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REPORT OF THE SUPERINTENDENT

OF THE

U. S. COAST AND GEODETIC SURVEY

SHOWING

THE PROGRESS OF THE WORK

DURING THE

FISCAL YEAR ENDING

WITH

JUNE, 1894.

IN TWO PARTS.

PART II.

APPENDICES RELATING TO THE METHODS, DISCUSSIONS, AND RESULTS OF THE COAST AND GEODETIC SURVEY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1895.

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Annual Report of the Superintendent of the Coast Survey

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PREFATORY NOTE RELATING TO A CHANGE IN THE FORM OF THIS REPORT.

The Report of the United States Coast and Geodetic Survey for the fiscal year 1891 is the first one in which the text was arranged for publication in two parts.

Part II of that report, as well as Part II of the reports for the years 1892 and 1893, was published in octavo, while the quarto form was retained for Part I.

It was thought advantageous to publish both parts of this report for the year ending June 30, 1894, in quarto, and the change has accordingly been made.

Part I contains the historical portion. It states the progress in field and office work, gives estimates for future progress, and a report of expenditures for the fiscal year. It is accompanied by maps of general progress, and by progress sketches more in detail.

Part II includes the professional papers relating to the methods, discussions, and results of the Survey which have been approved for publication during the year, such illustrations as are needed accompanying them.

Part I being of less general interest than Part II, in the future distribution of the Report Part II only will be sent, except in special cases.

W. W. DUFFIELD,
Superintendent.

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APPENDIX No. 1—1894.

RELATIVE DETERMINATIONS OF GRAVITY WITH HALF-SECOND PENDULUMS, AND OTHER PENDULUM INVESTIGATIONS,

By G. R. PUTNAM, ASSISTANT,

AND

A REPORT ON A GEOLOGIC EXAMINATION OF SOME COAST AND GEODETIC SURVEY GRAVITY STATIONS,

By G. K. GILBERT, GEOLOGIST, UNITED STATES GEOLOGICAL SURVEY.

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APPENDIX No. 1—1894.

RELATIVE DETERMINATIONS OF GRAVITY WITH HALF-SECOND PENDULUMS, AND OTHER PENDULUM INVESTIGATIONS.

By G. R. PUTNAM, Assistant.

Submitted for publication January 23, 1895.

The following report includes the results of various investigations carried out by the writer under the direction of Dr. T. C. Mendenhall. These are considered under the following heads: I. Relative measurements of gravity at twenty-six stations in the United States. II. Observations with quarter-second pendulums, and special pendulum investigations. III. Telegraphic comparisons between base stations in Washington, D. C. IV. Summary of the connections between American and European gravity stations by means of relative pendulum observations, and the reduction of absolute determinations of gravity to Washington.

There is also included in this report, as being intimately connected with the other work described, (V) a translation of an interesting paper by Commandant Defforges, of the "Service Géographique" of France, giving an outline of the results of his recent measurements in North America. A copy of this paper was sent to the Superintendent by Commandant Defforges, and it has since been published* in France. The absolute determination at Washington was made by order of General Derrécagaix, Director of the "Service Géographique," in courteous response to the request of the Superintendent, the elaborate instrumental outfit being sent from Paris especially for this purpose.

The writer desires to acknowledge his indebtedness to Mr. C. A. Schott, Mr. E. D. Preston, and Mr. O. H. Tittmann, of the Coast and Geodetic Survey, for their valuable advice in connection with the preparation of this report.

I.—RELATIVE MEASUREMENTS OF GRAVITY AT TWENTY-SIX STATIONS IN THE UNITED STATES.

Six of these determinations were made at various times in the spring of 1894, and the remaining twenty in a transcontinental series extending west from Washington to Utah during the summer of the same year, the whole forming the first extended series of gravity measurements carried out in the United States. As shown on the accompanying map (fig. 4), the greater part of the stations are in the neighborhood of the thirty-ninth parallel of latitude, following the general course of the transcontinental triangulation of the Survey and including many of its astronomically determined points. This line of gravity stations, commencing at the Atlantic coast, rises to near the crest of the Appalachian ridge, traverses the great smooth central plain, increasing in altitude gradually from 151 metres to 1841 metres; then rises to the high elevations of the main chain of the Rocky Mountains, reaching an altitude of 4285 metres at Pikes Peak, descends into the eroded valleys of the Grand and Green rivers, crosses the summit of the Wasatch ridge, and finally descends to the great western plateau of the continent. The wide variety of orographic features thus traversed so nearly in the same latitude makes this series peculiarly well adapted to throw light on the continental variations of gravity, on the question of the proper method of reduction to sea level, of utmost importance in connection with the application of gravity measurements to the geodetic problem of the figure of the earth, as well as on the questions of the nature and condition of the

* "Comptes Rendus de l'Académie des Sciences," January 29, 1894.

earth's crust. Several stations were included on account of peculiar features of their location, as, for instance, three points in the Yellowstone Park, because here only in the United States (exclusive of Alaska) are found the last signs of volcanic activity. The summit of Pikes Peak was occupied not only for the sake of including a station of considerable altitude, but also because a comparison of this result with that obtained at Colorado Springs, near the base of the mountain, affords the data for computing the mean density of the earth. With the exception of Moré, in India, this is the most elevated gravity station yet determined with modern methods. Incidental to the work, and as furnishing the most convenient facilities, observations were in a number of instances made at educational institutions, which in return will receive desired information in regard to the relative value of an important physical constant. Thus also absolute measurements of gravity which may be carried out at such institutions may be compared and utilized elsewhere, and may be referred to standard base stations for combination.

Another and most important object contemplated in the recent work was to make a comparison of relative gravity results obtained with various kinds of apparatus and different lengths of pendulums. To this end there were included four stations visited by Commandant Defforges in 1893, who used a half-metre reversible pendulum. The two stations of Commandant Defforges on the Pacific Coast had previously been determined by Dr. Mendenhall and Mr. Preston with the half-second (quarter-metre) invariable pendulums, thus giving a comparison at all of his stations in the United States. In addition to the regular series of observations made at each station of the past season with the half-second pendulums, there was also carried along the quarter-second (one-sixteenth metre) pendulum apparatus designed by Dr. Mendenhall and recently constructed. These pendulums were swung at three stations, as well as at Washington, before and after the trip. (See Part II.) An interesting test of the wear of knife-edges, as well as of the accuracy of observation, was made by swinging the half-second pendulums (which carry a plane in the head and swing upon a knife-edge) upon an additional or standard edge at Washington before and after the trip and at two of the other stations. As the ordinary edge was in use four times as long as the standard, valuable information was thus obtained on the subject of wear. Further, the swings on the standard edge gave independent determinations of gravity at these stations, thus testing the reliability of the system of observing.

In the prosecution of this work the writer had the efficient assistance at fifteen stations of Mr. C. E. Mendenhall, Extra Observer, and at three stations of Mr. S. B. Tinsley, Aid, while at the remaining eight places the work was conducted without assistance. In selecting locations for the apparatus endeavor was made to obtain the most favorable conditions for observing, such as constant temperature, stable foundation for the pendulum case, freedom from disturbing influences, and near proximity of the transit set up for time observations. To obtain such suitable places it was necessary to request the temporary use of basement rooms or cellars in public or private buildings, or those belonging to corporations or colleges. These rather unusual privileges were invariably granted most freely and courteously, and it is regretted that lack of space prevents the mentioning here of the many persons who, by their kindness in this respect or in the matter of furnishing valuable information and assistance, greatly aided the successful prosecution of the work.

Position and description of stations.—The latitudes and longitudes of the pendulum stations are mostly derived by connection with neighboring points whose geographical position had previously been determined by the Coast and Geodetic Survey or other good authority, either astronomically or geodetically. At eight stations, Deer Park, Cleveland, Chicago, Lower Basin, Grand Canyon, Norris Basin, Pleasant Valley, and Terre Haute, the positions were determined in connection with the pendulum work, the latitudes by observations on from two to four pairs of stars by Talcott's method, and the longitudes by transportation of two chronometers. The fact that a number of the other stations had been determined telegraphically gave a good opportunity of testing the accuracy of longitudes thus determined by carrying two chronometers on railway trains, and by other means of transportation. In the seven cases where the chronometers were carried directly between telegraphic longitude stations the discordance between the telegraphic and the chronometric difference of longitude ranges from 0·08 second (time) to 0·80 second, the average being 0·37 second, and the average distance traveled about 175 miles.

The elevations are based on the most accurate information available. For a majority of the

interior stations they depend on the data given in Mr. Gannett's Dictionary of Altitudes in the United States. Additional information in regard to the elevation of Pikes Peak was furnished by Mr. Gannett. The elevations of the stations in the Yellowstone Park are based on information furnished by Maj. W. A. Jones, United States Engineers, from a line of levels run from Cinnabar, Mont. The pendulum stations were in each case referred by hand level or otherwise to the railroad track, bench mark, or other known point. In many cases the writer is indebted to city engineers or college authorities for information in regard to bench marks in the neighborhood of the station.

The following (Table A) is a brief description of the location of the pendulum stations and of the support for the pendulum case at each, together with the measured flexure of the case and support. The figures in the last column represent the horizontal movement of the knife-edge when a force of 1·5 kilogrammes was applied horizontally in the plane of oscillation. The latitudes, longitudes, and elevations will be found in Table E.

TABLE A.—*Location of stations, support for pendulum case, and flexure.*

Station and location.	Support for pendulum case.	Flexure.
		Microns.
Washington, D. C. Office United States Coast and Geodetic Survey on Capitol Hill, pendulum room in southwest corner of basement.	Massive brick pier with capstone	1·0
Cambridge, Mass. Harvard College Observatory, basement room north of equatorial foundation.	Heavy stone doorsill	1·0
Boston, Mass. New addition to State House, vault in northeast part of basement.	Concrete floor	1·0
Ithaca, N. Y. "Lincoln Hall" (building of College of Civil Engineering), Cornell University, "metric room" in northeast part of basement.	Tall brick pier (new)	3·0
Charlottesville, Va. University of Virginia, basement of biological laboratory	Low brick pier (new)	8·0
Princeton, N. J. College of New Jersey, basement of "magnetic observatory" (or electrical building).	Tall brick pier	5·0
Philadelphia, Pa. University of Pennsylvania, small room in northwest corner of basement of "College Hall."	Concrete floor	1·0
Deer Park, Md. At east corner of swimming-pool building, west of Deer Park Hotel.	Low stone pier (new)	2·5
Cleveland, Ohio. Adelbert College, in "balance room" of Professor Morley, in west corner of basement.	Large brick pier with capstone	3·0
Chicago, Ill. Ryerson Physical Laboratory, University of Chicago, "constant temperature room," northeast part of main floor.	Massive brick pier with capstone	0·5
Lower Geyser Basin, Wyo. (Yellowstone Park). Basement of Fountain Hotel, unfinished room north end of central wing.	Low brick pier (new, poor cement)	8·0
Grand Canyon, Wyo. (Yellowstone Park). Unfinished basement of Canyon Hotel, west end of main building.	Low brick pier (new, poor cement)	7·0
Norris Geyser Basin, Wyo. (Yellowstone Park). Small room at entrance to storehouse, west of lunch station.	Three wooden posts driven in ground and well braced.	18·0
Salt Lake City, Utah. Small astronomical observatory in southeast corner of Temple Block.	Stone pier 1 metre high	7·0
Pleasant Valley Junction, Utah. West corner of cellar under residence of T. Arrowsmith, about 65 metres north of Rio Grande Western Railway station.	Low brick pier (new)	2·5
Green River, Utah. East corner of cellar under south part of Palmer House	Low brick pier on concrete floor	2·0
Grand Junction, Colo. Cellar under northeast corner of Brunswick Hotel, Main street, west of Fourth.	Low brick pier (new)	2·0
Gunnison, Colo. Small room beneath sidewalk at northeast corner of La Veta Hotel.	Heavy stone doorsill	1·0
Colorado Springs, Colo. Hagerman Hall, Colorado College, small room near northeast corner of basement.	Low pier on concrete floor	1·5
Pikes Peak, Colo. Small storeroom at south end of stone building on east side of summit.	Large stones cemented to concrete floor.	1·5
Denver, Colo. University Park, in Chamberlin Observatory of the University of Denver, basement south of equatorial foundation.	Large stones cemented to concrete floor.	2·5
Wallace, Kans. Basement of stone residence northwest of station, and belonging to Union Pacific Railway.	Stone doorsill	3·5
Ellsworth, Kans. Court-house of Ellsworth County, near center of basement.	Large stone doorsill	2·0
Kansas City, Mo. Franklin School, at northeast corner of Washington avenue and Fourteenth street, small storeroom in south part of basement.	On bricks cemented to concrete floor.	2·0
St. Louis, Mo. Chemical laboratory, Washington University, near northwest corner St. Charles and Seventeenth streets, south basement room.	Low pier on brick floor	5·0
Terre Haute, Ind. Main building, Rose Polytechnic Institute, west room of basement.	Large brick pier with slate top	3·5
Cincinnati, Ohio. Cincinnati Observatory on Mount Lookout, basement north of foundation of meridian circle.	Low brick pier on brick floor	4·0

Instruments.—The apparatus used in the greater part of the work consisted of half-second pendulums, A 4, A 5, and A 6, with the accompanying air-tight receiver, flash apparatus, dummy or temperature pendulum, etc., sidereal break-circuit chronometers Negus 1823 and 1824, thermometers, air pump, dry cells, and, for use in time observations, a light observatory tent (a ridge-pole tent specially designed for the purpose and weighing only 65 pounds), small meridian telescope (for either time or latitude, focal length, 66^{cm}; aperture, 52^{mm}; magnifying power, 50), light Saegmuller chronograph (weight about 50 pounds), and other accessories. Special attention was paid to portability, and considerable reductions in weight were secured in the time outfit, and important gain in economy and labor. The entire apparatus, packed for shipment, weighed about 700 pounds (318 kilogrammes).

The half-second pendulum apparatus of the Survey has been fully described and illustrated in United States Coast and Geodetic Survey Report for 1891, Appendix 15, since which time, however, it has been somewhat modified. A reversal of the usual relation of knife-edge and plane was made by Dr. Mendenhall, with the idea of obtaining greater invariability in the pendulum itself (see paper "On the use of planes and knife-edges in pendulums for gravity measurements," American Journal of Science, XLV, page 144). Each of the new pendulums, A 4, A 5, and A 6, carries an agate plane in its head and swings upon an agate knife-edge which is inserted in a heavy brass plate resting on the shelf in the receiver. The upper part of the stem of the pendulum (fig. 6 A) is forked, so that it passes beyond each end of the knife-edge, thus permitting both edge and plane to be single pieces of agate. Experience proved that the dividing of the agate knife-edge or plane is objectionable as offering an opportunity for the separated parts to be twisted out of the same plane by any strain in the surrounding metal. The plate in which the knife-edge is embedded is not screwed rigidly to the shelf in the receiver, as formerly, but rests on three rounded steel projections in this shelf, to which the plate is fitted, and is held firmly in place with a light screw. The agate knife-edge is formed by planes meeting at an angle of 130°, and has a total bearing length of 19^{mm}, being cut away in the center. A scale has been placed in the eye end of the observing telescope, so that by holding the slit open and noting the movement of the image reflected by the pendulum mirror across the scale the arc of oscillation may be read directly in minutes as long as the arc is not large.

Appliances have been provided for measuring statically the flexure of the support. A glass scale is mounted vertically above the knife-edge, adjustable so that it may be placed at different heights. With a weight, cord, pulley, and aluminum arm (to carry the tension over the edge of the receiver) a horizontal force in the plane of oscillation of the pendulum is applied directly behind the knife-edge. By means of a simple microscope, supported independently of the pier carrying the receiver, magnifying 160 diameters, and provided with an eyepiece scale with lines having an equivalent distance of 10 microns, the displacements of the scale above the knife-edge when the tension is applied by suspending the weight are noted to the nearest micron. The scale may be observed at two or more heights above the knife-edge, and thus the movement at the edge estimated.

The outside manometer and barometer, both troublesome additions, have been dispensed with, consequent upon the adoption of low pressures. The air pressure is now obtained by a small manometer set in the pendulum case. This manometer was always transported in a vertical position so as to prevent air working into the closed end. The same tube was used throughout, and it was tested before and after the field work and found correct. The same thermometer, Green 6604, was used on the dummy pendulum at all stations. Its corrections as determined by the Office of Weights and Measures were applied to all readings. As a check, readings were also taken of another thermometer hanging in the air in the pendulum case. This thermometer invariably indicated the change of temperature, reading higher than the dummy thermometer when the temperature was rising, and lower when falling.

The new air pump for exhausting the receiver weighs only about 6 pounds (2·7 kilogrammes). It is provided with a very ingenious self-packing piston, the invention of Mr. Fischer, Chief Mechanician. This piston, which is shown in fig. 1 by a section of a portion of the pump, is a leather cylinder stretched over a metal frame, with the hollow inside open to the outer air through the tubular piston rod and handle. As soon as the air is partially exhausted from the pump

cylinder, which has escape valves at each end, the atmospheric pressure on the inside of the piston makes a perfect elastic packing with minimum friction. The hollow piston rod also furnishes a ready means of lubrication.

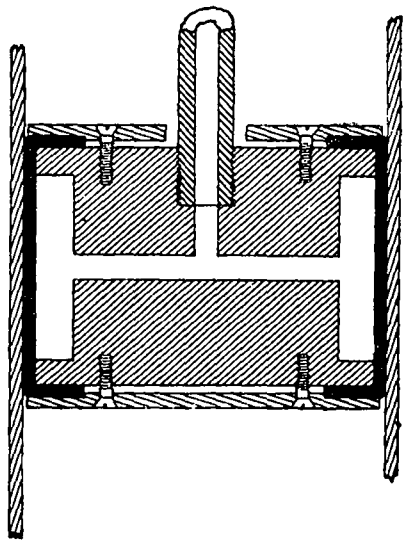


FIG. 1.—Section of portion of air pump, showing piston. (Leather indicated by solid black.)

Determination of coefficients.—The effects on the period of the pendulum of changes of temperature and atmospheric density, and of various degrees of flexibility of support, were determined experimentally in January and April, 1894. For this purpose pendulum B 4 was used as a standard to eliminate the rate of the chronometer, being swung in an adjoining room under uniform conditions, while A 4, A 5, and A 6 were successively swung under the various conditions desired to be investigated. Simultaneous swings were made with the pendulums, using the same chronometer to operate both flash apparatuses by means of suitable electrical connections. The true period of B 4 being known, the difference from this of the observed period must be due to rate of chronometer, which may therefore be computed for each swing, and the resulting rate correction applied to the observations with A. This elegant comparative method of determining pendulum coefficients was first used by Airy and has more recently been employed by Von Sterneck. The following is a summary of the results:

Temperature coefficient.

Pendulum.	At low temperatures.		At high temperatures.		Differences.		Increase of period for 1° C. increase of temperature.
	Temperature.	Period (corrected except for temperature).	Temperature.	Period (corrected except for temperature).	Temperature.	Period.	
	° C.	s.	° C.	s.	° C.	s.	s.
A 4 D	7·58	·500 8466	29·41	·500 9366	21·83	·000 0900	·000 00412
A 4 R	7·93	8474	29·41	9377	21·48	903	420
A 5 D	8·27	6758	29·33	7644	21·06	886	421
A 5 R	8·57	6768	29·19	7630	20·62	862	418
A 6 D	8·92	6425	27·27	7192	18·35	767	418
A 6 R	9·17	6428	26·94	7187	17·77	759	427
						Mean	·000 00419

The mean of these values, or ·000 00419^s, is adopted as the temperature coefficient for the three pendulums. As the range of period is small, it is sufficiently accurate to consider this coefficient a constant quantity.

Pressure coefficient.

Pendulum.	At low pressure.		At higher pressure.		Differences.		Increase in period for 1mm increase in pressure at 0° C.
	Pressure (reduced to 0° C.).	Period (corrected except for pressure).	Pressure (reduced to 0° C.).	Period (corrected except for pressure).	Pressure.	Period.	
	mm.	*s.*	*mm.*	*s.*	*mm.*	*s.*	*s.*
A 4	6·0	·500 8350	94·5	·500 8441	88·5	·000 0091	·000 000103
A 5	6·1	6619	96·1	6708	90·0	89	099
						Mean	·000 000101

The pressure correction in the neighborhood of 60mm, the adopted standard, is therefore $+0{\cdot}000\ 000101\left[60-\frac{Pr}{1+{\cdot}00367\,T}\right]$. At the first three of the stations a standard pressure of 500mm was used. The coefficient near 500mm was determined in the same manner, and found to be ·000 000077 second per millimetre, which value was employed for those stations. As in the manner of making and reducing these observations the pressure correction is always a small quantity, no appreciable error can arise from treating it as varying directly with the pressure.

Flexure coefficient.—The effect on the period of the pendulum of various degrees of flexibility of support was ascertained by determining the period under the different conditions (correcting for rate in the same manner as with the other coefficients), and measuring the flexure of the case and support statically with the appliances already mentioned, all the observations being made with pendulum A 4. In the following summary the column "Flexure" gives the horizontal movement of the knife-edge in microns when a force of 1·5 kilogrammes was applied horizontally in the plane of oscillation, and the column "Period" gives the period under the various conditions corrected, except for flexure.

Position of pendulum receiver.	Flexure.	Period.
	μ	*s.*
On stone pier	1·0	·500 8770
Concrete floor	2·0	8774
Wooden stand on concrete floor	4·5	8802
Means	2·5	·500 8782
Wooden stand resting on sheet rubber	35·5	·500 8992
Wooden packing box	47·0	9073
Means	41·2	·500 9032
Difference of means	38·7	·000 0250

From the means above it is seen that a difference in flexure of 38·7 microns (with weight of 1·5 kilogrammes) causes a difference in period of ·000 0250s, from which a flexure coefficient is computed, increase of period for 1μ increase of flexure, as measured statically with weight of 1·5 kilogrammes = ·000 00065s. The theoretical value* for these pendulums and weight is approximately ·000 00071s, computed from the formula $d\,T=\frac{P\varepsilon\,Th}{2\,\lambda\,\lambda}$ where T is the period of the pendulum dT is the change in period on account of flexure, ε is the elasticity (equals displacement divided by force applied), P is weight of pendulum, h is distance center of gravity to center of suspension, and λ is distance center of oscillation to center of suspension (or length of equivalent simple pendulum).

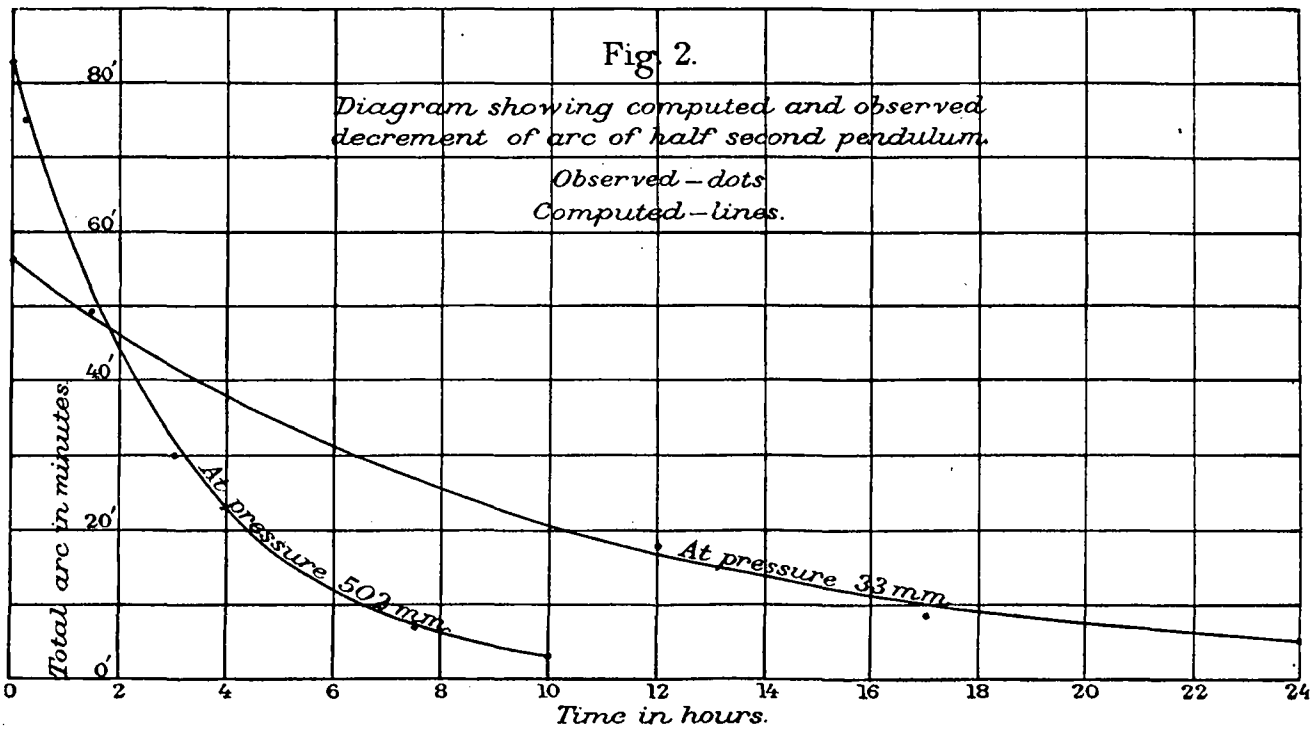
*The necessity for this important correction was first pointed out by Mr. Charles S. Peirce, of the Coast and Geodetic Survey, and the subject was investigated by him mathematically and experimentally. See Comptes Rendus de la Cinquième Conférence Géodésique Internationale à Stuttgart, 1877, Annexe I*a*, I*b*; also Report Coast and Geodetic Survey for 1881, Appendix 14.

The amount of flexure encountered in actual work will in general be so small as to render a slight uncertainty in this coefficient inappreciable. At the twenty-six stations where masonry supports were used it ranged from 0·5 microns to 8·0 microns, with weight of 1·5 kilogrammes. At a single station where it was necessary to use wooden support it was as high as 18 microns.

Method of observation.—Several modifications were made by the writer in the method of using the half-second pendulums in this work, resulting, it is believed, in diminished labor of observing as well as increased accuracy. These changes, some of which are applications for the first time to short pendulums of methods which have been already used with long pendulums and less portable apparatus, may be summarized as follows: First, use of low air pressures (60^{mm}); second, long swings (eight hours); third, consecutive swings covering entire interval between time observations and at least forty-eight hours; fourth, use of two chronometers; fifth, small initial arcs of oscillation (55′); sixth, observing coincidences by contacts of images; seventh, measurement of flexure of stand and support at all stations.

The general plan adopted* was to swing the pendulums continuously at each place for two

Fig. 2.



days, or longer if necessary, so as to begin and end with star observations for time. In case of unfavorable weather the swings were continued until time was obtained. The pendulums were swung at Washington (Coast and Geodetic Survey Office) before and after each trip, and the results are treated relatively. One swing (eight hours in length) was made with each of the three pendulums in each position, reversed and direct, making in all six swings at a station, except in the case of unfavorable weather. With the improved portable air pump it was found possible to exhaust the air from the receiver to less than one-tenth of an atmosphere in a few minutes. It was therefore decided to adopt a standard pressure of 60^{mm} in which to swing the pendulums, and also to lengthen the swings to eight hours, which could be done with ease at this low pressure. This improvement, besides lessening the labor of observing, obviating the necessity for much night work, and avoiding disturbances of the temperature conditions consequent on frequent observations and changes of the pendulum, further made it possible to dispense with barometer

*At the first three stations, Cambridge, Boston, and Ithaca, the method of observation differed somewhat from that described; the old standard pressure of 500^{mm} was used, the swings were each four hours long, and the observations with each pendulum covered twenty-four hours. The results are strictly comparable, however, as the preceding and following observations at Washington were made in the same manner as at the field stations in each case.

and outside manometer on the receiver. The diagram (fig. 2) shows the decrement of arc of a half-second pendulum, both observed and computed on the law of diminution in geometrical ratio, at two pressures, 502^{mm} and 33^{mm}, and indicates that if desired, continuous swings could be made at low pressures, of any length up to twenty-four hours. On account of its obvious advantages a small initial arc of oscillation, about 55′ total, was adopted, from which the arc diminishes in an eight-hour swing to about 20′. A modification in the method of observing coincidences was necessary for these small arcs, to explain which some description of the use of the coincidence apparatus must be given.

In this apparatus a chronometer breaking an electric circuit every second is connected with an electro-magnet carrying on the end of its extended armature two shutters so arranged that a flash of light is thrown through a slit every time the circuit is broken, and only then. (See illustration No. 26, Appendix 15, Report 1891.) This bright slit is seen in the observing telescope as reflected from two mirrors placed side by side, one stationary on the shelf in the receiver and the other carried by the swinging pendulum. These mirrors are so adjusted that when the pendulum is hanging freely at rest the two images will be seen in the same horizontal line in the telescope. When the pendulum is swinging the image as reflected from the pendulum mirror will change its position as seen each second in the field of the telescope, because of the fact that the pendulum makes a double oscillation in a little more than a second, and hence will be found slightly behind its former position at the end of each second when the flash is thrown. The moving image will therefore appear to travel up and down across the field of the telescope by successive jumps, and coincidences are observed by noting the time when the two images are in the same horizontal line. It is evident that in the interval between two such phenomena the pendulum has made one less than twice as many oscillations as the chronometer has beat seconds, and that in an interval of time between the first and last of a number of coincidences the number of oscillations of the pendulum will be twice the number of seconds less the number of coincidence intervals. But when small arcs of oscillation are used, the motion of the moving image across the field is slow, and the two images may overlap for a number of seconds. The modification introduced in observing is to note the contacts, or the time when these images touch and when they separate, and take the mean as the time of coincidence. By this means coincidences may be observed when the total arc of oscillation is as small as 5′, with an uncertainty of not more than one or two seconds, which is far within the requirements for long swings.

Only sufficient coincidences (usually three) were observed at each end of the swing to make sure that the total number occurring in the interval could be correctly estimated. The period was computed by combining the difference between the first and last "down" coincidences and the first and last "up" coincidences, thus eliminating all error due to imperfection of relative adjustment of the mirrors or possible change in this adjustment during the swing.

Two chronometers were used, coincidences being noted alternately with each. This may be done very readily with this flash apparatus and a suitable arrangement for switching either chronometer into circuit, and while increasing very little the labor of observing, affords an excellent check on the periods as well as a guard against accident to timepiece. It is believed that by swinging the pendulums continuously between time observations the effect of diurnal irregularities of rate is entirely eliminated, as it will not be by any other method, and this is strikingly shown by comparing the mean periods of the three pendulums as derived separately from the two chronometers (see Table G). The average difference at the various stations is about ·000 0001 second, and the maximum at any station ·000 0004 second, although the results for single swings often differ materially, in one case as much as ·000 0027 second (in a four-hour swing on March 9, swing No. 17, Table G), corresponding to a relative variation of daily rate of half a second. The use of a 50-ohm relay in the chronometer circuit rendered it more constant, and protected the chronometer from the stronger currents necessary to work the flash apparatus. The two chronometers were compared on a chronograph before and after time observations, during which, of course, only one was used. They were kept under as favorable conditions as possible regarding temperature, being in double leather cases, which were only opened once daily to wind. They were not moved during observations, as their breaks were carried to the chronograph in the observatory and to the flash apparatus by wire, and a sidereal watch was used as a hack both in

time observations and in noting coincidences. The seconds of the watch were frequently compared with the chronometers by ear through the fact that the latter omit to break the circuit at the sixtieth second.

The average time required for a station, including traveling and all delays of every sort, was five and a half days. In the transcontinental series of stations remarkably favorable weather conditions were experienced, only two days being lost on account of inability to obtain star observations, out of a total of one hundred and five days and twenty stations. The usual program followed in the observations was: First day, station prepared and instruments set up, star observations for time between 9 and 10 p. m., pendulum A 4 (reversed) started at 10 p. m.; second day, A 4 (direct) started at 6 a. m., A 5 (reversed) at 2 p. m., time observations at 9 p. m., A 5 (direct) started at 10 p. m.; third day, A 6 (reversed) started at 6 a. m., A 6 (direct) at 2 p. m., time observations at 9 p. m., pendulum stopped immediately afterwards; fourth day, instruments packed. If star observations were not obtained on the third night the swings were continued, repeating the above order. Usually about forty-five minutes were required for each time determination, and the same for each set of pendulum observations, including the final coincidences of one swing, the changing of the pendulum and exhausting the receiver, and the first coincidences of the next swing.

The following is an example of the record of observations for a single swing:

Station, Washington, D. C. (Coast and Geodetic Survey Office), October 31, 1894. Pendulum A 4 reversed, on knife-edge A I.

[Observer: G. R P.]

Coincidences							Total arc.	Pressure.	Thermometer on dummy pendulum.	Thermometer in air.
Chronometer 1824				Chronometer 1823.						
	h.	*m.*	*s.*		*h.*	*m.*	*s.*	′	*mm.*	° *C.*	° *C.*
Down	0	57	58	Down	0	57	25	52	64·2	17·85	17·9
Up	1	03	02	Up	1	02	22				
Down		08	02	Down		07	16				
Up	9	10	05	Up	9	06	49				
Down		15	06	Down		11	42				
Up		20	14	Up		16	43	19	64·2	17·45	17·5

Besides the above, latitude observations were made on one or two nights at each place where necessary, the station was connected as to elevation with some known point, and the time and pendulum computations were kept up from day to day. At two places, Colorado Springs and Terre Haute, meridian lines were laid out by request. At one station, Norris, Wyo., where only one day could be spent, the regular program was necessarily shortened, and each pendulum was swung in one position only. For this reason, and on account of the unsatisfactory mounting of the receiver, this result is less reliable than the others. At stations where the range of temperature was considerable, due to inability to secure a favorable location in this respect, thermometer readings were taken more frequently, and each was weighted according to the interval of time intervening. At only four stations, however, did the total range of temperature in the pendulum receiver exceed 4° C.

Rating of chronometers.—At most of the stations transit observations of about eight stars were made by the writer each favorable evening to determine the daily rate of the chronometers. These were recorded chronographically, as also were the comparisons between the chronometers. The meridian telescope was generally mounted on three wooden posts, set in the ground and well braced, though in a few cases masonry piers were built or found available. At Princeton, Denver, and St. Louis the use of fixed observatory instruments was courteously granted, and at Cambridge, Charlottesville, and Cincinnati the time observations were made by the observatory authorities and the rates kindly furnished. At Denver the observations were made by Mr. Mendenhall. The precautions taken with the chronometers have already been mentioned. The following table (B) gives a summary of the rates on sidereal time. After each station are given the average temperature and the elevation, as having an important influence on the rate. Chronometer 1828 was not used after the first two stations on account of the remarkable change in its rate. At Charlottesville and Princeton, where time observations were much interrupted by unfavorable weather, the daily chronometer rates were derived by comparison with the standard observatory clocks, the rate of the latter being assumed uniform between time observations.

TABLE B.—*Summary of rates of chronometers.*

Station. Average temperature and elevation.	Interval.	Daily rate +losing. −gaining. Negus 1823.	Negus 1828.
	1894.	*s.*	*s.*
Washington 10° 14m	Jan. 8–Jan. 11	+1·48	+ 2·99
	" 11– " 12	+1·33	+ 2·96
		Negus 1824.	Negus 1828.
Cambridge 3° 14m	Mar. 6–Mar. 7	+7·92	+21·01
	" 7– " 8	+7·98	+20·97
	" 8– " 9	+7·99	+20·81
Boston 19° 22m	" 10– " 11	+5·08	
	" 11– " 12	+4·95	
	" 12– " 13	+4·93	
	" 13– " 14	+4·74	
Ithaca 19° 247m	" 21– " 23	+4·38	
	" 23– " 24	+4·46	
		Negus 1824.	Negus 1823.
Washington 13° 14m	" 30– " 31	+5·79	+ 0·81
	" 31–Apr. 1	+5·56	+ 0·69
	Apr. 1– " 2	+5·69	+ 0·50
Washington 16° 14m	" 25– " 26		+ 0·83
	" 26– " 27		+ 0·74
Charlottesville 18° 166m	May 2–May 3	+4·96	+ 0·29
	" 3– " 4	+4·96	+ 0·83
	" 4– " 5	+5·20	+ 1·29
	" 5– " 6	+5·19	+ 1·16
Washington 19° 14m	" 10– " 11	+5·01	+ 0·99
	" 11– " 12	+5·26	+ 1·16
Princeton 17° 64m	" 16– " 17	+4·94	+ 0·93
	" 17– " 18	+4·94	+ 1·14
	" 18– " 19	+4·87	+ 1·18
	" 19– " 20	+4·88	+ 1·19
	" 20– " 21	+5·11	+ 1·43
	" 21– " 22	+5·21	+ 1·57
	" 22– " 23	+5·24	+ 1·64
Philadelphia 16° 16m	" 26– " 27	+4·86	+ 1·10
	" 27– " 28	+4·73	+ 0·78
Washington 17° 14m	" 31–June 1	+4·95	+ 1·01
	June 1– " 2	+4·77	+ 1·00
Washington 23° 14m	" 23– " 24	+4·85	+ 0·29
	" 24– " 25	+4·91	+ 0·17
	" 25– " 27	+5·02	+ 0·13
Deer Park 19° 770m	July 2–July 3	+4·45	+ 0·52
	" 3– " 4	+4·45	+ 0·61
Cleveland 20° 210m	" 7– " 8	+5·15	+ 0·88
	" 8– " 9	+4·81	+ 0·86

Station. Average temperature and elevation.	Interval.	Daily rate +losing. −gaining. Negus 1824.	Negus 1823.
	1894.	*s.*	*s.*
Chicago 23° 182m	July 11–July 12	+4·64	+0·57
	" 12– " 13	+5·17	+0·95
	" 13– " 14	+4·97	+0·81
	" 14– " 15	+5·02	+1·01
	" 15– " 16	+4·68	+0·74
Lower Basin 21° 2200m	" 24– " 25	+3·86	−0·18
	" 25– " 26	+3·64	−0·36
Grand Canyon 14° 2386m	" 28– " 29	+4·68	+0·14
	" 29– " 30	+4·53	+0·09
Norris Basin 14° 2276m	" 31–Aug. 1	+4·25	+0·43
Salt Lake 23° 1322m	Aug. 6– " 7	+4·24	+0·05
	" 7– " 8	+4·09	+0·02
Pleasant Valley 14° 2191m	" 10– " 11	+4·63	+0·34
	" 11– " 12	+4·97	+0·39
Green River 21° 1243m	" 13– " 14	+3·97	−0·10
	" 14– " 15	+4·08	+0·03
Grand Junction 23° 1398m	" 18– " 19	+4·40	+0·10
	" 19– " 20	+4·03	−0·16
Gunnison 16° 2340m	" 22– " 23	+3·77	−0·32
	" 23– " 24	+3·77	−0·42
Colorado Springs 18° 1841m	" 27– " 28	+3·77	−0·27
	" 28– " 29	+3·71	−0·16
Pikes Peak 8° 4293m	" 31–Sept. 2	+4·78	+0·40
	Sept. 2– " 2	+4·84	0·00
Denver 19° 1638m	" 5– " 6	+3·85	+0·56
	" 6– " 8	+3·98	+0·79
	" 8– " 10	+3·95	+0·64
Wallace 17° 1005m	" 14– " 15	+4·78	+1·34
	" 15– " 16	+4·43	+1·15
Ellsworth 21° 469m	" 18– " 19	+4·35	+1·25
	" 19– " 20	+4·50	+1·35
Kansas City 21° 278m	" 22– " 24	+4·82	+1·10
St. Louis 18° 154m	Oct. 11–Oct. 12	+5·02	+1·35
	" 12– " 13	+5·22	+1·38
Terre Haute 22° 151m	" 16– " 18	+4·87	+1·31
Cincinnati 18° 245m	" 22– " 23	+5·00	+1·28
	" 23– " 24	+4·58	+1·15
Washington 17° 14m	" 31–Nov. 1	+5·12	+1·30
	Nov. 1– " 2	+5·19	+1·50
	" 2– " 3	+4·99	+1·43
	" 3– " 4	+5·09	+1·61

Reduction of observations.—The methods of computation are mostly the same as those detailed in Report for 1891, pages 517 to 521. The periods are reduced to the standard conditions, arc infinitely small, temperature 15° C., pressure 60mm of mercury at 0° C. (instead of 500mm, except in work up to April 2), sidereal time, and inflexible support. The periods are computed separately from the first and last "up" coincidence, and the first and last "down" coincidence, and the mean of the two taken, thus eliminating the effect of any error in the adjustment of the fixed mirror. The corrections to the period in seconds may be summarized as follows:

Arc correction $= -\frac{PM}{32}\frac{\sin(\varphi+\varphi')\sin(\varphi-\varphi')}{\log\sin\varphi - \log\sin\varphi'}$, where P is period, M is modulus of common logarithmic system, φ and φ' are initial and final semiarcs.

Temperature correction $= +\,0{\cdot}000\,00419\,(15^\circ - T^\circ)$, where T° is observed temperature in degrees centigrade.

Pressure correction $= +\,0{\cdot}000\,000101\left[60 - \frac{Pr}{1+{\cdot}00367\ T^\circ}\right]$, where Pr is observed pressure in millimetres, and T° is temperature (except in work up to April 2, where reduction is to standard pressure of 500mm).

Rate correction = + 0·000 01157 RP, where P is period and R is daily rate on sidereal time in seconds (+ if losing, − if gaining).

Flexure correction = − 0·000 00065 D, where D is the observed displacement of knife-edge in microns when force of 1·5 kilogrammes is applied horizontally in the plane of oscillation.

Comparison of knife-edges.—Two agate knife-edges, known as A I and A II, were provided with this apparatus, each edge being set in its own metal block and provided with a lifting arm, so that either could be readily secured in the pendulum receiver. The regular swings with all three pendulums were made on A I at all stations with one accidental exception (Kansas City), but in order to guard against injury to it, and also to ascertain if there was any wear sufficient to affect the period, the second edge, A II, was carried along and a complete series of swings made on it at Washington before and after the transcontinental series, as well as at two stations, Chicago and Denver. The following is a summary of the reduced periods (mean of A 4, A 5, and A 6) on the two edges and their differences:

	Date.	Period on A I.	Period on A II.	Differences A I—A II.
	1894.	*s.*	*s.*	*s.*
Washington, D. C.	June 23–27	·500 7124	·500 7110	+·000 0014
" "	Oct. 31–Nov. 4	7121	7108	+ 13
Chicago, Ill.	July 11–16	6697	6689	+ 08
Denver, Colo.	Sept. 5–10	8409	8392	+ 17
			Mean	+·000 0013

The above indicates a fairly constant difference in period on the two knife-edges, although A I was used about 1,008 hours and A II about 264 hours only. It is safe to conclude, therefore, that there was no appreciable wear. This is further shown by a comparison of the periods at Washington in June and November, showing a diminution for A I of ·000 0003^s and for A II of ·000 0002^s, both insignificant quantities.

