U. S. DEPARTMENT OF COMMERCE
SINCLAIR WEEKS, Secretary
COAST AND GEODETIC SURVEY
ROBERT F. A. STUDDS, Director

SPECIAL PUBLICATION NO. 298

SEA WATER TEMPERATURE AND DENSITY REDUCTION TABLES

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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1953

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National Oceanic and Atmospheric Administration

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Beltsville, MD 20704-1387
January 1, 2006

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INTRODUCTION

The purpose of this publication is to furnish the tables and graphs needed for the reduction and use of the sea water temperature and density observations as obtained at harbor and coastal stations by the Coast and Geodetic Survey, and to present the formulas and methods used in their construction.

The instruments used in observing are glass hydrometers and liquid-in-glass thermometers. Thermometers are available in both Fahrenheit and centigrade scales. There are three groups of hydrometers graduated for the following ranges of density: 0.9960 to 1.0110, 1.0100 to 1.0210, and 1.0200 to 1.0310. (See Figure 1). The total range of these groups is

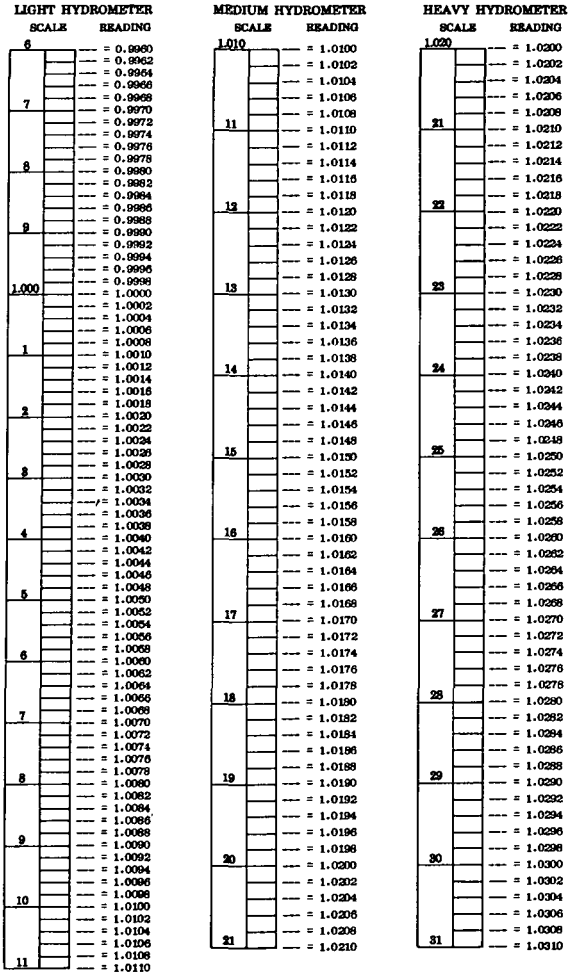

Figure 1. The three hydrometer scales with corresponding readings.

sufficient to include density of any sample from fresh water to the most saline water likely to be encountered. Recording thermometers have been installed in recent years at several stations in order to obtain a continuous record of temperature, but they have not supplanted the manual observations.

The hydrometers of the Coast and Geodetic Survey usually are graduated to indicate density at the standard temperature of 15°C. referred to pure water at a temperature of 4°C. as unity. This is referred to as the 15°/4°C. basis, and results published by the Bureau have been reduced to that basis. Hydrometers may be graduated on other bases. The Bureau has some in use that are graduated on a 60°/60°F. basis. When these instruments are used, their readings must first be corrected to refer them to the 15°/4°C. basis before the reduction tables can be entered. These corrections can be obtained from Table No. 28 of National Bureau of Standards Circular No. 19, "Standard Density and Volumetric Tables". For all Coast and Geodetic Survey hydrometers on the 60°/60°F. basis, the correction may be taken as -0.0010.

The glass thermometers and hydrometers are numbered for identification. They are usually tested for accuracy by the National Bureau of Standards, and those instruments not meeting prescribed standards are rejected. For a more complete description of these and other oceanographic instruments, see Coast and Geodetic Survey Special Publication No. 143, "Hydrographic Manual".

The observations that are obtained manually are made usually once a day and are recorded on Form 457 (See Figure 2). The observer draws a bucket of water from a foot or two below the surface and immediately observes its temperature before it has been affected by the surrounding air. This reading is entered in the column "Sea Water Temperature". Some of the water is poured into a glass hydrometer jar in which a thermometer is then suspended and a hydrometer floated. When the temperature of the water in the jar has become stable, the thermometer and hydrometer are read and the readings are recorded in the columns "Temperature, Water in Jar" and "Density, Observed Reading." The number of the hydrometer used is entered in the "Hydrometer No." column. The air temperature and time of observation are also recorded.

The density of sea water as observed depends not only upon the amount of matter held in solution but also upon the temperature of the water sample at the time of observation. Though a 15°/4°C. hydrometer may have been used, the temperature of the water in the jar at the time of observation is seldom 15°C. and in the office processing of these records, a correction from Table 3 or 4 is applied to each hydrometer reading to reduce it to density at this standard temperature, which makes all densities comparable. This reduced value is entered in the column "Density, Reduced Value." The maximum and minimum values in the sea water temperature and reduced density columns are entered by the processor in the spaces at the top of the form, and sums and means of these columns are computed and entered at the bottom.

For some purposes, salinity may be desired rather than density. Salinity expressed as parts per thousand (°/oo), represents the amount of matter held in solution. With all densities reduced to the standard temperature, the corresponding salinities can be obtained at once from Table 5.

Figure 3 permits the conversion of density at the standard temperature to density at any temperature apt to be encountered.

When ice at a station prevents observing during all or most of a month, the notation "ice" is entered in place of a mean temperature for that month. When observations are available for most of a month but are prevented by ice on a few days, a reasonably valid monthly mean temperature can be ob-

tained by estimating temperatures on those days with the help of Figure 4 which gives the freezing temperature of sea water of various densities and salinities.

The tables that follow are accompanied by a brief explanation of their construction and use.

Form 457
DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
Rev. Apr. 1948

TEMPERATURE AND DENSITY

Lat. 41°22'N.
Long. 72°06'W.

Station New London, Conn. Time Mer. 75°W

Month December Year 1952 Observer William Rogers

*Warmest Sea Water 47 Date 12th *Heaviest Sea Water 1.0201 Date 1st

*Coldest Sea Water 39 Date 29th - 31st *Lightest Sea Water 1.0091 Date 15th

DAY OF MONTH	TIME OF OBSERVATION	TEMPERATURE			HYDROMETER NO.	DENSITY		REMARKS
		OUTDOOR AIR	SEA WATER	WATER IN JAR		OBSERVED READING	*REDUCED VALUE	
	h. m.	°	°	°			15° C.	
1	16 50	30	46	45	1713	1.0 212	1.0 201	
2	13 30	32	46	45	"	1.0 210	1.0 199	
3	1442	40	45	45	"	1.0 206	1.0 195	
4	1539	45	45	45	"	1.0 206	1.0 195	
5	1545	46	45	45	"	1.0 208	1.0 197	
6	1230	46	45	45	"	1.0 210	1.0 199	
7						1.0	1.0	
8	1540	44	44	43	T-480	1.0 120	1.0 110	
9	1607	46	45	44	"	1.0 114	1.0 105	
10	1533	50	46	46	"	1.0 152	1.0 143	
11	1548	54	46	46	"	1.0 158	1.0 149	
12	1548	44	47	47	"	1.0 140	1.0 132	
13	1220	40	46	46	"	1.0 138	1.0 129	
14						1.0	1.0	
15	1530	36	43	42	3166	1.0 100	1.0 091	
16	1600	43	43	42	T-480	1.0 110	1.0 100	
17	1540	46	43	43	"	1.0 118	1.0 108	
18	1550	48	43	43	"	1.0 120	1.0 110	
19	1557	40	42	42	"	1.0 158	1.0 147	
20	1140	34	42	42	"	1.0 150	1.0 139	
21						1.0	1.0	
22	1550	33	41	41	T-480	1.0 186	1.0 174	
23	1510	36	41	41	"	1.0 180	1.0 168	
24	1535	48	41	41	"	1.0 124	1.0 114	
25						1.0	1.0	
26	1445	44	41	41	T-480	1.0 130	1.0 120	
27	1140	38	41	40	"	1.0 140	1.0 129	
28						1.0	1.0	
29	1600	37	39	38	T-480	1.0 176	1.0 163	
30	1545	41	39	39	"	1.0 170	1.0 158	
31	1435	36	39	38	"	1.0 176	1.0 163	
Sum		(36)	1124			(32)	26.3838	
Mean			42.2				1.0148	

*Not to be filled out by observer.

Reduced by FJ Date 1-12-53
Checked by GOT Date 1/22/53

Figure 2. Form 457 for recording daily temperature and density observations.

