Table 1.... City Water Maximum Temperature and Hardness

State	City	Max. Water Temp.,[a] F	Hardness[b] ppm	State	City	Max. Water Temp.,[a] F	Hardness[b] ppm	State	City	Max. Water Temp.,[a] F	Hardness[b] ppm
Ala.	Birmingham	84	43	Ind.	East Chicago	64	130	Minn.	St. Paul	80	160
	Gadsden	85[a]	54		Evansville	88	140		Rochester	70	275
	Mobile	90[a]	5		Fort Wayne	86[a]	95				
	Montgomery	90	13		Gary	75	131	Miss.	Jackson	84[a]	38
					Hammond	73[a]	131		Meridian	89[a]	7
Ark.	Little Rock	83	26								
	Fort Smith	83[a]	89		Indianapolis	84[a]	279	Mo.	Jefferson City	82	105
					Lafayette	60	380		Kansas City	84	90
Ariz.	Phoenix	81	210		Muncie	76[a]	280		Springfield	80[a]	187
	Tucson	80	222		South Bend	61	438		St. Joseph	84	
					Terre Haute	82	231		St. Louis	87	83
Calif.	Anaheim	60[a]	287–358								
	Berkeley	69[a]	22–183	Iowa	Cedar Rapids	85[a]	120	Mont.	Butte	54	63
	Burbank	69	169–241		Council Bluffs	85[a]	244		Helena	57	96
	Fresno	80[a]	55–163		Davenport	80[a]	150				
	Fullerton	75[a]	260–430		Des Moines	76[a]	340	Nebr.	Lincoln	63	188
									Omaha	87	135
	Glendale	70	404–523		Dubuque	60	224				
	Hollywood	75	207		Sioux City	62	548	Nev.	Reno	70[a]	114
	Long Beach	75	38–136		Waterloo	58[a]	268				
	Los Angeles	80[a]	86–664					N. H.	Manchester	76	11
	Oakland	70	22–183	Kans.	Kansas City	86[a]	230		Concord	73	16
					Topeka	88	92				
	Ontario	70[a]	137–163		Wichita	76	411	N. J.	Atlantic City	76[a]	12
	Pasadena	82[a]	51–237						Camden	70[a]	65
	Pomona	75	28–370	Ky.	Covington	85[a]	121		Clifton	70[a]	55
	Riverside	78[a]	80–116		Lexington	75	105		East Orange	66	112
	Sacramento	79[a]	34–324		Louisville	85	104		Elizabeth	70[a]	220
					Paducah	92	79		Jersey City	71[a]	48
	San Bernardino	70	112–304								
	San Diego	84[a]	198–366	La.	Baton Rouge	87	3		Newark	74	29
	San Francisco	71[a]	16–264		New Orleans	91[a]	150		Passaic	75	55
	San Jose	76[a]	180		Shreveport	90	36		Paterson	78	55
	Stockton	76	83–212						Perth Amboy	57[a]	54
	Whittier	75[a]	97–491	Me.	Augusta	72			Trenton	79	44
					Portland	70	12				
Colo.	Denver	75[a]	123					N. M.	Albuquerque	72[a]	155
	Pueblo	72	279	Md.	Baltimore	76[a]	50				
					Cumberland	70	96	N. Y.	Albany	70[a]	42
Conn.	Bridgeport	66	15						Binghamton	67	69
	Hartford	73	12	Mass.	Boston	79	15		Buffalo	78[a]	118
	New Haven	76	46		Brockton	65[a]	6		Brooklyn	72[a]	30
	Stamford	78[a]	30		Brookline	73[a]	49		Elmira	62	94
	Waterbury	76[a]	21		Cambridge	74[a]	46		Jamaica	56[a]	
					Fall River	76	10				
Del.	Wilmington	83	48						Jamestown	52[a]	103
					Haverhill	69	30		Mt. Vernon	74	20
D. C.	Washington	84	162		Holyoke	77[a]	23		New Rochelle	75	20
					Lawrence	62	21		New York	72	30
Fla.	Jacksonville	87[a]	305		Lowell	59	40		Niagara Falls	70	123
	Miami	82	78		Lynn	68	35		Poughkeepsie	79[a]	72
	Pensacola	75	7								
	Tampa	87[a]	100		Malden	69	15		Rochester	70	78
	W. Palm Beach	86			New Bedford	74	10		Schenectady	63	177
					Newton	65[a]	40		Syracuse	73	98
Ga.	Atlanta	87	14		Quincy	74[a]	15		Troy	73[a]	32
	Augusta	85[a]	18		Salem	68	47		Utica	70[a]	35
	Columbus	83	15						Yonkers	70[a]	11
	Macon	81	16		Somerville	69	15				
	Savannah	85	120		Springfield	65	18	N. C.	Asheville	76[a]	4
					Worcester	76	13		Charlotte	85	23
Idaho	Boise	65	71						Durham	79[a]	34
				Mich.	Bay City	78[a]	110		Raleigh	86	24
Ill.	Aurora	66	351		Battle Creek	54	222		Winston-Salem	82	24
	Chicago	78[a]	125		Detroit	78[a]	100				
	Cicero	76	125		Flint	80[a]	91	N. D.	Bismarck	80	172
	Decatur	90[a]	100		Grand Rapids	84[a]	137		Fargo	85	199
	Evanston	75	115		Highland Park	78	93				
								Ohio	Akron	76	100
	East St. Louis	90[a]	172		Jackson	58	279		Canton	55[a]	340
	Joliet	75	313		Kalamazoo	55	384		Cincinnati	84	120
	Moline	83[a]			Lansing	64	356		Cleveland	76[a]	121
	Oak Park	76[a]	125		Muskegon	71[a]	153		Cleveland Hgts	77[a]	121
	Peoria	67	386		Pontiac	55[a]	272				
					Saginaw	82	100		Columbus	82	85
	Rockford	61	317						Dayton	69	368
	Rock Island	86[a]	183	Minn.	Duluth	59[a]	54		Hamilton	70	394
	Springfield	82	164		Minneapolis	85[a]	172		Lakewood	81	113

