capacity of Various Alkalies (Table XII)15
- Nitrogen Content of Various Ammonia Derivatives (Table XIII)15
- Thermodynamic Properties of Ammonia (Figure 1)16
- Density vs. Temperature of Liquid Ammonia (Figure 2)17
- Specific Volume of Ammonia as Liquid and Vapor vs. Temperature (Figure 3)18
- Thermal Conductivity of Ammonia (Figure 6)21
- Viscosity of Ammonia (Figure 7)22
- Concentration Conversion Curve (Figure 8)23
- Temperature Conversion Nomograph (Figure 9)24
- IndexBack Cover

Table I
Thermodynamic Properties of Saturated Ammonia*
by Temperature

Temperature F	Pressure Lbs. Per Sq. In. Absolute	Specific Heat BTU/Lb. F	Specific Volume Cu. Ft. Per Lb.		Enthalpy of Liquid BTU/Lb.	Latent Heat of Evaporation BTU/Lb.	Enthalpy of Vapor BTU/Lb.	Entropy BTU/Lb. F		Density Pounds Per Cu. Ft.	
			LIQUID	VAPOR				LIQUID	VAPOR	LIQUID	VAPOR
-60	8.55	1.054	0.02278	44.73	-99.08	610.8	511.7	-0.2225	1.3061	43.91	0.02235
-50	7.67	1.058	0.02299	33.06	-88.51	604.3	515.8	-0.1964	1.2789	43.49	0.03023
-40	10.41	1.062	0.02322	24.86	-77.90	597.6	519.7	-0.1708	1.2534	43.08	0.04022
-30	13.90	1.066	0.02345	18.97	-67.24	590.7	523.5	-0.1457	1.2293	42.65	0.05271
-20	18.30	1.070	0.02369	14.68	-56.54	583.6	527.1	-0.1210	1.2066	42.22	0.06813
-10	23.74	1.075	0.02393	11.50	-45.79	576.4	530.6	-0.0969	1.1850	41.78	0.08695
0	30.42	1.080	0.02419	9.116	-34.98	568.9	533.9	-0.0732	1.1644	41.34	0.1097
10	38.51	1.085	0.02446	7.304	-24.11	561.1	537.0	-0.0499	1.1448	40.89	0.1369
20	48.21	1.091	0.02474	5.910	-13.19	553.1	539.9	-0.0270	1.1261	40.43	0.1692
30	58.74	1.097	0.02503	4.825	- 2.19	544.8	542.6	-0.0044	1.1082	39.96	0.2073
40	73.32	1.104	0.02533	3.971	8.87	536.2	545.1	0.0177	1.0910	39.49	0.2516
50	89.19	1.112	0.02564	3.294	20.04	527.3	547.3	0.0397	1.0745	39.00	0.3036
60	107.6	1.120	0.02597	2.751	31.28	518.1	549.4	0.0614	1.0586	38.50	0.3635
70	128.8	1.129	0.02632	2.312	42.64	508.6	551.2	0.0829	1.0432	38.00	0.4325
80	153.0	1.138	0.02668	1.955	54.09	498.7	552.8	0.1041	1.0283	37.48	0.5115
90	180.6	1.147	0.02707	1.661	65.65	488.5	554.1	0.1250	1.0138	36.95	0.6019
100	211.9	1.156	0.02747	1.419	77.31	477.8	555.1	0.1458	0.9997	36.40	0.7048
110	247.0	1.168	0.02790	1.217	89.11	466.7	555.8	0.1664	0.9858	35.84	0.8219
120	286.4	1.183	0.02836	1.047	101.08	455.0	556.1	0.1868	0.9719	35.26	0.9549
130	330.3	(1.197)	0.02885	.....	(113)	(443)	.....	.....	.....	34.66	.....
140	379.1	(1.213)	0.02938	.....	(125)	(430)	.....	.....	.....	34.04	.....
150	433.2	(1.23)	0.02995	.....	(138)	(416)	.....	.....	.....	33.39	.....
160	492.8	(1.25)	0.03056	.....	(151)	(401)	.....	.....	.....	32.72	.....
170	558.4	(1.27)	0.03124	.....	(163)	(388)	.....	.....	.....	32.01	.....
180	630.3	(1.30)	0.03198	.....	(177)	(369)	.....	.....	.....	31.27	.....
190	708.9	(1.34)	0.03281	.....	(191)	(351)	.....	.....	.....	30.48	.....
200	794.7	(1.38)	0.03375	.....	(205)	(332)	.....	.....	.....	29.63	.....
210	888.1	(1.43)	0.03482	.....	(218)	(310)	.....	.....	.....	28.72	.....
220	989.5	(1.49)	0.0361	.....	(235)	(287)	.....	.....	.....	27.7	.....
230	1098.5	(1.57)	0.0376	.....	(251)	(260)	.....	.....	.....	26.6	.....
240	1218.5	(1.70)	0.0395	.....	(268)	(229)	.....	.....	.....	25.3	.....
250	1347	(1.90)	0.0422	.....	(287)	(192)	.....	.....	.....	23.7	.....
260	1488	(2.33)	0.0463	.....	(309)	(142)	.....	.....	.....	21.6	.....
270	1635	(5.30)	0.0577	.....	(341)	(52)	.....	.....	.....	17.3	.....
271.4	1657	.....	0.0686	.....	(355)	0	.....	.....	.....	14.6	.....

Data from Bureau of Standards Circular No. 142

Base Temperature: 32F.

Note: The figures in parentheses were calculated from empirical equations given in Bureau of Standards Scientific papers Nos. 313 and 315 and represent values obtained by extrapolation beyond the range covered in the experimental work.

Table II
Thermodynamic Properties of Saturated Ammonia*
by Pressure

Pressure (psia)	Temperature (F)	Specific Volume (Cu. Ft. Per Lb.)		Enthalpy of Liquid (BTU Per Lb.)	Latent Heat of Evapora- tion (BTU Per Lb.)	Enthalpy of Vapor (BTU Per Lb.)	Entropy (BTU/lb F)		Density (Pounds Per Cu. Ft.)	
		LIQUID	VAPOR				LIQUID	VAPOR	LIQUID	VAPOR
5	-63.11	0.02271	49.31	-102.4	612.8	510.4	-0.2307	1.3149	44.03	0.02029
10	-41.34	0.02319	25.81	-79.3	598.5	519.2	-0.1742	1.2568	43.122	0.03874
15	-27.29	0.02354	17.67	-64.3	588.8	524.5	-0.1390	1.2230	42.48	0.05658
20	-18.84	0.02377	13.50	-52.9	581.2	528.3	-0.1130	1.1992	42.06	0.07405
30	-0.57	0.02416	9.236	-35.6	569.3	533.7	-0.0746	1.1656	41.39	0.1083
40	11.86	0.02449	7.047	-22.3	559.8	537.5	-0.0462	1.1417	40.83	0.1419
50	21.67	0.02478	5.710	-11.4	551.7	540.3	-0.0233	1.1231	40.36	0.1751
75	41.13	0.02536	3.887	10.1	535.2	545.3	0.0202	1.0891	39.43	0.2573
100	58.05	0.02583	2.852	26.8	521.8	548.6	0.0529	1.0648	38.71	0.3388
126	68.31	0.02625	2.381	40.7	510.2	550.9	0.0792	1.0458	38.10	0.4200
150	78.81	0.02663	1.994	52.7	499.9	552.6	0.1016	1.0301	37.55	0.5016
200	96.34	0.02732	1.502	73.0	481.8	554.8	0.1382	1.0048	36.80	0.6856
250	110.80	0.02793	1.202	90.1	465.8	555.9	0.1680	0.9847	35.80	0.8319
300	123.21	0.02852	0.999	105.0	461.1	556.1	0.1934	0.9675	35.06	1.0016

*Data from Bureau of Standards Circular No. 142

Base temperature: 32 F

Table III

Freezing Point of Aqueous Ammonia*

Wt. Fraction NH ₃	Freezing Point, F
1.00	-107.7
0.944	-113.6
0.899	-118.7
0.858	-123.7
0.807	-134.3
0.807	-134.7
0.775	-127.7
0.724	-116.0
0.689	-112.0
0.667	-111.5
0.654	-109.8
0.645	-110.0
0.633	-110.6
0.606	-113.8
0.599	-115.1
0.593	-116.1
0.589	-117.2
0.576	-121.4
0.556	-119.4
0.516	-112.4
0.488	-110.4
0.487	-110.2
0.479	-110.4
0.423	-117.4
0.408	-122.9
0.392	-126.8
0.384	-131.6
0.377	-133.1
0.3445	-142.8
0.327	-142.1
0.314	-126.5
0.285	-101.6
0.275	-91.8
0.264	-82.7
0.2545	-74.9
0.220	-46.3
0.193	-30.8
0.171	-19.48
0.0422	23.4
0.000	32.0
Eutectic I: 0.334	-148.5
Eutectic II: 0.571	-122.6
Eutectic III: 0.805	-134.5

Table IV

Density of Aqueous Ammonia Solutions at $\frac{20}{4}$ C. Computed from Values Given in the International Critical Tables.

Specific Gravity	Weight of NH ₃ in solution expressed in			Per Cent NH ₃	Degrees Baumé
	Grams per Liter	Pounds per U. S. Gallon	Pounds per Cubic Foot		
0.9939	9.939	0.08294	0.6205	1	10.9
0.9895	19.79	0.1652	1.235	2	11.5
0.9811	39.24	0.3275	2.450	4	12.7
0.9730	58.38	0.4872	3.645	6	13.9
0.9651	77.21	0.6443	4.820	8	15.1
0.9575	95.75	0.7991	5.978	10	16.2
0.9501	114.0	0.9515	7.118	12	17.3
0.9430	132.0	1.102	8.242	14	18.5
0.9362	149.8	1.250	9.352	16	19.5
0.9295	167.3	1.396	10.45	18	20.6
0.9229	184.5	1.540	11.52	20	21.7
0.9164	201.6	1.682	12.59	22	22.8
0.9101	218.4	1.823	13.64	24	23.8
0.9040	235.0	1.962	14.67	26	24.9
0.8980	251.4	2.098	15.70	28	25.9
0.8920	267.6	2.233	16.71	30	27.0

Table V

Solubility of Ammonia in Alcohols*

Gram Moles NH₃ Solute in 1 Liter of

Temperature Degrees C.	Methyl Alcohol	Ethyl Alcohol	N-Propyl Alcohol	Isopropyl Alcohol
0	13.65	8.65	7.07	6
10	10.65	6.82	5.3	4.55
15	9.66	5.89	4.65	4.05
20	8.42	5.02	4.15	3.48
25	7.30	4.32	3.82	2.98
30	6.19	3.79	3.25	2.52
35	5.34	3.30	2.39	2.25
40	4.60	...	...	...

