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RADIO-COMPASS BEARINGS

BY

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Mathematician

[redacted]

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PREFACE.

Since the radio compass is coming into very general use for the determination of the positions of vessels at sea, it seemed advisable to investigate the methods of plotting the bearings both on the Mercator projection and on the gnomonic projection. For practical use it is necessary to devise schemes that will be simple in application in order to obviate the need for laborious computations. Graphic charts are frequently very useful for this purpose and in this publication the elements of the reduction for the Mercator projection have been developed in such a form as to admit of graphic treatment.

Three graphic charts of this nature, Nos. R1, R2, and R3, are published by the U. S. Coast and Geodetic Survey. Nos. R1 and R2 are sheet [redacted], of a chart entitled "Graphic chart, semi[redacted]" Sheet 1 extends from the Equator [redacted] and sheet 2 extends from this point [redacted] 57°. No. R3 is entitled "Graphic chart, second reduction [redacted], true bearing to Mercator bearing." These charts may be obtained at 20 cents each from the Director, U. S. Coast and Geodetic Survey, Washington, D. C., or from any of the field stations or sales agencies of the U. S. Coast and Geodetic Survey. They can not be obtained from the Superin-[redacted] Documents, Government Printing Office.

[redacted] Mercator projection for the sphere is included in [redacted] used in obtaining the arguments for the [redacted]ful also in connection with the computations [redacted] functions, the method being fully developed in [redacted]

In considering [redacted]monic projection, tables have been computed which give the gnomonic azimuths at 10 radio-compass stations. These tables are based on the U. S. Hydrographic Office Chart No. 1280.

For convenience in practical applications, the description of the use of the graphic charts in connection with the Mercator projection is given first, followed by the Mercator table for the sphere. The necessary directions for the use of the gnomonic azimuth tables are given just preceding the tables. The theoretical discussions are placed in the last part of the publication, as they are of small use in practical applications.

RADIO-COMPASS BEARINGS.

By Oscar S. Adams,
Mathematician, U. S. Coast and Geodetic Survey.

CONTENTS.

INSTRUCTIONS FOR PLOTTING RADIO-COMPASS BEARINGS ON THE MERCATOR PROJECTION.

The graphic charts to be used in connection with this publication have for bottom argument the difference of longitude between the radio-compass station and the approximate position of the vessel, this being equal to $x_2 - x_1$ on the Mercator projection. This approximate position may be from dead reckoning, or in the absence of this the observations, without being corrected, may be plotted on the projection to determine an approximate position. The left-hand argument of the graphic chart for semiconvergence is derived by adding the "y" values, taken from the Mercator table on pages 7–15, corresponding to the latitude of the radio-compass station and the approximate latitude of the vessel. This argument is, therefore, $y_2 + y_1$, the y's being what may be called the Mercator latitudes or, as sometimes called, the meridional distances. On the graphic chart for the second term, the left-hand argument is equal to $y_2 - y_1$. The Mercator table gives the values in minutes, but all of the arguments for convenience in use should be expressed in degrees and fractions of a degree.

From the chart for the semiconvergence of the meridians, with the arguments $x_2 - x_1$ and $y_2 + y_1$, determine the proper u value and from the chart for the second reduction term, with the arguments x_2-x_1 and y_2-y_1, determine the proper value of v. Then the numerical value of the correction is equal to $u+v$; the plus sign is used for the point at the higher latitude and the minus sign for the point at the lower latitude. Then, since the curve representing the great circle is concave toward the Equator, this correction is added to the true bearing if the second point is east of the point at which the reduction is being made and if the points are in the Northern Hemisphere. If the points are in the Southern Hemisphere, the correction would be substracted with a similar relation of points. When the relative positions of the points are changed the correction must be applied with the reverse sign.

If an approximate position is not given by dead reckoning or otherwise, such an approximation can be determined by plotting the true bearings on the Mercator chart; this will generally give a position considerably in error, but after an approximate correction has been scaled from the charts a second plotting will give a pretty good approximate position of the vessel. Since the second term is small it will generally not have to be corrected for the new approximate position of the vessel.

The charts are applicable when one point is north of the Equator and the other point south of it. In this case one of the y's is negative and should be so used in forming the arguments. For example, if one point is in a certain north latitude and the other in the same latitude south of the Equator, the semiconvergence would be zero since y_2+y_1 would be zero. The y argument for the second term would be numerically equal to $2y_2$ since y_1 would be negative.

This method is of course applicable either in case the observations are made at the radio-compass station or upon the vessel. The reduction must be computed for the end in question, but after the Mercator bearing is found it can be laid off from the station just as well as from the approximate position of the vessel. In certain cases it is no doubt advantageous to observe upon the vessel rather than at the station; at times the vessel is able to receive the signals even when the station is not able to get signals from the vessel owing to the smaller power of the ship's equipment.

REDUCTION FROM TRUE BEARING TO MERCATOR BEARING.

EXAMPLE NO. 1.

A radio-compass bearing at Cape Hatteras was observed as 74° 30′ and a similar bearing at Bar Harbor on the same vessel was observed to be 118°. The approximate position of the vessel was given as latitude 39° 37′ N and longitude 56° 25′ W.

Cape Hatteras
(lat. 35° 14′), $y_1=2261.40$ minutes (see p. 10 of table).
Vessel
(lat. 39° 37′). $y_2=2592.75$ minutes (see p. 10 of table).

$y_2+y_1=4854.15$ minutes $=80.9$ degrees.
$y_2-y_1=\ 331.35$ minutes $=5.52$ degrees.

Cape Hatteras, long. = 75° 32.′
Vessel, long. = 56° 25.′

$x_2-x_1=-(19°\ 07′)=-19°.12.$

In using the charts no consideration needs to be given to the negative sign on this last argument.

From the semiconvergence chart No. 2, with the arguments 19°.12 and 80°.9, we get for the first term the value 5° 51′. With the arguments 19°.12 and 5°.52 from the chart for the second term, we get 9′ for its value. Since Cape Hatteras is south of the vessel, the second term must be subtracted from the first term of the correction. The value of the approximate correction is therefore 5° 51′ − 9′ = 5° 42.′

Since the vessel is east of Cape Hatteras this correction must be added to the observed true bearing. The approximate Mercator bearing therefore becomes 74° 30′ + (5° 42′) = 80° 12′.

Bar Harbor (lat. 44° 19′), $y_1 = 2972.30$ minutes (see p. 11 of table).

Vessel (lat. 39° 37′), $y_2 = 2592.75$ minutes (see p. 10 of table).

$$y_2 + y_1 = 5565.05 \text{ minutes} = 92.75 \text{ degrees}.$$
$$y_2 - y_1 = -379.55 \text{ minutes} = -6.33 \text{ degrees}.$$

Bar Harbor, long. = 68° 11′

Vessel, long. = 56° 25′

$$x_2 - x_1 = -(11° 46′) = -11°.77.$$

As before no attention needs to be paid to the signs of the arguments.

With the arguments 11°.77 and 92°.75 we get the value of the first term as 3° 57′ from the semiconvergence chart No. 2. From the chart for the second term we find the value to be 6′, using as the arguments 11°.77 and 6°.33. Since Bar Harbor is in higher latitude than the vessel, the second term must be added to the first term. The approximate value of the correction therefore becomes 3° 57′ + 6′ = 4° 03′.

Since the vessel is east of Bar Harbor, this correction must be added to the observed true bearing. The approximate Mercator bearing is given by the addition 118° 00′ + (4° 03′) = 122° 03′.

If these approximate Mercator bearings are plotted on a Mercator chart, their intersection will determine a more accurate position for the vessel, and with this position a more accurate value for the corrections can be scaled from the graphic charts. The change in the arguments would not in general be great enough to affect the second term, but the first term would in most cases need to be changed to conform to the more accurate position of the vessel.

EXAMPLE NO. 2.

A ship is by dead reckoning in lat. 48° 25′ N., long. 25° 30′ W., and obtains a radio-compass bearing from Sea View of 244° 45′ and from Ushant of 277°·30′.

Sea View (lat. 55° 22′), $y_1 = 4006.50$ minutes (see p. 12 of table).

Vessel (lat. 48° 45′), $y_2 = 3359.28$ minutes (see p. 11 of table).

$$y_2 + y_1 = 7365.78 \text{ minutes} = 122.76 \text{ degrees}.$$
$$y_2 - y_1 = -647.22 \text{ minutes} = -10.79 \text{ degrees}.$$

Sea View, long. 7° 19.5′ W.

Vessel, long. 25° 30′ W.

$$x_2 - x_1 = 18° 10.5′ = 18°.18$$

From the semiconvergence chart No. 2 with the arguments 18°.18 and 122°.76, we get for the first term the value 7° 12′. With the arguments 18°.18 and 10°.79 from the chart for the second term, we get 17′ for the value of this term. Since Sea View is north of the vessel, the second term must be added to the first term of the correction.

The value of the approximate correction is therefore 7° 12′ + 17′ = 7° 29′. Since the vessel is west of the station and in north latitude this correction must be subtracted from the true bearing. The approximate Mercator bearing from Sea View is therefore 244° 45′ − (7° 29′) = 237° 16′.

Ushant (lat. 48° 26.5′), y_1 = 3331.30 minutes (see p. 11 of table).
Vessel (lat. 48° 45′), y_2 = 3359.28 minutes (see p. 11 of table).

$$y_2 + y_1 = 6690.58 \text{ minutes} = 111.51 \text{ degrees.}$$
$$y_2 - y_1 = 27.98 \text{ minutes} = 0.47 \text{ degrees.}$$

Ushant, long. 5° 05.5′ W.
Vessel, long. 25° 30′ W.

$$x_2 - x_1 = 20° \ 24.5' = 20.41°.$$

With the arguments 20°.41 and 111°.51, we get the value of the first term as 7° 41′ from the semiconvergence chart No. 2. From the chart for the second term, we find the value of this term to be 1′ using as the arguments 20°.41 and 0°.47. Since Ushant is south of the vessel, this second term must be subtracted from the first term. The approximate value of the correction therefore becomes 7° 41′ − 1′ = 7° 40′. Since the vessel is west of Ushant, this correction must be subtracted from the true bearing. The approximate Mercator bearing at Ushant therefore becomes 277° 30′ − (7° 40′) = 269° 50′.

By plotting these approximate bearings, a better position of the vessel may be found from their intersection and the values for the corrections may be revised to make them conform more nearly to the correct position if the change is sufficient to make this revision desirable.

Mercator projection table for the sphere.

Lat.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	Lat.
′	′	′	′	′	′	′	′	′	′	′	′	
0	0.00	60.00	120.02	180.08	240.19	300.38	360.66	421.05	481.57	542.23	603.07	0
1	1.00	61.00	121.02	181.08	241.20	301.38	361.66	422.06	482.58	543.25	604.08	1
2	2.00	62.00	122.03	182.08	242.20	302.39	362.67	423.06	483.59	544.26	605.10	2
3	3.00	63.00	123.03	183.09	243.20	303.39	363.67	421.07	484.60	545.27	606.12	3
4	4.00	64.00	124.03	184.09	244.20	304.40	364.68	425.08	485.61	546.28	607.13	4
5	5.00	65.00	125.03	185.09	245.21	305.40	365.69	426.09	486.62	547.30	608.15	5
6	6.00	66.00	126.03	186.09	246.21	306.40	366.69	427.09	487.63	548.31	609.16	6
7	7.00	67.00	127.03	187.09	247.21	307.41	367.70	428.10	488.64	549.32	610.18	7
8	8.00	68.00	128.03	188.09	248.21	308.41	368.70	429.11	489.65	550.34	611.19	8
9	9.00	69.00	129.03	189.09	249.22	309.42	369.71	430.12	490.66	551.35	612.21	9
10	10.00	70.00	130.03	190.10	250.22	310.42	370.72	431.13	491.67	552.36	613.23	10
11	11.00	71.00	131.03	191.10	251.22	311.42	371.72	432.13	492.68	553.37	614.24	11
12	12.00	72.00	132.03	192.10	252.23	312.43	372.73	443.14	493.69	554.39	615.26	12
13	13.00	73.00	133.03	193.10	253.23	313.43	373.74	434.15	494.70	555.40	616.27	13
14	14.00	74.01	134.03	194.10	254.23	314.44	374.74	435.16	495.71	556.41	617.29	14
15	15.00	75.01	135.03	195.10	255.23	315.44	375.75	436.17	496.72	557.43	618.31	15
16	16.00	76.01	136.03	196.11	256.24	316.45	376.75	437.17	497.73	558.44	619.32	16
17	17.00	77.01	137.04	197.11	257.24	317.45	377.76	438.18	498.74	559.45	620.34	17
18	18.00	78.01	138.04	198.11	258.24	318.45	378.76	439.19	409.75	560.47	621.36	18
19	19.00	79.01	139.04	199.11	259.25	319.46	379.77	440.20	500.76	561.48	622.37	19
20	20.00	80.01	140.04	200.11	260.25	320.46	380.78	441.21	501.77	562.49	623.39	20
21	21.00	81.01	141.04	201.11	261.25	321.47	381.78	442.21	502.78	563.51	624.40	21
22	22.00	82.01	142.04	202.12	262.25	322.47	382.79	443.22	503.79	564.52	625.42	22
23	23.00	83.01	143.04	203.12	263.26	323.48	383.79	444.23	504.80	565.53	626.44	23
24	24.00	84.01	144.04	204.12	264.26	324.48	384.80	445.24	505.81	566.55	627.45	24
25	25.00	85.01	145.04	205.12	265.26	325.48	385.81	446.25	506.83	567.56	628.47	25
26	26.00	86.01	146.04	206.12	266.27	326.49	386.81	447.26	507.84	568.57	629.49	26
27	27.00	87.01	147.04	207.13	267.27	327.49	387.82	448.26	508.85	569.59	630.50	27
28	28.00	88.01	148.05	208.13	268.27	328.50	388.83	449.27	509.86	570.60	631.52	28
29	29.00	89.01	149.05	209.13	269.27	329.50	389.83	450.28	510.87	571.62	632.54	29
30	30.00	90.01	150.05	210.13	270.28	330.51	390.84	451.29	511.88	572.63	633.56	30
31	31.00	91.01	151.05	211.13	271.28	331.51	391.85	452.30	512.89	573.64	634.57	31
32	32.00	92.01	152.05	212.13	272.28	332.52	392.85	453.31	513.90	574.66	635.59	32
33	33.00	93.01	153.05	213.14	273.29	333.52	393.86	454.32	514.91	575.67	636.61	33
34	34.00	94.01	154.05	214.14	274.29	334.53	394.86	455.33	515.93	576.69	637.62	34
35	35.00	95.01	155.05	215.14	275.29	335.53	395.87	456.33	516.94	577.70	638.64	35
36	36.00	96.01	156.05	216.14	276.30	336.54	396.88	457.34	517.95	578.71	639.66	36
37	37.00	97.01	157.05	217.14	277.30	337.54	397.88	458.35	518.96	579.73	640.68	37
38	38.00	98.01	158.06	218.15	278.30	338.55	398.89	459.36	519.97	580.74	641.69	38
39	39.00	99.01	159.06	219.15	279.31	339.55	399.90	460.37	520.98	581.76	642.71	39
40	40.00	100.01	160.06	220.15	280.31	340.56	400.91	461.38	521.99	582.77	643.73	40
41	41.00	101.01	161.06	221.15	281.31	341.56	401.91	462.39	523.01	583.79	644.75	41
42	42.00	102.01	162.06	222.15	282.32	342.57	402.92	463.40	524.02	584.80	645.76	42
43	43.00	103.02	163.06	223.16	283.32	343.57	403.93	464.41	525.03	585.81	646.78	43
44	44.00	101.02	164.06	224.16	284.32	344.58	404.93	465.41	526.04	586.83	647.80	44
45	45.00	105.02	165.06	225.16	285.33	345.58	405.94	466.42	527.05	587.84	648.82	45
46	46.00	106.02	166.06	226.16	286.33	340.59	406.95	467.43	528.06	588.86	649.84	46
47	47.00	107.02	167.07	227.16	287.33	347.59	407.95	468.44	529.08	589.87	650.85	47
48	48.00	108.02	168.07	228.17	288.34	348.60	408.96	469.45	530.09	590.89	651.87	48
49	49.00	109.02	169.07	229.17	289.34	349.60	409.97	470.46	531.10	591.90	652.89	49
50	50.00	110.02	170.07	230.17	290.34	350.61	410.97	471.47	532.11	592.92	653.91	50
51	51.00	111.02	171.07	231.17	291.35	351.61	411.98	472.48	533.12	593.93	654.93	51
52	52.00	112.02	172.07	232.18	292.35	352.62	412.99	473.49	534.14	594.95	655.94	52
53	53.00	113.02	173.07	233.18	293.35	353.62	414.00	474.50	535.15	595.96	656.96	53
54	54.00	114.02	174.07	234.18	294.36	354.63	415.00	475.51	536.16	596.98	657.98	54
55	55.00	115.02	175.07	235.18	295.36	355.63	416.01	476.52	537.17	597.99	659.00	55
56	56.00	116.02	176.08	236.18	296.37	356.64	417.02	477.53	538.18	599.01	660.02	56
57	57.00	117.02	177.08	237.19	297.37	357.64	418.03	478.54	539.20	600.02	661.04	57
58	58.00	118.02	178.08	238.19	298.37	358.65	419.03	479.55	540.21	601.04	662.05	58
59	59.00	119.02	179.08	239.19	299.38	359.65	420.04	480.56	541.22	602.05	663.07	59
60	60.00	120.02	180.08	240.19	300.38	360.66	421.05	481.57	542.23	603.07	664.09	60

Mercator projection table for the sphere—Continued.

Lat.	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	Lat.
′	′	′	′	′	′	′	′	′	′	′	′
0	664.09	725.32	786.78	848.49	910.46	972.73	1035.30	1098.22	1161.49	1225.14	0
1	665.11	726.34	787.81	849.52	911.50	973.77	1036.35	1099.27	1162.54	1226.20	1
2	666.13	727.37	788.83	850.55	912.53	974.81	1037.40	1100.32	1163.60	1227.27	2
3	667.15	728.39	789.86	851.58	913.57	975.85	1038.44	1101.37	1164.66	1228.33	3
4	668.17	729.41	790.89	852.61	914.60	976.89	1039.49	1102.42	1165.72	1229.40	4
5	669.19	730.43	791.91	853.64	915.64	977.93	1040.53	1103.47	1166.78	1230.46	5
6	670.21	731.46	792.94	854.67	916.67	978.97	1041.58	1104.53	1167.83	1231.53	6
7	671.22	732.48	793.97	855.70	917.71	980.01	1042.63	1105.58	1168.89	1232.59	7
8	672.24	733.50	794.99	856.73	918.75	981.05	1043.67	1106.63	1169.95	1233.66	8
9	673.26	734.53	796.02	857.76	919.78	982.09	1044.72	1107.68	1171.01	1234.72	9
10	674.28	735.55	797.04	858.80	920.82	983.13	1045.77	1108.74	1172.07	1235.79	10
11	675.30	736.57	798.07	859.83	921.85	984.17	1046.81	1109.79	1173.13	1236.85	11
12	676.32	737.59	799.10	860.86	922.89	985.22	1047.86	1110.84	1174.19	1237.92	12
13	677.34	738.62	800.13	861.89	923.93	986.26	1048.91	1111.89	1175.24	1238.98	13
14	678.36	739.64	801.15	862.92	924.96	987.30	1049.95	1112.95	1176.30	1240.05	14
15	679.38	740.66	802.18	863.95	926.00	988.34	1051.00	1114.00	1177.36	1241.11	15
16	680.40	741.69	803.21	864.98	927.03	989.38	1052.05	1115.05	1178.42	1242.18	16
17	681.42	742.71	804.24	866.02	928.07	990.42	1053.09	1116.11	1179.48	1243.25	17
18	682.44	743.73	805.26	867.05	929.11	991.47	1054.14	1117.16	1180.54	1244.31	18
19	683.46	744.76	806.29	868.08	930.15	992.51	1055.19	1118.21	1181.60	1245.38	19
20	684.48	745.78	807.32	869.11	931.18	993.55	1056.24	1119.27	1182.66	1246.44	20
21	685.50	746.81	808.35	870.14	932.22	994.59	1057.28	1120.32	1183.72	1247.51	21
22	686.52	747.83	809.37	871.18	933.26	995.63	1058.33	1121.37	1184.78	1248.58	22
23	687.54	748.85	810.40	872.21	934.29	996.68	1059.38	1122.43	1185.84	1249.64	23
24	688.56	749.88	811.43	873.24	935.33	997.72	1060.43	1123.48	1186.90	1250.71	24
25	689.58	750.90	812.46	874.27	936.37	998.76	1061.48	1124.53	1187.96	1251.78	25
26	690.60	751.92	813.49	875.31	937.40	999.80	1062.52	1125.59	1189.02	1252.85	26
27	691.62	752.95	814.52	876.34	938.44	1000.85	1063.57	1126.64	1190.08	1253.91	27
28	692.64	753.97	815.54	877.37	939.48	1001.89	1064.62	1127.70	1191.14	1254.98	28
29	693.66	755.00	816.57	878.40	940.52	1002.93	1065.67	1128.75	1192.20	1256.05	29
30	694.68	756.02	817.60	879.44	941.56	1003.97	1066.72	1129.81	1193.26	1257.12	30
31	695.70	757.05	818.63	880.47	942.59	1005.02	1067.77	1130.86	1194.32	1258.18	31
32	696.72	758.07	819.66	881.50	943.63	1006.06	1068.81	1131.92	1195.39	1259.25	32
33	697.74	759.09	820.69	882.54	944.67	1007.10	1069.86	1132.97	1196.45	1260.32	33
34	698.76	760.12	821.71	883.57	945.71	1008.15	1070.91	1134.03	1197.51	1261.39	34
35	699.78	761.14	822.74	884.60	946.74	1009.19	1071.96	1135.08	1198.57	1262.45	35
36	700.80	762.17	823.77	885.64	947.78	1010.23	1073.01	1136.14	1199.63	1263.52	36
37	701.82	763.19	824.80	886.67	948.82	1011.28	1074.06	1137.19	1200.69	1264.59	37
38	702.85	764.22	825.83	887.70	949.86	1012.32	1075.11	1138.25	1201.75	1265.66	38
39	703.87	765.24	826.86	888.74	950.90	1013.36	1076.16	1139.30	1202.82	1266.73	39
40	704.89	766.27	827.89	889.77	951.94	1014.41	1077.21	1140.36	1203.88	1267.80	40
41	705.91	767.29	828.92	890.80	952.98	1015.45	1078.26	1141.41	1204.94	1268.87	41
42	706.93	768.32	829.95	891.84	954.01	1016.50	1079.31	1142.47	1206.00	1269.93	42
43	707.95	769.34	830.98	892.87	955.05	1017.54	1080.36	1143.52	1207.06	1271.00	43
44	708.97	770.37	832.00	893.91	956.09	1018.58	1081.41	1144.58	1208.13	1272.07	44
45	709.99	771.39	833.03	894.94	957.13	1019.63	1082.46	1145.64	1209.19	1273.14	45
46	711.02	772.42	834.06	895.97	958.17	1020.67	1083.51	1146.69	1210.25	1274.21	46
47	712.04	773.44	835.09	897.01	959.21	1021.72	1084.56	1147.75	1211.31	1275.28	47
48	713.06	774.47	836.12	898.04	960.25	1022.76	1085.61	1148.80	1212.38	1276.35	48
49	714.08	775.49	837.15	899.08	961.29	1023.81	1086.66	1149.86	1213.44	1277.42	49
50	715.10	776.52	838.18	900.11	962.33	1024.85	1087.71	1150.92	1214.50	1278.49	50
51	716.12	777.54	839.21	901.15	963.37	1025.90	1088.76	1151.97	1215.57	1279.56	51
52	717.15	778.57	840.24	902.18	964.41	1026.94	1089.81	1153.03	1216.63	1280.63	52
53	718.17	779.59	841.27	903.22	965.45	1027.99	1090.86	1154.09	1217.69	1281.70	53
54	719.19	780.62	842.30	904.25	966.49	1029.03	1091.91	1155.14	1218.76	1282.77	54
55	720.21	781.65	843.33	905.28	967.53	1030.08	1092.96	1156.20	1219.82	1283.84	55
56	721.23	782.67	844.36	906.32	968.57	1031.12	1094.01	1157.26	1220.88	1284.91	56
57	722.26	783.70	845.39	907.35	969.61	1032.17	1095.06	1158.32	1221.95	1285.98	57
58	723.28	784.73	846.42	908.39	970.65	1033.21	1096.11	1159.37	1223.01	1287.05	58
59	724.30	785.75	847.45	909.43	971.69	1034.26	1097.16	1160.43	1224.07	1288.13	59
60	725.32	786.78	848.49	910.46	972.73	1035.30	1098.22	1161.49	1225.14	1289.20	60

