APPENDIX OF CALCULATION DATA

CONTENTS

[1] For aqueous and organic solutions see page 161 on which is given approximate formulas.

[2] See also Fig. 13.14.

Temperature Difference Corrections[1]

Heat-transfer Data[2]

Layout Data

Fouling Factors

[1] See Index for corrections.
[2] See Index for other data.

TABLE 1. CONVERSION FACTORS AND CONSTANTS

Energy and power:

Btu = 0.252 kg-cal
Btu = 0.293 watt-hr
Btu = 0.555 pcu (pound centigrade unit)
Btu = 778 ft-lb
Btu/min = 0.236 hp
Hp = 42.4 Btu/min
Hp = 33,000 ft-lb/min
Hp = 0.7457 kw
Hp-hr = 2543 Btu
Kw = 1.3415 hp
Watt-hr = 3.415 Btu

Fluid flow:

Bbl/hr = 0.0936 cfm
Bbl/hr = 0.700 gpm
Bbl/day = 0.0292 gpm
Bbl/day = 0.0039 cfm
Cfm = 10.686 bbl/hr
Gpm = 1.429 bbl/hr
Gpm = 34.3 bbl/day
Gpm $\times$ s (specific gravity) = 500 $\times$ s lb/hr

Heat-transfer coefficients:

Btu/(hr)(ft^2)(°F) = 1.0 pcu/(hr)(ft^2)(°C)
Btu/(hr)(ft^2)(°F) = 4.88 kg-cal/(hr)(m^2)(°C)
Btu/(hr)(ft^2)(°F) = 0.00204 watts/(in.^{2})(°F)

Length, area, and volume:

Bbl = 42 gal
Bbl = 5.615 ft^3
Cm = 0.3937 in.
Ft^3 = 0.1781 bbl
Ft^3 = 7.48 gal
Ft^3 = 0.0283 m^3
M^3 = 6.290 bbl
M^3 = 35.314 ft^3
Ft = 30.48 cm
Ft = 0.3048 m
Gal = 0.02381 bbl
Gal = 0.1337 ft^3
Gal = 3.785 liter
Gal = 0.8327 gal (Imperial)
In. = 2.54 cm
Liter = 0.2642 gal
Liter = 1.0567 qt
M = 3.281 ft
Ft^2 = 0.0929 m^2
M^2 = 10.76 ft^2

Pressure:

Atm = 33.93 ft of water at 60°F
Atm = 29.92 in. Hg at 32°F
Atm = 760 mm Hg at 32°F
Atm = 14.696 psi
Atm = 2116.8 lb/ft²
Atm = 1.033 kg/cm²
Ft of water at 60°F = 0.4331 psi
In. of water at 60°F = 0.0361 psi
Kg/cm² = 14.223 psi
Psi = 2.309 Ft of water at 60°F

Temperature:

Temperature °C = $\frac{5}{9}$(°F − 32)
Temperature °F = $\frac{9}{5}$(°C + 32)
Temperature °F absolute (°R) = °F + 460
Temperature °C absolute (°K) = °C + 273

Thermal conductivity:

Btu/(hr)(ft²)(°F/ft) = 12 Btu/(hr)(ft²)(°F/in.)
Btu/(hr)(ft²)(°F/ft) = 1.49 kg-cal/(hr)(m²)(°C/m)
Btu/(hr)(ft²)(°F/ft) = 0.0173 watts/(cm²)(°C/cm)

Viscosity (additional factors are contained in Fig. 13):

Poise = 1 g/(cm)(sec)
Centipoise = 0.01 poise
Centipoise = 2.42 lb/(ft)(hr)

Weight:

Lb = 0.4536 kg
Lb = 7000 grains
Ton (short or net) = 2000 lb
Ton (long) = 2240 lb
Ton (metric) = 2205 lb
Ton (metric) = 1000 kg

Constants:

Acceleration of gravity = 32.2 ft/sec²
Acceleration of gravity = 4.18×10^8 ft/hr²
Density of a cubic foot of water = 62.5 lb/ft³

TABLE 2. THERMAL CONDUCTIVITIES OF SOME BUILDING AND INSULATING MATERIALS*

k = Btu/(hr)(ft²)(°F/ft)

Material	Apparent density ρ, lb/ft³ at room temperature	°F	k
Aerogel, silica, opacified	8.5	248	0.013
		554	0.026
Asbestos-cement boards	120	68	0.43
Asbestos sheets	55.5	124	0.096
Asbestos slate	112	32	0.087
	112	140	0.114
Asbestos	29.3	−328	0.043
	29.3	32	0.090
	36	32	0.087
	36	212	0.111
	36	392	0.120
	36	752	0.129
	43.5	−328	0.090
	43.5	32	0.135
Aluminum foil, 7 air spaces per 2.5 in	0.2	100	0.025
		351	0.038
Ashes, wood	.....	32–212	0.041
Asphalt	132	68	0.43
Boiler scale (ref. 364)			
Bricks			
Alumina (92–99% Al_2O_3 by weight) fused	.....	801	1.8
Alumina (64–65% Al_2O_3 by weight)	.....	2399	2.7
(See also Bricks, fire clay)	115	1472	0.62
	115	2012	0.63
Building brickwork	.....	68	0.4
Chrome brick (32% Cr_2O_3 by weight)	200	392	0.67
	200	1202	0.85
	200	2399	1.0
Diatomaceous earth, natural, across strata	27.7	399	0.051
	27.7	1600	0.077
Diatomaceous, natural, parallel to strata	27.7	399	0.081
	27 7	1600	0.106
Diatomaceous earth, molded and fired	38	399	0.14
	38	1600	0.18
Diatomaceous earth and clay, molded and fired	42.3	399	0.14
	42.3	1600	0.19
Diatomaceous earth, high burn, large pores	37	392	0.13
	37	1832	0.34

TABLE 2. THERMAL CONDUCTIVITIES OF SOME BUILDING AND INSULATING MATERIALS.*—(*Continued*)

Material	Apparent density ρ, lb/ft^3 at room temperature	°F	k
Bricks: (*Continued*)			
Fire clay, Missouri	.....	392	0.58
		1112	0.85
		1832	0.95
		2552	1.02
Kaolin insulating brick	27	932	0.15
	27	2102	0.26
Kaolin insulating firebrick	19	392	0.050
	19	1400	0.113
Magnesite (86.8% MgO, 6.3% Fe_2O_3, 3% CaO, 2.6% SiO_2 by weight)	158	399	2.2
	158	1202	1.6
	158	2192	1.1
Silicon carbide brick, recrystallized	129	1112	10.7
	129	1472	9.2
	129	1832	8.0
	129	2192	7.0
	129	2552	6.3
Calcium carbonate, natural	162	86	1.3
White marble	.....	.....	1.7
Chalk	96	.....	0.4
Calcium sulphate ($4H_2O$), artificial	84.6	104	0.22
Plaster, artificial	132	167	0.43
Building	77.9	77	0.25
Cambric, varnished	.....	100	0.09
Carbon, gas	.....	32–212	2.0
Cardboard, corrugated	.....	.....	0.037
Celluloid	87.3	86	0.12
Charcoal flakes	11.9	176	0.043
	15	176	0.051
Clinker, granular	.....	32–1292	0.27
Coke, petroleum	.....	212	3.4
		932	2.9
Coke, powdered	.....	32–212	0.11
Concrete, cinder	.....	.....	0.20
1:4 dry	.....	.....	0.44
Stone	.....	.....	0.54
Cotton wool	5	86	0.024
Cork board	10	86	0.025
Cork, ground	9.4	86	0.025
Regranulated	8.1	86	0.026

TABLE 2. THERMAL CONDUCTIVITIES OF SOME BUILDING AND INSULATING MATERIALS.*—(*Continued*)

Material	Apparent density ρ, lb/ft^3 at room temperature	°F	k
Diatomaceous earth powder, coarse	20.0	100	0.036
	20.0	1600	0.082
Fine	17.2	399	0.040
	17.2	1600	0.074
Molded pipe covering	26.0	399	0.051
	26.0	1600	0.088
4 vol. calcined earth and 1 vol. cement, poured and fired	61.8	399	0.16
	61.8	1600	0.23
Dolomite	167	122	1.0
Ebonite	.....	.....	0.10
Enamel, silicate	38	.....	0.5–0.75
Felt, wool	20.6	86	0.03
Fiber insulating board	14.8	70	0.028
Fiber, red	80.5	68	0.27
With binder, baked	.....	68–207	0.097
Gas carbon	.....	32–212	2.0
Glass	.....	.....	0.2–0.73
Boro-silicate type	139	86–167	0.63
Soda glass	.....	.....	0.3–0.44
Window glass	.....	.....	0.3–0.61
Granite	.....	.....	1.0–2.3
Graphite, dense, commercial	.....	32	86.7
Powdered, through 100 mesh	30	104	0.104
Gypsum, molded and dry	78	68	0.25
Hair, felt, perpendicular to fibers	17	86	0.021
Ice	57.5	32	1.3
Infusorial earth (see Diatomaceous earth)			
Kapok	0.88	68	0.020
Lampblack	10	104	0.038
Lava	.....	.....	0.49
Leather, sole	62.4	.....	0.092
Limestone (15.3 vol % H_2O)	103	75	0.54
Linen	.....	86	0.05
Magnesia, powdered	49.7	117	0.35
Magnesia, light carbonate	19	70	0.04
Magnesium oxide, compressed	49.9	68	0.32
Marble	.....	.....	1.2–1.7

TABLE 4. THERMAL CONDUCTIVITIES OF LIQUIDS*

k = Btu/(hr)(ft²)(°F/ft)

A linear variation with temperature may be assumed. The extreme values given constitute also the temperature limits over which the data are recommended.

Liquid	°F	k
Acetic acid 100%	68	0.099
50%	68	0.20
Acetone	86	0.102
	167	0.095
Allyl alcohol	77–86	0.104
Ammonia	5–86	0.29
Ammonia, aqueous 26%	68	0.261
	140	0.29
Amyl acetate	50	0.083
Alcohol (*n*-)	86	0.094
	212	0.089
	86	0.088
	167	0.087
Aniline	32–68	0.100
Benzene	86	0.092
	140	0.087
Bromobenzene	86	0.074
	212	0.070
Butyl acetate (*n*-)	77–86	0.085
Alcohol (*n*-)	86	0.097
	167	0.095
(iso-)	50	0.091
Calcium chloride brine 30%	86	0.32
15%	86	0.34
Carbon disulphide	86	0.093
	167	0.088
Tetrachloride	32	0.107
	154	0.094
Chlorobenzene	50	0.083
Chloroform	86	0.080
Cymene (para)	86	0.078
	140	0.079
Decane (*n*-)	86	0.085
	140	0.083
Dichlorodifluoromethane	20	0.057
	60	0.053
	100	0.048
	140	0.043
	180	0.038
Dichloroethane	122	0.082
Dichloromethane	5	0.111
	86	0.096
Ethyl acetate	68	0.101
Alcohol 100%	68	0.105
80%	68	0.137
60%	68	0.176
40%	68	0.224
20%	68	0.281
100%	122	0.087
Benzene	86	0.086
	140	0.082
Bromide	68	0.070
Ether	86	0.080
	167	0.078
Iodide	104	0.064
	167	0.063
Ethylene glycol	32	0.153
Gasoline	86	0.078
Glycerol 100%	68	0.164
80%	68	0.189
60%	68	0.220
40%	68	0.259
20%	68	0.278
100%	212	0.164
Heptane (*n*-)	86	0.081
	140	0.079
Hexane (*n*-)	86	0.080
	140	0.078
Heptyl alcohol (*n*-)	86	0.094
	167	0.091
Hexyl alcohol (*n*-)	86	0.093
	167	0.090
Kerosene	68	0.086
	167	0.081
Lauric acid	212	0.102
Mercury	82	4.83
Methyl aclohol 100%	68	0.124
80%	68	0.154
60%	68	0.190
40%	68	0.234
20%	68	0.284
100%	122	0.114
Chloride	5	0.111
	86	0.089
Nitrobenzene	86	0.095
	212	0.088
Nitromethane	86	0.125
	140	0.120
Nonane (*n*-)	86	0.084
	140	0.082
Octane (*n*-)	86	0.083
	140	0.081
Oils		
Castor	68	0.104
	212	0.100
Olive	68	0.097
	212	0.095
Oleic acid	212	0.0925
Palmitic acid	212	0.0835
Paraldehyde	86	0.084
	212	0.078
Pentane (*n*-)	86	0.078
	167	0.074
Perchloroethylene	122	0.092
Petroleum ether	86	0.075
	167	0.073
Propyl alcohol (*n*-)	86	0.099
	167	0.095
Alcohol (iso-)	86	0.091
	140	0.090
Sodium	212	49
	410	46
Sodium chloride brine 25.0%	86	0.33
12.5%	86	0.34
Stearic acid	212	0.0786
Sulfuric acid 90%	86	0.21
60%	86	0.25
30%	86	0.30
Sulfur dioxide	5	0.128
	86	0.111
Toluene	86	0.086
	167	0.084
β-trichloroethane	122	0.077
Trichloroethylene	122	0.080
Turpentine	59	0.074
Vaseline	59	0.106
Water	32	0.330
	86	0.356
	140	0.381
	176	0.398
Xylene (ortho-)	68	0.090
(meta-)	68	0.090

* From Perry, J. H., "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc., New York, 1950.

TABLE 5. THERMAL CONDUCTIVITIES OF GASES AND VAPORS*

k = Btu/(hr)(ft²)(°F/ft)

The extreme temperature values given constitute the experimental range. For extrapolation to other temperatures, it is suggested that the data given be plotted as log k vs. log T or that use be made of the assumption that the ratio $c\mu/k$ is practically independent of temperature (or of pressure, within moderate limits).

Substance	°F	k	Substance	°F	k
Acetone	32	0.0057	Dichlorodifluoromethane	32	0.0048
	115	0.0074		122	0.0064
	212	0.0099		212	0.0080
	363	0.0147		302	0.0097
Acetylene	−103	0.0068	Ethane	−94	0.0066
	32	0.0108		−29	0.0086
	122	0.0140		32	0.0106
	212	0.0172		212	0.0175
Air	−148	0.0095	Ethyl acetate	115	0.0072
	32	0.0140		212	0.0096
	212	0.0183		363	0.0141
	392	0.0226	Alcohol	68	0.0089
	572	0.0265		212	0.0124
Ammonia	−76	0.0095	Chloride	32	0.0055
	32	0.0128		212	0.0095
	122	0.0157		363	0.0135
	212	0.0185		413	0.0152
			Ether	32	0.0077
Benzene	32	0.0052		115	0.0099
	115	0.0073		212	0.0131
	212	0.0103		363	0.0189
	363	0.0152		413	0.0209
	413	0.0176	Ethylene	−96	0.0064
Butane (*n*-)	32	0.0078		32	0.0101
	212	0.0135		122	0.0131
(iso-)	32	0.0080		212	0.0161
	212	0.0139			
Carbon dioxide	−58	0.0068	Heptane (*n*-)	392	0.0112
	32	0.0085		212	0.0103
	212	0.0133	Hexane (*n*-)	32	0.0072
	392	0.0181		68	0.0080
	572	0.0228	Hexene	32	0.0061
Disulphide	32	0.0040		212	0.0109
	45	0.0042	Hydrogen	−148	0.065
Monoxide	−312	0.0041		−58	0.083
	−294	0.0046		32	0.100
	32	0.0135		122	0.115
Tetrachloride	115	0.0041		212	0.129
	212	0.0052		572	0.178
	363	0.0065	Hydrogen and carbon dioxide	32	
Chlorine	32	0.0043	0% H_2	.....	0.0083
Chloroform	32	0.0038	20%	.....	0.0165
	115	0.0046	40%	.....	0.0270
	212	0 0058	60%	.....	0.0410
	363	0.0077	80%	.....	0.0620
Cyclohexane	216	0.0095	100%	.....	0.10

TABLE 5. THERMAL CONDUCTIVITIES OF GASES AND VAPORS.*—(*Continued*)

Substance	°F	*k*	Substance	°F	*k*
Hydrogen and nitrogen	32		Nitric oxide	−94	0.0103
0% H_2	.....	0.0133		32	0.0138
20%	.....	0.0212	Nitrogen	−148	0.0095
40%	.....	0.0313		32	0.0140
60%	.....	0.0438		122	0.0160
80%	.....	0.0635		212	0.0180
Hydrogen and nitrous oxide	32		Nitrous oxide	−98	0.0067
0% H_2	.....	0.0002		32	0.0087
20%	.....	0.0170		212	0.0128
40%	.....	0.0270			
60%	.....	0.0410	Oxygen	−148	0.0095
80%	.....	0.0650		−58	0.0119
Hydrogen sulphide	32	0.0076		32	0.0142
				122	0.0164
Mercury	392	0.0197		212	0.0185
Methane	−148	0.0100			
	−58	0.0145	Pentane (*n*-)	32	0.0074
	32	0.0175		68	0.0083
	122	0.0215	(iso-)	32	0.0072
Methyl alcohol	32	0.0083		212	0.0127
	212	0.0128	Propane	32	0.0087
Acetate	32	0.0059		212	0.0151
	68	0.0068			
Methyl chloride	32	0.0053	Sulphur dioxide	32	0.0050
	115	0.0072		212	0.0069
	212	0.0094			
	363	0.0130	Water vapor	115	0.0120
	413	0.0148		212	0.0137
Methylene chloride	32	0.0039		392	0.0187
	115	0.0049		572	0.0248
	212	0.0063		752	0.0315
	413	0.0095		932	0.0441

* From Perry, J. H., "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc., New York, 1950.

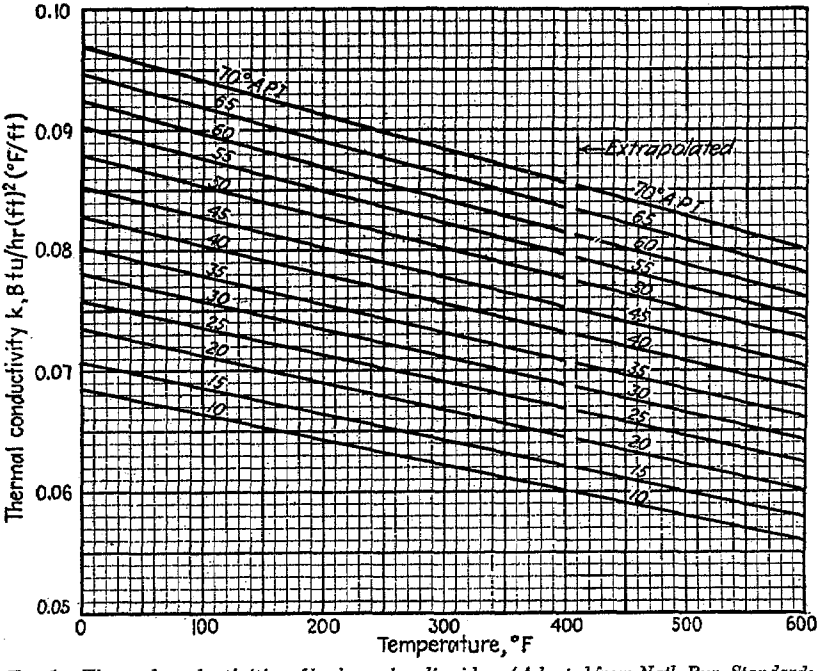
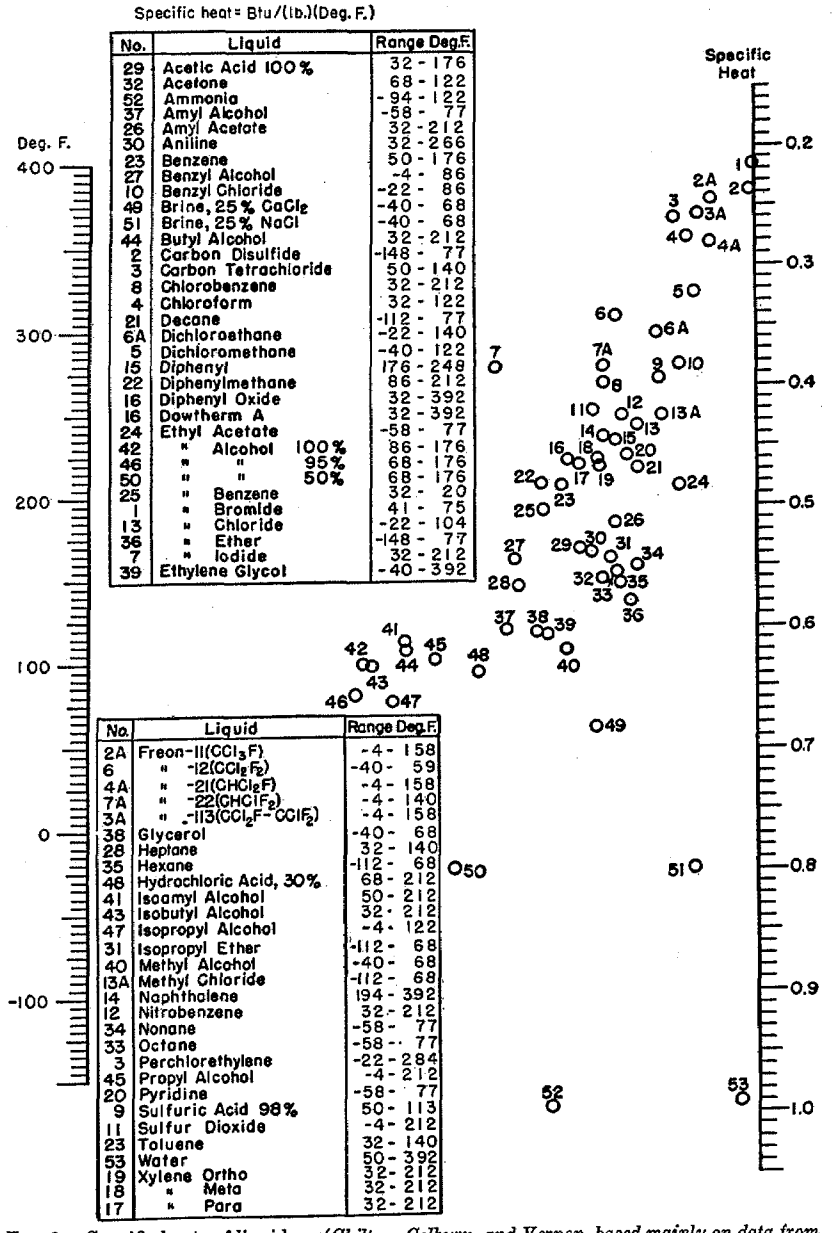


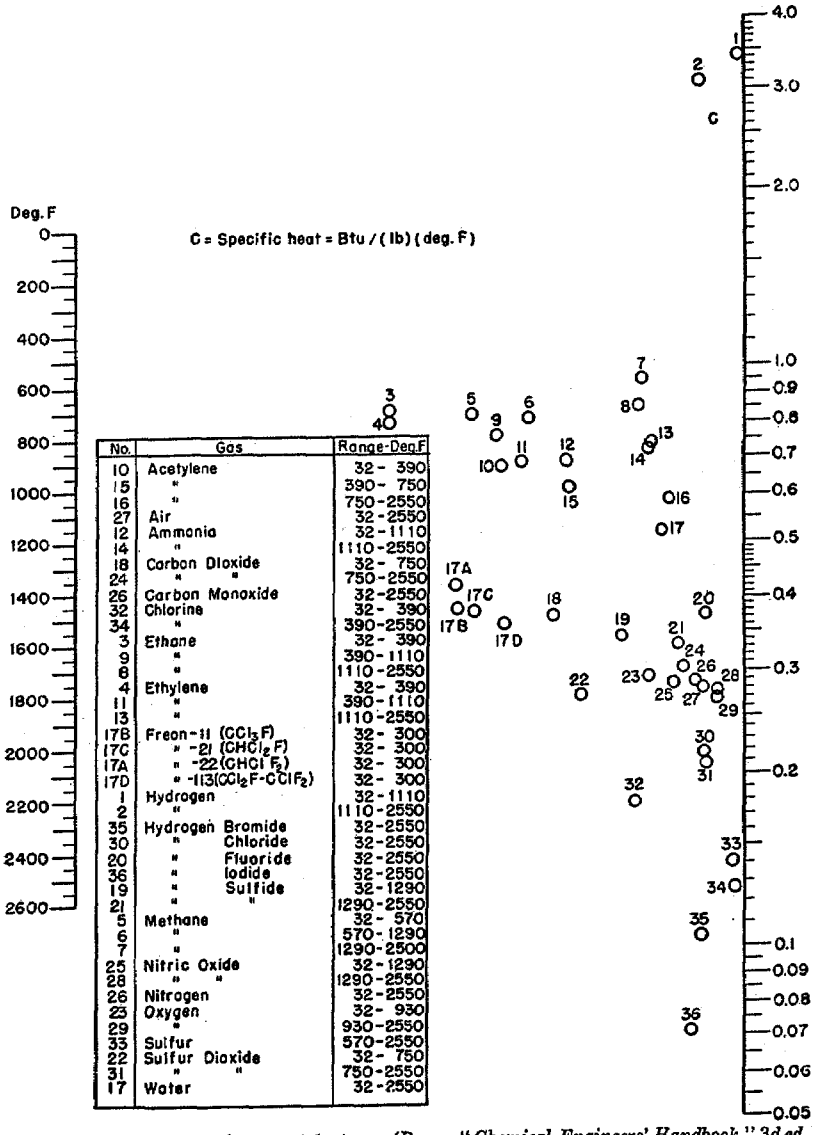
FIG. 1. Thermal conductivities of hydrocarbon liquids. (*Adapted from Natl. Bur. Standards Misc. Pub.* 97.)