Table VI
Thermodynamic Properties of Ammonia*
Superheated Vapor

PRESSURE psia (SAT. TEMP.)		TEMPERATURE F											
		-40	-20	0	20	40	60	80	100	120	140	160	180
0	h	524.1	533.9	543.8	553.7	563.6	573.6	583.6	593.6	603.7	613.9	624.2	634.6
5 (-63.11°)	v	52.36	54.97	57.55	60.12	62.69	65.24	67.79	70.33	72.87	75.41	77.95	80.48
	h	522.4	532.5	542.6	552.6	562.5	572.6	582.7	592.8	603.0	613.3	623.7	634.2
	s	1.3782	1.3677	1.3900	1.4113	1.4318	1.4515	1.4705	1.4890	1.5070	1.5244	1.5414	1.5581
10 (-41.34°)	v		27.26	28.58	29.90	31.20	32.49	33.78	35.07	36.35	37.62	38.90	40.17
	h		530.7	541.0	551.2	561.4	571.6	581.8	592.1	602.4	612.7	623.2	633.7
	s		1.2834	1.3065	1.3284	1.3492	1.3692	1.3885	1.4071	1.4252	1.4428	1.4599	1.4766
15 (-27.29°)	v		18.01	18.92	19.82	20.70	21.58	22.44	23.31	24.17	25.03	25.88	26.74
	h		528.5	539.3	549.9	560.3	570.6	581.0	591.3	601.7	612.1	622.6	633.2
	s		1.2323	1.2564	1.2789	1.3001	1.3204	1.3400	1.3588	1.3770	1.3947	1.4119	1.4287
20 (-16.64°)	v			14.09	14.78	15.45	16.12	16.78	17.43	18.08	18.73	19.37	20.02
	h			537.6	548.5	559.1	569.6	580.1	590.6	601.0	611.5	622.1	632.7
	s			1.2189	1.2430	1.2648	1.2854	1.3052	1.3242	1.3425	1.3604	1.3777	1.3945
30 (-0.57°)	v				9.731	10.20	10.65	11.10	11.55	11.99	12.43	12.87	13.30
	h				545.6	556.7	567.6	578.3	589.0	599.6	610.3	620.9	631.7
	s				1.1910	1.2137	1.2351	1.2553	1.2748	1.2934	1.3115	1.3290	1.3460
40 (11.66°)	v				7.203	7.568	7.922	8.268	8.609	8.945	9.278	9.609	9.938
	h				542.5	554.2	565.5	576.5	587.4	598.2	609.0	619.8	630.6
	s				1.1523	1.1762	1.1984	1.2192	1.2390	1.2580	1.2763	1.2940	1.3112
50 (21.67°)	v					5.988	6.280	6.564	6.843	7.117	7.387	7.655	7.921
	h					551.6	563.3	574.7	585.8	596.8	607.8	618.7	629.5
	s					1.1461	1.1691	1.1905	1.2108	1.2301	1.2487	1.2666	1.2840
75 (41.13°)	v						4.087	4.289	4.485	4.676	4.863	5.048	5.230
	h						557.6	569.8	581.7	593.2	604.6	615.8	627.0
	s						1.1131	1.1363	1.1578	1.1781	1.1974	1.2158	1.2336
100 (56.05°)	v							3.149	3.304	3.454	3.600	3.743	3.883
	h							564.7	577.3	589.4	601.3	612.9	624.4
	s							1.0953	1.1183	1.1396	1.1597	1.1787	1.1970
125 (66.31°)	v							2.461	2.593	2.719	2.840	2.958	3.074
	h							559.3	572.8	585.6	597.9	609.9	621.7
	s							1.0614	1.0860	1.1084	1.1294	1.1491	1.1679
150 (78.81°)	v								2.118	2.228	2.334	2.435	2.534
	h								568.0	581.5	594.4	606.9	619.0
	s								1.0581	1.0818	1.1037	1.1241	1.1434
200 (96.34°)	v									1.612	1.698	1.780	1.859
	h									573.0	587.1	600.5	613.4
	s									1.0369	1.0609	1.0829	1.1034
250 (110.80°)	v									1.240	1.316	1.386	1.453
	h									563.6	579.3	593.9	607.6
	s									0.9982	1.0248	1.0487	1.0706
300 (123.21°)	v										1.058	1.123	1.183
	h										570.6	586.6	601.6
	s										0.9924	1.0186	1.0421

*Data from Bureau of Standards Circular No. 142

Base temperature = 2 F

v - volume (cu. ft./Lb.)
h - enthalpy (BTU/Lb.)
s - entropy (BTU/Lb. °F)

TEMPERATURE F											PRESSURE pala (SAT. TEMP.)	
200	220	240	260	280	300	320	340	360	380	400		
645.1	655.7	666.4	677.2	688.1	699.1	710.2	721.4	732.7	744.1	755.6	h	0
83.10	85.66	88.23	90.78	93.31	95.84	98.39	100.93	103.47	106.01	108.54	v	5
644.7	655.2	665.9	676.8	687.8	698.8	710.0	721.2	732.5	743.9	755.4	h	(-63.11°)
1.5744	1.5904	1.6061	1.6216	1.6367	1.6515	1.6661	1.6803	1.6942	1.7077	1.7212	s	
41.45	42.73	44.03	45.32	46.58	47.85	49.13	50.41	51.68	52.96	54.23	v	10
644.3	654.9	665.7	676.5	687.5	698.6	709.7	720.9	732.2	743.6	755.2	h	(-41.34°)
1.4929	1.5089	1.5247	1.5402	1.5554	1.5702	1.5850	1.5991	1.6129	1.6265	1.6400	s	
27.59	28.44	29.30	30.16	31.01	31.86	32.71	33.57	34.42	35.28	36.13	v	15
643.8	654.5	665.3	676.2	687.2	698.2	709.4	720.6	732.0	743.4	754.9	h	(-27.29°)
1.4450	1.4610	1.4769	1.4924	1.5076	1.5225	1.5373	1.5515	1.5654	1.5790	1.5925	s	
20.66	21.30	21.94	22.59	23.23	23.86	24.51	25.15	25.79	26.44	27.07	v	20
643.3	654.1	664.9	675.8	686.8	697.9	709.1	720.4	731.7	743.2	754.7	h	(-16.64°)
1.4109	1.4270	1.4427	1.4583	1.4735	1.4885	1.5034	1.5177	1.5315	1.5452	1.5587	s	
13.73	14.16	14.59	15.02	15.45	15.87	16.30	16.74	17.17	17.60	18.02	v	30
642.4	653.2	664.1	675.1	686.2	697.3	708.5	719.8	731.2	742.7	754.3	h	(-0.57°)
1.3626	1.3787	1.3945	1.4100	1.4252	1.4403	1.4554	1.4697	1.4837	1.4975	1.5110	s	
10.27	10.59	10.92	11.24	11.56	11.88	12.21	12.53	12.85	13.18	13.50	v	40
641.5	652.4	663.4	674.4	685.5	696.7	708.0	719.3	730.7	742.2	753.8	h	(11.66°)
1.3279	1.3442	1.3601	1.3757	1.3909	1.4058	1.4212	1.4356	1.4496	1.4634	1.4770	s	
8.85	8.448	8.710	8.970	9.230	9.489	9.750	10.01	10.27	10.52	10.78	v	50
640.6	651.5	662.6	673.7	684.8	696.1	707.4	718.7	730.2	741.7	753.4	h	(21.67°)
1.3008	1.3172	1.3332	1.3489	1.3642	1.3792	1.3945	1.4091	1.4231	1.4370	1.4506	s	
5.410	5.589	5.767	5.943	6.119	6.294	6.468	6.642	6.815	6.987	7.160	v	75
638.2	649.4	660.8	671.9	683.2	694.5	705.9	717.4	728.9	740.5	752.2	h	(41.13°)
1.2509	1.2676	1.2838	1.2997	1.3152	1.3303	1.3457	1.3603	1.3745	1.3884	1.4022	s	
4.021	4.158	4.294	4.428	4.562	4.695	4.827	4.958	5.089	5.219	5.350	v	100
635.8	647.2	658.6	670.0	681.5	692.9	704.5	716.0	727.7	739.5	751.1	h	(56.05°)
1.2146	1.2316	1.2482	1.2642	1.2799	1.2952	1.3105	1.3253	1.3398	1.3539	1.3677	s	
3.187	3.289	3.409	3.519	3.627	3.735	3.842	3.948	4.054	4.158	4.264	v	125
633.4	645.1	656.6	668.2	679.8	691.4	703.0	714.7	726.4	738.2	750.0	h	(68.31°)
1.1859	1.2032	1.2200	1.2363	1.2522	1.2677	1.2828	1.2979	1.3124	1.3266	1.3406	s	
2.631	2.726	2.820	2.912	3.004	3.095	3.185	3.274	3.363	3.451	3.540	v	150
631.0	642.8	654.6	666.4	678.1	689.8	701.5	713.3	725.1	737.0	748.9	h	(76.81°)
1.1619	1.1796	1.1967	1.2132	1.2293	1.2449	1.2602	1.2751	1.2899	1.3042	1.3183	s	
1.935	2.009	2.082	2.154	2.225	2.295	2.364	2.432	2.500	2.568	2.636	v	200
626.0	638.4	650.5	662.6	674.6	686.6	698.6	710.6	722.6	734.6	746.6	h	(96.34°)
1.1227	1.1412	1.1588	1.1759	1.1923	1.2083	1.2239	1.2391	1.2539	1.2684	1.2827	s	
1.518	1.580	1.640	1.699	1.758	1.815	1.872	1.928	1.983	2.038	2.093	v	250
620.9	633.8	646.4	658.8	671.2	683.4	695.6	707.8	720.0	732.2	744.4	h	(110.80°)
1.0909	1.1102	1.1285	1.1460	1.1628	1.1793	1.1951	1.2106	1.2256	1.2403	1.2547	s	
1.239	1.294	1.346	1.397	1.447	1.496	1.544	1.592	1.639	1.686	1.732	v	300
615.6	628.0	642.1	655.0	667.6	680.2	692.6	705.0	717.4	729.8	742.2	h	(123.21°)
1.0836	1.0838	1.1028	1.1209	1.1382	1.1549	1.1711	1.1868	1.2021	1.2170	1.2316	s	