Mercator projection table for the sphere—Continued.

Lat.	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°	Lat.
′	′	′	′	′	′	′	′	′	′	′	′
0	1289.20	1353.69	1418.63	1484.06	1549.99	1616.47	1683.52	1751.16	1819.44	1888.38	0
1	1290.27	1354.76	1419.72	1485.15	1551.10	1617.58	1684.64	1752.29	1820.58	1889.53	1
2	1291.34	1355.84	1420.80	1486.25	1552.20	1618.70	1685.76	1753.43	1821.72	1890.69	2
3	1292.41	1356.92	1421.89	1487.34	1553.31	1619.81	1686.88	1754.56	1822.87	1891.84	3
4	1293.48	1358.00	1422.98	1488.44	1554.41	1620.92	1688.01	1755.69	1824.01	1893.00	4
5	1294.55	1359.08	1424.06	1489.53	1555.51	1622.04	1689.13	1756.83	1825.16	1894.15	5
6	1295.63	1360.16	1425.15	1490.63	1556.62	1623.15	1690.25	1757.96	1826.30	1895.31	6
7	1296.70	1361.24	1426.24	1491.72	1557.72	1624.26	1691.38	1759.09	1827.44	1896.46	7
8	1297.77	1362.32	1427.32	1492.82	1558.83	1625.38	1692.50	1760.23	1828.59	1897.62	8
9	1298.84	1363.40	1428.41	1493.91	1559.93	1626.49	1693.62	1761.36	1829.73	1898.78	9
10	1299.91	1364.48	1429.50	1495.01	1561.04	1627.61	1694.75	1762.50	1830.88	1899.93	10
11	1300.99	1365.56	1430.59	1496.11	1562.14	1628.72	1695.87	1763.63	1832.02	1901.09	11
12	1302.06	1366.64	1431.68	1497.20	1563.25	1629.84	1697.00	1764.77	1833.17	1902.25	12
13	1303.13	1367.72	1432.76	1498.30	1564.35	1630.95	1698.12	1765.90	1834.32	1903.40	13
14	1304.20	1368.80	1433.85	1499.40	1565.46	1632.06	1699.25	1767.04	1835.46	1904.56	14
15	1305.28	1369.88	1434.94	1500.49	1566.56	1633.18	1700.37	1768.17	1836.61	1905.72	15
16	1306.35	1370.96	1436.03	1501.59	1567.67	1634.29	1701.50	1769.31	1837.75	1906.88	16
17	1307.42	1372.04	1437.12	1502.69	1568.77	1635.41	1702.62	1770.44	1838.90	1908.03	17
18	1308.50	1373.12	1438.21	1503.78	1569.88	1636.52	1703.75	1771.58	1840.05	1909.19	18
19	1309.57	1374.20	1439.29	1504.88	1570.99	1637.64	1704.87	1772.71	1841.19	1910.35	19
20	1310.64	1375.28	1440.38	1505.98	1572.09	1638.76	1706.00	1773.85	1842.34	1911.51	20
21	1311.72	1376.36	1441.47	1507.08	1573.20	1639.87	1707.12	1774.98	1843.49	1912.67	21
22	1312.79	1377.44	1442.56	1508.17	1574.31	1640.99	1708.25	1776.12	1844.64	1913.83	22
23	1313.86	1378.52	1443.65	1509.27	1575.41	1642.10	1709.37	1777.26	1845.78	1914.98	23
24	1314.94	1379.61	1444.74	1510.37	1576.52	1643.22	1710.50	1778.39	1846.93	1916.14	24
25	1316.01	1380.69	1445.83	1511.47	1577.63	1644.34	1711.63	1779.53	1848.08	1917.30	25
26	1317.08	1381.77	1446.92	1512.57	1578.73	1645.45	1712.75	1780.67	1849.23	1918.46	26
27	1318.16	1382.85	1448.01	1513.67	1579.84	1646.57	1713.88	1781.81	1850.37	1919.62	27
28	1319.23	1383.93	1449.10	1514.76	1580.95	1647.69	1715.01	1782.94	1851.52	1920.78	28
29	1320.31	1385.02	1450.19	1515.86	1582.06	1648.80	1716.14	1784.08	1852.67	1921.94	29
30	1321.38	1386.10	1451.28	1516.96	1583.17	1649.92	1717.26	1785.22	1853.82	1923.10	30
31	1322.45	1387.18	1452.37	1518.06	1584.27	1651.04	1718.39	1786.36	1854.97	1924.26	31
32	1323.53	1388.26	1453.46	1519.16	1585.38	1652.16	1719.52	1787.50	1856.12	1925.43	32
33	1324.60	1389.35	1454.55	1520.26	1586.49	1653.27	1720.65	1788.63	1857.27	1926.59	33
34	1325.68	1390.43	1455.64	1521.36	1587.60	1654.39	1721.77	1789.77	1858.42	1927.75	34
35	1326.75	1391.51	1456.73	1522.46	1588.71	1655.51	1722.90	1790.91	1859.57	1928.91	35
36	1327.83	1392.59	1457.83	1523.56	1589.82	1656.63	1724.03	1792.05	1860.72	1930.07	36
37	1328.90	1393.68	1458.92	1524.66	1590.92	1657.75	1725.16	1793.19	1861.87	1931.23	37
38	1329.98	1394.76	1460.01	1525.76	1592.03	1658.87	1726.29	1794.33	1863.02	1932.40	38
39	1331.06	1395.84	1461.10	1526.86	1593.14	1659.98	1727.42	1795.47	1864.17	1933.56	39
40	1332.13	1396.93	1462.19	1527.96	1594.25	1661.10	1728.54	1796.61	1865.32	1934.72	40
41	1333.21	1398.01	1463.28	1529.06	1595.36	1662.22	1729.67	1797.75	1866.47	1935.88	41
42	1334.29	1399.10	1464.38	1530.16	1596.47	1663.34	1730.80	1798.89	1867.62	1937.05	42
43	1335.37	1400.18	1465.47	1531.26	1597.58	1664.46	1731.93	1800.03	1868.77	1938.21	43
44	1336.44	1401.26	1466.56	1532.36	1598.69	1665.58	1733.06	1801.17	1869.92	1939.37	44
45	1337.52	1402.35	1467.65	1533.46	1599.80	1666.70	1734.19	1802.31	1871.08	1940.54	45
46	1338.60	1403.43	1468.75	1534.56	1600.91	1667.82	1735.32	1803.45	1872.23	1941.70	46
47	1339.67	1404.52	1469.84	1535.66	1602.02	1668.94	1736.45	1804.59	1873.38	1942.86	47
48	1340.75	1405.60	1470.93	1536.77	1603.13	1670.06	1737.58	1805.73	1874.53	1944.03	48
49	1341.83	1406.69	1472.02	1537.87	1604.24	1671.18	1738.71	1806.87	1875.69	1945.19	49
50	1342.91	1407.77	1473.12	1538.97	1605.35	1672.30	1739.84	1808.01	1876.84	1946.36	50
51	1343.98	1408.86	1474.21	1540.07	1606.46	1673.42	1740.98	1809.15	1877.99	1947.52	51
52	1345.06	1409.94	1475.30	1541.17	1607.58	1674.54	1742.11	1810.30	1879.14	1948.69	52
53	1346.14	1411.03	1476.40	1542.27	1608.69	1675.66	1743.24	1811.44	1880.30	1949.85	53
54	1347.22	1412.11	1477.49	1543.38	1609.80	1676.79	1744.37	1812.58	1881.45	1951.02	54
55	1348.29	1413.20	1478.59	1544.48	1610.91	1677.91	1745.50	1813.72	1882.60	1952.18	55
56	1349.37	1414.28	1479.68	1545.58	1612.02	1679.03	1746.63	1814.86	1883.76	1953.35	56
57	1350.45	1415.37	1480.77	1546.69	1613.13	1680.15	1747.76	1816.01	1884.91	1954.51	57
58	1351.53	1416.46	1481.87	1547.79	1614.25	1681.27	1748.90	1817.15	1886.07	1955.68	58
59	1352.61	1417.54	1482.96	1548.89	1615.36	1682.39	1750.03	1818.29	1887.22	1956.85	59
60	1353.69	1418.63	1484.06	1549.99	1616.47	1683.52	1751.16	1819.44	1888.38	1958.01	60

Mercator projection table for the sphere—Continued.

Lat.	31°	32°	33°	34°	35°	36°	37°	38°	39°	40°	Lat.
′	′	′	′	′	′	′	′	′	′	′	′
0	1958.01	2028.38	2099.53	2171.48	2244.29	2317.99	2392.63	2468.26	2544.93	2622.69	0
1	1959.18	2029.56	2100.72	2172.69	2245.51	2319.22	2393.88	2469.53	2546.22	2624.00	1
2	1960.35	2030.74	2101.91	2173.89	2246.73	2320.46	2395.14	2470.80	2547.50	2625.30	2
3	1961.51	2031.92	2103.10	2175.10	2247.95	2321.70	2396.39	2472.07	2548.79	2626.61	3
4	1962.68	2033.10	2104.30	2176.31	2249.17	2322.93	2397.64	2473.34	2550.08	2627.91	4
5	1963.85	2034.28	2105.49	2177.51	2250.39	2324.17	2398.90	2474.61	2551.37	2629.22	5
6	1965.02	2035.46	2106.68	2178.72	2251.62	2325.41	2400.15	2475.88	2552.66	2630.53	6
7	1966.18	2036.64	2107.88	2179.93	2252.84	2326.65	2401.40	2477.15	2553.95	2631.84	7
8	1967.35	2037.82	2109.07	2181.14	2254.06	2327.89	2402.66	2478.42	2555.23	2633.14	8
9	1968.52	2039.00	2110.27	2182.35	2255.28	2329.12	2403.91	2479.69	2556.52	2634.45	9
10	1969.69	2040.19	2111.46	2183.55	2256.51	2330.36	2405.17	2480.97	2557.81	2635.76	10
11	1970.86	2041.37	2112.66	2184.76	2257.73	2331.60	2406.42	2482.24	2559.10	2637.07	11
12	1972.03	2042.55	2113.85	2185.97	2258.95	2332.84	2407.68	2483.51	2560.39	2638.38	12
13	1973.20	2043.73	2115.05	2187.18	2260.18	2334.08	2408.93	2484.78	2561.68	2639.69	13
14	1974.37	2044.91	2116.24	2188.39	2261.40	2335.32	2410.19	2486.06	2562.97	2641.00	14
15	1975.54	2046.10	2117.44	2189.60	2262.63	2336.56	2411.44	2487.33	2564.27	2642.31	15
16	1976.71	2047.28	2118.63	2190.81	2263.85	2337.80	2412.70	2488.60	2565.56	2643.62	16
17	1977.88	2048.46	2119.83	2192.02	2265.08	2339.04	2413.96	2489.88	2566.85	2644.93	17
18	1979.05	2049.64	2121.03	2193.23	2266.30	2340.28	2415.21	2491.15	2568.14	2646.24	18
19	1980.22	2050.83	2122.22	2194.44	2267.53	2341.52	2416.47	2492.43	2569.43	2647.55	19
20	1981.39	2052.01	2123.42	2195.65	2268.75	2342.76	2417.73	2493.70	2570.73	2648.86	20
21	1982.56	2053.19	2124.62	2196.86	2269.98	2344.00	2418.99	2494.97	2572.02	2650.17	21
22	1983.73	2054.38	2125.81	2198.07	2271.20	2345.25	2420.24	2496.25	2573.31	2651.49	22
23	1984.90	2055.56	2127.01	2199.29	2272.43	2346.49	2421.50	2497.52	2574.61	2652.80	23
24	1986.07	2056.75	2128.21	2200.50	2273.66	2347.73	2422.76	2498.80	2575.90	2654.11	24
25	1987.24	2057.93	2129.41	2201.71	2274.88	2348.97	2424.02	2500.08	2577.19	2655.43	25
26	1988.41	2059.11	2130.61	2202.92	2276.11	2350.21	2425.28	2501.35	2578.49	2656.74	26
27	1989.59	2060.30	2131.80	2204.14	2277.34	2351.46	2426.54	2502.63	2579.78	2658.05	27
28	1990.76	2061.49	2133.00	2205.35	2278.57	2352.70	2427.80	2503.91	2581.08	2659.37	28
29	1991.93	2062.67	2134.20	2206.56	2279.79	2353.95	2429.06	2505.18	2582.37	2660.68	29
30	1993.10	2063.86	2135.40	2207.78	2281.02	2355.19	2430.32	2506.46	2583.67	2662.00	30
31	1994.28	2065.04	2136.60	2208.99	2282.25	2356.43	2431.58	2507.74	2584.97	2663.31	31
32	1995.45	2066.23	2137.80	2210.20	2283.48	2357.68	2432.84	2509.02	2586.26	2664.63	32
33	1996.62	2067.41	2139.00	2211.42	2284.71	2358.92	2434.10	2510.30	2587.56	2665.94	33
34	1997.80	2068.60	2140.20	2212.63	2285.94	2360.17	2435.36	2511.58	2588.86	2667.26	34
35	1998.97	2069.79	2141.40	2213.84	2287.17	2361.41	2436.62	2512.86	2590.15	2668.58	35
36	2000.14	2070.97	2142.60	2215.06	2288.40	2362.66	2437.89	2514.14	2591.45	2669.89	36
37	2001.32	2072.16	2143.80	2216.27	2289.63	2363.90	2439.15	2515.41	2592.75	2671.21	37
38	2002.49	2073.35	2145.00	2217.49	2290.86	2365.15	2440.41	2516.69	2594.05	2672.53	38
39	2003.67	2074.54	2146.20	2218.70	2292.09	2366.40	2441.68	2517.97	2595.35	2673.85	39
40	2004.84	2075.72	2147.40	2219.92	2293.32	2367.64	2442.94	2519.25	2596.65	2675.16	40
41	2006.02	2076.91	2148.61	2221.14	2294.55	2368.89	2444.20	2520.54	2597.95	2676.48	41
42	2007.19	2078.10	2149.81	2222.35	2295.78	2370.14	2445.47	2521.82	2599.24	2677.80	42
43	2008.37	2079.29	2151.01	2223.57	2297.01	2371.38	2446.73	2523.10	2600.54	2679.12	43
44	2009.54	2080.48	2152.21	2224.79	2298.24	2372.63	2447.99	2524.38	2601.84	2680.44	44
45	2010.72	2081.67	2153.41	2226.00	2299.48	2373.88	2449.26	2525.66	2603.14	2681.76	45
46	2011.90	2082.86	2154.62	2227.22	2300.71	2375.13	2450.52	2526.95	2604.45	2683.08	46
47	2013.07	2084.04	2155.82	2228.44	2301.94	2376.38	2451.79	2528.23	2605.75	2684.40	47
48	2014.25	2085.23	2157.02	2229.66	2303.17	2377.63	2453.05	2529.51	2607.05	2685.72	48
49	2015.43	2086.42	2158.23	2230.87	2304.41	2378.87	2454.32	2530.79	2608.35	2687.04	49
50	2016.60	2087.61	2159.43	2232.09	2305.64	2380.12	2455.58	2532.08	2609.65	2688.36	50
51	2017.78	2088.80	2160.63	2233.31	2306.88	2381.37	2456.85	2533.36	2610.95	2689.69	51
52	2018.96	2089.99	2161.84	2234.53	2308.11	2382.62	2458.12	2534.65	2612.26	2691.01	52
53	2020.13	2091.19	2163.04	2235.75	2309.34	2383.87	2459.39	2535.93	2613.56	2692.33	53
54	2021.31	2092.38	2164.25	2236.97	2310.58	2385.12	2460.65	2537.22	2614.86	2693.65	54
55	2022.49	2093.57	2165.45	2238.19	2311.81	2386.37	2461.92	2538.50	2616.17	2694.98	55
56	2023.67	2094.76	2166.66	2239.41	2313.05	2387.62	2463.19	2539.79	2617.47	2696.30	56
57	2024.85	2095.95	2167.86	2240.63	2314.28	2388.88	2464.46	2541.07	2618.78	2697.63	57
58	2026.03	2097.14	2169.07	2241.85	2315.52	2390.13	2465.72	2542.36	2620.08	2698.95	58
59	2027.20	2098.33	2170.28	2243.07	2316.75	2391.38	2466.99	2543.64	2621.38	2700.27	59
60	2028.38	2099.53	2171.48	2244.29	2317.99	2392.63	2468.26	2544.93	2622.69	2701.60	60

Mercator projection table for the sphere—Continued.