No.	Liquid	Range Deg.F.
29	Acetic Acid 100%	32 - 176
32	Acetone	68 - 122
52	Ammonia	-94 - 122
37	Amyl Alcohol	-58 - 77
26	Amyl Acetate	32 - 212
30	Aniline	32 - 266
23	Benzene	50 - 176
27	Benzyl Alcohol	-4 - 86
10	Benzyl Chloride	-22 - 86
49	Brine, 25% $CaCl_2$	-40 - 68
51	Brine, 25% NaCl	-40 - 68
44	Butyl Alcohol	32 - 212
2	Carbon Disulfide	-148 - 77
3	Carbon Tetrachloride	50 - 140
8	Chlorobenzene	32 - 212
4	Chloroform	32 - 122
21	Decane	-112 - 77
6A	Dichloroethane	-22 - 140
5	Dichloromethane	-40 - 122
15	Diphenyl	176 - 248
22	Diphenylmethane	86 - 212
16	Diphenyl Oxide	32 - 392
16	Dowtherm A	32 - 392
24	Ethyl Acetate	-58 - 77
42	" Alcohol 100%	86 - 176
46	" " 95%	68 - 176
50	" " 50%	68 - 176
25	" Benzene	32 - 20
1	" Bromide	41 - 75
13	" Chloride	-22 - 104
36	" Ether	-148 - 77
7	" Iodide	32 - 212
39	Ethylene Glycol	-40 - 392

No.	Liquid	Range Deg.F.
2A	Freon-11(CCl_3F)	-4 - 158
6	" -12(CCl_2F_2)	-40 - 59
4A	" -21($CHCl_2F$)	-4 - 158
7A	" -22($CHClF_2$)	-4 - 140
3A	" -113($CCl_2F-CClF_2$)	-4 - 158
38	Glycerol	-40 - 68
28	Heptane	32 - 140
35	Hexane	-112 - 68
48	Hydrochloric Acid, 30%	68 - 212
41	Isoamyl Alcohol	50 - 212
43	Isobutyl Alcohol	32 - 212
47	Isopropyl Alcohol	-4 - 122
31	Isopropyl Ether	-112 - 68
40	Methyl Alcohol	-40 - 68
13A	Methyl Chloride	-112 - 68
14	Naphthalene	194 - 392
12	Nitrobenzene	32 - 212
34	Nonane	-58 - 77
33	Octane	-58 - 77
3	Perchlorethylene	-22 - 284
45	Propyl Alcohol	-4 - 212
20	Pyridine	-58 - 77
9	Sulfuric Acid 98%	50 - 113
11	Sulfur Dioxide	-4 - 212
23	Toluene	32 - 140
53	Water	50 - 392
19	Xylene Ortho	32 - 212
18	" Meta	32 - 212
17	" Para	32 - 212

FIG. 2. Specific heats of liquids. (*Chilton, Colburn, and Vernon, based mainly on data from International Critical Tables. Perry, "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc., New York,* 1950.)



No.	Gas	Range-Deg.F
10	Acetylene	32 - 390
15	"	390 - 750
16	"	750 - 2550
27	Air	32 - 2550
12	Ammonia	32 - 1110
14	"	1110 - 2550
18	Carbon Dioxide	32 - 750
24	" "	750 - 2550
26	Carbon Monoxide	32 - 2550
32	Chlorine	32 - 390
34	"	390 - 2550
3	Ethane	32 - 390
9	"	390 - 1110
8	"	1110 - 2550
4	Ethylene	32 - 390
11	"	390 - 1110
13	"	1110 - 2550
17B	Freon - 11 (CCl_3F)	32 - 300
17C	" - 21 ($CHCl_2F$)	32 - 300
17A	" - 22 ($CHClF_2$)	32 - 300
17D	" - 113 ($CCl_2F-CClF_2$)	32 - 300
1	Hydrogen	32 - 1110
2	"	1110 - 2550
35	Hydrogen Bromide	32 - 2550
30	" Chloride	32 - 2550
20	" Fluoride	32 - 2550
36	" Iodide	32 - 2550
19	" Sulfide	32 - 1290
21	" "	1290 - 2550
5	Methane	32 - 570
6	"	570 - 1290
7	"	1290 - 2500
25	Nitric Oxide	32 - 1290
28	" "	1290 - 2550
26	Nitrogen	32 - 2550
23	Oxygen	32 - 930
29	"	930 - 2550
33	Sulfur	570 - 2550
22	Sulfur Dioxide	32 - 750
31	" "	750 - 2550
17	Water	32 - 2550

FIG. 3. Specific heats of gases at 1 atm. (*Perry, "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc., New York*, 1950.)

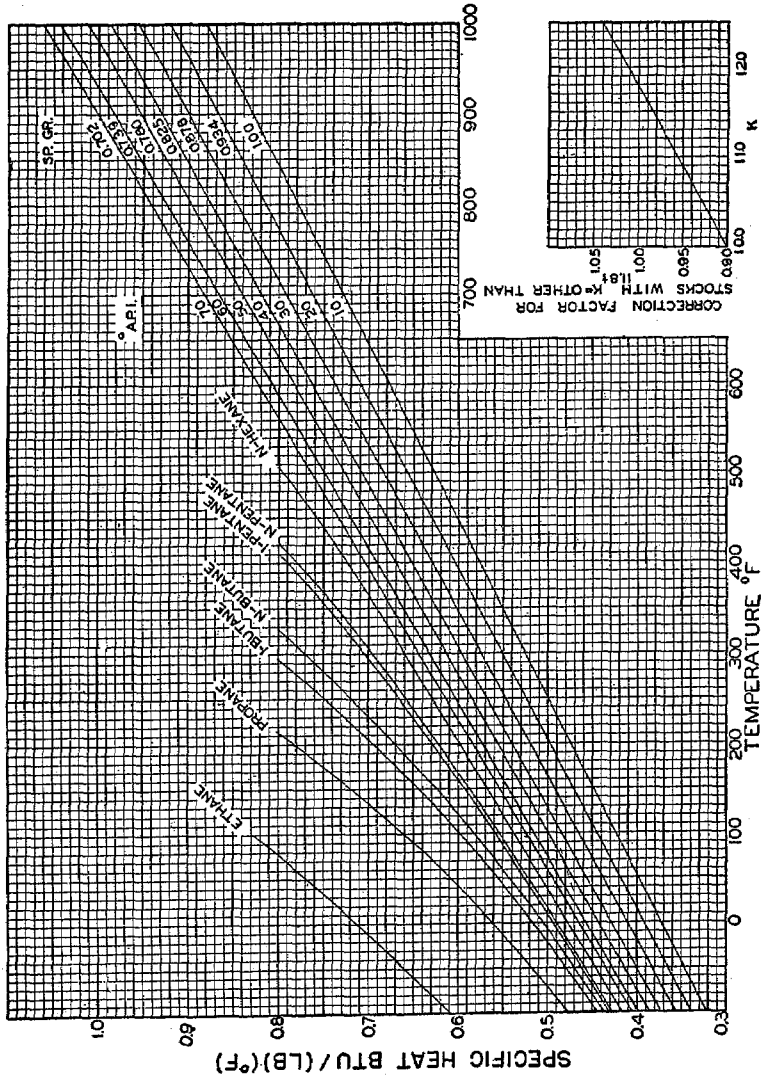


FIG. 4. Specific heats of hydrocarbon liquids. [*Holcomb and Brown, Ind. Eng. Chem.*, **34**, 595 (1942).]
† K = characterization factor.

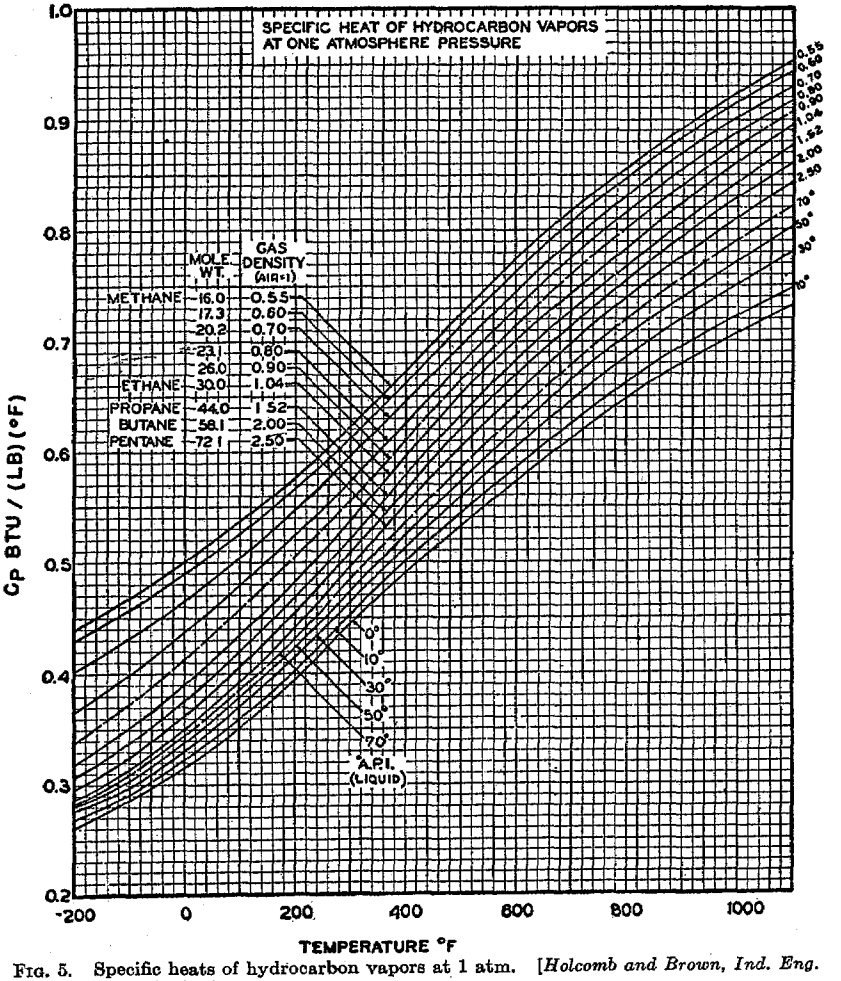


FIG. 5. Specific heats of hydrocarbon vapors at 1 atm. [*Holcomb and Brown, Ind. Eng. Chem.*, 34, 595 (1942).]

TABLE 6. SPECIFIC GRAVITIES AND MOLECULAR WEIGHTS OF LIQUIDS

Compound	Mol. wt.	s*	Compound	Mol. wt.	s*
Acetaldehyde	44.1	0.78	Ethyl iodide	155.9	1.93
Acetic acid, 100 %	60.1	1.05	Ethyl glycol	88.1	1.04
Acetic acid, 70 %	.....	1.07	Formic acid	46.0	1.22
Acetic anhydride	102.1	1.08	Glycerol, 100 %	92.1	1.26
Acetone	58.1	0.79	Glycerol, 50 %	.....	1.13
Allyl alcohol	58.1	0.86	*n*-Heptane	100.2	0.68
Ammonia, 100 %	17.0	0.61	*n*-Hexane	86.1	0.66
Ammonia, 26 %	.....	0.91	Isopropyl alcohol	60.1	0.79
Amyl acetate	130.2	0.88	Mercury	200.6	13.55
Amyl alcohol	88.2	0.81	Methanol, 100 %	32.5	0.79
Aniline	93.1	1.02	Methanol, 90 %	.....	0.82
Anisole	108.1	0.99	Methanol, 40 %	.....	0.94
Arsenic trichloride	181.3	2.16	Methyl acetate	74.9	0.93
Benzene	78.1	0.88	Methyl chloride	50.5	0.92
Brine, $CaCl_2$ 25 %	.....	1.23	Methyl ethyl ketone	72.1	0.81
Brine, NaCl 25 %	.....	1.19	Naphthalene	128.1	1.14
Bromotoluene, ortho	171.0	1.42	Nitric acid, 95 %	.....	1.50
Bromotoluene, meta	171.0	1.41	Nitric acid, 60 %	.....	1.38
Bromotoluene, para	171.0	1.39	Nitrobenzene	123.1	1.20
n-Butane	58.1	0.60	Nitrotoluene, ortho	137.1	1.16
i-Butane	58.1	0.60	Nitrotoluene, meta	137.1	1.16
Butyl acetate	116.2	0.88	Nitrotoluene, para	137.1	1.29
n-Butyl alcohol	74.1	0.81	*n*-Octane	114.2	0.70
i-Butyl alcohol	74.1	0.82	Octyl alcohol	130.23	0.82
n-Butyric acid	88.1	0.96	Pentachloroethane	202.3	1.67
i-Butyric acid	88.1	0.96	*n*-Pentane	72.1	0.63
Carbon dioxide	44.0	1.29	Phenol	94.1	1.07
Carbon disulfide	76.1	1.26	Phosphorus tribromide	270.8	2.85
Carbon tetrachloride	153.8	1.60	Phosphorus trichloride	137.4	1.57
Chlorobenzene	112.6	1.11	Propane	44.1	0.59
Chloroform	119.4	1.49	Propionic acid	74.1	0.99
Chlorosulfonic acid	116.5	1.77	*n*-Propyl alcohol	60.1	0.80
Chlorotoluene, ortho	126.6	1.08	*n*-Propyl bromide	123.0	1.35
Chlorotoluene, meta	126.6	1.07	*n*-Propyl chloride	78.5	0.89
Chlorotoluene, para	126.6	1.07	*n*-Propyl iodide	170.0	1.75
Cresol, meta	108.1	1.03	Sodium	23.0	0.97
Cyclohexanol	100.2	0.96	Sodium hydroxide, 50 %	.....	1.53
Dibromo methane	187.9	2.09	Stannic chloride	260.5	2.23
Dichloro ethane	99.0	1.17	Sulfur dioxide	64.1	1.38
Dichloro methane	88.9	1.34	Sulfuric acid, 100 %	98.1	1.83
Diethyl oxalate	146.1	1.08	Sulfuric acid, 98 %	.....	1.84
Dimethyl oxalate	118.1	1.42	Sulfuric acid, 60 %	.....	1.50
Diphenyl	154.2	0.99	Sulfuryl chloride	135.0	1.67
Dipropyl oxalate	174.1	1.02	Tetra chloroethane	167.9	1.60
Ethyl acetate	88.1	0.90	Tetra chloroethylene	165.9	1.63
Ethyl alcohol, 100 %	46.1	0.79	Titanium tetrachloride	189.7	1.73
Ethyl alcohol, 95 %	.....	0.81	Toluene	92.1	0.87
Ethyl alcohol, 40 %	.....	0.94	Trichloroethylene	131.4	1.46
Ethyl benzene	106.1	0.87	Vinyl acetate	86.1	0.93
Ethyl bromide	108.9	1.43	Water	18.0	1.0
Ethyl chloride	64.5	0.92	Xylene, ortho	106.1	0.87
Ethyl ether	74.1	0.71	Xylene, meta	106.1	0.86
Ethyl formate	74.1	0.92	Xylene, para	106.1	0.86

* At approximately 68°F. These values will be satisfactory, without extrapolation, for most engineering problems.

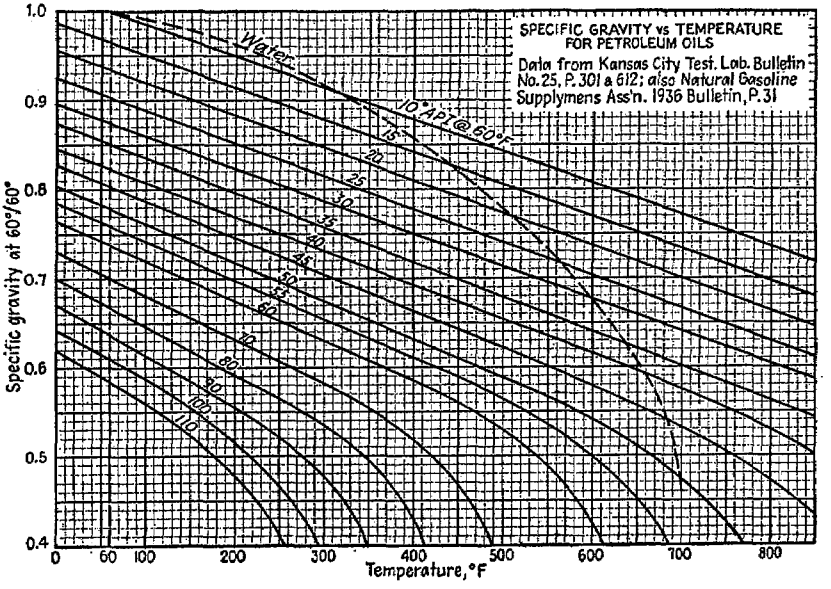


FIG. 6. Specific gravities of hydrocarbons.

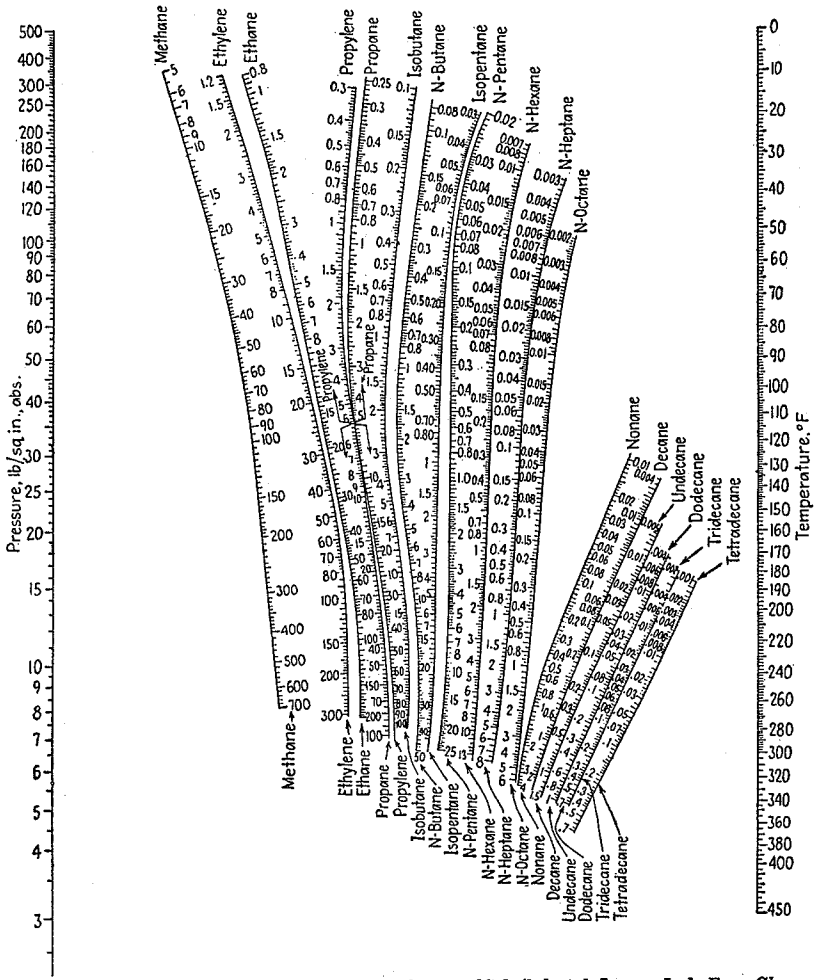


FIG. 7. Equilibrium constants for hydrocarbons. [*Scheibel and Jenny, Ind. Eng. Chem.*, **37**, 81 (1945).]