Table VII
Thermodynamic Properties of Aqueous Ammonia*
PRESSURE, psia

Concentration of NH ₃ in Liquid Phase Weight %		1	5	10	15	20	30	40	50
0	t	101.8	162.2	183.2	213.0	228.0	250.3	267.2	281.1
	h _f	89.7	130.1	161.1	181.0	196.0	218.8	235.9	250.0
	h _v	1106.0	1130.6	1143.0	1150.6	1156.0	1163.7	1169.2	1173.5
	y	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	t	89.3	148.7	179.5	199.7	214.8	237.4	254.5	268.4
	h _f	49.7	110.6	141.6	161.8	177.2	198.9	217.3	231.4
	h _v	979.5	1009.3	1029.6	1043.1	1052.8	1066.2	1075.8	1085.0
	y	30.2	27.83	24.48	22.27	21.14	19.92	18.82	18.09
4	t	78.0	136.7	167.3	187.7	203.0	225.5	242.8	256.8
	h _f	32.8	92.3	123.2	143.6	159.1	181.9	199.4	213.6
	h _v	876.2	908.9	934.7	952.4	964.9	982.8	995.5	1008.3
	y	52.2	47.56	43.37	40.63	38.60	35.81	33.97	32.64
6	t	68.0	126.1	156.5	176.5	192.4	214.9	232.1	246.1
	h _f	15.6	74.9	105.7	126.1	141.8	164.5	182.1	196.3
	h _v	793.0	827.2	856.5	876.7	891.4	912.3	927.3	942.4
	y	66.7	60.81	57.17	54.13	52.15	49.43	47.28	45.50
8	t	58.6	116.7	146.8	167.0	182.5	204.8	220.0	235.9
	h _f	-0.9	58.4	89.0	109.5	125.1	147.9	165.5	179.6
	h _v	727.7	762.3	793.3	814.7	830.7	853.5	869.8	886.2
	y	76.3	70.46	66.88	64.44	62.29	59.51	57.21	55.34
10	t	49.6	108.1	137.9	157.9	173.2	195.3	212.4	226.1
	h _f	-16.6	42.7	73.2	93.5	109.1	131.8	149.4	163.5
	h _v	678.0	712.0	743.3	764.8	781.4	805.1	822.0	838.8
	y	83.0	77.54	74.18	71.87	69.99	67.35	65.27	63.50
15	t	28.9	89.0	118.0	137.4	151.8	173.3	189.8	203.4
	h _f	-52.7	7.6	37.5	57.1	72.3	94.8	112.1	125.8
	h _v	624.3	650.8	675.5	691.7	706.9	728.5	743.8	757.4
	y	91.20	86.3	85.98	84.18	82.94	81.00	79.31	77.77
20	t	12.4	70.4	99.1	117.7	132.0	153.3	169.6	182.8
	h _f	-85.7	-26.3	3.3	22.6	37.4	59.6	76.8	90.4
	h _v	586.2	609.4	630.2	643.1	656.0	674.8	688.4	699.7
	y	96.0	93.97	92.49	91.45	90.52	88.80	87.66	86.60
30	t	-16.3	37.6	65.3	83.8	97.2	117.3	132.8	145.5
	h _f	-141.8	-86.8	-58.1	-38.9	-24.8	-3.3	13.6	27.3
	h _v	551.0	567.2	583.9	594.5	602.5	615.3	625.6	634.0
	y	99.5	98.85	98.15	97.75	97.39	96.70	96.06	95.52
40	t	-40.3	8.9	34.9	52.3	65.0	84.4	99.3	111.3
	h _f	-182.2	-131.8	-105.2	-87.0	-73.8	-53.0	-37.1	-24.1
	h _v	539.0	548.0	558.9	568.8	575.1	585.0	592.5	598.9
	y	99.99	99.86	99.75	99.58	99.44	99.17	98.96	98.69
50	t	-64.0	-16.7	7.8	24.3	36.5	54.9	69.1	80.6
	h _f	-208.6	-159.7	-134.5	-117.4	-104.8	-85.1	-70.1	-57.7
	h _v	522.0	534.4	545.5	552.8	557.3	565.7	571.4	576.4
	y	100.0	99.96	99.90	99.88	99.87	99.84	99.81	99.75
60	t	-83.4	-37.4	-13.3	2.1	14.5	32.5	46.4	57.8
	h _f	-219.8	-174.1	-149.2	-133.4	-120.2	-101.3	-86.4	-74.2
	h _v	510.9	523.7	534.2	540.6	545.8	553.0	558.3	562.6
	y	100.0	99.99	99.98	99.97	99.96	99.93	99.91	99.69
70	t	-95.1	-48.5	-25.8	-10.4	1.4	18.7	32.0	43.0
	h _f	-217.6	-169.5	-146.0	-129.8	-117.4	-99.0	-84.8	-72.8
	h _v	505.5	518.1	527.5	533.8	538.4	545.0	549.2	553.7
	y	100.0	100.0	100.0	99.99	99.99	99.97	99.97	99.95
80	t	-99.6	-56.0	-33.4	-18.3	-7.3	9.3	22.6	33.1
	h _f	-200.9	-153.4	-130.6	-114.8	-102.9	-85.1	-70.8	-58.4
	h _v	501.2	514.1	523.6	529.4	533.6	539.5	544.1	547.5
	y	100.0	100.0	100.0	100.00	99.99	99.99	99.99	99.99
90	t	-102.6	-60.3	-38.7	-24.0	-13.2	3.4	16.0	26.2
	h _f	-176.7	-131.0	-108.0	-92.3	-80.8	-62.8	-49.1	-38.2
	h _v	496.2	511.9	520.6	526.3	530.8	536.0	540.1	543.1
	y	100.0	100.0	100.0	100.0	100.0	99.99	99.99	99.99
100	t	-105.0	-63.1	-41.3	-27.3	-16.6	-0.6	11.7	21.4
	h _f	-146.0	-102.4	-79.3	-64.3	-52.9	-35.6	-22.3	-11.4
	h _v	490.7	510.4	519.2	524.5	528.3	533.7	537.5	540.3
	y	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*Data taken from B. N. Jennings and F. P. Shannon, Refrigerating Engineering, May, 1938.
 Enthalpy computation datum taken as saturated liquid at 32 F.

PRESSURE, psia

75	100	125	150	200	250	300	Concentration of NH ₃ in Liquid Phase Weight %	
307.6 277.3 1181.2 0.00	327.8 298.3 1196.6 0.00	344.3 315.6 1190.5 0.00	358.4 330.4 1193.5 0.00	381.8 355.3 1197.8 0.00	401.0 378.0 1200.5 0.00	417.3 393.9 1202.4 0.00	t hr hv y	0
295.1 258.9 1100.2 16.68	315.7 290.2 1112.9 15.38	332.8 297.6 1122.5 14.9	347.2 312.6 1129.7 13.33	370.4 337.9 1140.7 11.98	390.1 369.0 1148.1 10.84	406.8 377.4 1153.5 9.75	t hr hv y	2
283.7 241.0 1029.0 30.30	304.3 262.6 1047.2 28.36	321.7 280.1 1061.1 26.67	336.2 295.2 1071.6 26.16	369.4 320.8 1078.8 22.77	379.3 242.2 1098.8 20.96	396.3 360.8 1107.3 19.33	t hr hv y	4
272.9 223.8 96.70 41.92	293.7 245.5 989.0 38.88	311.1 263.0 1005.8 36.74	325.8 278.2 1018.7 34.95	349.0 304.2 1038.7 32.46	368.6 325.6 1052.8 30.41	385.8 344.3 1063.8 28.81	t hr hv y	6
262.6 207.1 914.4 51.74	283.8 228.8 937.6 48.92	300.8 248.5 956.2 46.21	315.2 261.8 970.7 44.21	338.8 287.5 993.5 41.46	358.3 309.1 1010.0 39.34	375.5 327.9 1022.9 37.53	t hr hv y	8
252.8 191.0 867.3 59.99	273.7 212.7 892.6 56.97	290.7 230.4 912.0 54.47	305.0 245.7 927.5 52.41	328.8 271.4 952.0 49.25	348.2 293.0 970.1 46.94	365.3 311.7 984.5 45.17	t hr hv y	10
229.6 153.1 783.9 74.88	250.1 174.3 808.2 72.36	266.6 192.2 823.1 70.16	280.6 207.7 838.0 68.28	304.4 232.6 862.4 65.25	324.2 253.5 882.3 62.68	340.8 271.6 898.9 60.60	t hr hv y	15
208.4 117.6 723.0 84.36	228.0 138.6 742.2 82.37	244.6 156.6 757.1 80.80	258.9 172.0 771.0 79.38	281.7 196.8 793.7 76.86	300.8 217.5 812.9 74.70	316.9 235.3 829.3 72.7	t hr hv y	20
189.9 54.2 650.3 84.42	188.7 75.2 663.9 83.23	204.2 92.8 675.6 92.35	217.6 108.2 686.5 91.44	239.8 133.5 703.7 89.68	257.7 153.2 717.5 86.64	273.2 172.4 730.3 87.44	t hr hv y	30
134.4 1.6 611.4 98.07	152.7 22.0 622.0 97.49	167.7 39.2 630.5 96.96	180.7 54.4 638.5 96.46	202.0 79.7 651.5 95.52	219.2 100.7 661.8 94.75	234.6 119.8 671.2 94.00	t hr hv y	40
103.7 -32.8 586.3 99.55	121.0 -13.5 594.4 99.19	135.2 2.4 601.0 98.87	147.4 16.1 606.6 98.62	167.7 39.8 616.0 98.09	184.5 59.5 623.4 97.67	198.9 77.1 629.6 97.43	t hr hv y	50
79.6 -50.6 570.4 99.84	96.3 -32.0 578.2 99.80	110.2 -16.2 581.5 99.66	122.0 -2.9 585.7 99.46	142.2 20.3 593.1 99.20	158.4 39.8 598.4 99.02	172.4 56.1 602.9 98.84	t hr hv y	60
64.0 -50.2 506.6 99.94	80.5 -31.7 565.4 99.93	93.9 -16.8 569.4 99.87	105.6 -3.5 573.3 99.75	124.9 18.8 578.8 99.63	140.8 37.5 582.4 99.58	154.4 53.4 585.8 99.52	t hr hv y	70
53.6 -36.9 553.6 99.97	69.5 -19.0 558.0 99.96	82.4 -4.3 561.3 99.93	93.7 8.5 564.2 99.88	112.6 30.4 568.4 99.84	127.6 48.2 570.9 99.81	141.6 64.6 573.6 99.78	t hr hv y	80
45.8 -16.5 548.5 99.99	61.4 0.5 552.5 99.98	73.9 14.4 555.2 99.97	85.1 27.2 557.4 99.96	103.2 48.2 560.6 99.94	118.2 65.6 562.5 99.93	130.1 81.0 563.6 99.92	t hr hv y	90
41.1 10.1 545.3 100.00	56.0 28.8 548.6 100.00	68.3 40.7 550.9 100.00	78.8 52.7 552.7 100.00	96.3 73.0 554.8 100.00	110.8 90.1 555.9 100.00	123.2 104.1 556.1 100.00	t hr hv y	100