Lat.	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	Lat.
′	′	′	′	′	′	′	′	′	′	′	′
0	2701.60	2781.71	2863.10	2945.81	3029.94	3115.55	3202.71	3291.53	3382.08	3474.47	0
1	2702.92	2783.06	2864.46	2947.21	3031.35	3116.99	3204.18	3293.02	3383.61	3476.03	1
2	2704.25	2784.40	2865.83	2948.60	3032.77	3118.43	3205.65	3294.52	3385.13	3477.59	2
3	2705.57	2785.75	2867.20	2949.99	3034.18	3119.87	3207.12	3296.01	3386.66	3479.14	3
4	2706.90	2787.09	2868.57	2951.38	3035.60	3121.31	3208.58	3297.51	3388.18	3480.70	4
5	2708.23	2788.44	2869.94	2952.77	3037.02	3122.75	3210.05	3299.01	3389.71	3482.26	5
6	2709.55	2789.79	2871.31	2954.16	3038.43	3124.19	3211.52	3300.51	3391.24	3483.82	6
7	2710.88	2791.14	2872.68	2955.56	3039.85	3125.63	3212.99	3302.00	3392.77	3485.38	7
8	2712.21	2792.49	2874.05	2956.95	3041.27	3127.08	3214.46	3303.50	3394.29	3486.94	8
9	2713.54	2793.84	2875.42	2958.34	3042.68	3128.52	3215.93	3305.00	3395.82	3488.50	9
10	2714.86	2795.19	2876.79	2959.74	3044.10	3129.96	3217.40	3306.50	3397.35	3490.06	10
11	2716.19	2796.54	2878.16	2961.13	3045.52	3131.41	3218.87	3308.00	3398.88	3491.62	11
12	2717.52	2797.89	2879.53	2962.53	3046.94	3132.85	3220.34	3309.50	3400.41	3493.18	12
13	2718.85	2799.24	2880.90	2963.92	3048.36	3134.30	3221.82	3311.00	3401.94	3494.74	13
14	2720.18	2800.59	2882.28	2965.32	3049.78	3135.75	3223.29	3312.50	3403.47	3496.31	14
15	2721.51	2801.94	2883.65	2966.71	3051.20	3137.19	3224.76	3314.00	3405.00	3497.87	15
16	2722.84	2803.29	2885.02	2968.11	3052.62	3138.64	3226.23	3315.50	3406.54	3499.43	16
17	2724.17	2804.64	2886.39	2969.50	3054.04	3140.08	3227.71	3317.00	3408.07	3501.00	17
18	2725.50	2805.99	2887.77	2970.90	3055.46	3141.53	3229.18	3318.51	3409.60	3502.56	18
19	2726.83	2807.34	2889.14	2972.30	3056.88	3142.98	3230.66	3320.01	3411.14	3504.13	19
20	2728.17	2808.70	2890.52	2973.70	3058.31	3144.42	3232.13	3321.52	3412.67	3505.70	20
21	2729.50	2810.05	2891.89	2975.09	3059.73	3145.87	3233.61	3323.02	3414.20	3507.26	21
22	2730.83	2811.40	2893.27	2976.49	3061.15	3147.32	3235.08	3324.53	3415.74	3508.83	22
23	2732.16	2812.76	2894.64	2977.89	3062.58	3148.77	3236.56	3326.03	3417.28	3510.40	23
24	2733.50	2814.11	2896.02	2979.29	3064.00	3150.22	3238.04	3327.54	3418.81	3511.97	24
25	2734.83	2815.46	2897.40	2980.69	3065.42	3151.67	3239.52	3329.04	3420.35	3513.54	25
26	2736.16	2816.82	2898.77	2982.09	3066.85	3153.12	3240.99	3330.55	3421.89	3515.11	26
27	2737.50	2818.17	2900.15	2983.49	3068.27	3154.57	3242.47	3332.06	3423.43	3516.68	27
28	2738.83	2819.53	2901.53	2984.89	3069.70	3156.03	3243.95	3333.56	3424.96	3518.25	28
29	2740.17	2820.88	2902.91	2986.29	3071.13	3157.48	3245.43	3335.07	3426.50	3519.82	29
30	2741.50	2822.24	2904.28	2987.70	3072.55	3158.93	3246.91	3336.58	3428.04	3521.39	30
31	2742.84	2823.60	2905.66	2989.10	3073.98	3160.38	3248.39	3338.09	3429.58	3522.96	31
32	2744.17	2824.95	2907.04	2990.50	3075.41	3161.84	3249.87	3339.60	3431.12	3524.54	32
33	2745.51	2826.31	2908.42	2991.90	3076.84	3163.29	3251.35	3341.11	3432.66	3526.11	33
34	2746.84	2827.67	2909.80	2993.31	3078.26	3164.74	3252.84	3342.62	3434.20	3527.68	34
35	2748.18	2829.03	2911.18	2994.71	3079.69	3166.20	3254.32	3344.14	3435.75	3529.26	35
36	2749.52	2830.39	2912.56	2996.12	3081.12	3167.65	3255.80	3345.65	3437.29	3530.83	36
37	2750.85	2831.74	2913.94	2997.52	3082.55	3169.11	3257.28	3347.16	3438.83	3532.41	37
38	2752.19	2833.10	2915.32	2998.93	3083.98	3170.57	3258.77	3348.67	3440.38	3533.99	38
39	2753.53	2834.46	2916.71	3000.33	3085.41	3172.02	3260.25	3350.19	3441.92	3535.56	39
40	2754.87	2835.82	2918.09	3001.74	3086.84	3173.48	3261.74	3351.70	3443.47	3537.14	40
41	2756.21	2837.18	2919.47	3003.14	3088.27	3174.94	3263.22	3353.21	3445.01	3538.72	41
42	2757.55	2838.54	2920.85	3004.55	3089.70	3176.40	3264.71	3354.73	3446.56	3540.30	42
43	2758.89	2839.90	2922.24	3005.96	3091.14	3177.85	3266.19	3356.24	3448.10	3541.88	43
44	2760.23	2841.27	2923.62	3007.36	3092.57	3179.31	3267.68	3357.76	3449.65	3543.45	44
45	2761.57	2842.63	2925.01	3008.77	3094.00	3180.77	3269.17	3359.28	3451.20	3545.04	45
46	2762.91	2843.99	2926.39	3010.18	3095.43	3182.23	3270.65	3360.79	3452.75	3546.62	46
47	2764.25	2845.35	2927.78	3011.59	3096.87	3183.69	3272.14	3362.31	3454.29	3548.20	47
48	2765.59	2846.71	2929.16	3013.00	3098.30	3185.15	3273.63	3363.83	3455.84	3549.78	48
49	2766.93	2848.08	2930.55	3014.41	3099.74	3186.61	3275.12	3365.35	3457.39	3551.36	49
50	2768.27	2849.44	2931.93	3015.82	3101.17	3188.07	3276.61	3366.87	3458.94	3552.94	50
51	2769.62	2850.81	2933.32	3017.23	3102.60	3189.54	3278.10	3368.39	3460.49	3554.53	51
52	2770.96	2852.17	2934.71	3018.64	3104.04	3191.00	3279.59	3369.91	3462.04	3556.11	52
53	2772.30	2853.53	2936.09	3020.05	3105.48	3192.46	3281.08	3371.43	3463.60	3557.70	53
54	2773.64	2854.90	2937.48	3021.46	3106.92	3193.92	3282.57	3372.95	3465.15	3559.28	54
55	2774.99	2856.26	2938.87	3022.87	3108.35	3195.39	3284.06	3374.47	3466.70	3560.87	55
56	2776.33	2857.63	2940.26	3024.29	3109.79	3196.85	3285.56	3375.99	3468.26	3562.45	56
57	2777.68	2858.99	2941.65	3025.70	3111.23	3198.32	3287.05	3377.51	3469.81	3564.04	57
58	2779.02	2860.36	2943.04	3027.11	3112.67	3199.78	3288.54	3379.04	3471.36	3565.63	58
59	2780.37	2861.73	2944.42	3028.52	3114.11	3201.25	3290.04	3380.56	3472.92	3567.22	59
60	2781.71	2863.10	2945.81	3029.94	3115.55	3202.71	3291 53	3382.08	3474.47	3568.81	60

Mercator projection table for the sphere—Continued.

Lat.	51°	52°	53°	54°	55°	56°	57°	58°	59°	60°	Lat.
′	′	′	′	′	′	′	′	′	′	′	′
0	3568.81	3665.19	3763.76	3864.64	3967.97	4073.90	4182.62	4294.30	4409.14	4527.37	0
1	3570.40	3666.82	3765.42	3866.34	3969.71	4075.69	4184.46	4296.19	4411.08	4529.37	1
2	3571.99	3668.44	3767.09	3868.04	3971.46	4077.48	4186.29	4298.07	4413.03	4531.37	2
3	3573.58	3670.07	3768.75	3869.74	3973.20	4079.27	4188.13	4299.96	4414.97	4533.37	3
4	3575.17	3671.70	3770.41	3871.45	3974.95	4081.06	4189.97	4301.85	4416.92	4535.38	4
5	3576.76	3673.32	3772.08	3873.15	3976.69	4082.86	4191.81	4303.74	4418.86	4537.38	5
6	3578.35	3674.95	3773.74	3874.86	3978.44	4084.65	4193.65	4305.64	4420.81	4539.39	6
7	3579.94	3676.58	3775.41	3876.56	3980.19	4086.44	4195.49	4307.53	4422.76	4541.39	7
8	3581.54	3678.21	3777.08	3878.27	3981.94	4088.24	4197.33	4309.42	4424.70	4543.40	8
9	3583.13	3679.84	3778.74	3879.98	3983.69	4090.03	4199.17	4311.32	4426.65	4545.41	9
10	3584.73	3681.47	3780.41	3881.68	3985.44	4091.83	4201.02	4313.21	4428.60	4547.42	10
11	3586.32	3683.10	3782.08	3883.39	3987.19	4093.62	4202.87	4315.11	4430.56	4549.43	11
12	3587.92	3684.73	3783.75	3885.10	3988.94	4095.42	4204.71	4317.01	4432.51	4551.44	12
13	3589.51	3686.36	3785.42	3886.81	3990.69	4097.22	4206.56	4318.91	4434.46	4553.45	13
14	3591.11	3687.99	3787.09	3888.52	3992.45	4099.02	4208.41	4320.80	4436.42	4555.47	14
15	3592.71	3689.63	3788.76	3890.23	3994.20	4100.82	4210.26	4322.70	4438.37	4557.48	15
16	3594.30	3691.26	3790.43	3891.95	3995.96	4102.62	4212.10	4324.61	4440.33	4559.50	16
17	3595.90	3692.90	3792.10	3893.66	3997.71	4104.42	4213.95	4326.51	4442.29	4561.52	17
18	3597.50	3694.53	3793.78	3895.37	3999.47	4106.22	4215.80	4328.41	4444.24	4563.53	18
19	3599.10	3696.17	3795.45	3897.09	4001.22	4108.02	4217.66	4330.31	4446.20	4565.55	19
20	3600.70	3697.80	3797.12	3898.80	4002.98	4109.82	4219.51	4332.22	4448.16	4567.57	20
21	3602.30	3699.44	3798.80	3900.52	4004.74	4111.63	4221.36	4334.12	4450.12	4569.59	21
22	3603.90	3701.08	3800.47	3902.23	4006.50	4113.44	4223.22	4336.03	4452.09	4571.61	22
23	3605.50	3702.71	3802.15	3903.95	4008.26	4115.24	4225.07	4337.94	4454.05	4573.64	23
24	3607.11	3704.35	3803.83	3905.67	4010.02	4117.05	4226.93	4339.84	4456.01	4575.66	24
25	3608.71	3705.99	3805.50	3907.38	4011.78	4118.85	4228.78	4341.75	4457.98	4577.69	25
26	3610.32	3707.63	3807.18	3909.10	4013.54	4120.66	4230.64	4343.66	4459.94	4579.71	26
27	3611.92	3709.27	3808.86	3910.82	4015.31	4122.47	4232.50	4345.57	4461.91	4581.74	27
28	3613.52	3710.91	3810.54	3912.54	4017.07	4124.28	4234.36	4347.48	4463.88	4583.77	28
29	3615.13	3712.56	3812.22	3914.26	4018.84	4126.09	4236.22	4349.40	4465.85	4585.80	29
30	3616.74	3714.20	3813.90	3915.99	4020.60	4127.90	4238.08	4351.31	4467.82	4587.83	30
31	3618.34	3715.84	3815.58	3917.71	4022.37	4129.72	4239.94	4353.23	4469.79	4589.86	31
32	3619.95	3717.48	3817.27	3919.43	4024.13	4131.53	4241.80	4355.14	4471.76	4591.89	32
33	3621.56	3719.13	3818.95	3921.16	4025.90	4133.34	4243.67	4357.06	4473.73	4593.92	33
34	3623.17	3720.77	3820.63	3922.88	4027.67	4135.16	4245.53	4358.97	4475.71	4595.96	34
35	3624.78	3722.42	3822.32	3924.61	4029.44	4136.97	4247.39	4360.89	4477.68	4598.00	35
36	3626.39	3724.06	3824.00	3926.33	4031.21	4138.79	4249.26	4362.81	4479.66	4600.03	36
37	3628.00	3725.71	3825.69	3928.06	4032.98	4140.61	4251.13	4364.73	4481.63	4602.07	37
38	3629.61	3727.36	3827.37	3929.79	4034.75	4142.42	4252.99	4366.65	4483.61	4604.11	38
39	3631.22	3729.01	3829.06	3931.51	4036.52	4144.24	4254.86	4368.57	4485.59	4606.15	39
40	3632.83	3730.66	3830.75	3933.24	4038.29	4146.06	4256.73	4370.50	4487.57	4608.19	40
41	3634.44	3732.30	3832.43	3934.97	4040.07	4147.88	4258.60	4372.42	4489.55	4610.23	41
42	3636.06	3733.95	3834.12	3936.70	4041.84	4149.70	4260.47	4374.34	4491.53	4612.27	42
43	3637.67	3735.61	3835.81	3938.43	4043.61	4151.52	4262.34	4376.27	4493.51	4614.32	43
44	3639.28	3737.26	3837.50	3940.16	4045.39	4153.35	4264.22	4378.20	4495.50	4616.36	44
45	3640.90	3738.91	3839.19	3941.90	4047.17	4155.17	4266.09	4380.12	4497.48	4618.41	45
46	3642.51	3740.56	3840.88	3943.63	4048.94	4157.00	4267.97	4382.05	4499.47	4620.45	46
47	3644.13	3742.21	3842.58	3945.36	4050.72	4158.82	4269.84	4383.98	4501.45	4622.50	47
48	3645.75	3743.87	3844.27	3947.10	4052.50	4160.65	4271.72	4385.91	4503.44	4624.55	48
49	3647.36	3745.52	3845.96	3948.83	4054.28	4162.47	4273.59	4387.84	4505.43	4626.60	49
50	3648.98	3747.18	3847.66	3950.57	4056.06	4164.30	4275.47	4389.77	4507.42	4628.65	50
51	3650.60	3748.83	3849.35	3952.31	4057.84	4166.13	4277.35	4391.70	4509.41	4630.71	51
52	3652.22	3750.49	3851.05	3954.04	4059.62	4167.96	4279.23	4393.64	4511.40	4632.76	52
53	3653.84	3752.15	3852.75	3955.78	4061.41	4169.79	4281.11	4395.57	4513.39	4634.81	53
54	3655.46	3753.80	3854.44	3957.52	4063.19	4171.62	4282.99	4397.51	4515.39	4636.87	54
55	3657.08	3755.46	3856.14	3959.26	4064.97	4173.45	4284.87	4399.44	4517.38	4638.93	55
56	3658.70	3757.12	3857.84	3961.00	4066.76	4175.28	4286.76	4401.38	4519.38	4640.98	56
57	3660.32	3758.78	3859.54	3962.74	4068.54	4177.12	4288.64	4403.32	4521.37	4643.04	57
58	3661.95	3760.44	3861.24	3964.48	4070.33	4178.95	4290.53	4405.26	4523.37	4645.10	58
59	3663.57	3762.10	3862.94	3966.22	4072.12	4180.78	4292.41	4407.20	4525.37	4647.16	59
60	3665.19	3763.76	3864.64	3967.97	4073.90	4182.62	4294.30	4409.14	4527.37	4649.23	60

Mercator projection table for the sphere—Continued.

Lat.	61°	62°	63°	64°	65°	66°	67°	68°	69°	70°	Lat.
′	′	′	′	′	′	′	′	′	′	′	′
0	4649.23	4774.98	4904.94	5039.42	5178.81	5323.51	5474.01	5630.82	5794.56	5965.92	0
1	4651.29	4777.11	4907.14	5041.70	5181.18	5325.97	5476.57	5633.49	5797.35	5968.84	1
2	4653.35	4779.25	4909.35	5043.99	5183.54	5328.43	5479.13	5636.16	5800.14	5971.77	2
3	4655.42	4781.38	4911.55	5040.27	5185.91	5330.90	5481.69	5638.84	5802.94	5974.70	3
4	4657.49	4783.51	4913.76	5048.56	5188.29	5333.36	5484.26	5641.51	5805.74	5977.63	4
5	4659.55	4785.65	4915.97	5050.85	5190.66	5335.83	5486.83	5644.19	5808.54	5980.57	5
6	4661.62	4787.79	4918.18	5053.14	5193.03	5338.30	5489.40	5646.87	5811.34	5983.50	6
7	4663.69	4789.92	4920.39	5055.43	5195.41	5340.77	5491.97	5649.56	5814.15	5986.44	7
8	4665.76	4792.06	4922.60	5057.72	5197.79	5343.24	5494.54	5652.24	5816.95	5989.38	8
9	4667.83	4794.20	4924.81	5060.01	5200.17	5345.71	5497.11	5654.93	5819.76	5992.33	9
10	4669.91	4796.34	4927.03	5062.30	5202.55	5348.18	5499.69	5657.61	5822.57	5995.27	10
11	4671.98	4798.49	4929.24	5064.60	5204.93	5350.66	5502.27	5660.30	5825.39	5998.22	11
12	4674.06	4800.63	4931.46	5066.90	5207.31	5353.14	5504.85	5663.00	5828.20	6001.17	12
13	4676.13	4802.77	4933.68	5069.19	5209.70	5355.61	5507.43	5665.69	5831.02	6004.13	13
14	4678.21	4804.92	4935.90	5071.49	5212.08	5358.09	5510.01	5668.38	5833.84	6007.08	14
15	4680.29	4807.07	4938.12	5073.80	5214.47	5360.58	5512.60	5671.08	5836.66	6010.04	15
16	4682.37	4809.21	4940.34	5076.10	5216.86	5363.06	5515.18	5673.78	5839.48	6013.00	16
17	4684.45	4811.36	4942.57	5078.40	5219.25	5365.55	5517.77	5676.48	5842.31	6015.96	17
18	4686.53	4813.51	4944.79	5080.71	5221.64	5368.03	5520.36	5679.19	5845.13	6018.93	18
19	4688.61	4815.67	4947.02	5083.01	5224.04	5370.52	5522.95	5681.89	5847.96	6021.90	19
20	4690.70	4817.82	4949.24	5085.32	5226.43	5373.01	5525.55	5684.60	5850.79	6024.87	20
21	4692.78	4819.97	4951.47	5087.63	5228.83	5375.50	5528.14	5687.31	5853.63	6027.84	21
22	4694.87	4822.13	4953.70	5089.94	5231.23	5378.00	5530.74	5690.02	5856.47	6030.81	22
23	4696.96	4824.29	4955.94	5092.25	5233.63	5380.49	5533.34	5692.73	5859.81	6033.79	23
24	4699.05	4826.44	4958.17	5094.57	5236.03	5382.99	5535.94	5695.45	5862.15	6036.77	24
25	4701.14	4828.60	4960.40	5096.88	5238.43	5385.49	5538.55	5698.17	5864.99	6039.75	25
26	4703.23	4830.76	4962.64	5099.20	5240.84	5387.99	5541.15	5700.89	5867.84	6042.74	26
27	4705.32	4832.93	4964.87	5101.52	5243.24	5390.49	5543.76	5703.61	5870.69	6045.73	27
28	4707.41	4835.09	4967.11	5103.84	5245.65	5392.99	5546.37	5706.33	5873.54	6048.72	28
29	4709.51	4837.25	4969.35	5106.16	5248.06	5395.50	5548.98	5709.06	5876.39	6051.71	29
30	4711.60	4839.42	4971.59	5108.48	5250.47	5398.01	5551.59	5711.78	5879.24	6054.70	30
31	4713.70	4841.58	4973.83	5110.80	5252.88	5400.52	5554.20	5714.51	5882.10	6057.70	31
32	4715.79	4843.75	4976.08	5113.13	5255.30	5403.03	5556.82	5717.25	5884.96	6060.70	32
33	4717.89	4845.92	4978.32	5115.45	5257.71	5405.54	5559.44	5719.98	5887.82	6063.71	33
34	4719.99	4848.09	4980.57	5117.78	5260.13	5408.05	5562.06	5722.71	5890.68	6066.71	34
35	4722.09	4850.26	4982.82	5120.11	5262.55	5410.57	5564.68	5725.45	5893.55	6069.71	35
36	4724.19	4852.43	4985.06	5122.44	5264.97	5413.08	5567.30	5728.19	5896.41	6072.72	36
37	4726.30	4854.61	4987.31	5124.77	5267.39	5415.60	5569.93	5730.93	5899.28	6075.73	37
38	4728.40	4856.78	4989.56	5127.11	5269.81	5418.12	5572.55	5733.68	5902.15	6078.75	38
39	4730.51	4858.96	4991.82	5129.44	5272.23	5420.64	5575.18	5736.42	5905.03	6081.76	39
40	4732.61	4861.13	4994.07	5131.78	5274.66	5423.17	5577.81	5739.17	5907.90	6084.78	40
41	4734.72	4863.31	4996.32	5134.11	5277.09	5425.69	5580.44	5741.92	5910.78	6087.81	41
42	4736.83	4865.49	4998.58	5136.45	5279.52	5428.22	5583.08	5744.67	5913.67	6090.83	42
43	4738.94	4867.67	5000.84	5138.79	5281.95	5430.75	5585.71	5747.43	5916.55	6093.86	43
44	4741.05	4869.86	5003.10	5141.14	5284.38	5433.28	5588.35	5750.18	5919.44	6096.89	44
45	4743.16	4872.04	5005.36	5143.48	5286.82	5435.81	5590.99	5752.94	5922.32	6090.92	45
46	4745.28	4874.22	5007.62	5145.83	5289.25	5438.35	5593.64	5755.70	5925.22	6102.95	46
47	4747.39	4876.41	5009.88	5148.17	5291.69	5440.88	5596.28	5758.46	5928.11	6105.99	47
48	4749.51	4878.60	5012.15	5150.52	5294.13	5443.42	5598.93	5761.23	5931.00	6109.03	48
49	4751.63	4880.79	5014.41	5152.87	5296.57	5445.96	5601.57	5763.99	5933.90	6112.07	49
50	4753.74	4882.98	5010.68	5155.22	5299.01	5448.50	5604.22	5766.76	5936.80	6115.12	50
51	4755.86	4885.17	5018.94	5157.57	5301.45	5451.05	5606.87	5769.53	5939.70	6118.16	51
52	4757.98	4887.36	5021.21	5159.93	5303.90	5453.59	5609.53	5772.31	5942.61	6121.21	52
53	4760.10	4889.55	5023.48	5162.28	5306.34	5456.14	5612.18	5775.08	5945.51	6124.26	53
54	4762.23	4891.75	5025.76	5104.64	5308.79	5458.68	5614.84	5777.86	5948.42	6127.32	54
55	4764.35	4893.94	5028.03	5167.00	5311.24	5461.23	5617.50	5780.64	5951.33	6130.38	55
56	4766.47	4896.14	5030.30	5169.36	5313.69	5463.78	5620.16	5783.42	5954.24	6133.44	56
57	4768.60	4898.34	5032.58	5171.72	5316.15	5466.34	5622.82	5786.20	5957.16	6136.50	57
58	4770.73	4900.54	5034.86	5174.08	5318.60	5468.89	5625.49	5788.98	5960.08	6139.56	58
59	4772.86	4902.74	5037.14	5176.44	5321.06	5471.45	5628.15	5791.77	5963.00	6142.63	59
60	4774.98	4904.94	5039.42	5178.81	5323.51	5474.01	5630.82	5794.56	5965.92	6145.70	60

Mercator projection table for the sphere—Continued.