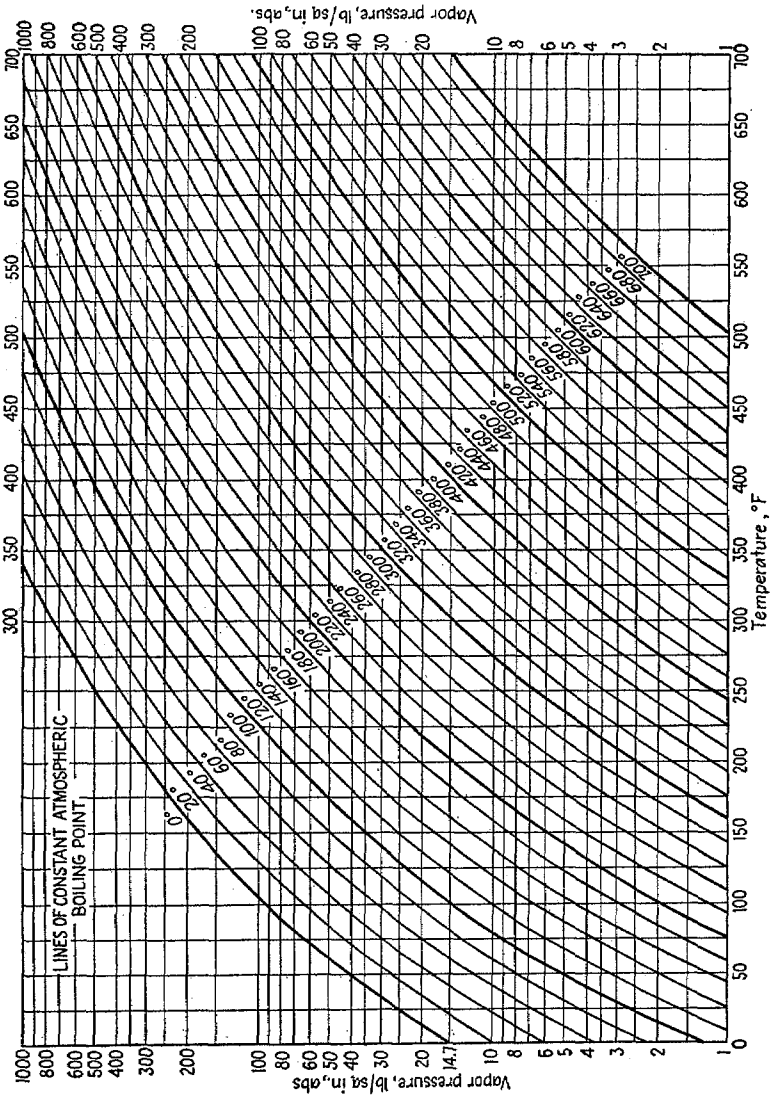


FIG. 8. Vapor pressures of hydrocarbons.

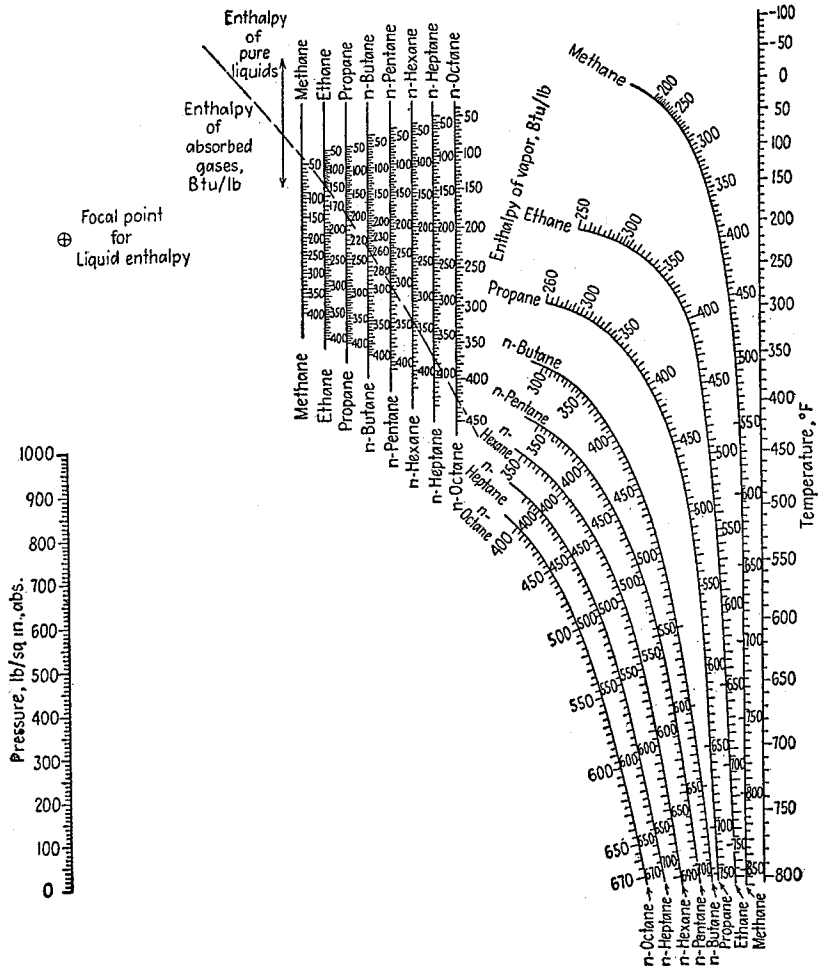


FIG. 9. Enthalpies of pure hydrocarbons. [*Scheibel and Jenny, Ind. Eng. Chem.*, **37**, 992 (1945).]

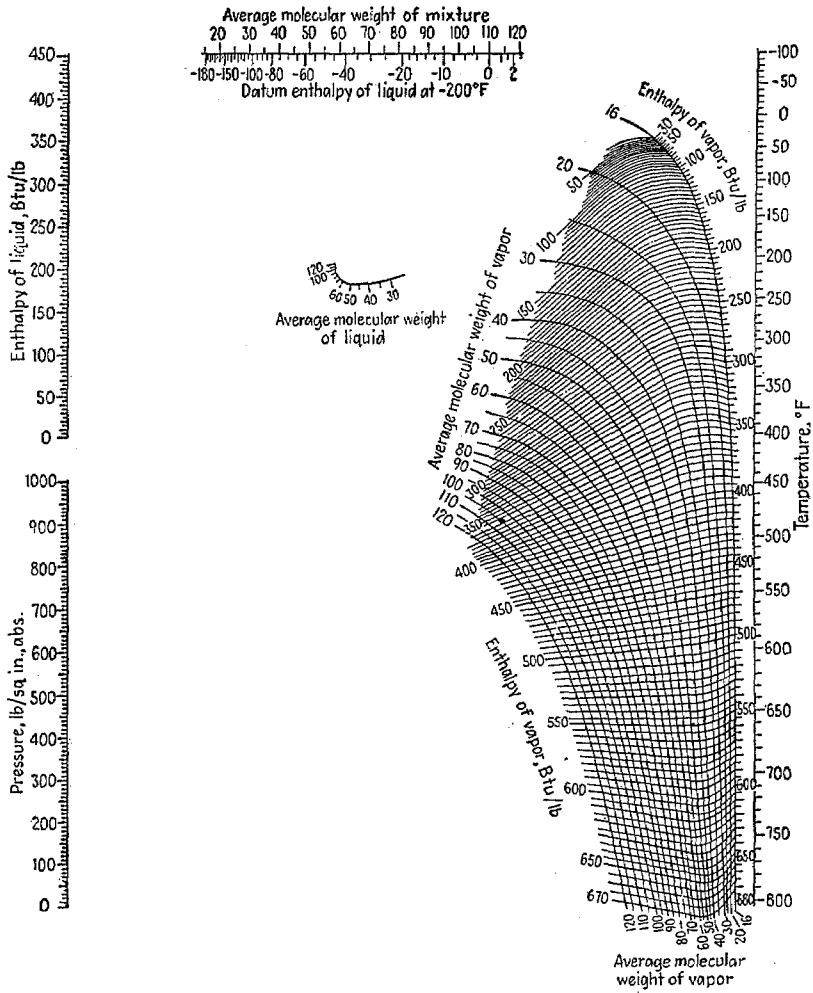


FIG. 10. Enthalpies of light hydrocarbons. [*Scheibel and Jenny, Ind. Eng. Chem.*, **37**, 993 (1945).]

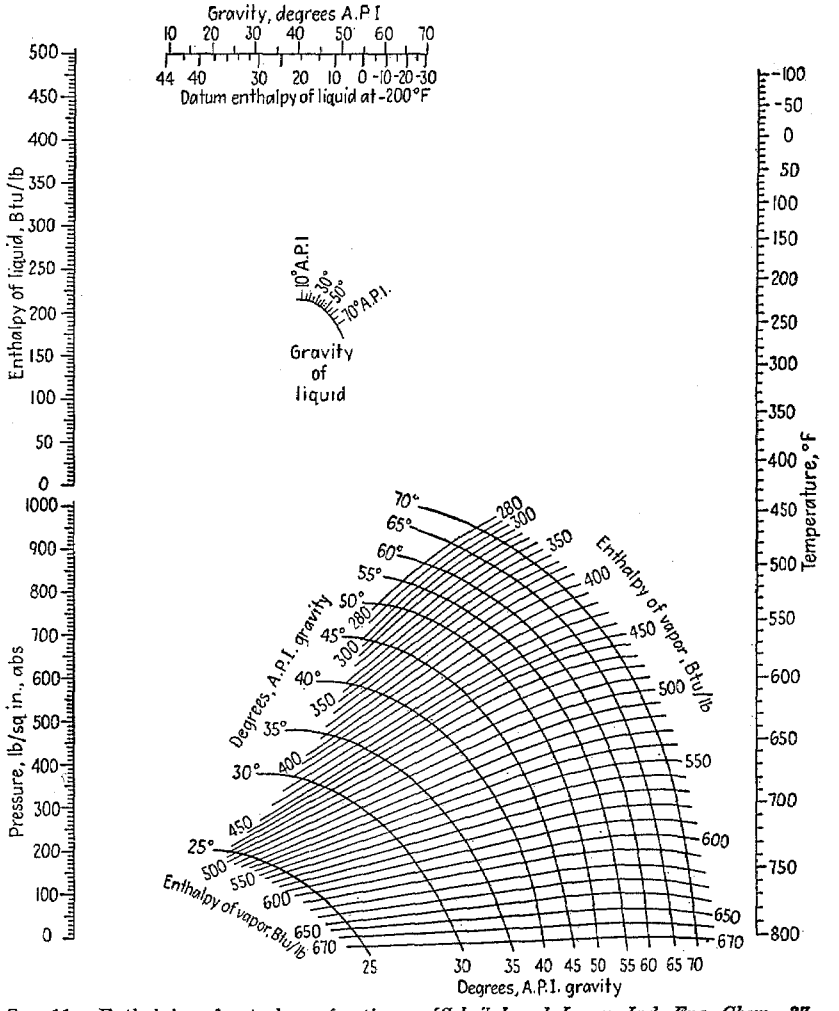
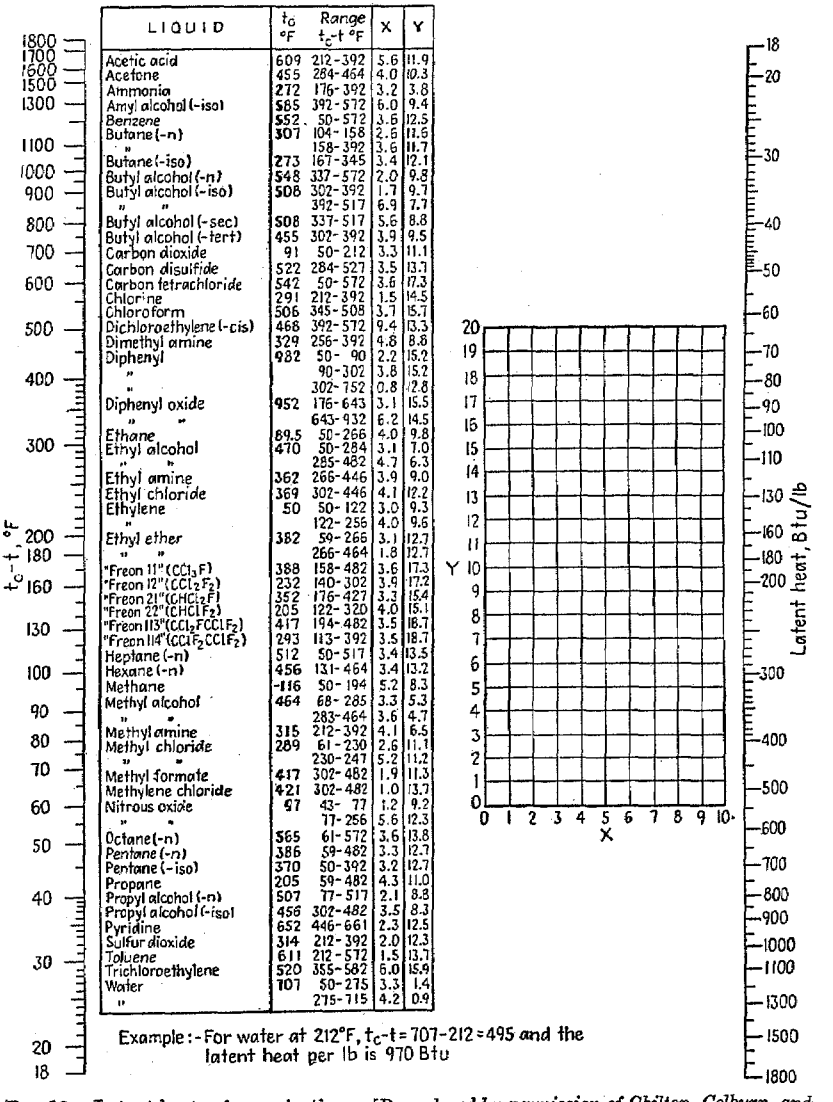


FIG. 11. Enthalpies of petroleum fractions. [*Scheibel and Jenny, Ind. Eng. Chem.*, **37**, 994 (1945).]



LIQUID	t_c °F	Range $t_c - t$ °F	X	Y
Acetic acid	609	212-392	5.6	11.9
Acetone	455	284-464	4.0	10.3
Ammonia	272	176-392	3.2	3.8
Amyl alcohol (-iso)	585	392-572	6.0	9.4
Benzene	552	50-572	3.6	12.5
Butane (-n)	307	104-158	2.6	11.6
"		158-392	3.6	11.7
Butane (-iso)	273	167-345	3.4	12.1
Butyl alcohol (-n)	548	337-572	2.0	9.8
Butyl alcohol (-iso)	508	302-392	1.7	9.7
" "		392-517	6.9	7.7
Butyl alcohol (-sec)	508	337-517	5.6	8.8
Butyl alcohol (-tert)	455	302-392	3.9	9.5
Carbon dioxide	91	50-212	3.3	11.1
Carbon disulfide	522	284-527	3.5	13.1
Carbon tetrachloride	542	50-572	3.6	17.3
Chlorine	291	212-392	1.5	14.5
Chloroform	506	345-508	3.7	15.7
Dichloroethylene (-cis)	468	392-572	9.4	13.3
Dimethyl amine	329	256-392	4.8	8.8
Diphenyl	982	50-90	2.2	16.2
"		90-302	3.8	15.2
"		302-752	0.8	12.8
Diphenyl oxide	952	176-643	3.1	15.5
" "		643-932	6.2	14.5
Ethane	89.5	50-266	4.0	9.8
Ethyl alcohol	470	50-284	3.1	7.0
" "		285-482	4.7	6.3
Ethyl amine	362	266-446	3.9	9.0
Ethyl chloride	369	302-446	4.1	12.2
Ethylene	50	50-122	3.0	9.3
"		122-256	4.0	9.6
Ethyl ether	382	59-266	3.1	12.7
" "		266-464	1.8	12.7
"Freon 11" (CCl_3F)	388	158-482	3.6	17.3
"Freon 12" (CCl_2F_2)	232	140-302	3.9	17.2
"Freon 21" ($CHCl_2F$)	352	176-427	3.3	15.4
"Freon 22" ($CHClF_2$)	205	122-320	4.0	15.1
"Freon 113" (CCl_2FCClF_2)	417	194-482	3.5	16.7
"Freon 114" ($CClF_2CClF_2$)	293	113-392	3.5	18.7
Heptane (-n)	512	50-517	3.4	13.5
Hexane (-n)	456	131-464	3.4	13.2
Methane	-116	50-194	5.2	8.3
Methyl alcohol	464	68-285	3.3	5.3
" "		283-464	3.6	4.7
Methyl amine	315	212-392	4.1	6.5
Methyl chloride	289	61-230	2.6	11.1
"		230-247	5.2	11.2
Methyl formate	417	302-482	1.9	11.3
Methylene chloride	421	302-482	1.0	13.7
Nitrous oxide	97	43-77	1.2	9.2
" "		77-266	5.6	12.3
Octane (-n)	565	61-572	3.6	13.8
Pentane (-n)	386	59-482	3.3	12.7
Pentane (-iso)	370	50-392	3.2	12.7
Propane	205	59-482	4.3	11.0
Propyl alcohol (-n)	507	77-517	2.1	8.8
Propyl alcohol (-iso)	456	302-482	3.5	8.3
Pyridine	652	446-661	2.3	12.5
Sulfur dioxide	314	212-392	2.0	12.3
Toluene	611	212-572	1.5	13.7
Trichloroethylene	520	355-582	6.0	15.9
Water	707	50-275	3.3	1.4
"		275-715	4.2	0.9

Example:- For water at 212°F, $t_c - t = 707 - 212 = 495$ and the latent heat per lb is 970 Btu

FIG. 12. **Latent heats of vaporization.** [*Reproduced by permission of Chilton, Colburn, and Vernon, personal communication (revised)* 1947.]