TABLES 1 AND 2. TEMPERATURE CONVERSION

These tables are for use in converting temperatures from the Fahrenheit scale to centigrade and vice versa. The formulas used in computing them are

$$F = 1.8\,C + 32 \quad \text{and} \quad C = 5/9\,(F - 32)$$

where F and C are temperatures in Fahrenheit and centigrade respectively

TABLE 1. TEMPERATURE CONVERSION - FAHRENHEIT TO CENTIGRADE

°F	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
25	-3.9	-3.8	-3.8	-3.7	-3.7	-3.6	-3.6	-3.5	-3.4	-3.4
26	-3.3	-3.3	-3.2	-3.2	-3.1	-3.1	-3.0	-2.9	-2.9	-2.8
27	-2.8	-2.7	-2.7	-2.6	-2.6	-2.5	-2.4	-2.4	-2.3	-2.3
28	-2.2	-2.2	-2.1	-2.1	-2.0	-1.9	-1.9	-1.8	-1.8	-1.7
29	-1.7	-1.6	-1.6	-1.5	-1.4	-1.4	-1.3	-1.3	-1.2	-1.2
30	-1.1	-1.1	-1.0	-0.9	-0.9	-0.8	-0.8	-0.7	-0.7	-0.6
31	-0.6	-0.5	-0.4	-0.4	-0.3	-0.3	-0.2	-0.2	-0.1	-0.1
32	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5
33	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.1
34	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.6
35	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.2
36	2.2	2.3	2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.7
37	2.8	2.8	2.9	2.9	3.0	3.1	3.1	3.2	3.2	3.3
38	3.3	3.4	3.4	3.5	3.6	3.6	3.7	3.7	3.8	3.8
39	3.9	3.9	4.0	4.1	4.1	4.2	4.2	4.3	4.3	4.4
40	4.4	4.5	4.6	4.6	4.7	4.7	4.8	4.8	4.9	4.9
41	5.0	5.1	5.1	5.2	5.2	5.3	5.3	5.4	5.4	5.5
42	5.6	5.6	5.7	5.7	5.8	5.8	5.9	5.9	6.0	6.1
43	6.1	6.2	6.2	6.3	6.3	6.4	6.4	6.5	6.6	6.6
44	6.7	6.7	6.8	6.8	6.9	6.9	7.0	7.1	7.1	7.2
45	7.2	7.3	7.3	7.4	7.4	7.5	7.6	7.6	7.7	7.7
46	7.8	7.8	7.9	7.9	8.0	8.1	8.1	8.2	8.2	8.3
47	8.3	8.4	8.4	8.5	8.6	8.6	8.7	8.7	8.8	8.8
48	8.9	8.9	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.4
49	9.4	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9
50	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5
51	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.0	11.1
52	11.1	11.2	11.2	11.3	11.3	11.4	11.4	11.5	11.6	11.6
53	11.7	11.7	11.8	11.8	11.9	11.9	12.0	12.1	12.1	12.2
54	12.2	12.3	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.7
55	12.8	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.2	13.3
56	13.3	13.4	13.4	13.5	13.6	13.6	13.7	13.7	13.8	13.8
57	13.9	13.9	14.0	14.1	14.1	14.2	14.2	14.3	14.3	14.4
58	14.4	14.5	14.6	14.6	14.7	14.7	14.8	14.8	14.9	14.9
59	15.0	15.1	15.1	15.2	15.2	15.3	15.3	15.4	15.4	15.5

TABLE 1. FAHRENHEIT TO CENTIGRADE -- Contd.

°F	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
60	15.6	15.6	15.7	15.7	15.8	15.8	15.9	15.9	16.0	16.1
61	16.1	16.2	16.2	16.3	16.3	16.4	16.4	16.5	16.6	16.6
62	16.7	16.7	16.8	16.8	16.9	16.9	17.0	17.1	17.1	17.2
63	17.2	17.3	17.3	17.4	17.4	17.5	17.6	17.6	17.7	17.7
64	17.8	17.8	17.9	17.9	18.0	18.1	18.1	18.2	18.2	18.3
65	18.3	18.4	18.4	18.5	18.6	18.6	18.7	18.7	18.8	18.8
66	18.9	18.9	19.0	19.1	19.1	19.2	19.2	19.3	19.3	19.4
67	19.4	19.5	19.6	19.6	19.7	19.7	19.8	19.8	19.9	19.9
68	20.0	20.1	20.1	20.2	20.2	20.3	20.3	20.4	20.4	20.5
69	20.6	20.6	20.7	20.7	20.8	20.8	20.9	20.9	21.0	21.1
70	21.1	21.2	21.2	21.3	21.3	21.4	21.4	21.5	21.6	21.6
71	21.7	21.7	21.8	21.8	21.9	21.9	22.0	22.1	22.1	22.2
72	22.2	22.3	22.3	22.4	22.4	22.5	22.6	22.6	22.7	22.7
73	22.8	22.8	22.9	22.9	23.0	23.1	23.1	23.2	23.2	23.3
74	23.3	23.4	23.4	23.5	23.6	23.6	23.7	23.7	23.8	23.8
75	23.9	23.9	24.0	24.1	24.1	24.2	24.2	24.3	24.3	24.4
76	24.4	24.5	24.6	24.6	24.7	24.7	24.8	24.8	24.9	24.9
77	25.0	25.1	25.1	25.2	25.2	25.3	25.3	25.4	25.4	25.5
78	25.6	25.6	25.7	25.7	25.8	25.8	25.9	25.9	26.0	26.1
79	26.1	26.2	26.2	26.3	26.3	26.4	26.4	26.5	26.6	26.6
80	26.7	26.7	26.8	26.8	26.9	26.9	27.0	27.1	27.1	27.2
81	27.2	27.3	27.3	27.4	27.4	27.5	27.6	27.6	27.7	27.7
82	27.8	27.8	27.9	27.9	28.0	28.1	28.1	28.2	28.2	28.3
83	28.3	28.4	28.4	28.5	28.6	28.6	28.7	28.7	28.8	28.8
84	28.9	28.9	29.0	29.1	29.1	29.2	29.2	29.3	29.3	29.4
85	29.4	29.5	29.6	29.6	29.7	29.7	29.8	29.8	29.9	29.9
86	30.0	30.1	30.1	30.2	30.2	30.3	30.3	30.4	30.4	30.5
87	30.6	30.6	30.7	30.7	30.8	30.8	30.9	30.9	31.0	31.1
88	31.1	31.2	31.2	31.3	31.3	31.4	31.4	31.5	31.6	31.6
89	31.7	31.7	31.8	31.8	31.9	31.9	32.0	32.1	32.1	32.2
90	32.2	32.3	32.3	32.4	32.4	32.5	32.6	32.6	32.7	32.7
91	32.8	32.8	32.9	32.9	33.0	33.1	33.1	33.2	33.2	33.3
92	33.3	33.4	33.4	33.5	33.6	33.6	33.7	33.7	33.8	33.8
93	33.9	33.9	34.0	34.1	34.1	34.2	34.2	34.3	34.3	34.4
94	34.4	34.5	34.6	34.6	34.7	34.7	34.8	34.8	34.9	34.9
95	35.0	35.1	35.1	35.2	35.2	35.3	35.3	35.4	35.4	35.5
96	35.6	35.6	35.7	35.7	35.8	35.8	35.9	35.9	36.0	36.1
97	36.1	36.2	36.2	36.3	36.3	36.4	36.4	36.5	36.6	36.6
98	36.7	36.7	36.8	36.8	36.9	36.9	37.0	37.1	37.1	37.2
99	37.2	37.3	37.3	37.4	37.4	37.5	37.6	37.6	37.7	37.7
100	37.8	37.8	37.9	37.9	38.0	38.1	38.1	38.2	38.2	38.3
101	38.3	38.4	38.4	38.5	38.6	38.6	38.7	38.7	38.8	38.8
102	38.9	38.9	39.0	39.1	39.1	39.2	39.2	39.3	39.3	39.4
103	39.4	39.5	39.6	39.6	39.7	39.7	39.8	39.8	39.9	39.9
104	40.0	40.1	40.1	40.2	40.2	40.3	40.3	40.4	40.4	40.5