Lat.	71°	72°	73°	74°	75°	76°	77°	78°	79°	80°	Lat.
′	′	′	′	′	′	′	′	′	′	′	′
0	6145.70	6334.84	6534.42	6745.74	6970.34	7210.07	7467.21	7744.57	8045.71	8375.20	0
1	6148.77	6338.08	6537.85	6749.37	6974.20	7214.20	7471.66	7749.38	8050.95	8380.96	1
2	6151.85	6341.32	6541.27	6753.01	6978.07	7218.35	7476.11	7754.20	8056.20	8386.73	2
3	6154.93	6344.56	6544.70	6756.64	6981.95	7222.49	7480.57	7759.02	8061.46	8392.52	3
4	6158.01	6347.81	6548.13	6760.28	6985.83	7226.64	7485.03	7763.86	8066.73	8398.31	4
5	6161.09	6351.06	6551.57	6763.93	6989.71	7230.80	7489.50	7768.70	8072.01	8404.11	5
6	6164.18	6354.31	6555.01	6767.58	6993.60	7234.96	7493.98	7773.55	8077.29	8409.92	6
7	6167.27	6357.56	6558.45	6771.23	6997.49	7239.12	7498.46	7778.40	8082.58	8415.74	7
8	6170.36	6360.82	6561.89	6774.89	7001.38	7243.29	7502.95	7783.26	8087.88	8421.57	8
9	6173.45	6364.08	6565.34	6778.55	7005.28	7247.47	7507.44	7788.12	8093.19	8427.42	9
10	6176.55	6367.35	6568.79	6782.21	7009.19	7251.65	7511.94	7793.00	8098.51	8433.27	10
11	6179.65	6370.61	6572.25	6785.88	7013.10	7255.83	7516.45	7797.88	8103.83	8439.13	11
12	6182.75	6373.88	6575.70	6789.55	7017.01	7260.02	7520.96	7802.76	8109.17	8445.00	12
13	6185.85	6377.16	6579.16	6793.22	7020.93	7264.22	7525.47	7807.66	8114.51	8450.88	13
14	6188.96	6380.43	6582.63	6796.90	7024.85	7268.42	7530.00	7812.56	8119.86	8456.77	14
15	6192.07	6383.71	6586.10	6800.58	7028.77	7272.62	7534.53	7817.46	8125.22	8462.67	15
16	6195.18	6386.99	6589.57	6804.27	7032.70	7276.83	7539.06	7822.38	8130.58	8468.58	16
17	6198.30	6390.28	6593.05	6807.96	7036.64	7281.05	7543.60	7827.30	8135.95	8474.50	17
18	6201.42	6393.57	6596.52	6811.65	7040.58	7285.27	7548.15	7832.23	8141.33	8480.43	18
19	6204.54	6396.86	6600.01	6815.35	7044.52	7289.49	7552.70	7837.16	8146.72	8486.37	19
20	6207.66	6400.15	6603.49	6819.05	7048.47	7293.72	7557.26	7842.10	8152.12	8492.32	20
21	6210.78	6403.44	6606.98	6822.75	7052.42	7297.96	7561.82	7847.05	8157.53	8498.28	21
22	6213.91	6406.74	6610.47	6826.46	7056.37	7302.20	7566.39	7852.01	8162.95	8504.25	22
23	6217.04	6410.05	6613.96	6830.18	7060.33	7306.44	7570.96	7856.97	8168.37	8510.23	23
24	6220.18	6413.35	6617.46	6833.89	7064.30	7310.69	7575.54	7861.94	8173.80	8516.22	24
25	6223.31	6416.66	6620.97	6837.61	7068.27	7314.95	7580.13	7866.91	8179.24	8522.22	25
26	6226.45	6419.97	6624.47	6841.34	7072.24	7319.21	7584.72	7871.90	8184.69	8528.23	26
27	6229.59	6423.29	6627.98	6845.07	7076.22	7323.47	7589.32	7876.89	8190.15	8534.26	27
28	6232.74	6426.61	6631.49	6848.80	7080.20	7327.74	7593.93	7881.89	8195.61	8540.29	28
29	6235.89	6429.93	6635.01	6852.53	7084.19	7332.02	7598.54	7886.89	8201.09	8546.33	29
30	6239.04	6433.25	6638.53	6856.27	7088.18	7336.30	7603.16	7891.91	8206.57	8552.38	30
31	6242.19	6436.58	6642.05	6860.02	7092.18	7340.55	7607.78	7896.93	8212.06	8558.45	31
32	6245.35	6439.91	6645.58	6863.77	7096.18	7344.88	7612.41	7901.95	8217.56	8564.52	32
33	6248.50	6443.24	6649.11	6867.52	7100.18	7349.18	7617.04	7906.98	8223.07	8570.61	33
34	6251.67	6446.58	6652.64	6871.27	7104.19	7353.48	7621.68	7912.03	8228.59	8576.70	34
35	6254.83	6449.92	6656.18	6875.03	7108.21	7357.79	7626.33	7917.08	8234.12	8582.81	35
36	6258.00	6453.26	6659.72	6878.80	7112.23	7362.10	7630.99	7922.13	8239.66	8588.93	36
37	6261.17	6456.61	6663.26	6882.56	7116.25	7366.42	7635.65	7927.19	8245.20	8595.06	37
38	6264.34	6459.95	6666.81	6886.34	7120.28	7370.74	7640.31	7932.26	8250.75	8601.20	38
39	6267.51	6463.31	6670.36	6890.11	7124.31	7375.07	7644.98	7937.34	8256.31	8607.35	39
40	6270.69	6466.66	6673.91	6893.89	7128.35	7379.40	7649.66	7942.43	8261.88	8613.51	40
41	6273.87	6470.02	6677.47	6897.68	7132.39	7383.74	7654.35	7947.52	8267.46	8619.68	41
42	6277.05	6473.38	6681.03	6901.46	7136.43	7388.08	7659.04	7952.62	8273.05	8625.86	42
43	6280.24	6476.74	6684.59	6905.25	7140.48	7392.43	7663.74	7957.72	8278.65	8632.05	43
44	6283.43	6480.11	6688.16	6909.05	7144.54	7396.79	7668.44	7962.84	8284.25	8638.26	44
45	6286.62	6483.48	6691.73	6912.85	7148.60	7401.15	7673.15	7967.96	8289.87	8644.47	45
46	6289.82	6486.86	6695.31	6916.65	7152.67	7405.51	7677.87	7973.09	8295.49	8650.70	46
47	6293.01	6490.23	6698.89	6920.46	7156.74	7409.88	7682.59	7978.23	8301.12	8656.94	47
48	6296.21	6493.61	6702.47	6924.27	7160.81	7414.26	7687.32	7983.37	8306.77	8663.19	48
49	6299.42	6497.00	6706.06	6928.09	7164.89	7418.64	7692.05	7988.52	8312.42	8669.45	49
50	6302.62	6500.38	6709.65	6931.91	7168.97	7423.03	7696.79	7993.68	8318.08	8675.72	50
51	6305.83	6503.77	6713.24	6935.73	7173.06	7427.42	7701.54	7998.85	8323.75	8682.00	51
52	6309.04	6507.17	6716.84	6939.56	7177.15	7431.82	7706.30	8004.03	8329.43	8688.29	52
53	6312.26	6510.56	6720.44	6943.40	7181.25	7436.22	7711.06	8009.21	8335.12	8694.60	53
54	6315.48	6513.96	6724.04	6947.23	7185.35	7440.63	7715.83	8014.40	8340.82	8700.92	54
55	6318.70	6517.36	6727.65	6951.07	7189.46	7445.05	7720.60	8019.60	8346.52	8707.25	55
56	6321.92	6520.77	6731.26	6954.92	7193.57	7449.47	7725.38	8024.81	8352.24	8713.59	56
57	6325.14	6524.18	6734.88	6958.77	7197.69	7453.89	7730.17	8030.02	8357.96	8719.94	57
58	6328.37	6527.59	6738.50	6962.62	7201.81	7458.33	7734.96	8035.24	8363.70	8726.30	58
59	6331.61	6531.01	6742.12	6966.48	7205.94	7462.76	7739.76	8040.47	8369.44	8732.68	59
60	6334.84	6534.42	6745.74	6970.34	7210.07	7467.21	7744.57	8045.71	8375.20	8739.06	60

Mercator projection table for the sphere—Continued.

Lat.	81°	82°	83°	84°	85°	86°	87°	88°	89°	Lat.
′	′	′	′	′	′	′	′	′	′	′
0	8739.06	9145.46	9605.82	10136.89	10764.62	11532.52	12522.11	13916.43	16299.56	0
1	8745.46	9152.65	9614.03	10146.46	10776.11	11546.88	12541.27	13945.20	16357.34	1
2	8751.87	9159.86	9622.27	10156.07	10787.65	11561.31	12560.54	13974.22	16416.11	2
3	8758.29	9167.08	9630.52	10165.70	10799.22	11575.80	12579.91	14003.48	16475.90	3
4	8764.73	9174.32	9638.80	10175.37	10810.82	11590.34	12599.40	14033.00	16536.76	4
5	8771.17	9181.57	9647.09	10185.05	10822.47	11604.95	12619.00	14062.77	16598.69	5
6	8777.63	9188.84	9655.40	10194.77	10834.16	11619.62	12638.70	14092.80	16661.78	6
7	8784.10	9196.13	9663.74	10204.51	10845.89	11634.36	12658.53	14123.09	16726.04	7
8	8790.58	9203.42	9672.09	10214.28	10857.65	11649.16	12678.46	14153.66	16791.53	8
9	8797.08	9210.74	9680.47	10224.08	10869.46	11664.02	12698.52	14184.49	16858.29	9
10	8803.58	9218.07	9688.86	10233.90	10881.31	11678.94	12718.69	14215.61	16926.36	10
11	8810.10	9225.41	9697.28	10243.75	10893.20	11693.93	12738.98	14247.01	16995.81	11
12	8816.63	9232.77	9705.71	10253.64	10905.13	11708.99	12759.39	14278.70	17066.70	12
13	8823.17	9240.15	9714.17	10263.54	10917.10	11724.11	12779.92	14310.68	17139.09	13
14	8829.73	9247.54	9722.64	10273.48	10929.11	11739.30	12800.58	14342.97	17213.03	14
15	8836.30	9254.95	9731.14	10283.45	10941.17	11754.56	12821.36	14375.56	17288.57	15
16	8842.88	9262.37	9739.66	10293.45	10953.26	11769.88	12842.26	14408.46	17365.83	16
17	8849.47	9269.81	9748.20	10303.47	10965.40	11785.27	12863.30	14441.68	17444.87	17
18	8856.07	9277.27	9756.76	10313.53	10977.59	11800.73	12884.46	14475.23	17525.77	18
19	8862.69	9284.74	9765.34	10323.61	10989.81	11816.26	12905.75	14509.10	17608.63	19
20	8869.32	9292.23	9773.94	10333.72	11002.08	11831.87	12927.18	14543.31	17693.49	20
21	8875.96	9299.73	9782.57	10343.86	11014.40	11847.54	12948.74	14577.87	17780.53	21
22	8882.62	9307.25	9791.21	10354.03	11026.75	11863.28	12970.44	14612.78	17869.83	22
23	8889.29	9314.79	9799.88	10364.24	11039.15	11879.10	12992.27	14648.04	17961.51	23
24	8895.97	9322.34	9808.57	10374.47	11051.60	11894.99	13014.25	14683.67	18055.70	24
25	8902.66	9329.91	9817.28	10384.73	11064.09	11910.95	13036.36	14719.67	18152.55	25
26	8909.37	9337.49	9826.02	10395.03	11076.63	11926.99	13058.62	14756.05	18252.20	26
27	8916.09	9345.10	9834.77	10405.85	11089.21	11943.10	13081.02	14792.83	18354.83	27
28	8922.82	9352.72	9843.55	10415.71	11101.84	11959.29	13103.58	14830.00	18460.62	28
29	8929.57	9360.35	9852.35	10426.09	11114.52	11975.55	13126.27	14867.57	18569.76	29
30	8936.33	9368.00	9861.17	10436.51	11127.24	11991.89	13149.12	14905.56	18682.49	30
31	8943.10	9375.67	9870.02	10446.96	11140.01	12008.31	13172.13	14943.98	18799.03	31
32	8949.88	9383.36	9878.88	10457.44	11152.82	12024.81	13195.28	14982.83	18919.67	32
33	8956.68	9391.06	9887.77	10467.95	11165.69	12041.39	13218.60	15022.12	19044.69	33
34	8963.49	9398.79	9896.69	10478.50	11178.60	12058.05	13242.07	15061.87	19174.44	34
35	8970.32	9406.53	9905.63	10489.08	11191.56	12074.79	13265.70	15102.08	19309.27	35
36	8977.16	9414.28	9914.59	10499.69	11204.57	12091.60	13289.50	15142.77	19449.61	36
37	8984.01	9422.05	9923.57	10510.33	11217.63	12108.51	13313.47	15183.94	19595.92	37
38	8990.87	9429.84	9932.57	10521.01	11230.74	12125.49	13337.60	15225.62	19748.73	38
39	8997.75	9437.65	9941.60	10531.71	11243.90	12142.57	13361.90	15267.80	19908.66	39
40	9004.65	9445.48	9950.66	10542.45	11257.11	12159.72	13386.37	15310.51	20076.39	40
41	9011.55	9453.32	9959.73	10553.23	11270.37	12176.96	13411.02	15353.76	20252.72	41
42	9018.47	9461.18	9968.83	10564.04	11283.68	12194.29	13435.85	15397.56	20438.59	42
43	9025.41	9469.06	9977.96	10574.88	11297.04	12211.71	13460.86	15441.92	20635.09	43
44	9032.36	9476.96	9987.11	10585.76	11310.46	12229.21	13486.05	15486.86	20843.50	44
45	9039.32	9484.87	9996.28	10596.67	11323.93	12246.81	13511.43	15532.40	21065.37	45
46	9046.29	9492.81	10005.48	10607.62	11337.45	12264.49	13537.00	15578.55	21302.55	46
47	9053.28	9500.76	10014.70	10618.60	11351.02	12282.26	13562.75	15625.32	21557.81	47
48	9060.29	9508.73	10023.95	10629.61	11364.65	12300.13	13588.71	15672.75	21832.48	48
49	9067.31	9516.71	10033.22	10640.67	11378.33	12318.09	13614.85	15720.83	22131.60	49
50	9074.34	9524.72	10042.52	10651.75	11392.06	12336.15	13641.20	15769.59	22459.26	50
51	9081.39	9532.74	10051.84	10662.87	11405.85	12354.30	13667.75	15819.06	22821.46	51
52	9088.45	9540.79	10061.19	10674.03	11419.70	12372.54	13694.52	15869.25	23226.39	52
53	9095.52	9548.85	10070.56	10685.22	11433.60	12390.89	13721.48	15920.19	23685.42	53
54	9102.61	9556.93	10079.96	10696.46	11447.56	12409.33	13748.67	15971.89	24215.35	54
55	9109.72	9565.03	10089.38	10707.72	11461.58	12427.87	13776.07	16024.38	24842.12	55
56	9116.84	9573.15	10098.83	10719.03	11475.65	12446.51	13803.68	16077.68	25609.23	56
57	9123.97	9581.29	10108.30	10730.37	11489.78	12465.26	13831.53	16131.82	26598.21	57
58	9131.12	9589.45	10117.81	10741.75	11503.97	12484.10	13859.60	16186.83	27992.10	58
59	9138.28	9597.62	10127.33	10753.17	11518.21	12503.05	13887.90	16242.74	30874.96	59
60	9145.46	9605.82	10136.89	10764.62	11532.52	12522.11	13916.43	16299.56	∞	60

INSTRUCTIONS FOR THE USE OF THE GNOMONIC AZIMUTH TABLES.

The tables of gnomonic azimuths have been computed for 10 radio-compass stations, the computation being based upon the great circle sailing chart of the North Atltanic Ocean, Hydrographic Office Chart No. 1280. The azimuths or true bearings run in a clockwise direction, starting at true north and extending continuously from 0° to 360°. To use the tables it is only necessary to find from the table for the given station the gnomonic azimuth or bearing corresponding to the observed true azimuth or bearing. This angle should be laid off from the meridian reckoning from north in a clockwise direction. To facilitate this operation, the meridian through the station should be drawn on the projection. This should also be done at each of the other stations on the projection once for all since the meridian will always be required as an aid in laying off the bearings accurately. The intersection of two plotted bearings will determine a position that may then be scaled from the map.

If the observations are made on the vessel they can be reduced to the station in the following manner: From the graphic chart "Semiconvergence of meridians," the semiconvergence can be scaled, using the approximate position of the vessel for determining the arguments as described on page 3. If the vessel is east of the station and both are in the Northern Hemisphere, the observed bearing minus twice the semiconvergence plus 180° will give what the azimuth would have been if it had been observed at the station. If the vessel is west of the station and both are north of the Equator, twice the semiconvergence must be added instead of subtracted. If the position of the vessel is much changed when the bearings are plotted, the semiconvergence should be redetermined to make it conform to the true position of the vessel.

Gnomonic azimuth tables.

CAPE RACE RADIO-COMPASS STATION.