TABLE 7. THERMODYNAMIC PROPERTIES OF STEAM

*Dry saturated steam: pressure table**

Abs press, psi	Temp, °F	Specific volume		Enthalpy			Entropy			Internal energy		Abs press., psi
		Sat. liquid	Sat. vapor	Sat. liquid	Evap	Sat. vapor	Sat. liquid	Evap	Sat. vapor	Sat. liquid	Sat. vapor	
p	t	v_f	v_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g	u_f	u_g	p
1.0	101.74	0.01614	333.6	69.70	1036.3	1106.0	0.1326	1.8456	1.9782	69.70	1044.3	**1.0**
2.0	126.08	0.01623	173.73	93.99	1022.2	1116.2	0.1749	1.7451	1.9200	93.98	1051.9	**2.0**
3.0	141.48	0.01630	118.71	109.37	1013.2	1122.6	0.2008	1.6855	1.8863	109.36	1056.7	**3.0**
4.0	152.97	0.01636	90.63	120.86	1006.4	1127.3	0.2198	1.6427	1.8625	120.85	1060.2	**4.0**
5.0	162.24	0.01640	73.52	130.13	1001.0	1131.1	0.2347	1.6094	1.8441	130.12	1063.1	**5.0**
6.0	170.06	0.01645	61.98	137.96	996.2	1134.2	0.2472	1.5820	1.8292	137.94	1065.4	**6.0**
7.0	176.85	0.01649	53.64	144.76	992.1	1136.9	0.2581	1.5586	1.8167	144.74	1067.4	**7.0**
8.0	182.86	0.01653	47.34	150.79	988.5	1139.3	0.2674	1.5383	1.8057	150.77	1059.2	**8.0**
9.0	188.28	0.01656	42.40	156.22	985.2	1141.4	0.2759	1.5203	1.7962	156.19	1070.8	**9.0**
10	193.21	0.01659	38.42	161.17	982.1	1143.3	0.2835	1.5041	1.7876	161.14	1072.2	**10**
14.696	212.00	0.01672	26.80	180.07	970.3	1150.4	0.3120	1.4446	1.7566	180.02	1077.5	**14.696**
15	213.03	0.01672	26.29	181.11	969.7	1150.8	0.3135	1.4415	1.7549	181.06	1077.8	**15**
20	227.96	0.01683	20.089	196.16	960.1	1156.3	0.3356	1.3962	1.7319	196.10	1081.9	**20**
25	240.07	0.01692	16.303	208.42	952.1	1160.6	0.3533	1.3606	1.7139	208.34	1085.1	**25**
30	250.33	0.01701	13.746	218.82	945.3	1164.1	0.3680	1.3313	1.6993	218.73	1087.8	**30**
35	259.28	0.01708	11.898	227.91	939.2	1167.1	0.3807	1.3063	1.6870	227.80	1090.1	**35**
40	267.25	0.01715	10.498	236.03	933.7	1169.7	0.3919	1.2844	1.6763	235.90	1092.0	**40**
45	274.44	0.01721	9.401	243.36	928.6	1172.0	0.4019	1.2650	1.6669	243.22	1093.7	**45**
50	281.01	0.01727	8.515	250.09	924.0	1174.1	0.4110	1.2474	1.6585	249.93	1095.3	**50**
55	287.07	0.01732	7.787	256.30	919.6	1175.9	0.4193	1.2316	1.6509	256.12	1096.7	**55**
60	292.71	0.01738	7.175	262.09	915.5	1177.6	0.4270	1.2168	1.6438	261.90	1097.9	**60**
65	297.97	0.01743	6.655	267.50	911.6	1179.1	0.4342	1.2032	1.6374	267.29	1099.1	**65**
70	302.92	0.01748	6.206	272.61	907.9	1180.6	0.4409	1.1906	1.6315	272.38	1100.2	**70**
75	307.60	0.01753	5.816	277.43	904.5	1181.9	0.4472	1.1787	1.6259	277.19	1101.2	**75**
80	312.03	0.01757	5.472	282.02	901.1	1183.1	0.4531	1.1676	1.6207	281.76	1102.1	**80**
85	316.25	0.01761	5.168	286.39	897.8	1184.2	0.4587	1.1571	1.6158	286.11	1102.9	**85**
90	320.27	0.01766	4.896	290.56	894.7	1185.3	0.4641	1.1471	1.6112	290.27	1103.7	**90**
95	324.12	0.01770	4.652	294.56	891.7	1186.2	0.4692	1.1376	1.6068	294.25	1104.5	**95**
100	327.81	0.01774	4.432	298.40	888.8	1187.2	0.4740	1.1286	1.6026	298.08	1105.2	**100**
110	334.77	0.01782	4.049	305.66	883.2	1188.9	0.4832	1.1117	1.5948	305.30	1106.5	**110**
120	341.25	0.01789	3.728	312.44	877.9	1190.4	0.4916	1.0962	1.5878	312.05	1107.6	**120**
130	347.32	0.01796	3.455	318.81	879.9	1191.7	0.4995	1.0817	1.5812	318.38	1108.6	**130**
140	353.02	0.01802	3.220	324.82	868.2	1193.0	0.5069	1.0682	1.5751	324.35	1109.6	**140**
150	358.42	0.01809	3.015	330.51	863.6	1194.1	0.5138	1.0556	1.5694	330.01	1110.5	**150**
160	363.53	0.01815	2.834	335.93	859.2	1195.1	0.5204	1.0436	1.5640	335.39	1111.2	**160**
170	368.41	0.01822	2.675	341.09	854.9	1196.0	0.5266	1.0324	1.5590	340.52	1111.9	**170**
180	373.06	0.01827	2.532	346.03	850.8	1196.9	0.5325	1.0217	1.5542	345.42	1112.5	**180**
190	377.51	0.01833	2.404	350.79	846.8	1197.6	0.5381	1.0116	1.5497	350.15	1113.1	**190**
200	381.79	0.01839	2.288	355.36	843.0	1198.4	0.5435	1.0018	1.5453	354.68	1113.7	**200**
250	400.95	0.01865	1.8438	376.00	825.1	1201.1	0.5675	0.9588	1.5263	375.14	1115.8	**250**
300	417.33	0.01890	1.5433	393.84	809.0	1202.8	0.5879	0.9225	1.5104	392.79	1117.1	**300**
350	431.72	0.01913	1.3260	409.69	794.2	1203.9	0.6056	0.8910	1.4966	408.45	1118.0	**350**
400	444.59	0.0193	1.1613	424.0	780.5	1204.5	0.6214	0.8630	1.4844	422.6	1118.5	**400**
450	456.28	0.0195	1.0320	437.2	767.4	1204.6	0.6356	0.8378	1.4734	435.5	1118.7	**450**
500	467.01	0.0197	0.9278	449.4	755.0	1204.4	0.6487	0.8147	1.4634	447.6	1118.6	**500**
550	476.94	0.0199	0.8424	460.8	743.1	1203.9	0.6608	0.7934	1.4542	458.8	1118.2	**550**
600	486.21	0.0201	0.7698	471.6	731.6	1203.2	0.6720	0.7734	1.4454	469.4	1117.7	**600**
650	494.90	0.0203	0.7083	481.8	720.5	1202.3	0.6826	0.7548	1.4374	479.4	1117.1	**650**
700	503.10	0.0205	0.6554	491.5	709.7	1201.2	0.6925	0.7371	1.4296	488.8	1116.3	**700**
750	510.86	0.0207	0.6092	500.8	699.2	1200.0	0.7019	0.7204	1.4223	598.0	1115.4	**750**
800	518.23	0.0209	0.5687	509.7	688.9	1198.6	0.7108	0.7045	1.4153	506.6	1114.4	**800**
850	525.26	0.0210	0.5327	518.3	678.8	1197.1	0.7194	0.6891	1.4085	515.0	1113.3	**850**
900	531.98	0.0212	0.5006	526.6	668.8	1195.4	0.7275	0.6744	1.4020	523.1	1112.1	**900**
950	538.43	0.0214	0.4717	534.6	659.1	1193.7	0.7355	0.6602	1.3957	530.9	1110.8	**950**
1000	544.61	0.0216	0.4456	542.4	649.4	1191.8	0.7430	0.6467	1.3897	538.4	1109.4	**1000**
1100	556.31	0.0220	0.4001	557.4	630.4	1187.8	0.7575	0.6205	1.3780	552.9	1106.4	**1100**
1200	567.22	0.0223	0.3619	571.7	611.7	1183.4	0.7711	0.5956	1.3667	566.7	1103.0	**1200**
1300	577.46	0.0227	0.3293	585.4	593.2	1178.6	0.7840	0.5719	1.3559	580.0	1099.4	**1300**
1400	587.10	0.0231	0.3012	598.7	574.7	1173.4	0.7963	0.5491	1.3454	592.7	1095.4	**1400**
1500	596.23	0.0235	0.2765	611.6	556.3	1167.9	0.8082	0.5269	1.3351	605.1	1091.2	**1500**
2000	635.82	0.0257	0.1878	671.7	463.4	1135.1	0.8619	0.4230	1.2849	662.2	1065.6	**2000**
2500	668.13	0.0287	0.1307	730.6	360.5	1091.1	0.9126	0.3197	1.2322	717.3	1030.6	**2500**
3000	695.36	0.0346	0.0858	802.5	217.8	1020.3	0.9731	0.1885	1.1615	783.4	972.7	**3000**
3206.2	705.40	0.0503	0.0503	902.7	0	902.7	1.0580	0	1.0580	872.9	872.9	**3206.2**

* Abridged "Thermodynamic Properties of Steam" by Joseph H. Keenan and Frederick G. Keyes, John Wiley & Sons, Inc., New York, 1937.

TABLE 7. THERMODYNAMIC PROPERTIES OF STEAM.—(*Continued*)
Dry saturated steam: temperature table*

Temp., °F	Abs press., psi	Specific volume			Enthalpy			Entropy			Temp., °F
		Sat. liquid	Evap.	Sat. vapor	Sat. liquid	Evap.	Sat. vapor	Sat. liquid	Evap.	Sat. vapor	
t	p	v_f	v_{fg}	v_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g	t
32	0.08854	0.01602	3306	3306	0.00	1075.8	1075.8	0.0000	2.1877	2.1877	32
35	0.09995	0.01602	2947	2947	3.02	1074.1	1077.1	0.0061	2.1709	2.1770	35
40	0.12170	0.01602	2444	2444	8.05	1071.3	1079.3	0.0162	2.1435	2.1597	40
45	0.14752	0.01602	2036.4	2036.4	13.06	1068.4	1081.5	0.0262	2.1167	2.1429	45
50	0.17811	0.01603	1703.2	1703.2	18.07	1065.6	1083.7	0.0361	2.0903	2.1264	50
60	0.2563	0.01604	1206.6	1206.7	28.06	1059.9	1088.0	0.0555	2.0393	2.0948	60
70	0.3631	0.01606	867.8	867.9	38.04	1054.3	1092.3	0.0745	1.9902	2.0647	70
80	0.5069	0.01608	633.1	633.1	48.02	1048.6	1096.6	0.0932	1.9428	2.0360	80
90	0.6982	0.01610	468.0	468.0	57.99	1042.9	1100.9	0.1115	1.8972	2.0087	90
100	0.9492	0.01613	350.3	350.4	67.97	1037.2	1105.2	0.1295	1.8531	1.9826	100
110	1.2748	0.01617	265.3	265.4	77.94	1031.6	1109.5	0.1471	1.8106	1.9577	110
120	1.6924	0.01620	203.25	203.27	87.92	1025.8	1113.7	0.1645	1.7694	1.9339	120
130	2.2225	0.01625	157.32	157.34	97.90	1020.0	1117.9	0.1816	1.7296	1.9112	130
140	2.8886	0.01629	122.99	123.01	107.89	1014.1	1122.0	0.1984	1.6910	1.8894	140
150	3.718	0.01634	98.06	97.07	117.89	1008.2	1126.1	0.2149	1.6537	1.8685	150
160	4.741	0.01639	77.27	77.29	127.89	1002.3	1130.2	0.2311	1.6174	1.8485	160
170	5.992	0.01645	62.04	62.06	137.90	996.3	1134.2	0.2472	1.5822	1.8293	170
180	7.510	0.01651	50.21	50.23	147.92	990.2	1138.1	0.2630	1.5480	1.8109	180
190	9.339	0.01657	40.94	40.96	157.95	984.1	1142.0	0.2785	1.5147	1.7932	190
200	11.526	0.01663	33.62	33.64	167.99	977.9	1145.9	0.2938	1.4824	1.7762	200
210	14.123	0.01670	27.80	27.82	178.05	971.6	1149.7	0.3090	1.4508	1.7598	210
212	14.696	0.01672	26.78	26.80	180.07	970.3	1150.4	0.3120	1.4446	1.7566	212
220	17.186	0.01677	23.13	23.15	188.13	965.2	1153.4	0.3239	1.4201	1.7440	220
230	20.780	0.01684	19.365	19.382	198.23	958.8	1157.0	0.3387	1.3901	1.7288	230
240	24.969	0.01692	16.306	16.323	208.34	952.2	1160.5	0.3531	1.3609	1.7140	240
250	29.825	0.01700	13.804	13.821	216.48	945.5	1164.0	0.3675	1.3323	1.6998	250
260	35.429	0.01709	11.746	11.763	228.64	938.7	1167.3	0.3817	1.3043	1.6860	260
270	41.858	0.01717	10.044	10.061	238.84	931.8	1170.6	0.3958	1.2769	1.6727	270
280	49.203	0.01726	8.628	8.645	249.06	924.7	1173.8	0.4096	1.2501	1.6597	280
290	57.556	0.01735	7.444	7.461	259.31	917.5	1176.8	0.4234	1.2238	1.6472	290
300	67.013	0.01745	6.449	6.466	269.59	910.1	1179.7	0.4369	1.1980	1.6350	300
310	77.68	0.01755	5.609	5.626	279.92	902.6	1182.5	0.4504	1.1727	1.6231	310
320	89.66	0.01765	4.896	4.914	290.28	894.9	1185.2	0.4637	1.1478	1.6115	320
330	103.06	0.01776	4.289	4.307	300.68	887.0	1187.7	0.4769	1.1233	1.6002	330
340	118.01	0.01787	3.770	3.788	311.13	879.0	1190.1	0.4900	1.0992	1.5891	340
350	134.63	0.01799	3.324	3.342	321.63	870.7	1192.3	0.5029	1.0754	1.5783	350
360	153.04	0.01811	2.939	2.957	332.18	862.2	1194.4	0.5158	1.0519	1.5677	360
370	173.37	0.01823	2.606	2.625	342.79	853.5	1196.3	0.5286	1.0287	1.5573	370
380	195.77	0.01836	2.317	2.335	353.45	844.6	1198.1	0.5413	1.0059	1.5471	380
390	220.37	0.01850	2.0651	2.0836	364.17	835.4	1199.6	0.5539	0.9832	1.5371	390
400	247.31	0.01864	1.8447	1.8633	374.97	826.0	1201.0	0.5664	0.9608	1.5272	400
410	276.75	0.01878	1.6512	1.6700	385.83	816.3	1202.1	0.5788	0.9386	1.5174	410
420	308.83	0.01894	1.4811	1.5000	396.77	806.3	1203.1	0.5912	0.9166	1.5078	420
430	343.72	0.01910	1.3308	1.3499	407.79	796.0	1203.8	0.6035	0.8947	1.4982	430
440	381.59	0.01926	1.1979	1.2171	418.90	785.4	1204.3	0.6158	0.8730	1.4887	440
450	422.6	0.0194	1.0799	1.0993	430.1	774.5	1204.6	0.6280	0.8513	1.4793	450
460	466.9	0.0196	0.9748	0.9944	441.4	763.2	1204.6	0.6402	0.8298	1.4700	460
470	514.7	0.0198	0.8811	0.9009	452.8	751.5	1204.3	0.6523	0.8083	1.4606	470
480	566.1	0.0200	0.7972	0.8172	464.4	739.4	1203.7	0.6645	0.7868	1.4513	480
490	621.4	0.0202	0.7221	0.7423	476.0	726.8	1202.8	0.6766	0.7653	1.4419	490
500	680.8	0.0204	0.6545	0.6749	487.8	713.9	1201.7	0.6887	0.7438	1.4325	500
520	812.4	0.0209	0.5385	0.5594	511.9	686.4	1198.2	0.7130	0.7006	1.4136	520
540	962.5	0.0215	0.4434	0.4649	536.6	656.6	1193.2	0.7374	0.6568	1.3942	540
560	1133.1	0.0221	0.3647	0.3868	562.2	624.2	1186.4	0.7621	0.6121	1.3742	560
580	1325.8	0.0228	0.2989	0.3217	588.9	588.4	1177.3	0.7872	0.5659	1.3532	580
600	1542.9	0.0236	0.2432	0.2668	617.0	548.5	1165.5	0.8131	0.5176	1.3307	600
620	1786.6	0.0247	0.1955	0.2201	646.7	503.6	1150.3	0.8398	0.4664	1.3062	620
640	2059.7	0.0260	0.1538	0.1798	678.6	452.0	1130.5	0.8679	0.4110	1.2789	640
660	2365.4	0.0278	0.1165	0.1442	714.2	390.2	1104.4	0.8987	0.3485	1.2472	660
680	2708.1	0.0305	0.0810	0.1115	757.3	309.9	1067.2	0.9351	0.2719	1.2071	680
700	3093.7	0.0369	0.0392	0.0761	823.3	172.1	995.4	0.9905	0.1484	1.1389	700
705.4	3206.2	0.0503	0	0.0503	902.7	0	902.7	1.0580	0	1.0580	705.4

* Abridged from "Thermodynamic Properties of Steam" by Joseph H. Keenan and Frederick G. Keyes, John Wiley & Sons, Inc., New York.

TABLE 7. THERMODYNAMIC PROPERTIES OF STEAM.—(*Continued*)
Properties of superheated steam*

Abs press., psi (sat temp)		Temp, °F												
		200	300	400	500	600	700	800	900	1000	1100	1200	1400	1600
	v	392.6	452.3	512.0	571.6	631.2	690.8	750.4	809.9	869.5	929.1	988.7	1107.8	1227.0
1	*h*	1150.4	1195.8	1241.7	1288.3	1335.7	1383.8	1432.8	1482.7	1533.5	1585.2	1637.7	1745.7	1857.5
(101.74)	*s*	2.0512	2.1153	2.1720	2.2233	2.2702	2.3137	2.3542	2.3923	2.4283	2.4625	2.4952	2.5566	2.6137
	v	78.16	90.25	102.26	114.22	126.16	138.10	150.03	161.95	173.87	185.79	197.71	221.6	245.4
5	*h*	1148.8	1195.0	1241.2	1288.0	1335.4	1383.6	1432.7	1482.6	1533.4	1585.1	1637.7	1745.7	1857.4
(162.24)	*s*	1.8718	1.9370	1.9942	2.0456	2.0927	2.1361	2.1767	2.2148	2.2509	2.2851	2.3178	2.3792	2.4363
	v	38.85	45.00	51.04	57.05	63.03	69.01	74.98	80.95	86.92	92.88	98.84	110.77	122.69
10	*h*	1146.6	1193.9	1240.6	1287.5	1335.1	1383.4	1432.5	1482.4	1533.2	1585.0	1637.6	1745.6	1857.3
(193.21)	*s*	1.7927	1.8595	1.9172	1.9689	2.0160	2.0596	2.1002	2.1383	2.1744	2.2086	2.2413	2.3028	2.3598
	v	.....	30.53	34.68	38.78	42.86	46.94	51.00	55.07	59.13	63.19	67.25	75.37	83.48
14.696	*h*	.....	1192.8	1239.9	1287.1	1334.8	1383.2	1432.3	1482.3	1533.1	1584.8	1637.5	1745.5	1857.3
(212.00)	*s*	.....	1.8160	1.8743	1.9261	1.9734	2.0170	2.0576	2.0958	2.1319	2.1662	2.1989	2.2603	2.3174
	v	.....	22.36	25.43	28.46	31.47	34.47	37.46	40.45	43.44	46.42	49.41	55.37	61.34
20	*h*	.....	1191.6	1239.2	1286.6	1334.4	1382.9	1432.1	1482.1	1533.0	1584.7	1637.4	1745.4	1857.2
(227.96)	*s*	.....	1.7808	1.8396	1.8918	1.9392	1.9829	2.0235	2.0618	2.0978	2.1321	2.1648	2.2263	2.2834
	v	.....	11.040	12.628	14.168	15.688	17.198	18.702	20.20	21.70	23.20	24.69	27.68	30.66
40	*h*	.....	1186.8	1236.5	1284.8	1333.1	1381.9	1431.3	1481.4	1532.4	1584.3	1637.0	1745.1	1857.0
(267.25)	*s*	.....	1.6994	1.7608	1.8140	1.8619	1.9058	1.9467	1.9850	2.0212	2.0555	2.0883	2.1498	2.2069
	v	.....	7.259	8.357	9.403	10.427	11.441	12.449	13.452	14.454	15.453	16.451	18.446	20.44
60	*h*	.....	1181.6	1233.6	1283.0	1331.8	1380.9	1430.5	1480.8	1531.9	1583.8	1636.6	1744.8	1856.7
(292.71)	*s*	.....	1.6492	1.7135	1.7678	1.8162	1.8605	1.9015	1.9400	1.9762	2.0106	2.0434	2.1049	2.1621
	v	.....	.....	6.220	7.020	7.797	8.562	9.322	10.077	10.830	11.582	12.332	13.830	15.325
80	*h*	.....	.....	1230.7	1281.1	1330.5	1379.9	1429.7	1480.1	1531.3	1583.4	1636.2	1744.5	1856.5
(312.03)	*s*	.....	.....	1.6791	1.7346	1.7836	1.8281	1.8694	1.9079	1.9442	1.9787	2.0115	2.0731	2.1303
	v	.....	.....	4.937	5.589	6.218	6.835	7.446	8.052	8.656	9.259	9.860	11.060	12.258
100	*h*	.....	.....	1227.6	1279.1	1329.1	1378.9	1428.9	1479.5	1530.8	1582.9	1635.7	1744.2	1856.2
(327.81)	*s*	.....	.....	1.6518	1.7085	1.7581	1.8029	1.8443	1.8829	1.9193	1.9538	1.9867	2.0484	2.1056
	v	.....	.....	4.081	4.636	5.165	5.683	6.195	6.702	7.207	7.710	8.212	9.214	10.213
120	*h*	.....	.....	1224.4	1277.2	1327.7	1377.8	1428.1	1478.8	1530.2	1582.4	1635.3	1743.9	1856.0
(341.25)	*s*	.....	.....	1.6287	1.6869	1.7370	1.7822	1.8237	1.8625	1.8990	1.9335	1.9664	2.0281	2.0854
	v	.....	.....	3.468	3.954	4.413	4.861	5.301	5.738	6.172	6.604	7.035	7.895	8.752
140	*h*	.....	.....	1221.1	1275.2	1326.4	1376.8	1427.3	1478.2	1529.7	1581.9	1634.9	1743.5	1855.7
(353.02)	*s*	.....	.....	1.6087	1.6683	1.7190	1.7645	1.8063	1.8451	1.8817	1.9163	1.9493	2.0110	2.0683
	v	.....	.....	3.008	3.443	3.849	4.244	4.631	5.015	5.396	5.775	6.152	6.906	7.656
160	*h*	.....	.....	1217.6	1273.1	1325.0	1375.7	1426.4	1477.5	1529.1	1581.4	1634.5	1743.2	1855.5
(363.53)	*s*	.....	.....	1.5905	1.6519	1.7033	1.7491	1.7911	1.8301	1.8667	1.9014	1.9344	1.9962	2.0535
	v	.....	.....	2.649	3.044	3.411	3.764	4.110	4.452	4.792	5.129	5.466	6.136	6.804
180	*h*	.....	.....	1214.0	1271.0	1323.5	1374.7	1425.6	1476.8	1528.6	1581.0	1634.1	1742.9	1855.2
(373.06)	*s*	.....	.....	1.5745	1.6373	1.6894	1.7355	1.7776	1.8167	1.8534	1.8882	1.9212	1.9831	2.0404
	v	.....	.....	2.361	2.726	3.060	3.380	3.693	4.002	4.309	4.613	4.917	5.521	6.123
200	*h*	.....	.....	1210.3	1268.9	1322.1	1373.6	1424.8	1476.2	1528.0	1580.5	1633.7	1742.6	1855.0
(381.79)	*s*	.....	.....	1.5594	1.6240	1.6767	1.7232	1.7655	1.8048	1.8415	1.8763	1.9094	1.9718	2.0287
	v	.....	.....	2.125	2.465	2.772	3.066	3.352	3.634	3.913	4.191	4.467	5.017	5.565
220	*h*	.....	.....	1206.5	1266.7	1320.7	1372.0	1424.0	1475.5	1527.5	1580.0	1633.3	1742.3	1854.7
(389.86)	*s*	.....	.....	1.5453	1.6117	1.6652	1.7120	1.7545	1.7939	1.8308	1.8656	1.8987	1.9607	2.0181
	v	.....	.....	1.9276	2.247	2.533	2.804	3.068	3.327	3.584	3.839	4.093	4.597	5.100
240	*h*	.....	.....	1202.5	1264.5	1319.2	1371.5	1423.2	1474.8	1526.9	1579.6	1632.9	1742.0	1854.5
(397.37)	*s*	.....	.....	1.5219	1.6003	1.6546	1.7017	1.7444	1.7839	1.8209	1.8558	1.8889	1.9510	2.0084
	v	.....	.....	.....	2.063	2.330	2.582	2.827	3.067	3.305	3.541	3.776	4.242	4.707
260	*h*	.....	.....	.....	1262.3	1317.7	1370.4	1422.3	1474.2	1526.3	1579.1	1632.5	1741.7	1854.2
(404.42)	*s*	.....	.....	.....	1.5897	1.6447	1.6922	1.7352	1.7748	1.8118	1.8467	1.8799	1.9420	1.9995
	v	.....	.....	.....	1.9047	2.156	2.392	2.621	2.845	3.066	3.286	3.504	3.938	4.370
280	*h*	.....	.....	.....	1260.0	1316.2	1369.4	1421.5	1473.5	1525.8	1578.6	1632.1	1741.4	1854.0
(411.05)	*s*	.....	.....	.....	1.5796	1.6354	1.6834	1.7265	1.7662	1.8033	1.8383	1.8716	1.9337	1.9912
	v	.....	.....	.....	1.7675	2.005	2.227	2.442	2.652	2.859	3.065	3.269	3.674	4.078
300	*h*	.....	.....	.....	1257.6	1314.7	1368.3	1420.6	1472.8	1525.2	1578.1	1631.7	1741.0	1853.7
(417.33)	*s*	.....	.....	.....	1.5701	1.6268	1.6751	1.7184	1.7582	1.7954	1.8305	1.8638	1.9260	1.9835
	v	.....	.....	.....	1.4923	1.7036	1.8980	2.084	2.266	2.445	2.622	2.798	3.147	3.493
350	*h*	.....	.....	.....	1251.5	1310.9	1365.5	1418.5	1471.1	1523.8	1577.0	1630.7	1740.3	1853.1
(431.72)	*s*	.....	.....	.....	1.5481	1.6070	1.6563	1.7002	1.7403	1.7777	1.8130	1.8463	1.9086	1.9663
	v	.....	.....	.....	1.2851	1.4770	1.6508	1.8161	1.9767	2.134	2.290	2.445	2.751	3.055
400	*h*	.....	.....	.....	1245.1	1306.9	1362.7	1416.4	1469.4	1522.4	1575.8	1629.6	1739.5	1852.5
(444.59)	*s*	.....	.....	.....	1.5281	1.5894	1.6398	1.6842	1.7247	1.7623	1.7977	1.8311	1.8936	1.9513

* Abridged from "Thermodynamic Properties of Steam," by Joseph H. Keenan and Frederick G. Keyes, John Wiley & Sons, Inc., New York, 1937.