t—temperature F,

hr—enthalpy of saturated liquid, BTU/Lb.,

hv—enthalpy of saturated vapor, BTU/Lb.

y—concentration of NH₃ in vapor phase, weight %

Table VIII
Solubility of Ammonia in Aqueous Salt Solution at 25 C*

Salt	Chemical Formula	Gram Moles NH ₃ Soluble In 1 Liter of		
		0.5 Normal Solution	1.0 Normal Solution	1.5 Normal Solution
Potassium Chloride	KCl	0.930	0.868	0.809
Potassium Bromide	KBr	0.950	0.904	0.857
Potassium Iodide	KI	0.970	0.942	0.900
Potassium Hydroxide	KOH	0.852	0.716	0.807
Sodium Chloride	NaCl	0.938	0.889	0.843
Sodium Bromide	NaBr	0.965	0.916	0.890
Sodium Iodide	NaI	0.995	0.992	0.985
Sodium Hydroxide	NaOH	0.876	0.789	0.716
Lithium Chloride	LiCl	0.980	1.008	1.045
Lithium Bromide	LiBr	1.001	1.040	1.090
Lithium Iodide	LiI	1.030	1.094	1.190
Lithium Hydroxide	LiOH	0.865	0.808	0.786
Potassium Fluoride	KF	0.839	0.722	0.626
Potassium Nitrate	KNO ₃	0.923	0.862	0.804
Potassium Nitrite	KNO ₂	0.920	0.855	0.798
Potassium Cyanide	KCN	0.926	0.858	0.802
Potassium Thiocyanate	KSCN	0.932	0.868	0.814
Potassium Sulfate	K ₂ SO ₄	0.875	0.772	0.678
Potassium Sulfite	K ₂ SO ₃	0.865	0.768	0.675
Potassium Carbonate	K ₂ CO ₃	0.788	0.650	0.554
Potassium Oxalate	K ₂ C ₂ O ₄	0.866	0.771	0.675
Potassium Chromate	K ₂ CrO ₄	0.866	0.771	0.675
Potassium Acetate	KC ₂ H ₃ O ₂	0.866	0.765	0.685
Potassium Formate	KCHO ₂	0.868	0.760	0.678
Potassium Borate, Meta	KBO ₂	0.814	0.677	0.560
Potassium Acid Phosphate	K ₂ HPO ₄	0.880	0.749	0.664
Sodium Sulfide	Na ₂ S	0.887	0.795	0.726
*Potassium Chlorate	KClO ₃	0.927	....	....
*Potassium Bromate	KBrO ₃	0.940	....	....
*Potassium Iodate	KIO ₃	0.951	....	....

* Concentration of these salts is 0.25 Normal.

* Data of Abegg; Riesenfeld, Z Phys. Ch., 40, 100 (1902).

Table IX
Ionization of Aqueous Ammonia at 25 C*

Moles of Base Per Liter	Ammonium Hydroxide			
	% Ionized	Gram Moles OH Per Liter	Grams OH Per Liter	pH
2.0	0.30	0.0060	0.1020	11.78
1.0	0.42	0.00420	0.0714	11.62
0.9	0.45	0.00405	0.0689	11.61
0.8	0.47	0.00376	0.0640	11.58
0.7	0.50	0.00350	0.0586	11.54
0.6	0.55	0.00330	0.0561	11.52
0.5	0.60	0.00300	0.0510	11.48
0.4	0.67	0.00268	0.0456	11.43
0.3	0.77	0.00231	0.0393	11.36
0.2	0.94	0.00188	0.0320	11.27
0.10	1.33	0.00133	0.0226	11.12
0.09	1.40	0.00126	0.0214	11.10
0.08	1.49	0.00119	0.0203	11.08
0.07	1.59	0.00111	0.0189	11.05
0.06	1.72	0.00103	0.0175	11.01
0.05	1.88	0.00094	0.0160	10.97
0.04	2.12	0.00085	0.0144	10.93
0.03	2.42	0.00073	0.0123	10.86
0.02	2.96	0.00059	0.0101	10.77
0.010	4.15	0.00042	0.0071	10.62
0.009	4.37	0.00039	0.0067	10.59
0.008	4.62	0.00037	0.0063	10.57
0.007	4.93	0.00035	0.0059	10.54
0.006	5.33	0.00032	0.0054	10.51
0.005	5.82	0.00029	0.0049	10.46
0.004	6.48	0.00026	0.0044	10.42
0.003	7.44	0.00022	0.0038	10.34
0.002	8.99	0.00018	0.0031	10.26
0.001	12.52	0.00013	0.0021	10.11

*Data from Van Nostrand's Chemical Annual (1934).

Table X
Corrosion Behavior of Materials in Ammonia*

- A. Ammonia (Corrosion less than 0.005 inches per year at temperatures below that at which dissociation of ammonia and nitriding of metals occurs).†
1. High-alloyed austenitic steels
 2. Cast silicon-iron (more than 14.5% Si.)
 3. Alloyed cast iron (2% Cr., 25-30% Cr., 14% Ni., 6% Cr., 5% Cu.)
 4. Nickel (Liquid NH_3 to 250 °C NH_3 gas)
 5. Nickel-Chromium alloys
 6. Monel
 7. Platinum, its alloys and less common metals
 8. Titanium
 9. Tantalum
 10. Concrete (Concrete must be well aged)
 11. Enamel
 12. Glass
 13. Graphite
 14. Porcelain
 15. Quartzware
 16. Stoneware
 17. Plastics
 - a. Haveg 41, 60
 - b. Teflon
 - c. Hostaflor
 - d. Fluorothene
 - e. Polyethylene, 150 F
 - f. Sulfur cements, 200 F
 - g. Epoxy Resins, 150 F
 18. Rubber (natural up to 150 F)
 19. Aluminum (99.5%)
 20. Hastelloy, B, C, D
- B. Ammonia (Corrosion rates not acceptable)
1. Nickel (500°C, NH_3 gas)
 2. Nickel-Copper Alloys
 3. Copper-base Alloys
 4. Plastics
 - a. Polyisobutylenes
 - b. Polyvinyl Chlorides
 - c. Styrene Copolymers, 200 F
 5. Wool
 6. Saran

C. Aqueous Solutions of NH_3 (Corrosion rate 0.02 inches per year)

1. 316 S.S.
2. Austenitic Steels
3. Silicon-iron (more than 14.5% Si.)
4. Alloyed cast iron
5. Nickel-Chromium alloys
6. Platinum, titanium
7. Tin
8. Enamel
9. Glass
10. Graphite
11. Porcelain, Quartzware
12. Polyisobutylenes
13. Havg 41, 60
14. Teflon
15. Hastaflo
16. Fluorothene
17. 20 C, 30% Pe-Ce fibre, Vinyon, Nylon, Perlon, Asbestos
18. Cast Iron
19. Lead
20. Aluminum
21. Hastelloy B, C, D
22. Polyethylene
23. Rubber (natural and synthetic)
24. Styrene Copolymers, 200 F
25. Zirconium

D. Aqueous solutions (Corrosion rates not acceptable)

1. Nickel
2. Monel
3. Tantalum
4. Silver
5. Wool
6. Saran
7. Copper
8. Bronze
9. Glass, 250 F
10. Brass
11. Steel, 300 C under pressure

*Recommend that each specific condition be checked for proper materials of construction.

Corrosion Handbook, H. H. Uhlig, Editor, John Wiley and Sons, New York (1948).

Chemical Engineer's Handbook, Perry.

Corrosion Guide by Erich Rabald (1968).

†Certain high tensile strength steels have developed stress-corrosion cracking in ammonia service. However, such cracking can be avoided by the addition of 0.2 percent water to the ammonia as an inhibitor.

Stationary steel pressure vessels for ammonia service shall comply with part 1910, Section 1910.111, Title 29 of the Code of Federal Regulations (OSHA).

Steel pressure vessels employed for the transportation of ammonia in interstate commerce shall comply with specifications as are appropriate and as are contained in parts 171-179 of Title 49 of the Code of Federal Regulations.