True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.
0°	0° 00'	73°	78° 12'	145°	145° 53'	217°	219° 46'	289°	292° 55'
1	1 02	74	79 13	146	146 49	218	220 52	290	293 50
2	2 04	75	80 13	147	147 44	219	221 58	291	294 45
3	3 06	76	81 14	148	148 41	220	223 04	292	295 40
4	4 08	77	82 14	149	149 37	221	224 10	293	296 35
5	5 11	78	83 15	150	150 33	222	225 15	294	297 30
6	6 14	79	84 15	151	151 30	223	226 21	295	298 25
7	7 17	80	85 14	152	152 26	224	227 26	296	299 20
8	8 20	81	86 14	153	153 23	225	228 32	297	300 15
9	9 23	82	87 14	154	154 20	226	229 38	298	301 10
10	10 27	83	88 14	155	155 17	227	230 43	299	302 05
11	11 31	84	89 12	156	156 14	228	231 48	300	302 59
12	12 34	85	90 11	157	157 11	229	232 53	301	303 54
13	13 38	86	91 09	158	158 09	230	233 58	302	304 49
14	14 43	87	92 08	159	159 06	231	235 03	303	305 43
15	15 47	88	93 06	160	160 04	232	236 08	304	306 38
16	16 51	89	94 04	161	161 02	233	237 13	305	307 33
17	17 56	90	95 02	162	162 00	234	238 17	306	308 27
18	19 01	91	96 00	163	162 59	235	239 22	307	309 22
19	20 05	92	96 57	164	163 57	236	240 26	308	310 16
20	21 10	93	97 55	165	164 56	237	241 30	309	311 11
21	22 16	94	98 52	166	165 55	238	242 34	310	312 06
22	23 21	95	99 49	167	166 54	239	243 38	311	313 00
23	24 26	96	100 46	168	167 53	240	244 41	312	313 55
24	25 31	97	101 43	169	168 53	241	245 45	313	314 50
25	26 37	98	102 40	170	169 52	242	246 48	314	315 45
26	27 42	99	103 36	171	170 52	243	247 51	315	316 40
27	28 48	100	104 33	172	171 52	244	248 54	316	317 35
28	29 53	101	105 29	173	172 52	245	249 57	317	318 30
29	30 59	102	106 25	174	173 53	246	250 59	318	319 25
30	32 05	103	107 21	175	174 54	247	252 02	319	320 20
31	33 11	104	108 17	176	175 55	248	253 04	320	321 15
32	34 17	105	109 13	177	176 56	249	254 06	321	322 10
33	35 23	106	110 08	178	177 57	250	255 08	322	323 06
34	36 29	107	111 04	179	178 58	251	256 09	323	324 01
35	37 35	108	111 59	180	180 00	252	257 11	324	324 57
36	38 40	109	112 55	181	181 02	253	258 12	325	325 53
37	39 46	110	113 50	182	182 04	254	259 13	326	326 49
38	40 52	111	114 45	183	183 06	255	260 13	327	327 44
39	41 58	112	115 40	184	184 08	256	261 14	328	328 41
40	43 04	113	116 35	185	185 11	257	262 14	329	329 37
41	44 10	114	117 30	186	186 14	258	263 15	330	330 33
42	45 15	115	118 25	187	187 17	259	264 15	331	331 30
43	46 21	116	119 20	188	188 20	260	265 14	332	332 26
44	47 26	117	120 15	189	189 23	261	266 14	333	333 23
45	48 32	118	121 10	190	190 27	262	267 14	334	334 20
46	49 38	119	122 05	191	191 31	263	268 14	335	335 17
47	50 43	120	122 59	192	192 34	264	269 12	336	336 14
48	51 48	121	123 54	193	193 38	265	270 11	337	337 11
49	52 53	122	124 49	194	194 43	266	271 09	338	338 09
50	53 58	123	125 43	195	195 47	267	272 08	339	339 06
51	55 03	124	126 38	196	196 51	268	273 06	340	340 04
52	56 08	125	127 33	197	197 56	269	274 04	341	341 02
53	57 13	126	128 27	198	199 01	270	275 02	342	342 00
54	58 17	127	129 22	199	200 05	271	276 00	343	342 59
55	59 22	128	130 16	200	201 10	272	276 57	344	343 57
56	60 26	129	131 11	201	202 16	273	277 55	345	344 56
57	61 30	130	132 06	202	203 21	274	278 52	346	345 55
58	62 34	131	133 00	203	204 26	275	279 49	347	346 54
59	63 38	132	133 55	204	205 31	276	280 46	348	347 53
60	64 41	133	134 50	205	206 37	277	281 43	349	348 53
61	65 45	134	135 45	206	207 42	278	282 40	350	349 52
62	66 48	135	136 40	207	208 48	279	283 36	351	350 52
63	67 51	136	137 35	208	209 53	280	284 33	352	351 52
64	68 54	137	138 30	209	210 59	281	285 29	353	352 52
65	69 57	138	139 25	210	212 05	282	286 25	354	353 53
66	70 59	139	140 20	211	213 11	283	287 21	355	354 54
67	72 02	140	141 15	212	214 17	284	288 17	356	355 55
68	73 04	141	142 10	213	215 23	285	289 13	357	356 56
69	74 06	142	143 06	214	216 29	286	290 08	358	357 57
70	75 08	143	144 01	215	217 35	287	291 04	359	358 58
71	76 09	144	144 57	216	218 40	288	291 59	360	360 00
72	77 11								

$u-u'=+161'.1 \sin 2u-3'.8 \sin 4u+0'.1 \sin 6u.$

Gnomonic azimuth tables—Continued.

BAR HARBOR RADIO-COMPASS STATION.

True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.
0°	0° 00′	73°	79° 30′	145°	142° 17′	217°	223° 26′	289°	290° 15′
1	1 10	74	80 24	146	143 16	218	224 32	290	291 06
2	2 21	75	81 17	147	144 15	219	225 38	291	291 56
3	3 32	76	82 11	148	145 14	220	226 44	292	292 47
4	4 43	77	83 04	149	146 13	221	227 50	293	293 37
5	5 54	78	83 57	150	147 13	222	228 55	294	294 28
6	7 05	79	84 50	151	148 13	223	230 00	295	295 19
7	8 17	80	85 43	152	149 14	224	231 04	296	296 10
8	9 28	81	86 35	153	150 15	225	232 08	297	297 01
9	10 40	82	87 27	154	151 16	226	233 12	298	297 52
10	11 52	83	88 19	155	152 18	227	234 15	299	298 44
11	13 03	84	89 11	156	153 20	228	235 18	300	299 35
12	14 15	85	90 03	157	154 22	229	236 20	301	300 27
13	15 27	86	90 54	158	155 25	230	237 22	302	301 19
14	16 38	87	91 45	159	156 28	231	238 24	303	302 11
15	17 50	88	92 37	160	157 32	232	239 25	304	303 03
16	19 02	89	93 28	161	158 36	233	240 26	305	303 55
17	20 14	90	94 19	162	159 41	234	241 26	306	304 48
18	21 25	91	95 09	163	160 45	235	242 27	307	305 41
19	22 36	92	96 00	164	161 51	236	243 26	308	306 34
20	23 48	93	96 51	165	162 56	237	244 26	309	307 27
21	24 59	94	97 41	166	164 02	238	245 25	310	308 21
22	26 10	95	98 32	167	165 09	239	246 23	311	309 14
23	27 20	96	99 22	168	166 15	240	247 22	312	310 08
24	28 31	97	100 13	169	167 22	241	248 20	313	311 03
25	29 41	98	101 03	170	168 30	242	249 17	314	311 57
26	30 52	99	101 53	171	169 37	243	250 14	315	312 52
27	32 02	100	102 43	172	170 45	244	251 11	316	313 47
28	33 11	101	103 33	173	171 54	245	252 08	317	314 43
29	34 21	102	104 24	174	173 02	246	253 04	318	315 38
30	35 30	103	105 14	175	174 11	247	254 00	319	316 34
31	36 39	104	106 04	176	175 20	248	254 56	320	317 31
32	37 47	105	106 54	177	176 30	249	255 51	321	318 27
33	38 56	106	107 44	178	177 40	250	256 46	322	319 24
34	40 04	107	108 35	179	178 50	251	257 41	323	320 22
35	41 11	108	109 25	180	180 00	252	258 36	324	321 19
36	42 19	109	110 15	181	181 10	253	259 30	325	322 17
37	43 26	110	111 06	182	182 21	254	260 24	326	323 16
38	44 32	111	111 56	183	183 32	255	261 17	327	324 15
39	45 38	112	112 47	184	184 43	256	262 11	328	325 14
40	46 44	113	113 37	185	185 54	257	263 04	329	326 13
41	47 50	114	114 28	186	187 05	258	263 57	330	327 13
42	48 55	115	115 19	187	188 17	259	264 50	331	328 13
43	50 00	116	116 10	188	189 28	260	265 43	332	329 14
44	51 04	117	117 01	189	190 40	261	266 35	333	330 15
45	52 08	118	117 52	190	191 52	262	267 27	334	331 16
46	53 12	119	118 44	191	193 03	263	268 19	335	332 18
47	54 15	120	119 35	192	194 15	264	269 11	336	333 20
48	55 18	121	120 27	193	195 27	265	270 03	337	334 22
49	56 20	122	121 19	194	196 38	266	270 54	338	335 25
50	57 22	123	122 11	195	197 50	267	271 45	339	336 28
51	58 24	124	123 03	196	199 02	268	272 37	340	337 32
52	59 25	125	123 55	197	200 14	269	273 28	341	338 36
53	60 26	126	124 48	198	201 25	270	274 19	342	339 41
54	61 26	127	125 41	199	202 36	271	275 09	343	340 45
55	62 27	128	126 34	200	203 48	272	276 00	344	341 51
56	63 26	129	127 27	201	204 59	273	276 51	345	342 56
57	64 26	130	128 21	202	206 10	274	277 41	346	344 02
58	65 25	131	129 14	203	207 20	275	278 32	347	345 09
59	66 23	132	130 08	204	208 31	276	279 22	348	346 15
60	67 22	133	131 03	205	209 41	277	280 13	349	347 22
61	68 20	134	131 57	206	210 52	278	281 03	350	348 30
62	69 17	135	132 52	207	212 02	279	281 53	351	349 37
63	70 14	136	133 47	208	213 11	280	282 43	352	350 45
64	71 11	137	134 43	209	214 21	281	283 33	353	351 54
65	72 08	138	135 38	210	215 30	282	284 24	354	353 02
66	73 04	139	136 34	211	216 39	283	285 14	355	354 11
67	74 00	140	137 31	212	217 47	284	286 04	356	355 20
68	74 56	141	138 27	213	218 56	285	286 54	357	356 30
69	75 51	142	139 24	214	220 04	286	287 44	358	357 40
70	76 46	143	140 22	215	221 11	287	288 35	359	358 50
71	77 41	144	141 19	216	222 19	288	289 25	360	360 00
72	78 36								

$u-u'=+360'.4 \sin 2u-13'.6 \sin 4u+0'.8 \sin 6u.$

Gnomonic azimuth tables—Continued.

CAPE COD RADIO-COMPASS STATION.

True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.
0°	0° 00′	73°	78° 22′	145°	141° 06′	217°	223° 25′	289°	288° 34′
1	1 12	74	79 14	146	142 06	218	224 30	290	289 24
2	2 24	75	80 06	147	143 06	219	225 34	291	290 15
3	3 37	76	80 58	148	144 07	220	226 39	292	291 05
4	4 49	77	81 50	149	145 09	221	227 42	293	291 56
5	6 01	78	82 42	150	146 10	222	228 46	294	292 47
6	7 14	79	83 33	151	147 12	223	229 49	295	293 38
7	8 26	80	84 24	152	148 15	224	230 51	296	294 29
8	9 39	81	85 15	153	149 18	225	231 53	297	295 20
9	10 52	82	86 06	154	150 22	226	232 55	298	296 12
10	12 04	83	86 57	155	151 25	227	233 56	299	297 04
11	13 16	84	87 47	156	152 30	228	234 57	300	297 56
12	14 29	85	88 38	157	153 34	229	235 58	301	298 48
13	15 41	86	89 28	158	154 39	230	236 58	302	299 40
14	16 53	87	90 18	159	155 45	231	237 57	303	300 33
15	18 05	88	91 08	160	156 51	232	238 57	304	301 26
16	19 17	89	91 58	161	157 57	233	239 56	305	302 19
17	20 29	90	92 48	162	159 04	234	240 54	306	303 12
18	21 40	91	93 38	163	160 11	235	241 52	307	304 06
19	22 52	92	94 28	164	161 18	236	242 50	308	305 00
20	24 03	93	95 17	165	162 26	237	243 47	309	305 54
21	25 14	94	96 07	166	163 34	238	244 44	310	306 48
22	26 24	95	96 57	167	164 43	239	245 41	311	307 43
23	27 35	96	97 46	168	165 52	240	246 37	312	308 38
24	28 45	97	98 36	169	167 01	241	247 33	313	309 33
25	29 55	98	99 26	170	168 10	242	248 29	314	310 29
26	31 04	99	100 15	171	169 20	243	249 24	315	311 25
27	32 13	100	101 05	172	170 30	244	250 20	316	312 22
28	33 22	101	101 55	173	171 41	245	251 14	317	313 18
29	34 31	102	102 44	174	172 51	246	252 09	318	314 15
30	35 39	103	103 34	175	174 02	247	253 03	319	315 13
31	36 46	104	104 24	176	175 13	248	253 57	320	316 11
32	37 54	105	105 14	177	176 25	249	254 50	321	317 09
33	39 01	106	106 04	178	177 36	250	255 44	322	318 08
34	40 07	107	106 54	179	178 48	251	256 37	323	319 07
35	41 14	108	107 44	180	180 00	252	257 29	324	320 06
36	42 19	109	108 34	181	181 12	253	258 22	325	321 06
37	43 25	110	109 24	182	182 24	254	259 14	326	322 06
38	44 30	111	110 15	183	183 37	255	260 06	327	323 06
39	45 34	112	111 05	184	184 49	256	260 58	328	324 07
40	46 39	113	111 56	185	186 01	257	261 50	329	325 09
41	47 42	114	112 47	186	187 14	258	262 42	330	326 10
42	48 46	115	113 38	187	188 26	259	263 33	331	327 12
43	49 49	116	114 29	188	189 39	260	264 24	332	328 15
44	50 51	117	115 20	189	190 52	261	265 15	333	329 18
45	51 53	118	116 12	190	192 04	262	266 06	334	330 22
46	52 55	119	117 04	191	193 16	263	266 57	335	331 25
47	53 56	120	117 56	192	194 29	264	267 47	336	332 30
48	54 57	121	118 48	193	195 41	265	268 38	337	333 34
49	55 58	122	119 40	194	196 53	266	269 28	338	334 39
50	56 58	123	120 33	195	198 05	267	270 18	339	335 45
51	57 57	124	121 26	196	199 17	268	271 08	340	336 51
52	58 57	125	122 19	197	200 29	269	271 58	341	337 57
53	59 56	126	123 12	198	201 40	270	272 48	342	339 04
54	60 54	127	124 06	199	202 52	271	273 38	343	340 11
55	61 52	128	125 00	200	204 03	272	274 28	344	341 18
56	62 50	129	125 54	201	205 14	273	275 17	345	342 26
57	63 47	130	126 48	202	206 24	274	276 07	346	343 34
58	64 44	131	127 43	203	207 35	275	276 57	347	344 43
59	65 41	132	128 38	204	208 45	276	277 46	348	345 52
60	66 37	133	129 33	205	209 55	277	278 36	349	347 01
61	67 33	134	130 29	206	211 04	278	279 26	350	348 10
62	68 29	135	131 25	207	212 13	279	280 15	351	349 20
63	69 24	136	132 22	208	213 22	280	281 05	352	350 30
64	70 20	137	133 18	209	214 31	281	281 55	353	351 41
65	71 14	138	134 15	210	215 39	282	282 44	354	352 51
66	72 09	139	135 13	211	216 46	283	283 34	355	354 02
67	73 03	140	136 11	212	217 54	284	284 24	356	355 13
68	73 57	141	137 09	213	219 01	285	285 14	357	356 25
69	74 50	142	138 08	214	220 07	286	286 04	358	357 36
70	75 44	143	139 07	215	221 14	287	286 54	359	358 48
71	76 37	144	140 06	216	222 19	288	287 44	360	360 00
72	77 29								

$u-u'=+825'.6 \sin 2u-15'.4 \sin 4u+1'.0 \sin 6u.$

Gnomonic azimuth tables—Continued.

MONTAUK RADIO-COMPASS STATION.

True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.
0°	0° 00′	73°	77° 45′	145°	140° 10′	217°	223° 34′	289°	287° 25′
1	1 14	74	78 36	146	141 11	218	224 38	290	288 15
2	2 27	75	79 27	147	142 13	219	225 42	291	289 05
3	3 41	76	80 18	148	143 15	220	226 45	292	289 56
4	4 54	77	81 08	149	144 18	221	227 48	293	290 46
5	6 08	78	81 58	150	145 21	222	228 50	294	291 37
6	7 22	79	82 49	151	146 24	223	229 52	295	292 28
7	8 35	80	83 39	152	147 28	224	230 53	296	293 19
8	9 49	81	84 28	153	148 33	225	231 54	297	294 10
9	11 02	82	85 18	154	149 38	226	232 55	298	295 02
10	12 16	83	86 08	155	150 43	227	233 55	299	295 53
11	13 29	84	86 57	156	151 49	228	234 54	300	296 45
12	14 42	85	87 46	157	152 55	229	235 53	301	297 37
13	15 55	86	88 36	158	154 02	230	236 52	302	298 30
14	17 08	87	89 25	159	155 09	231	237 50	303	299 23
15	18 21	88	90 14	160	156 17	232	238 48	304	300 16
16	19 33	89	91 03	161	157 25	233	239 46	305	301 09
17	20 45	90	91 52	162	158 33	234	240 43	306	302 03
18	21 57	91	92 41	163	159 42	235	241 40	307	302 57
19	23 09	92	93 30	164	160 51	236	242 36	308	303 51
20	24 20	93	94 19	165	162 01	237	243 32	309	304 45
21	25 31	94	95 08	166	163 11	238	244 28	310	305 40
22	26 42	95	95 56	167	164 21	239	245 23	311	306 36
23	27 52	96	96 45	168	165 32	240	246 18	312	307 31
24	29 02	97	97 34	169	166 42	241	247 13	313	308 27
25	30 11	98	98 23	170	167 54	242	248 07	314	309 24
26	31 21	99	99 12	171	169 05	243	249 01	315	310 20
27	32 30	100	100 01	172	170 17	244	249 55	316	311 17
28	33 38	101	100 50	173	171 29	245	250 48	317	312 15
29	34 46	102	101 39	174	172 42	246	251 41	318	313 13
30	35 53	103	102 28	175	173 54	247	252 34	319	314 11
31	37 01	104	103 17	176	175 07	248	253 26	320	315 10
32	38 07	105	104 07	177	176 20	249	254 18	321	316 09
33	39 14	106	104 56	178	177 33	250	255 11	322	317 09
34	40 20	107	105 46	179	178 46	251	256 02	323	318 09
35	41 25	108	106 35	180	180 00	252	256 54	324	319 09
36	42 30	109	107 25	181	181 14	253	257 45	325	320 10
37	43 34	110	108 15	182	182 27	254	258 36	326	321 11
38	44 38	111	109 05	183	183 41	255	259 27	327	322 13
39	45 42	112	109 56	184	184 54	256	260 18	328	323 15
40	46 45	113	110 46	185	186 08	257	261 08	329	324 18
41	47 48	114	111 37	186	187 22	258	261 58	330	325 21
42	48 50	115	112 28	187	188 35	259	262 49	331	326 24
43	49 52	116	113 19	188	189 49	260	263 39	332	327 28
44	50 53	117	114 10	189	191 02	261	264 28	333	328 33
45	51 54	118	115 02	190	192 16	262	265 18	334	329 38
46	52 55	119	115 53	191	193 29	263	266 08	335	330 43
47	53 55	120	116 45	192	194 42	264	266 57	336	331 49
48	54 54	121	117 37	193	195 55	265	267 46	337	332 55
49	55 53	122	118 30	194	197 08	266	268 36	338	334 02
50	56 52	123	119 23	195	198 21	267	269 25	339	335 09
51	57 50	124	120 16	196	199 33	268	270 14	340	336 17
52	58 48	125	121 09	197	200 45	269	271 03	341	337 25
53	59 46	126	122 03	198	201 57	270	271 52	342	338 33
54	60 43	127	122 57	199	203 09	271	272 41	343	339 42
55	61 40	128	123 51	200	204 20	272	273 30	344	340 51
56	62 36	129	124 45	201	205 31	273	274 19	345	342 01
57	63 32	130	125 40	202	206 42	274	275 08	346	343 11
58	64 28	131	126 36	203	207 52	275	275 56	347	344 21
59	65 23	132	127 31	204	209 02	276	276 45	348	345 32
60	66 18	133	128 27	205	210 11	277	277 34	349	346 42
61	67 13	134	129 24	206	211 21	278	278 23	350	347 54
62	68 07	135	130 20	207	212 30	279	279 12	351	349 05
63	69 01	136	131 17	208	213 38	280	280 01	352	350 17
64	69 55	137	132 15	209	214 46	281	280 50	353	351 29
65	70 48	138	133 13	210	215 53	282	281 39	354	352 42
66	71 41	139	134 11	211	217 01	283	282 28	355	353 54
67	72 34	140	135 10	212	218 07	284	283 17	356	355 07
68	73 26	141	136 09	213	219 14	285	284 07	357	356 20
69	74 18	142	137 09	214	220 20	286	284 56	358	357 33
70	75 11	143	138 09	215	221 25	287	285 46	359	358 46
71	76 02	144	139 09	216	222 30	288	286 35	360	360 00
72	76 54								

$u-u'=+352'.4 \sin 2u-18'.1 \sin 4u+1'.2 \sin 6u.$

Gnomonic azimuth tables—Continued.

FIRE ISLAND RADIO-COMPASS STATION.