TABLE 7. THERMODYNAMIC PROPERTIES OF STEAM.—(*Continued*)
Properties of superheated steam*

Abs Press., psi (sat temp)		Temp, °F													
		500	550	600	620	640	660	680	700	800	900	1000	1200	1400	1600
	v	1.1231	1.2155	1.3005	1.3332	1.3652	1.3967	1.4278	1.4584	1.6074	1.7516	1.8928	2.170	2.443	2.714
450	h	1238.4	1272.0	1302.8	1314.6	1326.2	1337.5	1348.8	1359.9	1414.3	1467.7	1521.0	1628.6	1738.7	1851.9
(456.28)	s	1.5095	1.5437	1.5735	1.5845	1.5951	1.6054	1.6153	1.6250	1.6699	1.7108	1.7486	1.8177	1.8803	1.9381
	v	0.9927	1.0800	1.1591	1.1893	1.2188	1.2478	1.2763	1.3044	1.4405	1.5715	1.6996	1.9504	2.197	2.442
500	h	1231.3	1266.8	1298.6	1310.7	1322.6	1334.2	1345.7	1357.0	1412.1	1466.0	1519.6	1627.6	1737.9	1851.3
(467.01)	s	1.4919	1.5280	1.5588	1.5701	1.5810	1.5915	1.6016	1.6115	1.6571	1.6982	1.7363	1.8056	1.8683	1.9262
	v	0.8852	0.9686	1.0431	1.0714	1.0989	1.1259	1.1523	1.1783	1.3038	1.4241	1.5414	1.7708	1.9957	2.219
550	h	1223.7	1261.2	1294.3	1306.8	1318.9	1330.8	1342.5	1354.0	1409.9	1464.3	1518.2	1626.6	1737.1	1850.6
(476.94)	s	1.4751	1.5131	1.5451	1.5568	1.5680	1.5787	1.5890	1.5991	1.6452	1.6868	1.7250	1.7946	1.8575	1.9155
	v	0.7947	0.8753	0.9463	0.9729	0.9988	1.0241	1.0489	1.0732	1.1899	1.3013	1.4096	1.6208	1.8279	2.033
600	h	1215.7	1255.5	1289.9	1302.7	1315.2	1327.4	1339.3	1351.1	1407.7	1462.5	1516.7	1625.5	1736.3	1850.0
(486.21)	s	1.4586	1.4990	1.5323	1.5443	1.5558	1.5667	1.5773	1.5875	1.6343	1.6762	1.7147	1.7846	1.8476	1.9056
	v	.....	0.7277	0.7934	0.8177	0.8411	0.8639	0.8860	0.9077	1.0108	1.1082	1.2024	1.3853	1.5641	1.7405
700	h	.....	1243.2	1280.6	1294.3	1307.5	1320.3	1332.8	1345.0	1403.2	1459.0	1515.9	1623.5	1734.8	1848.8
(503.10)	s	.....	1.4722	1.5084	1.5212	1.5333	1.5449	1.5559	1.5665	1.6147	1.6573	1.6963	1.7666	1.8299	1.8881
	v	.....	0.6154	0.6779	0.7006	0.7223	0.7433	0.7635	0.7833	0.8763	0.9633	1.0470	1.2088	1.3662	1.5214
800	h	.....	1229.8	1270.7	1285.4	1299.4	1312.9	1325.9	1338.6	1398.6	1455.4	1511.0	1621.4	1733.2	1847.5
(518.23)	s	.....	1.4467	1.4863	1.5000	1.5129	1.5250	1.5366	1.5476	1.5972	1.6407	1.6801	1.7510	1.8146	1.8729
	v	.....	0.5264	0.5873	0.6089	0.6294	0.6491	0.6680	0.6863	0.7716	0.8506	0.9262	1.0714	1.2124	1.3509
900	h	.....	1215.0	1260.1	1275.9	1290.9	1305.1	1318.8	1332.1	1393.9	1451.8	1508.1	1619.3	1731.6	1846.3
(531.98)	s	.....	1.4216	1.4653	1.4800	1.4938	1.5066	1.5187	1.5303	1.5814	1.6257	1.6656	1.7371	1.8009	1.8595
	v	.....	0.4533	0.5140	0.5350	0.5546	0.5733	0.5912	0.6084	0.6878	0.7604	0.8294	0.9615	1.0893	1.2146
1000	h	.....	1198.3	1248.8	1265.9	1281.9	1297.0	1311.4	1325.3	1389.2	1448.2	1505.1	1617.3	1730.0	1845.0
(544.61)	s	.....	1.3961	1.4450	1.4610	1.4757	1.4893	1.5021	1.5141	1.5670	1.6121	1.6525	1.7245	1.7886	1.8474
	v	.....	.....	0.4532	0.4738	0.4929	0.5110	0.5281	0.5445	0.6191	0.6866	0.7503	0.8716	0.9885	1.1031
1100	h	.....	.....	1236.7	1255.3	1272.4	1288.5	1303.7	1318.3	1384.3	1444.5	1502.2	1615.2	1728.4	1843.8
(556.31)	s	.....	.....	1.4251	1.4425	1.4583	1.4728	1.4862	1.4989	1.5535	1.5995	1.6405	1.7130	1.7775	1.8363
	v	.....	.....	0.4016	0.4222	0.4410	0.4586	0.4752	0.4909	0.5617	0.6250	0.6843	0.7967	0.9046	1.0101
1200	h	.....	.....	1223.5	1243.9	1262.4	1279.6	1295.7	1311.0	1379.3	1440.7	1499.2	1613.1	1726.9	1842.5
(567.22)	s	.....	.....	1.4052	1.4243	1.4413	1.4568	1.4710	1.4843	1.5409	1.5879	1.6293	1.7025	1.7672	1.8263
	v	.....	.....	0.3174	0.3390	0.3580	0.3753	0.3912	0.4062	0.4714	0.5281	0.5805	0.6789	0.7727	0.8640
1400	h	.....	.....	1193.0	1218.4	1240.4	1260.3	1278.5	1295.5	1369.1	1433.1	1493.2	1608 9	1723.7	1840.0
(587.10)	s	.....	.....	1.3639	1.3877	1.4079	1.4258	1.4419	1.4567	1.5177	1.5666	1.6093	1.6836	1.7489	1.8083
	v	.....	.....	.....	0.2733	0.2936	0.3112	0.3271	0.3417	0.4034	0.4553	0.5027	0.5906	0.6738	0.7545
1600	h	.....	.....	.....	1187.8	1215.2	1238.7	1259.6	1278.7	1358.4	1425.3	1487.0	1604.6	1720.5	1837.5
(604.90)	s	.....	.....	.....	1.3489	1.3741	1.3952	1.4137	1.4303	1.4964	1.5476	1.5914	1.6669	1.7328	1.7928
	v	.....	.....	.....	.....	0.2407	0.2597	0.2780	0.2907	0.3502	0.3986	0.4421	0.5218	0.5968	0.6693
1800	h	.....	.....	.....	.....	1185.1	1214.0	1238.5	1260.3	1347.2	1417.4	1480.8	1600.4	1717.3	1835.0
(621.03)	s	.....	.....	.....	.....	1.3377	1.3638	1.3855	1.4044	1.4765	1.5301	1.5752	1.6520	1.7185	1.7786
	v	.....	.....	.....	.....	0.1936	0.2161	0.2337	0.2489	0.3074	0.3532	0.3935	0.4668	0.5352	0.6011
2000	h	.....	.....	.....	.....	1145.6	1184.9	1214.8	1240.0	1335.5	1409.2	1474.5	1596.1	1714.1	1832.5
(635.82)	s	.....	.....	.....	.....	1.2945	1.3300	1.3564	1.3783	1.4576	1.5139	1.5603	1.6384	1.7055	1.7666
	v	.....	.....	.....	.....	.....	.....	0.1484	0.1686	0.2294	0.2710	0.3061	0.3678	0.4244	0.4784
2500	h	.....	.....	.....	.....	.....	.....	1132.3	1176.8	1303.6	1387.8	1458.4	1585.3	1706.1	1826.2
(668.13)	s	.....	.....	.....	.....	.....	.....	1.2687	1.3073	1.4127	1.4772	1.5273	1.6088	1.6775	1.7389
	v	.....	.....	.....	.....	.....	.....	.....	0.0984	0.1760	0.2159	0.2476	0.3018	0.3505	0.3966
3000	h	.....	.....	.....	.....	.....	.....	.....	1060.7	1267.2	1365.0	1441.8	1574.3	1698.0	1819.9
(695.36)	s	.....	.....	.....	.....	.....	.....	.....	1.1936	1.3696	1.4439	1.4984	1.5837	1.6540	1.7162
	v	.....	.....	.....	.....	.....	.....	.....	.....	0.1583	0.1981	0.2288	0.2806	0.3267	0.3703
3206.2	h	.....	.....	.....	.....	.....	.....	.....	.....	1250.5	1355.2	1434.7	1569.8	1694.6	1817.2
(705.40)	s	.....	.....	.....	.....	.....	.....	.....	.....	1.3508	1.4309	1.4874	1.5742	1.6452	1.7080
	v	.....	.....	.....	.....	.....	.....	.....	0.0306	0.1364	0.1762	0.2058	0.2546	0.2977	0.3381
3500	h	.....	.....	.....	.....	.....	.....	.....	780.5	1224.9	1340.7	1424.5	1563.3	1689.8	1813.6
	s	.....	.....	.....	.....	.....	.....	.....	0.9515	1.3241	1.4127	1.4723	1.5615	1.6336	1.6968
	v	.....	.....	.....	.....	.....	.....	.....	0.0287	0.1052	0.1462	0.1743	0.2192	0.2581	0.2943
4000	h	.....	.....	.....	.....	.....	.....	.....	763.3	1174.8	1314.4	1406.8	1552.1	1681.7	1807.2
	s	.....	.....	.....	.....	.....	.....	.....	0.9347	1.2757	1.3827	1.4482	1.5417	1.6154	1.6795
	v	.....	.....	.....	.....	.....	.....	.....	0.0276	0.0798	0.1226	0.1500	0.1917	0.2273	0.2602
4500	h	.....	.....	.....	.....	.....	.....	.....	753.5	1113.9	1286.5	1388 4	1540.8	1673.5	1800.9
	s	.....	.....	.....	.....	.....	.....	.....	0.9235	1.2204	1.3529	1.4253	1.5235	1.5990	1.6640
	v	.....	.....	.....	.....	.....	.....	.....	0.0268	0.0593	0.1036	0.1303	0.1696	0.2027	0.2329
5000	h	.....	.....	.....	.....	.....	.....	.....	746.4	1047.1	1256.5	1369.5	1529.5	1665.3	1794.5
	s	.....	.....	.....	.....	.....	.....	.....	0.9152	1.1622	1.3231	1.4034	1.5066	1.5839	1.6499
	v	.....	.....	.....	.....	.....	.....	.....	0.0262	0.0463	0.0880	0.1143	0.1516	0.1825	0.2106
5500	h	.....	.....	.....	.....	.....	.....	.....	741.3	985.0	1224.1	1349.3	1518.2	1657.0	1788.1
	s	.....	.....	.....	.....	.....	.....	.....	0.9090	1.1093	1.2930	1.3821	1.4908	1.5699	1.6360

* Abridged from "Thermodynamic Properties of Steam," by Joseph H. Keenan and Frederick G. Keyes, John Wiley & Sons, Inc., New York, 1937.

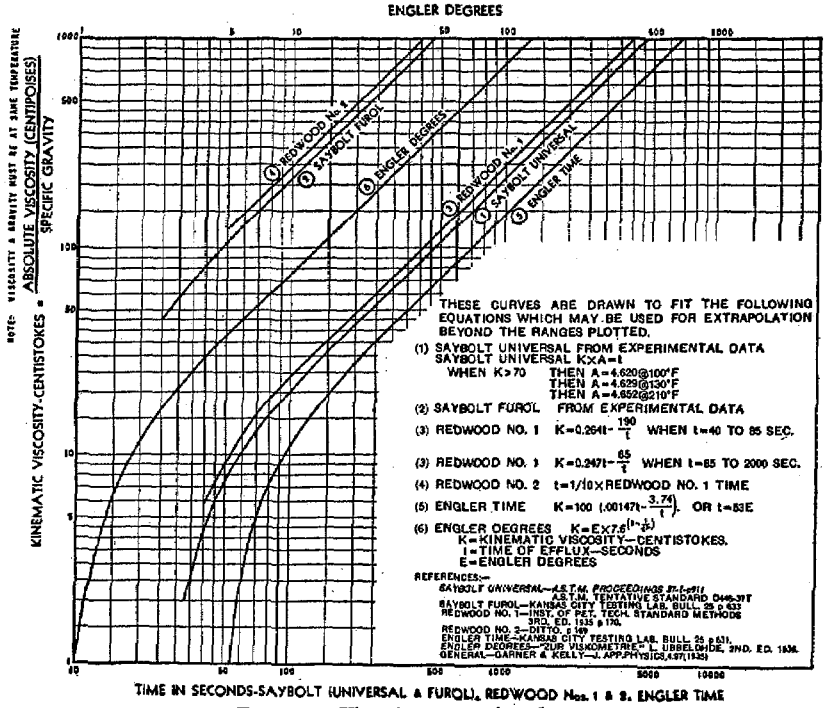


FIG. 13a. Viscosity conversion chart.

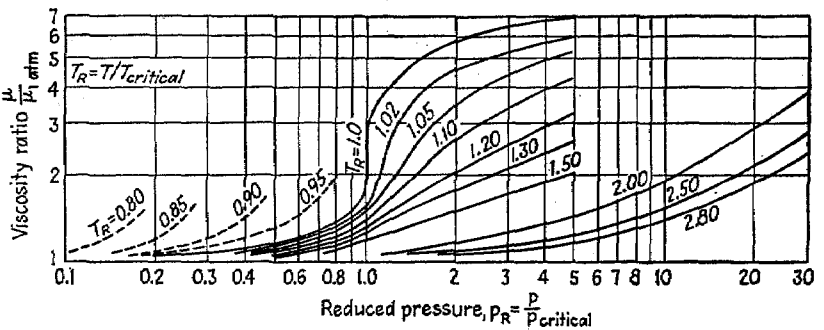


FIG. 13b. Viscosity correction chart for gases at different pressures. [*Comings and Egly, Ind. Eng. Chem.*, **32**, 715 (1940).]

VISCOSITIES OF PETROLEUM FRACTIONS
For temperature ranges employed in the text
Coordinates to be used with Fig. 14

	X	*Y*
76°API natural gasoline	14.4	6.4
56°API gasoline	14.0	10.5
42°API kerosene	11.6	16.0
35°API distillate	10.0	20.0
34°API mid-continent crude	10.3	21.3
28°API gas oil	10.0	23.6

VISCOSITIES OF ANIMAL AND VEGETABLE OILS*

	Acid No.	Sp gr, 20/4°C	*X*	*Y*
Almond	2.85	0.9188	6.9	28.2
Coconut	0.01	0.9226	6.9	26.9
Cod liver	.....	0.9138	7.7	27.7
Cottonseed	14.24	0.9187	7.0	28.0
Lard	3.39	0.9138	7.0	28.2
Linseed	3.42	0.9297	6.8	27.5
Mustard	.....	0.9237	7.0	28.5
Neatsfoot	13.35	0.9158	6.5	28.0
Olive	.....	0.9158	6.6	28.3
Palm kernel	9.0	0.9190	7.0	26.9
Perilla, raw	1.36	0.9297	8.1	27.2
Rapeseed	0.34	0.9114	7.0	28.8
Sardine	0.57	0.9384	7.7	27.3
Soybean	3.50	0.9228	8.3	27.5
Sperm	0.80	0.8829	7.7	26.3
Sunflower	2.76	0.9207	7.5	27.6
Whale, refined	0.73	0.9227	7.5	27.5

* Based on data at 100 and 210°F of A. R. Rescorla and F. L. Carnahan, *Ind. Eng. Chem.*, **28**, 1212–1213 (1936).

VISCOSITIES OF COMMERCIAL FATTY ACIDS*
250 to 400°F

	Sp gr at 300°F	*X*	*Y*
Lauric	0.792	10.1	23.1
Oleic	0.799	10.0	25.2
Palmitic	0.786	9.2	25.9
Stearic	0.789	10.5	25.5

* From data of D. Q. Kern and W. Van Nostrand, *Ind. Eng. Chem.*, **41**, 2209 (1949).

VISCOSITIES OF LIQUIDS*
Coordinates to be used with Fig. 14

Liquid	X	Y	Liquid	X	Y
Acetaldehyde	15.2	4.8	Freon-21	15.7	7.5
Acetic acid, 100%	12.1	14.2	Freon-22	17.2	4.7
Acetic acid, 70%	9.5	17.0	Freon-113	12.5	11.4
Acetic anhydride	12.7	12.8	Freon-114	14.6	8.3
Acetone, 100%	14.5	7.2	Glycerol, 100%	2.0	30.0
Acetone, 35%	7.9	15.0	Glycerol, 50%	6.9	19.6
Allyl alcohol	10.2	14.3	Heptane	14.1	8.4
Ammonia, 100%	12.6	2.0	Hexane	14.7	7.0
Ammonia, 26%	10.1	13.9	Hydrochloric acid, 31.5%	13.0	16.6
Amyl acetate	11.8	12.5	Isobutyl alcohol	7.1	18.0
Amyl alcohol	7.5	18.4	Isobutyric acid	12.2	14.4
Aniline	8.1	18.7	Isopropyl alcohol	8.2	16.0
Anisole	12.3	13.5	Mercury	18.4	16.4
Arsenic trichloride	13.9	14.5	Methanol, 100%	12.4	10.5
Benzene	12.5	10.9	Methanol, 90%	12.3	11.8
Brine, $CaCl_2$, 25%	6.6	15.9	Methanol, 40%	7.8	15.5
Brine, NaCl, 25%	10.2	16.6	Methyl acetate	14.2	8.2
Bromine	14.2	13.2	Methyl chloride	15.0	3.8
Bromotoluene	20.0	15.9	Methyl ethyl ketone	13.9	8.6
n-Butane	15.3	3.3	Naphthalene	7.9	18.1
Isobutane	14.5	3.7	Nitric acid, 95%	12.8	13.8
Butyl acetate	12.3	11.0	Nitric acid, 60%	10.8	17.0
Butyl alcohol	8.6	17.2	Nitrobenzene	10.6	16.2
Butyric acid	12.1	15.3	Nitrotoluene	11.0	17.0
Carbon dioxide	11.6	0.3	Octane	13.7	10.0
Carbon disulfide	16.1	7.5	Octyl alcohol	6.6	21.1
Carbon tetrachloride	12.7	13.1	Pentachloroethane	10.9	17.3
Chlorobenzene	12.3	12.4	Pentane	14.9	5.2
Chloroform	14.4	10.2	Phenol	6.9	20.8
Chlorosulfonic acid	11.2	18.1	Phosphorus tribromide	13.8	16.7
Chlorotoluene, ortho	13.0	13.3	Phosphorus trichloride	16.2	10.9
Chlorotoluene, meta	13.3	12.5	Propane	15.3	1.0
Chlorotoluene, para	13.3	12.5	Propionic acid	12.8	13.8
Cresol, meta	2.5	20.8	Propyl alcohol	9.1	16.5
Cyclohexanol	2.9	24.3	Propyl bromide	14.5	9.6
Dibromoethane	12.7	15.8	Propyl chloride	14.4	7.5
Dichloroethane	13.2	12.2	Propyl iodide	14.1	11.6
Dichloromethane	14.6	8.9	Sodium	16.4	13.9
Diethyl oxalate	11.0	16.4	Sodium hydroxide, 50%	3.2	25.8
Dimethyl oxalate	12.3	15.8	Stannic chloride	13.5	12.8
Diphenyl	12.0	18.3	Sulfur dioxide	15.2	7.1
Dipropyl oxalate	10.3	17.7	Sulfuric acid, 110%	7.2	27.4
Ethyl acetate	13.7	9.1	Sulfuric acid, 98%	7.0	24.8
Ethyl alcohol, 100%	10.5	13.8	Sulfuric acid, 60%	10.2	21.3
Ethyl alcohol, 95%	9.8	14.3	Sulfuryl chloride	15.2	12.4
Ethyl alcohol, 40%	6.5	16.6	Tetrachloroethane	11.9	15.7
Ethyl benzene	13.2	11.5	Tetrachloroethylene	14.2	12.7
Ethyl bromide	14.5	8.1	Titanium tetrachloride	14.4	12.3
Ethyl chloride	14.8	6.0	Toluene	13.7	10.4
Ethyl ether	14.5	5.3	Trichloroethylene	14.8	10.5
Ethyl formate	14.2	8.4	Turpentine	11.5	14.9
Ethyl iodide	14.7	10.3	Vinyl acetate	14.0	8.8
Ethylene glycol	6.0	23.6	Water	10.2	13.0
Formic acid	10.7	15.8	Xylene, ortho	13.5	12.1
Freon-11	14.4	9.0	Xylene, meta	13.9	10.6
Freon-12	16.8	5.6	Xylene, para	13.9	10.9

* From Perry, J. H., "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc., New York, 1950.