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TABLE 2. TEMPERATURE CONVERSION - CENTIGRADE TO FAHRENHEIT

°C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
-3	26.6	26.4	26.2	26.1	25.9	25.7	25.5	25.3	25.2	25.0
-2	28.4	28.2	28.0	27.9	27.7	27.5	27.3	27.1	27.0	26.8
-1	30.2	30.0	29.8	29.7	29.5	29.3	29.1	28.9	28.8	28.6
-0	32.0	31.8	31.6	31.5	31.3	31.1	30.9	30.7	30.6	30.4
0	32.0	32.2	32.4	32.5	32.7	32.9	33.1	33.3	33.4	33.6
1	33.8	34.0	34.2	34.3	34.5	34.7	34.9	35.1	35.2	35.4
2	35.6	35.8	36.0	36.1	36.3	36.5	36.7	36.9	37.0	37.2
3	37.4	37.6	37.8	37.9	38.1	38.3	38.5	38.7	38.8	39.0
4	39.2	39.4	39.6	39.7	39.9	40.1	40.3	40.5	40.6	40.8
5	41.0	41.2	41.4	41.5	41.7	41.9	42.1	42.3	42.4	42.6
6	42.8	43.0	43.2	43.3	43.5	43.7	43.9	44.1	44.2	44.4
7	44.6	44.8	45.0	45.1	45.3	45.5	45.7	45.9	46.0	46.2
8	46.4	46.6	46.8	46.9	47.1	47.3	47.5	47.7	47.8	48.0
9	48.2	48.4	48.6	48.7	48.9	49.1	49.3	49.5	49.6	49.8
10	50.0	50.2	50.4	50.5	50.7	50.9	51.1	51.3	51.4	51.6
11	51.8	52.0	52.2	52.3	52.5	52.7	52.9	53.1	53.2	53.4
12	53.6	53.8	54.0	54.1	54.3	54.5	54.7	54.9	55.0	55.2
13	55.4	55.6	55.8	55.9	56.1	56.3	56.5	56.7	56.8	57.0
14	57.2	57.4	57.6	57.7	57.9	58.1	58.3	58.5	58.6	58.8
15	59.0	59.2	59.4	59.5	59.7	59.9	60.1	60.3	60.4	60.6
16	60.8	61.0	61.2	61.3	61.5	61.7	61.9	62.1	62.2	62.4
17	62.6	62.8	63.0	63.1	63.3	63.5	63.7	63.9	64.0	64.2
18	64.4	64.6	64.8	64.9	65.1	65.3	65.5	65.7	65.8	66.0
19	66.2	66.4	66.6	66.7	66.9	67.1	67.3	67.5	67.6	67.8
20	68.0	68.2	68.4	68.5	68.7	68.9	69.1	69.3	69.4	69.6
21	69.8	70.0	70.2	70.3	70.5	70.7	70.9	71.1	71.2	71.4
22	71.6	71.8	72.0	72.1	72.3	72.5	72.7	72.9	73.0	73.2
23	73.4	73.6	73.8	73.9	74.1	74.3	74.5	74.7	74.8	75.0
24	75.2	75.4	75.6	75.7	75.9	76.1	76.3	76.5	76.6	76.8
25	77.0	77.2	77.4	77.5	77.7	77.9	78.1	78.3	78.4	78.6
26	78.8	79.0	79.2	79.3	79.5	79.7	79.9	80.1	80.2	80.4
27	80.6	80.8	81.0	81.1	81.3	81.5	81.7	81.9	82.0	82.2
28	82.4	82.6	82.8	82.9	83.1	83.3	83.5	83.7	83.8	84.0
29	84.2	84.4	84.6	84.7	84.9	85.1	85.3	85.5	85.6	85.8
30	86.0	86.2	86.4	86.5	86.7	86.9	87.1	87.3	87.4	87.6
31	87.8	88.0	88.2	88.3	88.5	88.7	88.9	89.1	89.2	89.4
32	89.6	89.8	90.0	90.1	90.3	90.5	90.7	90.9	91.0	91.2
33	91.4	91.6	91.8	91.9	92.1	92.3	92.5	92.7	92.8	93.0
34	93.2	93.4	93.6	93.7	93.9	94.1	94.3	94.5	94.6	94.8
35	95.0	95.2	95.4	95.5	95.7	95.9	96.1	96.3	96.4	96.6
36	96.8	97.0	97.2	97.3	97.5	97.7	97.9	98.1	98.2	98.4
37	98.6	98.8	99.0	99.1	99.3	99.5	99.7	99.9	100.0	100.2
38	100.4	100.6	100.8	100.9	101.1	101.3	101.5	101.7	101.8	102.0
39	102.2	102.4	102.6	102.7	102.9	103.1	103.3	103.5	103.6	103.8

TABLES 3 AND 4. DIFFERENCES TO CONVERT HYDROMETER READINGS TO DENSITY AT STANDARD TEMPERATURE.

These tables give differences to be applied to hydrometer readings made at any known temperature to reduce them to densities at the standard temperature of 15°C. (59°F.). Table 3 is for use when the temperature observations are in Fahrenheit and Table 4 when they are in centigrade.

The computations involved in their preparation are based on Martin Knudsen's "Hydrographische Tabellen,"* where density is expressed in terms of the Greek letter sigma with a subscript that refers to temperature. Thus, $\sigma_t = (S_t - 1)\ 1000$ where S_t is the density of sea water at t°C. referred to pure water at 4°C. as unity.

By using the formula, $\sigma_0 = \sigma_t + D$, and corresponding values of D from Knudsen, a table for σ_0 was prepared for values of σ_t from -4.00 to 34.00 at temperatures t from -2°C. to 33°C.

Then by substituting values of σ_0 from the first table and D from Knudsen in the formula $\sigma_t = \sigma_0 - D$, where t = 15°C., a second table was prepared which gave values of σ_{15} corresponding to values of σ_t from -4.00 to 34.00 at temperatures t from -2°C. to 33°C.

In practice, hydrometer readings do not equal density as represented by S_t because of the expansion of the glass of the hydrometer, and it is the hydrometer reading that is to be converted to density at 15°C. Therefore the values of σ_t in the second table were converted to S_t, which in turn were converted to hydrometer readings H_t by applying a correction for the expansion of glass (assuming an average coefficient of expansion of 0.000025 per degree C.), thus

$$H_t = S_t - 0.000025\ (15^\circ - t^\circ).$$

From this table it was then possible to obtain the differences between S_{15} (converted from σ_{15}) and H_t as given in Tables 3 and 4. Where required for accuracy, graphic instead of straight line interpolation was used, particularly for Table 3.

To use tables: At the left find the observed hydrometer reading and at the top the temperature of the water sample at the time the reading was made; at the intersection of the two arguments find the difference to be applied to the hydrometer reading to obtain density at 15°C. The differences are expressed in ten-thousandths of a unit and are to be applied according to sign to the observed hydrometer reading. Interpolate where necessary.

Example: If the hydrometer read 1.0244 and the temperature of the water in the jar at the time of this reading was 11.5°C., the table gives (by interpolation) a correction of -0.0006. The density of the sample at 15°C. is then 1.0244 -0.0006 = 1.0238.

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* Knudsen, Martin, "Hydrographische Tabellen," Copenhagen, G.E.C. Gad., 63 pp., 1901.

TABLE 3. DIFFERENCES TO CONVERT HYDROMETER READINGS AT ANY TEMPERATURE FAHRENHEIT TO DENSITY AT 59°F. (15°C.)

Obs'd Reading	Temperature of Water in Jar (°F.)															
	28°	29°	30°	31°	32°	33°	34°	35°	36°	37°	38°	39°	40°	41°	42°	43°
0.9960																
0.9970																
0.9980																
0.9990	-1	-2	-2	-3	-3	-4	-4	-5	-5	-5	-5	-6	-6	-6	-6	-6
1.0000	-2	-2	-3	-3	-4	-4	-5	-5	-5	-6	-6	-6	-6	-6	-6	-6
1.0010	-2	-3	-3	-4	-4	-5	-5	-6	-6	-6	-6	-6	-7	-7	-7	-7
1.0020	-3	-4	-4	-4	-5	-5	-6	-6	-6	-7	-7	-7	-7	-7	-7	-7
1.0030	-4	-4	-5	-5	-5	-6	-6	-7	-7	-7	-7	-7	-7	-7	-7	-7
1.0040	-4	-5	-5	-6	-6	-6	-7	-7	-7	-7	-8	-8	-8	-8	-8	-7
1.0050	-5	-5	-6	-6	-6	-7	-7	-7	-8	-8	-8	-8	-8	-8	-8	-8
1.0060	-6	-6	-6	-7	-7	-7	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
1.0070	-6	-7	-7	-7	-8	-8	-8	-8	-8	-8	-9	-9	-9	-8	-8	-8
1.0080	-7	-7	-7	-8	-8	-8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-8
1.0090	-7	-8	-8	-8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
1.0100	-8	-8	-9	-9	-9	-9	-10	-10	-10	-10	-10	-10	-10	-9	-9	-9
1.0110	-8	-9	-9	-9	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-9
1.0120	-9	-9	-10	-10	-10	-10	-10	-11	-11	-11	-10	-10	-10	-10	-10	-10
1.0130	-10	-10	-10	-10	-11	-11	-11	-11	-11	-11	-11	-11	-11	-10	-10	-10
1.0140	-10	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11	-10	-10
1.0150	-11	-11	-11	-11	-12	-12	-12	-12	-12	-12	-12	-11	-11	-11	-11	-10
1.0160	-11	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-12	-11	-11	-11	-11
1.0170	-12	-12	-12	-12	-12	-13	-13	-13	-13	-12	-12	-12	-12	-12	-11	-11
1.0180	-13	-13	-13	-13	-13	-13	-13	-13	-13	-13	-13	-12	-12	-12	-12	-11
1.0190	-13	-13	-13	-13	-13	-14	-14	-13	-13	-13	-13	-13	-12	-12	-12	-11
1.0200	-14	-14	-14	-14	-14	-14	-14	-14	-14	-14	-13	-13	-13	-12	-12	-12
1.0210	-14	-14	-14	-14	-14	-14	-14	-14	-14	-14	-14	-13	-13	-13	-12	-12
1.0220	-15	-15	-15	-15	-15	-15	-15	-15	-15	-14	-14	-14	-13	-13	-13	-12
1.0230	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15	-14	-14	-14	-13	-13	-12
1.0240	-16	-16	-16	-16	-16	-16	-16	-15	-15	-15	-15	-14	-14	-14	-13	-13
1.0250	-17	-16	-16	-16	-16	-16	-16	-16	-16	-15	-15	-15	-14	-14	-13	-13
1.0260	-17	-17	-17	-17	-17	-17	-16	-16	-16	-16	-15	-15	-15	-14	-14	-13
1.0270	-18	-18	-17	-17	-17	-17	-17	-17	-16	-16	-16	-15	-15	-14	-14	-13
1.0280	-18	-18	-18	-18	-18	-18	-17	-17	-17	-16	-16	-16	-15	-15	-14	-14
1.0290	-19	-19	-18	-18	-18	-18	-18	-17	-17	-17	-16	-16	-16	-15	-15	-14
1.0300	-19	-19	-19	-19	-19	-18	-18	-18	-18	-17	-17	-16	-16	-15	-15	-14
1.0310	-20	-20	-19	-19	-19	-19	-19	-18	-18	-18	-17	-17	-16	-16	-15	-14