True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.
0°	0° 00′	73°	77° 25′	145°	139° 35′	217°	223° 42′	289°	286° 44
1	1 14	74	78 16	146	140 37	218	224 46	290	287 34
2	2 29	75	79 06	147	141 39	219	225 49	291	288 24
3	3 43	76	79 56	148	142 42	220	226 52	292	289 14
4	4 58	77	80 45	149	143 46	221	227 54	293	290 04
5	6 12	78	81 35	150	144 50	222	228 55	294	290 54
6	7 27	79	82 24	151	145 54	223	229 56	295	291 45
7	8 42	80	83 14	152	146 59	224	230 57	296	292 36
8	9 56	81	84 03	153	148 04	225	231 57	297	293 27
9	11 10	82	84 52	154	149 10	226	232 57	298	294 18
10	12 24	83	85 40	155	150 16	227	233 56	299	295 10
11	13 38	84	86 29	156	151 23	228	234 55	300	296 02
12	14 52	85	87 18	157	152 30	229	235 53	301	296 54
13	16 05	86	88 06	158	153 38	230	236 51	302	297 47
14	17 18	87	88 55	159	154 46	231	237 49	303	298 40
15	18 31	88	89 43	160	155 55	232	238 46	304	299 33
16	19 44	89	90 32	161	157 04	233	239 43	305	300 26
17	20 56	90	91 20	162	158 14	234	240 39	306	301 20
18	22 09	91	92 08	163	159 23	235	241 35	307	302 14
19	23 20	92	92 56	164	160 34	236	242 31	308	303 08
20	24 32	93	93 45	165	161 44	237	243 26	309	304 03
21	25 43	94	94 33	166	162 55	238	244 20	310	304 58
22	26 54	95	95 21	167	164 07	239	245 15	311	305 54
23	28 04	96	96 10	168	165 19	240	246 09	312	306 50
24	29 14	97	96 58	169	166 31	241	247 03	313	307 46
25	30 24	98	97 46	170	167 43	242	247 56	314	308 43
26	31 33	99	98 35	171	168 56	243	248 50	315	309 40
27	32 41	100	99 23	172	170 09	244	249 42	316	310 37
28	33 50	101	100 12	173	171 22	245	250 35	317	311 35
29	34 57	102	101 00	174	172 36	246	251 27	318	312 34
30	36 04	103	101 49	175	173 49	247	252 19	319	313 32
31	37 11	104	102 38	176	175 03	248	253 11	320	314 32
32	38 18	105	103 27	177	176 17	249	254 02	321	315 31
33	39 23	106	104 16	178	177 31	250	254 53	322	316 31
34	40 29	107	105 05	179	178 46	251	255 44	323	317 32
35	41 34	108	105 55	180	180 00	252	256 35	324	318 33
36	42 38	109	106 44	181	181 14	253	257 25	325	319 35
37	43 42	110	107 34	182	182 29	254	258 16	326	320 37
38	44 46	111	108 24	183	183 43	255	259 06	327	321 39
39	45 49	112	109 14	184	184 58	256	259 56	328	322 42
40	46 52	113	110 04	185	186 12	257	260 45	329	323 46
41	47 54	114	110 54	186	187 27	258	261 35	330	324 50
42	48 55	115	111 45	187	188 42	259	262 24	331	325 54
43	49 56	116	112 36	188	189 56	260	263 14	332	326 59
44	50 57	117	113 27	189	191 10	261	264 03	333	328 04
45	51 57	118	114 18	190	192 24	262	264 52	334	329 10
46	52 57	119	115 10	191	193 38	263	265 40	335	330 16
47	53 56	120	116 02	192	194 52	264	266 29	336	331 23
48	54 55	121	116 54	193	196 05	265	267 18	337	332 30
49	55 53	122	117 47	194	197 18	266	268 06	338	333 38
50	56 51	123	118 40	195	198 31	267	268 55	339	334 46
51	57 49	124	119 33	196	199 44	268	269 43	340	335 55
52	58 46	125	120 26	197	200 56	269	270 32	341	337 04
53	59 43	126	121 20	198	202 09	270	271 20	342	338 14
54	60 39	127	122 14	199	203 20	271	272 08	343	339 23
55	61 35	128	123 08	200	204 32	272	272 56	344	340 34
56	62 31	129	124 03	201	205 43	273	273 45	345	341 44
57	63 26	130	124 58	202	206 54	274	274 33	346	342 55
58	64 20	131	125 54	203	208 04	275	275 21	347	344 07
59	65 15	132	126 50	204	209 14	276	276 10	348	345 19
60	66 09	133	127 46	205	210 24	277	276 58	349	346 31
61	67 03	134	128 43	206	211 33	278	277 46	350	347 43
62	67 56	135	129 40	207	212 41	279	278 35	351	348 56
63	68 50	136	130 37	208	213 50	280	279 23	352	350 09
64	69 42	137	131 35	209	214 57	281	280 12	353	351 22
65	70 35	138	132 34	210	216 04	282	281 00	354	352 36
66	71 27	139	133 32	211	217 11	283	281 49	355	353 49
67	72 19	140	134 32	212	218 18	284	282 38	356	355 03
68	73 11	141	135 31	213	219 23	285	283 27	357	356 17
69	74 02	142	136 31	214	220 29	286	284 16	358	357 31
70	74 53	143	137 32	215	221 34	287	285 05	359	358 46
71	75 44	144	138 33	216	222 38	288	285 55	360	360 00
72	76 35								

$u-u' = +372'.2 \sin 2u - 20'.1 \sin 4u + 1'.5 \sin 6u.$

Gnomonic azimuth tables—Continued.

SANDY HOOK RADIO-COMPASS STATION.

True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.
0°	0° 00′	73°	77° 15′	145°	139° 13′	217°	223° 49′	289°	286° 20′
1	1 15	74	78 05	146	140 15	218	224 52	290	287 10
2	2 30	75	78 55	147	141 18	219	225 55	291	287 59
3	3 45	76	79 44	148	142 21	220	226 57	292	288 49
4	5 00	77	80 33	149	143 25	221	227 59	293	289 39
5	6 16	78	81 22	150	144 30	222	229 00	294	290 29
6	7 31	79	82 11	151	145 35	223	230 00	295	291 20
7	8 46	80	83 00	152	146 40	224	231 01	296	292 11
8	10 00	81	83 48	153	147 46	225	232 00	297	293 02
9	11 15	82	84 37	154	148 52	226	233 00	298	293 53
10	12 29	83	85 25	155	149 59	227	233 59	299	294 45
11	13 44	84	86 13	156	151 07	228	234 57	300	295 36
12	14 58	85	87 02	157	152 15	229	235 55	301	296 29
13	16 12	86	87 50	158	153 23	230	236 52	302	297 21
14	17 25	87	88 38	159	154 32	231	237 50	303	298 14
15	18 38	88	89 26	160	155 41	232	238 46	304	299 07
16	19 52	89	90 14	161	156 51	233	239 42	305	300 00
17	21 04	90	91 02	162	158 01	234	240 38	306	300 54
18	22 16	91	91 50	163	159 12	235	241 34	307	301 48
19	23 28	92	92 38	164	160 23	236	242 29	308	302 43
20	24 40	93	93 25	165	161 34	237	243 24	309	303 37
21	25 51	94	94 13	166	162 46	238	244 18	310	304 33
22	27 02	95	95 01	167	163 58	239	245 12	311	305 28
23	28 12	96	95 49	168	165 10	240	246 05	312	306 24
24	29 22	97	96 37	169	166 23	241	246 58	313	307 21
25	30 32	98	97 25	170	167 36	242	247 52	314	308 18
26	31 41	99	98 13	171	168 50	243	248 44	315	309 15
27	32 50	100	99 01	172	170 04	244	249 36	316	310 13
28	33 58	101	99 50	173	171 17	245	250 28	317	311 11
29	35 05	102	100 38	174	172 32	246	251 20	318	312 09
30	36 13	103	101 26	175	173 46	247	252 12	319	313 08
31	37 19	104	102 15	176	175 00	248	253 03	320	314 08
32	38 25	105	103 04	177	176 15	249	253 54	321	315 08
33	39 31	106	103 52	178	177 30	250	254 44	322	316 08
34	40 36	107	104 42	179	178 45	251	255 35	323	317 09
35	41 41	108	105 31	180	180 00	252	256 25	324	318 11
36	42 45	109	106 20	181	181 15	253	257 15	325	319 13
37	43 49	110	107 10	182	182 30	254	258 05	326	320 15
38	44 52	111	107 59	183	183 45	255	258 55	327	321 18
39	45 55	112	108 49	184	185 00	256	259 44	328	322 21
40	46 57	113	109 39	185	186 16	257	260 33	329	323 25
41	47 59	114	110 29	186	187 31	258	261 22	330	324 30
42	49 00	115	111 20	187	188 46	259	262 11	331	325 35
43	50 00	116	112 11	188	190 00	260	263 00	332	326 40
44	51 01	117	113 02	189	191 15	261	263 48	333	327 46
45	52 00	118	113 53	190	192 29	262	264 37	334	328 52
46	53 00	119	114 45	191	193 44	263	265 25	335	329 59
47	53 59	120	115 36	192	194 58	264	266 13	336	331 07
48	54 57	121	116 29	193	196 12	265	267 02	337	332 15
49	55 55	122	117 21	194	197 25	266	267 50	338	333 23
50	56 52	123	118 14	195	198 38	267	268 38	339	334 32
51	57 50	124	119 07	196	199 52	268	269 26	340	335 41
52	58 46	125	120 00	197	201 04	269	270 14	341	336 51
53	59 42	126	120 54	198	202 16	270	271 02	342	338 01
54	60 38	127	121 48	199	203 28	271	271 50	343	339 12
55	61 34	128	122 43	200	204 40	272	272 38	344	340 23
56	62 29	129	123 37	201	205 51	273	273 25	345	341 34
57	63 24	130	124 33	202	207 02	274	274 13	346	342 46
58	64 18	131	125 28	203	208 12	275	275 01	347	343 58
59	65 12	132	126 24	204	209 22	276	275 49	348	345 10
60	66 05	133	127 21	205	210 32	277	276 37	349	346 23
61	66 58	134	128 18	206	211 41	278	277 25	350	347 36
62	67 52	135	129 15	207	212 50	279	278 13	351	348 50
63	68 44	136	130 13	208	213 58	280	279 01	352	350 04
64	69 36	137	131 11	209	215 05	281	279 50	353	351 17
65	70 28	138	132 09	210	216 13	282	280 38	354	352 32
66	71 20	139	133 08	211	217 19	283	281 26	355	353 46
67	72 12	140	134 08	212	218 25	284	282 15	356	355 00
68	73 03	141	135 08	213	219 31	285	283 04	357	356 15
69	73 54	142	136 08	214	220 36	286	283 52′	358	357 30
70	74 44	143	137 09	215	221 41	287	284 42	359	358 45
71	75 35	144	138 11	216	222 45	288	285 31	360	360 00
72	76 25								

$u-u'=+385'.6 \sin 2u-21'.6 \sin 4u+1'.6 \sin 6u.$

Gnomonic azimuth tables—Continued.

CAPE MAY RADIO-COMPASS STATION.

True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.
0°	0° 00′	73°	76° 16′	145°	138° 26′	217°	223° 32′	289°	285° 07′
1	1 16	74	77 05	146	139 30	218	224 34	290	285 56
2	2 31	75	77 54	147	140 34	219	225 35	291	286 46
3	3 47	76	78 42	148	141 39	220	226 36	292	287 36
4	5 03	77	79 30	149	142 44	221	227 36	293	288 27
5	6 18	78	80 19	150	143 50	222	228 36	294	289 17
6	7 34	79	81 07	151	144 57	223	229 36	295	290 08
7	8 49	80	81 55	152	146 04	224	230 34	296	290 59
8	10 04	81	82 43	153	147 11	225	231 33	297	291 51
9	11 18	82	83 31	154	148 19	226	232 31	298	292 42
10	12 33	83	84 19	155	149 28	227	233 29	299	293 34
11	13 47	84	85 06	156	150 36	228	234 26	300	294 27
12	15 01	85	85 54	157	151 46	229	235 22	301	295 19
13	16 15	86	86 41	158	152 56	230	236 19	302	296 12
14	17 28	87	87 29	159	154 06	231	237 14	303	297 06
15	18 41	88	88 16	160	155 17	232	238 10	304	297 59
16	19 54	89	89 04	161	156 28	233	239 05	305	298 53
17	21 06	90	89 51	162	157 40	234	239 59	306	299 48
18	22 18	91	90 39	163	158 52	235	240 54	307	300 43
19	23 29	92	91 26	164	160 04	236	241 47	308	301 38
20	24 40	93	92 14	165	161 17	237	242 41	309	302 34
21	25 51	94	93 02	166	162 30	238	243 34	310	303 30
22	27 01	95	93 49	167	163 44	239	244 27	311	304 26
23	28 10	96	94 37	168	164 58	240	245 19	312	305 23
24	29 19	97	95 24	169	166 12	241	246 11	313	306 20
25	30 28	98	96 12	170	167 26	242	247 03	314	307 18
26	31 36	99	97 00	171	168 41	243	247 55	315	308 16
27	32 44	100	97 48	172	169 56	244	248 46	316	309 15
28	33 51	101	98 36	173	171 11	245	249 37	317	310 14
29	34 58	102	99 24	174	172 26	246	250 28	318	311 14
30	36 04	103	100 13	175	173 42	247	251 18	319	312 14
31	37 09	104	101 02	176	174 57	248	252 08	320	313 15
32	38 14	105	101 50	177	176 13	249	252 58	321	314 16
33	39 19	106	102 39	178	177 28	250	253 48	322	315 18
34	40 23	107	103 28	179	178 44	251	254 37	323	316 20
35	41 26	108	104 17	180	180 00	252	255 27	324	317 23
36	42 29	109	105 07	181	181 16	253	256 16	325	318 26
37	43 32	110	105 56	182	182 31	254	257 05	326	319 30
38	44 34	111	106 46	183	183 47	255	257 54	327	320 34
39	45 35	112	107 36	184	185 03	256	258 42	328	321 39
40	46 36	113	108 27	185	186 18	257	259 30	329	322 44
41	47 36	114	109 17	186	187 34	258	260 19	330	323 50
42	48 36	115	110 08	187	188 49	259	261 07	331	324 57
43	49 36	116	110 59	188	190 04	260	261 55	332	326 04
44	50 34	117	111 51	189	191 18	261	262 43	333	327 11
45	51 33	118	112 42	190	192 33	262	263 31	334	328 19
46	52 31	119	113 34	191	193 47	263	264 19	335	329 28
47	53 29	120	114 27	192	195 01	264	265 06	336	330 36
48	54 26	121	115 19	193	196 15	265	265 54	337	331 46
49	55 22	122	116 12	194	197 28	266	266 41	338	332 56
50	56 19	123	117 06	195	198 41	267	267 29	339	334 06
51	57 14	124	117 59	196	199 54	268	268 16	340	335 17
52	58 10	125	118 53	197	201 06	269	269 04	341	336 28
53	59 05	126	119 48	198	202 18	270	269 51	342	337 40
54	59 59	127	120 43	199	203 29	271	270 39	343	338 52
55	60 54	128	121 38	200	204 40	272	271 26	344	340 04
56	61 47	129	122 34	201	205 51	273	272 14	345	341 17
57	62 41	130	123 30	202	207 01	274	273 02	346	342 30
58	63 34	131	124 26	203	208 10	275	273 49	347	343 44
59	64 27	132	125 23	204	209 19	276	274 37	348	344 58
60	65 19	133	126 20	205	210 28	277	275 24	349	346 12
61	66 11	134	127 18	206	211 36	278	276 12	350	347 26
62	67 03	135	128 16	207	212 44	279	277 00	351	348 41
63	67 55	136	129 15	208	213 51	280	277 48	352	349 56
64	68 46	137	130 14	209	214 58	281	278 36	353	351 11
65	69 37	138	131 14	210	216 04	282	279 24	354	352 26
66	70 28	139	132 14	211	217 09	283	280 13	355	353 42
67	71 18	140	133 15	212	218 14	284	281 02	356	354 57
68	72 08	141	134 16	213	219 19	285	281 50	357	356 13
69	72 58	142	135 18	214	220 23	286	282 39	358	357 28
70	73 48	143	136 20	215	221 26	287	283 28	359	358 44
71	74 37	144	137 23	216	222 29	288	284 17	360	360 00
72	75 27								

$u-u'=+400'.1 \sin 2u-23'.3 \sin 4u+1'.8 \sin 6u.$

Gnomonic azimuth tables—Continued.

HOG ISLAND RADIO-COMPASS STATION.

True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.
0°	0° 00′	73°	75° 13′	145°	137° 40′	217°	223° 10′	289°	283° 51′
1	1 16	74	76 01	146	138 45	218	224 11	290	284 41
2	2 32	75	76 49	147	139 51	219	225 11	291	285 31
3	3 48	76	77 37	148	140 57	220	226 11	292	286 21
4	5 04	77	78 25	149	142 04	221	227 10	293	287 12
5	6 20	78	79 12	150	143 11	222	228 08	294	288 03
6	7 36	79	80 00	151	144 19	223	229 06	295	288 54
7	8 51	80	80 47	152	145 28	224	230 04	296	289 46
8	10 06	81	81 34	153	146 37	225	231 01	297	290 37
9	11 21	82	82 21	154	147 46	226	231 58	298	291 30
10	12 35	83	83 09	155	148 56	227	232 54	299	292 22
11	13 49	84	83 56	156	150 07	228	233 50	300	293 15
12	15 03	85	84 43	157	151 18	229	234 46	301	294 08
13	16 16	86	85 30	158	152 29	230	235 40	302	295 02
14	17 29	87	86 17	159	153 41	231	236 35	303	295 56
15	18 42	88	87 04	160	154 54	232	237 29	304	296 50
16	19 54	89	87 51	161	156 06	233	238 23	305	297 45
17	21 06	90	88 38	162	157 19	234	239 16	306	298 40
18	22 17	91	89 25	163	158 33	235	240 09	307	299 36
19	23 28	92	90 12	164	159 47	236	241 02	308	300 32
20	24 38	93	91 00	165	161 01	237	241 54	309	301 28
21	25 47	94	91 47	166	162 16	238	242 46	310	302 25
22	26 57	95	92 34	167	163 31	239	243 38	311	303 23
23	28 05	96	93 21	168	164 46	240	244 29	312	304 20
24	29 14	97	94 09	169	166 01	241	245 20	313	305 19
25	30 21	98	94 57	170	167 17	242	246 11	314	306 18
26	31 28	99	95 44	171	168 33	243	247 01	315	307 17
27	32 35	100	96 32	172	169 49	244	247 52	316	308 17
28	33 41	101	97 20	173	171 05	245	248 42	317	309 17
29	34 46	102	98 08	174	172 21	246	249 31	318	310 18
30	35 51	103	98 57	175	173 38	247	250 21	319	311 20
31	36 56	104	99 45	176	174 54	248	251 10	320	312 22
32	37 59	105	100 34	177	176 11	249	251 59	321	313 24
33	39 03	106	101 23	178	177 27	250	252 48	322	314 27
34	40 06	107	102 12	179	178 44	251	253 36	323	315 31
35	41 08	108	103 02	180	180 00	252	254 25	324	316 35
36	42 09	109	103 51	181	181 16	253	255 13	325	317 40
37	43 10	110	104 41	182	182 32	254	256 01	326	318 45
38	44 11	111	105 31	183	183 48	255	256 49	327	319 51
39	45 11	112	106 21	184	185 04	256	257 37	328	320 57
40	46 11	113	107 12	185	186 20	257	258 25	329	322 04
41	47 10	114	108 03	186	187 36	258	259 12	330	323 11
42	48 08	115	108 54	187	188 51	259	260 00	331	324 19
43	49 06	116	109 46	188	190 06	260	260 47	332	325 28
44	50 04	117	110 37	189	191 21	261	261 34	333	326 37
45	51 01	118	111 30	190	192 35	262	262 21	334	327 46
46	51 58	119	112 22	191	193 49	263	263 09	335	328 56
47	52 54	120	113 15	192	195 03	264	263 56	336	330 07
48	53 50	121	114 08	193	196 16	265	264 43	337	331 18
49	54 46	122	115 02	194	197 29	266	265 30	338	332 29
50	55 40	123	115 56	195	198 42	267	266 17	339	333 41
51	56 35	124	116 50	196	199 54	268	267 04	340	334 54
52	57 29	125	117 45	197	201 06	269	267 51	341	336 06
53	58 23	126	118 40	198	202 17	270	268 38	342	337 19
54	59 16	127	119 36	199	203 28	271	269 25	343	338 33
55	60 09	128	120 32	200	204 38	272	270 12	344	339 47
56	61 02	129	121 28	201	205 47	273	271 00	345	341 01
57	61 54	130	122 25	202	206 57	274	271 47	346	342 16
58	62 46	131	123 23	203	208 05	275	272 34	347	343 31
59	63 38	132	124 20	204	209 14	276	273 21	348	344 46
60	64 29	133	125 19	205	210 21	277	274 09	349	346 01
61	65 20	134	126 18	206	211 28	278	274 57	350	347 17
62	66 11	135	127 17	207	212 35	279	275 44	351	348 33
63	67 01	136	128 17	208	213 41	280	276 32	352	349 49
64	67 52	137	129 17	209	214 46	281	277 20	353	351 05
65	68 42	138	130 18	210	215 51	282	278 08	354	352 21
66	69 31	139	131 20	211	216 56	283	278 57	355	353 38
67	70 21	140	132 22	212	217 59	284	279 45	356	354 54
68	71 10	141	133 24	213	219 03	285	280 34	357	356 11
69	71 59	142	134 27	214	220 06	286	281 23	358	357 27
70	72 48	143	135 31	215	221 08	287	282 12	359	358 44
71	73 36	144	136 35	216	222 09	288	283 02	360	360 00
72	74 25								

$u - u' = +416'.0 \sin 2u - 25'.2 \sin 4u + 2'.0 \sin 6u.$

Gnomonic azimuth tables—Continued.

CAPE HENRY RADIO-COMPASS STATION.