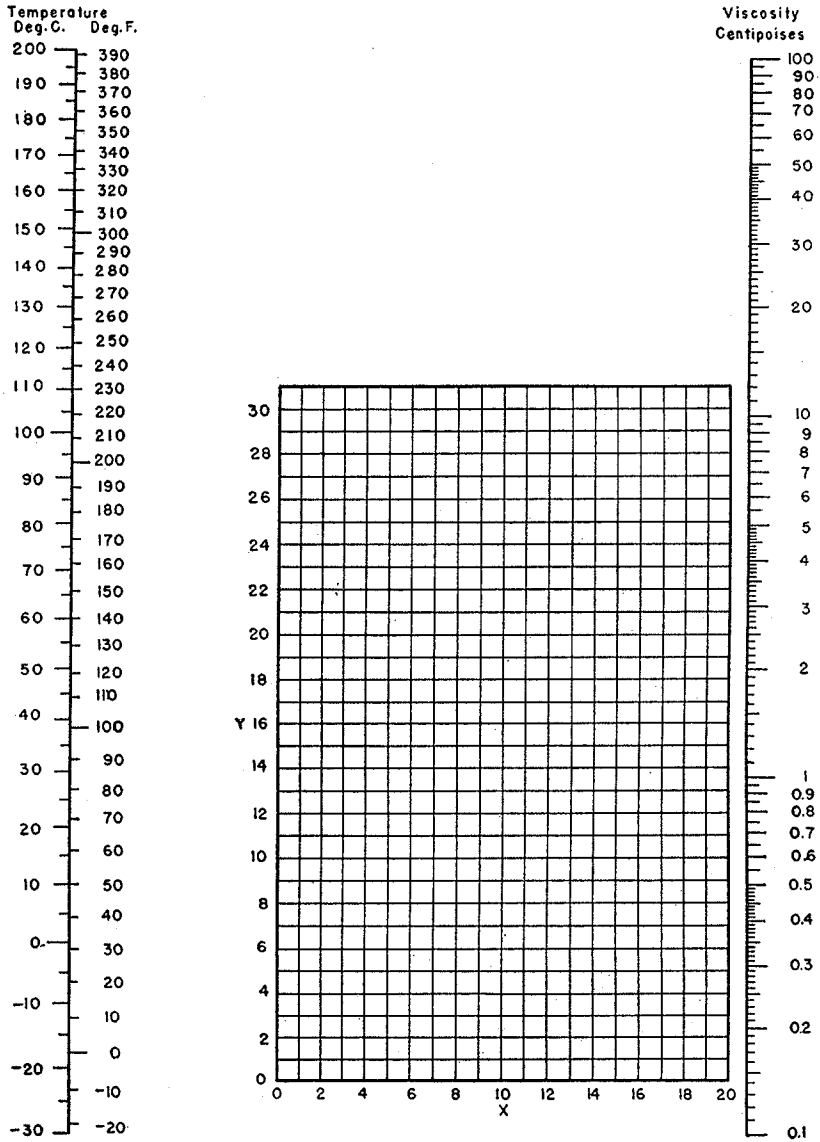


FIG. 14. Viscosities of liquids. (*Perry, "Chemical Engineers' Handbook," 3d ed., McGraw Hill Book Company, Inc., New York*, 1950.)

VISCOSITIES OF GASES*
Coordinates to be used with Fig. 15

Gas	X	Y
Acetic acid	7.7	14.3
Acetone	8.9	13.0
Acetylene	9.8	14.9
Air	11.0	20.0
Ammonia	8.4	16.0
Argon	10.5	22.4
Benzene	8.5	13.2
Bromine	8.9	19.2
Butene	9.2	13.7
Butylene	8.9	13.0
Carbon dioxide	9.5	18.7
Carbon disulfide	8.0	16.0
Carbon monoxide	11.0	20.0
Chlorine	9.0	18.4
Chloroform	8.9	15.7
Cyanogen	9.2	15.2
Cyclohexane	9.2	12.0
Ethane	9.1	14.5
Ethyl acetate	8.5	13.2
Ethyl alcohol	9.2	14.2
Ethyl chloride	8.5	15.6
Ethyl ether	8.9	13.0
Ethylene	9.5	15.1
Fluorine	7.3	23.8
Freon-11	10.6	15.1
Freon-12	11.1	16.0
Freon-21	10.8	15.3
Freon-22	10.1	17.0
Freon-113	11.3	14.0
Helium	10.9	20.5
Hexane	8.6	11.8
Hydrogen	11.2	12.4
$3H_2 + 1N_2$	11.2	17.2
Hydrogen bromide	8.8	20.9
Hydrogen chloride	8.8	18.7
Hydrogen cyanide	9.8	14.9
Hydrogen iodide	9.0	21.3
Hydrogen sulfide	8.6	18.0
Iodine	9.0	18.4
Mercury	5.3	22.9
Methane	9.9	15.5
Methyl alcohol	8.5	15.6
Nitric oxide	10.9	20.5
Nitrogen	10.6	20.0
Nitrosyl chloride	8.0	17.6
Nitrous oxide	8.8	19.0
Oxygen	11.0	21.3
Pentane	7.0	12.8
Propane	9.7	12.9
Propyl alcohol	8.4	13.4
Propylene	9.0	13.8
Sulfur dioxide	9.6	17.0
Toluene	8.6	12.4
2, 3, 3-Trimethylbutane	9.5	10.5
Water	8.0	16.0
Xenon	9.3	23.0

* From Perry, J. H., "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc., New York, 1950.

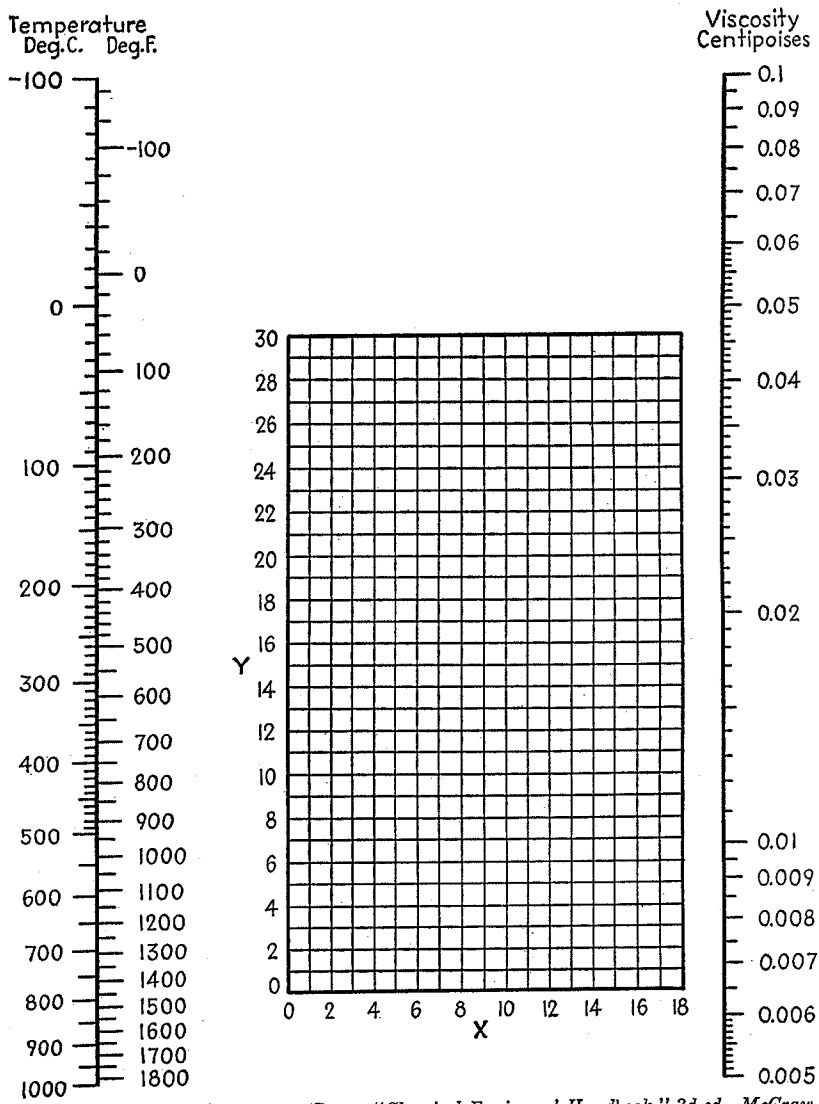


FIG. 15. Viscosities of gases. (*Perry, "Chemical Engineers' Handbook," 3d ed., McGraw-Hill Book Company, Inc., New York*, 1950.)

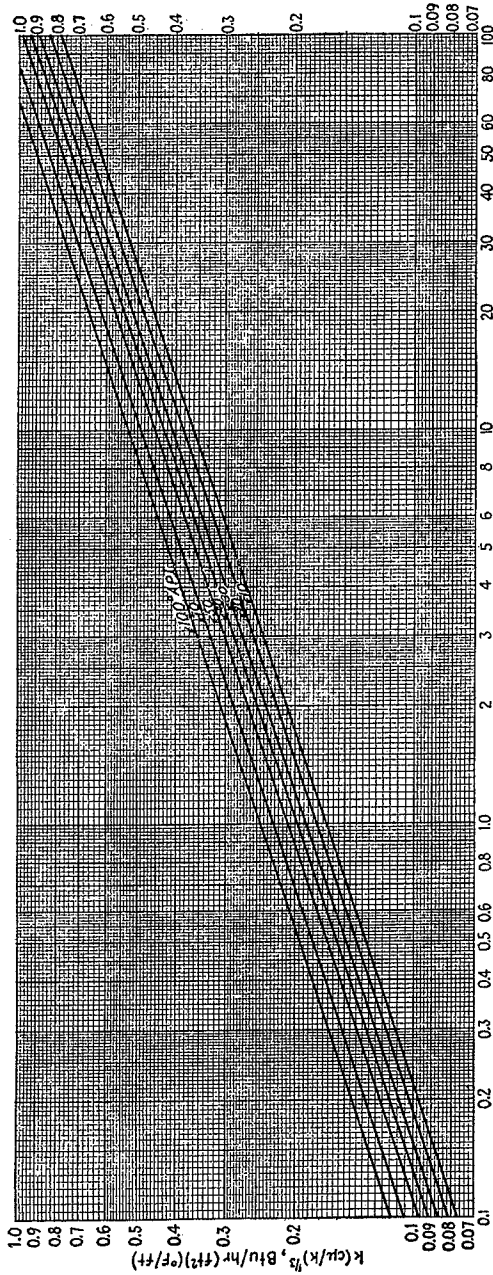


FIG. 16. Values of $k(c\mu/k)^{1/3}$ for hydrocarbons.

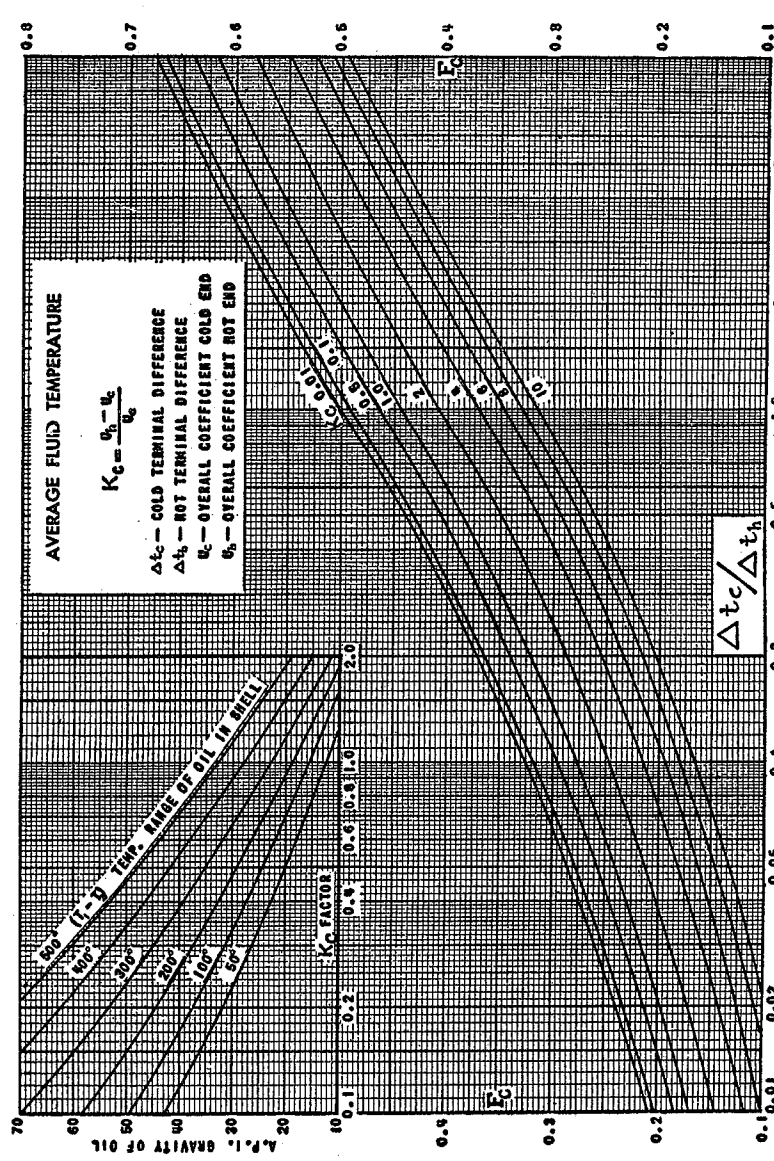


FIG. 17. The caloric temperature factor F_c. (*Standards of Tubular Exchanger Manufacturers Association, 2d ed., New York, 1949.*)

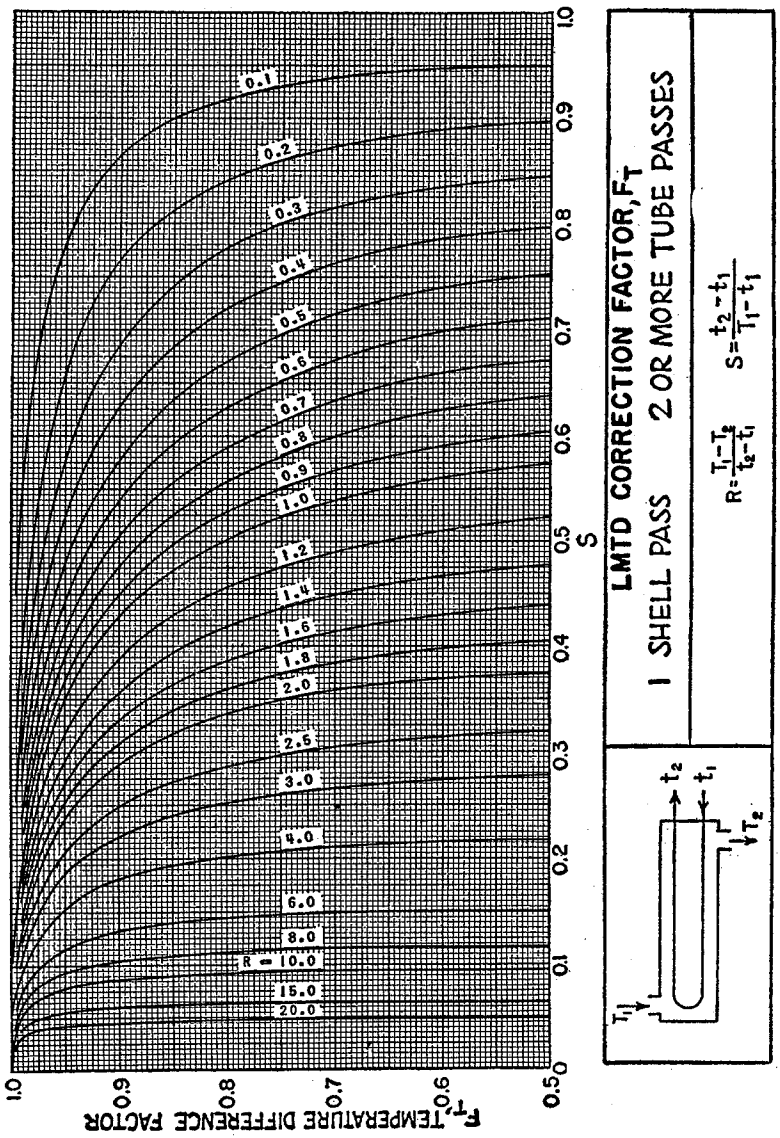


Fig. 18. LMTD correction factors for 1-2 exchangers. (*Standards of Tubular Exchanger Manufacturers Association*, 2d ed., *New York*, 1949.)

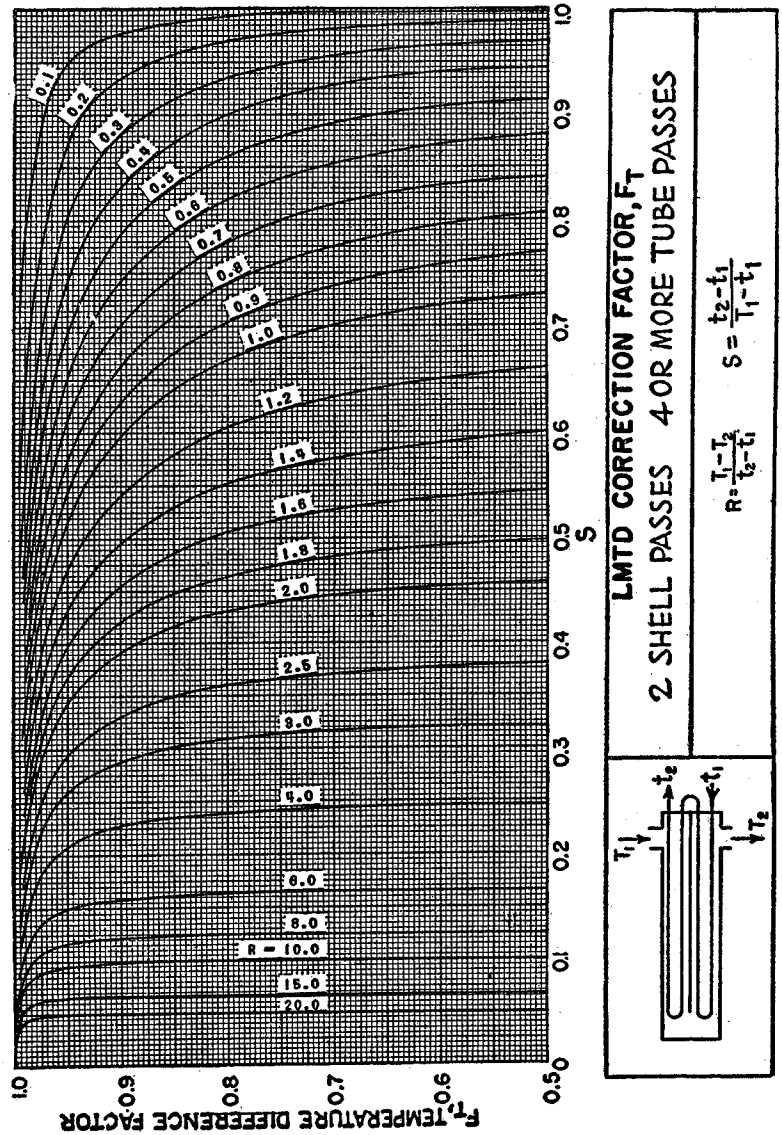


FIG. 19. LMTD correction factors for 2-4 exchangers. (*Standards of Tubular Exchanger Manufacturers Association 2d ed., New York*, 1949.)

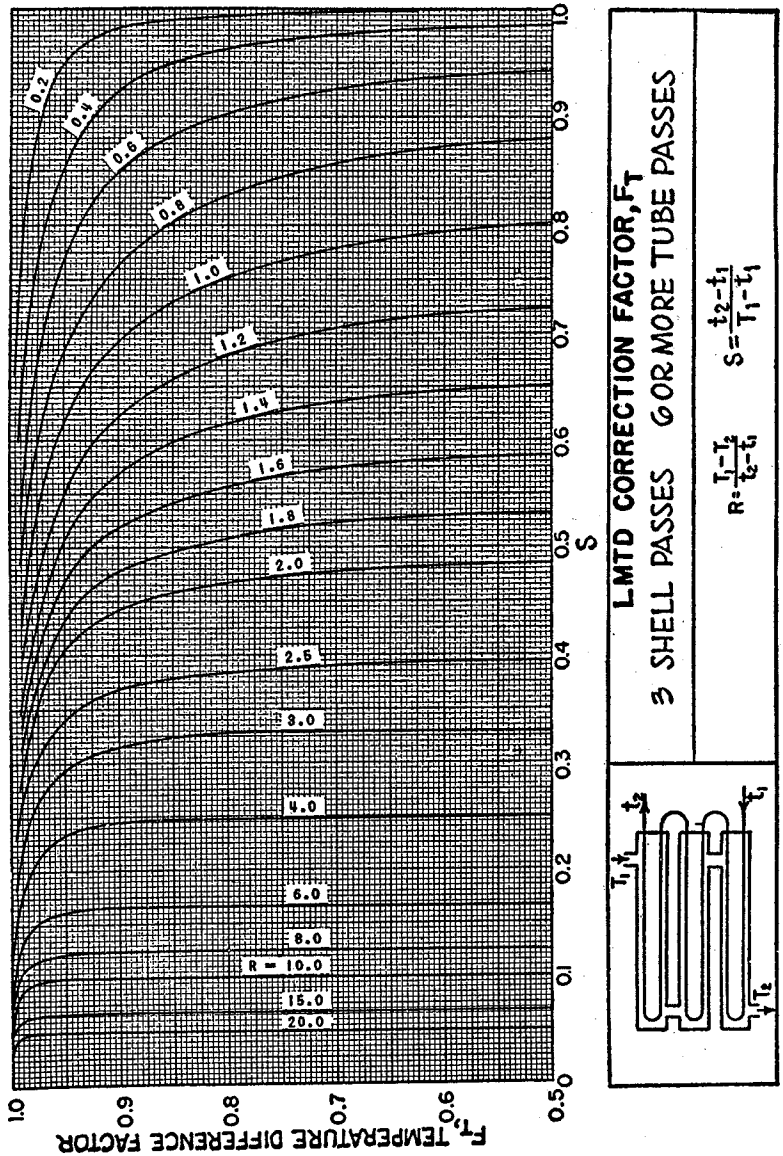


FIG. 20. LMTD correction factors for 3-6 exchangers. (*Standards of Tubular Exchanger Manufacturers Association, 2d ed., New York*, 1949.)