TABLE 3. DIFFERENCES TO CONVERT HYDROMETER READINGS AT ANY TEMPERATURE FAHRENHEIT TO DENSITY AT 59°F. (15°C.) -- Contd.

Obs'd Reading	Temperature of Water in Jar (°F.)															
	44°	45°	46°	47°	48°	49°	50°	51°	52°	53°	54°	55°	56°	57°	58°	59°
0.9960																
0.9970																
0.9980																
0.9990	-6	-6	-6	-5	-5	-5	-5	-4	-4	-3	-3	-2	-2	-1	-1	0
1.0000	-6	-6	-6	-6	-5	-5	-5	-4	-4	-4	-3	-2	-2	-1	-1	0
1.0010	-6	-6	-6	-6	-6	-5	-5	-5	-4	-4	-3	-3	-2	-1	-1	0
1.0020	-7	-7	-6	-6	-6	-5	-5	-5	-4	-4	-3	-3	-2	-1	-1	0
1.0030	-7	-7	-7	-6	-6	-6	-5	-5	-4	-4	-3	-3	-2	-1	-1	0
1.0040	-7	-7	-7	-6	-6	-6	-5	-5	-4	-4	-3	-3	-2	-1	-1	0
1.0050	-7	-7	-7	-7	-6	-6	-6	-5	-5	-4	-3	-3	-2	-1	-1	0
1.0060	-8	-7	-7	-7	-6	-6	-6	-5	-5	-4	-4	-3	-2	-2	-1	0
1.0070	-8	-8	-7	-7	-7	-6	-6	-5	-5	-4	-4	-3	-2	-2	-1	0
1.0080	-8	-8	-8	-7	-7	-6	-6	-6	-5	-4	-4	-3	-2	-2	-1	0
1.0090	-8	-8	-8	-7	-7	-7	-6	-6	-5	-4	-4	-3	-2	-2	-1	0
1.0100	-9	-8	-8	-8	-7	-7	-6	-6	-5	-4	-4	-3	-2	-2	-1	0
1.0110	-9	-9	-8	-8	-7	-7	-6	-6	-5	-5	-4	-3	-2	-2	-1	0
1.0120	-9	-9	-8	-8	-8	-7	-7	-6	-5	-5	-4	-3	-3	-2	-1	0
1.0130	-9	-9	-9	-8	-8	-7	-7	-6	-6	-5	-4	-3	-3	-2	-1	0
1.0140	-10	-9	-9	-8	-8	-7	-7	-6	-6	-5	-4	-3	-3	-2	-1	0
1.0150	-10	-10	-9	-9	-8	-8	-7	-6	-6	-5	-4	-4	-3	-2	-1	0
1.0160	-10	-10	-9	-9	-8	-8	-7	-6	-6	-5	-4	-4	-3	-2	-1	0
1.0170	-10	-10	-9	-9	-8	-8	-7	-7	-6	-5	-4	-4	-3	-2	-1	0
1.0180	-11	-10	-10	-9	-9	-8	-7	-7	-6	-5	-4	-4	-3	-2	-1	0
1.0190	-11	-10	-10	-9	-9	-8	-7	-7	-6	-5	-5	-4	-3	-2	-1	0
1.0200	-11	-11	-10	-10	-9	-8	-8	-7	-6	-5	-5	-4	-3	-2	-1	0
1.0210	-11	-11	-10	-10	-9	-8	-8	-7	-6	-5	-5	-4	-3	-2	-1	0
1.0220	-12	-11	-10	-10	-9	-9	-8	-7	-6	-6	-5	-4	-3	-2	-1	0
1.0230	-12	-11	-11	-10	-9	-9	-8	-7	-7	-6	-5	-4	-3	-2	-1	0
1.0240	-12	-12	-11	-10	-10	-9	-8	-7	-7	-6	-5	-4	-3	-2	-1	0
1.0250	-12	-12	-11	-10	-10	-9	-8	-8	-7	-6	-5	-4	-3	-2	-1	0
1.0260	-13	-12	-11	-11	-10	-9	-8	-8	-7	-6	-5	-4	-3	-2	-1	0
1.0270	-13	-12	-11	-11	-10	-9	-9	-8	-7	-6	-5	-4	-3	-2	-1	0
1.0280	-13	-12	-12	-11	-10	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0
1.0290	-13	-13	-12	-11	-10	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0
1.0300	-14	-13	-12	-11	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0
1.0310	-14	-13	-12	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0

TABLE 3. DIFFERENCES TO CONVERT HYDROMETER READINGS AT ANY TEMPERATURE FAHRENHEIT TO DENSITY AT 59°F. (15°C.) -- Contd.

Obs'd Reading	Temperature of Water in Jar (°F.)																
	59°	60°	61°	62°	63°	64°	65°	66°	67°	68°	69°	70°	71°	72°	73°	74°	75°
0.9960																	
0.9970													11	12	13	14	16
0.9980				2	3	4	5	6	7	8	9	10	11	12	13	14	16
0.9990	0	1	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16
1.0000	0	1	2	2	3	4	5	6	7	8	9	10	11	12	14	15	16
1.0010	0	1	2	2	3	4	5	6	7	8	9	10	11	12	14	15	16
1.0020	0	1	2	2	3	4	5	6	7	8	9	10	11	13	14	15	17
1.0030	0	1	2	2	3	4	5	6	7	8	9	11	12	13	14	15	17
1.0040	0	1	2	2	3	4	5	6	7	8	10	11	12	13	14	16	17
1.0050	0	1	2	2	3	4	5	6	7	9	10	11	12	13	14	16	17
1.0060	0	1	2	3	4	4	5	6	8	9	10	11	12	13	15	16	17
1.0070	0	1	2	3	4	5	5	7	8	9	10	11	12	14	15	16	18
1.0080	0	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	18
1.0090	0	1	2	3	4	5	6	7	8	9	10	11	13	14	15	17	18
1.0100	0	1	2	3	4	5	6	7	8	9	10	12	13	14	15	17	18
1.0110	0	1	2	3	4	5	6	7	8	9	11	12	13	14	16	17	18
1.0120	0	1	2	3	4	5	6	7	8	9	11	12	13	14	16	17	19
1.0130	0	1	2	3	4	5	6	7	8	9	11	12	13	15	16	17	19
1.0140	0	1	2	3	4	5	6	7	8	10	11	12	13	15	16	17	19
1.0150	0	1	2	3	4	5	6	7	9	10	11	12	14	15	16	18	19
1.0160	0	1	2	3	4	5	6	7	9	10	11	12	14	15	16	18	19
1.0170	0	1	2	3	4	5	6	8	9	10	11	13	14	15	17	18	20
1.0180	0	1	2	3	4	5	6	8	9	10	11	13	14	15	17	18	20
1.0190	0	1	2	3	4	5	6	8	9	10	12	13	14	15	17	18	20
1.0200	0	1	2	3	4	5	6	8	9	10	12	13	14	16	17	19	20
1.0210	0	1	2	3	4	6	7	8	9	10	12	13	14	16	17	19	20
1.0220	0	1	2	3	4	6	7	8	9	11	12	13	15	16	17	19	20
1.0230	0	1	2	3	4	6	7	8	9	11	12	13	15	16	18	19	21
1.0240	0	1	2	3	4	6	7	8	9	11	12	13	15	16	18	19	21
1.0250	0	1	2	3	5	6	7	8	10	11	12	14	15	16	18	19	21
1.0260	0	1	2	3	5	6	7	8	10	11	12	14	15	17	18	20	21
1.0270	0	1	2	3	5	6	7	8	10	11	13	14	15	17	18	20	21
1.0280	0	1	2	4	5	6	7	8	10	11	13	14	15	17	18	20	21
1.0290	0	1	2	4	5	6	7	9	10	11	13	14	16	17	18	20	22
1.0300	0	1	2	4	5	6	7	9	10	12	13	14	16	17	19	20	
1.0310	0	1	2	4	5												

TABLE 3. DIFFERENCES TO CONVERT HYDROMETER READINGS AT ANY TEMPERATURE FAHRENHEIT TO DENSITY AT 59°F. (15°C.) -- Contd.