True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.
0°	0° 00′	73°	74° 54′	145°	137° 25′	217°	223° 04′	289°	283° 27′
1	1 16	74	75 42	146	138 30	218	224 04	290	284 17
2	2 33	75	76 29	147	139 37	219	225 04	291	285 07
3	3 49	76	77 17	148	140 43	220	226 03	292	285 58
4	5 05	77	78 04	149	141 51	221	227 02	293	286 48
5	6 21	78	78 51	150	142 59	222	228 00	294	287 39
6	7 37	79	79 39	151	144 07	223	228 58	295	288 30
7	8 52	80	80 26	152	145 16	224	229 55	296	289 22
8	10 07	81	81 13	153	146 26	225	230 52	297	290 14
9	11 22	82	82 00	154	147 36	226	231 48	298	291 06
10	12 36	83	82 47	155	148 46	227	232 44	299	291 59
11	13 50	84	83 34	156	149 57	228	233 39	300	292 52
12	15 04	85	84 21	157	151 09	229	234 34	301	293 45
13	16 17	86	85 08	158	152 20	230	235 29	302	294 39
14	17 30	87	85 54	159	153 33	231	236 23	303	295 33
15	18 42	88	86 41	160	154 46	232	237 17	304	296 28
16	19 54	89	87 28	161	155 59	233	238 10	305	297 23
17	21 06	90	88 15	162	157 13	234	239 03	306	298 18
18	22 17	91	89 02	163	158 27	235	239 56	307	299 14
19	23 27	92	89 49	164	159 41	236	240 48	308	300 10
20	24 37	93	90 36	165	160 56	237	241 40	309	301 07
21	25 46	94	91 23	166	162 11	238	242 32	310	302 05
22	26 56	95	92 10	167	163 26	239	243 23	311	303 02
23	28 04	96	92 58	168	164 42	240	244 14	312	304 00
24	29 12	97	93 45	169	165 58	241	245 05	313	304 59
25	30 19	98	94 33	170	167 14	242	245 55	314	305 58
26	31 26	99	95 20	171	168 30	243	246 45	315	306 58
27	32 32	100	96 08	172	169 46	244	247 35	316	307 58
28	33 38	101	96 56	173	171 03	245	248 25	317	308 59
29	34 43	102	97 44	174	172 20	246	249 14	318	310 00
30	35 48	103	98 33	175	173 36	247	250 03	319	311 02
31	36 52	104	99 21	176	174 53	248	250 52	320	312 04
32	37 55	105	100 10	177	176 10	249	251 41	321	313 07
33	38 58	106	100 59	178	177 26	250	252 29	322	314 11
34	40 00	107	101 48	179	178 43	251	253 18	323	315 15
35	41 02	108	102 37	180	180 00	252	254 06	324	316 19
36	42 03	109	103 27	181	181 16	253	254 54	325	317 25
37	43 04	110	104 17	182	182 33	254	255 42	326	318 30
38	44 04	111	105 07	183	183 49	255	256 29	327	319 37
39	45 04	112	105 58	184	185 05	256	257 17	328	320 43
40	46 03	113	106 48	185	186 21	257	258 04	329	321 51
41	47 02	114	107 39	186	187 37	258	258 51	330	322 59
42	48 00	115	108 30	187	188 52	259	259 39	331	324 07
43	48 58	116	109 22	188	190 07	260	260 26	332	325 16
44	49 55	117	110 14	189	191 22	261	261 13	333	326 26
45	50 52	118	111 06	190	192 36	262	262 00	334	327 36
46	51 48	119	111 59	191	193 50	263	262 47	335	328 46
47	52 44	120	112 52	192	195 04	264	263 34	336	329 57
48	53 39	121	113 45	193	196 17	265	264 21	337	331 09
49	54 34	122	114 39	194	197 30	266	265 08	338	332 20
50	55 29	123	115 33	195	198 42	267	265 54	339	333 33
51	56 23	124	116 28	196	199 54	268	266 41	340	334 46
52	57 17	125	117 23	197	201 06	269	267 28	341	335 59
53	58 10	126	118 18	198	202 17	270	268 15	342	337 13
54	59 03	127	119 14	199	203 27	271	269 02	343	338 27
55	59 56	128	120 10	200	204 37	272	269 49	334	339 41
56	60 48	129	121 07	201	205 46	273	270 36	345	340 56
57	61 40	130	122 05	202	206 56	274	271 23	346	342 11
58	62 32	131	123 02	203	208 04	275	272 10	347	343 26
59	63 23	132	124 00	204	209 12	276	272 58	348	344 42
60	64 14	133	124 59	205	210 19	277	273 45	349	345 58
61	65 05	134	125 58	206	211 26	278	274 33	350	347 14
62	65 55	135	126 58	207	212 32	279	275 20	351	348 30
63	66 45	136	127 58	208	213 38	280	276 08	352	349 46
64	67 35	137	128 59	209	214 43	281	276 56	353	351 03
65	68 25	138	130 00	210	215 48	282	277 44	354	352 20
66	69 14	139	131 02	211	216 52	283	278 33	355	353 36
67	70 03	140	132 04	212	217 55	284	279 21	356	354 53
68	70 52	141	133 07	213	218 58	285	280 10	357	356 10
69	71 41	142	134 11	214	220 00	286	280 59	358	357 26
70	72 29	143	135 15	215	221 02	287	281 48	359	358 43
71	73 18	144	136 19	216	222 03	288	282 37	360	360 00
72	74 06								

$u-u'=+422'.0 \sin 2u-25'.9 \sin 4u+2'.1 \sin 6u.$

Gnomonic azimuth tables—Continued.

CAPE HATTERAS RADIO-COMPASS STATION.

True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.	True azimuth.	Gnomonic azimuth.
0°	0° 00′	73°	74° 00′	145°	137° 12′	217°	222° 29′	289°	282° 43′
1	1 16	74	74 47	146	138 19	218	223 28	290	283 33
2	2 32	75	75 35	147	139 26	219	224 27	291	284 24
3	3 47	76	76 22	148	140 34	220	225 25	292	285 15
4	5 03	77	77 10	149	141 42	221	226 23	293	286 07
5	6 18	78	77 57	150	142 51	222	227 21	294	286 58
6	7 33	79	78 44	151	144 00	223	228 17	295	287 50
7	8 47	80	79 32	152	145 10	224	229 14	296	288 43
8	10 02	81	80 19	153	146 20	225	230 10	297	289 35
9	11 16	82	81 06	154	147 31	226	231 05	298	290 28
10	12 29	83	81 53	155	148 42	227	232 01	299	291 22
11	13 42	84	82 40	156	149 54	228	232 55	300	292 16
12	14 55	85	83 27	157	151 06	229	233 50	301	293 10
13	16 07	86	84 14	158	152 19	230	234 44	302	294 04
14	17 19	87	85 01	159	153 32	231	235 37	303	295 00
15	18 30	88	85 48	160	154 45	232	236 30	304	295 55
16	19 41	89	86 35	161	155 59	233	237 23	305	296 51
17	20 52	90	87 22	162	157 13	234	238 15	306	297 47
18	22 02	91	88 10	163	158 28	235	239 07	307	298 44
19	23 11	92	88 57	164	159 42	236	239 59	308	299 41
20	24 20	93	89 44	165	160 57	237	240 51	309	300 39
21	25 28	94	90 32	166	162 13	238	241 42	310	301 37
22	26 36	95	91 19	167	163 28	239	242 33	311	302 36
23	27 43	96	92 07	168	164 44	240	243 23	312	303 35
24	28 50	97	92 55	169	166 00	241	244 14	313	304 35
25	29 56	98	93 43	170	167 16	242	245 04	314	305 35
26	31 02	99	94 31	171	168 32	243	245 53	315	306 36
27	32 07	100	95 19	172	169 49	244	246 43	316	307 37
28	33 12	101	96 08	173	171 05	245	247 32	317	308 38
29	34 16	102	96 56	174	172 22	246	248 21	318	309 41
30	35 20	103	97 45	175	173 38	247	249 10	319	310 44
31	36 22	104	98 34	176	174 55	248	249 59	320	311 47
32	37 25	105	99 23	177	176 11	249	250 47	321	312 51
33	38 27	106	100 13	178	177 28	250	251 36	322	313 55
34	39 28	107	101 03	179	178 44	251	252 24	323	315 00
35	40 29	108	101 53	180	180 00	252	253 12	324	316 06
36	41 29	109	102 43	181	181 16	253	254 00	325	317 12
37	42 29	110	103 33	182	182 32	254	254 47	326	318 19
38	43 28	111	104 24	183	183 47	255	255 35	327	319 26
39	44 27	112	105 15	184	185 03	256	256 22	328	320 34
40	45 25	113	106 07	185	186 18	257	257 10	329	321 42
41	46 23	114	106 58	186	187 33	258	257 57	330	322 51
42	47 21	115	107 50	187	188 47	259	258 44	331	324 00
43	48 17	116	108 43	188	190 02	260	259 32	332	325 10
44	49 14	117	109 35	189	191 16	261	260 19	333	326 20
45	50 10	118	110 28	190	192 29	262	261 06	334	327 31
46	51 05	119	111 22	191	193 42	263	261 53	335	328 42
47	52 01	120	112 16	192	194 55	264	262 40	336	329 54
48	52 55	121	113 10	193	196 07	265	263 27	337	331 06
49	53 50	122	114 04	194	197 19	266	264 14	338	332 19
50	54 44	123	115 00	195	198 30	267	265 01	339	333 32
51	55 37	124	115 55	196	199 41	268	265 48	340	334 45
52	56 30	125	116 51	197	200 52	269	266 35	341	335 59
53	57 23	126	117 47	198	202 02	270	267 22	342	337 13
54	58 15	127	118 44	199	203 11	271	268 10	343	338 28
55	59 07	128	119 41	200	204 20	272	268 57	344	339 42
56	59 59	129	120 39	201	205 28	273	269 44	345	340 57
57	60 51	130	121 37	202	206 36	274	270 32	346	342 13
58	61 42	131	122 36	203	207 43	275	271 19	347	343 28
59	62 33	132	123 35	204	208 50	276	272 07	348	344 44
60	63 23	133	124 35	205	209 56	277	272 55	349	346 00
61	64 14	134	125 35	206	211 02	278	273 43	350	347 16
62	65 04	135	126 36	207	212 07	279	274 31	351	348 32
63	65 53	136	127 37	208	213 12	280	275 19	352	349 49
64	66 43	137	128 38	209	214 16	281	276 08	353	351 05
65	67 32	138	129 41	210	215 20	282	276 56	354	352 22
66	68 21	139	130 44	211	216 22	283	277 45	355	353 38
67	69 10	140	131 47	212	217 25	284	278 34	356	354 55
68	69 59	141	132 51	213	218 27	285	279 23	357	356 11
69	70 47	142	133 55	214	219 28	286	280 13	358	357 28
70	71 36	143	135 00	215	220 29	287	281 03	359	358 44
71	72 24	144	136 06	216	221 29	288	281 53	360	360 00
72	73 12								

$u-u' = +416'.2 \sin 2u - 25'.2 \sin 4u + 2'.0 \sin 6u.$

DEVELOPMENT OF THE THEORY FOR PLOTTING RADIO-COMPASS BEARINGS ON A MERCATOR CHART.

When radio-compass bearings are plotted on a Mercator chart they must be corrected to reduce the observed true azimuths to what may be called the Mercator bearings. The Mercator projection is conformal, and hence angles upon the sphere are preserved in the projection, but the straight line joining two points represents a rhumb line and not the great circle joining the two points in question. The curve which represents a great circle on the projection is in all cases concave toward the Equator. The tangent to this curve at

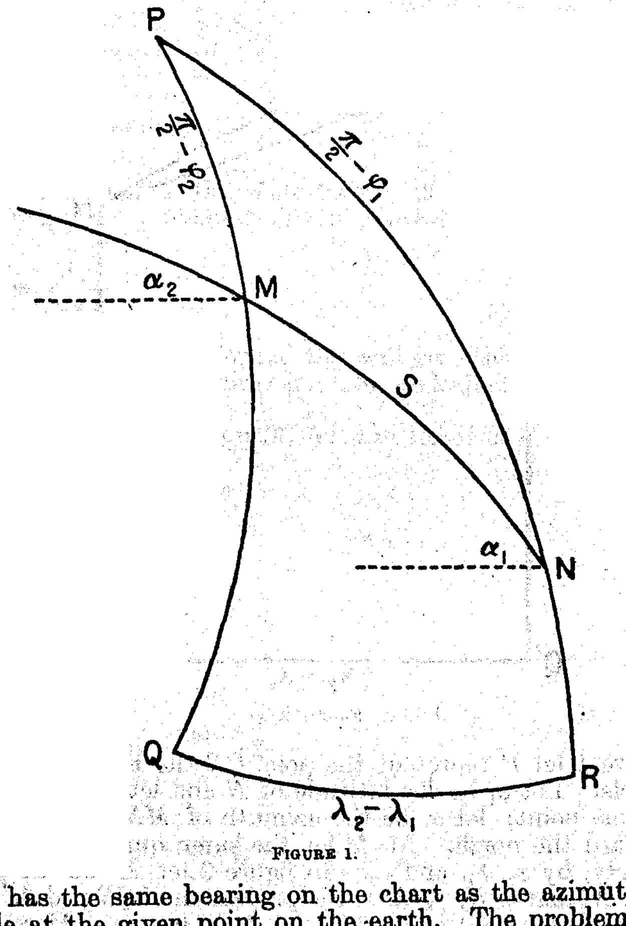

FIGURE 1.

any point has the same bearing on the chart as the azimuth of the great circle at the given point on the earth. The problem is then to determine a correction to the angle of this tangent at a radio-compass station so as to obtain the rhumb line bearing that will pass through the point which represents the approximate position of the vessel.

In determining this correction it is sufficiently exact to consider the earth as a sphere. In this case it will be assumed that the path of the wireless wave over the surface of the earth is a great circle joining the position of the vessel with that of the radio-compass station.

In any case that may arise in practice the vessel will have some approximate position derived at least by dead reckoning. This position can be used to determine an approximate correction to each of the two or more observed directions and then the plotting of these results will, by their intersection, determine a more accurate position of the vessel. With this position for the vessel a more accurate correction can be determined if desired, and so on to any degree of accuracy that may be required.

First will be derived rigid formulas that may be used for the computation of this correction and later these will be employed in the computations for a graphic chart.

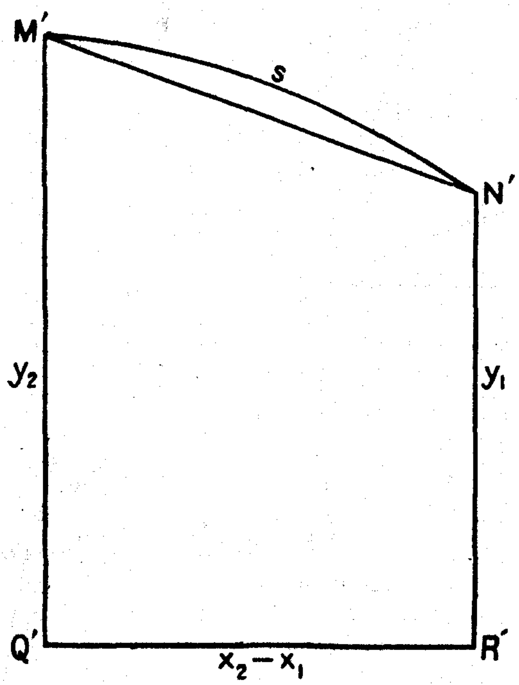

FIGURE 2.

In figure 1 let P represent the pole, QR the Equator, and MN a great circle. Let φ_1 be the latitude of N and let λ_1 be the longitude of the same point; let α_1 be the azimuth of MN reckoned from the west toward the north. At M let the same quantities be denoted, respectively, by φ_2, λ_2, and α_2. In figure 2 let M' be the projection of M and N' that of N; $Q'R'$ is the projection of QR and $M'sN'$ is the projection of the great circle MN. Let N' have the Mercator plane coordinates x_1, y_1 and let M' have the coordinates x_2, y_2.

Now the Mercator projection for a sphere with radius unity is determined by the relations

(1) $x = \lambda$,

(2) $y = \log_e \tan\left(\frac{\pi}{4} + \frac{\varphi}{2}\right)$.

The equation for y can be transformed in the following way:

$$(3) \qquad \tan\left(\frac{\pi}{4}+\frac{\varphi}{2}\right)=e^y,$$

$$(4) \qquad \frac{1+\tan\frac{\varphi}{2}}{1-\tan\frac{\varphi}{2}}=e^y,$$

or

$$(5) \qquad \tan\frac{\varphi}{2}=\frac{e^y-1}{e^y+1}=\frac{e^{y/2}-e^{-y/2}}{e^{y/2}+e^{-y/2}}.$$

Hence

$$(6) \qquad \tan\frac{\varphi}{2}=\tanh\frac{y}{2}.$$

If m is used to denote the scale factor, the scale factor along the meridian is given by evaluating the expression

$$(7) \qquad m=\frac{dy}{d\varphi}.$$

Since the projection is conformal this will give the value of the scale factor at a point for any direction, the scale factor being the same in all directions.

By differentiating equation (6) for y in terms of φ, we get

$$(8) \qquad \operatorname{sech}^2\frac{y}{2}\frac{dy}{d\varphi}=\sec^2\frac{\varphi}{2},$$

or

$$(9) \qquad \frac{dy}{d\varphi}=\cosh^2\frac{y}{2}\sec^2\frac{\varphi}{2}.$$

But

$$(10) \qquad \cosh^2\frac{y}{2}=\frac{1}{1-\tanh^2\frac{y}{2}},$$

$$(11) \qquad =\frac{1}{1-\tan^2\frac{\varphi}{2}}.$$

$$(12) \qquad \cosh^2\frac{y}{2}=\frac{\cos^2\frac{\varphi}{2}}{\cos^2\frac{\varphi}{2}-\sin^2\frac{\varphi}{2}},$$

$$(13) \qquad =\frac{\cos^2\frac{\varphi}{2}}{\cos\varphi}.$$

By substituting this value, we get

$$\text{(14)} \qquad \frac{dy}{d\varphi}=\frac{1}{\cos\varphi}=\sec\varphi,$$

or

$$\text{(15)} \qquad m=\sec\varphi.$$

On the other hand, we have

$$\text{(16)} \qquad \sec^2\frac{\varphi}{2}=1+\tan^2\frac{\varphi}{2},$$

$$\text{(17)} \qquad =1+\tanh^2\frac{y}{2},$$

$$\text{(18)} \qquad =\frac{\cosh^2\frac{y}{2}+\sinh^2\frac{y}{2}}{\cosh^2\frac{y}{2}},$$

$$\text{(19)} \qquad =\frac{\cosh y}{\cosh^2\frac{y}{2}}.$$

By substituting this value in (9), we get

$$\text{(20)} \qquad m=\cosh y,$$

or by combining (15) and (20), we have

$$\text{(21)} \qquad m=\sec\varphi=\cosh y.$$

From the relation between φ and y expressed in (21), we get

$$\text{(22)} \qquad (1+\cos\varphi)\sec\varphi=1+\cosh y,$$

$$\text{(23)} \qquad 2m\cos^2\frac{\varphi}{2}=2\cosh^2\frac{y}{2},$$

or finally

$$\text{(24)} \qquad \cos\frac{\varphi}{2}=\frac{1}{\sqrt{m}}\cosh\frac{y}{2}.$$

In a similar way, we have

$$\text{(25)} \qquad (1-\cos\varphi)\sec\varphi=\cosh y-1$$

$$\text{(26)} \qquad 2m\sin^2\frac{\varphi}{2}=2\sinh^2\frac{y}{2},$$

or

$$\text{(27)} \qquad \sin\frac{\varphi}{2}=\frac{1}{\sqrt{m}}\sinh\frac{y}{2}.$$

In figure 1, let the arc MN be denoted by S. Then from the Gauss equations for the spherical triangle, we have

$$\text{(28)} \qquad \cos\frac{1}{2}(\alpha_1-\alpha_2)\cos\frac{S}{2}=\cos\frac{1}{2}(\varphi_2-\varphi_1)\cos\frac{1}{2}(\lambda_2-\lambda_1),$$

$$\text{(29)} \qquad \sin\frac{1}{2}(\alpha_1-\alpha_2)\cos\frac{S}{2}=\sin\frac{1}{2}(\varphi_2+\varphi_1)\sin\frac{1}{2}(\lambda_2-\lambda_1),$$

$$\text{(30)} \qquad \cos\frac{1}{2}(\alpha_1+\alpha_2)\sin\frac{S}{2}=\cos\frac{1}{2}(\varphi_2+\varphi_1)\sin\frac{1}{2}(\lambda_2-\lambda_1),$$

$$\text{(31)} \qquad \sin\frac{1}{2}(\alpha_1+\alpha_2)\sin\frac{S}{2}=\sin\frac{1}{2}(\varphi_2-\varphi_1)\cos\frac{1}{2}(\lambda_2-\lambda_1).$$

By development we get

$$\text{(32)} \qquad \cos\frac{1}{2}(\varphi_2-\varphi_1)=\cos\frac{\varphi_2}{2}\cos\frac{\varphi_1}{2}+\sin\frac{\varphi_2}{2}\sin\frac{\varphi_1}{2}.$$

In the right hand member of this equation introduce the values given in (24) and (27) and it becomes

$$\text{(33)} \qquad \cos\frac{1}{2}(\varphi_2-\varphi_1)=\frac{1}{\sqrt{m_1m_2}}\left(\cosh\frac{y_2}{2}\cosh\frac{y_1}{2}+\sinh\frac{y_2}{2}\sinh\frac{y_1}{2}\right),$$

$$\text{(34)} \qquad =\frac{1}{\sqrt{m_1m_2}}\cosh\frac{1}{2}(y_2+y_1).$$

By setting $\frac{1}{\sqrt{m_1m_2}}$ equal to c and by expanding the other functions in φ and then expressing them in terms of y, the Gauss formulas for the spherical triangle become

$$\text{(35)} \qquad \cos\frac{1}{2}(\alpha_1-\alpha_2)\cos\frac{S}{2}=c\cosh\frac{1}{2}(y_2+y_1)\cos\frac{1}{2}(x_2-x_1),$$

$$\text{(36)} \qquad \sin\frac{1}{2}(\alpha_1-\alpha_2)\cos\frac{S}{2}=c\sinh\frac{1}{2}(y_2+y_1)\sin\frac{1}{2}(x_2-x_1),$$

$$\text{(37)} \qquad \cos\frac{1}{2}(\alpha_1+\alpha_2)\sin\frac{S}{2}=c\cosh\frac{1}{2}(y_2-y_1)\sin\frac{1}{2}(x_2-x_1),$$

$$\text{(38)} \qquad \sin\frac{1}{2}(\alpha_1+\alpha_2)\sin\frac{S}{2}=c\sinh\frac{1}{2}(y_2-y_1)\cos\frac{1}{2}(x_2-x_1).$$

It should be noted that in the above equations use is made of the relation given in (1) for the expression of the λ's in terms of the x's.