The following is a summary of all the determinations that have thus far been made on knife-edge A I at Washington with the system of low-pressure swings:

Station.	Date.	Approximate average temperature.	Corrected periods on knife-edge A I.			
			Pendulum A 4.	Pendulum A 5.	Pendulum A 6.	Mean of three pendulums.
	1894.	° *C.*	*s.*	*s.*	*s.*	*s.*
Washington, D. C. (C. and G. S. Office)	Apr. 25–Apr. 27	16	·500 8406	·500 6662	·500 6300	·500 7123
	May 10–May 12	19	8404	6666	6304	7124
	May 31–June 2	17	8408	6664	6302	7124
	June 23–June 25	23	8408	6662	6302	7124
	Oct. 31–Nov. 2	17	8400	6656	6306	7121
	1895.					
	Jan. 11–Jan. 13	11	8404	6677	6294	7125

The above means indicate a very satisfactory permanency of period. As these determinations are distributed over different portions of the year, they may also be taken as evidence within the error of observation as to the invariability of gravity. As the temperature at which the observations were made was different at these various seasons, they further confirm the reliability of the temperature coefficient, though of course some of these elements may compensate each other. It is possible that the change of period which has been found in many series of observations on redetermining the period at a base station after a gravity expedition is due to the fact that the knife-edge was often used immediately after grinding. There are possibly slight irregularities in a new edge, and there may be some change of period until it becomes slightly worn. The fact that the knife-edge is not in the pendulum will probably not diminish its effect on the period in this respect. The knife-edges A I and A II had both had considerable use previous to this work. As the system used of making an entirely independent set of swings on the standard edge added considerably to the time and labor consumed, the plan of using successively two or three knife-edges in the regular set of observations will probably be preferable. This will give a constant

check on their permanency, will make the results with the separate pendulums more independent, and thus avoid the objection to swinging three pendulums on a single edge without increasing the time consumed.

Results.—In Table G are given the details of the observations and reductions for each swing in the regular series, the details of the extra observations on knife-edge A II, and with the quarter-second pendulums being omitted. In Table C are collected the mean periods for each pendulum and station, all reduced to the standard conditions, arc infinitely small, temperature 15° C., pressure 60^{mm} at 0° C., sidereal time, and inflexible support. For this purpose the quantity ·000 0360^{s} (found by experiment) was subtracted from the periods up to April 2, to reduce from 500^{mm} to 60^{mm}, as up to that date a standard pressure of 500^{mm} was used, as already stated. The differences of the period of each pendulum from the mean of the three are also given as a test of the work. If the observations were perfect and the pendulums invariable these differences should of course be constant. As will be seen, the variations of the differences are inconsiderable.

TABLE C.—*Summary of corrected periods.*

ON KNIFE-EDGE A I.

Station.	Date.	Periods.				Differences from mean (seventh decimal place).		
		Pendulum A 4.	Pendulum A 5.	Pendulum A 6.	Mean of three pendulums.	A 4.	A 5.	A 6.
	1894.	s.	s.	s.	s.			
Washington	Jan. 8–11	·500 8405	·500 6670	·500 6312	·500 7129	+1276	—459	—817
"	Mar. 30–Apr. 2	8405	6658	6296	7120	+1285	—462	—824
Cambridge	Mar. 6–9	7672	5940	5570	6394	+1278	—454	—824
Boston	Mar. 11–14	7684	5942	5574	6400	+1284	—458	—826
Ithaca	Mar. 21–24	7929	6178	5827	6645	+1284	—467	—818
Washington	Apr. 25–27	8406	6662	6300	7123	+1283	—461	—823
"	May 10–12	8404	6666	6304	7124	+1280	—458	—821
"	May 31–June 2	8408	6664	6302	7124	+1284	—460	—822
Charlottesville	May 2–6	8860	7110	6747	7572	+1288	—462	—825
Princeton	May 17–23	8248	6496	6143	6962	+1286	—466	—819
Philadelphia	May 26–28	8195	6456	6096	6916	+1279	—460	—820
Washington	June 23–25	8408	6662	6302	7124	+1284	—462	—822
"	Oct. 31–Nov. 2	8400	6656	6306	7121	+1279	—465	—815
Deer Park	July 2–4	8858	7105	6758	7574	+1284	—469	—816
Cleveland	July 7–9	8079	6334	5966	6793	+1286	—459	—827
Chicago	July 11–16	7972	6239	5879	6697	+1275	—458	—818
Lower Basin	July 24–26	8861	7120	6763	7581	+1280	—461	—818
Grand Canyon	July 28–30	8934	7210	6852	7665	+1269	—455	—813
Norris Basin	July 31–Aug. 1	8818	7068	6722	7536	+1282	—468	—814
Salt Lake City	Aug. 6–8	9196	7457	7082	7912	+1284	—455	—830
Pleasant Valley	Aug. 10–12	9939	8187	7838	8655	+1284	—468	—817
Green River	Aug. 13–15	9610	7883	7524	8339	+1271	—456	—815
Grand Junction	Aug. 18–20	9636	7888	7517	8347	+1289	—459	—830
Gunnison	Aug. 22–24	1 0375	8638	8260	9091	+1284	—453	—831
Colorado Springs	Aug. 27–29	0 9986	8258	7893	8712	+1274	—454	—819
Pikes Peak	Aug. 31–Sept. 2	1 1365	9622	9266	1 0084	+1281	—462	—818
Denver	Sept. 5–7	0 9684	7946	7596	8409	+1275	—463	—813
Wallace	Sept. 14–16	9313	7586	7208	8036	+1277	—450	—828
Ellsworth	Sept. 18–20	8878	7137	6778	7598	+1280	—461	—820
St. Louis	Oct. 11–13	8692	6948	6579	7406	+1286	—458	—827
Terre Haute	Oct. 16–18	8510	6752	6406	7223	+1287	—471	—817
Cincinnati	Oct. 22–24	8678	6943	6571	7397	+1281	—454	—826

ON KNIFE-EDGE A II.

Washington	June 25–27	·500 8395	·500 6652	·500 6283	·500 7110	+1285	—458	—827
"	Nov. 2–4	8388	6650	6286	7108	+1280	—458	—822
Chicago	July 13–15	7970	6230	5867	6689	+1281	—459	—822
Denver	Sept. 7–10	9673	7932	7570	8392	+1281	—460	—822
Kansas City	Sept. 22–24	8700	6964	6595	7420	+1280	—456	—825

From these mean periods gravity at the various stations was computed from the relation $g_o = \frac{P_w^2}{P_o^2} g_w$, gravity at Washington Coast and Geodetic Survey Office (g_w) being assumed to be 980·098 dynes, and the mean of the periods at Washington before and after each series being taken for P_w.

Although an elaborate measurement of the absolute force of gravity was made at Washington in October, 1893, by Commandant Defforges,* it is thought best to adhere for the present to the provisional value previously adopted for Washington (Smithsonian Institution), giving the above value at Coast and Geodetic Survey Office, so as to make these results directly comparable with those already published. Large discrepancies appear among the results of the best determinations of absolute gravity made at the base stations in Europe, as will be seen by examining the table of values reduced to Washington in Part IV of this report. The mean of the twenty-nine results there given is not very different from the adopted provisional value.

The results for g computed separately for each pendulum and station, with the mean and differences from the mean, are given in Table D.

TABLE D.—*Values of g computed from each pendulum and knife-edge.*

No.	Station.	Knife-edge.	g (in dynes).				Differences from mean (in dynes).		
			Pendulum A 4.	Pendulum A 5.	Pendulum A 6.	Mean of three pendulums.	A 4.	A 5.	A 6.
1	Washington (C. and G. S.)	I and II				980·098			
2	Cambridge	I	980·385	980·382	980·386	980·384	+·001	—·002	+·002
3	Boston	I	980·381	980·381	980·384	980·382	— 1	— 1	+ 2
4	Ithaca	I	980·284	980·288	980·285	980·286	— 2	+ 2	— 1
5	Charlottesville	I	979·922	979·925	979·926	979·924	— 2	+ 1	+ 2
6	Princeton	I	980·163	980·166	980·163	980·164	— 1	+ 2	— 1
7	Philadelphia	I	980·183	980·182	980·182	980·182	+ 1	0	0
8	Deer Park	I	979·920	979·923	979·920	979·921	— 1	+ 2	— 1
9	Cleveland	I	980·225	980·225	980·230	980·227	— 2	— 2	+ 3
10	Chicago	I	980·267	980·262	980·264	980·264	+ 3	— 2	0
	"	II	980·263	980·263	980·262	980·263	0	0	— 1
11	Lower Basin	I	979·919	979·918	979·918	979·918	+ 1	0	0
12	Grand Canyon	I	979·890	979·882	979·884	979·885	+ 5	— 3	— 1
13	Norris Basin	I	979·935	979·938	979·934	979·936	— 1	+ 2	— 2
14	Salt Lake City	I	979·788	979·785	979·793	979·789	— 1	— 4	+ 4
15	Pleasant Valley	I	979·497	979·500	979·497	979·498	— 1	+ 2	— 1
16	Green River	I	979·626	979·619	979·620	979·622	+ 4	— 3	— 2
17	Grand Junction	I	979·616	979·618	979·623	979·619	— 3	— 1	+ 4
18	Gunnison	I	979·327	979·324	979·332	979·328	— 1	— 4	+ 4
19	Colorado Springs	I	979·479	979·472	979·476	979·476	+ 3	— 4	0
20	Pikes Peak	I	978·940	978·939	978·941	978·940	0	— 1	+ 1
21	Denver	I	979·597	979·595	979·592	979·595	+ 2	0	— 3
	"	II	979·597	979·597	979·595	979·596	+ 1	+ 1	— 1
22	Wallace	I	979·743	979·735	979·744	979·741	+ 2	— 6	+ 3
23	Ellsworth	I	979·912	979·911	979·913	979·912	0	— 1	+ 1
24	Kansas City	II	979·977	979·973	979·979	979·976	+ 1	— 3	+ 3
25	St. Louis	I	979·985	979·985	979·990	979·987	— 2	— 2	+ 3
26	Terre Haute	I	980·056	980·061	980·058	980·058	— 2	+ 3	0
27	Cincinnati	I	979·991	979·987	979·993	979·990	+ 1	— 1	+ 3

Reduction to sea level.—The reduction known as Bouguer's formula (sometimes improperly called Young's rule) has been very generally applied in reducing pendulum observations to the level of the sea. This formula is $dg = + \frac{2gH}{r}\left(1 - \frac{3\delta}{4\triangle}\right)$, where dg is the correction to observed gravity, g is gravity at sea level, H is elevation above sea level, r is radius of the earth, δ is density of

* See Part V of this report. For description of the apparatus and elegant methods developed and used by Commandant Defforges see Mémorial du Dépôt Général de la Guerre, Tome XV, Observations du Pendule, Paris, 1894; also Proces-Verbaux du Comité International des Poids et Mesures pour 1891, Mesure de l'Intensité absolue de la Pesanteur à Breteuil; and various papers in Comptes Rendus de l'Association Géodésique Internationale, from 1887 to 1893.

matter lying above sea level, and $\triangle$ is mean density of the earth. The first term takes account of the distance from the earth's center, and the second term of the vertical attraction of the matter lying between the sea level and station, on the supposition that the latter is located on an indefinitely extended horizontal plain. Wherever the topography about a station departs materially from this condition of a horizontal plain a third term must be added to the above formula, being a correction to the second term or to observed gravity on account of such irregularities.* This, which may be called the topographical correction, will always be positive, as the effect of all deviations from the horizontal plain, whether hills or mountains rising above the station, or valleys or canyons lying below it, will be to diminish the force of gravity. It is evident that an elevation of any sort exactly neutralizes the vertical attraction of a similar but inverted mass below the station level, so that the removal of both would not change the force of gravity at the station. This correction may be readily computed for any point where contour maps of the surrounding country are available, by describing thereon concentric circles about the station and drawing radial lines therefrom at equal angular distances, as shown in figure 3 (or this design may be drawn on a sheet of tracing paper to be laid over the map).

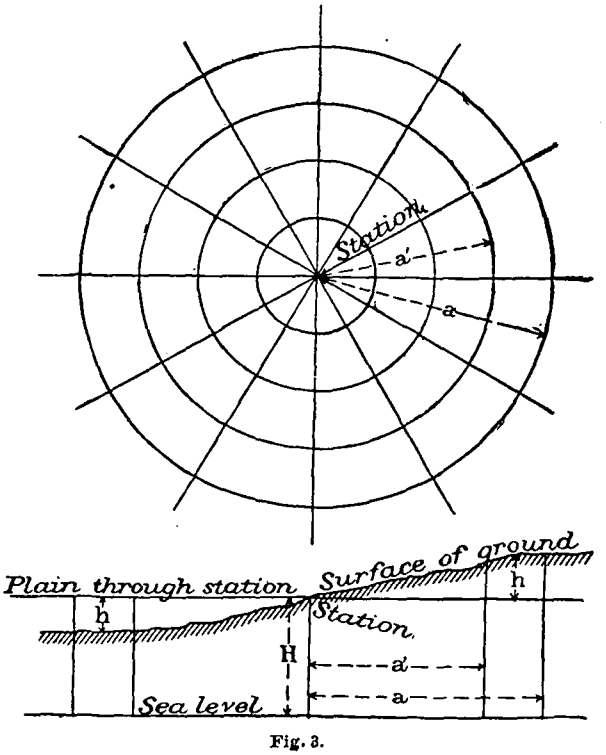


Fig. 3.

The space included between two circles may be designated as a zone, and the part of a zone between two radii as a compartment. The vertical attraction of a cylinder of radius a, height h, and density δ on a point at one extremity of its axis will be $2\pi\delta\,(a + h - \sqrt{a^2 + h^2})$. As a zone is the difference between two cylinders, say of radii a and a', its vertical attraction will be $2\pi\delta\,(a - a' - \sqrt{a^2 + h^2} + \sqrt{a'^2 + h^2})$. The attraction at its surface of the earth considered as a sphere is $\frac{4}{3}\pi \triangle r$ where $\triangle$ is the mean density and r the radius of the earth. Therefore the effect

* The method of computing this correction described here is similar to that given by Dr. Helmert, Geodäsie, Vol. II, page 169. It is much simpler in application than the method used in reducing the Indian series of pendulum observations, described in Vol. V, G. T. Survey of India. This subject is also discussed at length in Pratt's Figure of the Earth. See also Die Schwerkraft im Hochgebirge, by Dr. F. R. Helmert, 1890.

on gravity of a zone is $dg = \frac{3\,g\,\delta}{2\,r\,\triangle}(a - a' - \sqrt{a^2+h^2} + \sqrt{a'^2+h_2})$, which becomes with a sufficient degree of approximation, when h is small compared with a, $dg = \frac{3\,g\,\delta}{2\,r\,\triangle}\frac{h^2}{2}\left(\frac{1}{a'} - \frac{1}{a}\right)$, or $dg = k\frac{h^2}{2}\left(\frac{1}{a'} - \frac{1}{a}\right)$ where $k = \frac{3\,g\,\delta}{2\,r\,\triangle}$.* This approximate formula may be readily computed with a table of squares and reciprocals if convenient numbers are taken for a' and a, and will be sufficiently accurate except when the topography is very uneven near the station, in which case the preceding formula must be used. h is to be taken for each compartment as the difference in elevation, regardless of sign, between the station and the average surface of the compartment. As this will vary for different portions of a zone, the parts of the formula involving h must be computed separately for each compartment therein, and the mean applied in the formula for the zone. When these zones have been carried to such a distance from a station that their effect begins to become insignificant, the vertical attraction of the remaining region may be readily computed by the formula $dg = k\,(\sqrt{a^2+h^2} - a)$, where a is the outer radius of the last zone, this being the formula for the difference between an infinite plain of thickness h and a cylinder of height h and radius a. The area immediately about the station within the first circle may often be neglected as approximately level, or otherwise the effect of its irregularity may be computed by taking the difference between a cylinder and a cone, the formula becoming $dg = k\left(a - \frac{a^2}{\sqrt{a^2+h^2}}\right)$, where a is the radius and h the difference of elevation at distance a from the station, taken for each compartment separately, keeping in mind always that we are computing only the correction to the vertical attraction of an infinite horizontal plain through the station, and therefore only need take account of deviations therefrom. The total correction for a station will of course be the sum of the corrections for the separate zones. Where the station is at the summit of a small hill rising out of a comparatively level country, it will generally suffice to treat the hill as a cone without dividing the country into compartments; the formula for this case is $dg = k\frac{h^2}{\sqrt{a^2+h^2}}$, which represents the difference between the vertical attraction of an infinite plain of thickness h and a cone of height h and radius a.

The effect of topographical irregularities has been investigated in the manner described for all the stations of the past season, using wherever available the contour maps of the Geological Survey. Although applied in all cases where appreciable, at only one station, Pikes Peak, was this correction found to be of real importance. This is partly due to the favorable location of the stations, but also to the fact that except on the summit of rugged mountains or very close to their base, or in deep, narrow valleys, this correction must necessarily be small. The effect of placing an infinite horizontal plain 114 feet (35 metres) in thickness, or a sphere 338 feet (103 metres) in diameter, and of density equal to one-half the mean density of the earth, immediately above a station would be to diminish gravity by only ·004 dyne, or about the $\frac{1}{250\,000}$th part, which may at present be taken as the utmost limit of probable accuracy of observation. These considerations indicate that for a majority of stations in open country a rough estimate will show that the topographical correction is inappreciable.

The question of the proper reduction of pendulum observations to the level of the sea, involving as it does the various theories of the condition of the earth's crust, and affecting very materially the use of such observations in deducing the figure of the earth, is a most important one, and has led to the expression of many different opinions. Bouguer's reduction, above described, has been very generally adopted. Professor Helmert, in the masterly discussion of pendulum observations in his Höhere Geodäsie, develops and uses the condensation method, assuming a surface 21 kilometres below the sea level, to which all the overlying material is condensed. As approximately applied by him in the discussion of continental stations this reduction amounts to omitting the correction for attraction (second term) in Bouguer's formula, but not so in coast and oceanic island stations, where the effect of the lesser density of sea water is taken into account.

* Taking $g = 979{\cdot}5$, $\delta = 2{\cdot}56$, $\triangle = 5{\cdot}58$, $r = 20\,890\,000$ feet, or $6\,367\,000$ metres, $k = {\cdot}000\,0323$ with h and a in feet, or $k = {\cdot}000\,1059$ with h and a in metres.

M. Faye, in papers published in Comptes Rendus in 1880 and 1883, advocates that the continental attraction term in Bouguer's formula be omitted, but that all local deviations of the elevation of the station from the general level of the land surface or sea bottom be allowed for, as, for instance, the attraction of a mountain on a station at its summit, or of an isolated island. This subject has also been discussed by Stokes, Peirce, Ferrel, and many others. In the recent reports on pendulum observations in the Proceedings of the International Geodetic Association, the reductions have been made by two methods: First, with Bouguer's formula, and second, using the reduction for elevation, omitting the attraction term; and the same plan is followed in the summary of results given in Table E. The surface densities here given have been kindly furnished by Mr. G. K. Gilbert, of the United States Geological Survey, who visited personally many of the stations and made careful estimates for all.* They represent the average for the mass above sea level at each station. The value 5·58 has been used for the mean density of the earth. So as to be able to study the results more intelligently, the values at sea level have been compared with those computed by an assumed theoretical formula $g = 978{\cdot}066\,(1 + {\cdot}005\,243\,\sin^2\varphi)$, which is based on Clairant's theorem, Clarke's figure of the earth, and the assumption that gravity is normal on the eastern coast of the United States. Finally, this table gives the differences observed, minus computed gravity, for both methods of reduction to sea level. These differences are shown graphically in the diagrams in connection with the map (fig. 4), where also are included two stations, San Francisco and Mount Hamilton, previously determined.

While it is somewhat unsafe to draw general conclusions from a single series of observations, yet the favorable and systematic situation of these stations with respect to an unusual variety of continental conditions perhaps warrants the pointing out of a few possible inferences. With Bouguer's reduction there is apparently a considerable defect of gravity under the western mountains and plateaus having a striking relation in amount to the average continental elevations. This can not be accounted for to any great extent by a supposed abnormal condition in the mass above sea level, as it would require that that mass should have a density of zero to offset this defect; the presumption is, therefore, that there is a deficiency of density below sea level which in general compensates the elevated masses. Contrary to a recent assertion, the residuals do not appear to have

* Mr. Gilbert also furnished the following enumeration of the more important underlying rocks, stated in the order of their relative thickness, for each of the gravity stations except Boston, Cambridge, and Philadelphia:

Princeton,	Shale, sandstone.
Washington (Coast and Geodetic Survey),	Sand, clay.
Washington (Smithsonian),	Sand, clay.
Ithaca,	Shale.
Charlottesville,	Gneiss.
Deer Park,	Sand, shale.
Cleveland,	Shale.
Cincinnati,	Shale, limestone.
Terre Haute,	Shale, sandstone, limestone.
Chicago,	Limestone.
St. Louis,	Limestone, shale.
Kansas City,	Shale, limestone.
Ellsworth,	Shale, sandstone.
Wallace,	Shale, sandstone.
Colorado Springs,	Shale, sandstone, limestone.
Denver,	Sandstone, shale.
Pikes Peak,	Granite.
Gunnison,	Granite, sandstone, gravel.
Grand Junction,	Shale, sandstone, gravel.
Green River,	Shale, sandstone.
Grand Canyon,	Shale, sandstone, rhyolite, limestone.
Norris Basin,	Shale, sandstone, rhyolite, limestone.
Lower Basin,	Shale, sandstone, rhyolite, limestone.
Pleasant Valley,	Shale, sandstone, limestone.
Salt Lake City,	Sand, clay, gravel.
Mount Hamilton,	Sandstone.
San Francisco,	Sandstone.

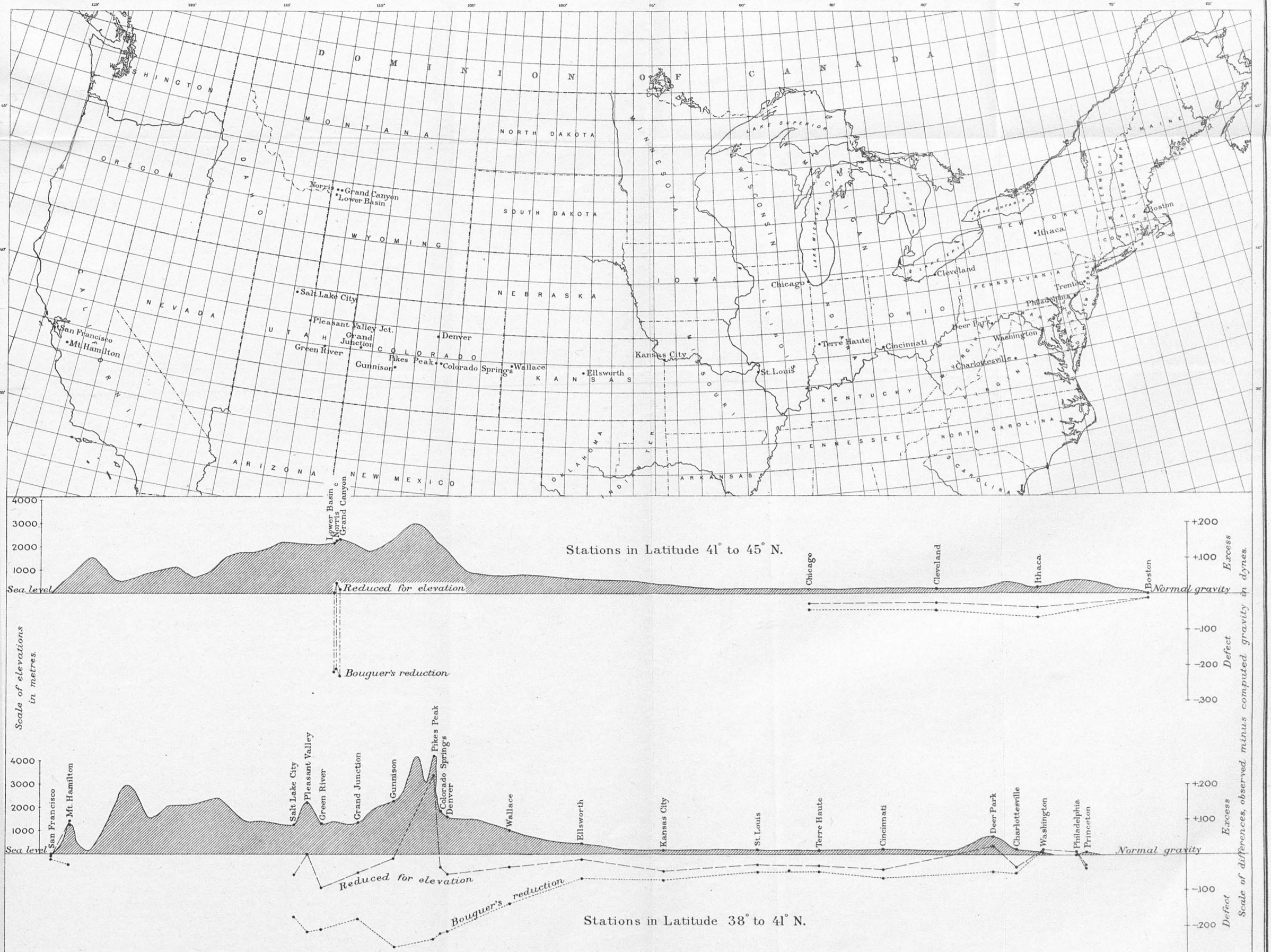


Fig. 4. *Diagrams showing relative positions of stations in elevation and longitude and differences observed minus computed gravity when sea level reduction is made by Bouguer's formula (dotted line), or by correction for elevation only (dashed line). (Denver is slightly displaced in longitude).*

any relation to distance from the sea, or to the elevation of the particular point of observation, as is shown by the fairly horizontal lines under that part of the central plain (Cincinnati to Ellsworth) where the altitude is nearly the same, and the nearly equal deficiencies found at stations which, like Gunnison, Pikes Peak, Colorado Springs, and Denver, vary enormously in elevation. With the reduction for elevation only the apparent defect of gravity largely disappears, as shown by the nearly horizontal line of residuals under the great central plains, where the altitude varies from 151 to 1841 metres (495 to 6041 feet), and by the average result in the mountain regions. In the latter, however, the line shows considerable departures from the normal, both positive and negative, the residuals showing a striking relation to the elevations of the stations as compared with the elevations of the surrounding country. Pikes Peak, Pleasant Valley, Mount Hamilton, and the Yellowstone station are above the average level and show an excess of gravity, while the remaining Rocky Mountain stations are below the general level and all show a defect of gravity. This condition is especially marked in the case of Green River and Grand Junction, in the bottom of great eroded valleys, and Pikes Peak station, on the summit of an isolated mountain. The residuals are not proportional to the elevation of the station itself above sea level, as is at once seen by comparing Mount Hamilton, Salt Lake, Green River, Grand Junction, and Denver, which are of nearly equal elevation. Finally, with either system of reduction the residuals point to the probability that gravity is large on the seacoast as compared with the interior. Whether this can have any connection with the effects of erosion and deposition of continental matter is a question upon which the observations in this series are far too limited to throw any clear light, but for investigating which certain portions of the United States would furnish an excellent field.

The results of this series would therefore seem to lead to the conclusion that general continental elevations are compensated by a deficiency of density in the matter below sea level, possibly in much the same way that the portion of an iceberg standing above sea level is compensated by the difference in density of ice and water below the surface, but that local topographical irregularities, whether elevations or depressions, are not compensated for, such irregularities being maintained by the partial rigidity of the earth's crust.

The residuals with Bouguer's reduction should then be interpreted as a measure of the deficiency of density, and, on the other hand, the residuals with the reduction for elevation should be taken as a measure of the lack of compensation, after allowing for uncertainties of observation and the effects of local geological conditions. Developing the idea of M. Faye, observed values of g may be corrected for this lack of compensation by adding or subtracting the vertical attraction of a horizontal plain whose thickness is the difference in elevation between the station and the average surrounding surface. This correction may be expressed $dg = 2\ g\ \frac{h}{r}\frac{3}{4}\frac{\delta}{\Delta}$, which represents the attraction of an indefinitely extended horizontal plain of thickness h and density δ, and the correction is positive for stations below the average level and negative for those above. This method has been tested by applying it to the stations most affected in the present series, the average elevation being approximately estimated from a contour map for the country within an arbitrarily adopted radius of 100 miles of each station. The resulting corrections are shown in the following table, together with the residuals, g observed minus g computed (under the head of "Faye's reduction"), when this compensation correction was applied, together with the elevation and topographical corrections. These residuals are also compared with those obtained by the two methods of reduction in Table C. The sums of the residuals (regardless of sign) for the fourteen stations are—

With reduction	by Bouguer's method	2·577	dynes.
"	" for elevation	0·677	"
"	" by Faye's method	0·175	"

indicating apparently a considerable advantage for the latter. It is probable that no particular significance attaches to these residuals remaining after the application of Faye's reduction, for several reasons; other values would certainly result if a different area were considered in estimating the average surrounding elevation, or if weight were given according to proximity to the station in making this estimation; and the average elevations here given are subject to some uncertainty, as they were obtained from a small scale map.

Station.	Elevation.			Correction to observed g for lack of compensation $2g\frac{h}{r}\frac{3}{4}\frac{\delta}{\Delta}$	Residuals, g observed $-g$ computed.		
	Average within radius of 100 miles of station H_1.	Station H.	Difference, average minus station $h=H_1-H$.		Faye's reduction.	Reduced for elevation.	Bouguer's reduction.
Appalachian.	*Metres.*	*Metres.*	*Metres.*	*Dynes.*	*Dynes.*	*Dynes.*	*Dynes.*
Ithaca	345	247	+ 98	+·010	—·029	—·039	— ·063
Charlottesville	341	166	+ 175	+·019	—·019	—·038	— ·056
Deer Park	479	770	— 291	—·029	—·005	+·024	— ·053
Central plains.				Sums	·053	·101	·172
Colorado Springs	2258	1841	+ 417	+·041	+·003	—·038	— ·221
Denver	2212	1638	+ 574	+·056	·000	—·056	— ·215
Rocky Mountains.				Sums	·003	·094	·436
Pikes Peak	2258	4293	—2035	—·220	+·006	+·226	— ·239
Gunnison	2724	2340	+ 384	+·042	+·035	—·007	— ·263
Grand Junction	2251	1398	+ 853	+·085	+·033	—·052	— ·192
Green River	2112	1243	+ 869	+·087	—·003	—·090	— ·214
Grand Canyon	2137	2386	— 249	—·026	—·010	+·016	— ·236
Norris Basin	2137	2276	— 139	—·014	+·016	+·030	— ·205
Lower Basin	2137	2200	— 63	—·007	—·001	+·006	— ·221
Pleasant Valley	2044	2191	— 147	—·015	—·013	+·002	— ·220
Salt Lake City	1894	1322	+ 572	+·055	+·002	—·053	— ·179
				Sums	·119	·482	1·969

An inspection of the table shows that the residuals with Bouguer's reduction are very nearly proportional to the average surrounding elevations, though bearing no relation to the actual station elevations.

The true reduction of gravity observations to sea level would appear to be one that would take account not only of the attraction of matter above the sea level but also of the general differences of density below, as well as of the local lack of compensation if the latter can be proved to have a systematic relation to the topographical situation of the point of observation, as is strongly indicated by these results. With such a method it is quite possible that the so-called anomalies of gravity will largely disappear and that the distribution of gravity on the earth's surface will be found to follow Clairaut's law sufficiently closely to greatly enhance the value of pendulum observations in relation to the problem of the earth's figure.

As furnishing further evidence on this subject, there is collected in Table F a summary of the various other Coast and Geodetic Survey series of gravity measurements based on Washington, and made by Dr. Mendenhall, Mr. Preston, and Mr. Smith. As these include a number of oceanic island and coast stations, it was necessary in applying Faye's idea of reduction to take account of the difference in density between sea water and land. This was done by assuming the water as condensed down until its density equaled that of land, and using the upper surface of this condensed mass in estimating the average elevation of the surrounding region. In application, the depth of sea water at any point, multiplied by $\left(1-\frac{\delta_1}{\delta}\right)$, where δ_1 is density of sea water and δ is density of land beneath the station, gives the depression below sea level of the assumed surface. By taking these depressions as negative elevations, the average surrounding elevation may be conveniently estimated for all stations, whether on large or small islands or continental coasts, the principal difficulty being the lack of sufficient data as to ocean depths, and of contour maps, and the uncertainty as to how large an area should be considered for each station. A similar treatment could be applied to continental stations where the regions surrounding varied considerably in density. In Table F are given the elevations of the stations, the average elevations within a radius of 100 miles, considering the water as condensed (estimated in nearly all cases from very imperfect data), the observed values of gravity, and the residuals, observed g minus computed g for both Bouguer's and Faye's reduction to sea level. These reductions were applied

in the same manner as before; the same theoretical formula was used for computed g, and average values were taken for the density of land (2·56) and of sea water (1·03). The mean residuals for each group and method of reduction, including also the results of the past season, are plotted to scale in the diagram (fig. 5), showing graphically the excess of gravity on islands and the defect on

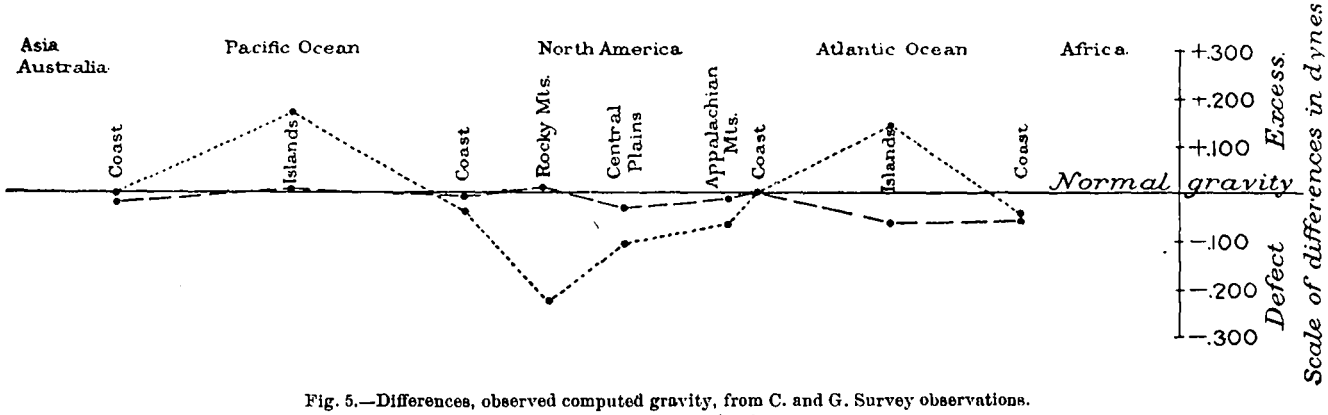


Fig. 5.—Differences, observed computed gravity, from C. and G. Survey observations.
Using Bouguer's reduction to sea level.....
" Faye's " " " " — — — —

continents when the sea-level reduction is made by Bouguer's formula, as has been pointed out from other series of observations. These apparent anomalies very largely disappear, however, on applying the theory of Faye. Most important light would be thrown on this subject by the measurement of gravity on the open sea, which may some day be accomplished by working on large fields of ice.

TABLE E.—*Summary of results, with reduction to sea level, and comparison with theoretical formula.*

No.	Station.	Latitude.	Longitude.	Elevation. H	Surface density. δ	g observed.	Reductions to sea level.			g reduced to sea level.		g_0 computed.	Residuals.	
							Elevation. $2g\frac{H}{r}$	Attraction. $2g\frac{H}{r}\frac{3}{4}\frac{\delta}{\Delta}$	Topographical correction.	Bouguer's formula g_1	Corrected for elevation. g_2		g_1-g_0	g_2-g_0
	Atlantic coast.	° ′ ″	° ′ ″	*Mtrs.*		*Dynes.*	*Dynes.*	*Dynes.*	*Dynes.*	*Dynes.*	*Dynes.*	*Dynes.*	*Dynes.*	*Dynes.*
3	Boston, Mass.	42 21 33	71 03 50	22	[2·5]	980·382	+ ·007	− ·002	·000	980·387	980·389	980·394	− ·007	− ·005
2	Cambridge, Mass.	42 22 48	71 07 45	14	[2·5]	980·384	+ ·004	− ·001	·000	980·387	980·388	980·396	− ·009	− ·008
6	Princeton, N. J.	40 20 57	74 39 28	64	2·44	980·164	+ ·020	− ·006	·000	980·178	980·184	980·216	− ·038	− ·032
7	Philadelphia, Pa.	39 57 06	75 11 40	16	[2·5]	980·182	+ ·005	− ·002	·000	980·185	980·187	980·181	+ ·004	+ ·006
1	Washington (C. and G. S.).	38 53 13	77 00 32	14	2·3	980·098	+ ·004	− ·001	·000	980·101	980·102	980·087	+ ·014	+ ·015
0	Washington (Smithsonian).	38 53 20	77 01 32	10	2·3	[980·100]	+ ·003	− ·001	·000	980·102	980·103	980·087	+ ·015	+ ·016
	Appalachian elevation.													
4	Ithaca, N. Y.	42 27 04	76 29 00	247	2·4	980·286	+ ·076	− ·024	+ ·001	980·339	980·363	980·402	− ·063	− ·039
5	Charlottesville, Va.	38 02 01	78 30 16	166	2·65	979·924	+ ·051	− ·018	·000	979·957	979·975	980·013	− ·056	− ·038
8	Deer Park, Md.	39 25 02	79 19 50	770	2·42	979·921	+ ·237	− ·077	·000	980·081	980·158	980·134	− ·053	+ ·024
	Central plains.													
9	Cleveland, Ohio	41 30 22	81 36 38	210	2·4	980·227	+ ·065	− ·021	·000	980·271	980·292	980·318	− ·047	− ·026
27	Cincinnati, Ohio	39 08 20	84 25 20	245	2·45	979·990	+ ·075	− ·025	+ ·001	980·041	980·066	980·109	− ·068	− ·043
26	Terre Haute, Ind.	39 28 42	87 23 49	151	2·35	980·058	+ ·046	− ·015	·000	980·089	980·104	980·139	− ·050	− ·035
10	Chicago, Ill.	41 47 25	87 36 03	182	2·63	980·264	+ ·056	− ·020	·000	980·300	980·320	980·343	− ·043	− ·023
25	St. Louis, Mo.	38 38 03	90 12 13	154	2·6	979·987	+ ·047	− ·017	·000	980·017	980·034	980·065	− ·048	− ·031
24	Kansas City, Mo.	39 05 50	94 35 21	278	2·5	979·976	+ ·086	− ·029	·000	980·033	980·062	980·105	− ·072	− ·043
23	Ellsworth, Kans.	38 43 43	98 13 32	469	2·4	979·912	+ ·144	− ·046	·000	980·010	980·056	980·073	− ·063	− ·017
22	Wallace, Kans.	38 54 44	101 35 26	1005	2·4	979·741	+ ·309	− ·100	·000	979·950	980·050	980·089	− ·139	− ·039
19	Colorado Springs, Colo.	38 50 44	104 49 02	1841	2.4	979·476	+ ·566	− ·183	+ ·003	979·862	980·045	980·083	− ·221	− ·038
21	Denver, Colo.	39 40 36	104 56 55	1638	2·35	979·595	+ ·504	− ·159	+ ·001	979·941	980·100	980·156	− ·215	− ·056
	Rocky Mountains.													
20	Pikes Peak, Colo.	38 50 20	105 02 02	4293	2·62	978·940	+ 1·321	− ·465	+ ·048	979·844	980·309	980·083	− ·239	+ ·226
18	Gunnison, Colo.	38 32 33	106 56 02	2340	2·65	979·328	+ ·720	− ·256	+ ·002	979·794	980·050	980·057	− ·263	− ·007
17	Grand Junction, Colo.	39 04 09	108 33 56	1398	2·42	979·619	+ ·430	− ·140	+ ·002	979·911	980·051	980·103	− ·192	− ·052
16	Green River, Utah	38 59 23	110 09 56	1243	2·42	979·622	+ ·383	− ·124	+ ·001	979·882	980·006	980·096	− ·214	− ·090
12	Grand Canyon, Wyo.	44 43 16	110 29 44	2386	2·55	979·885	+ ·734	− ·252	+ ·002	980·369	980·621	980·605	− ·236	+ ·016
13	Norris Geyser Basin, Wyo.	44 44 09	110 42 02	2276	2·5	979·936	+ ·700	− ·235	·000	980·401	980·636	980·606	− ·205	+ ·030
11	Lower Geyser Basin, Wyo.	44 33 21	110 48 08	2200	2·5	979·918	+ ·677	− ·227	+ ·001	980·369	980·596	980·590	− ·221	+ ·006
15	Pleasant Valley Junction, Utah	39 50 47	111 00 46	2191	2·45	979·498	+ ·674	− ·222	+ ·001	979·951	980·173	980·171	− ·220	+ ·002
14	Salt Lake City, Utah	40 46 04	111 53 46	1322	2·3	979·789	+ ·407	− ·126	+ ·004	980·074	980·200	980·253	− ·179	− ·053

TABLE F.—*Summary of former gravity determinations based on Washington.*

Station.	Latitude.	Elevation of station.	Average elevation within 100 miles.	g observed (not reduced to sea level).	g observed − g computed.	
					Bouguer's reduction.	Faye's reduction.
Continental stations.						
Asia and Australia, east coast:	° ′	*Metres.*	*Metres.*	*Dynes.*	*Dynes.*	*Dynes.*
Tokio, Japan	+35 42	6	− 180	979·774	−·037	−·056
Singapore	+ 1 17	14	0	978·070	+·004	+·004
Sydney, Australia	−33 52	43	− 300	979·670	+·020	−·011
				Means	−·004	−·021
North America, west coast:						
Yakutat Bay, Alaska	+59 32	4	+ 690	981·821	−·054	+·019
Pyramid Harbor, Alaska	+59 10	5	+1000	981·808	−·039	+·067
Juneau, Alaska	+58 18	5	+ 800	981·730	−·047	+·038
Sitka, Alaska	+57 03	9	− 60	981·680	+·005	−·001
Wrangell, Alaska	+56 28	7	+ 500	981·589	−·039	+·014
Burroughs Bay, Alaska	+55 59	0	+ 500	981·492	−·097	−·044
Port Simpson, British Columbia	+54 34	6	+ 370	981·450	−·019	+·021
Seattle, United States	+47 36	74	+ 530	980·712	−·135	−·079
San Francisco, United States (1891)	+37 47	114	− 280	979·951	−·017	−·047
Mount Hamilton, United States (1891)	+37 20	1282	+ 80	979·646	−·039	−·030
				Means	−·048	−·004
North America, east coast:						
Hoboken, United States	+40 44	11	0	980·256	+·008	+·008
Baltimore, United States	+39 18	30	0	980·083	−·034	−·034
Washington, United States (Smithsonian).	+38 53	10	0	980·100	+·015	+·015
				Means	−·004	−·004
Africa, west coast:						
Loanda, Angola	− 8 49	46	− 220	978·137	−·040	−·063
Cape Town, Cape Colony	−33 56	11	− 70	979·606	−·056	−·064
				Means	−·048	−·064
Oceanic island stations.						
Pacific Ocean:						
St. Paul, Alaska	+57 07	12	− 60	981·661	−·018	−·025
Honolulu, Hawaiian Islands	+21 18	6	−1930	978·936	+·194	−·010
Waikiki, Hawaiian Islands	+21 16	3	−1930	978·922	+·182	−·023
Haiku, Hawaiian Islands	+20 56	117	−1930	978·900	+·203	−·002
Lahaiua, Hawaiian Islands	+20 52	3	−1930	978·850	+·134	−·071
Pakaoao, Hawaiian Islands	+20 43	3001	−1930	978·266	+·214	+·010
Kawaihae, Hawaiian Islands	+20 02	2	−1670	978·803	+·136	−·041
Mauna Kea, Hawaiian Islands	+19 49	3981	−1670	978·060	+·244	+·068
Kalaieha, Hawaiian Islands	+19 43	2030	−1670	978·490	+·260	+·083
Caroline Islands	−10 00	2	−1800	978·361	+·141	−·050
Auckland, New Zealand	−36 52	80	− 80	980·020	+·124	+·115
				Means	+·165	+·005
Atlantic Ocean:						
St. Georges, Bermuda	+32 23	2	−2400	979·753	+·217	−·037
Georgetown, Ascension	− 7 56	5	−1560	978·237	+·074	−·092
Green Mountain, Ascension	− 7 57	686	−1560	978·084	+·065	−·100
Jamestown, St. Helena	−15 55	10	−2400	978·659	+·209	−·045
Longwood, St. Helena	−15 57	533	−2400	978·520	+·179	−·075
				Means	+·149	−·070

Mean density of the earth from Pikes Peak pendulum observations.—A value for the mean density of the earth has been deduced from the gravity measurements made on the summit of the Peak and at Colorado Springs, near the base. This method of comparing the known mass of a mountain with the unknown mass of the earth has been used on at least four previous occasions, but not, it is believed, under as favorable conditions as the present, for in this case contour maps of the Peak and surrounding country were available, and the mountain itself was found to be composed of rock of an unusually uniform density. Mr. Whitman Cross, of the United States Geological Survey, who has studied the geology of the vicinity, kindly furnished data in regard

to the specific gravity of the rock of which the Peak is composed. Twelve specimens collected from various parts and determined under Mr. Gilbert's direction gave values as follows: 2·57, 2·60, 2·61, 2·61, 2·62, 2·67, 2·57, 2·58, 2·61, 2·61, 2·63, 2·71. The mean, 2·615, has been adopted.