Obs'd Reading	Temperature of Water in Jar (°F.)																
	76°	77°	78°	79°	80°	81°	82°	83°	84°	85°	86°	87°	88°	89°	90°	91°	92°
0.9960			19	20	22	23	25	26	28	29	31	32	34	36	38	39	41
0.9970	17	18	19	21	22	23	25	26	28	29	31	33	34	36	38	40	41
0.9980	17	18	20	21	22	24	25	27	28	30	31	33	35	36	38	40	42
0.9990	17	18	20	21	23	24	26	27	29	30	32	33	35	37	39	40	42
1.0000	17	19	20	21	23	24	26	27	29	31	32	34	35	37	39	41	42
1.0010	18	19	20	22	23	25	26	28	29	31	32	34	36	38	39	41	43
1.0020	18	19	20	22	23	25	26	28	29	31	33	34	36	38	40	41	43
1.0030	18	19	21	22	24	25	27	28	30	31	33	35	36	38	40	42	44
1.0040	18	20	21	22	24	25	27	29	30	32	33	35	37	39	40	42	44
1.0050	18	20	21	23	24	26	27	29	30	32	34	35	37	39	41	43	44
1.0060	19	20	21	23	24	26	28	29	31	32	34	36	37	39	41	43	45
1.0070	19	20	22	23	25	26	28	29	31	33	34	36	38	40	41	43	45
1.0080	19	20	22	23	25	27	28	30	31	33	35	36	38	40	42	44	45
1.0090	19	21	22	24	25	27	28	30	32	33	35	37	38	40	42	44	46
1.0100	20	21	22	24	25	27	29	30	32	34	35	37	39	41	42	44	46
1.0110	20	21	23	24	26	27	29	30	32	34	35	37	39	41	43	45	46
1.0120	20	21	23	24	26	28	29	31	32	34	36	38	39	41	43	45	47
1.0130	20	21	23	25	26	28	29	31	33	34	36	38	40	42	43	45	47
1.0140	20	22	23	25	26	28	30	31	33	35	36	38	40	42	44	46	47
1.0150	21	22	24	25	27	28	30	32	33	35	37	38	40	42	44	46	48
1.0160	21	22	24	25	27	28	30	32	34	35	37	39	41	43	44	46	48
1.0170	21	22	24	25	27	29	30	32	34	36	37	39	41	43	45	47	48
1.0180	21	23	24	26	27	29	31	32	34	36	37	39	41	43	45	47	49
1.0190	21	23	24	26	28	29	31	33	34	36	38	40	41	43	45	47	49
1.0200	22	23	25	26	28	29	31	33	35	36	38	40	42	44	46	48	49
1.0210	22	23	25	26	28	30	31	33	35	37	38	40	42	44	46	48	50
1.0220	22	23	25	27	28	30	32	33	35	37	39	40	42	44	46	48	50
1.0230	22	24	25	27	28	30	32	34	35	37	39	41	43	45	46	48	50
1.0240	22	24	25	27	29	30	32	34	36	37	39	41	43	45	47	49	51
1.0250	22	24	26	27	29	31	32	34	36	38	39	41	43	45	47	49	51
1.0260	23	24	26	27	29	31	33	34	36	38	40	42	43	45	47	49	51
1.0270	23	24	26	28	29	31	33	35	36	38	40						
1.0280	23	25	26	28	30	31	33										
1.0290	23	25															
1.0300																	
1.0310																	

TABLE 4. DIFFERENCES TO CONVERT HYDROMETER READINGS AT ANY TEMPERATURE CENTIGRADE TO DENSITY AT 15°C. (59°F.)

Obs'd Reading	Temperature of Water in Jar (°C.)												
	-2.0°	-1.0°	0.0°	1.0°	2.0°	3.0°	4.0°	5.0°	6.0°	7.0°	8.0°	9.0°	10.0°
0.9960													
0.9970													
0.9980													
0.9990	-1	-2	-3	-4	-5	-5	-6	-6	-6	-6	-6	-5	-5
1.0000	-2	-3	-4	-5	-5	-6	-6	-6	-6	-6	-6	-5	-5
1.0010	-3	-4	-4	-5	-6	-6	-6	-7	-7	-6	-6	-6	-5
1.0020	-3	-4	-5	-6	-6	-7	-7	-7	-7	-7	-6	-6	-5
1.0030	-4	-5	-6	-6	-7	-7	-7	-7	-7	-7	-6	-6	-5
1.0040	-4	-5	-6	-7	-7	-7	-8	-8	-7	-7	-7	-6	-6
1.0050	-5	-6	-6	-7	-8	-8	-8	-8	-8	-7	-7	-6	-6
1.0060	-6	-6	-7	-8	-8	-8	-8	-8	-8	-8	-7	-6	-6
1.0070	-6	-7	-8	-8	-8	-8	-8	-8	-8	-8	-7	-7	-6
1.0080	-7	-8	-8	-9	-9	-9	-9	-9	-8	-8	-7	-7	-6
1.0090	-7	-8	-9	-9	-9	-9	-9	-9	-9	-8	-8	-7	-6
1.0100	-8	-9	-9	-10	-10	-10	-10	-9	-9	-8	-8	-7	-6
1.0110	-9	-9	-10	-10	-10	-10	-10	-10	-9	-9	-8	-7	-6
1.0120	-9	-10	-10	-10	-10	-10	-10	-10	-10	-9	-8	-7	-7
1.0130	-10	-10	-11	-11	-11	-11	-11	-10	-10	-9	-8	-8	-7
1.0140	-10	-11	-11	-11	-11	-11	-11	-11	-10	-10	-9	-8	-7
1.0150	-11	-11	-12	-12	-12	-12	-11	-11	-10	-10	-9	-8	-7
1.0160	-12	-12	-12	-12	-12	-12	-12	-11	-11	-10	-9	-8	-7
1.0170	-12	-12	-12	-13	-13	-12	-12	-12	-11	-10	-9	-8	-7
1.0180	-13	-13	-13	-13	-13	-13	-12	-12	-11	-10	-9	-8	-7
1.0190	-13	-13	-14	-14	-13	-13	-13	-12	-12	-11	-10	-9	-8
1.0200	-14	-14	-14	-14	-14	-13	-13	-12	-12	-11	-10	-9	-8
1.0210	-14	-14	-14	-14	-14	-14	-13	-13	-12	-11	-10	-9	-8
1.0220	-15	-15	-15	-15	-15	-14	-14	-13	-12	-11	-10	-9	-8
1.0230	-15	-15	-15	-15	-15	-15	-14	-13	-12	-12	-10	-9	-8
1.0240	-16	-16	-16	-16	-15	-15	-14	-14	-13	-12	-11	-10	-8
1.0250	-16	-16	-16	-16	-16	-15	-15	-14	-13	-12	-11	-10	-8
1.0260	-17	-17	-17	-16	-16	-16	-15	-14	-13	-12	-11	-10	-8
1.0270	-18	-17	-17	-17	-17	-16	-15	-14	-14	-12	-11	-10	-9
1.0280	-18	-18	-18	-17	-17	-16	-16	-15	-14	-13	-11	-10	-9
1.0290	-19	-18	-18	-18	-17	-17	-16	-15	-14	-13	-12	-10	-9
1.0300	-19	-19	-19	-18	-18	-17	-16	-15	-14	-13	-12	-10	-9
1.0310	-20	-19	-19	-19	-18	-17	-16	-16	-15	-13	-12	-10	-9

TABLE 4. DIFFERENCES TO CONVERT HYDROMETER READINGS AT ANY TEMPERATURE CENTIGRADE TO DENSITY AT 15°C. (59°F.) -- Contd.