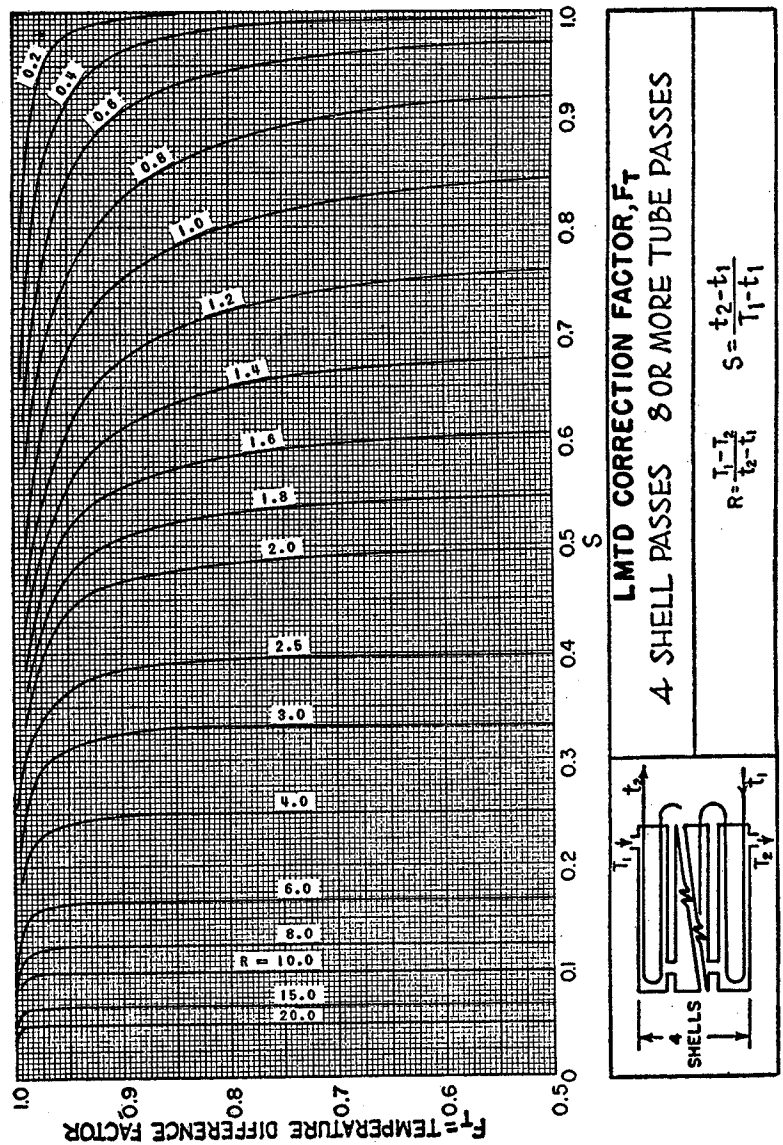


FIG. 21. LMTD correction factors for 4-8 exchangers. (*Standards of Tubular Exchanger Manufacturers Association, 2d ed., New York*, 1949.)

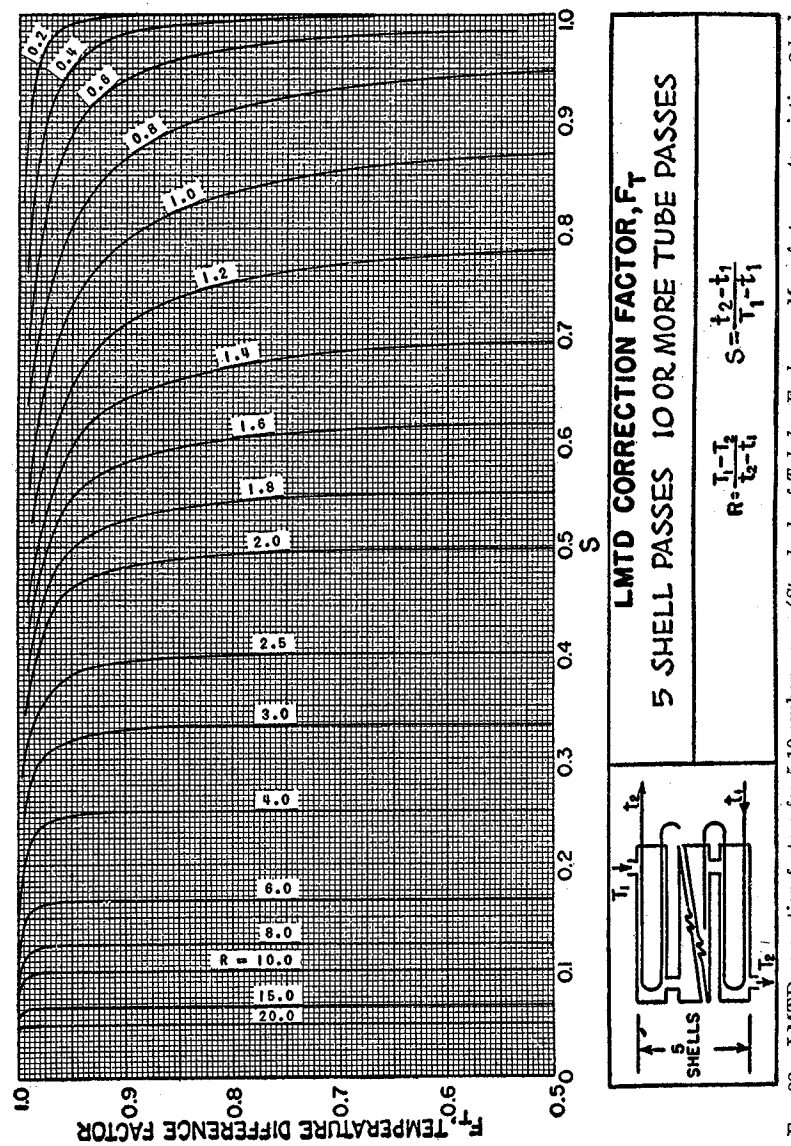


FIG. 22. LMTD correction factors for 5-10 exchangers. (*Standards of Tubular Exchanger Manufacturers Association, 2d ed., New York, 1949.*)

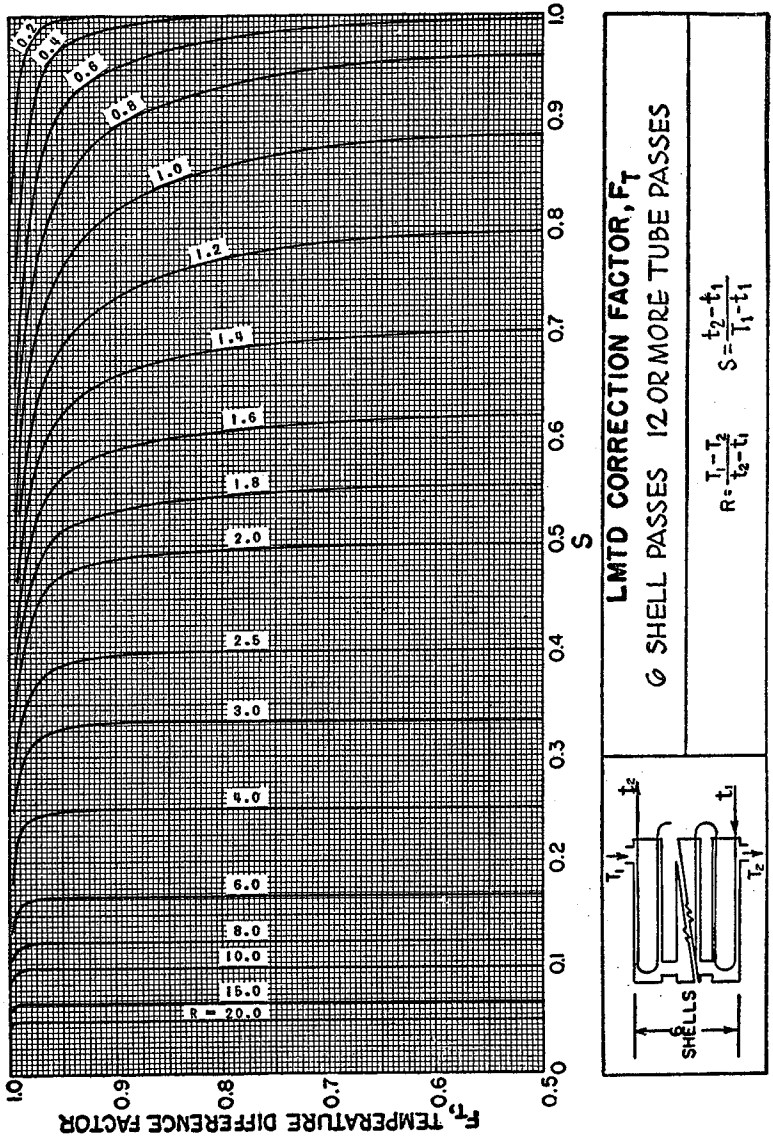


FIG. 23. LMTD correction factors for 6-12 exchangers. (*Standards of Tubular Exchanger Manufacturers Association, 2d ed., New York*, 1949.)

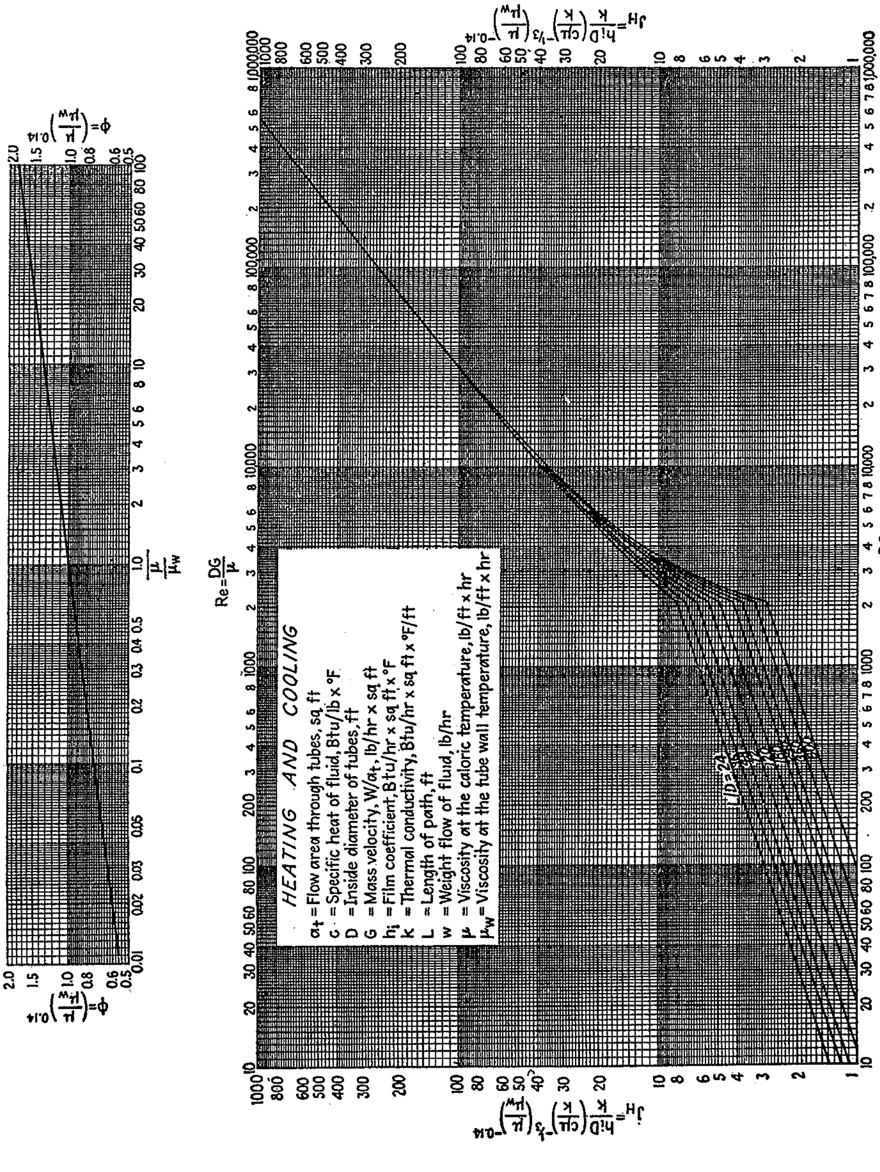
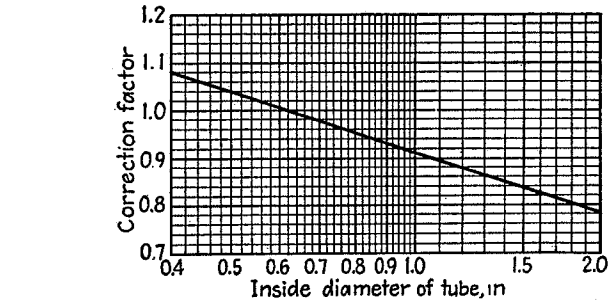


FIG. 24. Tube-side heat-transfer curve. (*Adapted from Sieder and Tate.*)



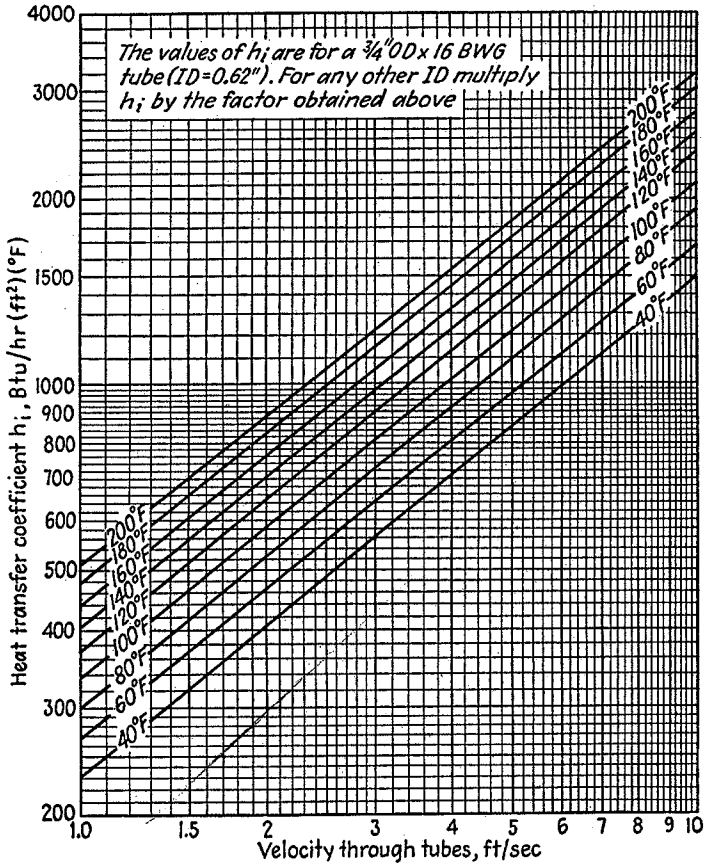


FIG. 25. Tube-side water-heat-transfer curve. [*Adapted from Eagle and Ferguson, Proc. Roy. Soc.*, **A127**, 540 (1930).]

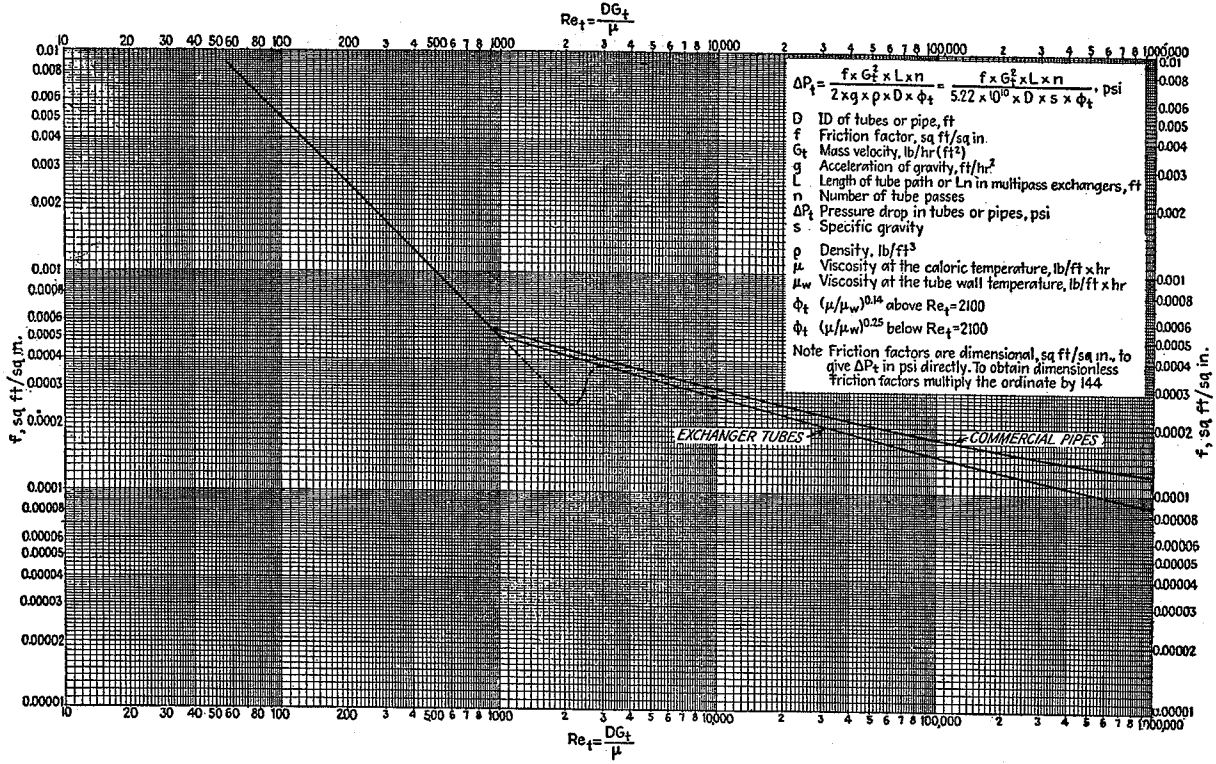


FIG. 26. Tube-side friction factors. (*Standards of Tubular Exchanger Manufacturers Association*, 2d ed., *New York*, 1949.)

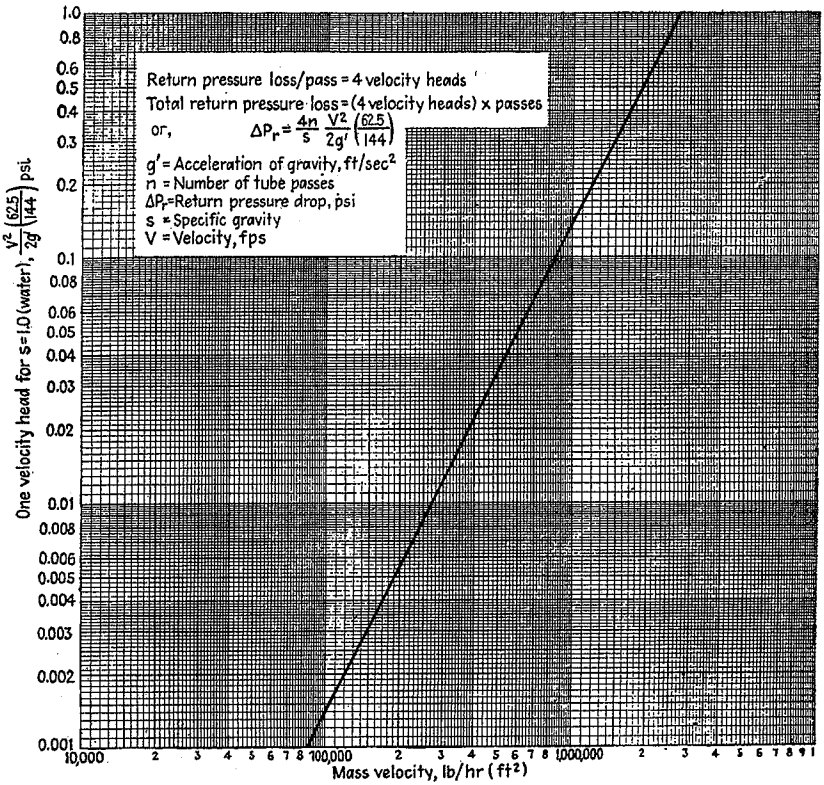


FIG. 27. Tube-side return pressure loss.

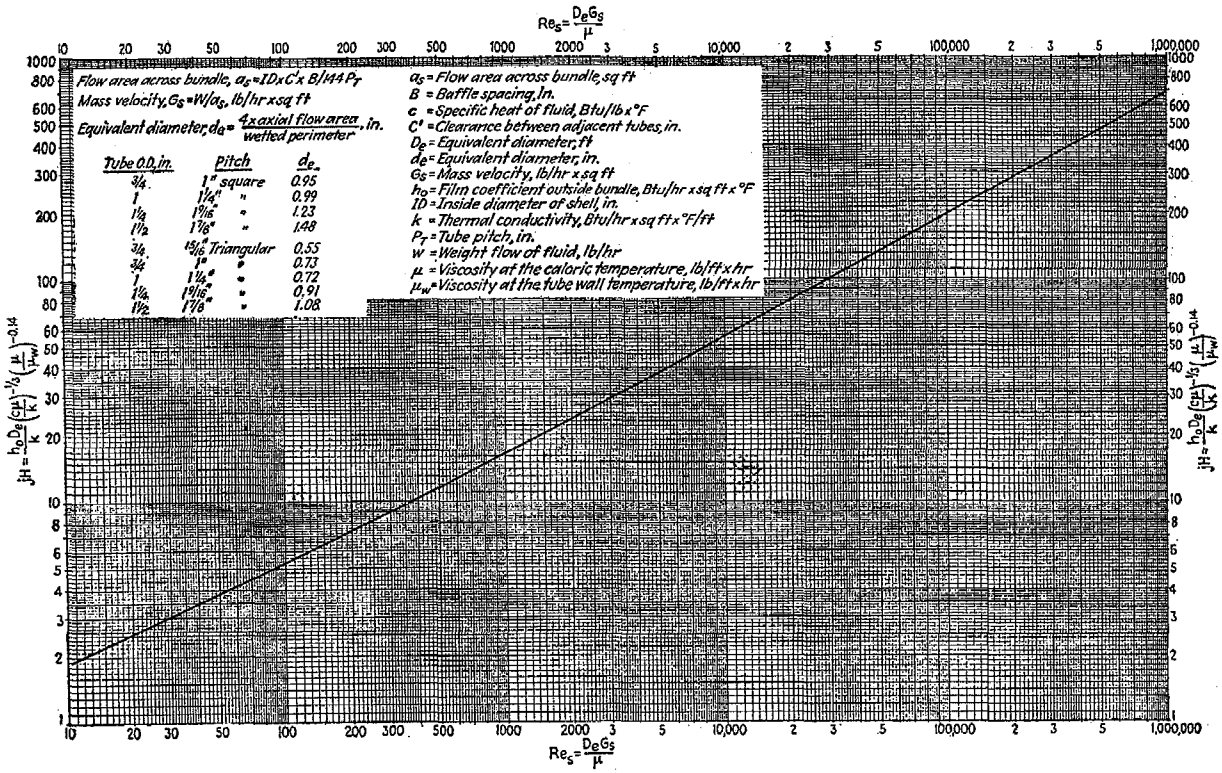


FIG. 28. Shell-side heat-transfer curve for bundles with 25% cut segmental baffles.