The difference in gravity at the base and summit of a mountain will be, by Bouguer's formula,

$$dg = \frac{2gH}{r}\left(1 - \frac{3}{4}\frac{\delta}{\triangle}\right) = \frac{2gH}{r} - \frac{3}{2}\frac{g\delta}{r\triangle}H,$$

considering the upper station as on an infinite horizontal plain, the lower station as unaffected by the attraction of the mountain, and neglecting the insignificant effect of change in centrifugal force. Here H is the difference in elevation of the two stations (2452 meters), r is the radius of the earth, δ is the density of the mountain (2·615), and $\triangle$ is the mean density of the earth. The correction to observed gravity for local topographical irregularities (or departure from the condition of a horizontal plain) was carefully computed for these two stations as described in discussing the reduction to the sea level, and found to be for Pikes Peak $+\frac{3g\delta}{2r\triangle}$ 439, and for Colorado Springs $+\frac{3g\delta}{2r\triangle}$ 27 (using the metre as unit of length). The observed values of gravity were for Pikes Peak 978·940, and for Colorado Springs 979·476, to which must be applied the above corrections for topographical irregularities to obtain dg for the above formula, which then becomes:

$$dg = \left(979{\cdot}476 + \frac{3g\delta}{2r\triangle}27\right) - \left(978{\cdot}940 + \frac{3g\delta}{2r\triangle}439\right) = \frac{2g}{r}2452 - \frac{3g\delta}{2r\triangle}2452$$

which reduces to $\cdot 536 = \frac{2g}{r}\left(2452 - \frac{\delta}{\triangle}1530\right)$ or $\triangle = 2{\cdot}153\,\delta = 5{\cdot}63$.

The value for the mean density of the earth derived from the Pikes Peak observations is therefore 5·63. In this computation no account has been taken of the estimated difference in density below the level of Colorado Springs.

TABLE G.*—*Pendulum observations and reductions.*

WASHINGTON, D. C. (COAST AND GEODETIC SURVEY).

Swing No.	Pendulum.	Position.	Date.	Coincidence interval.		Total arc.		Temperature.	Pressure.	Period uncorrected.		Corrections (seventh decimal place).						Period corrected.		
				1828.	1823.	Initial.	Final.			1828.	1823.	Arc.	Temperature.	Pressure.	Rate 1828.	Rate 1823.	Flexure.	1828.	1823.	Mean.
			1894.	s.	s.	′	′	° C.	mm.	s.	s.							s.	s.	s.
1	A4	D	Jan. 8	297·43	294·56	39	9	10·63	499	·500 8419	·500 8501	−3	+183	+1	+173	+86	−6	·500 8767	·500 8762	·500 8764
2	A4	D	9	297·42	294·52	42	12	10·50	500	8420	8503	−4	+188	0	+173	+86	−6	8771	8767	8769
3	A4	D	9	297·77	294·58	42	12	10·45	499	8410	8501	−4	+191	+1	+173	+86	−6	8765	8769	8767
4	A4	R	9	297·94	294·58	37	12	10·47	498	8405	8501	−4	+190	+1	+173	+86	−6	8759	8768	8764
5	A4	R	9	297·75	294·64	37	12	10·47	498	8410	8499	−4	+190	+1	+173	+86	−6	8764	8766	8765
6	A4	R	9	297·98	294·65	37	10	10·43	499	8404	8499	−3	+191	+1	+173	+86	−6	8760	8768	8764
7	A5	D	9	375·91	370·03	41	13	10·45	496	·500 6659	·500 6765	−4	+191	+3	+173	+86	−6	·500 7016	·500 7035	·500 7026
8	A5	D	10	375·15	370·09	41	13	10·45	497	6673	6764	−4	+191	+3	+173	+86	−6	7030	7034	7032
9	A5	D	10	375·21	370·21	42	10	10·35	496	6672	6762	−4	+195	+3	+173	+86	−6	7033	7035	7034
10	A5	R	10	376·02	371·26	42	12	10·20	494	6658	6743	−4	+201	+4	+173	+86	−6	7026	7024	7025
11	A5	R	10	375·60	371·75	42	12	10·07	494	6665	6734	−4	+207	+4	+173	+86	−6	7039	7021	7030
12	A5	R	10	376·10	371·80	42	11	9·97	495	6656	6733	−4	+211	+4	+173	+86	−6	7034	7024	7029
13	A6	D	10	398·60	392·90	42	14	10·02	496	·500 6280	·500 6371	−5	+209	+3	+173	+86	−6	·500 6654	·500 6658	·500 6656
14	A6	D	11	397·40	391·80	42	12	10·02	496	6299	6389	−4	+209	+3	+173	+86	−6	6674	6677	6676
15	A6	D	11	397·40	391·30	42	12	10·02	497	6299	6397	−4	+209	+2	+173	+86	−6	6673	6684	6678
16	A6	R	11	396·60	391·70	37	12	10·40	493	6311	6391	−4	+192	+5	+173	+86	−6	6671	6664	6668
17	A6	R	11	396·30	391·10	39	12	10·43	493	6316	6400	−4	+191	+5	+173	+86	−6	6675	6672	6674
18	A6	R	11	395·80	390·60	39	12	10·45	494	6324	6409	−4	+191	+5	+173	+86	−6	6683	6681	6682
																		·500 7489	·500 7490	·500 7489

* In this table, in the column "Position," D (direct) denotes face of pendulum with date toward observer, and R the reverse position he average number of seconds in one coincidence interval is given for each chronometer used; the temperature is the corrected mean for the swing, weighted, where intermediate readings were taken; the pressure is reduced to 0° C.; the rate correction is applied for each chronometer separately; the final mean period is derived by combining the separate means for each pendulum in each position.

TABLE G.—*Pendulum observations and reductions*—Continued.

CAMBRIDGE, MASS.

Swing No.	Pendulum.	Position.	Date.	Coincidence interval. 1824.	Coincidence interval. 1828.	Total arc. Initial.	Total arc. Final.	Temperature.	Pressure.	Period uncorrected. 1824.	Period uncorrected. 1828.	Corrections (seventh decimal place). Arc.	Temperature.	Pressure.	Rate 1824.	Rate 1828.	Flexure.	Period corrected. 1824.	Period corrected. 1828.	Period corrected. Mean.
			1894.	*s.*	*s.*	′	′	°*C.*	*mm.*	*s.*	*s.*							*s.*	*s.*	*s.*
1	A4	R	Mar. 6	352·53	393·82	35	10	3·40	511	·500 7102	·500 6356	−3	+486	− 8	+458	+1215	− 6	·500 8029	·500 8040	·500 8034
2	A4	R	6	354·82	396·97	34	11	2·60	506	7056	6305	−3	+520	− 5	+458	+1215	− 6	8020	8026	8023
3	A4	R	7	355·06	398·36	35	11	2·40	498	7051	6284	−3	+528	+ 2	+458	+1215	− 6	8030	8020	8025
4	A4	D	7	353·91	397·47	37	14	2·50	502	7074	6298	−4	+524	− 1	+458	+1215	− 6	8045	8026	8036
5	A4	D	7	354·20	397·56	35	12	2·40	502	7068	6296	−3	+528	− 2	+458	+1215	− 6	8043	8028	8036
6	A4	D	7	354·12	397·14	37	12	2·50	503	7070	6303	−4	+524	− 2	+458	+1215	− 6	8040	8030	8035
7	A5	R	7	468·78	547·29	38	13	2·60	497	·500 5339	·500 4573	−4	+520	+ 2	+462	+1213	− 6	·500 6313	·500 6298	·500 6306
8	A5	R	7	468·72	546·46	35	13	2·55	503	5340	4578	−4	+522	− 2	+462	+1213	− 6	6312	6301	6306
9	A5	R	8	469·37	545·81	35	12	2·50	509	5332	4585	−3	+524	− 7	+462	+1213	− 6	6302	6306	6304
10	A5	D	8	471·54	550·46	35	10	2·45	495	5307	4546	−3	+526	+ 4	+462	+1213	− 6	6290	6280	6285
11	A5	D	8	471·31	548·77	35	12	2·40	496	5310	4560	−3	+528	+ 3	+462	+1213	− 6	6294	6295	6294
12	A5	D	8	470·30	545·24	37	11	2·45	507	5321	4589	−4	+526	− 5	+462	+1213	− 6	6294	6313	6304
13	A6	R	8	504·95	594·36	34	10	2·55	494	·500 4955	·500 4210	−3	+522	+ 4	+462	+1204	− 6	·500 5934	·500 5931	·500 5932
14	A6	R	8	504·13	593·31	37	9	2·52	505	4964	4217	−3	+523	− 4	+462	+1204	− 6	5936	5931	5934
15	A6	R	9	505·27	590·97	36	14	2·50	501	4953	4233	−3	+524	− 1	+462	+1204	− 6	5929	5951	5940
16	A6	D	9	505·26	591·16	38	12	2·52	503	4953	4232	−4	+523	− 2	+462	+1204	− 6	5926	5947	5936
17	A6	D	9	504·59	596·97	39	13	2·50	512	4960	4191	−4	+524	− 9	+462	+1204	− 6	5927	5900	5914
18	A6	D	9	505·82	594·96	39	13	2·50	497	4947	4205	−4	+524	+ 2	+462	+1204	− 6	5925	5925	5925
																		·500 6755	·500 6753	·500 6754

BOSTON, MASS.

1	A4	R	Mar. 11	314·56		40	14	19·77	491	·500 7960		−4	−200	+ 7	+294		− 6	·500 8051		
2	A4	R	12	314·82		38	13	19·54	496	7954		−4	−190	+ 3	+290		− 6	8047		
3	A4	R	12	315·11		37	12	19·42	498	7946		−4	−185	+ 2	+286		− 6	8039		
4	A4	D	12	315·67		38	11	19·20	496	7932		−4	−176	+ 3	+286		− 6	8035		
5	A4	D	12	315·53		39	11	19·02	503	7936		−4	−168	− 2	+286		− 6	8042		
6	A4	D	12	315·44		39	12	19·10	498	7939		−4	−172	+ 2	+286		− 6	8045		
7	A5	D	12	403·20		45	16	19·22	503	·500 6208		−6	−177	− 2	+285		− 6	·500 6302		
8	A5	D	12	403·07		38	11	19·17	508	6210		−4	−175	− 6	+285		− 6	6304		
9	A5	D	13	403·38		40	13	19·22	500	6205		−4	−177	0	+285		− 6	6303		
10	A5	R	13	403·12		39	12	19·22	502	6209		−4	−177	− 2	+285		− 6	6305		
11	A5	R	13	404·21		38	9	19·14	496	6192		−3	−173	+ 3	+285		− 6	6298		
12	A5	R	13	403·36		39	11	19·14	505	6206		−4	−173	− 4	+280		− 6	6299		
13	A6	R	13	427·61		37	11	19·42	498	·500 5853		−4	−185	+ 2	+274		− 6	·500 5934		
14	A6	R	14	427·54		38	9	19·42	495	5854		−3	−185	+ 4	+274		− 6	5938		
15	A6	R	14	427·61		40	12	19·42	495	5853		−4	−185	+ 4	+274		− 6	5936		
16	A6	D	14	428·24		39	11	19·20	498	5845		−4	−176	+ 1	+274		− 6	5934		
17	A6	D	14	426·74		40	15	19·34	513	5865		−5	−182	−10	+274		− 6	5936		
18	A6	D	14	428·17		41	12	19·34	502	5846		−4	−182	− 1	+274		− 6	5927		
																		·500 6760		

TABLE G.—*Pendulum observations and reductions*—Continued.

ITHACA, N. Y.

Swing No.	Pendulum.	Position.	Date.	Coincidence interval.		Total arc.		Temperature.	Pressure.	Period uncorrected.		Corrections (seventh decimal place).						Period corrected.		
				1824.	1828.	Initial.	Final.			1824.	1828.	Arc.	Temperature.	Pressure.	Rate 1824.	Rate 1828.	Flexure.	1824.	1828.	Mean.
			1894.	*s.*	*s.*	′	′	° *C.*	*mm*	*s.*	*s.*							*s.*	*s.*	*s.*
1	A4	R	Mar. 21	303·99		35	12	19·44	494	·500 8237		−3	−186	+ 4	+253		−19	·500 8286		
2	A4	R	22	303·92		35	12	19·44	496	8239		−3	−186	+ 3	+253		−19	8287		
3	A4	R	22	303·86		36	10	19·44	498	8241		−3	−186	+ 2	+253		−19	8288		
4	A4	D	22	303·42		37	12	19·44	499	8253		−4	−186	+ 1	+253		−19	8298		
5	A4	D	22	303·68		36	9	19·40	499	8246		−3	−184	+ 1	+253		−19	8294		
6	A4	D	22	303·98		36	11	19·34	500	8237		−4	−182	0	+253		−19	8285		
7	A5	R	22	385·59		37	12	19·37	504	·500 6493		−4	−183	− 3	+253		−19	·500 6537		
8	A5	R	23	385·46		38	9	19·32	505	6494		−3	−181	− 4	+253		−19	6540		
9	A5	R	23	385·33		37	12	19·32	505	6496		−4	−181	− 4	+253		−19	6541		
10	A5	D	23	385·68		35	12	19·34	498	6490		−3	−182	+ 1	+253		−19	6540		
11	A5	D	23	386·15		35	12	19·30	500	6483		−3	−180	0	+253		−19	6534		
12	A5	D	23	386·20		34	9	19·20	500	6482		−3	−176	0	+253		−19	6537		
13	A6	R	23	408·67		35	11	19·17	501	·500 6125		−3	−175	− 1	+258		−19	·500 6185		
14	A6	R	24	409·02		37	9	19·04	502	6120		−3	−169	− 1	+258		−19	6186		
15	A6	R	24	409·37		35	10	18·84	502	6114		−3	−161	− 2	+258		−19	6187		
16	A6	D	24	409·40		36	10	18·73	505	6114		−3	−156	− 4	+258		−19	6190		
17	A6	D	24	409·71		35	10	18·61	506	6109		−3	−151	− 5	+258		−19	6189		
18	A6	D	24	410·10		35	10	18·48	507	6104		−3	−146	− 5	+258		−19	6189		
																		·500 7005		

WASHINGTON, D. C. (COAST AND GEODETIC SURVEY).

Swing No.	Pendulum.	Position.	Date.	Coincidence. interval.		Total Arc.		Temperature.	Pressure.	Period uncorrected.		Corrections (seventh decimal place).						Period corrected.		
				1824.	1823.	Initial.	Final.			1824.	1823.	Arc.	Temperature.	Pressure.	Rate 1824.	Rate 1823.	Flexure.	1824.	1823.	Mean.
			1824.	*s.*	*s.*	′	′	° *C.*	*mm*	*s.*	*s.*							*s.*	*s.*	*s.*
1	A4	R	Mar. 30	300·76	290·54	36	11	12·60	488	·500 8326	·500 8620	−4	+101	+ 9	+335	+47	− 6	·500 8761	·500 8767	·500 8764
2	A4	R	31	301·00	290·78	37	10	12·60	488	8319	8612	−4	+101	+ 9	+335	+47	− 6	8754	8759	8756
3	A4	R	31	301·08	290·81	37	11	12·55	488	8317	8611	−4	+103	+ 9	+335	+47	− 6	8754	8760	8757
4	A4	D	31	300·56	290·22	35	12	12·55	506	8332	8629	−3	+103	− 5	+335	+47	− 6	8756	8765	8760
5	A4	D	31	299·72	290·36	33	13	12·63	497	8355	8624	−3	+100	+ 2	+335	+47	− 6	8763	8764	8774
6	A4	D	31	299·25	289·90	37	11	12·73	500	8368	8639	−4	+ 95	0	+335	+47	− 6	8788	8771	8780
7	A5	D	31	378·17	363·65	38	12	12·85	489	·500 6619	·500 6884	−4	+ 90	+ 8	+321	+40	− 6	·500 7028	·500 7012	·500 7020
8	A5	D	Apr. 1	377·95	363·26	36	11	13·00	490	6623	6891	−3	+ 84	+ 8	+321	+40	− 6	7027	7014	7020
9	A5	D	1	377·43	362·61	38	9	13·13	490	6632	6904	−3	+ 78	+ 8	+321	+40	− 6	7030	7021	7026
10	A5	R	1	378·58	362·68	38	12	13·35	486	6612	6902	−4	+ 69	+11	+321	+40	− 6	7003	7012	7008
11	A5	R	1	378·16	361·85	38	13	13·50	486	6620	6918	−4	+ 63	+11	+321	+40	− 6	7005	7022	7014
12	A5	R	1	377·47	361·30	38	10	13·70	487	6632	6929	−3	+ 55	+10	+321	+40	− 6	7009	7025	7017
13	A6	R	1	398·11	380·81	36	12	13·99	485	·500 6288	·500 6574	−3	+ 42	+11	+321	+40	− 6	·500 6653	·500 6658	·500 6656
14	A6	R	2	397·90	380·50	34	10	14·09	485	6291	6579	−3	+ 38	+11	+321	+40	− 6	6652	6659	6656
15	A6	R	2	397·57	380·37	37	11	14·16	486	6296	6581	−3	+ 35	+11	+329	+29	− 6	6662	6647	6654
16	A6	D	2	397·01	379·37	36	11	14·26	497	6305	6598	−3	+ 31	+ 2	+329	+29	− 6	6658	6651	6654
17	A6	D	2	396·72	378·38	37	11	14·39	498	6310	6616	−3	+ 26	+ 2	+329	+29	− 6	6658	6664	6661
18	A6	D	2	396·74	378·24	37	10	14·42	498	6309	6618	−3	+ 24	+ 2	+329	+29	− 6	6655	6664	6660
																		·500 7480	·500 7480	·500 7480

WASHINGTON, D. C. (COAST AND GEODETIC SURVEY).

1	A4	R	Apr. 25		297·70	55	21	16·19	54		·500 8412	−9	− 50	+ 6		+48	− 6		·500 8401	
2	A4	D	26		297·50	53	21	16·04	58		8418	−8	− 44	+ 2		+48	− 6		8410	
3	A5	R	26		374·92	55	21	16·14	55		·500 6677	−9	− 48	+ 5		+48	− 6		·500 6667	
4	A5	D	26		374·68	53	21	16·39	56		6681	−8	− 58	+ 4		+43	− 6		6656	
5	A6	R	27		395·97	52	21	16·46	53		·500 6321	−8	− 61	+ 7		+43	− 6		·500 6296	
6	A6	D	27		394·50	55	21	16·69	57		6345	−9	− 71	+ 3		+43	− 6		6305	
																			·500 7123	

TABLE G.—*Pendulum observations and reductions*—Continued.

CHARLOTTESVILLE, VA.

Swing No.	Pendulum.	Position.	Date.	Coincidence interval. 1824.	Coincidence interval. 1828.	Total arc. Initial.	Total arc. Final.	Temperature.	Pressure.	Period uncorrected. 1824.	Period uncorrected. 1823.	Corrections (seventh decimal place). Arc.	Temperature.	Pressure.	Rate 1824.	Rate 1823.	Flexure.	Period corrected. 1824.	Period corrected. 1823.	Period corrected. Mean.
			1894.	s.	s.	′	′	° C.	mm	s.	s.							s.	s.	s.
1	A4	R	May 2	286·00	277·08	53	19	18·38	57	·500 8757	·500 9039	−8	−142	+3	+287	+17	−52	·500 8845	·500 8857	·500 8851
7	A4	R	4	285·58	278·14	53	20	18·48	60	8769	9004	−8	−146	0	+301	+75	−52	8864	8873	8868
11	A4	R	6	285·18	277·90	53	20	18·91	60	8782	9012	−8	−164	0	+300	+67	−52	8858	8855	8856
2	A4	D	3	286·43	277·82	55	20	17·98	59	8744	9015	−8	−125	+1	+287	+17	−52	8847	8848	8848
8	A4	D	5	285·41	278·04	53	21	18·48	60	8775	9008	−8	−146	0	+301	+75	−52	8870	8877	8874
3	A5	R	3	356·73	343·94	56	20	18·23	65	·500 7018	·500 7279	−9	−135	−5	+287	+17	−52	·500 7104	·500 7095	·500 7100
9	A5	R	5	355·58	344·78	57	20	18·73	61	7041	7261	−9	−156	−1	+301	+75	−52	7124	7118	7121
10	A5	R	5	355·63	344·26	57	20	18·91	62	7040	7272	−9	−164	−2	+300	+67	−52	7113	7112	7112
4	A5	D	3	356·66	344·73	56	20	18·21	66	7019	7263	−9	−134	−6	+287	+48	−52	7105	7110	7108
5	A6	R	4	376·94	364·06	53	21	18·15	54	·500 6641	·500 6876	−9	−132	+6	+287	+48	−52	·500 6741	·500 6737	·500 6739
12	A6	R	6	374·42	361·82	53	20	19·04	58	6686	6919	−8	−169	+2	+300	+67	−52	6759	6759	6759
6	A6	D	4	375·54	363·08	53	17	18·43	59	6666	6895	−8	−144	+1	+287	+48	−52	6750	6740	6745
																		·500 7572	·500 7572	·500 7572

WASHINGTON, D. C. (COAST AND GEODETIC SURVEY).

1	A4	R	May 10	301·27	292·98	52	19	19·44	61	·500 8312	·500 8547	−8	−186	−1	+290	+57	− 6	·500 8401	·500 8403	·500 8402
2	A4	D	11	301·21	292·93	53	21	19·42	61	8314	8549	−8	−185	−1	+290	+57	− 6	8404	8406	8405
3	A5	R	11	381·24	368·25	56	21	19·42	58	·500 6566	·500 6798	−9	−185	+2	+290	+57	− 6	·500 6658	·500 6657	·500 6658
4	A5	D	11	381·28	367·47	55	20	19·42	60	6565	6812	−9	−185	0	+304	+67	− 6	6669	6679	6674
5	A6	R	12	404·20	389·33	53	21	19·34	58	·500 6193	·500 6430	−8	−182	+2	+304	+67	− 6	·500 6303	·500 6303	·500 6303
6	A6	D	12	403·85	389·44	55	21	19·37	56	6198	6428	−9	−183	+4	+304	+67	− 6	6308	6301	6304
																		·500 7124	·500 7125	·500 7124

PRINCETON, N. J.

1	A4	R	May 17	310·61	302·06	53	19	16·55	60	·500 8062	·500 8290	−8	− 65	0	+286	+66	−32	·500 8243	·500 8251	·500 8247
7	A4	R	19	308·44	300·20	53	21	17·78	62	8118	8342	−8	−116	−2	+282	+69	−32	8242	8253	8248
13	A4	R	21	311·42	303·16	52	20	16·26	63	8041	8260	−8	− 53	−3	+301	+91	−32	8246	8255	8250
2	A4	D	18	310·91	302·41	53	21	16·38	59	8054	8281	−8	− 58	+1	+286	+66	−32	8243	8250	8246
12	A4	D	21	310·07	302·30	53	21	17·04	62	8075	8284	−8	− 85	−2	+295	+83	−32	8243	8240	8242
18	A4	D	23	312·20	304·54	53	21	15·52	61	8020	8223	−8	− 22	−1	+303	+95	−32	8260	8255	8258
3	A5	R	18	394·81	381·70	55	21	16·81	60	·500 6340	·500 6558	−9	− 76	0	+286	+66	−32	·500 6509	500 6507	·500 6508
8	A5	R	20	392·43	380·04	55	20	17·91	62	6379	6587	−9	−122	−2	+282	+69	−32	6496	6491	6494
14	A5	R	22	402·40	387·54	52	21	15·46	59	6252	6459	−8	− 19	+1	+301	+91	−32	6495	6492	6494
4	A5	D	18	394·29	381·09	53	19	16·98	58	6348	6569	−8	− 83	+2	+281	+68	−32	6508	6516	6512
11	A5	D	21	398·72	386·06	53	20	16·12	61	6278	6484	−8	− 47	−1	+295	+83	−32	6485	6479	6482
17	A5	D	23	401·88	389·16	53	21	15·04	61	6228	6432	−8	− 2	−1	+303	+95	−32	6488	6484	6486
5	A6	R	19	418·24	404·15	53	21	17·08	58	·500 5985	·500 6194	−8	− 87	+2	+281	+68	−32	·500 6141	·500 6137	·500 6139
9	A6	R	20	416·72	402·70	53	21	17·55	62	6006	6216	−8	−107	−2	+282	+69	−32	6139	6136	6138
15	A6	R	22	424·78	410·00	52	20	15·29	61	5892	6105	−8	− 12	−1	+301	+91	−32	6140	6143	6142
6	A6	D	19	416·90	402·62	53	21	17·48	58	6004	6217	−8	−104	+2	+281	+68	−32	6143	6143	6143
10	A6	D	20	420·29	405·21	53	20	16·54	60	5955	6177	−8	− 64	0	+295	+83	−32	6146	6156	6151
16	A6	D	22	425·28	410·30	53	21	15·16	59	5885	6101	−8	− 7	+1	+303	+95	−32	6142	6150	6146
																		·500 6962	·500 6963	·500 6962

PHILADELPHIA, PA.

1	A4	R	May 26	314·52	306·16	52	21	15·94	58	·500 7961	·500 8179	−8	− 39	+2	+281	+64	− 6	·500 8191	·500 8192	·500 8192
2	A4	D	27	314·14	305·95	56	21	15·89	60	7971	8185	−9	− 37	0	+281	+64	− 6	8200	8197	8198
3	A5	R	27	401·24	387·18	53	21	16·14	60	·500 6239	·500 6465	−8	− 48	0	+281	+64	− 6	·500 6458	·500 6467	·500 6462
4	A5	D	27	400·46	386·76	53	19	16·36	60	6251	6472	−8	− 57	0	+273	+45	− 6	6453	6446	6450
5	A6	R	28	424·87	409·78	52	21	16·49	63	·500 5891	·500 6108	−8	− 62	−3	+273	+45	− 6	·500 6085	·500 6074	·500 6080
6	A6	D	28	423·54	406·67	50	20	16·61	59	5910	6155	−8	− 67	+1	+273	+45	− 6	6103	6120	6112
																		·500 6915	·500 6916	·500 6916

TABLE G.—*Pendulum observations and reductions*—Continued.

WASHINGTON, D. C. (COAST AND GEODETIC SURVEY).

Swing No.	Pendulum.	Position.	Date.	Coincidence interval.		Total arc.		Temperature.	Pressure.	Period uncorrected.		Corrections (seventh decimal place).						Period corrected.		
				1824.	1823.	Initial.	Final.			1824.	1823.	Arc.	Temperature.	Pressure.	Rate 1824.	Rate 1823.	Flexure.	1824.	1823.	Mean.
			1894.	*s.*	*s.*	′	′	° C.	*mm*	*s.*	*s.*							*s.*	*s.*	*s.*
1	A4	R	May 31	303·68	295·38	53	17	17·55	66	·500 8246	·500 8478	− 7	−107	−6	+286	+58	− 6	·500 8406	·500 8410	·500 8408
2	A4	D	June 1	303·95	295·70	53	20	17·28	67	8238	8469	− 8	− 96	−7	+286	+58	− 6	8407	8410	8408
3	A5	R	1	385·26	372·76	53	19	17·18	68	·500 6497	·500 6715	− 8	− 91	−8	+286	+58	− 6	·500 6670	·500 6660	·500 6665
4	A5	D	2	385·17	373·08	53	19	17·11	68	6499	6710	− 8	− 88	−8	+276	+58	− 6	6665	6658	6662
5	A6	R	2	407·80	394·48	52	20	17·21	68	·500 6138	·500 6345	− 8	− 92	−8	+276	+58	− 6	·500 6300	·500 6289	·500 6294
6	A6	D	2	407·82	392·28	53	21	17·28	66	6138	6381	− 8	− 96	−6	+276	+58	− 6	6298	6323	6310
																		·500 7124	·500 7125	·500 7124

WASHINGTON, D. C. (COAST AND GEODETIC SURVEY).

1	A4	R	June 23	295·70	286·65	53	21	23·04	59	·500 8469	·500 8737	− 8	−337	+1	+280	+17	− 6	·500 8399	·500 8404	·500 8402
2	A4	D	24	295·28	286·21	53	21	23·01	60	8481	8750	− 8	−336	0	+280	+17	− 6	8411	8417	8414
3	A5	R	24	371·42	357·53	55	22	23·19	59	·500 6740	·500 7002	− 8	−343	+1	+280	+17	− 6	·500 6664	·500 6663	·500 6664
4	A5	D	24	371·63	356·98	53	20	23·31	60	6736	7013	− 8	−348	0	+284	+10	− 6	6658	6661	6660
5	A6	R	25	391·74	375·44	53	21	23·58	59	·500 6390	·500 6668	− 8	−360	+1	+284	+10	− 6	·500 6301	·500 6305	·500 6303
6	A6	D	25	390·73	374·97	59	21	23·90	58	6407	6676	−10	−373	+2	+284	+10	− 6	6304	6299	6302
																		·500 7123	·500 7125	·500 7124

DEER PARK, MD.

1	A4	R	July 2	285·28	277·83	53	19	18·99	56	·500 8779	·500 9014	− 8	−167	+4	+257	+30	−16	·500 8849	·500 8857	·500 8853
2	A4	D	3	283·74	276·76	52	21	19·59	61	8826	9049	− 8	−192	−1	+257	+30	−16	8866	8862	8864
3	A5	R	3	351·92	341·52	55	24	20·50	58	·500 7114	·500 7331	−10	−230	+2	+257	+30	−16	·500 7117	·500 7107	·500 7112
4	A5	D	4	359·07	348·38	53	22	17·42	61	6972	7186	− 9	−101	−1	+257	+35	−16	7102	7094	7098
5	A6	R	4	376·88	364·40	52	21	18·11	59	·500 6642	·500 6870	− 8	−130	+1	+257	+35	−16	·500 6746	·500 6752	·500 6749
6	A6	D	4	372·26	360·02	55	23	19·65	57	6725	6954	− 9	−195	+3	+257	+35	−16	6765	6772	6768
																		·500 7575	·500 7574	·500 7574

CLEVELAND, OHIO.

1	A4	R	July 7	311·18	301·84	55	20	20·84	58	·500 8046	·500 8296	− 9	−245	+2	+298	+51	−20	·500 8072	·500 8075	·500 8074
2	A4	D	8	311·58	302·29	51	17	20·39	58	8036	8284	− 7	−226	+2	+298	+51	−20	8083	8084	8084
3	A5	R	8	397·50	382·74	52	21	20·54	54	·500 6297	·500 6540	− 8	−232	+6	+298	+51	−20	·500 6341	·500 6337	·500 6339
4	A5	D	8	397·66	383·49	52	18	20·24	60	6295	6528	− 8	−220	0	+278	+50	−20	6325	6330	6328
6	A6	R	9	421·29	406·02	53	20	20·34	58	·500 5941	·500 6165	− 8	−224	+2	+278	+50	−20	·500 5969	·500 5965	·500 5967
5	A6	D	9	422·39	406·80	53	21	20·07	57	5926	6153	− 8	−212	+3	+278	+50	−20	5967	5966	5966
																		·500 6793	·500 6793	·500 6793

CHICAGO, ILL.

1	A4	R	July 11	311·76	302·73	52	20	22·79	58	·500 8031	·500 8272	− 8	−326	+2	+268	+33	− 3	·500 7964	·500 7970	·500 7967
7	A4	R	15	310·95	302·12	55	23	23·50	53	8053	8288	− 9	−356	+7	+270	+43	− 3	7962	7970	7966
2	A4	D	12	311·46	302·59	53	19	22·64	60	8039	8276	− 8	−320	0	+268	+33	− 3	7976	7978	7977
8	A4	D	16	310·58	301·96	57	20	23·26	60	8062	8292	− 9	−346	0	+270	+43	− 3	7974	7977	7976
3	A5	R	12	394·69	380·97	56	22	23·53	62	·500 6342	·500 6571	− 9	−357	−2	+268	+33	− 3	·500 6239	·500 6233	·500 6236
9	A5	R	16	394·75	381·63	56	21	23·58	62	6341	6560	− 9	−360	−2	+270	+43	− 3	6237	6229	6233
4	A5	D	12	396·34	381·12	53	21	23·53	67	6316	6568	− 8	−357	−7	+299	+55	− 3	6240	6248	6244
5	A6	R	13	421·00	404·15	55	21	23·46	60	·500 5945	·500 6194	− 9	−354	0	+299	+55	− 3	·500 5878	·500 5883	·500 5880
6	A6	D	13	420·45	404·20	53	20	23·63	59	5953	6193	− 8	−362	+1	+299	+55	− 3	5880	5876	5878
																		·500 6696	·500 6698	·500 6697

TABLE G.—*Pendulum observations and reductions*—Continued.

LOWER GEYSER BASIN, WYO.

Swing No.	Pendulum.	Position.	Date.	Coincidence interval. 1824.	Coincidence interval. 1823.	Total arc. Initial.	Total arc. Final.	Temperature.	Pressure.	Period uncorrected. 1824.	Period uncorrected. 1823.	Corrections (seventh decimal place). Arc.	Temperature.	Pressure.	Rate 1824.	Rate 1823.	Flexure.	Period corrected. 1824.	Period corrected. 1823.	Mean.
			1894.	*s.*	*s.*	′	′	° C.	*mm*	*s.*	*s.*							*s.*	*s.*	*s.*
1	A4	R	July 24	281·42	274·26	53	21	20·00	56	·500 8899	·500 9132	− 8	−210	+4	+223	−10	−52	·500 8856	·500 8856	·500 8856
2	A4	D	25	280·69	273·36	55	20	20·24	61	8922	9161	− 9	−220	−1	+223	−10	−52	8863	8869	8866
3	A5	R	25	343·69	332·86	53	19	22·46	62	·500 7285	·500 7522	− 8	−313	−2	+223	−10	−52	·500 7133	·500 7137	·500 7135
4	A5	D	25	345·51	334·99	53	19	21·92	58	7246	7474	− 8	−290	+2	+210	−21	−52	7108	7105	7106
5	A6	R	26	365·17	353·49	53	19	20·89	59	·500 6855	·500 7082	− 8	−247	+1	+210	−21	−52	·500 6759	·500 6755	·500 6757
6	A6	D	26	362·77	350·82	53	21	21·88	56	6901	7136	− 8	−288	+4	+210	−21	−52	6767	6771	6769
																		·500 7581	·500 7582	·500 7581

GRAND CANYON, WYO.

1	A4	R	July 28	290·01	281·55	53	20	13·10	56	·500 8635	·500 8895	− 8	+ 80	+4	+271	+ 8	−46	·500 8936	·500 8933	·500 8934
2	A4	D	29	290·96	282·29	53	19	12·34	62	8607	8872	− 8	+111	−2	+271	+ 8	−46	8933	8935	8934
3	A5	R	29	356·05	343·18	53	21	15·76	55	·500 7031	·500 7295	− 8	− 32	+5	+271	+ 8	−46	·500 7221	·500 7222	·500 7222
4	A5	D	29	359·50	346·81	53	20	14·41	59	6964	7219	− 8	+ 25	+1	+262	+ 5	−46	7198	7196	7197
5	A6	R	30	378·27	364·14	53	21	14·67	55	·500 6618	·500 6875	− 8	+ 14	+5	+262	+ 5	−46	·500 6845	·500 6845	·500 6845
6	A6	D	30	373·08	359·16	53	16	16·48	61	6710	6970	− 7	− 62	−1	+262	+ 5	−46	6856	6859	6858
																		·500 7665	·500 7665	·500 7665

NORRIS GEYSER BASIN, WYO.

1	A4	R	July 31	288·12	281·34	52	20	14·74	60	·500 8692	·500 8902	− 8	+ 11	0	+246	+25	−117	·500 8824	·500 8813	·500 8818
2	A5	R	Aug. 1	369·49	357·34	48	16	11·03	61	·500 6775	·500 7006	− 6	+166	−1	+246	+25	−117	·500 7063	·500 7073	·500 7068
3	A6	R	1	374·79	362·68	55	27	16·87	58	·500 6679	·500 6903	−11	− 78	+2	+246	+25	−117	·500 6721	·500 6724	·500 6722
																		·500 7536	·500 7537	·500 7536

SALT LAKE CITY, UTAH.

1	A4	R	Aug. 6	268·38	261·82	53	17	22·97	56	·500 9332	·500 9566	− 8	−334	+4	+245	+ 3	− 46	·500 9193	·500 9185	·500 9189
2	A4	D	7	269·08	262·14	56	21	22·01	65	9308	9555	− 9	−294	−5	+245	+ 3	− 46	9199	9204	9202
3	A5	R	7	327·05	316·78	56	20	24·16	59	·500 7656	·500 7904	− 9	−384	+1	+245	+ 3	− 46	·500 7463	·500 7469	·500 7466
4	A5	D	7	327·79	318·00	57	20	23·86	61	7638	7874	− 9	−371	−1	+236	+ 1	− 46	7447	7448	7448
5	A6	R	8	347·33	336·26	53	19	22·58	62	·500 7208	·500 7445	− 8	−318	−2	+236	+ 1	− 46	·500 7070	·500 7072	·500 7071
6	A6	D	8	343·80	333·04	55	21	23·77	63	7282	7518	− 9	−367	−3	+236	+ 1	− 46	7093	7094	7094
																		·500 7911	·500 7912	·500 7912

PLEASANT VALLEY JUNCTION, UTAH.

1	A4	R	Aug. 10	259·43	252·98	53	19	13·86	61	·500 9655	·500 9902	− 8	+ 48	−1	+268	+20	−16	·500 9946	·500 9945	·500 9946
2	A4	D	11	260·24	253·56	52	19	13·52	62	9624	9879	− 8	+ 62	−2	+268	+20	−16	9928	9935	9932
3	A5	R	11	317·45	307·60	53	21	13·69	61	·500 7888	·500 8141	− 8	+ 55	−1	+268	+20	−16	·500 8186	·500 8191	·500 8188
4	A5	D	11	318·01	308·44	53	19	13·62	59	7874	8118	− 8	+ 58	+1	+287	+22	−16	8196	8175	8186
5	A6	R	12	333·70	322·13	55	21	13·45	59	·500 7503	·500 7773	− 9	+ 65	+1	+287	+22	−16	·500 7831	·500 7836	·500 7834
6	A6	D	12	333·64	321·28	53	20	13·48	62	7504	7793	− 8	+ 64	−2	+287	+22	−16	7829	7853	7841
																		·500 8653	·500 8656	·500 8655

GREEN RIVER, UTAH.

1	A4	R	Aug. 13	259·26	253·39	53	16	21·31	60	·500 9661	·500 9885	− 7	−264	0	+229	− 6	− 13	·500 9606	·500 9595	·500 9600
2	A4	D	14	259·94	253·55	53	20	20·50	59	9636	9879	− 7	−230	+1	+229	− 6	− 13	9616	9624	9620
3	A5	R	14	316·30	306·93	56	21	20·72	60	·500 7916	·500 8158	− 9	−240	0	+229	− 6	− 13	·500 7883	·500 7890	·500 7886
4	A5	D	14	316·21	307·46	53	17	21·01	59	7919	8145	− 7	−252	+1	+236	+ 2	− 13	7884	7876	7880
5	A6	R	15	331·07	320·92	55	21	21·09	56	·500 7563	·500 7802	− 9	−255	+4	+236	+ 2	− 13	·500 7526	·500 7531	·500 7528
6	A6	D	15	331·07	321·04	55	21	21·26	55	7563	7799	− 9	−262	+5	+236	+ 2	− 13	7520	7522	7521
																		·500 8339	·500 8340	·500 8339

TABLE G.—*Pendulum observations and reductions*—Continued.

GRAND JUNCTION, COLO.

Swing No.	Pendulum.	Position.	Date.	Coincidence interval.		Total arc.		Temperature.	Pressure.	Period uncorrected.		Corrections (seventh decimal place).					Period corrected.		
				1824.	1823.	Initial.	Final.			1824.	1823.	Arc.	Temperature.	Pressure.	Rate 1824.	Rate 1823.	Flexure.	1824.	1823.	Mean.
			1894.	*s.*	*s.*	′	′	° *C.*	*mm*	*s.*	*s.*							*s.*	*s.*	*s.*
1	A4	R	Aug.18	256·76	250·74	53	17	23·21	62	·500 9756	·500 9990	−7	−344	−2	+254	+ 6	−13	·500 9644	·500 9630	·500 9637
2	A4	D	19	257·71	251·02	53	16	22·69	64	9720	9979	−7	−322	−4	+254	+ 6	−13	9628	9639	9634
3	A5	R	19	311·66	302·32	53	21	23·50	61	·500 8034	·500 8283	−8	−356	−1	+254	+ 6	−13	·500 7910	·500 7911	·500 7910
4	A5	D	19	313·41	304·24	53	19	23·01	59	7989	8231	−8	−336	+1	+233	− 9	−13	7866	7866	7866
5	A6	R	20	328·49	318·48	52	20	22·67	61	·500 7622	·500 7862	−8	−321	−1	+233	− 9	−13	·500 7512	·500 7510	·500 7511
6	A6	D	20	326·51	316·34	53	21	23·58	59	7669	7915	−9	−360	+1	+233	− 9	−13	7521	7525	7523
																		·500 8347	·500 8347	·500 8347

GUNNISON, COLO.