Obs'd Reading	Temperature of Water in Jar (°C.)											
	11.0°	12.0°	13.0°	14.0°	15.0°	16.0°	17.0°	18.0°	18.5°	19.0°	19.5°	20.0°
0.9960												
0.9970												
0.9980							3	4	5	6	7	8
0.9990	-4	-3	-2	-1	0	1	3	4	5	6	7	8
1.0000	-4	-3	-2	-1	0	1	3	4	5	6	7	8
1.0010	-4	-3	-2	-1	0	1	3	4	5	6	7	8
1.0020	-4	-3	-2	-1	0	1	3	4	5	6	7	8
1.0030	-4	-3	-2	-1	0	1	3	4	5	6	7	8
1.0040	-5	-4	-3	-1	0	2	3	5	6	6	7	8
1.0050	-5	-4	-3	-1	0	2	3	5	6	7	8	9
1.0060	-5	-4	-3	-1	0	2	3	5	6	7	8	9
1.0070	-5	-4	-3	-2	0	2	3	5	6	7	8	9
1.0080	-5	-4	-3	-2	0	2	3	5	6	7	8	9
1.0090	-5	-4	-3	-2	0	2	3	5	6	7	8	9
1.0100	-5	-4	-3	-2	0	2	3	5	6	7	8	9
1.0110	-5	-4	-3	-2	0	2	3	5	6	7	8	9
1.0120	-6	-4	-3	-2	0	2	3	5	6	7	8	9
1.0130	-6	-4	-3	-2	0	2	4	5	6	7	8	10
1.0140	-6	-4	-3	-2	0	2	4	5	6	8	9	10
1.0150	-6	-4	-3	-2	0	2	4	5	6	8	9	10
1.0160	-6	-5	-3	-2	0	2	4	6	7	8	9	10
1.0170	-6	-5	-3	-2	0	2	4	6	7	8	9	10
1.0180	-6	-5	-3	-2	0	2	4	6	7	8	9	10
1.0190	-6	-5	-3	-2	0	2	4	6	7	8	9	10
1.0200	-6	-5	-3	-2	0	2	4	6	7	8	9	10
1.0210	-6	-5	-3	-2	0	2	4	6	7	8	9	10
1.0220	-7	-5	-3	-2	0	2	4	6	7	8	9	11
1.0230	-7	-5	-4	-2	0	2	4	6	7	8	9	11
1.0240	-7	-5	-4	-2	0	2	4	6	7	8	10	11
1.0250	-7	-5	-4	-2	0	2	4	6	7	8	10	11
1.0260	-7	-5	-4	-2	0	2	4	6	7	9	10	11
1.0270	-7	-5	-4	-2	0	2	4	6	7	9	10	11
1.0280	-7	-6	-4	-2	0	2	4	6	8	9	10	11
1.0290	-7	-6	-4	-2	0	2	4	6	8	9	10	11
1.0300	-7	-6	-4	-2	0	2	4	6	8	9	10	12
1.0310	-8	-6	-4	-2	0	2	4					

TABLE 4. DIFFERENCES TO CONVERT HYDROMETER READINGS AT ANY TEMPERATURE CENTIGRADE TO DENSITY AT 15°C. (59°F.) -- Contd.

Obs'd Reading	Temperature of Water in Jar (°C.)												
	20.5°	21.0°	21.5°	22.0°	22.5°	23.0°	23.5°	24.0°	24.5°	25.0°	25.5°	26.0°	26.5°
0.9960											19	20	21
0.9970			10	11	12	14	15	16	17	18	19	20	22
0.9980	9	10	11	12	13	14	15	16	17	18	19	21	22
0.9990	9	10	11	12	13	14	15	16	17	18	20	21	22
1.0000	9	10	11	12	13	14	15	16	17	19	20	21	22
1.0010	9	10	11	12	13	14	15	17	18	19	20	21	23
1.0020	9	10	11	12	13	14	16	17	18	19	20	22	23
1.0030	9	10	11	12	13	15	16	17	18	19	21	22	23
1.0040	9	10	11	12	14	15	16	17	18	20	21	22	23
1.0050	10	11	12	13	14	15	16	17	19	20	21	22	24
1.0060	10	11	12	13	14	15	16	18	19	20	21	23	24
1.0070	10	11	12	13	14	15	17	18	19	20	21	23	24
1.0080	10	11	12	13	14	16	17	18	19	20	22	23	24
1.0090	10	11	12	13	15	16	17	18	19	21	22	23	25
1.0100	10	11	12	14	15	16	17	18	20	21	22	24	25
1.0110	10	12	13	14	15	16	17	19	20	21	22	24	25
1.0120	10	12	13	14	15	16	18	19	20	21	23	24	25
1.0130	11	12	13	14	15	16	18	19	20	22	23	24	26
1.0140	11	12	13	14	15	17	18	19	20	22	23	24	26
1.0150	11	12	13	14	16	17	18	20	21	22	23	25	26
1.0160	11	12	13	14	16	17	18	20	21	22	24	25	26
1.0170	11	12	13	15	16	17	18	20	21	22	24	25	27
1.0180	11	12	14	15	16	17	19	20	21	23	24	25	27
1.0190	11	12	14	15	16	18	19	20	21	23	24	26	27
1.0200	11	13	14	15	16	18	19	20	22	23	24	26	27
1.0210	12	13	14	15	17	18	19	21	22	23	25	26	27
1.0220	12	13	14	15	17	18	19	21	22	23	25	26	28
1.0230	12	13	14	16	17	18	20	21	22	24	25	26	28
1.0240	12	13	14	16	17	18	20	21	22	24	25	27	28
1.0250	12	13	15	16	17	18	20	21	23	24	25	27	28
1.0260	12	13	15	16	17	19	20	22	23	24	26	27	29
1.0270	12	14	15	16	17	19	20	22	23	24	26	27	29
1.0280	12	14	15	16	18	19	20	22	23	25	26	28	29
1.0290	13	14	15	16	18	19	21	22	23				
1.0300	13	14	15	16	18								
1.0310													

TABLE 4. DIFFERENCES TO CONVERT HYDROMETER READINGS AT ANY TEMPERATURE CENTIGRADE TO DENSITY AT 15°C. (59°F.) -- Contd.

Obs'd Reading	Temperature of Water in Jar (°C.)												
	27.0°	27.5°	28.0°	28.5°	29.0°	29.5°	30.0°	30.5°	31.0°	31.5°	32.0°	32.5°	33.0°
0.9960	23	24	25	27	28	29	31	32	34	35	37	38	40
0.9970	23	24	26	27	28	30	31	33	34	36	37	39	40
0.9980	23	25	26	27	29	30	31	33	34	36	38	39	41
0.9990	24	25	26	28	29	30	32	33	35	36	38	39	41
1.0000	24	25	26	28	29	31	32	34	35	37	38	40	41
1.0010	24	25	27	28	30	31	32	34	35	37	39	40	42
1.0020	24	26	27	28	30	31	33	34	36	37	39	41	42
1.0030	25	26	27	29	30	32	33	35	36	38	39	41	42
1.0040	25	26	28	29	30	32	33	35	36	38	40	41	43
1.0050	25	26	28	29	31	32	34	35	37	38	40	42	43
1.0060	25	27	28	30	31	32	34	36	37	39	40	42	44
1.0070	26	27	28	30	31	33	34	36	38	39	41	42	44
1.0080	26	27	29	30	32	33	35	36	38	39	41	43	44
1.0090	26	28	29	30	32	33	35	36	38	40	41	43	45
1.0100	26	28	29	31	32	34	35	37	38	40	42	43	45
1.0110	27	28	30	31	32	34	36	37	39	40	42	44	45
1.0120	27	28	30	31	33	34	36	37	39	41	42	44	46
1.0130	27	29	30	32	33	35	36	38	39	41	43	44	46
1.0140	27	29	30	32	33	35	36	38	40	41	43	45	46
1.0150	28	29	31	32	34	35	37	38	40	42	43	45	47
1.0160	28	29	31	32	34	35	37	39	40	42	44	45	47
1.0170	28	30	31	33	34	36	37	39	40	42	44	46	47
1.0180	28	30	31	33	34	36	38	39	41	42	44	46	48
1.0190	29	30	32	33	35	36	38	39	41	43	44	46	48
1.0200	29	30	32	33	35	37	38	40	41	43	45	47	48
1.0210	29	31	32	34	35	37	38	40	42	43	45	47	49
1.0220	29	31	32	34	36	37	39	40	42	44	45	47	49
1.0230	30	31	33	34	36	37	39	41	42	44	46	47	49
1.0240	30	31	33	34	36	37	39	41	42	44	46	48	49
1.0250	30	31	33	35	36	38	39	41	43	44	46	48	50
1.0260	30	32	33	35	37	38	40	41	43	45	46	48	50
1.0270	30	32	34	35	37	38	40						
1.0280	31	32											
1.0290													
1.0300													
1.0310													

TABLE 5. CORRESPONDING DENSITIES AND SALINITIES.

This table is for converting densities at 59°F. (15°C.) to corresponding salinities. Salinity is defined as the number of grams of solid material dissolved in 1000 grams of water and is expressed in parts per thousand with the symbol 0/00. The table was taken largely from Knudsen's "Hydrographische Tabellen" which includes a table of salinities corresponding to densities at 0°C. Before entering Knudsen's table, densities at 15°C., for which salinities were desired, were converted to densities at 0°C. by means of the previously described table that was based on the formula

$$\sigma_0 = \sigma_t + D$$

For values beyond the limits of Knudsen's table, the following formula was used:

$$\sigma_0 = -0.093 + 0.8149\ S - 0.000482\ S^2 + 0.00000685\ S^3$$

where σ_0 is the density term at 0°C. as previously defined and S is salinity.