Table 1.... City Water Maximum Temperature and Hardness (Concluded)

State	City	Max. Water Temp.,[a] F	Hardness[b] ppm	State	City	Max. Water Temp.,[a] F	Hardness[b] ppm	State	City	Max. Water Temp.,[a] F	Hardness[b] ppm
Ohio	Lima	80[a]	231	R. I.	Cranston	68[a]	21	Texas	Wichita Falls	85[a]	269
	Springfield	71	277		Providence	74	26				
	Toledo	82	140		Pawtucket	74[a]	24	Utah	Ogden	63[a]	138
	Youngstown	78[a]	91		Woonsocket	72[a]	18		Salt Lake City	65[a]	140
	Warren	80[a]	160								
				S. C.	Charleston	85[a]	18	Vt.	Burlington	68	60
Okla.	Oklahoma City	86	100		Columbia	82	28				
	Tulsa	85	80		Greenville	81[a]		Va.	Fredericksburg	75[a]	
					Spartansburg	81			Lynchburg	74	12
Ore.	Eugene	60[a]							Norfolk	83[a]	14
	Portland	64	10	S. D.	Sioux Falls	65[a]	489		Richmond	84[a]	57
									Roanoke	64	130
Pa.	Allentown	67[a]	170	Tenn.	Chattanooga	84	87				
	Altoona	74[a]	57		Knoxville	90[a]	135	Wash.	Olympia	58[a]	
	Bethlehem	78[a]	150		Memphis	85[a]	39		Seattle	62	23
	Erie	75	124		Nashville	90[a]	102		Spokane	55[a]	147
	Harrisburg	68	58						Tacoma	65[a]	32
				Texas	Amarillo	70[a]	248				
	Johnstown	74[a]	13		Austin	90[a]	81	W. Va.	Charleston	84	34
	Lancaster	77[a]	162		Beaumont	88[a]	41		Huntington	85	85
	McKeesport	81	107		Dallas	88	75		Wheeling	81[a]	125
	Philadelphia	85[a]	98		El Paso	85[a]	160				
	Pittsburgh	86[a]	95		Fort Worth	85	164	Wis.	Kenosha	67[a]	130
									LaCrosse	58[a]	278
	Reading	80[a]	86		Galveston	90	68		Madison	60[a]	338
	Scranton	70[a]	30		Houston	90	120		Milwaukee	75[a]	126
	Wilkes-Barre	72	31		Port Arthur	85	53		Racine	69[a]	130
	Williamsport	70	13		San Antonio	78	221		Green Bay	55	197
	York	68	31		Waco	86	134				
								Wyo.	Cheyenne	60	