1	A4	R	Aug.22	244·44	239·08	53	19	16·88	60	·501 0248	·501 0478	−8	− 79	0	+218	−18	− 6	·501 0373	·501 0367	·501 0370
2	A4	D	23	244·76	239·10	55	21	16·46	60	0235	0478	−9	− 61	0	+218	−18	− 6	0377	0384	0380
3	A5	R	23	294·65	286·50	57	20	16·49	57	·500 8499	·500 8741	−9	− 62	+3	+218	−18	− 6	·500 8643	·500 8649	·500 8646
4	A5	D	23	295·39	287·38	56	22	16·24	56	8478	8714	−9	− 52	+4	+218	−24	− 6	8633	8627	8630
5	A6	R	24	310·15	300·81	55	21	15·66	57	·500 8074	·500 8324	−9	− 28	+3	+218	−24	− 6	·500 8252	·500 8260	500 8256
6	A6	D	24	309·18	299·88	55	22	16·09	58	8099	8351	−9	− 46	+2	+218	−24	− 6	8258	8268	8263
																		·500 9089	·500 9093	·500 9091

COLORADO SPRINGS, COLO.

1	A4	R	Aug.27	253·30	247·64	53	19	17·65	60	·500 9889	·501 0116	−8	−111	0	+218	−16	−10	·500 9978	·500 9971	·500 9974
2	A4	D	28	253·12	247·18	53	21	17·38	59	9896	0134	−8	−100	+1	+218	−16	−10	9997	1 0001	9999
3	A5	R	28	306·10	297·58	55	22	17·68	63	·500 8181	·500 8415	−9	−112	−3	+218	−16	−10	·500 8265	·500 8265	·500 8265
4	A5	D	28	306·91	298·75	53	19	17·60	56	8159	8382	−8	−109	+4	+214	− 9	−10	8250	8250	8250
5	A6	R	29	321·16	311·72	53	17	17·45	62	·500 7796	·500 8033	−8	−103	−2	+214	− 9	−10	·500 7887	·500 7901	·500 7894
6	A6	D	29	320·37	311·58	56	21	17·75	62	7815	8036	−9	−115	−2	+214	− 9	−10	7893	7891	7892
																		·500 8712	·500 8713	·500 8712

PIKES PEAK, COLO.

1	A4	R	Aug.31	232·01	226·71	52	17	7·23	78	·501 0799	·501 1052	−7	+326	−18	+276	+23	−10	·501 3166	·501 1366	·501 1366
2	A4	D	Sept. 1	231·98	226·73	52	20	7·88	50	0800	1048	−8	+298	+10	+276	+23	−10	1366	1361	1364
3	A5	R	1	273·28	266·12	52	21	9·64	60	·500 9165	·500 9412	−8	+225	0	+276	+23	−10	·500 9648	·500 9642	·500 9645
4	A5	D	1	277·91	269·84	52	17	7·44	59	9012	9282	−7	+317	+ 1	+276	+23	−10	9589	9606	9598
5	A6	R	2	288·67	279·60	53	21	7·40	60	·500 8675	·500 8957	−8	+318	0	+280	0	−10	·500 9255	·500 9257	·500 9256
6	A6	D	2	285·43	276·68	51	20	9·34	57	8774	9052	−8	+237	+ 3	+280	0	−10	9276	9274	9275
																		·501 0083	·501 0085	·501 0084

DENVER, COLO.

1	A4	R	Sept. 5	259·06	254·59	53	19	19·37	60	·500 9669	·500 9839	−8	−183	0	+222	+32	−16	·500 9684	·500 9664	·500 9674
2	A4	D	6	259·08	253·86	53	19	19.27	57	9668	9867	−8	−179	+ 3	+222	+32	−16	9690	9699	9694
3	A5	R	6	315·50	307·86	56	19	19·55	61	·500 7937	·500 8133	−9	−191	− 1	+222	+32	−16	·500 7942	·500 7948	·500 7945
4	A5	D	6	315·96	308·82	56	19	19·39	58	7925	8108	−9	−184	+ 2	+230	+46	−16	7948	7947	7948
5	A6	R	7	330·82	322·50	55	20	19·37	58	·500 7568	·500 7764	−9	−183	+ 2	+230	+46	−16	·500 7592	·500 7604	·500 7598
6	A6	D	7	330·88	322·91	56	15	19·32	60	7567	7754	−7	−181	0	+230	+46	−16	7593	7596	7594
																		·500 8408	·500 8410	·500 8409

WALLACE, KANS.

1	A4	R	Sept.14	274·86	269·20	52	20	15·99	55	·500 9112	·500 9304	−8	− 41	+ 5	+276	+77	−23	·500 9321	·500 9314	·500 9318
2	A4	D	15	275·48	269·43	53	19	15·76	59	9091	9296	−8	− 32	+ 1	+276	+77	−23	9305	9311	9308
3	A5	R	15	335·45	326·93	56	21	17·65	56	·500 7464	·500 7659	−9	−111	+ 4	+276	+77	−23	·500 7601	·500 7597	·500 7599
4	A5	D	15	335·15	327·22	53	20	17·91	57	7470	7652	−8	−122	+ 3	+256	+66	−23	7576	7568	7572
5	A6	R	16	353·41	343·98	55	20	17·71	59	·500 7084	·500 7278	−9	−114	+ 1	+256	+66	−23	·500 7195	·500 7199	·500 7197
6	A6	D	16	351·56	342·29	53	19	18·21	56	7121	7314	−8	−134	+ 4	+256	+66	−23	7216	7219	7218
																		·500 8036	·500 8034	·500 8036

TABLE G.—*Pendulum observations and reductions*—Continued.

ELLSWORTH, KANS.

Swing No.	Pendulum.	Position.	Date.	Coincidence interval. 1824.	Coincidence interval. 1823.	Total arc. Initial.	Total arc. Final.	Temperature.	Pressure.	Period uncorrected. 1824.	Period uncorrected. 1823.	Corrections (seventh decimal place). Arc.	Temperature.	Pressure.	Rate 1824.	Rate 1823.	Flexure.	Period corrected. 1824.	Period corrected. 1823.	Period corrected. Mean.
			1894.	*s.*	*s.*	°	′	° *C.*	*mm*	*s.*	*s.*							*s.*	*s.*	*s.*
1	A^4	R	Sept. 18	281·68	276·44	53	20	20·83	57	·500 8891	·500 9060	−8	−244	+ 3	+251	+72	−13	·500 8880	·500 8870	·500 8875
2	A4	D	19	281·52	275·76	53	21	20·91	59	8896	9082	−8	−248	+ 1	+251	+72	−13	8879	8886	8882
3	A5	R	19	349·45	340·81	55	20	21·16	58	·500 7164	·500 7346	−9	−258	+ 2	+251	+72	−13	·500 7137	·500 7140	·500 7138
4	A5	D	19	349·29	341·10	55	20	21·39	57	7168	7340	−9	−268	+ 3	+260	+78	−13	7141	7131	7136
5	A6	R	20	368·36	358·37	53	21	21·40	56	·500 6796	·500 6986	−9	−268	+ 4	+260	+78	−13	·500 6770	·500 6778	·500 6774
6	A6	D	20	367·54	357·85	55	16	21·52	58	6811	6996	−7	−273	+ 2	+260	+78	−13	6780	6783	6782
																		·500 7598	·500 7598	·500 7598

KANSAS CITY, MO. (ON A II).

1	A4	R	Sept. 22	284·92	278·77	53	20	22·91	59	·500 8790	·500 8984	−8	−331	+ 1	+279	+64	−13	·500 8718	·500 8697	·500 8708
2	A4	D	23	287·66	280·62	52	21	21·55	60	8705	8925	−8	−274	0	+279	+64	−13	8689	8694	8692
3	A5	R	23	359·76	348·64	53	20	21·13	60	·500 6959	·500 7181	−8	−257	0	+279	+64	−13	·500 6960	·500 6967	·500 6964
4	A5	D	23	360·18	349·66	52	20	20·73	61	6950	7160	−8	−240	− 1	+279	+64	−13	6967	6962	6964
5	A6	R	24	382·14	369·35	50	19	20·42	60	·500 6551	·500 6778	−8	−227	0	+279	+64	−13	·500 6582	·500 6594	·500 6588
6	A6	D	24	381·11	368·38	53	21	20·54	59	6568	6796	−8	−232	+ 1	+279	+64	−13	6595	6608	6602
																		·500 7419	·500 7420	·500 7420

ST. LOUIS, MO.

1	A4	R	Oct. 11	292·85	286·47	53	21	17·68	60	·500 8551	·500 8742	−8	−112	0	+290	+78	−32	·500 8689	·500 8668	·500 8678
2	A4	D	12	291·61	284·02	55	21	18·31	62	8588	8818	−9	−139	− 2	+290	+78	−32	8696	8714	8705
3	A5	R	12	363·87	352·76	53	20	19·13	61	·500 6880	·500 7097	−8	−173	− 1	+290	+78	−32	·500 6956	·500 6961	·500 6958
4	A5	D	12	368·46	357·39	53	20	17·65	61	6794	7005	−8	−111	− 1	+302	+80	−32	6944	6933	6938
5	A6	R	13	388·74	375·54	53	21	17·74	64	·500 6439	·500 6666	−8	−115	− 4	+302	+80	−32	·500 6582	·500 6587	·500 6584
6	A6	D	13	391·56	377·78	53	21	17·15	57	6393	6626	−8	− 90	+ 3	+302	+80	−32	6568	6579	6574
																		·500 7406	·500 7407	·500 7406

TERRE HAUTE, IND.

1	A4	R	Oct. 16	294·57	287·12	52	19	21·19	60	·500 8501	·500 8722	−8	−259	0	+281	+76	−23	·500 8492	·500 8508	·500 8500
2	A4	D	17	292·84	286·04	55	21	21·72	58	8551	8755	−9	−282	+ 2	+281	+76	−23	8520	8519	8520
3	A5	R	17	366·93	356·34	56	23	22·33	56	·500 6823	·500 7026	−9	−307	+ 4	+281	+76	−23	·500 6769	·500 6767	·500 6768
4	A5	D	17	372·26	361·71	53	10	20·53	62	6725	6921	−8	−232	− 2	+281	+76	−23	6741	6732	6736
5	A6	R	18	390·74	378·37	53	21	21·11	63	·500 6407	·500 6616	−8	−256	− 3	+281	+76	−23	·500 6398	·500 6402	·500 6400
6	A6	D	18	386·89	374·74	53	21	22·48	58	6470	6680	−8	−313	+ 2	+281	+76	−23	6409	6414	6412
																		·500 7221	·500 7224	·500 7223

CINCINNATI, OHIO.

1	A4	R	Oct. 22	291·96	284·54	53	19	19·17	60	·500 8577	·500 8802	−8	−175	0	+289	+74	−26	·500 8657	·500 8667	·500 8662
2	A4	D	23	292·58	285·69	53	21	17·74	62	8559	8766	−8	−115	− 2	+289	+74	−26	8697	8689	8693
3	A5	R	23	367·03	356·12	53	21	17·71	60	·500 6821	·500 7030	−8	−114	0	+289	+74	−26	·500 6962	·500 6956	·500 6959
4	A5	D	23	367·48	357·46	53	19	17·65	61	6812	7003	−8	−111	− 1	+265	+66	−26	6931	6923	6927
5	A6	R	24	388·36	376·32	53	20	17·53	62	·500 6446	·500 6652	−8	−106	− 2	+265	+66	−26	·500 6569	·500 6576	·500 6572
6	A6	D	24	388·99	376·88	53	20	17·33	62	6435	6642	−8	− 98	− 2	+265	+66	−26	6566	6574	6570
																		·500 7397	·500 7398	·500 7397

WASHINGTON, D. C. (COAST AND GEODETIC SURVEY).

1	A4	R	Oct. 31	304·39	296·59	52	19	17·58	60	·500 8227	·500 8443	−8	−108	0	+296	+75	− 6	·500 8401	·500 8396	·500 8398
2	A4	D	Nov. 1	304·81	296·85	53	21	17·25	60	8215	8436	−8	− 94	0	+296	+75	− 6	8403	8403	8403
3	A5	R	1	386·94	374·05	53	21	17·23	61	·500 6469	·500 6692	−8	− 93	− 1	+296	+75	− 6	·500 6657	·500 6659	·500 6658
4	A5	D	1	387·36	375·28	53	20	17·15	61	6462	6671	−8	− 90	− 1	+300	+87	− 6	6657	6653	6655
5	A6	R	2	410·06	396·10	52	21	17·08	61	·500 6104	·500 6320	−8	− 87	− 1	+300	+87	− 6	·500 6302	·500 6305	·500 6304
6	A6	D	2	409·62	395·35	53	20	17·23	61	6111	6332	−8	− 93	− 1	+300	+87	− 6	6303	6311	6307
																		·500 7120	·500 7121	·500 7121

II.—OBSERVATIONS WITH QUARTER-SECOND PENDULUMS, AND SPECIAL PENDULUM INVESTIGATIONS.

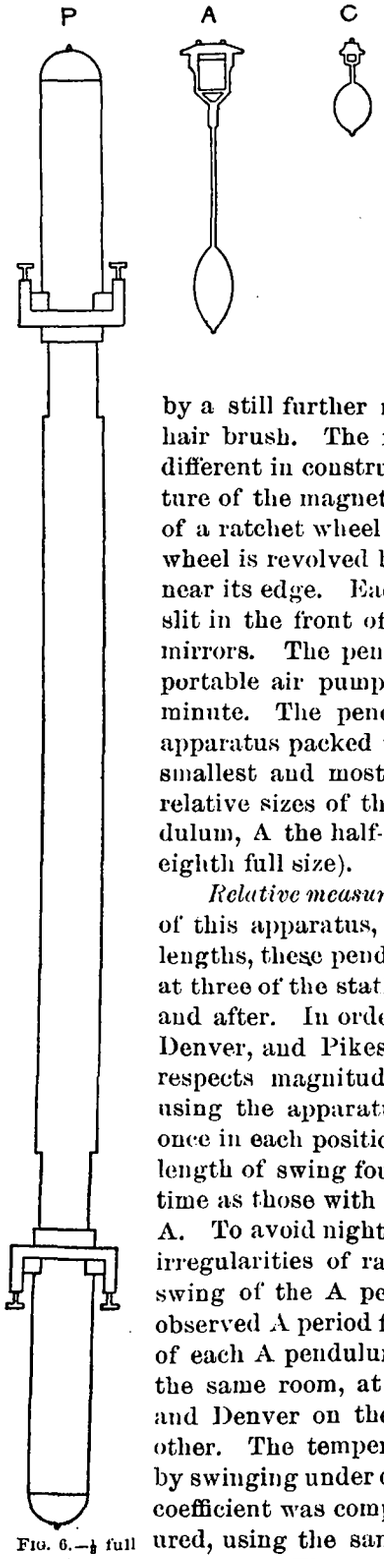


FIG. 6.—$\frac{1}{8}$ full size.

Description of quarter-second pendulum apparatus.—With the idea of obtaining instruments for measuring relative gravity still more portable than those heretofore used, early in 1894 there was constructed, as planned by Dr. Mendenhall, a set of quarter-second pendulums, with receiver and flash apparatus correspondingly reduced in size. No detailed description is necessary, as the whole is very similar, except in size, to the half-second apparatus. An ingenious starting and stopping device, designed by Mr. E. G. Fischer, Chief Mechanician, has been added to the case. By turning an arm on the outside of the receiver the pendulum is pushed out of the vertical, with an adjustment for any desired amplitude of oscillation. A further movement of the same arm automatically releases the pendulum, setting it in oscillation, and by a still further movement it is gently brought to rest by the contact of a camel's-hair brush. The flash apparatus, which has also been designed by Mr. Fischer, is different in construction from that used with the half-second pendulums. The armature of the magnet, instead of directly moving a shutter across a slit, releases a tooth of a ratchet wheel each time the circuit is broken by the chronometer. This ratchet wheel is revolved by a suspended weight, and carries with it a disk having slits cut near its edge. Each time a tooth is released a slit in this disk passes across a fixed slit in the front of the flash box, and light is thrown upon the pendulum and fixed mirrors. The pendulum receiver is about 13^{cm} by 15^{cm}, and 17^{cm} high. With the portable air pump the air may be exhausted from this receiver to 40^{mm} in half a minute. The pendulums weigh about 300 grammes (0·7 pound) each. The entire apparatus packed weighs about 48 kilogrammes (106 pounds), and is undoubtedly the smallest and most compact ever used for the purpose. In figure 6 are shown the relative sizes of three types of pendulums, P being the Peirce reversible metre pendulum, A the half-second, and C the quarter-second, all drawn to the same scale (one-eighth full size).

Relative measurements with quarter-second pendulums.—In order to test the efficiency of this apparatus, as well as the agreement of results with pendulums of different lengths, these pendulums were swung simultaneously with the half-second pendulums at three of the stations of the transcontinental series, as well as at Washington before and after. In order to increase the value of the test, the stations selected, Chicago, Denver, and Pikes Peak, were such as to give a maximum range of conditions as respects magnitude of g and difference of temperature. The method adopted in using the apparatus was to swing each of the three pendulums, C 1, C 2, and C 3, once in each position, with an air pressure of 40^{mm}, initial total arc about $1^{\circ}\ 20'$, and length of swing four hours. The swings of the C pendulums were made at the same time as those with the A pendulums, two C swings covering the same interval as one A. To avoid night work the C swings were only made during the day, and the diurnal irregularities of rate are eliminated by deducing the rate from the corresponding swing of the A pendulum, by comparing the mean A period for the station, the observed A period for the swing, and the average of the differences at all the stations of each A pendulum from the mean. Both sets of apparatus were always set up in the same room, at Washington and Chicago on distinct piers, and at Pikes Peak and Denver on the same concrete floor, but sufficiently distant to not affect each other. The temperature and pressure coefficients were determined at Washington by swinging under different conditions, in the manner before described, and the flexure coefficient was computed from the theoretical formula. The flexure was always measured, using the same appliances as with the A apparatus and a weight of 1·5 kilogrammes. The corrections to the periods in seconds were applied as follows:

Arc correction $= -\frac{P\,M \sin(\varphi + \varphi') \sin(\varphi - \varphi')}{32 \quad \log \sin \varphi - \log \sin \varphi'}$, where P is period, M is modulus, φ and φ' are initial and final semiarcs.

Temperature correction $= + 0{\cdot}000\ 00235\ (15^\circ - T^\circ)$, where T° is observed temperature in degrees centigrade.

Pressure correction $= + 0{\cdot}000\ 000066 \left(40 - \frac{Pr}{1 + {\cdot}00367\ T^\circ}\right)$, where Pr is observed pressure in millimetres and T° is temperature.

Rate correction $= + 0{\cdot}000\ 01157\ R\ P$, where P is period and R is daily rate on sidereal time in seconds (+ if losing, − if gaining).

Flexure correction $= - 0{\cdot}000\ 00037\ D$, where D is the observed displacement of knife-edge in microns when force of 1·5 kilogrammes is applied horizontally in the plane of oscillation.

The periods were reduced to standard conditions, arc infinitely small, temperature 15° C., pressure 40^{mm} at 0° C., sidereal time, and inflexible support. Below are given the corrected periods at each station for each pendulum and also the values of gravity deduced therefrom, based as before on g at Washington (Coast and Geodetic Survey Office) = 980·098 dynes. The rather large change in period at Washington, considering the slight use of the pendulums, may be due to the fact that the knife-edge was nearly new when used in June. The change in period at Washington has been distributed uniformly in computing g for the other stations.

Station.	Date.	Periods (corrected). Pendulum C 1.	Pendulum C 2.	Pendulum C 3.	Mean of three pendulums.	Differences from mean. C 1.	C 2.	C 3.
	1894.	s.	s.	s.	s.			
Washington	June 24–27	·250 2929	·250 2236	·250 2034	·250 2400	+529	−164	−366
"	Nov. 1–3	2920	2223	2033	2392	+528	−169	−359
Chicago	July 13–14	2738	2034	1844	2205	+533	−171	−361
Pikes Peak	Sept. 1–2	4405	3708	3495	3869	+536	−161	−374
Denver	Sept. 6–8	3564	2873	2679	3039	+525	−166	−360

GRAVITY (IN DYNES).

Washington (Coast and Geodetic Survey)				980·098			
Chicago	980·246	980·254	980·247	980·249	−.003	+·005	−·002
Pikes Peak	978·940	978·941	978.955	978·945	− 5	− 4	+ 10
Denver	979·595	979·591	979·592	979·593	+ 2	− 2	− 1

From the agreement of the pendulums and the accord of the results with those obtained with the more elaborate observations with the half-second pendulums, it is indicated that quarter-second pendulums may give results of nearly the same order of precision as larger apparatus. Their smallness, however, renders their use inconvenient in some respects, and the increased labor of observing resulting from the necessarily shorter swings tends to offset the gain in portability. As the weight of the pendulum apparatus itself is not more than half that of the entire outfit necessary for accurate gravity measurements, a reduction in it alone is not a very important gain in ordinary work. Undoubtedly there will be special cases, however, where this saving of weight will be an extremely important consideration, and for such this apparatus will be most valuable.

A curious phenomenon was noted in connection with the use of these short pendulums. When lowered on the knife-edge and brought perfectly to rest, they were found in a short time to take up a slight oscillation, amounting sometimes to two minutes of arc. This was undoubtedly the effect of earth tremors, and was noticed at all places where they were used, including the summit of Pikes Peak. At Washington this oscillation was observed to be greater in the daytime than at

night, but was still present after the movement of cable cars and other local disturbing causes had ceased.*

Comparison of results with different pendulums.—In the following table are collected the results for gravity, all based on the same value for Washington (Coast and Geodetic Survey Office), at all stations where independent relative determinations have been made with more than one of the following sets of apparatus:

.First. Half-second (one-fourth metre) invariable pendulums A 4, A 5, and A 6 on knife-edge A I (including also two stations, San Francisco and Mount Hamilton, determined in 1891 by Dr. Mendenhall with pendulums A 1, A 2, and A 3).

Second. Same on knife-edge A II.

Third. Quarter-second (one-sixteenth metre) invariable pendulums C 1, C 2, and C 3.

Fourth. Three-quarter-second (one-half metre) "reversible inversable" pendulum; observations made by Commandant Defforges in 1893. (See Part V of this report.) The values given are those of Commandant Defforges with a constant quantity (·069) subtracted, so that they will be based on the same value at Washington as the others.

The stations are arranged in the order of magnitude of g, and the results are the mean of three pendulums, except those of Defforges, which were obtained with a single pendulum, swung in different positions.

Station.	Elevation.	Results for gravity in dynes (not reduced to sea level).				Differences in dynes.	
		A ½ sec. pend's on knife A I.	A ½ sec. pend's on knife A II.	C ¼ sec. pend's.	Deffo.ges.	A — C.	A — Deffor ges.
	Metres.						
Chicago	182	980·264	980·263	980·249	980·276	+·015	−·012
Washington	14	·098	·098	·098	·098	·000	·000
San Francisco	114	979·951			979·947		+·004
Salt Lake City	1322	·789			·747		+·042
Mount Hamilton	1282	·646			·614		+·032
Denver	1638	·595	979·596	979·593	·615	+·002	−·020
Pikes Peak	4293	978·940		978·945		−·005	

The value 979·651 was obtained for Mount Hamilton by Mr. Preston with half-second pendulums B 1, B 2, and B 3, in 1892.

The half-second pendulum stations of 1894 were nearly identical with those of Commandant Defforges in 1893. At Washington the same pier was used; at Chicago the same pier, though built about 1 metre higher than in 1893; at Salt Lake the same high stone pier, though a capstone found loose was removed in 1894; at Denver the same concrete floor, but the half-second pendulum case was set nearer the outer foundation wall, where this floor is more solid.

Experiments with knife-edges of various widths and angles.†—A number of experiments in regard to knife-edges were made by Dr. Mendenhall in 1892. An experimental pendulum was used, having a steel plane set in its head, and this was swung upon a steel knife-edge which was set in a heavy metal block, so arranged that it could be taken from the receiver and reground at will. Alternate swings were made with the same pendulum upon an agate knife-edge whose condition was not changed during the operations, and from these corrections for variations in the rates of the two chronometers used were deduced and applied. Experiments were first made with different widths of the steel knife-edge, it being originally ground to a sharp edge by Mr. Fischer, and then from time to time slightly flattened by rubbing on a fine stone. The successive widths of edge

* The effect of earth vibrations on pendulum observations has recently received some attention. See paper by C. E. Schiötz, published by Die norwegische Gradmessung Commission, Kristiana, 1894. Our own experience would indicate that such effects are negligible, as no systematic differences have been detected between observations made during day and night, or on different days.

† See paper "On the use of planes and knife-edges in pendulums for gravity measurements," by Dr. T. C. Mendenhall, American Journal of Science, Vol. XLV, page 144.

were measured by Dr. Mendenhall with a microscope, but on account of difficulties of illumination they can be considered as only approximately correct. The following table gives the corrected periods on the edges of different widths, indicating a rapid diminution of period, or acceleration of the pendulum as excessive widths are reached:

Width of edge.	Period (corrected).	Loss of period.
μ	s.	s.
1	·500 8880	
2	8839	·000 0041
5	8756	0124
6·5	8503	0377
10	7626	1254

In the same manner the periods were determined with the steel knife-edge ground to different angles, with the following results:

Angle at which planes meet to form edge.	Period (corrected).
°	s.
90	·500 8875
110	8880
130	8884
150	8874
160	8852

As a result of this experiment the angle of 130° has been adopted.

Variation of period at different arcs.—A preliminary investigation of this subject was made by swinging two pendulums simultaneously on independent piers, using the same chronometers. One pendulum used as a standard was restarted each hour and a half, the successive swings being made under exactly the same conditions, while the other was allowed to swing continuously for ten hours, the arc gradually diminishing meanwhile, observations being made each hour and a half. Thus the period of the latter (A 4) was obtained at various arcs, free from errors of rate. This pendulum swings upon an agate knife-edge which had had comparatively little use. The results as given below seem to indicate that the period will differ somewhat at different arcs, even after the arc correction has been applied, undoubtedly due to the fact that different portions of the knife-edge are brought into use. This is an experimental proof of what has already been supposed to be the case, and justifies the precautions usually taken to use uniform limits of arc in a series of observations.

No.	Total arc.		Period (corrected).
	Initial.	Final.	
	′	′	s.
1	84	49	·500 8784
2	49	30	8781
3	30	18	8771
4	18	12	8775
5	12	7	8770
6	7	4½	8775
7	4½	3½	8778

A diagram (fig. 2) has been given showing observations of the decrement of arc of pendulum A 4 (half second) when swinging in the receiver at a pressure of 502^{mm}, and also with the receiver exhausted to 33^{mm}. The full lines indicate the theoretical decrement between the observed limits

on the supposition that the arc diminishes in a geometrical ratio as the time increases. On this theory, on which Borda's formula for arc correction is based, the arcs at equal intervals of time will be expressed by a series of terms, as $\varphi, \varphi r, \varphi r^2, \varphi r^3 \ldots \ldots \varphi r^{n-1}$, where φ is the initial arc, n the number of terms, and r the ratio; if φ' is the final arc $(=\varphi r^{n-1})$ then $r=\sqrt[n-1]{\frac{\varphi'}{\varphi}}$. The dots represent observed values and indicate that the pendulums follow this law closely, the greatest difference (2′ or 3′) being so small as to have a negligible effect on the arc correction.

Use of pendulum apparatus for investigating chronometers.—The use of invariable pendulums. as time standards has been suggested by Dr. Mendenhall.* A special application of this idea would be the use of the half-second apparatus for investigating the temperature compensation of chronometers, as well as diurnal fluctuations of rate and the rate changes due to other causes, as moisture, atmospheric pressure, etc. By comparison with a pendulum whose period is known it is possible to obtain the rate of a break-circuit chronometer with considerable precision in half an hour. Of course for other than break-circuit chronometers some intermediate means of comparison would be necessary. The effect of rapid changes of temperature on chronometers Negus 1829 and 1823 was tested in this way, as shown below, the pendulum swings being an hour long, and about an hour and a half being allowed for the chronometer to acquire the changed temperature.

Chronometer.	Period of pendulum corrected except for rate.	Corrected period of pendulum previously determined.	Difference, correction for rate.	Resulting daily rate of chronometer.	Temperature of chronometer.
	s.	*s.*	*s.*	*s.*	° *C.*
Negus 1829	·500 8744	·500 8765	+·000 0021	+0·36	14·0
" "	8745	8765	+ 20	+0·35	21·0
" "	8755	8765	+ 10	+0·17	30·7
Negus 1823	8753	8765	+ 12	+0·21	14·0
" "	8746	8765	+ 19	+0·33	20·2
" "	8728	8765	+ 37	+0·64	29·5

III.—TELEGRAPHIC COMPARISON BETWEEN BASE STATIONS IN WASHINGTON, D. C.

Mention of this work and its objects has already been made (Report 1891, Part II, p. 563). A room having been fitted up for pendulum work in the basement of the Coast and Geodetic Survey Office, it was desired to compare this station with the former base station at the Smithsonian Institution, so that relative gravity observations referred to either point as a base could be reduced to a common system. For this purpose the telegraphic method was employed, which consists in the simultaneous swinging of two pendulums at stations connected by wire, so that the same timepiece may be used at both, thus freeing the observations from the rate of the chronometer, and avoiding the necessity for time observations. If the pendulums are then interchanged between the stations and the operation repeated, or if they are compared at the same place before or afterwards, the difference in the force of gravity may be deduced. The telegraphic method has been employed in Europe,† but is modified in the present instance by the alternate use of a chronometer at each end of the line, with the object of thus eliminating the effect of any variation in the transmission time that might occur during a swing.‡

Description of stations.—At the Coast and Geodetic Survey Office observations were made in the pendulum room already described. At the Smithsonian Institution the pendulums were swung in the room in the northeast basement, which had previously been used for this purpose. The receiver was placed on the same brick pier on which the half-second pendulums were swung in March, 1891. This station is about 1430 metres west and 180 metres north of the Coast and Geodetic Survey Office, and the elevation above mean sea level is 10 metres.

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* Report United States Coast and Geodetic Survey, 1891, Part II, page 523.

† Philosophical Transactions of the Royal Society, 1856, page 297, G. B. Airy. Mittheilungen des kaiserl. königl. Militär-Geographischen Institutes, Vol. III, page 59, Von Sterneck. Comptes Rendus de l'Association Géodésique Internationale, Nice, 1887, Appendix V, Defforges.

‡ Report Coast and Geodetic Survey for 1891, Part II, page 528.

Apparatus.—The A and B sets of half-second pendulum apparatus were used, but only one pendulum of each set was swung, B 1 and A 4. B 1 is one of the original type of these pendulums carrying a knife-edge, while A 4 is of the modified form with agate plane in head, as described in the first part of this report. Break-circuit sidereal chronometers Negus 1823 and 1824 were used, 1823 being at the Smithsonian and 1824 at the office in the comparison between the stations. The thermometers and barometers had their errors carefully determined.

The diagram (fig. 7) shows the general arrangement of circuits. Through the courtesy of Mr. Marean, a Western Union wire was used between the stations. In addition to key and sounder for communication there were two local circuits at each station, one containing flash apparatus,

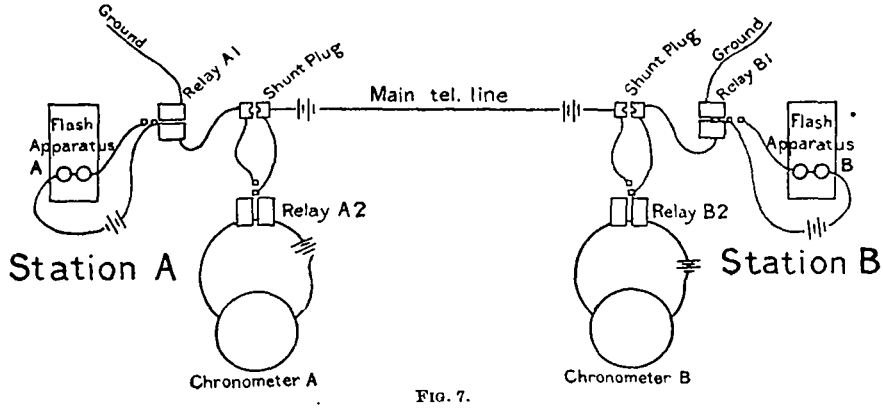

FIG. 7.

battery, and the points of a 50-ohm relay whose magnet was in the main line, and the other containing the chronometer, a single cell, and the magnet of a 20-ohm relay whose break-circuit points were in the main line. Either chronometer could be cut out from the main line by a shunt plug.

Plan of observations.—Endeavor was made to make the swings of the pendulums at the two stations as nearly simultaneous as possible. A convenient code of signals was arranged so that the observers could readily communicate with each other. The two pendulums were started swinging at the same time and four coincidences observed with the chronometer at Station B, breaking the main line circuit. This chronometer was then cut out and that at Station A put in, and four more coincidences observed. At the end of the swing of about an hour's length the same order was followed. The temperature, pressure, and arc were read immediately after the first and last coincidences with each chronometer. The observations with B 1 were made by the writer, and with A 4 by H. B. von der Trenck, Acting Aid.

Reductions and determination of coefficients.—The separate swings with each pendulum and chronometer were reduced to standard conditions, arc infinitely small, temperature 15° C., pressure 500^{mm} at 0° C., in the manner already described, the only difference being that no rate correction was applied, as the rate was eliminated in the final combination of periods, and no time observations for rating of chronometers were made. The temperature coefficients of the two pendulums were determined by the comparative method, using first one and then the other pendulum as a standard, and varying the temperature conditions of the remaining one. Six results were obtained for each pendulum, each deduced by comparing swings at high and low temperatures (range about 25° C.), as follows:

Position.	Pendulum A 4.	Pendulum B 1.
	s.	*s.*
Direct	·00000 416	·00000 422
"	417	420
"	419	421
Reversed	420	417
"	420	418
"	420	421
Mean	·00000 419	·00000 420

The above mean temperature coefficients (representing increase of period for 1° C. increase of temperature) were used for the two pendulums, respectively.

Table H gives a summary of the reduced periods, and the differences A—B, for each chronometer and swing. In these tables of differences it will be noted that large values with one chronometer are in general accompanied by small values with the other, probably indicating the effect of variations in the line, as the chronometers were at the two ends. The last column in this table shows the precision with which successive comparisons of the periods of two pendulums can be made under unchanged conditions, the greatest discrepancy from the mean of any group being about one-millionth part of the period.

Results.—Below are collected the mean periods for each relation of the pendulums, averaging also the results by the two chronometers:

Pendulum.	I A at office. B at office.		II A at office. B at Smithsonian.		III B at office. A at Smithsonian.	
	Direct.	Reversed.	Direct.	Reversed.	Direct.	Reversed.
	s.	*s.*	*s.*	*s.*	*s.*	*s.*
A4	·500 8636	·500 8661	·500 8648	·500 8650	·500 8675	·500 8688
B1	·500 7615	·500 7648	·500 7620	·500 7631	·500 7657	·500 7680

The relation between the force of gravity of the two places may be computed in three ways from the above relative periods. Thus, if A_o B_o be the periods and g_o the force of gravity at one station, and A_s, B_s, and g_s the periods and force of gravity at the other, we have expressions for gravity at the unknown station, as shown in the following table, where are also given the resulting computed values (based on g_s at Smithsonian assumed to be 980·100). The three results will, of course, not be independent, as will be seen at once by multiplying together the first two formulas. The third expression may be put in the more convenient form for computation $g_o = g_s\left[1 + \frac{A_s - A_o}{A_o} + \frac{B_s - B_o}{B_o}\right]$, neglecting an inappreciable term. The difference in gravity at the two stations is therefore $g_o - g_s = g_s\left[\frac{A_s - A_o}{A_o} + \frac{B_s - B_o}{B_o}\right]$.

Sets combined.	Formula.	Gravity at Coast and Geodetic Survey Office.		
		Pendulums direct.	Pendulums reversed.	Mean.
		Dynes.	*Dynes.*	*Dynes.*
I and II	$g_o = g_s\left(\frac{A_o}{B_o} \times \frac{B_s}{A_o}\right)^2$	980·097	980·098	980·098
I and III	$g_o = g_s\left(\frac{B_o}{A_o} \times \frac{A_s}{B_o}\right)^2$	980·099	980·098	980·098
II and III	$g_o = g_s\left(\frac{B_s}{A_o} \times \frac{A_s}{B_o}\right)$	980·098	980·098	980·098

From the above gravity is seen to be 0·002 dyne smaller at the Coast and Geodetic Survey Office than at the Smithsonian. The difference in elevation, 4 metres, would account for a difference of about 0·001 dyne.

TABLE H.—*Periods corrected except for rate.*

I.—BOTH A AND B AT COAST AND GEODETIC SURVEY OFFICE.

No. of swing.	Date.	Pendulums and positions.	Periods. Pendulum A. Chron'r 1823.	Periods. Pendulum A. Chron'r 1824.	Periods. Pendulum B. Chron'r 1823.	Periods. Pendulum B. Chron'r 1824.	Difference in periods, A—B (seventh decimal place). Chron'r 1823.	Difference in periods, A—B (seventh decimal place). Chron'r 1824.	Difference in periods, A—B (seventh decimal place). Mean.
	1893.		s.	s.	s.	s.			
1	Jan. 7	A4 D B1 D	·500 8680	·500 8626	·500 7656	·500 7606	1024	1020	1022
2	7		8683	8628	7662	7603	21	25	23
3	9		8654	8592	7637	7575	17	17	17
4	9		8658	8605	7640	7582	18	23	20
5	9		8665	8604	7645	7580	20	24	22
13	12		8653	8579	7634	7555	19	24	22
	Means		·500 8666	·500 8606	·500 7646	·500 7584			1021
6	Jan. 10	A4 R B1 R	·500 8683	·500 8629	·500 7668	·500 7618	1015	1011	1013
7	10		8687	8646	7676	7631	11	15	13
8	10		8686	8635	7675	7622	11	13	12
	Means		·500 8685	·500 8637	·500 7673	·500 7624			1013

II.—A AT COAST AND GEODETIC SURVEY OFFICE, B AT SMITHSONIAN.

14	Jan. 14	A4 D B1 D	·500 8774	·500 8534	·500 7749	·500 7508	1025	1026	1026
15	15		8764	8533	7743	7501	21	32	26
16	16		8764	8516	7733	7486	31	30	30
17	16		8766	8507	7740	7479	26	28	27
20	18		8765	8493	7739	7458	26	35	30
21	19		8789	8518	7762	7486	27	32	30
22	19		8784	8526	7755	7504	29	22	26
23	19		8790	8546	7760	7515	30	31	30
	Means		·500 8774	·500 8522	·500 7748	·500 7492			1028
18	Jan. 17	A4 R B1 R	·500 8782	·500 8517	·500 7765	·500 7496	1017	1021	1019
19	18		8751	8490	7732	7472	19	18	18
24	20		8775	8550	7760	7532	15	18	16
25	20		8779	8552	7758	7530	21	22	22
	Means		·500 8772	·500 8527	·500 7754	·500 7508			1019

III.—B AT COAST AND GEODETIC SURVEY OFFICE, A AT SMITHSONIAN.

26	Jan. 22	A4 D B1 D	·500 8785	·500 8535	·500 7768	·500 7519	1017	1016	1016
27	23		8756	8556	7737	7542	19	14	16
30	23		8782	8603	7764	7587	18	16	17
31	23		8776	8605	7756	7586	20	19	20
	Means		·500 8775	·500 8575	·500 7756	·500 7558			1017
28	Jan. 23	A4 R B1 R	·500 8774	·500 8601	·500 7765	·500 7593	1009	1008	1008
29	23		8778	8600	7773	7591	05	09	07
	Means		·500 8776	·500 8600	·500 7769	·500 7592			1008

IV.—SUMMARY OF THE CONNECTIONS BETWEEN AMERICAN AND EUROPEAN GRAVITY STATIONS BY MEANS OF RELATIVE PENDULUM OBSERVATIONS, AND THE REDUCTION OF ABSOLUTE DETERMINATIONS OF GRAVITY TO WASHINGTON.

The rapidly increasing number of gravity observations in various countries renders it desirable that a preliminary discussion should be made of the existing data which may be used in connecting those determinations which depend on Washington with the work that has been referred to the

principal base stations of Europe. The following is a list (in chronological order) of the various pendulum expeditions which give, either directly or through some intermediate station, the connection desired:

1. *Freycinet*, 1817–20, using three invariable pendulums, starting from Paris. Stations in common with Americans: Mauwi (only one pendulum used), identical with Preston's station, Lahaina, 1883–87; Port Jackson, less than 1 mile from and 10 metres lower in elevation than Smith's station, Sydney, 1883–84; Cape of Good Hope, identical with Preston, 1889-90. Results published in Voyage Autour du Monde par M. Louis de Freycinet, Vol. V, Paris, 1826.

2. *Duperrey*, 1822–25, using two invariable pendulums, starting from Paris. Stations in common: Port Jackson, probably same as Freycinet's, and hence bearing same relation to Smith's station, Sydney, 1883–84; Ascension (only one pendulum used), very nearly same as Preston, 1889–90 (Georgetown). Results published in Connaissance des Tems, 1830, page 83.

3. *Sabine*, 1822–24, using two invariable Kater pendulums, starting from London (Mr. Browne's house, Portland place). Stations in common: New York, Columbia College, latitude 40° 42′ 43″ N., elevation 67 feet (20 metres); this is about 10 metres more elevated and 1″5 south of the station at Hoboken, Peirce, 1876–77; Herschel, 1881–82; Mendenhall, 1891. Results published in An Account of Experiments to Determine the Figure of the Earth, by Edward Sabine, London, 1825.

4. *Fallows*, 1825–28, one invariable Kater pendulum swung at London (Mr. Browne's house) and at Cape of Good Hope, same station as Preston, 1889–90. Philosophical Transactions, 1830, page 153.

5. *Lütke*, 1826–29, one invariable Kater pendulum, Russian expedition, including Greenwich; St. Helena, not distant from and nearly same elevation as Preston, 1889–90 (Jamestown); Sitka, supposed to be near station of Mendenhall, 1891. Mémoires Prés. a l'Académie imp. de St. Petersbourg, 1837.

6. *Foster*, 1828–31, four Kater pendulums, two invariable and two reversible, starting from London (Mr. Browne's house). Among the stations are: Ascension, identical with Preston, 1889–90 (Georgetown); St. Helena, not distant from and about same elevation as Preston, 1889–90 (Jamestown); Cape of Good Hope, same as Preston, 1889–90. Memoirs of the Royal Astronomical Society, Vol. VII, London, 1834.