TABLE 5. CORRESPONDING DENSITIES AND SALINITIES

(Density at 15°C. -- Salinity in parts per 1,000)

Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity
0.9991	0.0	1.0046	7.1	1.0101	14.2	1.0156	21.4	1.0211	28.6	1.0266	35.8
0.9992	0.0	1.0047	7.2	1.0102	14.4	1.0157	21.6	1.0212	28.8	1.0267	35.9
0.9993	0.2	1.0048	7.3	1.0103	14.5	1.0158	21.7	1.0213	28.9	1.0268	36.0
0.9994	0.3	1.0049	7.5	1.0104	14.6	1.0159	21.8	1.0214	29.0	1.0269	36.2
0.9995	0.4	1.0050	7.6	1.0105	14.8	1.0160	22.0	1.0215	29.1	1.0270	36.3
0.9996	0.6	1.0051	7.7	1.0106	14.9	1.0161	22.1	1.0216	29.3	1.0271	36.4
0.9997	0.7	1.0052	7.9	1.0107	15.0	1.0162	22.2	1.0217	29.4	1.0272	36.6
0.9998	0.8	1.0053	8.0	1.0108	15.2	1.0163	22.4	1.0218	29.5	1.0273	36.7
0.9999	0.9	1.0054	8.1	1.0109	15.3	1.0164	22.5	1.0219	29.7	1.0274	36.8
1.0000	1.1	1.0055	8.2	1.0110	15.4	1.0165	22.6	1.0220	29.8	1.0275	37.0
1.0001	1.2	1.0056	8.4	1.0111	15.6	1.0166	22.7	1.0221	29.9	1.0276	37.1
1.0002	1.3	1.0057	8.5	1.0112	15.7	1.0167	22.9	1.0222	30.1	1.0277	37.2
1.0003	1.5	1.0058	8.6	1.0113	15.8	1.0168	23.0	1.0223	30.2	1.0278	37.3
1.0004	1.6	1.0059	8.8	1.0114	16.0	1.0169	23.1	1.0224	30.3	1.0279	37.5
1.0005	1.7	1.0060	8.9	1.0115	16.1	1.0170	23.3	1.0225	30.4	1.0280	37.6
1.0006	1.9	1.0061	9.0	1.0116	16.2	1.0171	23.4	1.0226	30.6	1.0281	37.7
1.0007	2.0	1.0062	9.2	1.0117	16.3	1.0172	23.5	1.0227	30.7	1.0282	37.9
1.0008	2.1	1.0063	9.3	1.0118	16.5	1.0173	23.7	1.0228	30.8	1.0283	38.0
1.0009	2.2	1.0064	9.4	1.0119	16.6	1.0174	23.8	1.0229	31.0	1.0284	38.1
1.0010	2.4	1.0065	9.6	1.0120	16.7	1.0175	23.9	1.0230	31.1	1.0285	38.2
1.0011	2.5	1.0066	9.7	1.0121	16.9	1.0176	24.1	1.0231	31.2	1.0286	38.4
1.0012	2.6	1.0067	9.8	1.0122	17.0	1.0177	24.2	1.0232	31.4	1.0287	38.5
1.0013	2.8	1.0068	9.9	1.0123	17.1	1.0178	24.3	1.0233	31.5	1.0288	38.6
1.0014	2.9	1.0069	10.1	1.0124	17.3	1.0179	24.4	1.0234	31.6	1.0289	38.8
1.0015	3.0	1.0070	10.2	1.0125	17.4	1.0180	24.6	1.0235	31.8	1.0290	38.9
1.0016	3.2	1.0071	10.3	1.0126	17.5	1.0181	24.7	1.0236	31.9	1.0291	39.0
1.0017	3.3	1.0072	10.5	1.0127	17.7	1.0182	24.8	1.0237	32.0	1.0292	39.2
1.0018	3.4	1.0073	10.6	1.0128	17.8	1.0183	25.0	1.0238	32.1	1.0293	39.3
1.0019	3.5	1.0074	10.7	1.0129	17.9	1.0184	25.1	1.0239	32.3	1.0294	39.4
1.0020	3.7	1.0075	10.8	1.0130	18.0	1.0185	25.2	1.0240	32.4	1.0295	39.6
1.0021	3.8	1.0076	11.0	1.0131	18.2	1.0186	25.4	1.0241	32.5	1.0296	39.7
1.0022	3.9	1.0077	11.1	1.0132	18.3	1.0187	25.5	1.0242	32.7	1.0297	39.8
1.0023	4.1	1.0078	11.2	1.0133	18.4	1.0188	25.6	1.0243	32.8	1.0298	39.9
1.0024	4.2	1.0079	11.4	1.0134	18.6	1.0189	25.8	1.0244	32.9	1.0299	40.1
1.0025	4.3	1.0080	11.5	1.0135	18.7	1.0190	25.9	1.0245	33.1	1.0300	40.2
1.0026	4.5	1.0081	11.6	1.0136	18.8	1.0191	26.0	1.0246	33.2	1.0301	40.3
1.0027	4.6	1.0082	11.8	1.0137	19.0	1.0192	26.1	1.0247	33.3	1.0302	40.4
1.0028	4.7	1.0083	11.9	1.0138	19.1	1.0193	26.3	1.0248	33.5	1.0303	40.6
1.0029	4.8	1.0084	12.0	1.0139	19.2	1.0194	26.4	1.0249	33.6	1.0304	40.7
1.0030	5.0	1.0085	12.2	1.0140	19.3	1.0195	26.5	1.0250	33.7	1.0305	40.8
1.0031	5.1	1.0086	12.3	1.0141	19.5	1.0196	26.7	1.0251	33.8	1.0306	41.0
1.0032	5.2	1.0087	12.4	1.0142	19.6	1.0197	26.8	1.0252	34.0	1.0307	41.1
1.0033	5.4	1.0088	12.6	1.0143	19.7	1.0198	26.9	1.0253	34.1	1.0308	41.2
1.0034	5.5	1.0089	12.7	1.0144	19.9	1.0199	27.1	1.0254	34.2	1.0309	41.4
1.0035	5.6	1.0090	12.8	1.0145	20.0	1.0200	27.2	1.0255	34.4	1.0310	41.5
1.0036	5.8	1.0091	12.9	1.0146	20.1	1.0201	27.3	1.0256	34.5	1.0311	41.6
1.0037	5.9	1.0092	13.1	1.0147	20.3	1.0202	27.5	1.0257	34.6	1.0312	41.7
1.0038	6.0	1.0093	13.2	1.0148	20.4	1.0203	27.6	1.0258	34.8	1.0313	41.9
1.0039	6.2	1.0094	13.3	1.0149	20.5	1.0204	27.7	1.0259	34.9	1.0314	42.0
1.0040	6.3	1.0095	13.5	1.0150	20.6	1.0205	27.8	1.0260	35.0	1.0315	42.1
1.0041	6.4	1.0096	13.6	1.0151	20.8	1.0206	28.0	1.0261	35.1	1.0316	42.3
1.0042	6.6	1.0097	13.7	1.0152	20.9	1.0207	28.1	1.0262	35.3	1.0317	42.4
1.0043	6.7	1.0098	13.9	1.0153	21.0	1.0208	28.2	1.0263	35.4	1.0318	42.5
1.0044	6.8	1.0099	14.0	1.0154	21.2	1.0209	28.4	1.0264	35.5	1.0319	42.7
1.0045	6.9	1.0100	14.1	1.0155	21.3	1.0210	28.5	1.0265	35.7	1.0320	42.8

FIGURE 3. SEA WATER DENSITY AT VARIOUS TEMPERATURES.

For some practical uses of density information, it is more important to know the density at the temperature apt to be encountered than at the standard temperature. Figure 3 provides for converting density at 59°F. (15°C.) as published in Coast and Geodetic Survey Special Publications 279 and 281 to density at other temperatures. The graph was derived from Knudsen's "Hydrographische Tabellen," specifically from the previously mentioned table that was based on the formula $\sigma_t = \sigma_0 - D$ (described under Tables 3 and 4). Since it is intended for use with true density and not with observed hydrometer readings, no glass correction was included. The limits of the graph both as to density and temperature are as fixed by the values given in Knudsen's tables and are wide enough to include all values likely to be encountered in the work of the Bureau.

To convert a density at 59°F. to density at another temperature, enter the graph horizontally from the left with the known density and downward from the top with the desired temperature; the position of the point of intersection with respect to the curves gives the density at the desired temperature. Interpolate between curves when necessary.

Example: If certain water has a density of 1.0274 at 59°F. (15°C.) what would its density be at a temperature of 79°F.? Entering the graph from the side and top with these values, it is found that the point of intersection lies about 4/10 of the way between curves 1.0240 and 1.0250, so that the density at 79° is 1.0244.