By dividing (36) by (35) we obtain

$$(39) \qquad \tan \frac{1}{2} (\alpha_1 - \alpha_2) = \tanh \frac{1}{2} (y_2 + y_1) \tan \frac{1}{2} (x_2 - x_1),$$

and when (38) is divided by (37)

$$(40) \qquad \tan \frac{1}{2} (\alpha_1 + \alpha_2) = \tanh \frac{1}{2} (y_2 - y_1) \cot \frac{1}{2} (x_2 - x_1).$$

By dividing the sum of the squares of (37) and (38) by the sum of the squares of (35) and (36), we also obtain

$$(41) \qquad \tan^2 \frac{S}{2} = \frac{\sinh^2 \frac{1}{2} (y_2 - y_1) \cos^2 \frac{1}{2} (x_2 - x_1) + \cosh^2 \frac{1}{2} (y_2 - y_1) \sin^2 \frac{1}{2} (x_2 - x_1)}{\cosh^2 \frac{1}{2} (y_2 + y_1) \cos^2 \frac{1}{2} (x_2 - x_1) + \sinh^2 \frac{1}{2} (y_2 + y_1) \sin^2 \frac{1}{2} (x_2 - x_1)},$$

$$(42) \qquad = \frac{\sinh^2 \frac{1}{2} (y_2 - y_1) + \sin^2 \frac{1}{2} (x_2 - x_1)}{\sinh^2 \frac{1}{2} (y_2 + y_1) + \cos^2 \frac{1}{2} (x_2 - x_1)}.$$

By these equations the sum and difference of α_1 and α_2 are determined as well as the value of S, all expressed in terms of the x's and y's of the projections of the end points of the great-circle arc.

By using these equations the remaining parts of the spherical triangle can be computed. With the Mercator table for the sphere given on pages 7–15, the y values can be found from the given values of φ.

If a table of the hyperbolic functions is not available, the required values can be found by use of a trigonometric table. In equation (21) we have given

$$(43) \qquad \cosh y = \sec \varphi.$$

Therefore

$$(44) \qquad \cosh^2 y - 1 = \sec^2 \varphi - 1,$$

or

$$(45) \qquad \sinh^2 y = \tan^2 \varphi,$$

hence

$$(46) \qquad \sinh y = \tan \varphi.$$

By dividing (46) by (43), we obtain

$$(47) \qquad \tanh y = \sin \varphi.$$

Now if we wish to get the hyperbolic function of any value, we find the value of φ corresponding to the given value of y by use of the Mercator table on pages 7–15 and then the corresponding trigonometric function of this value of φ will be the hyperbolic function required.

As a matter of fact we are not directly interested in the elements of the spherical triangle but what we do wish to determine is the correction that must be applied to the azimuth of a great circle to reduce the same to the Mercator bearing; that is, to the rhumb-line bearing.

If t denotes the Mercator bearing reckoned from the west point toward the north, we have at once

(48) $$\tan t = \frac{y_2 - y_1}{x_2 - x_1}.$$

Therefore

(49) $$\frac{\tan \frac{1}{2}(\alpha_1 + \alpha_2)}{\tan t} = \frac{\tanh \frac{1}{2}(y_2 - y_1)}{\frac{y_2 - y_1}{2}} \div \frac{\tan \frac{1}{2}(x_2 - x_1)}{\frac{x_2 - x_1}{2}}$$

(50) $$= \frac{1 - \frac{1}{3}\left(\frac{y_2 - y_1}{2}\right)^2 + \frac{2}{15}\left(\frac{y_2 - y_1}{2}\right)^4 - \cdots\cdots}{1 + \frac{1}{3}\left(\frac{x_2 - x_1}{2}\right)^2 + \frac{2}{15}\left(\frac{x_2 - x_1}{2}\right)^4 + \cdots\cdots}$$

In order to abbreviate the formal reduction we shall denote $y_2 - y_1$ by a and $x_2 - x_1$ by b; (50) then becomes

(51) $$\frac{\tan \frac{1}{2}(\alpha_1 + \alpha_2)}{\tan t} = \frac{1 - \frac{a^2}{12} + \frac{a^4}{120} - \cdots\cdots}{1 + \frac{b^2}{12} + \frac{b^4}{120} + \cdots\cdots}$$

But

(52) $$\tan\left[t - \frac{1}{2}(\alpha_1 + \alpha_2)\right] = \frac{\tan t - \tan \frac{1}{2}(\alpha_1 + \alpha_2)}{1 + \tan t \tan \frac{1}{2}(\alpha_1 + \alpha_2)},$$

(53) $$= \frac{\left(1 - \dfrac{1 - \frac{a^2}{12} + \frac{a^4}{120} - \cdots\cdots}{1 + \frac{b^2}{12} + \frac{b^4}{120} + \cdots\cdots}\right) \tan t}{1 + \dfrac{1 - \frac{a^2}{12} + \frac{a^4}{120} - \cdots\cdots}{1 + \frac{b^2}{12} + \frac{b^4}{120} + \cdots\cdots} \tan^2 t},$$

(54) $$= \frac{d \sin 2t}{1 + d \cos 2t},$$

in which

$$(55)\qquad d=\frac{1-\dfrac{1-\dfrac{a^2}{12}+\dfrac{a^4}{120}-\cdots}{1+\dfrac{b^2}{12}+\dfrac{b^4}{120}+\cdots}}{1+\dfrac{1-\dfrac{a^2}{12}+\dfrac{a^4}{120}-\cdots}{1+\dfrac{b^2}{12}+\dfrac{b^4}{120}+\cdots}},$$

$$(56)\qquad =\frac{\dfrac{b^2+a^2}{12}+\dfrac{b^4-a^4}{120}+\cdots}{2+\dfrac{b^2-a^2}{12}+\dfrac{b^4+a^4}{120}+\cdots},$$

$$(57)\qquad =\frac{b^2+a^2}{24}\left[1+\frac{7}{120}(b^2-a^2)+\cdots\right].$$

In order to transform (54) to render it convenient for computation, it is best to expand it first in a Fourier series in t. This series is obtained most easily in the following way.

We have

$$(58)\qquad \log_e(1+de^{2it})=de^{2it}-\frac{d^2}{2}e^{4it}+\frac{d^3}{3}e^{6it}-\cdots,$$

in which i denotes as usual $\sqrt{-1}$.

But

$$(59)\qquad \log_e(1+de^{2it})=\frac{1}{2}\log_e(1+2d\cos 2t+d^2)+i\tan^{-1}\left(\frac{d\sin 2t}{1+d\cos 2t}\right);$$

also

$$(60)\qquad de^{2it}-\frac{d^2}{2}e^{4it}+\frac{d^3}{3}e^{6it}-\cdots= d\cos 2t+id\sin 2t-\frac{d^2}{2}\cos 4t-i\frac{d^2}{2}\sin 4t+\frac{d^3}{3}\cos 6t+i\frac{d^3}{3}\sin 6t-\cdots.$$

By equating the imaginary parts of the two expressions fo $\log_e(1+de^{2it})$, we get

$$(61)\qquad \tan^{-1}\left(\frac{d\sin 2t}{1+d\cos 2t}\right)=d\sin 2t-\frac{d^2}{2}\sin 4t+\frac{d^3}{3}\sin 6t-\cdots,$$

or

$$(62)\qquad t-\frac{1}{2}(\alpha_1+\alpha_2)=d\sin 2t-\frac{d^2}{2}\sin 4t+\frac{d^3}{3}\sin 6t-\cdots.$$

Now, from (48), we have

(63) $$\tan t=\frac{a}{b},$$

therefore

(64) $$\sin 2t=\frac{2\tan t}{1+\tan^2 t}=\frac{2\,ba}{b^2+a^2}$$

(65) $$\sin 4t=\frac{4\tan t\,(1-\tan^2 t)}{(1+\tan^2 t)^2}=\frac{4ba\,(b^2-a^2)}{(b^2+a^2)^2}.$$

By substituting these values in the series (62), we get as an approximation for its value from the first two terms the expression

(66) $$t-\frac{1}{2}\,(\alpha_1+\alpha_2)=\frac{ba}{12}\,(1+\frac{b^2-a^2}{60}+\;.\;.\;.\;.\;.).$$

For the determination of the required correction we have now the two equations

(67) $$\tan\frac{1}{2}\,(\alpha_1-\alpha_2)=\tanh\frac{y_2+y_1}{2}\tan\frac{x_2-x_1}{2},$$

and, after substituting the values of a and b in (66),

(68) $$t-\frac{1}{2}\,(\alpha_1+\alpha_2)=\frac{(y_2-y_1)\;(x_2-x_1)}{12}\left[1-\frac{(y_2-y_1)^2-(x_2-x_1)^2}{60}\right],$$

(68) being an approximation sufficiently exact for practical purposes.

In (68) all quantities in the right-hand member must be expressed in radians; the left-hand member will then be expressed in radians and can be reduced to degrees, to minutes, or to seconds as may be desired

Let us now denote $\frac{1}{2}\,(\alpha_1-\alpha_2)$ by u and $t-\frac{1}{2}\,(\alpha_1+\alpha_2)$ by v; then we get

(69) $$\alpha_1-t=u-v,$$

and

(70) $$\alpha_2-t=-u-v.$$

We thus have the rule that the numerical value of the correction at one end is equal to the difference between u and v and at the other end it is equal to the sum of u and v. In practice it is not necessary to pay any attention to the signs of these quantities. The larger numerical value belongs to the end that lies at the higher latitude; also the curve representing the great circle is always concave toward the Equator, so that consideration of this fact will show whether the correction is to be added to or subtracted from the true bearing to reduce it to the Mercator bearing.

Now we may note that the quantity u is one-half of what is called the convergence of the meridians. Instead of using the equations expressed in terms of the x's and y's, we may compute this quantity from the original spherical formulas.

From (28) and (29), we have

$$\cos u \cos \frac{S}{2} = \cos \frac{1}{2} (\varphi_2 - \varphi_1) \cos \frac{1}{2} (\lambda_2 - \lambda_1), \tag{71}$$

and

$$\sin u \cos \frac{S}{2} = \sin \frac{1}{2} (\varphi_2 + \varphi_1) \sin \frac{1}{2} (\lambda_2 - \lambda_1). \tag{72}$$

By dividing (72) by (71), we get

$$\tan u = \frac{\sin \frac{1}{2} (\varphi_2 + \varphi_1)}{\cos \frac{1}{2} (\varphi_2 - \varphi_1)} \tan \frac{1}{2} (\lambda_2 - \lambda_1). \tag{73}$$

This equation will serve for the computation of u if this form should be preferred.

For the extent of longitude usually covered by radio-compass observations, the series for v in (68) may be approximated to the first term. We have then for the determination of the desired correction the two equations

$$\tan u = \tanh \frac{1}{2} (y_2 + y_1) \tan \frac{1}{2} (x_2 - x_1), \tag{74}$$

and

$$v = \frac{1}{12} (y_2 - y_1) (x_2 - x_1). \tag{75}$$

From equation (74) we note that u is a function of two arguments and from (75) we also note that v is a function of two arguments. If then we determine a family of curves for various values of u and plot these on a graphic chart, we may scale off from this chart any value of u when we have given the arguments $x_2 - x_1$ and $y_2 + y_1$ belonging to the value sought. Such a chart of u curves is published by the U. S. Coast and Geodetic Survey in two parts with the title "Graphic chart, semiconvergence of meridians" (see Preface). The chart extends 50° in longitude; sheet 1 includes values of $y_2 + y_1$ from 0 to 72°, while sheet 2 extends from 72 to 144°. The two parts together form one continuous chart extending from the equator to the value of 144° for $y_2 + y_1$. This would be a mean latitude of something like 57°; it would, of course, be less than this value if one of the points was much higher in latitude.

In the same way a family of v curves can be plotted on a graphic chart which may then be used in a similar way. This chart would have the arguments x_2-x_1 and y_2-y_1, the second argument being different from that of the u chart. Such a family of v curves is shown on a chart published by the U. S. Coast and Geodetic Survey with the title "Graphic chart, second reduction term, true bearing to Mercator bearing." (See Preface.) The curves on the u charts are plotted for every 10 minutes of u while those on the v chart are plotted for every minute of the value of v.

DEVELOPMENT OF THE THEORY FOR PLOTTING RADIO-COMPASS BEARINGS ON A GNOMONIC CHART.

In plotting radio-compass bearings the gnomonic projection has the advantage that all great circles are represented by straight lines. However, the distortion is such that a table of gnomonic azimuths has to be computed for the chart that is to be used. This table gives the angle that must be laid off from the meridian at the station in order that the straight line upon the projection may represent the great circle with the given azimuth. For all stations for which tables are to be computed, it is necessary to solve the spherical triangle to determine the azimuth of the center of the projection as seen from the given station as also the great circle distance between the station and this projection center.

The great-circle sailing chart of the North Atlantic Ocean, Hydrographic Office Chart No. 1280, has the point of tangency or projection center at latitude 30° N. and longitude 30° W. Tables for ten stations have been computed for this chart (see pp. 17–26). These stations are given below with their positions, the true azimuth from the station to the center of the chart, and the great-circle radial distance from the center of the projection.

Station.	Latitude.	Longitude.	Azimuth.	Radial distance.
Cape Race	46° 39′ 10″	53° 05′ 05″	124° 48′ 58″	24° 25′ 52″
Bar Harbor	44 18 36	68 11 27	102 23 44	33 14 44
Cape Cod	42 02 58	70 04 32	97 24 54	34 12 41
Montauk	41 03 09	71 57 27	94 31 58	35 30 30
Fire Island	40 38 07	73 12 32	93 03 15	36 25 32
Sandy Hook	40 28 12	74 01 06	92 16 06	37 01 56
Cape May	38 56 41	74 53 10	89 41 38	37 40 25
Hog Island	37 22 36	75 42 37	87 12 31	38 21 50
Cape Henry	36 55 16	75 59 51	86 28 44	38 37 03
Cape Hatteras	35 14 22	75 31 42	84 36 35	38 22 12

The gnomonic projection of a sphere with radius unity is defined by the equation

$$\rho=\tan\theta, \tag{76}$$

in which θ is the great circle distance from the center of the projection. The scale factor along the radius is given by the value of $\frac{d\rho}{d\theta}$. But

$$\frac{d\rho}{d\theta}=\sec^2\theta. \tag{77}$$

If ω is the azimuth from the center upon the sphere, the arc of an almucantar circle on the sphere is equal to $\omega \sin \theta$. This arc upon the projection is represented by a circular arc equal to $\omega \tan \theta$. Therefore the scale along this almucantar is given by the expression

$$\frac{\omega \tan \theta}{\omega \sin \theta} = \sec \theta. \tag{78}$$

By the principle of Tissot's indicatrix,[1] any small circle around a given point upon the sphere is projected into an ellipse with major axis along the radius from the center of the projection and with minor axis in the direction of the almucantar through the point. If the radius of the circle upon the sphere is considered as unity, the semimajor axis of the ellipse will be equal to $\sec^2 \theta$ and the semiminor axis will be equal to $\sec \theta$. If u' denotes the bearing of the line on the projection representing any great circle the true bearing of which, reckoned from the great circle joining the station and the center of the projection, is denoted by u, we shall have the relation

$$\tan u' = \frac{\sec \theta}{\sec^2 \theta} \tan u, \tag{79}$$

or

$$\tan u' = \cos \theta \tan u. \tag{80}$$

Now we have the relation

$$\tan (u - u') = \frac{\tan u - \tan u'}{1 + \tan u \tan u'}, \tag{81}$$

$$= \frac{(1 - \cos \theta) \tan u}{1 + \cos \theta \tan^2 u}, \tag{82}$$

$$= \frac{(1 - \cos \theta) \sin 2u}{1 + \cos \theta + (1 - \cos \theta) \cos 2u}, \tag{83}$$

or, finally,

$$\tan (u - u') = \frac{\tan^2 \frac{\theta}{2} \sin 2u}{1 + \tan^2 \frac{\theta}{2} \cos 2u}. \tag{84}$$

Therefore from an analysis similar to that given on page 34, we get

$$u - u' = \tan^2 \frac{\theta}{2} \sin 2u - \frac{1}{2} \tan^4 \frac{\theta}{2} \sin 4u + \frac{1}{3} \tan^6 \frac{\theta}{2} \sin 6u - \cdots \tag{85}$$

[1] See U. S. Coast and Geodetic Survey Special Publication No. 57, General Theory of Polyconic Projections, p. 153.

If $u-u'$ is to be expressed in minutes, each of the coefficients in (85) must be divided by arc 1′. The equation then becomes

$$(86) \quad u-u'=\frac{\tan^2\frac{\theta}{2}}{\text{arc }1'}\sin 2u-\frac{1}{2}\frac{\tan^4\frac{\theta}{2}}{\text{arc }1'}\sin 4u+\frac{1}{3}\frac{\tan^6\frac{\theta}{2}}{\text{arc }1'}\sin 6u-\ldots\ldots$$

As already stated u must be reckoned from the great circle joining the station to the point of tangency of the projection; u' will then be reckoned from the major axis of the ellipse or from the straight line joining the projection of the station to the projection of the point of tangency of the map. It is sufficiently accurate to take the azimuth to the point of tangency from the station in degrees and minutes. In radio-compass work azimuths are reckoned from the north in clockwise direction.

In the table on page 37 in the column headed "Radial distance," there are given the θ angles for the various stations for which tables have been computed. With these values of θ, the equations for $u-u'$ for the stations become, respectively—

Cape Race	$u-u'=+161'.1 \sin 2u-\ \ 3'.8 \sin 4u+0'.1 \sin 6u.$
Bar Harbor	$u-u'=+306'.4 \sin 2u-13'.6 \sin 4u+0'.8 \sin 6u.$
Cape Cod,	$u-u'=+325'.6 \sin 2u-15'.4 \sin 4u+1'.0 \sin 6u.$
Montauk,	$u-u'=+352'.4 \sin 2u-18'.1 \sin 4u+1'.2 \sin 6u.$
Fire Island,	$u-u'=+372'.2 \sin 2u-20'.1 \sin 4u+1'.5 \sin 6u.$
Sandy Hook,	$u-u'=+385'.6 \sin 2u-21'.6 \sin 4u+1'.6 \sin 6u.$
Cape May,	$u-u'=+400'.1 \sin 2u-23'.3 \sin 4u+1'.8 \sin 6u.$
Hog Island,	$u-u'=+416'.0 \sin 2u-25'.2 \sin 4u+2'.0 \sin 6u.$
Cape Henry,	$u-u'=+422'.0 \sin 2u-25'.9 \sin 4u+2'.1 \sin 6u.$
Cape Hatteras,	$u-u'=+416'.2 \sin 2u-25'.2 \sin 4u+2'.0 \sin 6u.$

Since azimuths are reckoned from the north in clockwise direction and since at Cape Race $u=0$ when the azimuth is 124° 49′, the value of u when the azimuth is zero is 360° − (124° 49′) = 235° 11′. For the azimuth of 1° the value of u is 236° 11′; and so on for the other azimuths.

If the correction to the azimuth zero is found to be $u_0-u_0'=c_0$ and if at azimuth α_n we find $u_n-u_n'=c_n$, then the correction to be *added to* α_n is given by c_0-c_n. This is done because we are interested only in the angle between the meridian on the projection and the straight line that represents the given great circle.

If the gnomonic projection should be found to be more servicable for plotting radio-compass bearings than the Mercator projection, it would seem advisable to construct such a projection of the east coast of the United States with point of tangency somewhat centrally located to the region to be represented. Tables of gnomonic azimuths could then be computed for this chart and the distortions in angle would not be as great as those shown in the tables included in this publication It should be noted, however, that these angular distortions do not detract from the accuracy of the plottings. A more restricted chart would permit of more accurate scaling of the position determined by the intersection of the plotted bearings.

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