Table XI

PART 1. Physical and Thermodynamic Properties of Ammonia

Molecular Weight of NH ₃	17.031
Critical Temperature	270.3 F
Critical Pressure	1,636 psi
Critical Density	14.67 lb/ft ³
Melting Temperature of NH ₃ Solid at 1 atm.	-107.9 F
Heat of Fusion of NH ₃ Solid at 1 atm., -107.9 F	142.8 BTU/lb
Boiling Temperature of NH ₃ Liquid at 1 atm.	-28.17 F
Heat of Vaporization of NH ₃ Liquid at 1 atm., -28.17 F	589.8 BTU/lb
Density of Saturated NH ₃ Vapor at 1 atm., -28.17 F	0.0555 lb/ft ³
Density of Saturated NH ₃ Liquid at 1 atm., -28.17 F	42.57 lb/ft ³
Heat of Formation of NH ₃ Vapor at 1 atm., 77 F	-1,167 BTU/lb
Heat of Formation of NH ₃ Liquid at 1 atm., 77 F	-1,760 BTU/lb
Free Energy of Formation of NH ₃ Vapor at 1 atm., 77 F	-420.6 BTU/lb
Heat of Combustion of NH ₃ Vapor at 1 atm., 77 F	10,022 BTU/lb
Thermal Conductivity of NH ₃ Vapor, k at 1 atm., 32 F at 1 atm., 212 F	0.0128 BTU-ft/(h-ft ² -F) 0.0185 BTU-ft/(h-ft ² -F)
Thermal Conductivity of NH ₃ Liquid at 50 F	0.29 BTU-ft/(h-ft ² -F)
Prandtl Number, $\left(\frac{C_p \mu}{k}\right)$, for NH ₃ Vapor at 1 atm., 212 F	0.78
Diffusion Coefficient of NH ₃ Vapor, D in air at 1 atm., 77 F	0.246 x 10 ⁻³ ft ² /sec
Schmidt Number, $\left(\frac{\mu}{\rho D}\right)$, for NH ₃ Vapor in air at 1 atm., 212°F	0.67
Dielectric Constant of NH ₃ Vapor at 1 atm., 32°F, and 10 ⁶ cycles/sec of NH ₃ Liquid at 1 atm., -11°F, and 4 x 10 ⁸ cycles/sec. of NH ₃ Solid at 1 atm., -130°F, and 4 x 10 ⁸ cycles/sec.	1.0072 22.0 4.01
Electrical Conductivity of NH ₃ Liquid at -110 F	33 x 10 ⁸ mho/in
Heat capacity of NH ₃ Vapor at 1 atm, 59 F	0.5232 BTU/lb-F

PART 2. Viscosity of Saturated Ammonia Liquid and Ammonia Vapor at Various Temperatures

Temperature	Viscosity of NH ₃ Liquid, μ	Viscosity of NH ₃ Vapor, μ
-28.3 F	0.266 Centipoise	0.00810 Centipoise
-4 F	0.210 Centipoise	0.00860 Centipoise
14 F	0.190 Centipoise	0.00900 Centipoise
32 F	0.170 Centipoise	0.00926 Centipoise
50 F	0.150 Centipoise	0.00960 Centipoise
68 F	0.125 Centipoise	0.00990 Centipoise

Table XII
Relative Neutralizing Capacity of Various Alkalies

Alkali	Pounds
Ammonia (NH₃)	1.00
Caustic Soda (NaOH)	2.35
Soda Ash (Na₂CO₃)	3.11
Aqueous Ammonia (29.4% NH₃ in H₂O)	3.40
Liquid caustic solution (50% NaOH in H₂O)	4.70

Table XIII
Nitrogen Content of Various Ammonia Derivatives

Compound	Formula	Molecular Weight	Total Nitrogen % by Weight
Ammonia	NH₃	17.03	82.3
Urea	CO(NH₂)₂	60.06	46.6
Ammonium Nitrate	NH₄NO₃	80.05	35.0
Ammonium Carbonate	(NH₄)₂CO₃·H₂O	114.11	24.5
Di Ammonium Phosphate	(NH₄)₂HPO₄	132.07	21.2
Ammonium Sulfate	(NH₄)₂SO₄	132.14	21.2
Tri Ammonium Phosphate	(NH₄)₃PO₄·3H₂O	203.14	20.6
Ammonium Bicarbonate	NH₄HCO₃	79.06	17.7
Sodium Nitrate	NaNO₃	85.01	16.5
Potassium Nitrate	KNO₃	101.10	13.7
Ammonium Bisulfate	NH₄HSO₄	115.11	12.2
Mono Ammonium Phosphate	NH₄H₂PO₄	115.04	12.2
Calcium Nitrate	Ca(NO₃)₂·4H₂O	236.16	11.8

Figure 1

THERMODYNAMIC PROPERTIES OF AMMONIA

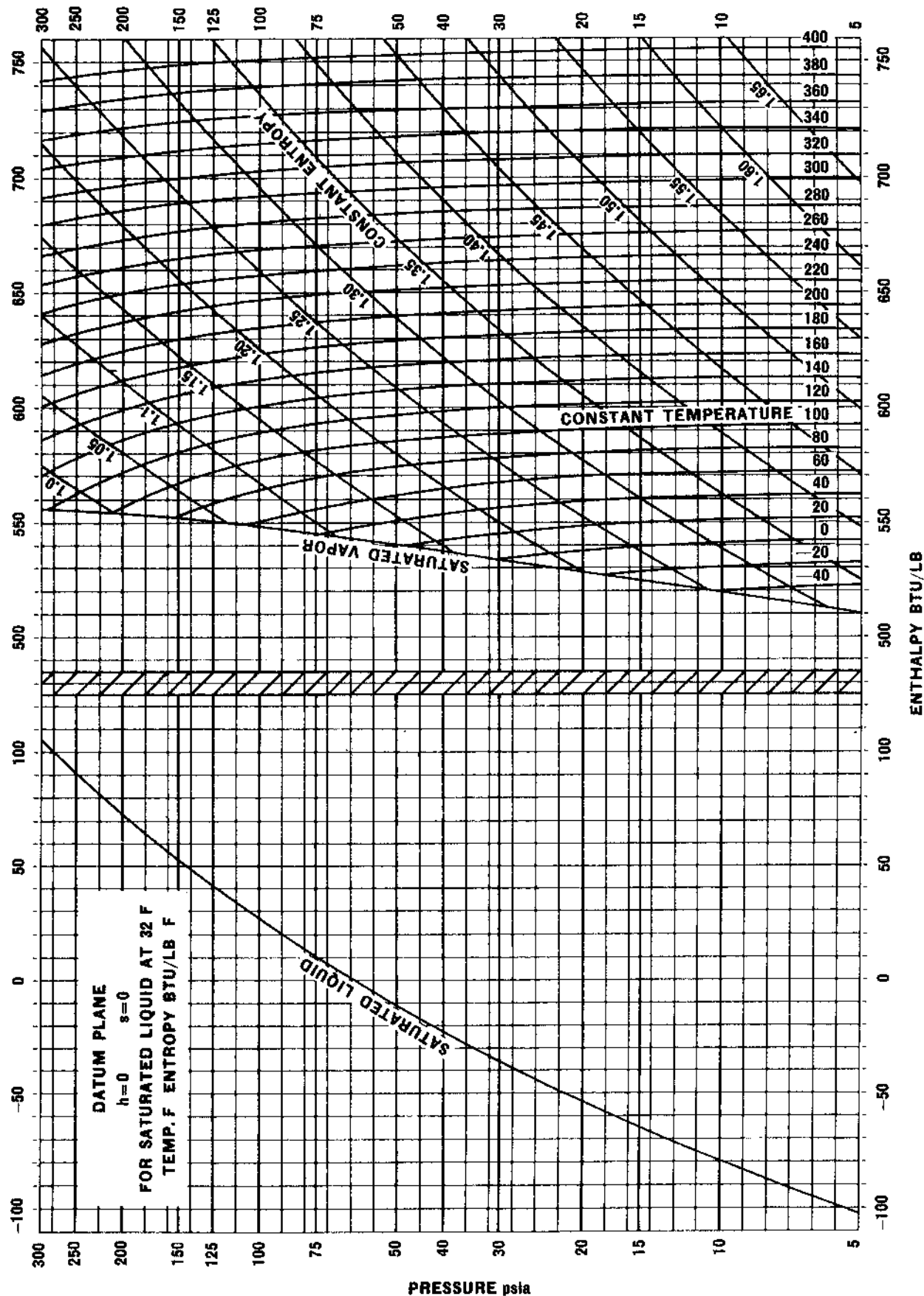
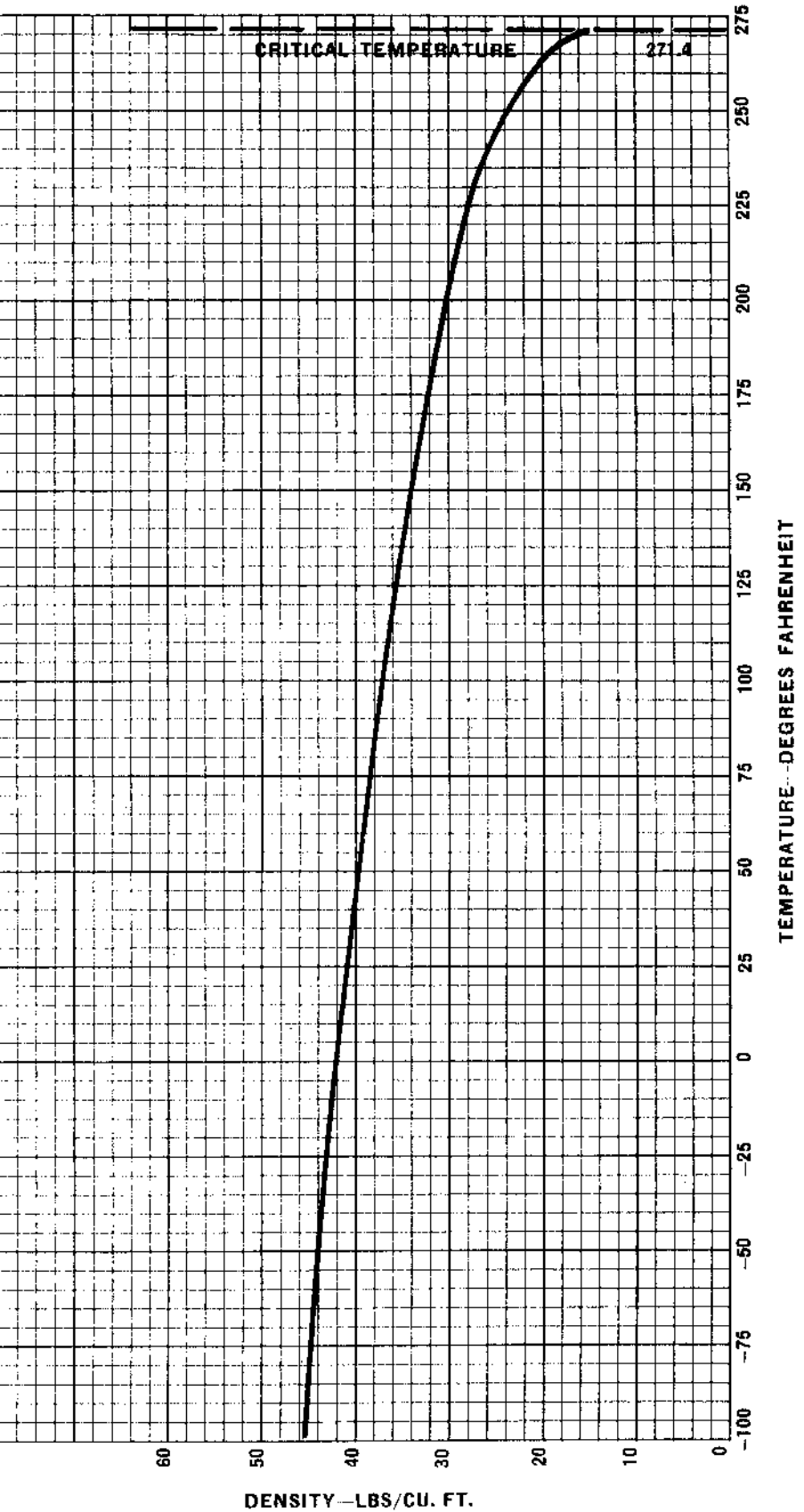