[a] The maximum water temperatures, except those marked a, were adopted by the National Electrical Manufacturers Association in 1938 for the selection of condensing units. Temperatures marked a were obtained from the local water company or other sources.

[b] Hardness, expressed in parts per million (ppm), is a rough measure of the scale forming properties of the water, and represents the total hardness of tap water, or the amount of calcium carbonate equivalent to the calcium and magnesium content. Water supplies may be classified by hardness, expressed as ppm of calcium carbonate, in four groups:
A. Less than 60—Soft. B. 60–120—Medium
C. 120–180—Hard D. Over 180—Very Hard.
The wide range of hardness of California waters reflects the multiplicity of supplies that have developed. Data are from *California Domestic Water Supply Statistics*, Department of Public Health, State of California, 1958.

k = thermal conductivity of tube material, Btu per (hour) (square foot) (Fahrenheit degree per inch).

Note: L/k applies to prime surface. When extended surface is used, this factor should be modified. A reasonable approximation is $(L/k)\ S_R$.

Values of the internal film coefficient h_i will be found in Reference 1. For turbulent flow, at values of DG/μ exceeding 10,000 in horizontal tubes, using average water temperatures, the general equation for condensing[1] is:

$$\frac{h_i D}{k_f} = 0.023 \left(\frac{DG}{\mu}\right)^{0.8} \left(\frac{c_p \mu}{k_f}\right)^{0.4} \quad (3)$$

where

D = inside tube diameter, feet.
k_f = thermal conductivity, Btu per (hour) (square foot) (Fahrenheit degree per foot).
G = mass velocity, pounds per (hour) (square foot of cross section area).
μ = viscosity (based on arithmetic mean temperature of the water, = 2.42 × viscosity in centipoises), pounds per foot hour.
c_p = specific heat at constant pressure, Btu per (pound) (Fahrenheit degree).

For a given condenser tube and a given range of operating conditions, Equation 3 may be simplified to:

$$h_i = CV^{0.8} \quad (4)$$

where

C = a constant, derived by combining all known quantities from Equation 3.
V = velocity, feet per second.

The values of the external or refrigerant-side coefficient h_o should be determined from test data, since it varies with the physical construction of the condenser and type of tube. A number of studies have been made to determine refrigerant coefficients but complete accord as to conclusions has yet to be reached. One experiment[2] indicates external coefficients ranging from 400 to 550 for Refrigerant 12, based on tests of an 8 in. × 3 ft condenser having 40 copper tubes (¾-in. OD nominal size) with 16 fins per inch, 0.063 in. high. An early study[3] on a horizontal ammonia condenser having 2-in. OD tubes indicated an external coefficient of 1635 Btu per (hr) (sq ft) (F deg) for saturated gas entering the condenser. In most refrigeration systems, the refrigerant enters the condenser as superheated vapor, in which case the coefficient for ammonia would be between 900 and 1300 Btu per (hr) (sq ft) (F deg).

Fouling Factors

Manufacturers' ratings are based on commercially clean equipment. It is generally agreed that this refers to new equipment which has been cleaned, mechanically or with acid, immediately prior to the performance test. On copper or other nonferrous tubes, this condition can often be reestab-