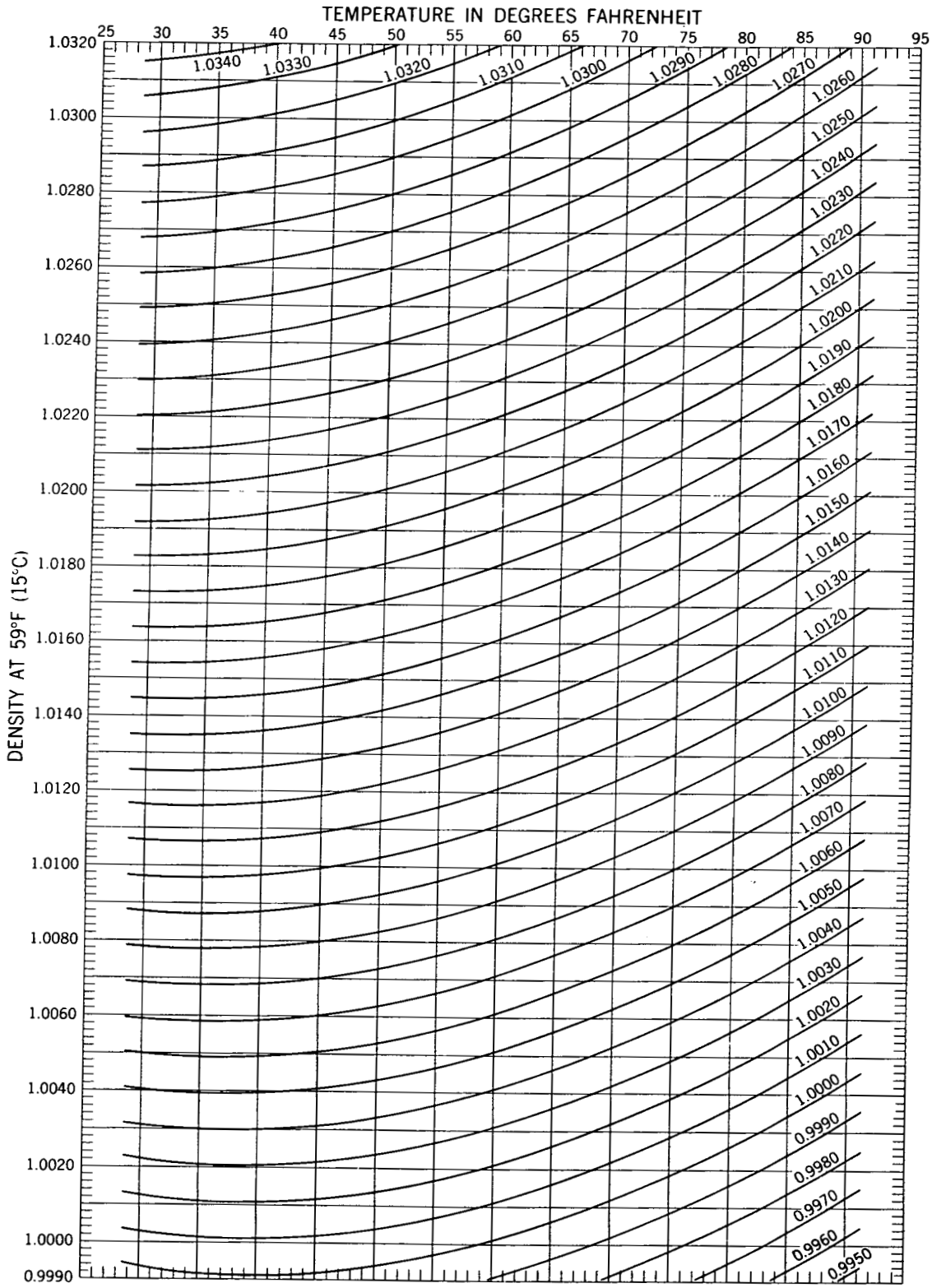

Figure 3. Sea water density at various temperatures.

FIGURE 4. FREEZING POINT OF SEA WATER OF VARIOUS SALINITIES.

It is sometimes desirable to have an estimate of the temperatures of the water on days when the frozen surface prevents obtaining a sample. When used with observed values obtained during most of the month, a few such estimates may, for instance, permit obtaining a reasonably valid monthly mean. The graph is based on the following formula from Thompson* for the lowering of the freezing point, P, for various chlorinities, Cl:

$$P = -0.0966\ Cl - 0.0000052\ Cl^3$$

and on the following relation between salinity, S, and chlorinity

$$S = 0.030 + 1.805\ Cl$$

The freezing points are the temperatures at which ice crystals begin to form under certain ideal conditions that may not always obtain in nature, and hence they must be considered as approximations.

The graph is arranged so that if entered with either salinity or density at 15°C., it will provide the freezing point in either centigrade or Fahrenheit.

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*Thompson, Thomas G., "Physical Properties of Sea Water," Physics of the Earth - V, Oceanography, pp. 63-94, National Research Council Bulletin No. 85, Washington, D. C., 1932

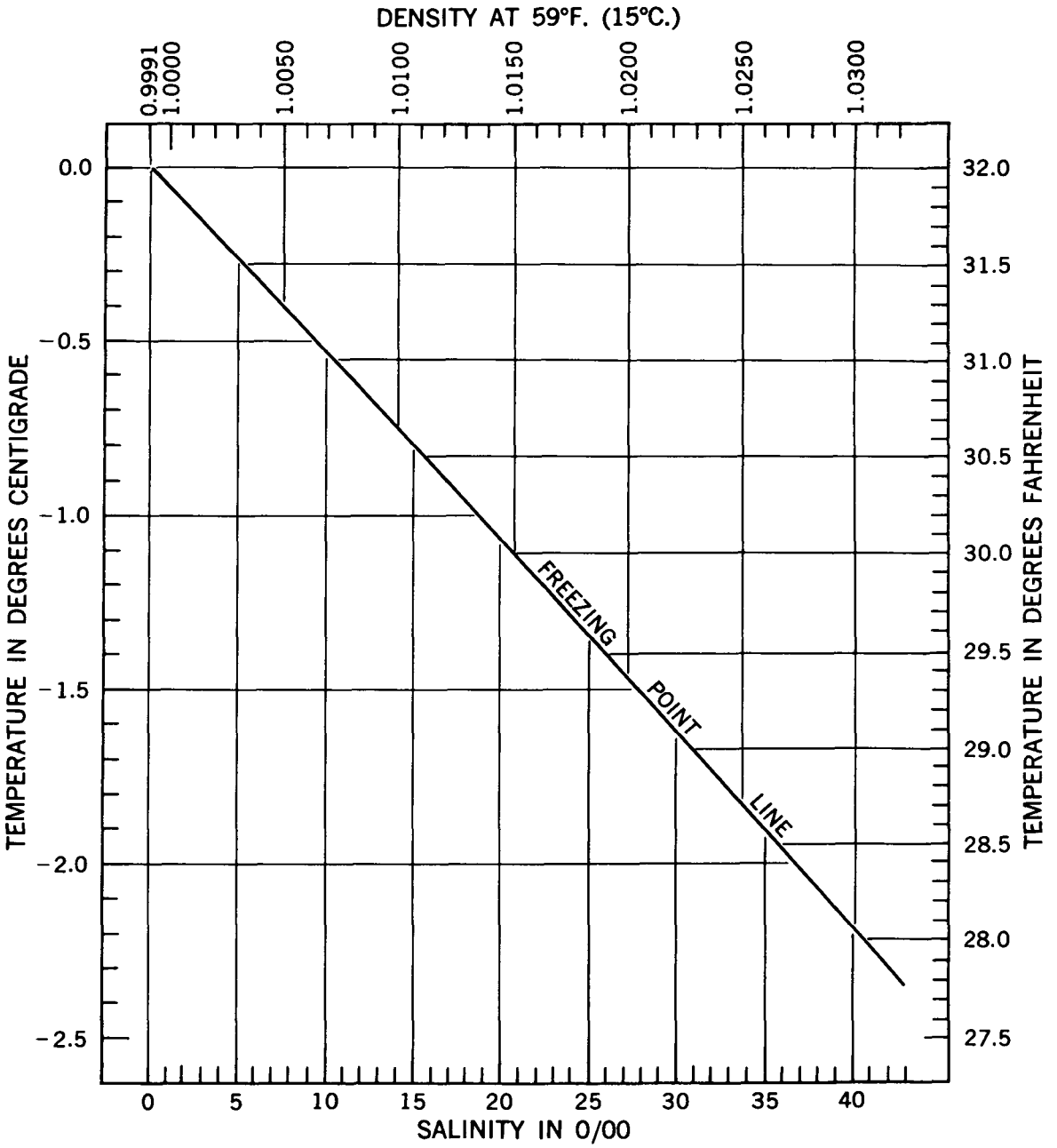

Figure 4. Freezing point of sea water of various salinities.

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