Figure 2

*DENSITY VS. TEMPERATURE OF LIQUID AMMONIA



*Refer to Table I, Page 3

From Bureau of Standards Circular No. 142 Data

Figure 3
SPECIFIC VOLUME OF AMMONIA
AS LIQUID AND VAPOR
VS. TEMPERATURE

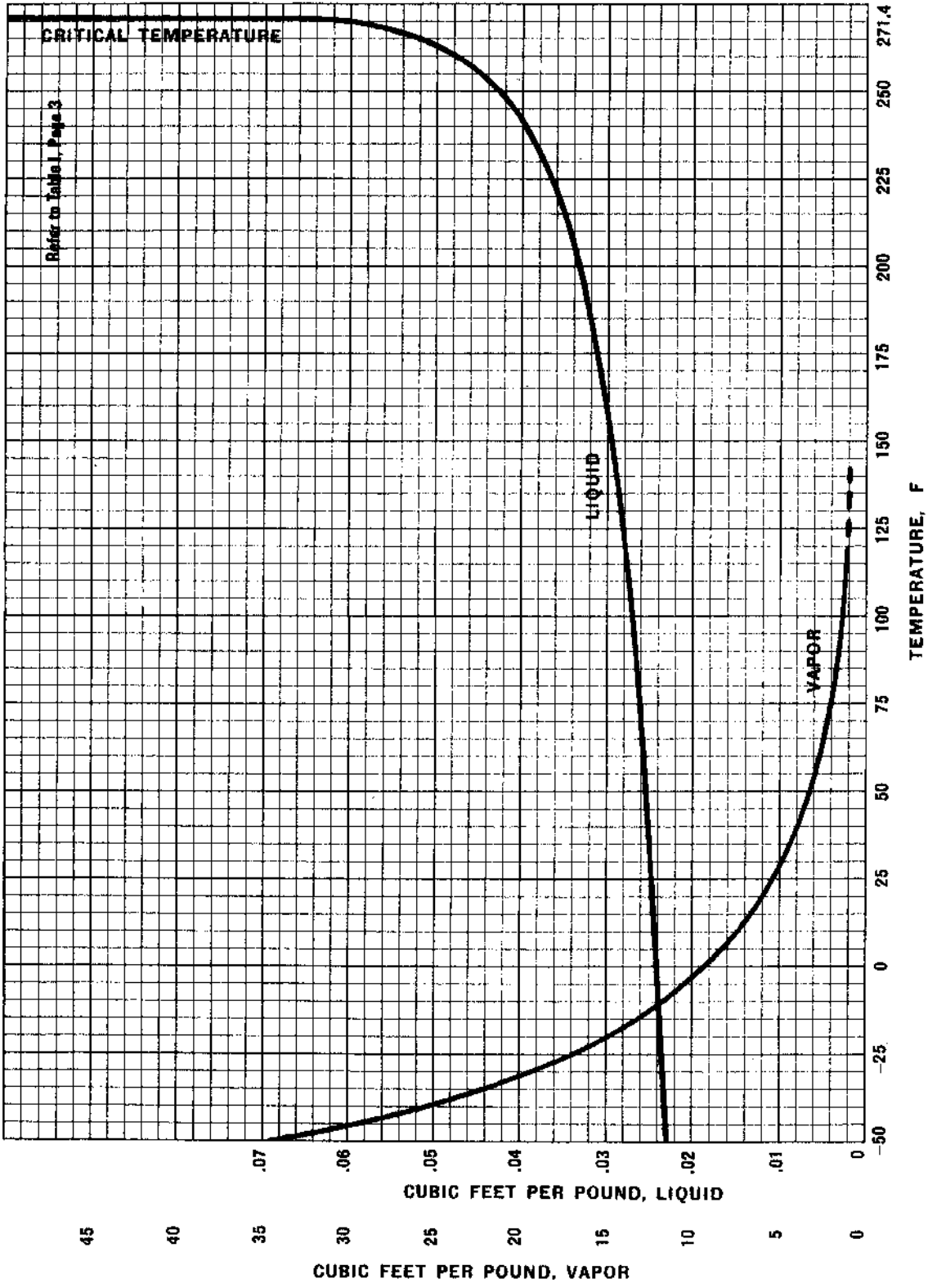


Figure 4
FREEZING POINT OF AQUEOUS AMMONIA*

* Data: S. Postma, Revue des Travaux Chimiques des Pays-Bas 39, 515 (1920)