7. *Peirce*, 1876–77, one Repsold reversible pendulum. Absolute determinations of gravity made at the European base stations: Paris, Observatory, Hall of the Meridian, 74 metres elevation; Berlin, comparison room of the Imperial Eichungsamt, garden of the Observatory, 35 metres elevation; Kew, at the Observatory, 7 metres elevation. The pendulum was also swung at Hoboken (same station as Herschel, 1881–82, and Mendenhall, 1891), but only a relative value deduced. The results at the European stations were also combined relatively. American Journal of Science, Vol. 20, 1880, page 327; Report United States Coast and Geodetic Survey, 1876, Appendix 15. Geneva was not included in this relative comparison on account of change in the pendulum after the work there.

8. *Herschel*, 1881–82, three invariable Kater pendulums, swung at London, Langham place, 116 metres distant from and 4 metres lower than Mr. Browne's house; Kew; Greenwich; Washington, Smithsonian Institution; Hoboken, same as Peirce, 1876–77; Mendenhall, 1891. Philosophical Transactions Royal Society, 1890, vol. 181, page 558. The results with pendulum No. 11 at the three stations near London were not used, as they are discordant.

9. *Smith*, 1883–84, three Kater invariable pendulums, at Sydney, near, but 10 metres higher than, stations of Freycinet and Duperrey; Tokio, near place where Mendenhall made absolute determination in 1880; Washington, Smithsonian Institution. Report United States Coast and Geodetic Survey, 1884, Appendix 14, page 472. Result with pendulum No. 4 at Tokio not used.

10. *Preston*, 1883–87, one Peirce reversible pendulum swung at Lahaina, same as Freycinet's station, Mauwi, 1817–20. Connection with Washington by way of San Francisco. Report United States Coast and Geodetic Survey, 1888, Appendix 14, pages 531, 563.

11. *Preston*, 1889–90, two Peirce reversible pendulums, starting from Washington (Smithsonian Institution). Stations in common: St. Helena (Jamestown), nearly same as Lütke, 1826-29, and Foster, 1828–31; Ascension (Georgetown), same as Duperrey, 1822–25, Sabine, 1822–24, Foster, 1828–31; Cape of Good Hope (Cape Town), same as Freycinet, 1817-20, Fallows, 1825–28, Foster, 1828-31. Report United States Coast and Geodetic Survey, 1890, Appendix 12, page 684.

12. *Mendenhall*, 1891, three invariable half-second pendulums, starting from Washington (Smithsonian Institution). At Sitka, probably near station of Lütke, 1826-29; at Hoboken, same as Peirce, 1876–77, Herschel, 1881–82. Report United States Coast and Geodetic Survey, 1891, Part II, page 561.

13. *Defforges*, 1893, one "reversible inversable" pendulum swung at Paris and Washington, Coast and Geodetic Survey Office. Comptes Rendus, January 29, 1894. Value for Paris taken from Mémorial du Dépôt Général de la Guerre, Tome XV, 1894.

For the first six expeditions in this summary, the results as given by Helmert in Höhere Geodäsie, Vol. II, were used. These are mostly based on Baily's discussion and correction of the original observations, Memoirs Royal Astronomical Society, VII, 1834. The values are reduced to sea level (with the exception of Sabine's; see remark by Peirce, Report United States Coast and Geodetic Survey, 1881, Appendix 15, page 442), so that for the purposes of this discussion the elevation correction is reapplied so as to reduce them back to the point of observation. For expeditions seven to thirteen original authorities were consulted. Allowances were made for

differences of elevation and latitude of connecting stations when they were not identical. The difference between the two stations in Washington was also applied, and all results were finally referred to the Coast and Geodetic Survey Office in Washington, and in Europe to one of the following: Peirce's stations in Paris, Berlin, and Kew; London (Mr. Browne's house), or Greenwich (Observatory).

Collecting the results from all the above connections and expressing them differentially, we have the following table (I), in which the last column is the excess of gravity at the European station over gravity at Washington in dynes:

TABLE I.—*Connections between Washington (Coast and Geodetic Survey Office) and European gravity stations (not reduced to sea level).*

European base station.	Observers and dates.			Connection.	Excess of gravity at European station.
					Dynes.
Paris (Observatory)	Preston 1889-90	Duperrey	1822-25	Via Ascension	0·763
	Preston 1889-90	Freycinet	1817-20	Via Cape of Good Hope	0·774
	Preston 1883-87	Freycinet	1817-20	Via Lahaina (Mauwi)	0·787
	Smith 1882-84	Freycinet	1817-20	Via Sydney (Port Jackson)	0·789
	Smith 882-84	Duperrey	1822-25	Via Sydney (Port Jackson)	0·825
	Defforges 1893			Direct	0·831
	Mendenhall 1891 / Herschel 1881-82	Peirce	1876-77	Via Hoboken	0·865
					0·805
London (Browne's house)	Preston 1889-90	Fallows	1825-28	Via Cape of Good Hope	1·026
	Preston 1889-90	Sabine	1822-24	Via Ascension	1·029
	Preston 1889-90	Foster	1828-31	Via Ascension	1·033
	Preston 1889-90	Foster	1828-31	Via Cape of Good Hope	1·063
	Herschel 1881-82			Direct	1·089
	Mendenhall 1891 / Herschel 1881-82	Sabine	1822-24	Via Hoboken and New York	1·089
	Preston 1889-90	Foster	1828-31	Via St. Helena	1·093
					1·060
Greenwich	Herschel 1881-82			Direct	1·062
	Preston 1889-90	Lütke	1826-29	Via St. Helena	1·071
	Mendenhall 1891	Lütke	1826-29	Via Sitka	1·087
					1·073
Kew	Herschel 1881-82			Direct	1·100
	Mendendall 1891 / Herschel 1881-82	Peirce	1876-77	Via Hoboken	1·106
					1·103
Berlin (Observatory)	Mendendall 1891 / Herschel 1881-82	Peirce	1876-77	Via Hoboken	1·167
					1·167

No attempt is made at present to weight or adjust these connections, which are in some cases quite discordant. Several direct connections between the European base stations have been made, some of which have not yet been published. When more of these are available an adjustment can be made of the connections between Washington and the base stations, and the direct connections between the latter, and the more direct and reliable results can be given greater weight.

Taking the mean of the results for each group, we have:

	Dynes.
g at Paris (Observatory) $-$ g at Washington (Coast and Geodetic Survey)	$= +$ 0·805
g at London (Browne's house) $-$ g at Washington (Coast and Geodetic Survey)	$= +$ 1·060
g at Greenwich (Observatory) $-$ g at Washington (Coast and Geodetic Survey)	$= +$ 1·073
g at Kew (Observatory) $-$ g at Washington (Coast and Geodetic Survey)	$= +$ 1·103
g at Berlin (Observatory) $-$ g at Washington (Coast and Geodetic Survey)	$= +$ 1·167

As nearly all of the most important absolute determinations of gravity have been made either at one of these base stations or at points which have been referred relatively to them these values can now be reduced to Washington. This has been done, and the resulting values of g for Washington are collected in the following table (K). Of course the results are not free from the errors of the relative connections, but these are probably small compared with the actual discrepancies which appear in the absolute measurements themselves. The difference between the smallest and largest value (omitting Kater's) amounts to about the one seven-thousandth part of g. The simple mean of the twenty-nine values (omitting Kater's) is 980.107, not very different from the provisional value adopted for Washington. No determinations are included in this list previous to that of Borda in 1792.

TABLE K.—*Absolute determinations of the force of gravity, with results reduced to Washington, Coast and Geodetic Survey Office (not reduced to sea level).*

No.	Observer.	Date.	Place of determination.	Apparatus.	Result reduced to Washington, Coast and Geodetic Survey Office.	
					Length sec. pend.	Gravity.
					cm.	*Dynes.*
1	Peters	1869	Berlin	Lohmeier reversible pendulum	99·2995	980·047
2	Preston	1890	Washington	Peirce reversible pendulum	·2998	·050
3	Sabine	1829	Greenwich	Kater convertible pendulum	·3005	·056
4	Lorenzoni	1886	Padua	Repsold reversible pendulum	·3007	·058
5	Anton	1878	Berlin		·3011	·062
6	Peters	1869	Altona	Lohmeier reversible pendulum	·3013	·065
7	Peters	1870	Königsberg	" " "	·3017	·068
8	Bessel	1826–27	Königsberg	Ball and wire, 2 lengths, differential	·3021	·072
9	Peirce	1875	Geneva	Bessel reversible pendulum	·3022	·073
10	Plantamour	1869	Berne	" " "	·3024	·075
11	Plantamour	1865–71	Geneva	" " "	·3028	·079
12	Mahlke	1891	Hamburg		·3033	·084
13	Heaviside	1874	Kew	Kater convertible pendulum	·3036	·087
14	Peirce	1876	Berlin	Bessel reversible pendulum	·3048	·099
15	Peirce	1876	Kew	" " "	·3051	·102
16	Biot	1825	Padua		·3054	·105
17	Bessel	1835	Berlin	Ball and wire, 2 lengths, differential	·3055	·106
18	Biot	1824	Milan		·3062	·113
19	Pucci and Pisati	1882	Rome	Bessel wire pendulum	·3065	·116
20	Oppolzer	1884	Vienna	Repsold reversible pendulum	·3085	·135
21	Von Orff	1877	Munich	" " "	·3088	·138
22	Messerschmitt	1889	Zürich	" " "	·3092	·143
23	Biot	1824	Paris		·3098	·148
24	Borda	1792	Paris	Ball and wire	·3102	·153
25	Peirce	1876	Paris	Bessel reversible pendulum	·3109	·159
26	Mendenhall	1880	Tokio	Ball and wire	·3114	·164
27	Defforges	1893	Washington	Two reversible pendulums, differential	·3115	·165
28	Defforges	1888	Greenwich	" " " "	·3134	·184
29	Defforges	1889–90	Paris	" " " "	·3144	·194
30	Kater	1817	London	Kater convertible pendulum	[·3236]	[·285]
				Mean	99·3056	980·107

Authorities and references for the values of absolute gravity referred to Washington, as given in the table:

Nos. 1, 4, 5, 6, 10, 11, 12, 17, 20, 21, 22 are from the values given for Vienna by Von Sterneck (Mittheilungen des k. u. k. milit. geograph. Institutes," Vol. XII, 1892, p. 40), and are reduced to Berlin by his relative connection between Vienna and Berlin. Nos. 1, 5, 17 are also given for Berlin directly, and Nos. 6, 12 for Hamburg (p. 39), as furnished by Helmert, with corrections supplied by him.

No. 2, Preston, Report United States Coast and Geodetic Survey, 1890, Appendix 12, page 683.

Nos. 3, 13, 30, Herschel, G. T. Survey of India, Vol. V, Appendix 4, page 99; the scare values as recomputed and corrected by Herschel.

Nos. 7, 8, Helmert, Höhere Geodäsie, Vol. II, page 209. The values there given are reduced to sea level, so that this correction is subtracted. They are then referred to Berlin by applying the mean of the results of Bessel and Peters for the difference between Berlin and Königsberg; the values are really, therefore, not independent of Nos. 1 and 17.

No. 9 is taken from Von Sterneck's table as above, and reduced to Berlin, and a slight correction applied, so that the correction for the length of the standard referred to shall agree with Nos. 14, 15, 26.

Nos. 14, 15, 25, Peirce, Report United States Coast and Geodetic Survey, 1876, Appendix 15, page 320; also American Journal of Science, Vol. 20, 1880, page 327. To the lengths of the seconds pendulum there given a correction of —·000 0094 metre is applied, based on later investigation of the reference standard of length (No. 49). Bulletin No. 17, United States Coast and Geodetic Survey. The values as used are combinations of relative and absolute determinations.

Nos. 16, 18, 19, Lorenzoni, Atti del R. Istituto Veneto di scienze, lettere ed arti, Tomo V, Serie VII, 1893-94, page 293. These results are given referred to Vienna, and are reduced from Vienna to Berlin by Von Sterneck's relative value, as in the first group.

Nos. 23, 24, Peirce, Report United States Coast and Geodetic Survey, 1881, Appendix 17, page 462. These are the values as corrected by Peirce.

No. 26, Mendenhall, Memoirs of the Science Department, Tokio Daigaku (University of Tokio) No. 5, 1881, page 7. Referred to Washington by connection with Kater pendulums (1882-84).

No. 27, Defforges, Comptes Rendus, January 29, 1894.

Nos. 28, 29, Defforges, Mémorial du Dépôt Général de la Guerre, Tome XV, Observations du Pendule, Paris, 1894.

V.—ANOMALIES IN THE FORCE OF GRAVITY ON THE CONTINENT OF NORTH AMERICA, BY COMMANDANT DEFFORGES.

[Translation.]

The studies of the force of gravity undertaken by the "Service Géographique" of the army have permitted the formulation of some interesting empirical laws, which were submitted on July 15, 1893, to the judgment of the Academy by the minister of war.

It is shown by the recent measures, and by a certain number of older determinations which can be combined with certainty with the contemporary observations, that the shore of the same sea appears to possess a characteristic force of gravity, the variation of which along that shore follows sufficiently exactly the law of the sine squared of the latitude announced by Clairant. But, on the one hand, the islands which arise from the great depths of the sea present a considerable excess of gravity, as has been inferred since the first discussions of observations with the pendulum made during the old voyages of circumnavigation; and, on the other hand, upon the continents of Europe, Africa, and Asia there is proved a defect of gravity which seems in the distribution of the masses of the terrestrial crust to counterbalance the excess of the islands of the ocean.

It was of interest to extend and confirm this last law, and to ascertain if the American continent actually presented, like the other continents, this negative anomaly of gravity, and to what degree. Taking advantage of a voyage of duty to the United States, I have been able, with the aid of funds generously placed at my disposition by the Academy, to execute with the "reversible inversable" pendulum relative observations of the force of gravity at seven stations on the continent of North America.

Furthermore, upon a courteous request addressed by Dr. T. C. Mendenhall, Superintendent of the Coast and Geodetic Survey, to the director of the "Service Géographique" of the army, I have measured the absolute force of gravity at Washington with the pendulums of Brunner.

The relative stations have been chosen in such a manner as to bring out as much as possible the continental anomalies. Two of the stations, San Francisco and Washington, are situated near the shores of the oceans, and within a few degrees upon the same parallel. A central station, at Salt Lake City, not distant from the Great Salt Lake, occupies a point in the lowest part of the great plateau between the Rocky Mountains and the Sierra Nevada. Another station at the observatory recently founded at Denver, on the other side of the Rocky Mountains, at more than 1,600 metres elevation, is situated upon the vast plateau which serves as a pedestal to the Rocky Mountains and descends by insensible degrees to the valley of the Mississippi.

These two stations, Salt Lake City and Denver, are sufficiently distant from the most elevated mountain masses to escape the topographic attraction, and their situation upon the solid mass itself of the backbone of the American continent render them well suited to reveal the continental defect of gravity with its greatest value.

The other stations, Mount Hamilton, Chicago, and Montreal, situated on both sides of the stations of the great plateau, serve for transition to the stations on the borders of the oceans, and permit the following of the variation of the anomaly, referred to gravity observed at Paris, until beyond its change of sign, which takes place at some distance from the ocean shore, following the law already established in Europe and Algeria.

The absolute force of gravity, measured at Washington in the pendulum room of the Coast and Geodetic Survey Office, is

$$g = 9{\cdot}80\ 165 \text{ metres}$$

The relative measure gave, between Paris and Washington,

$$g = 9{\cdot}80\ 169 \text{ metres}$$

The accord of the two values is entirely satisfactory. I have adopted for Washington the mean

$$g = 9{\cdot}80\ 167 \text{ metres}$$

The table which follows includes the values of g measured, relatively to Paris, at the seven American stations, and for each of these: First, the reduction to the level of the sea, following the formula of Bouguer; second, the theoretic gravity, calculated according to the law of Clairaut and with the flattening of Clarke, considering as normal the force of gravity at Paris; and finally, third, the anomaly of the observed gravity.

Station.	Latitude.	Altitude.	g observed.	Reduction of Bouguer.	g		Anomaly.
					Reduced.	Computed.	
	G.	*m.*	*m.*		*m.*	*m.*	
Washington	*43·21	10	9·80167	+ 2	9·80169	9·80127	+ 42
Montreal	50·57	100	9·80729	+ 18	9·80747	9·80716	+ 31
Chicago	46·46	165	9·80345	+ 30	9·80375	9·80386	— 11
Denver	44·33	1645	9·79684	+299	9·79983	9·80216	—233
Salt Lake City	45·30	1288	9·79816	+234	9·80050	9·80293	—243
Mount Hamilton	41·47	1282	9·79683	+233	9·79916	9·79991	— 75
San Francisco	41·98	114	9·80016	+ 21	9·80037	9·80030	+ 7

*Latitude = 38° 53′·2 = 43·21 G. Incorrectly given in original.

The curve (here omitted) gives a very clear idea of the general change of the anomaly of gravity on the American continent.*

Although the deviations of the vertical have not yet been determined at the American stations, the largest values which experience has given for this deviation on the globe would not affect the anomalies to a sensible amount.

These results entirely confirm the facts of observation announced in the note of July 15 last. It is interesting to note that the continental anomaly upon the high American plateau is very nearly equal and of opposite sign to the anomalies of the islands in the great depths of the Pacific and Atlantic.

Atlantic islands.		American continent.		Pacific islands.	
	m.		*m.*		*m.*
St. Thomas	+·00 172	Denver	—·00 233	Ualan	+·00 283
Ascension	+ 151	Salt Lake City	— 243	Guam	+ 197
St. Helena	+ 225			Mauwi	+ 180
Fernando de Noronha	+ 196			Ile de France	+ 224
Mean anomaly	+·00 186		—·00 238		+·00 221

*The two extremities of the curve of anomalies are elevated above the level of the sea in consequence of the adoption of gravity at Paris as normal. Gravity at Paris is, in fact, affected by a slight continental defect.

A REPORT ON A GEOLOGIC EXAMINATION OF SOME COAST AND GEODETIC SURVEY GRAVITY STATIONS.

By G. K. GILBERT, Geologist United States Geological Survey.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., March 19, 1895.

DEAR SIR: In accordance with an informal arrangement made a year ago between this office and the Superintendent of the Coast Survey, Mr. G. K. Gilbert was instructed to make some special geological examinations in conjunction with the work of Mr. Putnam in the measurement of gravity. As this work on behalf of the Geological Survey was merely accessory to that of the Coast Survey, it seems proper that its results should be published by the Coast Survey in conjunction with the report by its own officer. I therefore transmit to you herewith Mr. Gilbert's report, which is in the form of a letter addressed to yourself.

Yours, with respect,

CHAS. D. WALCOTT, *Director.*

Gen. W. W. DUFFIELD,
Superintendent United States Coast and Geodetic Survey.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., March 19, 1895.

SIR: About a year ago Dr. T. C. Mendenhall, then Superintendent of the Coast and Geodetic Survey, invited me to make suggestions as to the selection of points for gravity stations. He was at that time planning a transcontinental chain of stations, approximately in latitude 39°, and he desired to have the points of observation so chosen as to give light not only on geodetic problems but also on problems of peculiar interest to geologists. In one of the conferences on this subject it was suggested that special geologic examination of stations occupied was desirable, and as I was to be engaged in field work in Colorado while the gravity determinations were made, it was informally arranged that the precise points occupied by the observer should be communicated to me in Colorado, and I should visit as many stations as practicable on my way back to Washington in the autumn. This arrangement was afterwards carried out, permission therefor being granted by the Director of the Geological Survey, and all necessary information as to places, etc., being forwarded to me by Mr. G. R. Putnam, the Assistant in charge of the work. The stations visited by me were Colorado Springs, Denver, Wallace, Ellsworth, Kansas City, St. Louis, Terre Haute, Chicago, Cincinnati, and Cleveland.

As the mean density of the earth is greater than the density of the visible crust, there must be a general increase of density downward. So far as zones of equal density are spheroidal shells parallel to the superficial spheroid of reference, the distribution of densities may be regarded as regular or normal. To whatever extent the different parts of a spheroidal shell vary in density

the distribution is irregular. The geodesist and the geologist alike are interested in the determination of the nature and extent of such irregularities. With the outermost portion of the lithosphere the geologist has some acquaintance, and he knows that it is not of uniform density. He suspects that the zone of heterogeneity extends farther, characterizing all that indefinitely limited portion of the lithosphere which he calls crust, and he hopes that with the multiplication of pendulum stations much may be learned of the extent and distribution of crustal inequalities.

If the heterogeneity indicated by the pendulum is confined to the zone which is subject to direct observation or clear inference by the geologist, or if it resides chiefly in that zone, then the application of a correction properly based on geologic observations should render the measurements of local gravity more harmonious. If the application of such a correction fails to diminish the discrepancies of gravity determinations, the chief cause of local variation would seem to lie farther beneath the surface, or at least to range farther from the surface.

At each station visited I examined the formations visible at the surface, collected samples to be used afterwards for the determination of specific gravities, and compiled such data as were available from wells and the labors of other geologists as to the character of underlying formations.

The densities, or specific gravities, of the specimens collected were determined by Mr. George W. Stose, Assistant Geologist, United States Geological Survey. For this purpose blocks of the size known as hand specimens were employed wherever practicable, and care was taken to obtain the specific gravity of the rock as saturated with water, except in the case of specimens representing formations which lay above water line. Determinations were also made of a considerable number of other specimens in order to obtain average values for the densities of such rocks as were reported in well records, but were not available for specific determination.

A great region, including the stations visited, is characterized by sedimentary rocks lying in nearly horizontal beds. These are of such vertical extent that at none of the stations have they been completely traversed by the drill; but it is legitimately inferred from a study of the relations of these rocks as exhibited elsewhere that they have a total thickness ranging from one-half mile to 3 miles, and that beneath them are crystalline rocks which are not similarly arranged in horizontal strata, but are disposed in beds of less regular shape whose boundaries are often highly inclined or vertical. The particular disposition and arrangement of these crystalline rocks in the vicinity of any of the stations can not be inferred from data now in the possession of the geologist, so that they must be classed for the purposes of this discussion with the subcrust of unknown density. Nevertheless, as the sedimentary columns are of unequal height, their attraction can not be compared to advantage without making some assumption as to the density of the crystallines on whose uneven surface they stand. The particular assumption on which the computations and accompanying tables are based is that the average density of the crystallines is 2·70. An average density of 2·65 was also assumed, and the computations repeated, but the results were so nearly identical that they are omitted to avoid prolix repetition.

The standard density, 2·70, was subtracted from the densities of the various sedimentary rocks determined, reported, or inferred to occur beneath each of the gravity stations, and the differences were employed in the subsequent computations.

In Table I the stations are listed in the order of their longitudes from east to west. The thickness of the sedimentary rocks was in each case partly determined by local well records and partly estimated by the aid of well records or surface measurements at other points. In the cases of Ellsworth and Wallace the wells are shallow, and the bases of inference were so slender that the estimates of thickness have small value. In the computation of mean densities the measured densities of individual formations were used so far as possible, and in the absence of direct measurements limestones were estimated at 2·70, shales at 2·43, and sandstones at 2·40. The densities ascribed to the rocks at Wallace and Ellsworth are interpolations. The corrections to the local determinations of gravity (column 6) were computed by means of the formula

$$dg = 2g\,\frac{H}{r}\,\frac{3}{4}\,\frac{\delta - 2{\cdot}7}{\triangle}$$

where H represents the thickness of the sedimentary rocks, δ their mean density, $\triangle$ the earth's mean density, and r the earth's radius. The quantities in column 7 are residuals derived from those in column 6 by subtracting the mean of the quantities in column 6 from the several quantities.

TABLE I.—*Influence of sedimentary rocks on local values of gravity.*

1	2	3	4	5	6	7
Station.	Altitude of station.	Order of abundance of limestone, sandstone and shale.	Estimated thickness of sedimentary rocks.	Mean density (δ) of sedimentary rocks.	Correction to attraction for difference of density.	Residuals from column 6.
	Feet.		*Feet.*		*Dynes.*	*Dynes.*
Cleveland	689	ls. sh. ss.	4500	2·56	+·008	—·008
Cincinnati	804	ls. sh. ss.	3000	2·58	+·005	—·011
Terre Haute	495	sh. ls. ss.	7000	2·53	+·015	—·001
Chicago	597	ss. ls. sh.	2800	2·52	+·006	—·010
St. Louis	505	ls. ss. sh.	4500	2·60	+·006	—·010
Kansas City	917	ls. sh. ss.	5500	2·60	+·007	—·009
Ellsworth	1539	sh. ls. ss.	[6000]	[2·50]	+·015	—·001
Wallace	3297	sh. ss. ls.	[6000]	[2·45]	+·019	+·003
Colorado Springs	6039	sh. ss. ls.	7700	2·43	+·026	+·010
Denver	5374	sh. ss. ls.	15800	2·42	+·056	+·040
				Mean	·016	·010

In considering the effect of applying such geologic corrections as appear in column 6 of Table I to local observation of gravity two quite distinct and opposing points of view should be kept in mind:

(*a*) *High rigidity.*—The earth's crust may be regarded as rigid, or at least stiff enough to support the continents by its stiffness. In this case no necessary relation exists between altitude and density of crust. On this theory every measurement of gravity on land should be corrected by subtracting from it the attraction due to the matter lying between the station and the surface of the spheroid of reference.

(*b*) *Isostasy.*—The earth's crust may be regarded as relatively weak and plastic. In this case the continental masses and ocean beds are in quasi-hydrostatic equilibrium, and altitude is inversely related to the density of the crust beneath. On this hypothesis the correction should not be applied.

The method employed in discussing the effect of the geologic corrections was (1) to make the determinations as homogeneous as possible by applying all corrections except the geologic one, and then note the outstanding discordance as shown by the residuals, or differences between individual measures and the mean of all the measures; (2) to repeat the process, including the geologic corrections, and thus derive a second series of residuals; and (3) compare the two series of residuals.

In Table II, postulating the theory of high rigidity, column 8 gives the observed values of gravity after correction for latitude, altitude, local topography, and the attraction of matter above sea level. The adjustment for latitude consisted in reducing each value to its equivalent at latitude 40°. The corrections for altitude and for the defect of attraction ascribable to the local topographic relief were those tabulated by Mr. Putnam. The correction for the attraction of matter above sea level assumed the density of that matter to be 2·70. It should be noted in this connection that the (positive) correction for altitude and the (negative) correction for the attraction of matter above sea level are both too small under the theory of high rigidity; for these corrections, as computed, are proportional to the height of the stations above the geoid, whereas they should be proportional to the height of the stations above the spheroid of reference; and the theory of continents upheld by terrestrial rigidity implies that the geoid in continental areas lies above the spheroid of reference. It is probable that if due account were taken of this factor the divergence of the values in column 8 would be somewhat reduced. The values of gravity in column 9 were obtained by adding to the values in column 8 the geologic corrections of column 6 (Table I). The discordances of the values in columns 8 and 9 are exhibited by the residuals in columns 10 and 11.

TABLE II.—*Effect of applying correction for density of local sedimentary rocks to observed values of gravity previously corrected under the hypothesis of high rigidity.*

Station.	8	9	10	11
	Observed gravity corrected for latitude, altitude, topography, and attraction of matter above sea level.	Obseverd gravity corrected as in column 8, and also for density of sedimentary rocks (column 6).	Residuals from column 8.	Residuals from column 9.
	Dynes.	*Dynes.*	*Dynes.*	*Dynes.*
Cleveland	980·135	980·143	+·055	+·047
Cincinnati	980·114	980·119	+·034	+·023
Terre Haute	980·132	980·147	+·052	+·051
Chicago	980·141	980·147	+·061	+·051
St. Louis	980·136	980·142	+·056	+·046
Kansas City	980·110	980·117	+·030	+·021
Ellsworth	980·115	980·130	+·035	+·034
Wallace	980·033	980·052	—·047	—·044
Colorado Springs	979·940	979·966	—·140	—·130
Denver	979·945	980·001	—·135	—·095
Mean	980·080	980·096	·064	·054

It appears from the footings of the table that the gravity determinations at the ten stations, if compared under the hypothesis of rigidity (but without allowance for the deformation of the geoid), exhibit a diversity or discordance measured by the mean of residuals, 0·064 dynes; and that the application of the geologic correction reduces the discordance to 0·054 dynes. If these measures of discordance be further compared with the measure of the diversity of the geologic corrections, 0·010 dynes (column 7, Table I), it appears that the geologic corrections have the maximum possible effect in the direction of harmony, for it is only through their own diversity that they affect the diversity of the quantities to which they are applied.

If any general conclusion may be drawn from these data, it would seem to be that corrections for the densities of the local formations may advantageously be applied to gravity determinations discussed under the hypothesis of terrestrial rigidity.

Table III is based on computations in which isostasy is postulated. The values of gravity in column 12 were corrected as before for latitude, altitude, and local topography, but not for the attraction of matter between the surface and sea level. In this case the correction for altitude needs little qualification for the deformation of the geoid. The values of gravity after the application of the geologic correction appear in column 13. The quantities in columns 14 and 15 are residuals from columns 12 and 13, respectively.

TABLE III.—*Effect of applying correction for density of local sedimentary rocks to observed values of gravity previously corrected under the hypothesis of isostasy.*

Station.	12	13	14	15
	Observed gravity corrected for latitude, altitude, and topography.	Observed gravity corrected as in column 12, and also for density of sedimentary rocks (column 6).	Residuals from column 12.	Residuals from column 13.
	Dynes.	*Dynes.*	*Dynes.*	*Dynes.*
Cleveland	980·158	980·166	+·009	+·001
Cincinnati	·141	·146	—·008	—·019
Terre Haute	·149	·164	·000	—·001
Chicago	·161	·167	+·012	+·002
St. Louis	·153	·159	+·004	—·006
Kansas City	·141	·148	—·008	—·017
Ellsworth	·167	·182	+·018	+·017
Wallace	·145	·164	—·004	—·001
Colorado Springs	·146	·172	—·003	+·007
Denver	·128	·184	—·021	+·019
Mean	980·149	980·165	·009	·009

From the footings of this table it appears that the gravity determinations at the ten stations, if compared under the hypothesis of isostasy, exhibit a discordance measured by 0·009 dynes, and that the application of the geologic correction does not reduce the discordance. No evident advantage, therefore, results from applying a correction for the local density of the rocks accessible for examination when the observations are treated under the hypothesis that the altitude of the surface is a function of the density of the underlying crust.

Acknowledgments are due to Prof. F. W. Cragin, of Colorado Springs, Colo.; Mr. Sheriff, of Ellsworth, Kans.; Dr. G. Hambach and Messrs. Robert E. McMath, M. J. Murphy, and B. H. Colby, of St. Louis, Mo.; Dr. J. T. Scoville and Profs. G. L. Mees and M. A. Howe, of Terre Haute, Ind.; Mr. C. H. Gordon, of Chicago, Ill., and Prof. H. P. Cushing and Mr. Percy Rice, of Cleveland, Ohio, for geologic and topographic data.

Very respectfully,

G. K. GILBERT,
Geologist United States Geological Survey.

Gen. W. W. DUFFIELD,
Superintendent United States Coast and Geodetic Survey.
(Through Hon. C. D. Walcott, Director United States Geological Survey.)

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APPENDIX No. 2—1894.

TELEGRAPHIC DETERMINATION OF THE FORCE OF GRAVITY AT BALTIMORE, MD., FROM SIMULTANEOUS PENDULUM OBSERVATIONS AT WASHINGTON AND BALTIMORE.

By E. D. PRESTON, Assistant.

Submitted for publication February 15, 1895.

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TELEGRAPHIC DETERMINATION OF THE FORCE OF GRAVITY AT BALTIMORE, MD., FROM SIMULTANEOUS PENDULUM OBSERVATIONS AT WASHINGTON AND BALTIMORE.

By E. D. PRESTON, Assistant.

Submitted for publication February 15, 1895.

In obedience to instructions of June 29, 1893, a determination of the relative force of gravity between Washington, D. C., and Baltimore, Md., was undertaken. The exact points occupied were the Coast and Geodetic Survey Office in this city and the Johns Hopkins University at Baltimore. Through the kindness of President Gilman and Professor Rowland the basement of the physical laboratory was placed at our disposal. The height above mean tide is 100 feet (30·5 metres).

At Washington the pendulum was 45 feet (13·7 metres) above mean tide. The instruments used were the recently constructed half-second pendulums, and the method was that of swinging simultaneously two pendulums, the periods of both being determined by means of the same chronometer. The signals were transmitted telegraphically. The distance from Washington to Baltimore is 40 miles. It is obvious that in the application of such a plan it is unnecessary to know the rate of the chronometer, and hence we may dispense with the star observations, a very laborious part of the usual scheme in the relative determinations of gravity.

This method, the first account of which appeared in the report of Dr. T. C. Mendenhall on the transfer of our initial gravity station from the Smithsonian Institution in this city to the Coast and Geodetic Survey Office, promises to be one of surprising accuracy. The work just referred to, executed by Mr. G. R. Putnam, Assistant, Coast and Geodetic Survey, and Mr. Von der Trenck, Acting Aid, gave results in which the greatest discrepancy from the mean was only one part in two and a half millions (Appendix No. 15, Report for 1891). The line, however, was short; but there is no reason why the distance between the stations should enter as a function of the accuracy, granting that the electrical connections, batteries, etc., remain the same from day to day.

For details regarding the execution of the present work reference may be made to Appendix No. 15, above cited. The system followed in the Washington-Baltimore determinations was essentially the same and need not be retold. The use of two chronometers, one at each station, eliminated from the result any error arising from the variation of the transmission time of the electric current during the experiment.

The pendulums used were A_4, A_5, and A_6 at one station, and B_1, B_2, and B_3 at the other. A_4 and B_1 were swung simultaneously, as likewise were A_5 and B_2, and finally A_6 and B_3. The B pendulums are of the old form, having the knife-edge on the pendulum and the plane on the support. The A pattern has the plane on the pendulum and the knife-edge on the support.

After three days' work with B at Washington and A at Baltimore the pendulums and receivers were interchanged and another set was made with A at Washington and B at Baltimore.

Finally, the pendulums were simultaneously swung at Washington, A_4 being compared with B_1, A_5 with B_2, and A_6 with B_3.

The pendulums were swung in the prime vertical at both stations. Sidereal chronometer Negus No. 1823 was used at Washington and No. 1824 at Baltimore throughout the work.

From these three sets, that is, from the swings before and after the interchange, and from direct comparison at the same place, it is possible to deduce a value for the difference of the force of gravity between Washington and Baltimore and also two values for the difference of the times of oscillation of the pendulums. A complete and symmetrical scheme would necessitate another direct comparison at the second station (Baltimore), which would furnish another value for the difference of gravity also.

Letting $\triangle t_p$ = the difference of the periods of two pendulums swinging at the same place.

$\triangle t_g$ = the difference of the periods of the same pendulum when swinging at different places, and representing the pendulums by capital letters and the places by exponents, as

A^B = the period of pendulum A at Baltimore,

B^W = the period of pendulum B at Washington,

from the work before the interchange we have

$$A^B - B^W = \triangle t_p + \triangle t_g \qquad (1)$$

and after interchange

$$A^W - B^B = \triangle t_p - \triangle t_g \qquad (2)$$

These equations will give $\triangle t_p$ and $\triangle t_g$.

The period of A is greater than that of B at the same place, and the period of the same pendulum is greater at Baltimore than at Washington.

From the direct comparison at Washington we get

$$A^W - B^W = \triangle t_p$$

This value serves as a check on the value of $\triangle t_p$ derived from the interchange, and it also gives us a criterion to judge of the consistency of the values of $\triangle t_g$ from equations (1) and (2) by its substitution therein, but it throws no new light on the mean value of $\triangle t_g$, since it must be substituted in equations which have already given this value.

For each swing the pendulums were used in the direct and reverse positions, and both chronometers were used, so that we have four values for each pair of pendulums. These may be combined in different ways for the sake of comparing results obtained under like conditions as regards chronometers, position, etc. Moreover, the mean values for each pendulum may be treated by deducing values of $\triangle t_p$ from the separate consideration of the periods of the different pendulums in the same place and by deducing values of $\triangle t_g$ from the same pendulums in different places.

The mean results of $\triangle t_p$ and $\triangle t_g$ from these separate treatments will of course be the same.

Subtracting the differences $A^B - B^W$ and $A^W - B^B$ in the times of oscillation of the two pendulums at the two stations before and after the interchange, we have

$$(A^B - A^W) + (B^B - B^W) \qquad (3)$$

which terms represent two independent determinations of the relative force of gravity by the transportation of both pendulums from one station to the other.

Adding the differences, we have

$$(A^B - B^B) + (A^W - B^W) \qquad (4)$$

in which case the terms represent a comparison of the pendulums in two different places.

In both the above cases by taking the mean we of course arrive at the same result which we would have obtained by solving equations (1) and (2).

The second term of (4) was determined by direct experiment. We therefore have two values for the difference of period of the two pendulums, but since the difference of gravity must be obtained from equation (1) and (2), where we have

from (1) $$\triangle t_g = (A^B - B^W) - \triangle t_p \qquad (5)$$

and from (2) $$-\triangle t_g = (A^W - B^B) - \triangle t_p \qquad (6)$$

$\triangle t_p$ is eliminated in the solution and the same value of $\triangle t_g$ results whatever the value of $\triangle t_p$.

It is true that from (1) and (2), by using the direct determination of $\triangle t_p$, we may by substitution get values of $\triangle t_g$ corresponding to the work before and after the interchange, and these values will be different from that furnished by (1) and (2) in the ordinary solution; but the mean reverts the original value for the reason above stated.

The observations at Baltimore were made by Mr. F. A. Wolff, jr., those at Washington being made by myself. The apparatus was set up and the electrical connections arranged at both places by Mr. Wolff, who also made a complete reduction of the work. This has been checked by Mr. Putnam and myself.

The periods of oscillation were reduced to an infinitely small arc, to a temperature of 24° C. (a mean value), and to a pressure of 500^{mm} at 0° C.

The constants employed were slightly different from those previously used and given in Appendix No. 15. They were changed by a subsequent discussion, but the temperature varied so little during the time of experiment and the pressure was maintained so near the standard adopted that either set of constants would have answered for the reductions.

A correction for "lag"—that is, for the difference of temperature, between that indicated by the thermometer and that actually existing in the pendulum—has usually been applied to work of this kind. In the present case, however, this quantity is without any real influence, because it is insignificant when compared with errors of reading and graduation.

The following tables give the individual results for the different days in the two positions and for the two chronometers used. The numbers given are units in the seventh decimal place, and to each result the quantity 0·500^s is to be prefixed. For example, the value of B_1 at Washington on July 17 in the direct position and by chronometer No. 1823 is understood to be 0·500 8118^s, and likewise for the others.

A_4 AND B_1.

Date.	Position.	Washington B_1.			Baltimore A_4.		
		Chron. No. 1823.	Chron. No. 1824.	Means by position.	Chron. No. 1823.	Chron. No. 1824.	Means by position.
1893. July 17	D	8118	8066	8092·0	9156	9105	9130·5
	R	8137	8052	8109·5	9160	9106	9133·0
Means by chronometers.		8127·5	8074·0	8100·8	9158·0	9105·5	9131·8
		Washington A_4.			Baltimore B_1.		
July 25	D	9137	9070	9103·5	8172	8110	8141
	R	9137	9073	9105·0	8186	8122	8154
Means by chronometers.		9137·0	9071·5	9104·2	8179·0	8116·0	8147·5
$A_4^B - B_1^W = +$ 1031·0				$\triangle t_p = +$ 993·8			
$A_4^W - B_1^B = +$ 956·7				$\triangle t_g = +$ 37·2			
		Washington B_1.			Washington A_4.		
Aug. 11	D	8118	8063		9121	9062	
	R	8136	8077		9125	9062	
Aug. 28	D	8142	8069		9138	9064	
Aug. 29	R	8151	8112		9136	9097	
	R	8158	8115		9145	9099	
	Means	8141·0	8087·2	8114·1	9133·0	9076·8	9104·9

$A_4^W - B_1^W = +$ 990·8

A_5 AND B_2.

Date.	Position.	Washington B_2.			Baltimore A_5.		
		Chron. No. 1823.	Chron. No. 1824.	Means by position.	Chron. No. 1823.	Chron. No. 1824.	Means by position.
1893. July 19	D	7293	7222	7257·5	7415	7351	7383·0
	R	7250	7181	7215·5	7409	7349	7379·0
21	D	7295	7225	7260·0	7429	7363	7396·0
	R	7257	7191	7224·0	7422	7358	7390·0
	Means	7273·8	7204·8	7239·2	7418·8	7355·2	7387·0
		Washington A_5.			Baltimore B_2.		
July 28	D	7374	7320	7347·0	7318	7271	7294·5
	R	7371	7333	7352·0	7281	7236	7258·5
	Means	7372·5	7326·5	7349·5	7299·5	7253·5	7276·5

$A_5^B - B_2^W = +\ 147{\cdot}8$ $\qquad \triangle t_p = +\ 110{\cdot}4$

$A_5^W - B_2^B = +\ 73{\cdot}0$ $\qquad \triangle t_g = +\ 37{\cdot}4$

		Washington A_5.			Washington B_2.		
Aug. 5	D	7394	7328		7297	7234	
	R	7391	7323		7265	7190	
26	D	7397	7355		7299	7261	
	R	7403	7355		7274	7224	
30	D	7397	7360		7298	7262	
	R	7396	7352		7264	7228	
	Means	7396·3	7345·5	7370·9	7282·8	7233·2	7258·0

$A_5^W - B_2^W = +\ 112{\cdot}9$

A_6 AND B_3.

Date.	Position.	Washington B_3. Chron. No. 1823.	Chron. No. 1824.	Means by position.	Baltimore A_6. Chron. No. 1823.	Chron. No. 1824.	Means by position.
1893. July 20	D	6619	6557	6588·0	7059	6998	7028·5
	R	6636	6573	6604·5	7061	6998	7029·5
	Means	6627·5	6565·0	6596·2	7060·0	6998·0	7029·0
		Washington A_6.			Baltimore B_3.		
July 29	D	7030	6964	6997·0	6682	6615	6648·5
	R	7041	6974	7007·5	6692	6628	6660·0
	Means	7035·5	6969·0	7002·2	6687·0	6621·5	6654·2
		$A_6^B - B_3^W = +432·8$			$\triangle t_p = +390·4$		
		$A_6^W - B_3^B = +348·0$			$\triangle t_g = +42·4$		
		Washington A_6.			Washington B_3.		
Aug. 12	D	7019	6974		6624	6582	
	R	7019	6974		6646	6601	
25	D	7029	6986		6629	6587	
	R	7037	6989		6658	6609	
	Means	7026·0	6980·8	7003·4	6639·2	6594·8	6617·0

$$A_6^W - B_3^W = +386·4$$

From the foregoing values, when swinging was done simultaneously at the two stations, we have the following results:

Set.	Pendulums.	$\triangle t_p$	$\triangle t_g$	Date.
				1893.
I	$A_4 - B_1$	+993·8	+37·2	July 17 and 25.
II	$A_5 - B_2$	+110·4	+37·4	July 19, 21, and 28.
III	$A_6 - B_3$	+390·4	+42·4	July 20 and 29.