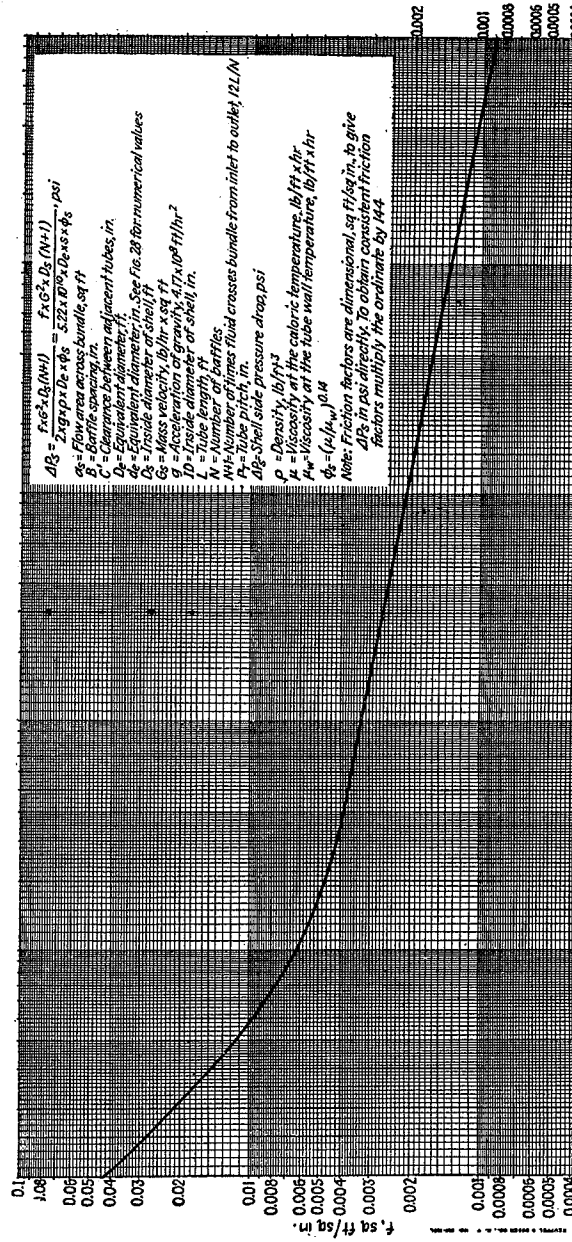


FIG. 29. Shell-side friction factors for bundles with 25% cut segmental baffles.

TABLE 8. APPROXIMATE OVERALL DESIGN COEFFICIENTS

Values include total dirt factors of 0.003 and allowable pressure drops of 5 to 10 psi on the controlling stream

Coolers

Hot fluid	Cold fluid	Overall U_D
Water	Water	250–500§
Methanol	Water	250–500§
Ammonia	Water	250–500§
Aqueous solutions	Water	250–500§
Light organics*	Water	75–150
Medium organics†	Water	50–125
Heavy organics‡	Water	5–75‖
Gases	Water	2–50¶
Water	Brine	100–200
Light organics	Brine	40–100

Heaters

Hot fluid	Cold fluid	Overall U_D
Steam	Water	200–700§
Steam	Methanol	200–700§
Steam	Ammonia	200–700§
Steam	Aqueous solutions:	
Steam	Less than 2.0 cp	200–700
Steam	More than 2.0 cp	100–500§
Steam	Light organics	100–200
Steam	Medium organics	50–100
Steam	Heavy organics	6–60
Steam	Gases	5–50¶

Exchangers

Hot fluid	Cold fluid	Overall U_D
Water	Water	250–500§
Aqueous solutions	Aqueous solutions	250–500§
Light organics	Light organics	40–75
Medium organics	Medium organics	20–60
Heavy organics	Heavy organics	10–40
Heavy organics	Light organics	30–60
Light organics	Heavy organics	10–40

* *Light organics* are fluids with viscosities of less than 0.5 centipoise and include benzene, toluene, acetone, ethanol, methyl ethyl ketone, gasoline, light kerosene, and naphtha.

† *Medium organics* have viscosities of 0.5 to 1.0 centipoise and include kerosene, straw oil, hot gas oil, hot absorber oil, and some crudes.

‡ *Heavy organics* have viscosities above 1.0 centipose and include cold gas oil, lube oils, fuel oils, reduced crude oils, tars, and asphalts.

§ Dirt factor 0.001.

‖ Pressure drop 20 to 30 psi.

¶ These rates are greatly influenced by the operating pressure.

TABLE 9. TUBE-SHEET LAYOUTS (TUBE COUNTS)
Square Pitch

¾ in. OD tubes on 1-in. square pitch						1 in. OD tubes on 1¼-in. square pitch					
Shell ID, in.	1-P	2-P	4-P	6-P	8-P	Shell ID, in.	1-P	2-P	4-P	6-P	8-P
8	32	26	20	20		8	21	16	14		
10	52	52	40	36		10	32	32	26	24	
12	81	76	68	68	60	12	48	45	40	38	36
13¼	97	90	82	76	70	13¼	61	56	52	48	44
15¼	137	124	116	108	108	15¼	81	76	68	68	64
17¼	177	166	158	150	142	17¼	112	112	96	90	82
19¼	224	220	204	192	188	19¼	138	132	128	122	116
21¼	277	270	246	240	234	21¼	177	166	158	152	148
23¼	341	324	308	302	292	23¼	213	208	192	184	184
25	413	394	370	356	346	25	260	252	238	226	222
27	481	460	432	420	408	27	300	288	278	268	260
29	553	526	480	468	456	29	341	326	300	294	286
31	657	640	600	580	560	31	406	398	380	368	358
33	749	718	688	676	648	33	465	460	432	420	414
35	845	824	780	766	748	35	522	518	488	484	472
37	934	914	886	866	838	37	596	574	562	544	532
39	1049	1024	982	968	948	39	665	644	624	612	600
1¼ in. OD tubes on 1 31/32-in. square pitch						1½ in. OD tubes on 1⅞-in. square pitch					
10	16	12	10								
12	30	24	22	16	16	12	16	16	12	12	
13¼	32	30	30	22	22	13¼	22	22	16	16	
15¼	44	40	37	35	31	15¼	29	29	25	24	22
17¼	56	53	51	48	44	17¼	39	39	34	32	29
19¼	78	73	71	64	56	19¼	50	48	45	43	39
21¼	96	90	86	82	78	21¼	62	60	57	54	50
23¼	127	112	106	102	96	23¼	78	74	70	66	62
25	140	135	127	123	115	25	94	90	86	84	78
27	166	160	151	146	140	27	112	108	102	98	94
29	193	188	178	174	166	29	131	127	120	116	112
31	226	220	209	202	193	31	151	146	141	138	131
33	258	252	244	238	226	33	176	170	164	160	151
35	293	287	275	268	258	35	202	196	188	182	176
37	334	322	311	304	293	37	224	220	217	210	202
39	370	362	348	342	336	39	252	246	237	230	224

TABLE 9. TUBE-SHEET LAYOUTS (TUBE COUNTS).—(*Continued*)
Triangular Pitch

¾ in. OD tubes on 15/16-in. triangular pitch					
Shell ID, in.	1-P	2-P	4-P	6-P	8-P
8	36	32	26	24	18
10	62	56	47	42	36
12	109	98	86	82	78
13¼	127	114	96	90	86
15¼	170	160	140	136	128
17¼	239	224	194	188	178
19¼	301	282	252	244	234
21¼	361	342	314	306	290
23¼	442	420	386	378	364
25	532	506	468	446	434
27	637	602	550	536	524
29	721	692	640	620	594
31	847	822	766	722	720
33	974	938	878	852	826
35	1102	1068	1004	988	958
37	1240	1200	1144	1104	1072
39	1377	1330	1258	1248	1212

¾ in. OD tubes on 1-in. triangular pitch					
Shell ID, in.	1-P	2-P	4-P	6-P	8-P
8	37	30	24	24	
10	61	52	40	36	
12	92	82	76	74	70
13¼	109	106	86	82	74
15¼	151	138	122	118	110
17¼	203	196	178	172	166
19¼	262	250	226	216	210
21¼	316	302	278	272	260
23¼	384	376	352	342	328
25	470	452	422	394	382
27	559	534	488	474	464
29	630	604	556	538	508
31	745	728	678	666	640
33	856	830	774	760	732
35	970	938	882	864	848
37	1074	1044	1012	986	870
39	1206	1176	1128	1100	1078

1 in. OD tubes on 1¼-in. triangular pitch					
8	21	16	16	14	
10	32	32	26	24	
12	55	52	48	46	44
13¼	68	66	58	54	50
15¼	91	86	80	74	72
17¼	131	118	106	104	94
19¼	163	152	140	136	128
21¼	199	188	170	164	160
23¼	241	232	212	212	202
25	294	282	256	252	242
27	349	334	302	296	286
29	397	376	338	334	316
31	472	454	430	424	400
33	538	522	486	470	454
35	608	592	562	546	532
37	674	664	632	614	598
39	766	736	700	688	672

1¼ in. OD tubes on 1 9/16-in. triangular pitch					
10	20	18	14		
12	32	30	26	22	20
13¼	38	36	32	28	26
15¼	54	51	45	42	38
17¼	69	66	62	58	54
19¼	95	91	86	78	69
21¼	117	112	105	101	95
23¼	140	136	130	123	117
25	170	164	155	150	140
27	202	196	185	179	170
29	235	228	217	212	202
31	275	270	255	245	235
33	315	305	297	288	275
35	357	348	335	327	315
37	407	390	380	374	357
39	449	436	425	419	407

1½ in. OD tubes on 1⅞-in. triangular pitch					
12	18	14	14	12	12
13¼	27	22	18	16	14
15¼	36	34	32	30	27
17¼	48	44	42	38	36
19¼	61	58	55	51	48
21¼	76	72	70	66	61
23¼	95	91	86	80	76
25	115	110	105	98	95
27	136	131	125	118	115
29	160	154	147	141	136
31	184	177	172	165	160
33	215	206	200	190	184
35	246	238	230	220	215
37	275	268	260	252	246
39	307	299	290	284	275

TABLE 10. HEAT EXCHANGER AND CONDENSER TUBE DATA

Tube OD, in.	BWG	Wall thickness, in.	ID, in.	Flow area per tube, in.²	Surface per lin ft, ft²		Weight per lin ft, lb steel
					Outside	Inside	
½	12	0.109	0.282	0.0625	0.1309	0.0748	0.493
	14	0.083	0.334	0.0876		0.0874	0.403
	16	0.065	0.370	0.1076		0.0969	0.329
	18	0.049	0.402	0.127		0.1052	0.258
	20	0.035	0.430	0.145		0.1125	0.190
¾	10	0.134	0.482	0.182	0.1963	0.1263	0.965
	11	0.120	0.510	0.204		0.1335	0.884
	12	0.109	0.532	0.223		0.1393	0.817
	13	0.095	0.560	0.247		0.1466	0.727
	14	0.083	0.584	0.268		0.1529	0.647
	15	0.072	0.606	0.289		0.1587	0.571
	16	0.065	0.620	0.302		0.1623	0.520
	17	0.058	0.634	0.314		0.1660	0.469
	18	0.049	0.652	0.334		0.1707	0.401
1	8	0.165	0.670	0.355	0.2618	0.1754	1.61
	9	0.148	0.704	0.389		0.1843	1.47
	10	0.134	0.732	0.421		0.1916	1.36
	11	0.120	0.760	0.455		0.1990	1.23
	12	0.109	0.782	0.479		0.2048	1.14
	13	0.095	0.810	0.515		0.2121	1.00
	14	0.083	0.834	0.546		0.2183	0.890
	15	0.072	0.856	0.576		0.2241	0.781
	16	0.065	0.870	0.594		0.2277	0.710
	17	0.058	0.884	0.613		0.2314	0.639
	18	0.049	0.902	0.639		0.2361	0.545
1¼	8	0.165	0.920	0.665	0.3271	0.2409	2.09
	9	0.148	0.954	0.714		0.2498	1.91
	10	0.134	0.982	0.757		0.2572	1.75
	11	0.120	1.01	0.800		0.2644	1.58
	12	0.109	1.03	0.836		0.2701	1.45
	13	0.095	1.06	0.884		0.2775	1.28
	14	0.083	1.08	0.923		0.2839	1.13
	15	0.072	1.11	0.960		0.2896	0.991
	16	0.065	1.12	0.985		0.2932	0.900
	17	0.058	1.13	1.01		0.2969	0.808
	18	0.049	1.15	1.04		0.3015	0.688
1½	8	0.165	1.17	1.075	0.3925	0.3063	2.57
	9	0.148	1.20	1.14		0.3152	2.34
	10	0.134	1.23	1.19		0.3225	2.14
	11	0.120	1.26	1.25		0.3299	1.98
	12	0.109	1.28	1.29		0.3356	1.77
	13	0.095	1.31	1.35		0.3430	1.56
	14	0.083	1.33	1.40		0.3492	1.37
	15	0.072	1.36	1.44		0.3555	1.20
	16	0.065	1.37	1.47		0.3587	1.09
	17	0.058	1.38	1.50		0.3623	0.978
	18	0.049	1.40	1.54		0.3670	0.831

TABLE 11. DIMENSIONS OF STEEL PIPE (IPS)

Nominal pipe size, IPS, in.	OD, in.	Schedule No.	ID, in.	Flow area per pipe, in.^{2}	Surface per lin ft, ft.^{2}/ft.		Weight per lin ft, lb steel
					Outside	Inside	
⅛	0.405	40*	0.269	0.058	0.106	0.070	0.25
		80†	0.215	0.036		0.056	0.32
¼	0.540	40*	0.364	0.104	0.141	0.095	0.43
		80†	0.302	0.072		0.079	0.54
⅜	0.675	40*	0.493	0.192	0.177	0.129	0.57
		80†	0.423	0.141		0.111	0.74
½	0.840	40*	0.622	0.304	0.220	0.163	0.85
		80†	0.546	0.235		0.143	1.09
¾	1.05	40*	0.824	0.534	0.275	0.216	1.13
		80†	0.742	0.432		0.194	1.48
1	1.32	40*	1.049	0.864	0.344	0.274	1.68
		80†	0.957	0.718		0.250	2.17
1¼	1.66	40*	1.380	1.50	0.435	0.362	2.28
		80†	1.278	1.28		0.335	3.00
1½	1.90	40*	1.610	2.04	0.498	0.422	2.72
		80†	1.500	1.76		0.393	3.64
2	2.38	40*	2.067	3.35	0.622	0.542	3.66
		80†	1.939	2.95		0.508	5.03
2½	2.88	40*	2.469	4.79	0.753	0.647	5.80
		80†	2.323	4.23		0.609	7.67
3	3.50	40*	3.068	7.38	0.917	0.804	7.58
		80†	2.900	6.61		0.760	10.3
4	4.50	40*	4.026	12.7	1.178	1.055	10.8
		80†	3.826	11.5		1.002	15.0
6	6.625	40*	6.065	28.9	1.734	1.590	19.0
		80†	5.761	26.1		1.510	28.6
8	8.625	40*	7.981	50.0	2.258	2.090	28.6
		80†	7.625	45.7		2.000	43.4
10	10.75	40*	10.02	78.8	2.814	2.62	40.5
		60	9.75	74.6		2.55	54.8
12	12.75	30	12.09	115	3.338	3.17	43.8
14	14.0	30	13.25	138	3.665	3.47	54.6
16	16.0	30	15.25	183	4.189	4.00	62.6
18	18.0	20‡	17.25	234	4.712	4.52	72.7
20	20.0	20	19.25	291	5.236	5.05	78.6
22	22.0	20‡	21.25	355	5.747	5.56	84.0
24	24.0	20	23.25	425	6.283	6.09	94.7

* Commonly known as standard.
† Commonly known as extra heavy.
‡ Approximately.

TABLE 12. FOULING FACTORS*

Temperature of heating medium	Up to 240°F		240–400°F†	
Temperature of water	125°F or less		Over 125°F	
Water	Water velocity, fps		Water velocity, fps	
	3 ft and less	Over 3 ft	3 ft and less	Over 3 ft
Sea water	0.0005	0.0005	0.001	0.001
Brackish water	0.002	0.001	0.003	0.002
Cooling tower and artificial spray pond:				
Treated make-up	0.001	0.001	0.002	0.002
Untreated	0.003	0.003	0.005	0.004
City or well water (such as Great Lakes)	0.001	0.001	0.002	0.002
Great Lakes	0.001	0.001	0.002	0.002
River water:				
Minimum	0.002	0.001	0.003	0.022
Mississippi	0.003	0.002	0.004	0.003
Delaware, Schuylkill	0.003	0.002	0.004	0.003
East River and New York Bay	0.003	0.002	0.004	0.003
Chicago sanitary canal	0.008	0.006	0.010	0.008
Muddy or silty	0.003	0.002	0.004	0.003
Hard (over 15 grains/gal)	0.003	0.003	0.005	0.005
Engine jacket	0.001	0.001	0.001	0.001
Distilled	0.0005	0.0005	0.0005	0.0005
Treated boiler feedwater	0.001	0.0005	0.001	0.001
Boiler blowdown	0.002	0.002	0.002	0.002

† Ratings in the last two columns are based on a temperature of the heating medium of 240 to 400°F. If the heating medium temperature is over 400°F, and the cooling medium is known to scale these ratings should be modified accordingly.

Petroleum Fractions

Oils (industrial):		Liquids (industrial):	
Fuel oil	0.005	Organic	0.001
Clean recirculating oil	0.001	Refrigerating liquids, heating, cooling, or evaporating	0.001
Machinery and transformer oils	0.001	Brine (cooling)	0.001
Quenching oil	0.004	Atmospheric distillation units:	
Vegetable oils	0.003	Residual bottoms, less than 25°API	0.005
Gases, vapors (industrial):		Distillate bottoms, 25°API or above	0.002
Coke-oven gas, manufactured gas	0.01	Atmospheric distillation units:	
Diesel-engine exhaust gas	0.01	Overhead untreated vapors	0.0013
Organic vapors	0.0005	Overhead treated vapors	0.003
Steam (non-oil bearing)	0.0	Side-stream cuts	0.0013
Alcohol vapors	0.0	Vacuum distillation units:	
Steam, exhaust (oil bearing from reciprocating engines)	0.001	Overhead vapors to oil:	
Refrigerating vapors (condensing from reciprocating compressors)	0.002	From bubble tower (partial condenser)	0.001
Air	0.002	From flash pot (no appreciable reflux)	0.003

* *Standards of Tubular Exchanger Manufacturers Association, 2d ed., New York,* 1949.

TABLE 12. FOULING FACTORS.*—(*Continued*)

Overhead vapors in water-cooled condensers:	
From bubble tower (final condenser)	0.001
From flash pot	0.04
Side stream:	
To oil	0.001
To water	0.002
Residual bottoms, less than 20°API	0.005
Distillate bottoms, over 20°API	0.002
Natural gasoline stabilizer units:	
Feed	0.0005
O.H. vapors	0.0005
Product coolers and exchangers	0.0005
Product reboilers	0.001
H_2S Removal Units:	
For overhead vapors	0.001
Solution exchanger coolers	0.0016
Reboiler	0.0016
Cracking units:	
Gas oil feed:	
Under 500°F	0.002
500°F and over	0.003
Naphtha feed:	
Under 500°F	0.002
500°F and over	0.004
Separator vapors (vapors from separator, flash pot, and vaporizer)	0.006
Bubble-tower vapors	0.002
Residuum	0.010
Absorption units:	
Gas	0.002
Fat oil	0.002
Lean oil	0.002
Overhead vapors	0.001
Gasoline	0.0005
Debutanizer, Depropanizer, Depentanizer, and Alkylation Units:	
Feed	0.001
Overhead vapors	0.001
Product coolers	0.001
Product reboilers	0.002
Reactor feed	0.002
Lube treating units:	
Solvent oil mixed feed	0.002
Overhead vapors	0.001
Refined oil	0.001
Refined oil heat exchangers water cooled‡	0.003
Gums and tars:	
Oil-cooled and steam generators	0.005
Water-cooled	0.003
Solvent	0.001
Deasphaltizing units:	
Feed oil	0.002
Solvent	0.001
Asphalt and resin:	
Oil-cooled and steam generators	0.005
Water-cooled	0.003
Solvent vapors	0.001
Refined oil	0.001
Refined oil water cooled	0.003
Dewaxing units:	
Lube oil	0.001
Solvent	0.001
Oil wax mix heating	0.001
Oil wax mix cooling‡	0.003

‡ Precautions must be taken against deposition of wax.

Crude Oil Streams

	0–199°F			200–299°F			300–499°F			500°F and over		
	Velocity, fps											
	Under 2 ft	2–4 ft	4 ft and over	Under 2 ft	2–4 ft.	4 ft and over	Under 2 ft	2–4 ft	4 ft and over	Under 2 ft	2–4 ft	4 ft and over
Dry..	0.003	0.002	0.002	0.003	0.002	0.002	0.004	0.003	0.002	0.005	0.004	0.003
Salt§	0.003	0.002	0.002	0.005	0.004	0.004	0.006	0.005	0.004	0.007	0.006	0.005

§ Refers to a wet crude—any crude that has not been dehydrated.