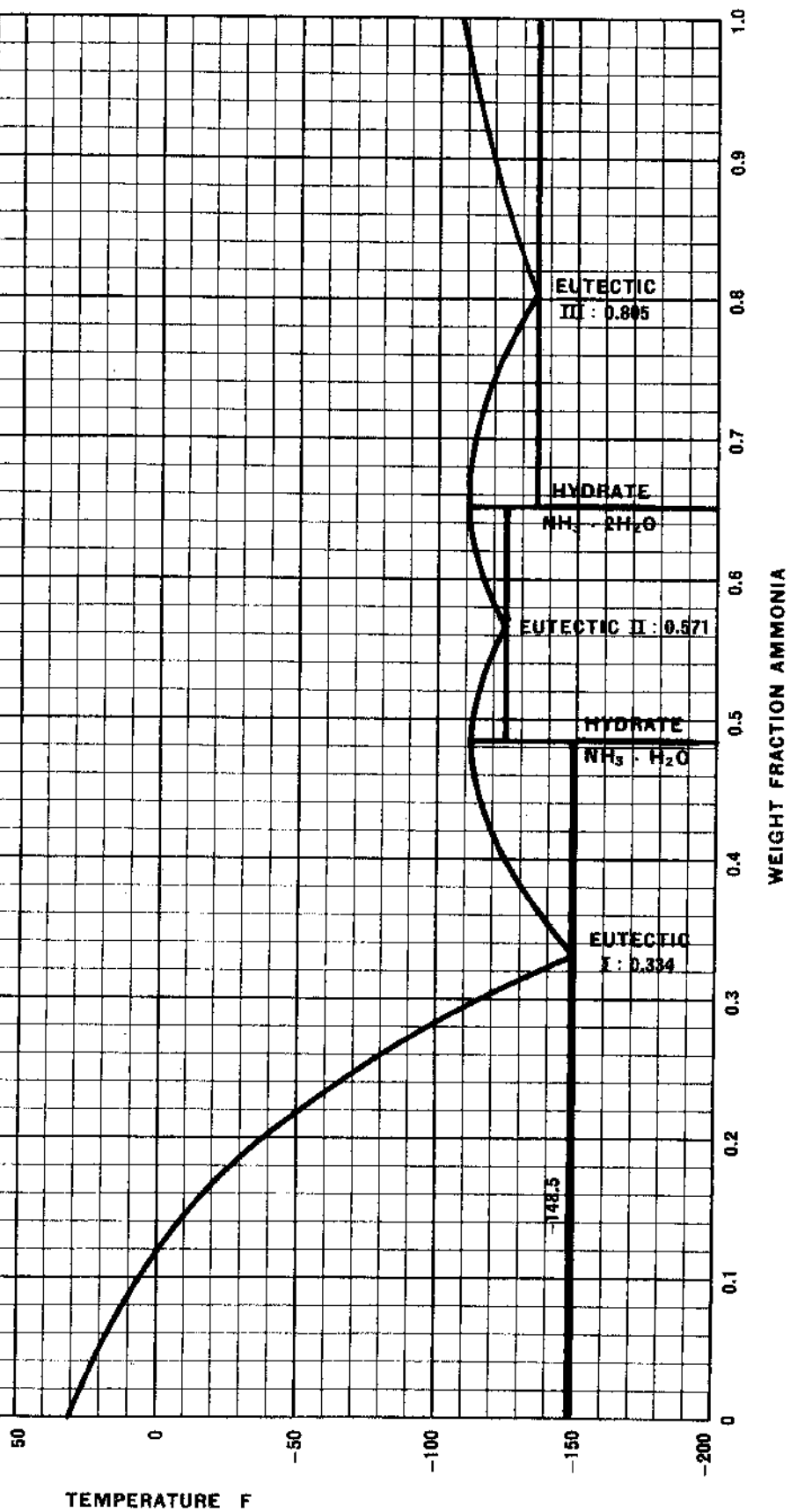


Figure 5
DENSITY OF AQUEOUS AMMONIA
SOLUTIONS AT 20 C.*
4

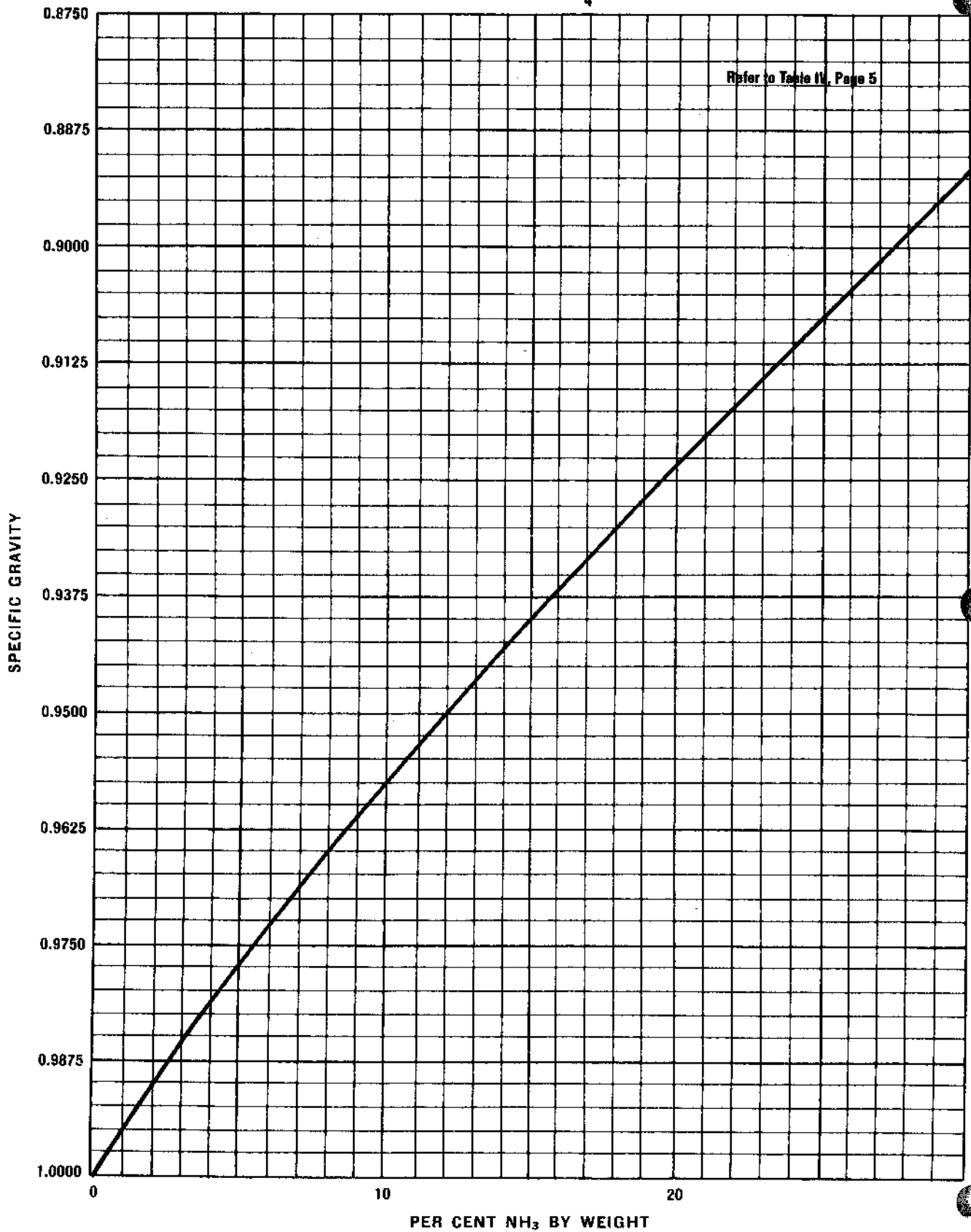


Figure 6

THERMAL CONDUCTIVITY OF AMMONIA

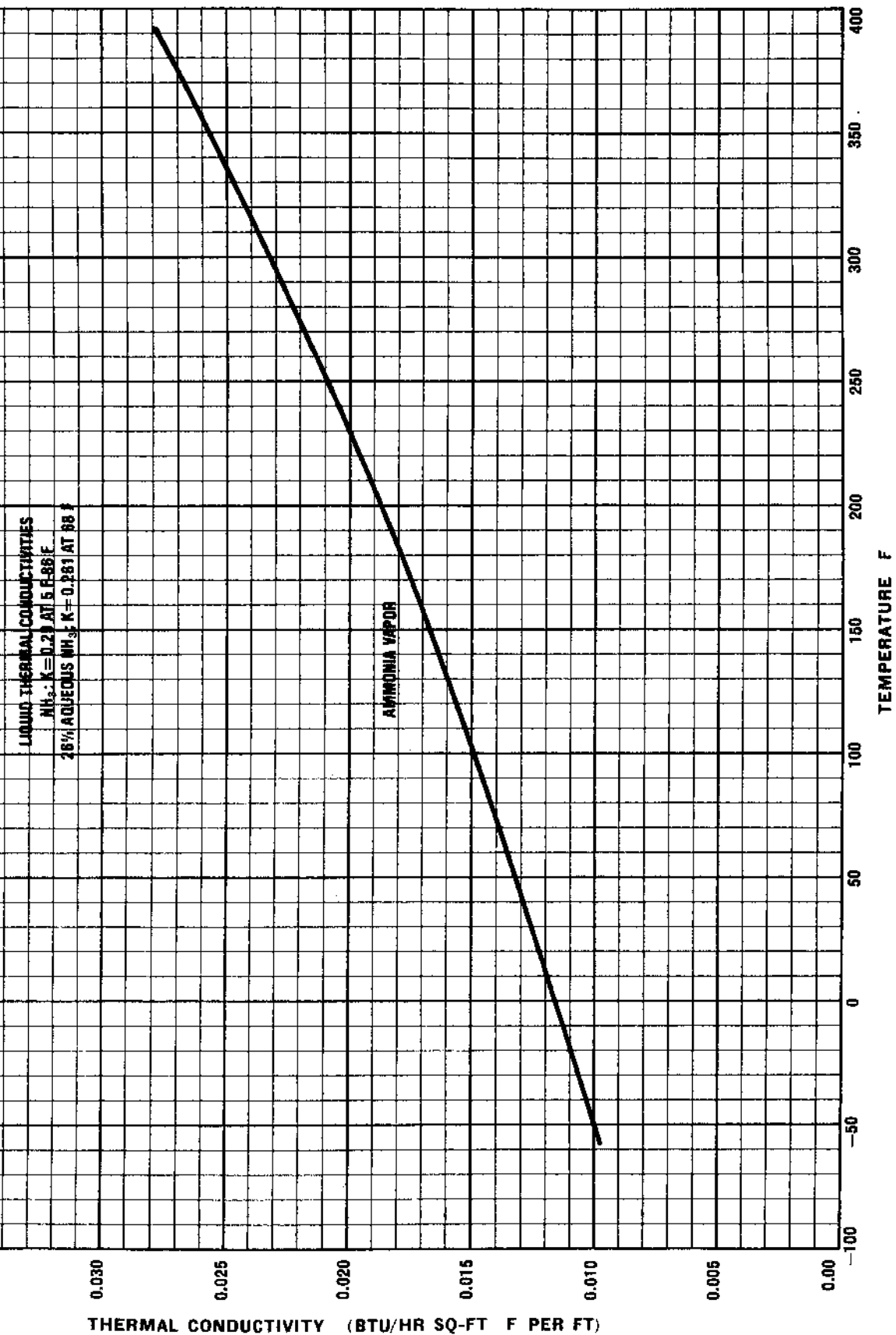
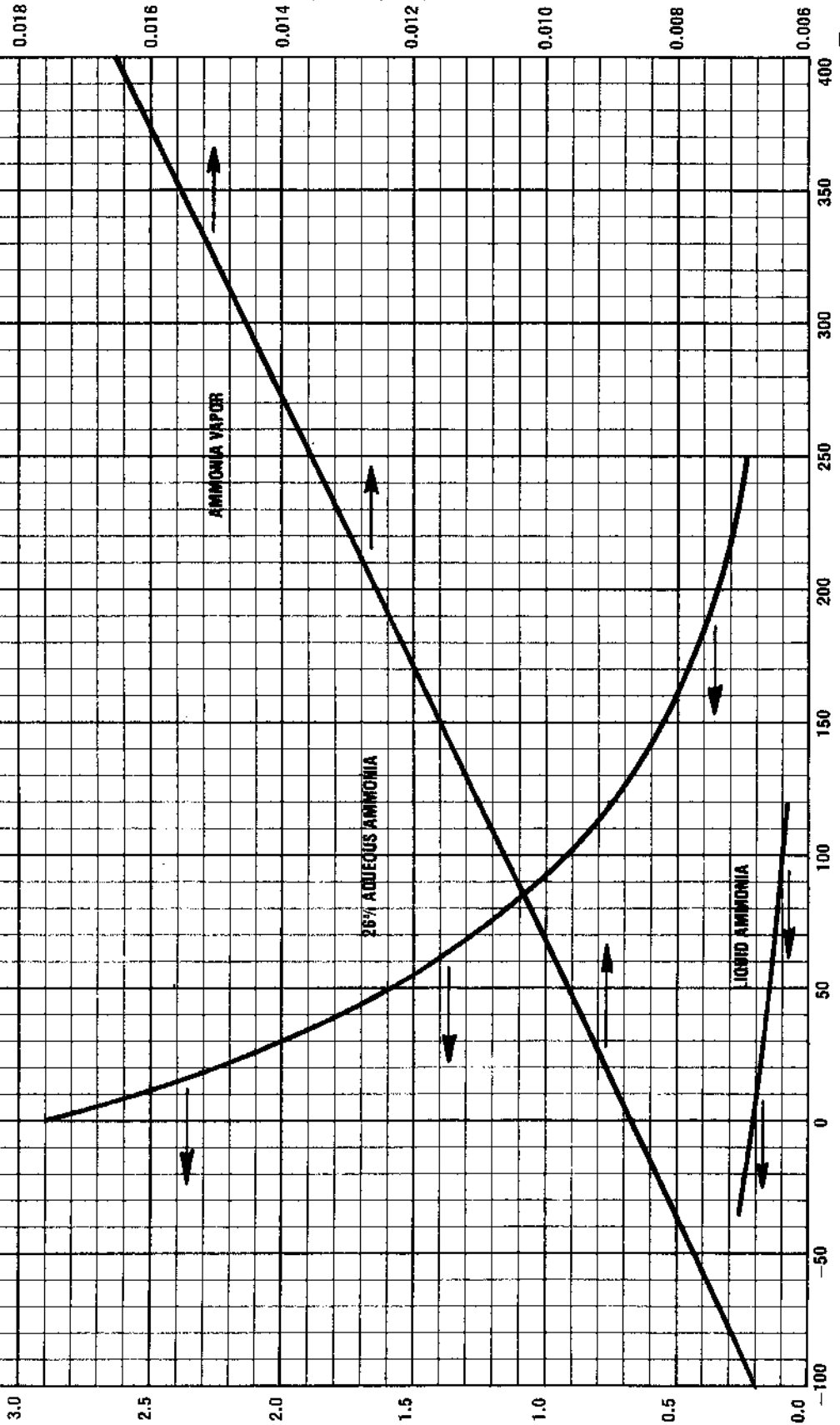