From direct comparison of the pendulums at the same station we have $\triangle t_p$ and $\triangle t_g$ as follows ($\triangle t_p$ being substituted in equations (5) and (6) gives $\triangle t_g = +1031·0 - 990·8 = +40·2$, and so on):

Set.	Pendulums.	$\triangle t_p$	$\triangle t_g$		Date.
			Before.	*After.*	1893.
I	$A_4 - B_1$	+990·8	+40·2	+34·1	Aug. 11, 28, and 29.
II	$A_5 - B_2$	+112·9	+34·9	+39·9	Aug. 5, 26, and 30.
III	$A_6 - B_3$	+386·4	+46·4	+38·4	Aug. 12 and 25.

the mean value of $\triangle t_g$ before and after the interchange being the same as that obtained above by the elimination. We therefore have in units of one-millionth of a sidereal second for the mean difference in the time of oscillation of a half-second pendulum

$$\text{(Baltimore)} - \text{(Washington)} = +3·90$$

and for the mean differences in the pendulum periods

$$A_4 - B_1 = + 99{\cdot}1$$
$$A_5 - B_3 = + 11{\cdot}3$$
$$A_6 - B_3 = + 38{\cdot}6$$

The difference in the time of oscillation of the three pendulums is entirely without influence on the values of $\triangle t_g$ in the three sets. In passing from Washington to Baltimore the length of the period is increased by only one hundred thousandth part of itself, so that even if the pendulums differed in their times by $0{\cdot}001^s$ this would not influence the above results. As a matter of fact, they differ by only one-tenth of this.

The following tables show the difference, in the seventh decimal place, of the times of oscillation for the different positions of the pendulums:

DIRECT MINUS REVERSE.

Date.	A_4.		A_5.		A_6.	
	1823.	1824.	1823.	1824.	1823.	1824.
1893.						
July 17	— 4	— 1				
19			+ 6	+ 1		
20					— 2	0
21			+ 7	+ 5		
25	0	— 3				
28			+ 3	—13		
29					—11	—10
Aug. 5			+ 3	+ 5		
11	— 4	0				
12					0	0
25					— 8	— 3
26			— 6	0		
30			+ 1	+ 8		
Means	— 3	— 1	+ 2	+ 1	— 5	— 3

	B_1.		B_2.		B_3.	
July 17	—19	—16				
19			+43	+41		
20					—17	—16
21			+38	+34		
25	—14	—12				
28			+37	+35		
29					—10	—13
Aug. 5			+32	+44		
11	—18	—14				
12					—22	—19
25					—29	—22
26			+25	+37		
30			+34	+34		
Means	—17	—14	+35	+37	—19	—18

Hence—
Dir. — Rev. for
$A_4 = - 2^s \times 10^{-7}$
$A_5 = + 2 \times 10^{-7}$
$A_6 = - 4 \times 10^{-7}$

Hence—
Dir. — Rev. for
$B_1 = - 16^s \times 10^{-7}$
$B_2 = + 36 \times 10^{-7}$
$B_3 = + 18 \times 10^{-7}$

Assuming the value of g at the Coast Survey Office to be 980·098 dynes, the value at the Johns Hopkins University would be 980·083.

The value of the difference of gravity between the two places is known with much greater accuracy than the absolute value at Washington; indeed, the absolute value of gravity is not known anywhere to the degree of precision indicated above, and can not be so known with the appliances now at our disposal and by using the present methods.

It is assuming all that is warranted by work hitherto done to state the absolute value of g at Baltimore as 980·08 dynes.

Since in general only one swing was made with each pair of pendulums before and after the interchange, a comparison of these results would hardly form a means of judging of the ability of the pendulums to repeat themselves under similar conditions.

The greatest discrepancy from the mean, in the results by the different pairs of pendulums, for the excess of the period at Baltimore over that at Washington, is less than one part in two million.

It is of course understood that the preceding treatment implies nearly equal periods in the two pendulums that are interchanged. It is assumed that the change in A in passing from Baltimore to Washington is the same as that in B in passing from Washington to Baltimore. For examples, our first experiment gave

$$A^B - B^W = +1031{\cdot}0^s \times 10^{-7}$$

When A is transported to Washington, we have for its period $A^B - \delta A$, and when B is taken to Baltimore, its period becomes $B^W + \delta B$. The difference given by direct observation was

$$\begin{aligned} A^W - B^B &= (A^B - \delta A) - (B^W + \delta B) = +956{\cdot}7^s \times 10^{-7} \\ &= A^B - B^W - \delta A - \delta B = \quad " \end{aligned}$$

hence by subtraction

$$\delta A + \delta B = +74{\cdot}3$$

so that when we give $+37{\cdot}2$ as the effect of gravity, the supposition is that $\delta A = \delta B$. δA and δB here represent the actual change in the period in consequence of a change of the force of gravity, and are expressed in units of the seventh decimal place of sidereal seconds. Assuming their equality, the absolute difference between the pendulums at the same place results from the following equations:

$$\begin{aligned} A^B - B^W &= +1031{\cdot}0 = \triangle t_p + \triangle t_g \\ \delta A &= +\ 37{\cdot}2 \\ A^B - \delta A - B^W &= A^W - B^W = +993{\cdot}8 = \triangle t_p \end{aligned}$$

If the periods of A and B are widely different, the above method can not be employed, because the change in the time of oscillation of a pendulum depending on a change in the accelerating force is a function of the period. In the case where the value for A is twice as large as for B, that is, when a metre pendulum is employed at one place and a quarter-metre one at the other, the value corresponding to $2\triangle t_g$ in the solution of equations (1) and (2) would be composed of two parts, one of which would be twice as large as the other and would be $\triangle t_g$ from the A pendulum, the remainder being $\triangle t_g$ from the B pendulum. There would, however, be no way of finding the respective values of $\triangle t_g$ from a simple interchange of positions.

Within the limits of the United States, say from latitude 25° to latitude 49°, the greatest change of period of a pendulum would be about one thousandth part of itself (more exactly, 0·001 036). Hence, if quarter-metre pendulums are employed, the value of δA would be $0{\cdot}000\ 518^s$. If the pendulums differed in their periods by one thousandth of a second, the value of δB would be $0{\cdot}000\ 519^s$. In this case the assumption that δA and δB are equal would involve an error of half a unit in the sixth place of decimals. This would make it necessary to have the difference between the periods of A and B not greater than one five-hundredth part in order to have the sixth decimal place accurate in the result for any determination within the latitudes given.

The effect of a change of elevation on the force of gravity is such that the above limit of one thousandth of the period would not be reached in any mountains in this country, the change in gravity being the same for 15 feet of elevation as it is for one minute of latitude between 25° and 49°, viz, 0·000 00144th part of itself. This does not take any account of the matter lying between the upper and lower station, but is purely the effect of the increased distance from the earth's center.

We can therefore say that for all work in the United States it is sufficient and necessary that the quarter-metre pendulums employed in the telegraphic method of finding differences of the force of gravity should not differ as much as one thousandth of a second in their periods.

The telegraphic determination of the difference of the force of gravity between two places by simultaneous oscillations gives rise to two methods of treatment—that of differences and ratios. The following is a statement of these methods, with an application of the data already given in the case of one set of pendulums, A_4 and B_1.

In considering the ratio of the times of oscillation of the pendulums we shall treat this quantity as A ÷ B. The ratio of the places will be taken as the time of oscillation of the pendulum at Baltimore divided by the time at Washington.

Before the exchange we have

(7) $K_1 = \frac{A^B}{B^W} = \frac{A^B}{B^B} \cdot \frac{B^B}{B^W}$ = ratio of pendulums at Baltimore multiplied by ratio of places from B pendulum.

(8) $= \frac{A^B}{B^W} = \frac{A^B}{A^W} \cdot \frac{A^W}{B^W}$ = ratio of pendulums at Washington multiplied by ratio of places from A pendulums.

or K_1 = ratio of pendulums multiplied by ratio of places.

After the exchange

(9) $K_2 = \frac{B^B}{A^W} = \frac{B^B}{A^B} \cdot \frac{A^B}{A^W}$ = inverse ratio of pendulums at Baltimore multiplied by ratio of places from A pendulum.

(10) $= \frac{B^B}{A^W} = \frac{B^B}{B^W} \cdot \frac{B^W}{A^W}$ = inverse ratio of pendulums at Washington multiplied by ratio of places from B pendulum.

or K_2 = inverse ratio of pendulums multiplied by ratio of places.

In general terms we can say that the value of K_1 is equal to the ratio of the pendulums at the place indicated in the numerator multiplied by the ratio of the places as determined by the pendulum indicated in the denominator, or, which gives the same thing, the ratio of the pendulums at the place indicated in the denominator multiplied by the ratio of the places as determined by the pendulum indicated in the numerator. A similar statement can be made in regard to K_2.

It may be mentioned, although the fact is evident from the interchange, that in order to bring out the factors composing K_1 we introduce precisely the quantities B^B and A^W, which are directly observed in the new position, and which determine the value of K_2. If, in introducing the identical factors in the two equivalent expressions for K_1, they are chosen so that the ratios of the pendulums in the two places are equal, the ratio of the places must necessarily be equal, and vice versa in the case of K_2.

Multiplying (7) and (9)

$$K_1 K_2 = \frac{A^B}{A^W} \cdot \frac{B^B}{B^W} = (\text{ratio of places})^2$$

dividing (7) by (9)

$$\frac{K_1}{K_2} = \frac{A^W}{B^W} \cdot \frac{A^B}{B^B} = (\text{ratio of pendulums})^2$$

We have the following numerical data:

Before exchange.	After exchange.
$A^B = 0{\cdot}500\ 91318^s$	$A^W = 0{\cdot}500\ 91042^s$
$B^W = 0{\cdot}500\ 81008$	$B^B = 0{\cdot}500\ 81475$

The last decimal place is uncertain. It is carried along merely to avoid discrepancies.

From the above we have by the differential method

$$A^B - B^W = +\ 1031{\cdot}0 = \triangle t_p + \triangle t_g$$
$$A^W - B^B = +\ 956{\cdot}7 = \triangle t_p - \triangle t$$

from which

$$\triangle t_p = 993{\cdot}8$$
$$\triangle t_g = 37{\cdot}2$$

By the method of ratios we have

$$K_1 = \frac{A^B}{B^W} = \frac{0{\cdot}500\ 91318}{0{\cdot}500\ 81008} = 1{\cdot}000\ 20587$$
$$K_2 = \frac{B^B}{A^W} = \frac{0{\cdot}500\ 81475}{0{\cdot}500\ 91042} = 0{\cdot}999\ 80901$$
$$K_1\ K_2 = (\text{ratio of places})^2 = 1{\cdot}000\ 01484$$
$$\text{ratio of places} = 1{\cdot}000\ 0074$$

The ratio of the places would be found by the differential method thus:

$$A^B = 0{\cdot}500\ 9131{\cdot}8$$
$$\triangle t_p = \underline{37{\cdot}2} = A^W \text{ (calculated)}$$
$$0{\cdot}500\ 9094{\cdot}6$$
$$\text{ratio of places} = \frac{A^B}{A^W} = \frac{0{\cdot}500\ 9131{\cdot}8}{0{\cdot}500\ 9094{\cdot}6} = 1{\cdot}000\ 0074$$

The result for the ratio of the places is the same whether we use the differences or the quotients of the observed quantities.

The same may be shown in finding the ratio of the two pendulums.

By the method of differences we had

$$A^B = 0{\cdot}500\ 91318$$
$$\triangle t_p = \underline{9938}$$
$$B^B \text{ (calculated)} = 0{\cdot}500\ 81380$$

and the ratio of the pendulums is

$$\frac{A^B}{B^B} = \frac{0{\cdot}500\ 91318}{0{\cdot}500\ 81380} = 1{\cdot}000\ 1984$$

By the method of ratios

$$\frac{K_1}{K_2} = \frac{1{\cdot}000\ 20586}{0{\cdot}999\ 80900} = 1{\cdot}000\ 39693 = (\text{ratio of pendulums})^2$$
$$1{\cdot}000\ 1984 \quad = \text{ratio of pendulums as before.}$$

These two ways of reducing the observations are each capable of bringing out the final values for the difference of the force of gravity in the two places, and also the difference of the times of oscillation of the two pendulums in the same place.

There is still another way in which the observations may be combined. Although viewed from a different standpoint, it leads precisely to the same result.

Inasmuch as the entire operation consists essentially of oscillating each of the two pendulums at each place, we may simply compare the times of the oscillations in the two places for the difference of gravity and the times of the two pendulums in the same place for the difference of the pendulums. The values of the difference of gravity for the two pendulums will not be equal; neither will the values for the difference of the pendulums in the different places be so, but the mean value for gravity in the first case and the mean difference in the pendulums in the second will be identical with the values heretofore obtained by the other two methods. This is shown in the following scheme (see p. 61). As heretofore, we are using units in the seventh place of decimals

$A^B = 9131{\cdot}8$
$A^W = 9104{\cdot}2$

$27{\cdot}6 = \triangle t_g =$ difference of periods at Baltimore and Washington from A pendulum.

$B^B = 8147{\cdot}5$
$B^W = 8100{\cdot}8$

$46{\cdot}7 = \triangle t_g =$ difference of periods at Baltimore and Washington from B pendulum.

The mean of these is 37·2, as before.

Likewise for the difference of the pendulum periods

$$\begin{aligned} A^B &= 9131{\cdot}8 \\ B^B &= 8147{\cdot}5 \\ \hline & 984{\cdot}3 = \triangle t_p = \text{difference of periods of A and B at Baltimore.} \\ A^W &= 9104{\cdot}2 \\ B^W &= 8100{\cdot}8 \\ \hline & 1003{\cdot}4 = \triangle t_p = \text{difference of periods of A and B at Washington.} \end{aligned}$$

The mean being 993·8, as before.

By means of the values of $\triangle t_p$ and $\triangle t_g$ we may reduce the period of either pendulum at either place to the other pendulum at the other place. For example:

Pendulum A at Baltimore	$= A^B$	$= 0{\cdot}500\ 9131{\cdot}8$
Reduction from pendulum A to pendulum B	$= \triangle t_p =$	$993{\cdot}8$
Pendulum B at Baltimore (calculated)	$= B^B$	$= 0{\cdot}500\ 8138{\cdot}0$
Reduction from Baltimore to Washington	$= \triangle t_g =$	$37{\cdot}2$
Pendulum B at Washington	$= B^W$	$= 0{\cdot}500\ 8100{\cdot}8$

In the same way B^B may be reduced to A^W, and of course the reduction may take place inversely.

The value for B^B (calculated) does not agree with that observed.

$$\begin{aligned} \text{We have } B^B \text{ (observed)} &= 8147{\cdot}5 \\ B^B \text{ (calculated)} &= 8138{\cdot}0 \\ \hline \text{Difference} &= 9{\cdot}5 \end{aligned}$$

This is owing to the fact that on account of minute errors of observation and slight imperfections of workmanship the pendulums will not repeat themselves in two successive independent experiments.

If we reduce A^W to B^W we have

$$\begin{aligned} A^W &= 9104{\cdot}2 \text{ (observed)} \\ 993{\cdot}8 &= \triangle t_p \\ \hline 8110{\cdot}4 &= B^W \text{ (calculated)} \\ 8100{\cdot}8 &= B^W \text{ (observed)} \\ \hline 9{\cdot}6 &= \text{difference.} \end{aligned}$$

The sum of these two differences = 19·1, which is the difference between the two values for $\triangle t_p$ found at Baltimore and Washington.

We must bear in mind, however, in these last examples that we are making the reduction from one pendulum to the other by means of a mean value for the differences of the pendulums. If we transform the value of A at Baltimore, or A^B, into B at Baltimore, or B^B, by means of the difference of the pendulums determined at Baltimore, there would be no discrepancy; as, for instance,

$$\begin{aligned} A^B &= 0{\cdot}500\ 9131{\cdot}8^s \\ A^B - B^B &= + \quad 984{\cdot}3 \\ \hline B^B &= 8147{\cdot}5 = B^B \text{ (observed)} \end{aligned}$$

and similarly for Washington.

In regard to the determinations by ratios, it may be added that the ratio of the two places may be found by taking the mean for the two pendulums as long as the individual values do not differ more than about one thousandth part.

In our numerical data we had

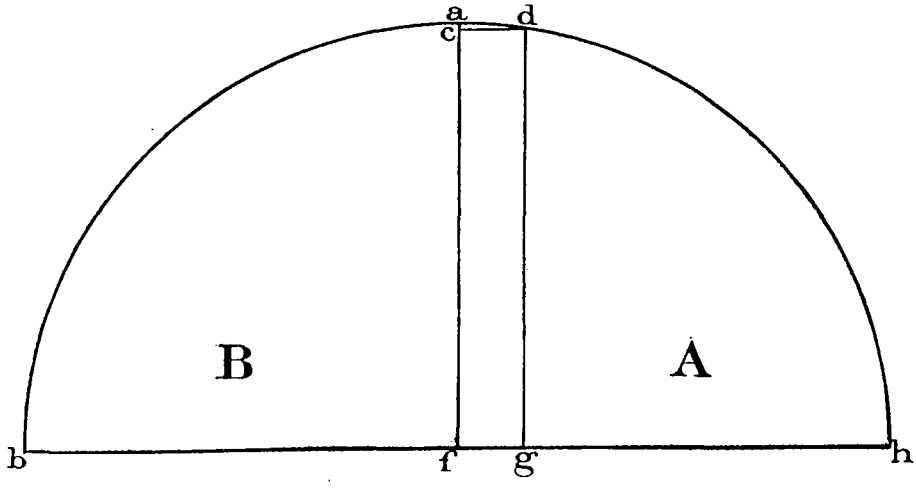
$$K_1 K_2 = \frac{A^B}{B^W} \cdot \frac{B^B}{A^W} = \frac{0{\cdot}500\ 91318^s}{0{\cdot}500\ 81008} \cdot \frac{0{\cdot}500\ 81475}{0{\cdot}500\ 91042}$$

A combination of the numerator of the first fraction with the denominator of the second, and vice versa, gives the respective values for the ratio of the period at Baltimore to that at Washington, first by the A pendulum, and second by the B pendulum. Moreover, this method of treatment makes the fractions more convergent in a series, which is much the easiest way of evaluating them. We have from

Pendulum A	1·000 00551
Pendulum B	1·000 00932

The question now arising is how great this disparity between the two pendulums may be without vitiating the result when we simply take the arithmetical mean, the true value sought being a mean proportional between them, or the square root of their product.

It appears by mere inspection that in order to have the mean of two quantities equal to the square root of their product to the nearest millionth part the quantities should differ only by about one thousandth part; but a clear conception of the case may be had, as well as a rigorous solution obtained, by reference to the following diagram:



Any vertical line being a mean proportional between the two parts into which it divides the diameter, we only need to find the sine of an arc, $c\,d$, whose versed sine $a\,c$ is one millionth part of the radius. This gives us at once $c\,d = \cdot0014$ for a value of $a\,c = 0{\cdot}000\ 001$; so that the two ratios should not differ more than one seven-hundredth part if the result is carried to six decimal places.

The radius being taken to represent the ratio of the places when the values given by the two pendulums are equal, $f\,h$ may be taken for A and $f\,b$ for B. The mean of these will be $a\,f$, which will also be a mean proportional between them. If the two values are unequal and we represent the one from pendulum A by $g\,h$, and the one from B by $g\,b$, their mean will still be $a\,f$, but the square root of their product will be $g\,d$, and this will differ from the direct mean by only one millionth when the difference between the respective values or $f\,g$ is one seven-hundredth part.

It has already been found that the greatest variation of gravity within the territory of the United States dependent on either a change of latitude or of elevation would not modify the period of a pendulum by more than about one thousandth part, so that for the case under consideration we may neglect the influence of a change of the force of gravity.

The conclusion is that the method by differences is to be preferred on account of its dealing with small numbers, the method of ratios requiring either eight-place logarithms or else some approximate way of evaluating the fractions. The precautions to be taken in order to insure correct results within the limits of our own country are:

With half-second or quarter-metre pendulums, that the times of oscillation of the two pendulums vibrating under similar conditions should not differ more than one thousandth of a second, and when the reductions are made by the method of ratios the direct mean may be taken between the results for the two pendulums considered independently as long as they do not differ by one seven-hundredth part.

We now compare the results obtained in the foregoing paper with the theoretical values of the force of gravity deduced from a general empirical formula. Professor Harkness gives* the following equation for the variation of gravity (g) with the latitude (φ);

$$g = 9{\cdot}779886^{m} + 0{\cdot}052210^{m} \sin^2 \varphi$$

Taking the latitude of the Coast Survey Office as 38° 53′ 13″, and that of the Johns Hopkins University as 39° 17′ 50″, we deduce the following table:

Station.	φ	h	g calculated.	g observed.	C − O.
	° ′ ″	*Feet.*	*Dynes.*	*Dynes.*	*Dynes.*
Washington, D. C. (Coast Survey Office)	38 53 13	45	980·042	980·098	−0·056
Baltimore, Md. (Johns Hopkins University)	39 17 50	100	980·074	980·083	−0·009

From this it would appear that the force of gravity at Washington is in excess of the normal value by 0·056 dynes, and at Baltimore we have also an excess of 0·009 dynes.

* The Solar Parallax and its Related Constants. Washington, 1891, page 139.

APPENDIX No. 3—1894.

STANDARD GEODETIC POSITIONS IN SOUTHEASTERN ALASKA, DEPENDING ON ASTRONOMICAL OBSERVATIONS MADE DURING 1892, 1893, AND 1894.

By C. A. SCHOTT, Assistant.

Reports of December 27, 1893, March 28 and August 7, 1894.

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REPORT OF DECEMBER 27, 1893.

I have the honor to present herewith the results of the difference of longitude between Tacoma, Wash., and Sitka, Alaska, also between Sitka and Yakutat, Alaska, from observations made in 1892 and computed at the office by Mr. D. L. Hazard.

For the purpose of determining the longitudes of certain standard stations in Alaska, to begin with, two chronometric expeditions were fitted out in 1892, one to fix the longitude of the astronomic station at Sitka, the chronometers being carried on board the Pacific Coast Steamship Company's steamer *Queen*, the other to fix the longitude of the astronomic station on Khantaak Island, Yakutat Bay, the chronometers being carried on board the Coast and Geodetic Survey steamer *Hassler*. Between June and September the *Queen* made six round trips between Tacoma and Sitka, and between May and September the *Hassler* made seven round trips between Sitka and Yakutat.

At Tacoma transit observations for time were made by Assistant J. F. Pratt. He used meridian telescope No. 13 (aperture $5\frac{1}{2}^{cm}$) and observing (Sid.) chronometer Hutton No. 207. There were also kept at the observatory and rated by comparisons the auxiliary mean time chronometers Frodsham No. 2490 and Hutton No. 231. A table of the resulting chronometer corrections and rates is given in Supplement A. July 18, chronometer Hutton No. 231 was transferred to the *Queen*.

At Sitka transit observations for time were made by Subassistant F. Morse. He used meridian instrument No. 1 (aperture 7^{cm}) and observing (Sid.) chronometer Hutton No. 194. There were also kept at the observatory and rated by comparisons the auxiliary (Sid.) chronometer Frodsham No. 3479 and (M. T.) chronometer Fletcher No. 1707. A table of the resulting chronometer corrections and rates is given in Supplement B, and the rate of the chronometer as a function of the temperature is graphically represented. Additional observations for time were made on the sun by means of a vertical circle and a sextant.

At Khantaak Island, Yakutat, transit observations for time were made by Assistant J. H. Turner. He used meridian telescope No. 16 (aperture $6{\cdot}6^{cm}$) and observing (Sid.) chronometer Bond & Son No. 380. There were also kept at the observatory and rated by comparisons the auxiliary (M. T.) chronometer No. 4969 and (Sid.) chronometer No. 387. A table of the resulting chronometer corrections and rates is given in Supplement C. Between July 9 and August 31 we have chronographic record. Some supplementary observations of the sun, for time, were made with a vertical circle and a Lorieux sextant, but the former were not needed. The party at Yakutat Bay was in charge of Assistant J. E. McGrath.

The usual precautions for protecting the timekeepers from undue exposure were taken. All comparisons were made by means of coincidences of beats, and when in port at any of the above three places the comparison with the local time was effected by means of a hack, the chronometers remaining on board. The instruments on the *Queen* were in charge of Mr. T. D. Davidson; those on the *Hassler* in charge of Lieutenant Chase, U. S. N. The two steamers were at Sitka at the same time each trip.

The method of reduction of the observations for longitude was as follows: The traveling or sea rates of the chronometers were deduced from the comparisons at the observing or first station, made just before starting and immediately after the return thereto, for each trip, the accumulated rates while at the second station having been deducted. Thus, each chronometer for each round trip furnishes a result for longitude. Similarly, as furnishing another combination, the starting and returning is made from the second station, but in this case instead of n, all-round trips, there will be only $n - 1$.

The advantage of making these two combinations lies in this, that the presence of any consistent accelerated (or retarded) rate would be indicated by the results, and it serves to some extent as a check to the computations. To the $n - 1$ results that deduced from the first outer and the last return trip can be added, thus making use of all observations. To get a measure for the relative performance of the timekeepers and accordingly to assign weights to the results by the several chronometers, their variations in rates during the several trips were made the criterion. Thus, let l_1, l_2, l_3 .... l_n be the values for the difference of longitude for the different trips by any chronometer, and let l be its mean value; then the weight p to the chronometric result is given by

$$p = \frac{\varkappa (n-1)}{[(l - l_n)^2]}$$

where n = number of round trips and $\varkappa$ a constant introduced for the sake of convenience. The resulting difference of longitude of each round trip was further subject to weighting, depending on the duration of the trip, and was taken inversely proportional to the number of days consumed. A further refinement for (roughly) taking into account the loss in time occasioned by unfavorable weather for transit observations, in which case the rate of the observing chronometer had to be depended on, is readily made by adding this interval to the days of actual travel.

The symmetry of the arrangement was interfered with toward the close of the work by exchanging or transferring certain chronometers from one steamer to the other. The object was to strengthen the result from the last round trip between Tacoma and Sitka. It had, however, the effect of rendering the results from the two determinations (longitudes of Sitka and of Yakutat) to some extent dependent upon one another as to weights of the chronometers carried in both expeditions.

Summary of results for difference of longitude of Tacoma, Wash., and Sitka, Alaska, from six round trips of the steamer Queen in 1892.

FIRST COMBINATION.

Number and kind of chronometers.	First trip, June 5-17.	Second trip, June 20-July 2.	Third trip, July 5-17.	Fourth trip, July 20-Aug. 2.	Fifth trip, Aug. 4-16.	Sixth trip, Aug. 19-Sept. 4.	$\Delta\lambda$ Means by each chronometer.	Weight p
	m. *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	
297 (hack) M. T.	51 36·79	51 37·25	51 34·11	51 39·75	51 36·81	51 38·14	51 37·14	3
223 S.	33·57	34·63	34·62	34·43	32·98	31·93	33·69	11
2637 S.	33·74	32·91	33·11	33·00	33·86	34·61	33·54	21
2535 M. T.	34·31	34·25	34·37	33·00	34·34	34·00	34·05	16
557 "	33·80	33·91	34·67	34·13	-----	-----	34·13	8
1510 "	34·05	34·06	33·52	33·46	-----	-----	33·77	30
214 "	32·71	36·04	37·04	36·38	-----	-----	35·54	2
229 "	33·53	34·71	33·31	32·41	39·49	32·61	34·34	1
231 "				33·97	34·33	34·24	34·18	20
4794 "						33·10	33·10	*24
1745 "						33·65	33·65	*19
1639 "						33·58	33·58	*38
1327 "						34·62	34·62	*31
1110 "						34·89	34·89	*25
1347 "						34·59	34·59	*31
Means	51 34·06	51 34·72	51 34·34	51 34·50	51 35·30	51 34·16		
Weight p	92	92	92	112	72	240		
Weighted means	51 34·00	51 34·04	51 33·90	51 33·75	51 34·16	51 34·09		

* These chronometers were taken from the *Hassler*, and the weights are the same as derived from the computation of $\Delta\lambda$ Sitka and Yakutat.

First combination: Resulting value, weighted mean, $51^m\ 34^s{\cdot}00 \pm 0^s{\cdot}04$.

N. B.—The durations of the several round trips are so nearly equal that no special weights were demanded on account of this difference.

Summary of results for difference of longitude of Sitka, Alaska, and Tacoma, Wash., from six round trips of the steamer Queen in 1892.

SECOND COMBINATION.

Number and kind of chronometers.	First trip, June 11–27.	Second trip, June 27–July 10.	Third trip, July 11–26.	Fourth trip, July 26–Aug. 10.	Fifth trip, Aug. 10–27.	Aug. 27–Sept. 4, sixth trip down, and first trip up, June 5–11.	$\triangle\lambda$ Means by each chronometer.	Weight p
	m. *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	
297 (hack) M. T.	51 34·43	51 37·22	51 38·95	51 36·20	51 39·63	51 35·80	51 37·04	3
223 S.	33·08	34·07	33·27	34·47	32·85	34·85	33·76	11
2637 S.	34·54	34·07	32·94	32·55	33·22	33·54	33·48	21
2535 M. T.	33·69	35·91	33·10	33·55	33·90	33·93	34·01	16
557 "	33·38	35·59	33·27	36·40	-----	-----	34·66	8
1510 "	35·07	35·10	35·04	33·58	-----	-----	34·70	30
214 "	34·75	39·45	34·38	32·31	-----	-----	35·22	2
229 "	34·22	35·86	36·05	39·97	38·34	21·82	34·38	1
231 "				35·15	34·25	33·16	34·19	20
4794 "					32·22	-----	32·22	24
1745 "					33·92	-----	33·92	19
1639 "					33·28	-----	33·28	38
1327 "					34·25	-----	34·25	31
1110 "					33·44	-----	33·44	25
1347 "					33·51	-----	33·51	31
Means	51 34·14	51 35·91	51 34·62	51 34·91	51 34·40	51 32·18		
Weight p	92	92	92	112	240	72		
Weighted mea s	51 34·29	51 35·10	51 33·98	51 34·05	51 33·59	51 33·66		

Second combination: Resulting value, weighted mean, $51^m\ 34^s{\cdot}01 \pm 0^s{\cdot}15$.

Final result for $\triangle\lambda$.

	m.	s.	s.
By first combination	51	34·00	$\pm$ 0·04
By second combination	51	34·01	$\pm$ 0·15
$\triangle\lambda$ Tacoma and Sitka	51	34·00	$\pm$ 0·10

Summary of results for difference of longitude of Sitka, Alaska, and Khantaak Island, Yakutat Bay, Alaska, from seven round trips of the steamer Hassler in 1892.

FIRST COMBINATION.

Number and kind of chronometers.	First trip, May 13–June 9.	Second trip, June 11–26.	Third trip, June 27–July 10.	Fourth trip, July 12–26.	Fifth trip, July 27–Aug. 10.	Sixth trip, Aug. 10–24.	Seventh trip, Aug. 27–Sept. 5.	$\triangle\lambda$ Means by each chronometer.	Weight p
	m. *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	
1327 M. T.	17 46·61	17 47·28	17 47·92	17 47·91	17 47·83	17 -----	17 -----	17 47·51	31
1110 "	46·63	47·03	47·61	47·46	48·13	-----	-----	47·37	25
1347 "	47·03	47·37	47·76	47·91	47·79	-----	-----	47·57	31
1639 "	47·06	47·54	47·70	47·75	47·79	-----	-----	47·57	38
1745 "	46·53	47·16	47·55	48·12	48·15	-----	-----	47·50	19
2167 "	46·50	47·01	47·33	47·99	48·06	47·71	47·78	47·48	34
4794 "	47·07	47·05	47·76	47·88	47·95	-----	-----	47·54	24
208 "	46·74	46·85	47·43	47·82	48·02	47·60	47·70	47·45	39
557 "						47·73	47·30	47·52	*8
214 "						47·41	47·46	47·44	*2
1510 "						47·70	47·88	47·79	*30
4969 "							46·61	46·61	†5
380 S.							47·88	47·88	†5
387 S.							48·72	48·72	†5
Means	17 46·77	17 47·16	17 47·63	17 47·86	17 47·96	17 47·63	17 47·67		
Weight p	241	241	241	241	241	113	128		
Weighted means w.	17 46·78	17 47·17	17 47·62	17 47·85	17 47·95	17 47·67	17 47·74		
	½								

*These chronometers were taken from the *Queen*, and the weights are the same as derived from the computation for $\triangle\lambda$ Tacoma and Sitka.
† Little weight has been assigned to these results, stationary rates having been used.

The durations of the several round trips are nearly equal, except the first, which is nearly double the average value, and there is greater uncertainty in the time determination by sextant; it has therefore the combination weight ½.

First combination: Resulting value, weighted mean, $17^m\ 47^s{\cdot}58 \pm 0^s{\cdot}11$.

Summary of results for difference of longitude of Khantaak Island, Yakutat Bay, Alaska, and Sitka, Alaska, from seven round trips of the steamer Hassler in 1892.

SECOND COMBINATION.

Number and kind of chronometers.	First trip, June 8–13.	Second trip, June 24–29.	Third trip, July 8–14.	Fourth trip, July 23–29.	Aug. 8–10, fifth trip down, and first up, May 13–22.	Sixth trip, Aug. 23–29.	Aug. 29–Sept. 5, seventh trip down, and sixth up, Aug. 10–12.	$\triangle\lambda$ Means by each chronometer.	Weight p
	m. *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	
1327 M. T.	17 47·13	17 46·83	17 48·17	17 47·92	17 47·80	17	17	17 47·57	31
1110 "	47·22	46·68	48·20	48·00	46·82	-----	-----	47·38	25
1347 "	47·11	46·62	48·24	47·86	48·24	-----	-----	47·61	31
1639 "	47·23	46·67	48·10	47·80	48·29	-----	-----	47·62	38
1745 "	47·36	46·33	48·13	48·27	47·64	-----	-----	47·55	19
2167 "	47·31	46·60	47·85	48·06	47·19	47·60	47·96	47·51	34
4794 "	47·14	46·38	48·33	48·00	48·01	-----	-----	47·57	24
208 "	47·21	46·47	47·82	48·11	47·49	47·64	47·63	47·48	39
557 "						48·16	46·60	47·38	8
214 "						48·07	46·37	47·22	2
1510 "						47·40	48·36	47·88	30
Means	17 47·21	17 46·57	17 48·10	17 48·00	17 47·69	17 47·77	17 47·38		
Weight p	241	241	241	241	241	113	113		
Weighted means w.	17 47·21	17 46·60	17 48·08	17 47·99	17 47·70 ½	17 47·61	17 47·82		

Second combination: Resulting value, weighted mean, $17^m\ 47^s{\cdot}54 \pm 0^s{\cdot}13$.

Final result for $\triangle\lambda$.

	m. s. s.
By first combination	17 47·58 ± 0·11
By second combination	17 47·54 ± 0·13
$\triangle\lambda$ Sitka and Yakutat	17 47·56 ± 0·12

DESCRIPTION OF LONGITUDE STATIONS.

At Tacoma, Wash., the astronomical station of 1892 was established by Assistant Pratt in the northeast corner of Wright Park. It is connected with the triangulation of Puget Sound.

At Sitka, Alaska, the new astronomical station was located in May, 1892, by Subassistant Morse. The older stations of 1867, 1869, and 1874 were on the Parade Ground,* and that of 1880 on Japonski Island,† but in 1892 these locations were found undesirable for various reasons. The new station is in front of the Presbyterian church, on an outcropping ledge. A pier of brick and cement was constructed and capped with a block of granite. At the close of the season the pier was left standing. Its position is further secured by a number of witness marks. Assistant Davidson's station of 1867 (also of 1869) was relocated and found to be nearly 32·6 metres south and 21·8 metres east of the 1892 station. These numbers correspond to $\triangle\varphi = +1''{\cdot}05$ and $\triangle\lambda = +1''{\cdot}30$ to reduce the old to the new station. The station of 1874 was also on the Parade Ground, in front of the officers' quarters. It is not identical with, though near to, the station of 1867–69.

At Yakutat Bay the astronomical station of 1892 was located on the narrow strip of land known as Turners Point, at the southeastern end of Khantaak Island, Port Mulgrave. It is to the northwest of the Indian village and separated from it by a small lagoon. A pier was built of brick laid in cement and surmounted by a stone cap. It is supposed to be sufficiently off the beach not to be disturbed by the winter storms. The position is also secured by two reference marks (copper bolts in rocks). The Dall and Baker astronomical station of 1874 ‡ was southeasterly of the 1892 station and nearer to the end of the point of land. It is nearly 294 metres, or 9″·50, south, and 301 metres, or 19″·17, east of the new station, according to Assistant Turner's topographic survey.

* Coast Pilot of Alaska, first part (G. Davidson), 1869. Washington, 1869, page 120.

† See Pacific Coast Pilot, Alaska, Part I (Dall and Baker), 1883. Washington, 1883, pages 141 and 150.

‡ Pacific Coast Pilot, Part I, Washington, 1883, page 208.

As soon as the telegraphic longitude of Tacoma becomes known the absolute (Greenwich) longitudes of Sitka and Yakutat can be assigned.

In Supplement D will be found some particulars respecting the results for longitude of Port Simpson, British Columbia, and of Sitka, by means of chronometers carried by the Coast and Geodetic Survey steamer *Hassler*, in command of Lieut. G. B. Harbor, on the first trip up the coast in 1892.

SUPPLEMENT A.

Corrections and daily rates of sidereal chronometer Hutton No. 207 at Tacoma, Wash.

1892.	Sidereal epoch.	Δ T	δ T	1892.	Sidereal epoch.	Δ T	δ T
	h.	*s.*	*s.*		*h.*	*s.*	*s.*
June 1	17·0	−11·72	+0·89	July 19	17·9	−11·41	−0·13
3	16·0	− 9·98	+1·11	20	16·8	−11·53	−0·33
4	19·3	− 8·72	+0·91	31	18·1	−15·17	−0·48
5	18·0	− 7·84	+0·55	Aug. 1	17·9	−15·65	−0·39
6	15·2	− 7·35	+0·56	2	17·9	−16·04	−0·25
7	14·8	− 6·79	+0·86	3	18·0	−16·29	−0·81
8	14·8	− 5·93	+0·56	4	18·4	−17·11	−0·26
9	14·8	− 5·37	−0·18	5	18·2	−17·37	−0·23
13	15·4	− 6·10	−0·26	15	19·1	−19·65	−0·14
16	19·2	− 6·91	−0·23	16	18·1	−19·78	+0·03
17	15·3	− 7·10	−0·08	17	18·2	−19·75	−0·15
21	16·2	− 7·41	−0·09	18	18·3	−19·90	−0·51
22	15·2	− 7·50	−0·32	19	18·2	−20·41	−0·31
23	15·4	− 7·82	−0·50	20	18·4	−20·72	+0·03
24	15·2	− 8·32	+0·06	30	19·2	−20·45	+0·38
July 1	16·6	− 7·92	−0·07	31	19·2	−20·07	+0·29
2	16·2	− 7·99	−0·32	Sept. 1	19·2	−19·78	−0·05
3	16·2	− 8·31	−0·22	2	19·2	−19·83	−0·16
5	16·4	− 8·53	−0·90	3	19·0	−19·99	+0·02
7	16·0	−10·31	−0·06	4	19·1	−19·97	−0·05
16	17·7	−10·82	−0·20	5	20·3	−20·02	−0·19
17	17·1	−11·02	−0·05	6	19·2	−20·20	
18	17·5	−11·07	−0·33				

N. B.—The chronometer appears to be slightly accelerated by increase of temperature, though the change is very small and not regular.

SUPPLEMENT B.

Corrections and daily rates of sidereal chronometer Hutton No. 194 at Sitka, Alaska.

1892.	Sidereal epoch.	Δ T	δ T	1892.	Sidereal epoch.	Δ T	δ T
	h.	*s.*	*s.*		*h.*	*s.*	*s.*
May 22	14·0	−21·10	+1·49	July 10	16·5	−16·75	−2·23
26	14·0	−15·14	+0·73	11	17·0	−19·03	−1·26
27	14·0	−14·41	+1·02	12	16·5	−20·26	−0·70
28	14·0	−13·39	+0·93	25	16·5	−29·39(?)	−1·18
31	14·0	−10·61	+0·35	26	18·0	−30·59	−0·96
June 3	14·0	− 9·57	−0·76	28	17·5	−32·49	−0·92
4	14·0	−10·33	−1·22	29	17·5	−33·41	−0·96
5	14·0	−11·55	−0·75	Aug. 1	17·5	−36·30(?)	−0·85
6	14·0	−12·30	−0·17	5	20·0	−39·75	−0·48
7	14·5	−12·47(?)	−0·01	9	18·0	−41·63	−0·91
11	15·5	−12·52(?)	−0·63	13	18·0	−45·28	−1·24
13	15·5	−13·78	−0·11	17	18·0	−50·24	−1·66
15	15·0	−14·00	+0·07	18	18·0	−51·90	−1·56
16	15·5	−13·93	−0·21	19	18·0	−53·46	−0·96
19	17·0	−14·56	+0·32	23	18·0	−57·30(?)	−0·50
20	15·0	−14·27	−0·32	25	17·5	−58·28(?)	−0·53
21	15·0	−14·59	−1·22	29	18·0	−60·43	−0·37
22	15·5	−15·81	−0·21	30	18·0	−60·80	−1·87
28	16·0	−17·08	+0·16	Sept. 1	18·5	−64·57	−1·14
July 4	16·5	−16·11	+0·20	2	18·5	−65·71	−1·26
9	16·5	−15·10(?)	−1·62	3	18·5	−66·97	−1·05
9	20·5	−15·37	−1·66	10	18·5	−74·35	

Plotting the rate and observed temperature as coordinates, it was found that the former followed closely the latter, as shown in the accompanying diagram. Accordingly we have the expression for the rate:

$$r = -0^{s}\cdot48 - 0\cdot192\ (t - 58^{\circ}\cdot85)$$

where t = temperature of exposure of chronometer, expressed in F.'s scale.

SUPPLEMENT C.

Corrections and daily rates of sidereal chronometer Bond & Son No. 380 at Yakutat Bay, Alaska.

1892.	Sidereal epoch.	ΔT	δT
	h.	*h. m. s.*	*s.*
June 3	15·52	—1 07 23·36	
5	14·73	—1 07 18·46	+2·49
17	18·28	—1 06 47·85	+2·52
20	16·95	— 1 39·92	+2·69
July 9	17·42	— 58·18	+2·19
10	17·41	— 56·18	+2·00
13	17·30	— 49·35	+2·28
Aug. 4	18·98	— 3·15	+2·09
5	18·45	— 1·58	+1·60
13	21·16	+ 14·79	+2·02
17	23·22	+ 25·01	+2·50
18	22·92	+ 27·30	+2·32
30	22·25	+ 58·50	+2·61
31	20·27	+ 60·51	+2·19

SUPPLEMENT D.