Figure 7

VISCOSITY OF AMMONIA
Viscosity of Ammonia Vapor (Centipoises)



VISCOSITY OF AQUEOUS AMMONIA (CENTIPOISES)

Figure 8
CONCENTRATION CONVERSION CURVE

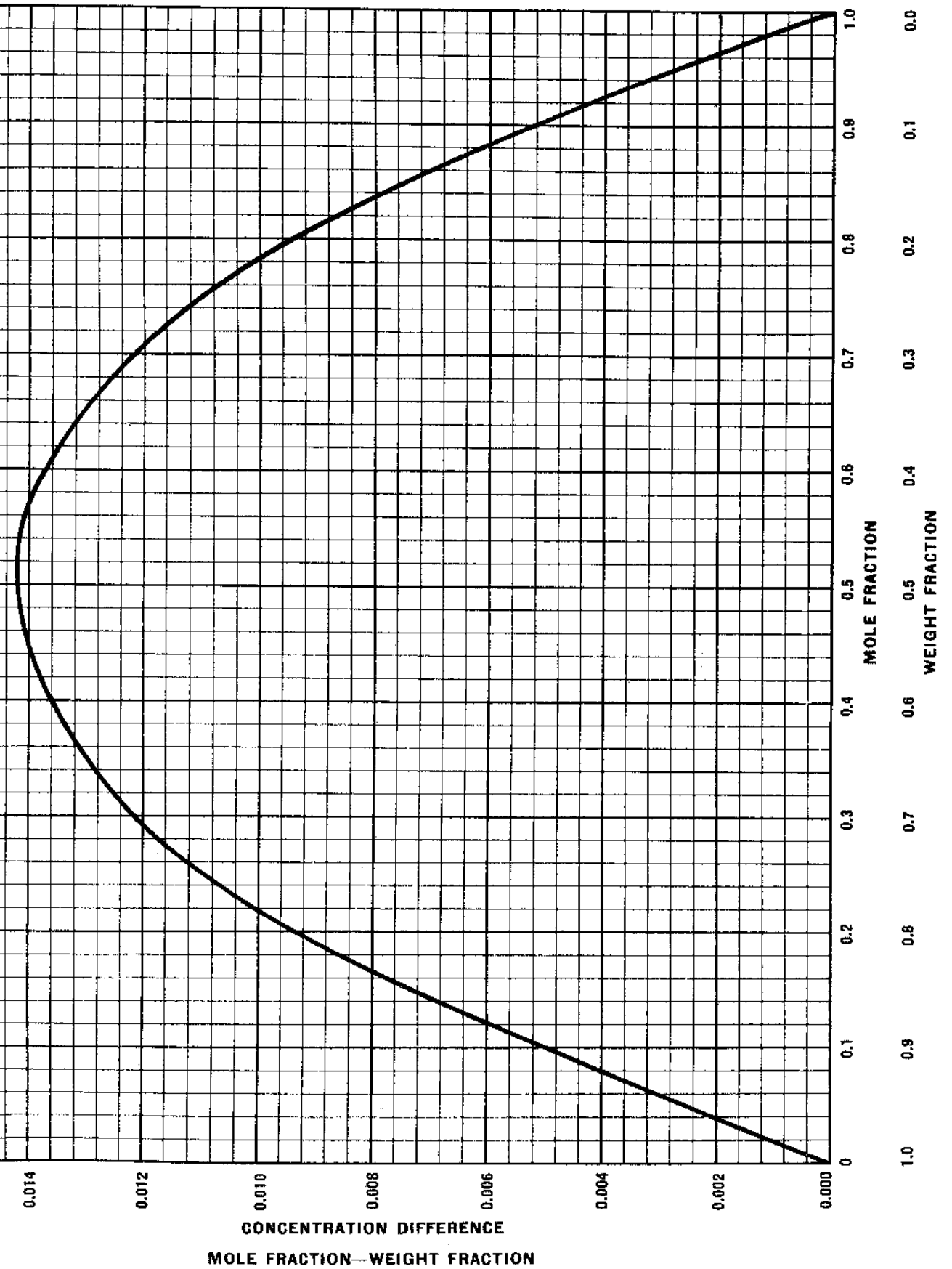
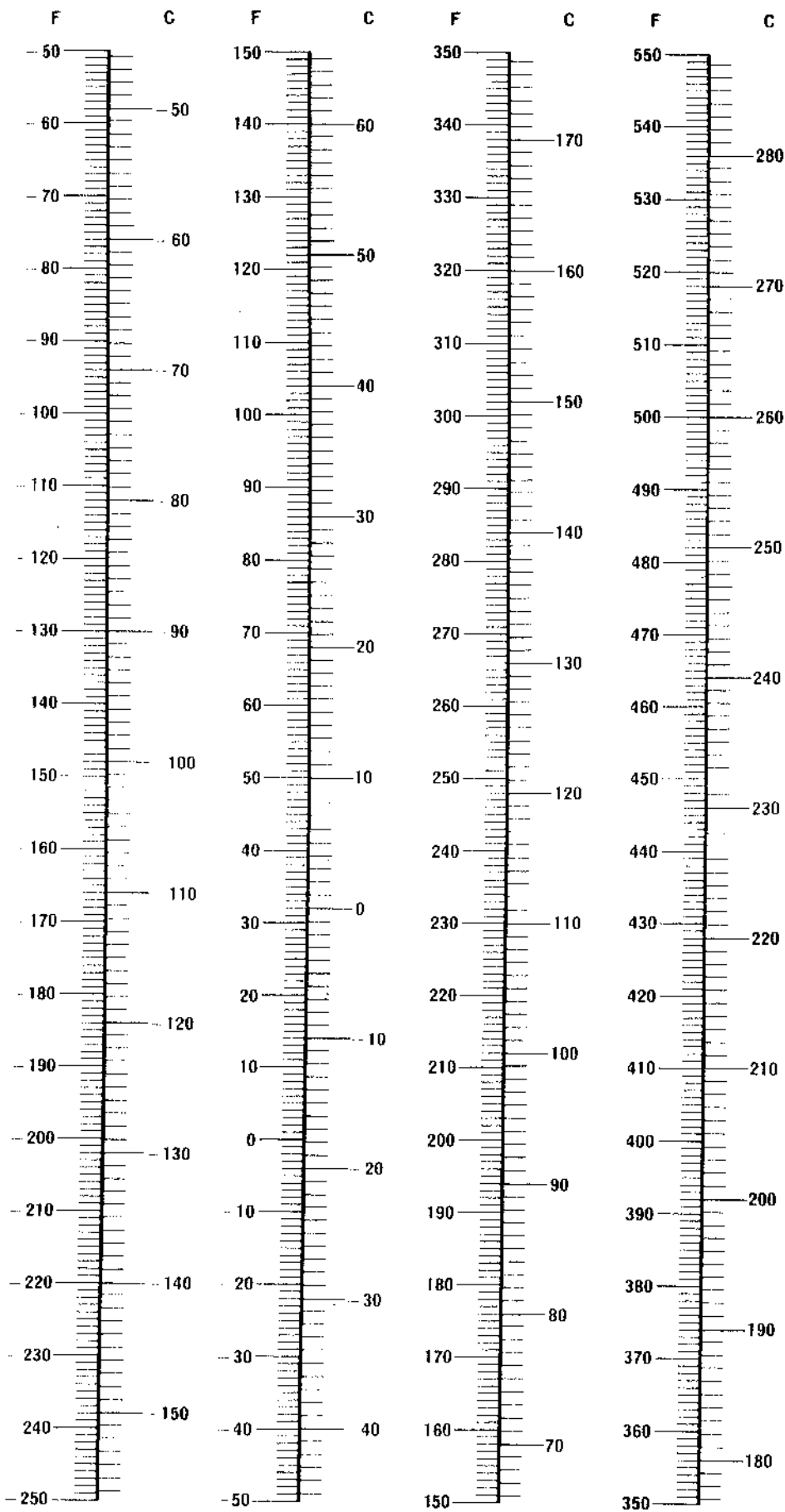


Figure 9

TEMPERATURE CONVERSION NOMOGRAPH



Index

Concentration Conversion Curve (Figure 8)	23
Corrosive Behavior of Materials in Ammonia (Table X)	12, 13
Density of Aqueous Ammonia Solutions at 20/4° C (Table IV & Figure 5)	5, 20
Density vs. Temperature of Liquid Ammonia (Figure 2)	17
Freezing Point of Aqueous Ammonia (Table III & Figure 4)	5, 19
Ionization of Aqueous Ammonia at 25°C (Table IX)	11
Nitrogen Content of Various Ammonia Derivatives (Table XIII)	15
Physical and Thermodynamic Properties of Ammonia (Table XI, Part 1)	14
Relative Neutralizing Capacity of Various Alkalies (Table XII)	15
Solubility of Ammonia in Alcohols (Table V)	5
Solubility of Ammonia in Aqueous Salt Solutions at 25°C (Table VIII)	10
Specific Volume of Ammonia as Liquid and Vapor vs. Temperature (Figure 3)	18
Temperature Conversion Nomograph (Figure 9)	24
Thermal Conductivity of Ammonia (Figure 6)	21
Thermodynamic Properties of Ammonia (Figure 1)	16
Thermodynamic Properties of Ammonia Superheated Vapor (Table VI)	6, 7
Thermodynamic Properties of Aqueous Ammonia (Table VII)	8, 9
Thermodynamic Properties of Saturated Ammonia (Table I & II)	3, 4
Viscosity of Ammonia (Figure 7)	22
Viscosity of Saturated Ammonia Liquid and Ammonia Vapor of Various Temperatures (Table XI, Part 2)	14