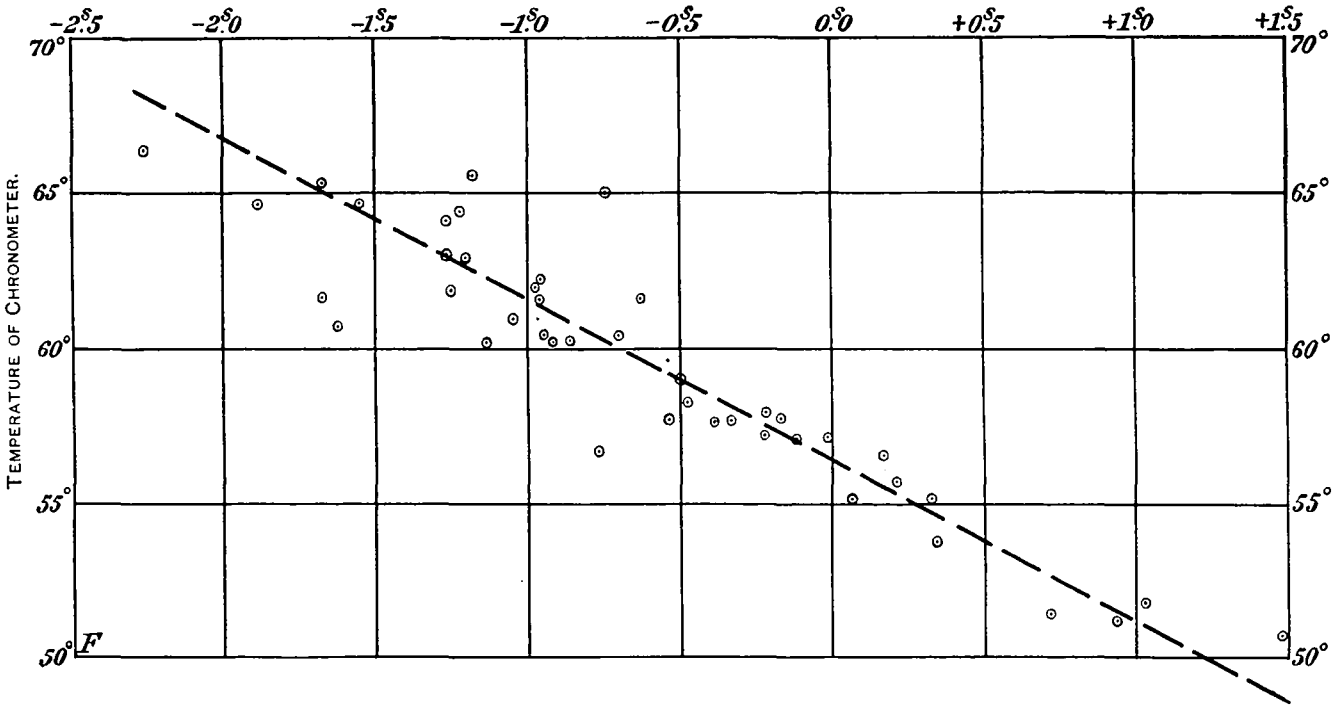
The steamer *Hassler*, after receiving the Greenwich noon signals on April 25 and April 28, 1892, at Port Townsend, as telegraphed from the Mare Island Navy-Yard, Cal., started from that port for Sitka with fourteen chronometers on board. A short stop was made at Port Simpson where a set of transit observations were made by Ensign H. C. Poundstone, May 6, for a determination of the longitude of this place. The *Hassler* reached Sitka May 14.

The sea rate of any of the chronometers was then unknown, and a first trial was made for determining λ Sitka, using the mixed rates as found at Port Townsend for Sid. chronometers 380 and 387 and M. T. chronometer 4969, the stationary rates as found at Sitka for Sid. chronometers 3479 and 194 and M. T. chronometer 1707, and the rates for M. T. chronometers 1327, 1347, and 1745 were made to depend on the rate curve, a function of temperature as determined at the Mare Island Navy-Nard. The results from this proceeding proved unsatisfactory, and a second computation was made, employing the sea rates as found from the first round trip from Sitka to Yakutat, but omitting the six chronometers first named as of little importance. The results for λ Sitka and those for Port Simpson worked out by this second more satisfactory method are as follows:

Chronometers.	λ Sitka.	*p*	λ Port Simpson.
	h. m. s.		*h. m. s.*
1327 M. T.	9 01 22·89	3	8 41 45·80
1110 "	22·01	3	45·35
1347 "	18·42	3	42·23
1639 "	20·60	4	44·22
1745 "	19·04	2	43·01
2167 "	20·41	3	44·57
4794 "	17·97	2	41·25
208 "	21·54	4	45·32
Weighted mean*	$9^{h}\ 01^{m}\ 20^{s}\cdot57 \pm 0^{s}\cdot40$		Weighted mean $8^{h}\ 41^{m}\ 44^{s}\cdot19 \pm 0^{s}\cdot36$

* For final value see Report of August 7, 1894, page 84.

DAILY RATE OF CHRONOMETER, HUTTON NO. 194, AT SITKA, 1892.



{+Indicates losing rate.
{− " " gaining "

For Port Simpson we have several determinations, viz:

		h.	m.	s.
In 1867	Davidson and Mosman	8	41	40·30
" 1883	Lieutenant Nichols and Morse			42·24
" 1885	Lieutenant Clover and Marr			42·51
" 1886	Lieutenant Snow and Marsh			42·20
" 1892	Ensign Poundstone			44·19

The several stations are not identical, hence no combination can be made until they are locally connected by triangulation.

The latitude of Port Simpson was observed by Assistant F. Morse in July, 1882. He found 54° 33′ 28″·4.

REPORT OF MARCH 28, 1894.

I have the honor to submit herewith the results for difference of longitude of three stations in southeastern Alaska, in continuation of what was done last year for the establishment of certain standard positions in the Territory.

The differences of longitude determined in 1893 are the results of chronometer transportations from and to Sitka, as the standard station, and comprise the astronomical and geodetic stations Taku, Fort Wrangell, and Burroughs Bay. The method of reduction is the same as that adopted for last year's work and is fully explained in my report of December 27, 1893.

The office computation was made by Mr. D. L. Hazard.

Time observations at Sitka.—The transit observations were made by Subassistant F. Morse, at the Parade Ground station of 1892, with meridian telescope No. 16, between May 16 and August 25, 1893. This instrument is one of the larger meridian telescopes and needs no further description here. Transits were noted over nine lines. Time was kept by observing chronometer Hutton No. 194 (sidereal). Daily comparisons were made with M. T. chronometer No. 1713 and sidereal chronometer No. 1458.

Time observations at Taku.—Meridian telescope No. 9, one of the smaller instruments, was used for the determination of time; Aid O. B. French, observer (H. G. Ogden, chief of party), from May 16 to September 1, 1893. Transits were noted over five lines. Time was kept by observing chronometer Fletcher No. 1507 (M. T.) between May 16 and 21. After that time sidereal chronometer Hutton No. 202 was used. M. T. chronometers Hutton No. 231 and Negus 1542 were compared at the station and kept rated.

Time observations at Fort Wrangell.—At this place meridian telescope No. 13 was mounted. Observations for time were made by Subassistant G. R. Putnam and Aid H. C. Lord (O. H. Tittmann, chief of party) between May 12 and September 2, 1893. Though thirteen lines were ruled on the diaphragm, but five were used in the transit work. Sidereal chronometer Negus No. 1771 was observing chronometer. Sidereal chronometer Negus No. 1841 was compared with it and rated until June 1, when its mainspring broke. On June 17 sidereal chronometer Negus No. 1589 took its place. M. T. chronometer Hutton No. 229 was also rated at this place, but found very poor. Personal equation was observed on July 7, and the observations made by Lord between July 22 and August 1 were referred to Putnam, observer.

Time observations at Burroughs Bay.—Meridian telescope No. 7 was used here for time observations between May 16 and September 2, 1893; H. W. Edmonds, observer (E. F. Dickens, chief of party). But five of the fifteen lines of the diaphragm were used. Sidereal chronometer Hutton No. 223 was employed for observing; M. T. chronometer Bond No. 177 and sidereal chronometer Hutton No. 207 were kept rated; No. 177, however, proved undesirable.

Chronometer transportation on the United States Coast and Geodetic Survey steamer Hassler.—The chronometers on board the steamer were in charge of H. C. Lord (F. Morse, chief of party). Daily comparisons were made between the nine chronometers carried by the *Hassler*, and seven round trips were made from Sitka to the other stations, which were visited in succession. The resulting differences of longitude were tabulated, following the plan adopted the previous year,

viz, first determining the rates from the round trips, starting from and returning to the base station, and secondly, determining the rates from round trips, starting from and returning to the outer station, and combining the first and last half trip to get an equal number of values. Weights are made to depend on the agreement of the results from the several trips, and the latter individually received weights depending on the sum of the weights of the individual chronometers carried and on the duration of the trip, i. e., inversely to the actual traveling time, inclusive of the interval between the comparisons with the observatory chronometers (three in number) and the nearest time set at the station.

1893. Difference of longitude of Sitka and Fort Wrangell, Alaska. Summary of results from seven round trips, starting from Sitka.

Chronometers, M. T. or sidereal.		First trip, May 17–22.	Second trip, June 5–11.	Third trip, June 14–22.	Fourth trip, June 30–July 8.	Fifth trip, July 18–24.	Sixth trip, July 31–Aug. 10.	Seventh trip, Aug. 18–26.	Means $\Delta\lambda$	Weights.
		m. *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	
M. T.	208	11 47·68	11 47·33	11 48·84	11 47·74	11 48·26	11 48·71	11 48·48	11 48·15	3
	2167	48·01	48·60	48·54	48·37	48·66	49·14	48·25	48·51	11
	1728	48·45	48·95	48·86	47·97	48·79	48·67	48·26	48·56	1
	196	48·18	48·93	48·90	49·28	49·01	49·23	47·99	48·79	5
	1717	48·17	48·72	48·96	48·66	48·81	49·28	48·33	48·70	10
	1542	-----	48·12	48·86	48·54	48·69	49·14	48·60	48·66	10
	2821	-----	-----	48·71	48·08	48·63	48·85	48·34	48·52	13
Sidereal	1589	47·83	48·10	-----	-----	-----	-----	-----	47·96	6
	387	47·70	49·09	49·06	48·75	49·25	49·12	48·74	48·82	3
	380	47·51	49·67	49·36	50·29	48·49	49·16	48·56	49·01	2
Means		11 47·94	11 48·61	11 48·90	11 48·63	11 48·73	11 49·03	11 48·39	11 48·60	
Weighted means		47·99	48·47	48·81	48·51	48·77	49·08	48·37	48·60	
Weight p		5	8	7	9	6	8	5		

C_1 weighted mean, $11^m\ 48^s{\cdot}61 \pm 0^s{\cdot}09$.

1893. Difference of longitude of Sitka and Fort Wrangell, Alaska. Summary of results from six round and two half round trips, starting from Fort Wrangell.

Chronometers, M. T. or sidereal.		First trip, May 20–June 8.	Second trip, June 8–17.	Third trip, June 21–July 3.	Fourth trip, July 7–20.	Fifth trip, July 22–Aug. 2.	Sixth trip, Aug. 8–20.	Seventh trip, Aug. 20–Sept. 1.	Means $\Delta\lambda$	Weights.
		m. *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	
M. T.	208	11 47·19	11 48·41	11 48·59	11 47·98	11 48·19	11 48·61	11 48·66	11 48·23	3
	2167	48·56	48·54	48·67	48·33	48·95	48·55	48·59	48·60	11
	1728	45·75	48·38	48·84	47·82	48·68	48·45	50·36	48·33	1
	196	48·53	48·71	48·91	49·39	49·08	48·24	48·56	48·77	5
	1717	48·37	48·89	49·14	48·64	49·03	48·79	48·57	48·78	10
	1542	-----	48·47	48·88	48·57	48·71	48·77	48·73	48·69	10
	2821	-----	-----	48·75	48·38	48·59	48·33	49·24	48·66	13
Sidereal.	1589	48·16	48·29	-----	-----	-----	-----	-----	48·22	6
	387	49·72	49·00	48·86	49·08	49·31	48·69	49·58	49·18	3
	380	48·84	49·90	49·01	50·04	48·97	48·79	50·05	49·37	2
Means		11 48·14	11 48·73	11 48·85	11 48·69	11 48·83	11 48·58	11 49·15	11 48·71	
Weighted means		48·38	48·61	48·85	48·60	48·83	48·57	48·89	48·69	
Weight p		5·5	7	7	11	5·5	9·5	3·5		

C_2 weighted mean, $11^m\ 48^s{\cdot}65 \pm 0^s{\cdot}04$.

Mean of C_1 and C_2, Fort Wrangell east of Sitka, $11^m\ 48^s{\cdot}63 \pm 0^s{\cdot}07$.

Same corrected for personal equation, $11^m\ 48^s{\cdot}72 \pm 0^s{\cdot}07$.

1893. Difference of longitude of Sitka and Taku, Alaska. Summary of results from seven round trips starting from Sitka.

Chronometers, M. T. or sidereal.		First trip, May 17–22.	Second trip, June 5–11.	Third trip, June 14–22.	Fourth trip, June 30–July 8.	Fifth trip, July 18–24.	Sixth trip, July 31–Aug. 10.	Seventh trip, Aug. 18–26.	Means $\Delta\lambda$	Weights.
		m. *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	
M. T.	208	5 23·71	5 22·85	5 23·75	5 22·53	5 22·95	5 23·19	5 24·59	5 23·37	3
	2167	23·73	24·04	23·73	23·83	23·37	23·83	23·81	23·76	11
	1728	24·05	24·31	23·93	23·24	23·32	23·33	23·84	23·72	1
	196	23·86	24·51	23·88	24·24	23·80	24·03	23·11	23·92	5
	1717	23·92	24·07	23·84	23·71	23·64	23·94	23·80	23·85	10
	1542	-----	23·76	23·78	23·47	23·42	23·72	24·29	23·74	10
	2821	-----	-----	23·54	23·28	23·48	23·70	23·50	23·50	13
Sidereal	1589	23·72	23·41	-----	-----	-----	-----	-----	23·56	6
	387	23·33	24·58	24·08	23·92	23·94	24·69	23·98	24·07	3
	380	23·91	24·55	24·20	24·89	23·41	23·76	24·52	24·18	2
Means		5 23·78	5 24·01	5 23·86	5 23·68	5 23·48	5 23·80	5 23·94	5 23·79	
Weighted means		23·79	23·95	23·77	23·62	23·50	23·82	23·84	23·75	
Weight p		5	7	5	9	7	4·5	3·5		

C_1 weighted mean, $5^m\ 23^s{\cdot}74 \pm 0^s{\cdot}04$.

1893. Difference of longitude of Sitka and Taku, Alaska. Summary of results from six round and two half trips, starting from Taku.

Chronometers, M. T. or sidereal.		First trip, May 21–June 6.	Second trip, June 6–15.	Third trip, June 15–July 1.	Fourth trip, July 1–19.	Fifth trip, July 19–Aug. 1.	Sixth trip, Aug. 1–21.	First and seventh trips, May 17–21, Aug. 21–26.	Means $\Delta\lambda$	Weights.
		m. *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	
M. T.	208	5 23·17	5 23·82	5 23·06	5 22·84	5 22·87	5 23·85	5 24·30	5 23·42	3
	2167	24·03	23·79	23·97	23·36	23·79	23·57	23·23	23·68	11
	1728	22·63	23·58	23·74	22·79	23·25	23·54	30·46	24·28	1
	196	24·16	23·88	24·01	24·18	23·95	22·96	24·49	23·95	5
	1717	23·98	23·96	24·02	23·58	23·90	23·84	23·27	23·79	10
	1542	24·07	23·78	23·70	23·41	23·47	23·79	-----	23·70	10
	2821	-----	-----	23·62	23·51	23·51	23·14	23·64	23·48	13
Sidereal	1589	23·69	23·51	-----	-----	-----	-----	-----	23·60	6
	387	24·61	24·15	23·88	24·07	24·49	23·94	21·45	23·80	3
	380	24·42	24·61	24·01	24·40	23·90	23·97	22·73	24·01	2
Means		5 23·86	5 23·90	5 23·78	5 23·57	5 23·68	5 23·62	5 24·20	5 23·79	
Weighted means		23·97	23·85	23·80	23·55	23·72	23·55	23·56	23·71	
Weight p		9	5	6·5	9	5·5	4	3		

C_2 weighted mean, $5^m\ 23^s{\cdot}74 \pm 0^s{\cdot}05$.

Mean of C_1 and C_2, Taku east of Sitka, $5^m\ 23^s{\cdot}74 \pm 0^s{\cdot}05$.

1893. Difference of longitude of Fort Wrangell and Burroughs Bay, Alaska. Summary of results from six round trips, starting from Fort Wrangell.

Chronometers, M. T. or sidereal.		First trip, May 17–22.	Second trip, June 5–11.	Third trip, June 17–20.	Fourth trip, July 3–7.	Fifth trip, July 20–22.	Sixth trip, Aug. 2–7.	Means $\Delta\lambda$	Weights.
		m. *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	*m.* *s.*	
M. T.	208	5 08·75	5 09·28	5 08·34	5 08·39	5 07·94	5 07·86	5 08·43	3
	2167	09·13	08·75	08·25	08·36	08·96	08·23	08·61	11
	1728	08·99	08·56	08·52	08·47	08·11	07·77	08·40	1
	196	09·21	08·66	08·56	08·63	08·13	08·15	08·56	5
	1717	09·09	08·48	08·52	08·54	08·04	08·01	08·45	10
	1542	-----	08·88	08·49	08·45	08·05	07·96	08·37	10
	2821	-----	-----	08·46	08·06	08·09	07·90	08·13	13
Sidereal	1589	08·79	08.81	-----	-----	-----	-----	08·80	6
	387	09·38	08·60	08·50	08·26	08·29	08·12	08·52	3
	380	08·85	08·87	08·64	07·69	08·11	08·45	08·44	2
Means		5 09·02	5 08·77	5 08·48	5 08·32	5 08·19	5 08·05	5 08·47	
Weighted means		09·05	08·74	08·45	08·34	08·25	08·04	08·44	
Weight p		4	4	9	6	7	6		

C_1 weighted mean, $5^m\ 08^s{\cdot}42 \pm 0^s{\cdot}09$.

1893. Difference of longitude of Fort Wrangell and Burroughs Bay, Alaska. Summary of results from five round trips and two half trips, starting from Burroughs Bay.

Chronometers, M. T. or sidereal.		First trip, May 19–June 9.	Second trip, June 9–18.	Third trip, June 18–July 4.	Fourth trip, July 4–21.	Fifth trip, July 21–Aug. 4.	First and sixth trips, May 17–19, Aug. 4–10.	Means $\Delta\lambda$	Weights.
		m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	
M. T.	208	5 08·91	5 08·69	5 08·34	5 08·27	5 07·58	5 07·48	5 08·21	3
	2167	09·03	08·41	08·33	08·37	08·98	08·32	08·57	11
	1728	08·06	08·75	08·81	07·77	08·07	10·04	08·58	1
	196	08·96	08·76	08·05	08·52	08·02	08·79	08·52	5
	1717	08·79	08·65	08·49	08·28	07·88	08·12	08·37	10
	1542	-----	08·71	08·28	08·35	07·78	08·76	08·38	10
	2821	-----	-----	08·27	08·27	07·69	08·52	08·19	13
Sidereal	1589	08·86	08·93	-----	-----	-----	-----	08·90	6
	387	09·38	08·67	08·03	08·41	08·20	07·53	08·37	3
	380	08·98	09·08	07·74	07·59	09·01	07·75	08·36	2
Means		5 08·87	5 08·74	5 08·26	5 08·20	5 08·13	5 08·37	5 08·43	
Weighted means		08·93	08·68	08·28	08·30	08·08	08·37	08·41	
Weight p		6	5	7	8	6	4		

C_2 weighted mean, $5^m\ 08^s{\cdot}42 \pm 0^s{\cdot}09$.

Mean of C_1 and C_2, Burroughs Bay east of Fort Wrangell, $5^m\ 08^s{\cdot}42 \pm 0^s{\cdot}09$.

RECAPITULATION OF RESULTS.

Fort Wrangell, astronomic station of 1882 and 1893, east of Sitka, astronomic station of 1892–93,

$$11^m\ 48^s{\cdot}72 \pm 0^s{\cdot}07$$

Taku, astronomic station of 1893, east of Sitka, astronomic station of 1892–93,

$$5^m\ 23^s{\cdot}74 \pm 0^s{\cdot}05$$

Burroughs Bay, astronomic station of 1893, east of Fort Wrangell, astronomic station of 1882 and 1893,

$$5^m\ 08^s{\cdot}42 \pm 0^s{\cdot}09$$

REPORT OF AUGUST 7, 1894.

I have the honor to report herewith the results of the determination of several standard astronomic positions in southeastern Alaska, the observations having been made during 1892, 1893, and 1894.

The chronometric longitude expeditions of Alaska in 1892 and 1893 depend for their results on the longitude of Tacoma, Wash. In May and June, 1894, this place was connected with the telegraphic longitude system at Seattle, Wash., with the following result from the office computation:

Tacoma west of Seattle, $0^h\ 00^m\ 27^s{\cdot}159 \pm 0^s{\cdot}0098$ (see Supplement 1).

Longitude of Tacoma, $8^h\ 09^m\ 47^s{\cdot}48 \pm 0^s{\cdot}08$ (see Supplement 2).

The results of the chronometric expeditions to Sitka and Yakutat in 1892 are given in my report of December 27, 1893, and the results of the expeditions in 1893 to Fort Wrangell, to Taku, and to Burroughs Bay are contained in my report of March 28, 1894. The latitudes of these stations were likewise reported. Putting the results together, we get the following values for λ of standard positions in southeastern Alaska. They are connected with local triangulations and they form the basis upon which the survey of this part of Alaska will depend for its geographical positions.

Resulting longitudes of astronomic stations in Alaska, 1892–94.

	h.	m.	s.	± s.
λ Tacoma, 1894	8	09	47·48	± 0·08
△ λ Tacoma and Sitka, 1892	+	51	34·00	± 0·10
λ Sitka	9	01	21·48	± 0·13
△ λ Sitka and Yakutat, 1892	+	17	47·56	± 0·12
λ Yakutat	9	19	09·04	± 0·18
λ Sitka	9	01	21·48	± 0·13
△ λ Sitka and Fort Wrangell, 1893	—	11	48·72	± 0·07
λ Fort Wrangell	8	49	32·76	± 0·15
△ λ Sitka and Taku, 1893	—	5	23·74	± 0·05
λ Taku	8	55	57·74	± 0·14
△ λ Fort Wrangell and Burroughs Bay, 1893	—	5	08·42	± 0·09
λ Burroughs Bay	8	44	24·34	± 0·17

Final results of geographic positions (astronomic stations).

	Latitude.				Longitude (arc).				Longitude (time).			
	°	′	″	″	°	′	″	″	h.	m.	s.	s.
Tacoma, Wash., 1892, north end of Wright's Park	47	15	46·38	---	122	26	52·20	± 1·20	8	09	47·48	± ·08
Sitka, Alaska, 1892, in front of Presbyterian church	57	02	52·94	± ·08	135	20	22·20	± 1·95	9	01	21·48	± ·13
Yakutat, Alaska, 1892, Khantaak Island	59	33	50·5	± 1·5	139	47	15·60	± 2·70	9	19	09·04	± ·18
Fort Wrangell, Alaska, 1882 and 1893, southern edge United States reservation	56	28	16·46	± ·09	132	23	11·40	± 2·25	8	49	32·76	± ·15
Taku, Alaska, 1893, northern island southeast side of inlet	58	26	15·64	± ·06	133	59	26·10	± 2·10	8	55	57·74	± ·14
Burroughs Bay, Alaska, 1893, near B. B. cannery, head of bay	56	02	11·57	± ·10	131	06	05·10	± 2·55	8	44	24·34	± ·17

Respecting local deflections in longitude at Tacoma, Seattle, and Port Townsend, we have the geodetic and astronomic difference of Tacoma and Seattle as follows: $\triangle \lambda_g = 6' 49''{\cdot}417$ and $\triangle \lambda_a = 27^s{\cdot}159 = 6' 47''{\cdot}39$, hence differential local deflection $2''{\cdot}02$, a reasonably small quantity, showing that the deflection at Tacoma is very much larger.

SUPPLEMENT 1.

Difference of telegraphic longitude between Seattle, grounds of the University, Wash., and Tacoma, Wright's Park, Wash., from exchange of arbitrary signals in May and June, 1894.

Stations.	Seattle, Wash.	Tacoma, Wash.
Observers.	G. Davidson and C. H. Sinclair.	C. H. Sinclair and G. Davidson.
Instruments.	C. and G. Survey transit No. 18, made at the office in 1888. For description see App. 9, Rep. for 1889. Aperture, 7·5cm; focal length, 94cm. Magnifying power, 104 diameters. Glass diaphragm of 13 lines, 11 of which were used in 3 tallies of 3, 5, and 3 lines. Pivot inequality for band W. —0s·064, as determined at El Paso, Tex., in 1893. One division of striding level, 1″·674, as determined at the office in December, 1892. Sidereal break-circuit chronometer Hutton No. 211, breaks every even second and the first. Chronograph Fauth & Co. No. 7; telegraph apparatus No. 1.	C. and G. Survey transit No. 19, made at the office in 1888. For description see App. 9, Rep. for 1889. Aperture, 7·5cm; focal length, 94cm. Magnifying power, about 104 diameters. Glass diaphragm of 13 lines, 11 of which were used in 3 tallies of 3, 5, and 3 lines. Pivot inequality for band W. + 0s·028, as determined at Little Rock, Ark., in 1893. One division of striding level, 1″·85, as determined at the office in March, 1893. Sidereal break-circuit chronometer Negus No. 1769, breaks the even seconds and the fifty-ninth. Chronograph Fauth & Co. No. 9; telegraph switch board No. 2.

Telegraph lines and batteries.—The length of the connecting telegraph line is 40 miles and is of No. 9 galvanized wire, grounded at Tacoma and provided with a battery of 73 gravity cells at Seattle.

Time determinations.—Two sets of transits were observed on every night of exchange at an interval of about one hour, and the same stars were observed, weather permitting, at both stations. A set usually consists of ten stars, one-half of the number observed with collimation east, the other with collimation west, and each part containing one azimuth and four time stars, two north and two south of the zenith, if practicable.

Time exchanges.—They took place between the two sets of the transit observations, and consist of two or three dozen arbitrary break signals, sent and received at each station. During these exchanges the chronograph was run at double speed.

Personal equation.—The differential personal equation as deduced from the longitude results themselves is D — S = — 0s·342 ± 0s·008, a large value, but in perfect accord with the value found at Carson City and Lake Tahoe in August, 1893; the first observer giving earlier time.

Computations and results.—The field computations were made by the observers, and the office computation by D. L. Hazard. The method of reduction is explained in Appendix No. 8, Report for 1889. Probable error of a time determination by a single star (referred to the equator) for transit No. 18 ± 0s·034, and for No. 19 ± 0s.035; also for Davidson, observer, ± 0s·043 and for Sinclair, observer, ± 0s·026.

Summary of results for difference of longitude, Tacoma and Seattle, Wash.

Date.	Observers at Tacoma	Observers at Seattle.	From west or Tacoma signals.	From east or Seattle signals.	W. — E.	Mean of W. and E. signals.	Corr'n for pers. eq'n.	Difference of long. $\Delta\lambda$	Comb'n weight p	Residual v
1894.			*h. m. s.*	*h. m. s.*		*h. m. s.*	*s.*	*h. m. s.*		*s.*
May 21	S.	D.	0 00 27·467	0 00 27·500	[—·033]	0 00 27·484	—0·342	0 00 27·142	5	—0·017
22	S.	D.	·395	·388	·007	·392		·050	3	— ·109
23	S.	D.	·509	·496	·013	·502		·160	7	+ ·001
24	S.	D.	·563	·558	·005	·560		·218	4	+ ·059
25	S.	D.	·524	·527	—·003	·526		·184	5	+ ·025
				Mean	·005	27·493				
May 28	D.	S.	0 00 26·793	0 00 26·786	·007	0 00 26·790	+ ·342	·132	7	— ·027
31	D.	S.	·785	·781	·004	·783		·125	3	— ·034
June 1	D.	S.	·850	·841	·009	·846		·188	6	+ ·029
11	D.	S.	·863	·854	·009	·858		·200	6	+ ·041
13	D.	S.	·769	·768	·001	·768		·110	2	— ·049
				Mean	·006	26·809		27·151		
					Weighted mean			0 00 27·159 ± 0ˢ·0098		

Transmission or wave and armature time.—Omitting the value of May 21, we have for the transmission time 0ˢ·003 ± 0ˢ·0005.

Location and station marks.—The astronomic station at Tacoma was located in 1892 by Assistant J. F. Pratt. It is in the north end of Wright's Park, on the east side, near G street, and in the prolongation of First street south to the west. The pier is on a small knoll and is a few paces north of the park walk; it is dressed to 24 by 15½ inches at the top and has cut on the upper surface:

U. S.
C. &
G. S.

There is a copper bolt to mark the station, as described by Assistant Pratt. Assistant Davidson placed a granite pier 3½ feet long to the south of the observatory and in the meridian of the transit instrument, 498½ feet distant; and farther south, on the western edge of a spur, a second granite pier, 934 feet from the station, was planted in the same meridian. It is intended that these stones shall serve for a meridian line for the use of surveyors.

At Seattle the station of 1888 was used. It was originally described by Assistant Gilbert in 1886, but was slightly remodeled by Assistant Smith in 1888. It is located in the grounds of the University. Since the location of the University is to be changed, the present grounds may be converted into a city park.

Final result for difference of longitude: Tacoma west of Seattle, 0ʰ 00ᵐ 27ˢ·159 ± 0ˢ·0098.

SUPPLEMENT 2.

Telegraphic longitude of Tacoma, Wash.

	h.	m.	s.	
(*a*) Northern route:				
λ Detroit [App. 11, Rep. for 1884]	5	32	12·170	
△λ Detroit and Chicago, 1891	+0	18	17·272	
△λ Chicago and Minneapolis, 1891	+0	22	27·414	
△λ Minneapolis and Bismarck, 1890	+0	30	11·078	
△λ Bismarck and Helena, 1890	+0	45	00·852	
△λ Helena and Wallawalla, 1888	+0	25	14·510	
△λ Wallawalla and Seattle, 1888	+0	15	57·028	
△λ Seattle and Tacoma, 1894	+0	00	27·159	
λ Tacoma	8	09	47·483	$w=3$
(*b*) Central route:				
λ Kansas City [App. 11, Rep. for 1884]	6	18	21·370	
△λ Kansas City and Colorado Springs, 1885	+0	40	55·327	
△λ Colorado Springs and Salt Lake, 1886	+0	28	18·471	
△λ Salt Lake and Wallawalla, 1887	+0	25	48·186	
△λ Wallawalla and Tacoma, as above	+0	16	24·187	
λ Tacoma	8	09	47·541	$w=2$
(*c*) Southern route:				
λ St. Louis [App. 11, Rep. for 1884]	6	00	49·163	
△λ St. Louis and Kansas City, 1882	+0	17	32·199	
△λ Kansas City and Little Rock, 1885	−0	09	15·644	
△λ Little Rock and El Paso, 1893	+0	56	51·687	
△λ El Paso and Nogales, 1892	+0	17	48·532	
△λ Nogales and Yuma, 1892	+0	14	43·698	
△λ Yuma and Los Angeles, 1892	+0	14	31·986	
△λ Los Angeles and San Francisco, 1889	+0	16	41·252	
△λ San Francisco and Portland, 1887	+0	00	59·981	
△λ Portland and Seattle, 1888	−0	01	22·476	
△λ Seattle and Tacoma, 1894	+0	00	27·159	
λ Tacoma	8	09	47·537	$w=1$

Weighted mean, λ Tacoma, $8^h\ 09^m\ 47^s{\cdot}51 \pm 0^s{\cdot}08$, estimated.

Other combinations made gave a value about $0^s{\cdot}05$ less; I have consequently adopted, for the present, $8^h\ 09^m\ 47^s{\cdot}48 \pm 0^s{\cdot}08$.

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APPENDIX No. 4—1894.

DISTRIBUTION OF THE MAGNETIC DECLINATION IN ALASKA AND ADJACENT WATERS FOR THE YEAR 1895, AND CONSTRUCTION OF AN ISOGONIC CHART FOR THE SAME EPOCH.

By C. A. SCHOTT, Assistant.

Submitted for publication December 19, 1894.

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Prior to the year 1892 our knowledge of the annual change of the magnetic declination was very imperfect over the vast region comprising the coast of Alaska, and still more for the interior. Since that time, however, observations made by the Coast and Geodetic Survey, especially those in connection with the survey of the boundary during the years 1889–1894, as well as information gathered from other sources, greatly aided in assigning improved values to the annual change and in clearing up obscure cases and giving new information at certain points. In the higher latitudes the evaluation of the annual change presents special difficulties in consequence of the paucity of the material and the comparatively large diurnal variation which has to be allowed for in the resulting declination. As an illustration of the change brought about by the additional testimony of late observations, the case of Sitka may be taken. Here the records up to 1881 and deduced curve given in Appendix No. 7, Report for 1888, pages 285–287 and plate No. 22, strongly indicated decreasing declination for the present time; yet the observations of 1892, 1893, and 1894, made at the same spot, flatly contradicted this inference and established the fact of an increasing easterly declination at this place,* and consequently also for a considerable region about it. Further proof of an increasing easterly declination in southeastern Alaska was obtained at Fort Wrangell in 1893. At Port Simpson, however, no fresh evidence has been forthcoming since 1885, when a small increase was indicated. In this region, up to 1892, it was believed that the direction of the magnetic needle was either stationary or slightly moving westward. This uncertainty of what was going on extended even as far south as the State of Washington. Observations had to be specially ordered for Seattle and Tacoma, with the result that here also the easterly declination was found to be still advancing (May, 1894). Further evidence of this motion resulted from a discussion of observations collected for Esquimalt (Victoria), Vancouver Island, between the years 1858 and 1892. All this shows that the ribbon, shown on the chart in Appendix No. 7, Report for 1888, covering the space of stationary condition of the magnetic needle, needs correction and must be located more toward the eastern part of the State of Washington. The difficulty of ascertaining the annual change for places in Alaska may be further illustrated in the case of Yakutat Bay, where the survey of 1892 brought out the fact of a deflection of the needle of 47′ at Khantaak Island, as compared with other places on the bay, and these later observations demanded the cancellation of the annual change of +8′·8 on the isogonic chart for 1890 (constructed in October, 1889)† placed against this locality and the substitution of the words "annual change inappreciable."

* In consequence of this the compass placed on the older harbor charts had to be corrected in the new issues by nearly 1 degree.

† Chart No. 26, Appendix No. 11, Report for 1889.

With respect to the interior of Alaska, the most important station where information was secured in 1889 and 1890 is Fort Yukon, where the declination was found decreasing a few minutes per annum, in entire conformity with the easterly decline noticed to take place all along the shores washed by Bering Sea and the Arctic Ocean. The fortunate recovery of Bering's magnetic observations made on his first voyage to the coasts of Kamchatka and eastern Asia in the years 1725 to 1730, and their discussion by me in December, 1890 (published in Bulletin No. 20, December 12, 1890, and in Appendix No. 5, Report for 1891), greatly extended and improved our knowledge of the secular variation of the declination in this part of the world and modified the former values of the annual change at stations on the opposite or American coast.

Fully five years have elapsed since the production by the Coast and Geodetic Survey of an isogonic chart covering the whole of Alaska Territory and adjacent regions, during which interval so much of new information has become available, either in the shape of discovery of old records or of new observations, together with recent discussions, that an entire reconstruction of the isogonic chart became a necessity in order that the charts of this territory and the approaches thereto may have their compass variations correctly indicated. For this the epoch 1895·0 was determined upon, leaving future improvements to be made for a chart for the year 1900.

For the reduction of the observed declinations to the epoch I have made use of all information at present available, resorting to interpolation in regions where only an approximate or no value for the annual change could be obtained. It is the uncertainty arising from this circumstance which determined me to adopt 1895 rather than 1900 for the epoch. The values adopted for the annual change at thirty-seven localities, distributed over the whole area are given below. The entire absence of late observations, or rather my inability to procure any, in the western part of Bering Sea and along the coast of eastern Siberia and Kamchatka, rendered it desirable to restrict the geographical extent of the investigation in the west to about 175° west longitude, as otherwise imperfect data near the Asiatic coast would have an injurious influence on our results.

There are two ways of constructing isogonic curves—by means of a graphical and by means of an analytical process. The former is here out of the question by reason of the large geographic extent involved and the scarcity and irregularity of distribution of the observations. In fact, the graphical treatment is better adapted for investigations of magnetically disturbed regions, i. e., for the construction of isabnormal lines or curves of equal anomaly.

The declination (D) (reduced to epoch) at any place within the spherical surface under consideration may be expressed as a function of the latitude (φ) and of the longitude (λ). The form and number of terms of the function adopted is the same as used by me in the preceding investigation in 1889, and is as follows:

$$D = D_0 + r\,.\,\triangle\varphi + s\,.\,\triangle\lambda\cos\varphi + t\,.\,\triangle\varphi^2 + u\,.\,\triangle\varphi\,\triangle\lambda\cos\varphi + v\,.\,\triangle\lambda^2\cos^2\varphi + w\,.\,\triangle\varphi^3 + x\,.\,\triangle\varphi^2\,\triangle\lambda\cos\varphi + y\,.\,\triangle\varphi\,\triangle\lambda^2\cos^2\varphi + z\,.\,\triangle\lambda^3\cos^3\varphi$$

where $\triangle\varphi = \varphi - \varphi_0$, $\triangle\lambda = \lambda - \lambda_0$, and r, s, t, u, v, w, x, y, z, represent unknown numerical coefficients to be determined from the observations themselves. Terms involving higher powers in φ and λ than the third could be dispensed with. The values of φ_0 and λ_0 represent the average latitude and the average longitude of the magnetic stations, respectively, and D_0 is the value of the declination corresponding to it. For the latter we take the approximate value D_1 and find the correction, q, to it; hence $D_0 = D_1 + q$. Applying the method of least squares to the problem, the observation equations take the form

$$0 = \begin{cases} D_1 - D + q \\ + \varphi_1\,.\,r + \lambda_1\cos\varphi\,.\,s \\ + \varphi_1^2\,.\,t + \varphi_1\,\lambda_1\cos\varphi\,.\,u + \lambda_1^2\cos^2\varphi\,.\,v \\ + \varphi_1^3\,.\,w + \varphi_1^2\,\lambda_1\cos\varphi\,.\,x + \varphi_1\,\lambda_1^2\cos^2\varphi\,.\,y + \lambda_1^3\cos^3\varphi\,.\,z \end{cases}$$

where for shortness we write φ_1 for $\triangle\varphi$ and λ_1 for $\triangle\lambda$.

Of these equations there are as many as there are observations, but as any large number would be either cumbersome or unmanageable, the observations need to be contracted into mean values, *i. e.*, groups or so-called normals. The next step is the formation of the ten normal equations and the evaluation of the unknowns q.....z. The success of the work is to be measured by

the degree of approximation between the computed and observed declinations at the normal places, and the probable error of a single representation is given by the formula $r = 0{\cdot}674\sqrt{\frac{[dd]}{n-n_1}}$ where n = number of normal places or groups, and n_1 = number of normal equations.

The numerical equation expressive of D being thus established, a sufficient number of points for the delineation of any isogonic line can readily be computed, and consequently the whole system of isogonic curves laid down on a suitable chart.

The selection of the groups depends primarily on the geographic positions of the magnetic stations, but must be such as to cover implicitly the whole area, and with the groups distributed over it in such a way as to give great weight to the coefficients of the equation determining the declinations. Theoretically, ten groups suffice; but the greater their number the better will be the general representation.

Of the material on hand only the later observations were introduced, as less liable to error when reduced to the epoch.* The data themselves were taken from the general collection of magnetic observations on file in the Computing Division.† As usual in the Survey, east declination is expressed by a minus sign prefixed, and the same sign is given the annual increase (a); for a decrease (a) would be positive. Groups may consist of any number of observed values, located sufficiently close together to be united into a mean. Here the numbers vary between one and fifteen, but the mean values are all taken as of the same weight.

Formation of groups.

Group and name of station.	Lat. φ	Long. λ	Year of obser'n.	Obs'd D	Red'n to 1895.	$D_{1895{\cdot}0}$	a	Remarks.
	°	°		°	°	°	′	
I. *Puget Sound.*							−2	
Seattle	47·61	122·33	1894·4	−22·68	— ·02	−22·70		
Tacoma	47·26	122·45	1894·4	−22·51	— ·02	−22·53		
Mean	47·44	122·39				−22·62		
II. *Strait of Juan de Fuca.*							−2·5	
Esquimalt and Victoria	48·43	123·46	1892·7	−23·22	— ·10	−23·32		D of east side Point Roberts excluded.
Port Townsend	48·12	122·75	1888·5	−22·81	— ·27	−23·08		
Dungeness	48·18	123·11	1892·7	−23·44	— ·10	−23·54		
Discovery	48·42	123·22	1892·7	−23·18	— ·10	−23·28		
Beechey Head. Weight = ½	48·33	123·66	1892·8	−24·62	— ·09	−24·71		
Striped Peak	48·16	123·68	1893·5	−23·20	— ·06	−23·26		
Sheringham	48·38	123·92	1893·5	−22·72	— ·06	−22·78		
Admiralty Head	48·15	122·68	1857·5	−21·90	−1·56	−23·46		
Bellingham Bay	48·55	122·45	1859·5	−22·15	−1·48	−23·63		
West side Point Robert	48·98	123·08	1859·5	−21·75	−1·48	−23·23		
Weighted mean	48·37	123·16				−23·33		
III. *Cape Flattery.*							−2	
Neeah Bay	48·36	124·63	1881·8	−22·74	— ·44	−23·18		Station Arch Rock omitted as too far east and D of too large a value.
Tatoosh Island	48·39	124·73	1893·7	−23·75	— ·04	−23·79		
Classet	48·39	124·66	1893·7	−23·11	— ·04	−23·15		
Waadah	48·38	124·60	1893·6	−23·44	— ·05	−23·49		
Slip	48·26	124·24	1893·6	−23·51	— ·05	−23·56		
Vancouver	48·58	124·64	1893·6	−23·86	— ·05	−23·91		
Clattam Bay	48·25	124·27	1864·5	−22·50	−1·02	−23·52		
Hecate Bay	49·25	125·93	1861·5	−22·65	−1·12	−23·77		
Onchucklin Harbor	49·00	125·00	1861·5	−24·22	−1·12	−25·34		
Mean	48·54	124·74				−23·75		

*Many of the results for annual change contained in Appendix No. 7, Report for 1888, have since become obsolete or were found defective, and are now superseded by more reliable ones depending on the latest accessible data.

†The latest Alaskan observations published are contained in Appendix No. 11, Report for 1892.

Formation of groups—Continued.

Group and name of station.	Lat. φ	Long. λ	Year of obser'n.	Obs'd D	Red'n to 1895.	$D_{1895\cdot0}$	a	Remarks.
	°	°		°	°	°	′	
IV. *Nootka and Quatsino Sounds.*							—1·5	
Friendly Cove	49·59	126·62	1881·7	—23·60	— ·33	—23·93		
Quatsino Sound, north harbor	50·49	128·06	1881·7	—24·90	— ·33	—25·23		
Mean	50·04	127·34				—24·58		
V. *Thompson River.*							—1	
Town of Yale	49·57	121·42	1871·5	—24·00	— ·39	—24·39		
Mouth of Thompson River	50·22	121·60	1871·5	—25·00	— ·39	—25·39		
Thompson River, mouth of Nicola	50·45	121·37	1871·5	—25·50	— ·39	—25·89		
Thompson River	50·68	120·20	1871·5	—24·00	— ·39	—24·39		
Thompson River near Kamloops	50·70	120·50	1877·5	—24·25	— ·29	—24·54		
Thompson River	50·77	121·08	1871·5	—23·50	— ·39	—23·89		
On Little Shushwap	50·83	119·77	1871·5	—24·50	— ·39	—24·89		
North Thompson River	50·95	120·47	1871·5	—23·88	— ·39	—24·27		
North Thompson River	51·20	120·37	1871·5	—24·12	— ·39	—24·51		
North Thompson River	51·47	120·42	1873·5	—25·33	— ·36	—25·69		
Mean	50·68	120·72				—24·78		
VI. *Great Fork Frazer River.*							—1	
Clearwater River	52·20	120·20	1873·5	—24·50	— ·36	—24·86		Fort McLeod excluded; too far north.
Tête Jeanne Cache	52·97	119·83	1876·5	—26·33	— ·31	—26·64		
Jasper House	53·27	118·17	1871·5	—26·00	— ·39	—26·39		
Mouth of Chilaccot River.	53·83	123·00	1875·5	—28·25	— ·33	—28·58		
Weight ½								
Weighted mean	52·96	119·91				—26·34		
VII. *Queen Charlotte Island.*							—1·5	
Rose Harbor	52·15	131·25	1881·7	—26·01	— ·33	—26·34		
VIII. *At sea,* northeast Pacific Ocean*	45·00	135·00				—21·75	(?)	
IX. *At sea,† northeast Pacific Ocean*	45·00	128·50				—21·75	(?)	Value of a (?)
X. *At sea,* northeast Pacific Ocean*	47·00	155·00				—19·75	(?)	
XI. *At sea,† northeast Pacific Ocean*	51·00	145·00				—23·80	(?)	
XII. *Port Simpson and Skeena River.*							—2	
Port Simpson	54·57	130·43	1885·4	—28·06	— ·32	—28·38		South base, Portland Canal omitted; value of D too large.
Port Essington	54·23	129·78	1879·5	—27·33	— ·52	—27·85		
Head of Work Inlet	54·30	129·72	1879.5	—27·50	— ·52	—28·02		
Twenty miles up the Skeena	54·32	129·32	1879·5	—27·33	— ·52	—27.85		
Thirty miles up the Skeena	54·37	129·00	1879·5	—26·75	— ·52	—27·27		
Fifty miles up the Skeena	54·50	128·58	1879·5	—26·50	— ·52	—27·02		
Howcan Mission	54·83	132·83	1881·7	—27·06	— ·44	—27·50		
Bay, Portland Canal	55·22	130·06	1888·7	—27·74	— ·21	—27·95		
Mean	54·54	129·96				—27·73		

* The values for 1895·0 were deduced from the following observations by comparing them with the isogonic curves of 1890 and taking a mean difference (with regard to number of points):

	° ′	° ′	° ′		
1894	$\varphi = 42\ 25$	$\lambda = 156\ 24$	$D = -16\ 25$	Pt. 1	U. S. S. Adams.
1886	42 41	132 46	−19 35	8	Alert.
1889	43 40	150 42	−18 15	1	Adams.
1886	45 32	151 36	−19 00	8	Alert.
1894	47 30	135 00	−22 40	1	Adams.
1894	48 10	132 00	−23 10	1	Adams.

† Obtained by interpolation, using the isogonic lines of 1890 differentially.

Formation of groups—Continued.

Group and name of station.	Lat. φ	Long. λ	Year of obser'n.	Obs'd D	Red'n to 1895.	$D_{1895\cdot0}$	a	Remarks.
	°	°		°	°	°	′	
XIII. *Fort Wrangell.*							−1·9	
Fort Wrangell, astronomic station	56·47	132·38	1893·5	−29·64	— ·05	−29·69		
Tamgas Harbor	55·07	131·47	1883·6	−28·58	— ·36	−28·94		
Pen Island	55·38	131·73	1885·6	−28·12	— ·30	−28·42		
Union Bay	55·74	132·19	1885·6	−30·50	— ·30	−30·80		
Kasaan Bay	55·50	132·32	1880·4	−27·80	— ·46	−28·26		
Dewey Anchorage	55·93	132·36	1886·7	−28·50	— ·26	−28·76		
Port McArthur	56·07	134·10	1886·6	−27·83	— ·27	−28·10		
Point Chican	56·15	133·61	1886·6	−29·42	— ·27	−29·69		
Shakan	56·15	133·63	1881·6	−30·05	— ·42	−30·47		
Red Bay, Sumner Strait	56·33	133·25	1886·4	−29·67	— ·27	−29·94		
Fort Wrangell, north base	56·46	132·38	1886·5	−29·33	— ·27	−29·60		
Frederic Sound, south base	56·91	132·85	1887·4	−29·63	— ·24	−29·87		
Duncan Canal, east base	56·60	133·10	1887·6	−30·10	— ·23	−30·33		
Wards Cove	55·38	131·73	1882·7	−28·30	— ·39	−28·69		
Burroughs Bay, astronomic station	56·04	131·10	1893·2	−30·40	— ·06	−30·46		
Mean	56·01	132·55				−29·47		
XIV. *Sitka.*							−2	
Sitka, astronomic station	57·05	135·34	1894·4	−29·61	— ·02	−29·63		Principal secular variation station.
XV. *Lynn Canal and vicinity.*							−1·5	
Muir Glacier	58·83	136·08	1890·7	−30·43	— ·11	−30·54		Holkham Bay and Port Althorp excluded; local deflections.
Taku River	58·44	133·99	1893·6	−30·27	— ·04	−30·31		
Auke Point	58·19	134·55	1890·5	−30·73	— ·11	−30·84		
Funter Bay	58·23	134·91	1890·7	−30·25	— ·11	−30·36		
Chilkat	59·19	135·45	1890·5	−30·65	— ·11	−30·76		
Point Lena	58·39	134·77	1890·4	−30·40	— ·12	−30·52		
Mean	58·54	134·96				−30·56		
XVI. *Yakutat Bay.*							(?)	
Khantaak Island. Weight 4	59·56	139·78	1892·7	−29·93	-----	−29·93		
Malaspina, south base	59·72	140·20	1892·6	−30·90	-----	−30·90		Measures with compass declinometer.
Malaspina, north base	59·76	140·09	1892·6	−30·70	-----	−30·70		
Mount Hoorts	59·75	139·53	1892·6	−30·85	-----	−30·85		
Ocean Cape	59·54	139·86	1892·7	−30·40	-----	−30·40		
Weighted mean	59·63	139·85				−30·32		
XVII. *Vicinity of Mount Lorne.*							+1	
Lake Lyndeman	59·78	135·08	1887·5	−32·28	+ ·12	−32·16		
Marsh Lake	60·35	134·29	1887·5	−32·77	+ ·12	−32·65		
Cañon	60·70	135·07	1887·6	−30·92	+ ·12	−30·80		
Lewis River	62·08	136·07	1887·6	−33·91	+ ·12	−33·79		
Mean	60·73	135·13				−32·35		
XVIII. *Port Etches.*							+3	
Port Etches	60·35	146·63	1874·4	−29·16	+1·03	−28·13		
Phipps Point. Weight ½	60·35	146·84	1894·5	−27·40	+ ·03	−27·37		
Weighted mean						−27·88		
XIX. *Cook Inlet.*							+4	
Dangerous Cape. Weight ⅓	59·40	151·88	1880·5	−24·54	+ ·97	−23·57		
Coal Point	59·60	151·40	1880·5	−25·81	+ ·97	−24·84		
Weighted mean	59·50	151·64				−24·52		
XX. *Kadiak Island.*							+4	
St. Paul	57·80	152·36	1880·5	−25·15	+ ·97	−24·18		

Formation of groups—Continued.

Group and name of station.	Lat. φ	Long. λ	Year of obser'n.	Obs'd D	Red'n to 1895.	$D_{1895\cdot0}$	a	Remarks.
	°	°		°	°	°	°	
XXI. *Semidi Islands.*							+4	
Chirikof Island	55·80	155·72	1874·4	—23·02	+1·37	—21·65		
Semidi Island	56·08	156·65	1874·5	—22·95	+1·37	—21·58		
Chignik Bay	56·32	158·40	1874·5	—22·03	+1·37	—20·66		
Mean	56·07	156·92				—21·30		
XXII. *Shumagin Islands.*							+4	
Little Koniuski Island	55·05	159·38	1880·5	—21·42	+ ·97	—20·45		
Dolgoi Island Settlement	55·08	162·00	1880·6	—21·43	+ ·96	—20·47		
Humboldt Harbor	55·32	160·52	1880·6	—20·28	+ ·96	—19·32		
Chiachi Island	55·87	159·08	1874·5	—21·93	+1·37	—20·56		
Port Moeller	55·92	160·58	1874·6	—21·37	+1·37	—20·00		
Baileys Harbor	55·15	162·12	1879·5	—21·13	+1·03	—20·10		
Mean	55·40	160·61				—20·15		
XXIII. *Unalaska Island.*							+3	
Iliuliuk	53·88	166·52	1891·5	—18·11	-----	—18·07		Principal secular change station.
XXIV. *Pribilof Islands.*							+3.6	
St. Paul Island	57·12	170·32	1891·6	—17·01	+ ·20	—16·81		
XXV. *Hagmeister, Island.*							+4·5	
Hagmeister Island	58·80	160·83	1874·6	—22·88	+1·53	—21·35		
XXVI. *Nunivak Island.*							+5	
Nunivak Island	60·42	166·13	1874·6	—21·56	+1·70	—19·86		
XXVII. *Vicinity of Upper Ramparts, Yukon River.*							+2	
Fort Selkirk	62·79	137·42	1887·6	—34·28	+ ·25	—34·03		
White River	63·20	139·63	1887·6	—34·46	+ ·25	—34·21		
Stewart River	63·37	139·48	1887·7	—33·88	+ ·24	—33·64		
Forty Mile River	64·42	140·53	1887·7	—35·01	+ ·24	—34·77		
Mean	63·44	139·26				—34·16		
XXVIII. *Vicinity of Boundary Mount, Yukon River.*							+3	
Near Boundary	64·68	140·90	1888·1	—35·78	+ ·35	—35·43		
Camp Davidson	64·70	140·95	1890·6	—35·75	+ ·22	—35·53		
Mean	64·69	140·93				—35·48		Mean of three years' observation.
XXIX. *St. Michael.*							+6·5	
St. Michael	63·48	162·09	1890·6	—23·14	+ ·48	—22·66		Mean of three measures.
XXX. *Port Clarence.*							+7·3	
Port Clarence	65·27	166·83	1880·7	—22·88	+1·74	—21·14		Combination value.
XXXI. *Kotzebue Sound.*							+7·1	
Chamisso Island	66·22	161·82	1880·7	—26·82	+1·69	—25·13		
XXXII. *Cape Lisburne and vicinity.*							+8·5	
Off Point Hope	68·32	166·77	1889·7	—23·17	+ ·75	—22·42		U. S. S. Thetis.
Near Cape Lisburne	68·88	166·10	1880·6	—25·71	+2·04	—23·67		
Mean	68·60	166·44				—23·04		

Formation of groups—Continued.

Group and name of station.	Lat. φ	Long. λ	Year of obser'n.	Obs'd D	Red'n to 1895.	$D_{1895\cdot0}$	α	Remarks.
	°	°		°	°	°	°	
XXXIII. *Icy Cape and vicinity.*							+ 9·5	
At sea, Arctic Ocean	69·97	162·63	1881·6	−31·92	+2·12	−29·80		
At sea, off Icy Cape	70·08	162·10	1881·6	−32·23	+2·12	−30·11		
At sea, off Icy Cape	70·25	161·92	1881·6	−32·20	+2·12	−30·08		
Near Icy Cape	70·22	162·25	1880·6	−30·10	+2·28	−27·82		
Indian Village	70·29	161·88	1889·7	−28·85	+ ·84	−28·01		U. S. S. Thetis.
Wainwright Inlet	70·62	160·05	1849·5	−36·68	+7·20	−29·48		
Mean	70·24	161·80				−29·22		
XXXIV. *Fort Yukon.*							+ 4·4	
Fort Yukon	66·56	145·30	1890·6	−35·20	+ ·32	−34·88		
XXXV. *Porcupine River at Boundary.*							+ 6	
Camp Colonna	67·42	140·98	1890·5	−38·11	+ ·45	−37·66		
XXXVI. *Valley of Three Rivers.*							+ 8	
Three Rivers	68·61	141·00	1890·3	−40·55	+ ·63	−39·92		
XXXVII. *Firth River.*							+10	
Mouth of Firth River	69·39	140·00	1890·3	−43·37	+ ·78	−42·59		
Herschel Island	69·55	138·95	1889·6	−43·67	+ ·90	−42·77		U. S. S. Thetis.
Mean	69·47	139·48				−42·68		
XXXVIII. *Cross Island.*							+12	
Off Cross Island	70·46	147·88	1889·6	−38·67	+1·08	−37·59		U. S. S. Thetis.
XXXIX. *Point Barrow.*							+21	
Off Point Barrow	71·33	156·25	1881·6	−37·30	+2·68	−34·62		Plover Point, observations of 1853 not available.
Uglaamie, U. S. Polar Station	71·30	156·66	1883·3	−35·62	+2·34	−33·28		
Cape Smyth Signal Station	71·31	156·65	1889·6	−33·67	+1·08	−32·59		U. S. S. Thetis.
Mean	71·31	156·52				−33·50		

Recapitulation of normal values of magnetic declinations in Alaska and adjacent parts for January, 1895.

No. of group.	Designation of group.	No. of stations.	Lat.	Long.	$D_{1895\cdot0}$
			°	°	°
I	Puget Sound	2	47·44	122·39	—22·62
II	Strait of Juan de Fuca	10	48·37	123·16	—23·33
III	Cape Flattery	9	48·54	124·74	—23·75
IV	Nootka and Quatsino Sounds	2	50·04	127·34	—24·58
V	Thompson River	10	50·68	120·72	—24·78
VI	Great Fork Frazer River	4	52·96	119·91	—26·34
VII	Queen Charlotte Island	1	52·15	131·25	—26·34
VIII	At sea, northeast Pacific Ocean*	3	45·00	135·00	—21·75
IX	At sea, northeast Pacific Ocean*	1	45·00	128·50	—21·75
X	At sea, northeast Pacific Ocean*	3	47·00	155·00	—19·75
XI	At sea, northeast Pacific Ocean*	4	51·00	145·00	—23·80
XII	Port Simpson and Skeena River	8	54·54	129·96	—27·73
XIII	Fort Wrangell	15	56·01	132·55	—29·47
XIV	Sitka	1	57·05	135·34	—29·63
XV	Lynn Canal and vicinity	6	58·54	134·96	—30·56
XVI	Yakutat Bay	5	59·63	139·85	—30·32
XVII	Vicinity of Mount Lorne	4	60·73	135·13	—32·35
XVIII	Port Etches	1	60·35	146·63	—27·88
XIX	Cook Inlet	2	59·50	151·64	—24·52
XX	Kadiak Island	1	57·80	152·36	—24·18
XXI	Semidi Islands	3	56·07	156·92	—21·30
XXII	Shumagin Islands	6	55·40	160·61	—20·15
XXIII	Unalaska Island	1	53·88	166·52	—18·07
XXIV	Pribilof Islands	1	57·12	170·32	—16·81
XXV	Hagmeister Island	1	58·80	160·83	—21·35
XXVI	Nunivak Island	1	60·42	166·13	—19·86
XXVII	Vicinity of Upper Ramparts, Yukon River	4	63·44	139·26	—34·16
XXVIII	Vicinity of Boundary Mount, Yukon River	2	64·69	140·93	—35·48
XXIX	St. Michael	1	63·48	162·09	—22·66
XXX	Port Clarence	1	65·27	166·83	—21·14
XXXI	Kotzebue Sound	1	66·22	161·82	—25·13
XXXII	Cape Lisburne and vicinity	2	68·60	166·44	—23·04
XXXIII	Icy Cape and vicinity	6	70·24	161·80	—29·22
XXXIV	Fort Yukon	1	66·56	145·30	—34·88
XXXV	Porcupine River at Boundary	1	67·42	140·98	—37·66
XXXVI	Valley of Three Rivers	1	68·61	141·00	—39·92
XXXVII	Firth River	2	69·47	139·48	—42·68
XXXVIII	Cross Island	1	70·46	147·88	—37·59
XXXIX	Point Barrow	3	71·31	156·52	—33·50

* by interpolation, using the isogonic curves of 1890, values uncertain.

The total number of stations involved is 131.

An approximate central value of latitude is $\varphi_0 = 59°{\cdot}02$ and of longitude $\lambda_0 = 145°{\cdot}12$.**

For D_1, the corresponding declination, we assume the value $D_1 = -27°{\cdot}16$.

With the above thirty-nine values, directly taken from observations, and the adopted values for φ_0, λ_0, and D_1, we get thirty-nine observation equations, of which number a few (the first dozen only) are here given as specimens. The ten normal equations are as follows:†

** Originally derived from thirty-seven stations; two were added afterwards.

† For the formation of the observation equations and the establishment and solution of the normal equations I am indebted to Assistant F. D. Granger and Mr. C. H. Kummell, of the Computing Division.

	q	r	s	t	u	v	w	x	y	z
$0=-4\cdot54$	1	−11·58	−15·37	134·1	+178·0	236	−1553	−2061	−2733	−3631
−3·83	1	−10·65	−14·58	113·4	+155·3	213	−1208	−1653	−2268	−3099
3·41	1	−10·48	−13·49	109·8	+141·4	182	−1151	−1480	−1907	−2455
−2·58	1	− 8·98	−11·41	80·6	+102·5	130	− 724	− 920	−1167	−1485
−2·38	1	− 8·34	−15·47	69·6	+129·0	239	− 580	−1077	−1993	−3702
−0·82	1	− 6·06	− 15·18	36·7	+ 92·0	230	− 223	− 557	−1394	−3498
−0·82	1	− 6·87	− 8·52	47·2	+ 58·5	73	− 324	− 402	− 502	− 618
−5·41	1	−14·02	− 7·15	196·6	+100·2	51	−2756	−1406	− 715	− 366
−5·41	1	−14·02	−11·75	196·6	+164·7	138	−2756	−2310	−1936	−1622
−7·41	1	−12·02	+ 6·74	144·5	− 81·0	45	−1737	+ 974	− 541	+ 306
−3·36	1	− 8·02	− 0·08	64·3	+ 0·6	0	− 516	− 5	0	0
+0·57	1	− 4·48	− 8·79	20·1	+ 39·4	77	− 90	− 177	− 345	− 679
etc.										

Normal equations.

l	q	r	s	t	u	v	w	x	y	z
$0=-9\cdot21$	+39	− 21·99	− 40·2	+ 2278	+ 1235	+ 2729	− 4195	− 8214	− 14794	− 12206
$0=+1166\cdot4$		+2278·0	+1235·3	− 4195	− 8214	− 14794	+ 260427	+ 142745	+ 186643	+ 197444
$0=-464\cdot7$			+2729·1	− 8214	− 14794	− 12206	+ 142745	+ 186643	+ 197444	+ 402244
$0=+573\cdot3$				+260427	+142745	+186643	− 923336	− 1156106	− 1600099	− 1806471
$0=-3428\cdot4$					+186643	+197444	− 1156106	− 1600099	− 1806471	− 2913556
$0=-10706\cdot8$						+402244	− 1600099	− 1806471	− 2913556	− 3047116
$0=+130052$							+36030692	+19578540	+21757970	+22180996
$0=+26785$								+21757970	+22180996	+30317458
$0=+63688$									+30317458	+37786092
$0=-12880$										+74580184

To facilitate the solution and to reduce the factors to the same order of magnitude, put

$q=+0\cdot0+q'$	$t=-0\cdot02+t'$	$10\,t'=t''$ or $t=-\cdot02+\cdot1\,t''$	$w=-0\cdot0003+w'$	$100\,w'=w''$ or $w=-\cdot0003+\cdot01\,w''$	
$r=-0\cdot8+r'$	$u=+0\cdot07+u'$	$10\,u'=u''$ $\quad u=+\cdot07+\cdot1\,u''$	$x=+0\cdot002+x'$	$100\,x'=x''$ $\quad x=+\cdot002+\cdot01\,x''$	
$s=+0\cdot7+s'$	$v=+0\cdot01+v'$	$10\,v'=v''$ $\quad v=+\cdot01+\cdot1\,v''$	$y=+0\cdot0006+y'$	$100\,y'=y''$ $\quad y=+\cdot0006+\cdot01\,y''$	
			$z=-0\cdot0005+z'$	$100\,z'=z''$ $\quad z=-\cdot0005+\cdot01\,z''$	

where the third, fourth, and fifth equations were divided by 10 and the remaining ones by 100, in order to preserve the character of normal equations. Hence we have the modified normal equations:

Modified normal equations.

l'	q'	r'	s'	t''	u''	v''	w''	x''	y''	z''
$0=+30\cdot48$	+39	− 21·99	− 40·2	+ 227·8	+ 123·5	+ 272·9	− 41·95	− 82·14	− 147·94	− 122·06
$0=-209\cdot684$		+2278·0	+1235·3	− 419·5	− 821·4	−1479·4	+2604·27	+1427·45	+1866·43	+1974·44
$0=-288\cdot123$			+2729·1	− 821·4	−1479·4	−1220·6	+1427·45	+1866·43	+1974·44	+4022·44
$0=+273\cdot750$				+2604·27	+1427·45	+1866·4	− 923·34	−1156·11	−1600·10	−1806·47
$0=+249\cdot108$					+1866·43	+1974·4	−1156·11	−1600·10	−1806·47	−2913·56
$0=+333\cdot737$						+4022·44	−1600·10	−1806·47	−2913·56	−3047·12
$0=-265\cdot176$							+3603·07	+1957·85	+2175·80	+2218·10
$0=-279\cdot182$								+2175·80	+2218·10	+3031·75
$0=-338\cdot698$									+3031·75	+3778·61
$0=-481\cdot929$										+7458·02

Solving these equations, we get the following results for the coefficients:

			Residuals in original normal equations.
$q' = -0.568751$	$q = -0.56875$		(1) .000
$r' = +0.083118$	$r = -0.71688$		(2) −.01
$s' = +0.037312$	$s = +0.73731$		(3) −.01
$t'' = -0.039820$	$t' = -0.0039820$	$t = -0.0239820$	(4) +.01
$u'' = +0.008927$	$u' = +0.0008927$	$u = +0.0708927$	(5) −.73
$v'' = +0.009148$	$v' = +0.0009148$	$v = +0.0109148$	(6) −.2
$w'' = -0.027445$	$w' = -0.00027445$	$w = -0.00057445$	(7) − 4
$x'' = +0.056132$	$x' = +0.00056132$	$x = +0.00256132$	(8) − 2
$y'' = -0.040440$	$y' = -0.00040440$	$y = +0.00019560$	(9) − 2
$z'' = +0.016575$	$z' = +0.00016575$	$z = -0.00033425$	(10) − 4

The expression for the distribution of the magnetic declination in and about Alaska for the epoch 1895·0 is as follows:

$$\begin{aligned} D = -27^\circ.7288 &- 0.71688\ \varphi_1 + 0.73731\ \lambda_1 \cos\varphi \\ &- 0.023982\ \varphi_1^2 + 0.070893\ \varphi_1\lambda_1 \cos\varphi + 0.010915\ \lambda_1^2 \cos^2\varphi \\ &- 0.0005744\ \varphi_1^3 + 0.0025613\ \varphi_1^2\lambda_1 \cos\varphi + 0.0001956\ \varphi_1\lambda_1^2 \cos^2\varphi - 0.0003342\ \lambda_1^3 \cos^3\varphi \end{aligned}$$

where $\varphi_1 = \varphi - 59^\circ.02$ and $\lambda_1 = \lambda - 145^\circ.12$.

By means of this formula the declination was computed for each of the normal groups, and the differences between the observed and computed values ($C - O$) show the closeness with which the observed facts are represented, as well as the deviations from a regular distribution of magnetism (as implied by the formula).

Group No.	Obs'd D.	Comp'd D.	$C-O$	Group No.	Obs'd D.	Comp'd D.	$C-O$	Group No.	Obs'd D.	Comp'd D.	$C-O$
	°	°	°		°	°	°		°	°	°
I	−22·62	−22·49	+0·13	XIV	−29·63	−29·29	+0·34	XXVII	−34·16	−34·21	−0·05
II	23·33	23·18	+0·15	XV	30·56	30·77	−0·21	XXVIII	35·48	34·81	+0·67
III	23·75	23·47	+0·28	XVI	30·32	30·18	+0·14	XXIX	22·66	22·57	+0·09
IV	24·58	24·62	−0·04	XVII	32·35	32·96	−0·61	XXX	21·14	20·93	+0·21
V	24·78	24·65	+0·13	XVIII	27·88	28·09	−0·21	XXXI	25·13	24·60	+0·53
VI	26·34	26·83	−0·49	XIX	24·52	25·41	−0·89	XXXII	23·04	23·84	−0·80
VII	26·34	26·01	+0·33	XX	24·18	24·22	−0·04	XXXIII	29·22	28·78	+0·44
VIII	21·75	22·04	−0·29	XXI	21·30	21·84	−0·54	XXXIV	34·88	34·65	+0·23
IX	21·75	22·04	−0·29	XXII	20·15	20·34	−0·19	XXXV	37·66	38·16	−0·50
X	19·75	19·57	+0·18	XXIII	18·07	18·14	−0·07	XXXVI	39·92	39·77	+0·15
XI	23·80	23·13	+0·67	XXIV	16·81	16·96	−0·15	XXXVII	42·68	41·92	+0·76
XII	27·73	28·09	−0·36	XXV	21·35	21·16	+0·19	XXXVIII	37·59	38·19	−0·60
XIII	−29·47	−29·00	+0·47	XXVI	−19·86	−19·21	+0·65	XXXIX	−33·50	−33·78	−0·28

The sums of the positive and negative residuals balance well enough, and the probable error of a single representation becomes

$$r = 0.674\sqrt{\frac{[v\,v]}{n - n_1}}$$

where n = number of groups and n_1 = number of unknown quantities introduced, i. e., number of normal equations, and $v = C - O$, or difference between computed and observed values; we get

$$r = 0.674\sqrt{\frac{6.6477}{39 - 10}} = \pm\ 0^\circ.323 \text{ or } \pm\ 19'$$

This is an improvement on the value of $r = \pm\ 26'$ as found in the representation for the epoch 1890; this is supposed due to the improved values for the secular change and the addition of more modern observations.

The differences $C - O$ are made up of four distinct sources of error, viz, errors of observation, errors in the reduction to epoch, errors due to imperfection or inefficiency of the analytical formulæ employed, and, lastly and chiefly, to irregularities in the local distribution of terrestrial magnetism, and of which the general formula can not take cognizance. The largest discrepancy in the 1890 representation was 1°·6, and the next largest 1°·2; whereas in the present case for 1895 the two largest differences are but 0°·9 and 0°·8.

For the construction of the isogonic curves we need for any desired isogonic line a sufficient number of intersections with given parallels or meridians in order to trace out the curve by a free hand through these points. It is most convenient to compute the intersections with a given parallel of latitude, and, after accommodating the general expression for D to this particular parallel, to solve the resulting cubic equations. Of such *special* equations found convenient for the computation of the intersections, and derived from D by introducing the several values for φ, we present a few selected from a large number:

For latitude 45°	$D = -20{\cdot}8091 + 0{\cdot}17455\,\lambda_1$	$+0{\cdot}004086\,\lambda_1^2$	$-0{\cdot}0001181\,\lambda_1^3$	
50	$-22{\cdot}7922 + 0{\cdot}19685$	$+0{\cdot}003781$	$-0{\cdot}0000888$	
55	$-25{\cdot}1972 + 0{\cdot}28318$	$+0{\cdot}003332$	$-0{\cdot}0000631$	
60	$-28{\cdot}4548 + 0{\cdot}40463$	$+0{\cdot}002777$	$-0{\cdot}0000418$	
65	$-32{\cdot}9961 + 0{\cdot}52947$	$+0{\cdot}002159$	$-0{\cdot}0000253$	
70	$-39{\cdot}2517 + 0{\cdot}62400$	$+0{\cdot}001528$	$-0{\cdot}0000134$	

where $\lambda_1 = \lambda - 145°{\cdot}12$.

By means of these equations the latitudes and longitudes of a number of points for any desired isogonic curve were readily obtained. The subjoined table contains a few of such positions for some of the leading isogonics. The computation and curves, however, should be limited to the area roughly bounded by the positions of the normals, and the curves themselves had to be modified near this boundary, and in particular in the North Pacific, in order to accommodate them to the conditions prevailing just outside the limit of this investigation.

Intersections for the construction of some of the principal isogonic curves.

[Values of λ (west of Greenwich).]

φ	$D=-15°$	$D=-20°$	$D=-25°$	$D=-30°$	$D=-35°$	$D=-40°$	$D=-45°$
°	°	°	°	°	°	°	°
70	-----	174·4	167·0	159·4	151·8	143·9	135·7
65	176·6	168·1	159·5	150·7	141·2	131·1	-----
60	175·0	164·1	153·2	141·2	125·7	-----	
57	175·4	162·5	149·1	132·1	-----		
54	-----	160·7	143·8	-----			

D / φ	$-23°$	$-24°$	$-25°$	$-26°$	$-27°$	$-28°$	$-29°$	$-30°$	$-31°$	$-32°$
°	°	°	°	°	°	°	°	°	°	°
60								141·2	138·5	135·7
58								135·8	132·1	
57							136·3	132·1		
56							132·4			
55						133·2	125·3			
54					134·4	125·0				
52				129·6						
51			121·5							
50		120·2								
48	123·5									

The accompanying isogonic chart of Alaska exhibits the resulting distribution of the magnetic declination in 1895. For the western part of Bering Sea this is only roughly indicated by a few lines from want of recent data, and the same is true for that part of the North Pacific adjacent to the Gulf of Alaska where the uncertainty in the declination is indicated by broken lines. This uncertainty may amount to half a degree, but is not supposed to exceed 1° about the southern and western limits of the curves. In this part of the North Pacific the want of recent and reliable observations is much felt and the annual change is unknown. South of latitude 45° and between longitudes 130° and 135° about and when approaching the Tropic of Cancer the lines flatten out and farther south change the sign of their curvature. According to Mr. Curtis J. Lyon, of the Hawaiian Government Survey, the east declination on these islands was on the

increase between 1850 and 1884, and the continuation of this motion has since been confirmed by the observations made by E. D. Preston, Assistant, Coast and Geodetic Survey, in 1892, at Waimea, at one of Mr. Lyon's stations. At this place ($\varphi = +20^\circ 02'.0, \lambda = 155^\circ 37'.0$ W.) we have:

In 1852,	observed declination	$-7^\circ 52'$	C. J. Lyon	Resulting annual increase $-1'.8$.
1872,	observed declination	$-8\ 30$	C. J. Lyon	
1892, July,	observed declination	$-9\ 06$	E. D. Preston	

Even the earliest observation, that by Captain Cook in 1779 at Karakakoa Bay $\varphi = 19^\circ 28'$, $\lambda = 156^\circ 00'$, and the one by Assistant Preston at the same place in August, 1892 (station called Napoopoo, $\varphi = 19^\circ 29'$, $\lambda = 155^\circ 59'$), when compared, point to the same direction of change.

The singular oval area of west declination lying across the east coast of Asia, which was formed, or rather left in place, by the breaking through, about the close of the first quarter of the present century, of the area of eastern declination across its southern neck, is apparently encroaching upon the western part of Bering Sea. Its central maximum declination has increased from 7° to 10° and the agonic line at its eastern boundary is now supposed to pass in the vicinity of Pétropavlovsk. At this place, in particular, new observations are needed before reliable results of the distribution of the declination over the western Bering Sea can be deduced.

U. S. COAST AND GEODETIC SURVEY

W. W. Duffield Superintendent

ISOGONIC CHART FOR THE EPOCH 1895

U.S.Coast and Geodetic Survey Report, 1894 Appendix 4.

No.2.

The Isogonic Lines or Curves of Equal Magnetic Declination for the year 1895 (January) are shown by full lines, and by dashes when only approximately known. Their eastern declination is given by index numbers.

U.S.Coast and Geodetic Survey

W.W.Duffield Superintendent

BASE MAP OF ALASKA

Scale 13 $\frac{1}{700\,000}$

1895

Statute Miles

100 75 50 25 0 100 200 300 400 500

Nautical Miles

100 75 50 25 0 100 200 300 400 500

ARCTIC OCEAN

EASTERN SIBERIA

BERING SEA

NORTH PACIFIC OCEAN

ALEUTIAN ISLANDS

ALASKA

GULF OF ALASKA

OKHOTSK SEA

Kamchatka

Wrangell I

Herald I

Point Barrow

Sea Horse Is

Ice Cape

Cape Lisburne

Point Hope

Kotzebue Sound

Chosie Peninsula

Arctic Circle

Mackenzie River

East Cape

Cape Prince of Wales

Port Clarence

Plover Bay

Gulf of Anadir

St. Lawrence I

Penjina Gulf

Norton Sound

Nulato

Unalakleet

St. Michaels

Anvik

Ikogmut

Kolmakof Redoubt

St. Matthew I

Nunivak I

Hagmeister I

Bristol Bay

Port Moeller

St. Paul I

Pribilof Is

St. George I

Petropavlovsk

Commandorski Is

Attu I

Ryska I

Amchitka I

Atka I

Adalska I

Aamak I

Akutan Pass

Iliuliuk

Unalaska I

Shumagin Is

Sannakh I

Kenai Peninsula

Kadiak I

Semidi Is

Chirikof I

Yakutat Bay

Icy Bay

Mt. St. Elias

Sitka

Port Simpson

Queen Charlotte Is

Vancouver I

Victoria

Cape Flattery

Neah Bay

Tacoma

Columbia River

Fuca Str

Strait of Juan de Fuca

Gulf of Georgia

Fraser R.

Middleton I

Prince Rupert

Ft. Simpson

Ft. Nelson

Dease Lake

Teslin Lake

Lake Bennett

Atlin Lake

Dawson

Circle City

Fort Yukon

Rampart City

Tanana R.

Koyukuk R.

Yukon R.

45°E. 40°E. 35°E. 30°E. 25°E. 20°E. 15°E. 10°E. 5°E. 0° 5°E. 10°E. 15°E. 20°E. 23°E. 24°E. 25°E. 26°E. 27°E. 28°E. 29°E. 30°E. 31°E. 32°E.

60° 55° 50° 45°

150°E. from Greenwich 170° 180° 170° 160° 150° 140° 130°W. from Greenwich

DECEMBER 1894

U.S. COAST AND GEODETIC SURVEY

W. W. Duffield Superintendent

NORMAL STATIONS OF MAGNETIC DECLINATION FOR 1895

U.S. Coast and Geodetic Survey Report, 1894 Appendix 4. No. 3.

The dots show the positions of the normal values for 1895 of the magnetic declinations selected for discussion. The numbers attached give the amount of east declination.

U.S. Coast and Geodetic Survey

W.W. Duffield Superintendent

BASE MAP OF ALASKA

Scale 13 $\frac{1}{700\,000}$

1895

Statute Miles

100 75 50 25 0 100 200 300 400 500

Nautical Miles

100 75 50 25 0 100 200 300 400 500

ARCTIC OCEAN
Wrangell I
Herald I
Point Barrow -33°5
-37°6
-42°7
Mackenzie River
Sea Horse Is
-29°2
Ice Cape
-39°9
-37°7
Cape Lisburne
-23°0
Point Hope
Arctic Circle
-34°9
EASTERN SIBERIA
Kotzebue Sound
Chuka Peninsula
-25°1
-35°5
-34°2
East Cape
Bering Strait
Cape Pr. of Wales
-21°1
Port Clarence
Plover Bay
Gulf of Anadir
Yukon River
-32°3
Nulato
Penjina Gulf
Norton Sound
-22°7
St. Michaels
Unalakleet
Anvik
St. Lawrence I
-27°9
Ikogmut
Kolmakof Redoubt
Middleton I
Yakutat Bay
Lituya Bay
-30°3
-30°6
Juneau
Sitka
-29°6
-29°5
Archipelago
Port Simpson
-26°3
-27°7
-24°5
Portland Canal
-24°8
Vancouver I
Victoria
-23°3
-22°6
-24°6
-23°8
Cape Flattery
Juan de Fuca Str.
Tacoma
Columbia River
OKHOTSK SEA
Kamchatka
BERING SEA
St. Mathew I
-19°9
Nunivak I
-21°4
Hagmeister I
Bristol Bay
Alaska Peninsula
Mognak
-24°2
Kadiak I
GULF OF ALASKA
Queen Charlotte Is
-26°3
-16°8
St. Paul I
Pribilof Is
St. George I
Port Moeller
-21°3
Semidi Is
Chirikof I
Petropavlovsk
Comandorski Is
Amak I
Shumagin Is
-20°2
Sannakh I
Attu I
ALEUTIAN ISLANDS
Aleutian Pass
Iliuliuk -18°1
Unalaska I
-23°8(?)
Kyska I
Amchitka I
Atka I
Adakh I
-21°7(?)
NORTH PACIFIC OCEAN

160°E from Greenwich 170° 180° 170° 160° 150° 140° 130° W from Greenwich

DECEMBER 1894 ●-19°8(?)

APPENDIX No. 5—1894.

THE LENGTH OF THE HOLTON BASE LINE, INDIANA, WITH RELATED EXPERIMENTAL MEASURES DURING PART OF JULY, AUGUST, SEPTEMBER, AND OCTOBER, 1891; A. T. MOSMAN, ASSISTANT, IN CHARGE OF THE PARTY.

Reported by CHARLES A. SCHOTT, Assistant.

Submitted for publication August 23, 1894.

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Introduction.—The Holton base is one of the linear measures which support the transcontinental triangulation. It is located in Ripley County, southeastern Indiana, distant about 330 kilometres from the St. Albans base, West Virginia, to the eastward, and distant about 240 kilometres from the Olney base, Illinois, to the westward. Its middle point is in latitude 39° 03′·3, and in longitude 85° 22′·2 west of Greenwich. The line is inclined to the meridian 4° 06′·3, the azimuth of the north end being 175° 53′·8 (counted from south to west). The length of the base is 5·501 kilometres nearly, and the approximate height above the average sea level 283 metres. Appendix No. 8, Coast and Geodetic Survey Report for 1892, contains a full account of the measurement of this base by the observers, A. T. Mosman, who had general charge; by R. S. Woodward, Assistant, in charge of the measures with the bar-in-ice apparatus and experiments with metallic tapes, and by O. H. Tittmann, Assistant, in charge of the contact-slide base apparatus. This appendix gives the reports of these observers, headed with a preface by the Superintendent. It comprises 174 pages, and renders it unnecessary to enter here into certain detail matter already stated or discussed in that place, except when directly connected with the base measures or computations.

The primary base lines heretofore measured by the Survey, as well as all other lengths determined by it, depend for their unit on the Committee metre of 1799, the property of the American Philosophical Society of Philadelphia, but this unit of length was superseded in 1890 upon the receipt by the United States of the National Prototype metres. The Holton base is the first prominent one which depends for its length on this new standard unit, and in consequence an account must be given here of some intermediate operations, introduced with a view to express the measured length of the base in terms of the prototype. For this purpose a new and most accurate base apparatus was designed and brought into use by Assistant Woodward, for a description of which see Chapter I of Appendix No. 8. This bar-in-ice apparatus was used for standardizing the new contact-slide bars employed in the measure of the base after its own length had been compared with that of the prototype metre. The same appendix treats at length of the experiments and results of tape measures. These are of less importance in connection with the Holton base, but will be found more fully referred to in the report on the length of the St. Albans base.

The Holton base and its measures.—The site for the base was selected by Assistant Mosman in October and November, 1890. It is on a nearly level table-land between the towns of Holton and

New Marion, with its north end about 1½ kilometres east of the former place, and the south end about three-fourths of a kilometre north of the village of New Marion. To get the elevation above the sea (about 283 metres) a line of spirit levels connects the base with the transcontinental line of levels which starts from tide water at Sandy Hook, N. J. The base passes over grassy soil and plowed fields, and in part through woods. At certain places and times the ground was found wet and springy, and unfavorable for the stability of the trestles.

The whole length of the base, with two extra measures of part of it, was measured twice with the contact-slide apparatus, and 1 kilometre of it also with the bar-in-ice apparatus, going over it four times. All measures with the contact bars were with rising temperatures, and in direction one measure of the base was made forward, the other backward.

The surface monuments and subsurface marks of the ends of the base are described and illustrated in Appendix No. 8.* Section stones set in concrete and marked each with a fine cross, cut on the head of a copper bolt secured in it, were placed at distances of 1·2, 2·1, 3·0, 4·0, and 5·0 kilometres from south end. Stones were also set at 3·9 and 4·9 kilometres to mark the end points of the kilometres intended for the measure with the bar-in-ice. These stones are marked by spherical-headed bolts in connection with the use of the so-called cut-off apparatus.

At the camp near Holton there was also established under a covered shed a standard 100-metre comparator. Its length was found from measures with the bar-in-ice apparatus, and it served for comparing or testing the combined length of the contact-slide bars as well as for ascertaining in particular the length of metallic tapes and for other purposes. Its terminals were provided with bolts for the cut-off apparatus.

Length of the 5-metre steel bar No. 17.—This being the bar by means of which the contact-slide bars were standardized, a first and important step was to obtain its length in terms of the International Prototype metre, or its equivalent, one of the National Prototype metres, for which No. 21 has been selected. Designating it by P_{21}, its length is given by

$$P_{21} = 1^{m} + 2{\cdot}5\ \mu + 8{\cdot}665\ \mu\ T + 0{\cdot}0010\ \mu\ T^{2}, \quad (\pm\ {\cdot}15)$$

where μ denotes a micron or thousandth part of a millimetre and T the number of degrees of temperature of the centigrade scale of a hydrogen thermometer.† Bar No. 17, or simply B_{17}, was made in 1891, cross section 8·2 by 32·2^{mm}. Its length is defined by the distance of two lines transverse to two longitudinal ones and intercepted between them. The lines are drawn on highly polished platinum-iridium plugs, their surfaces lying in the neutral plane of the bar. Four independent determinations of its length were made, viz:

(*a*) Determination of length of B_{17} on office comparator, Washington, D. C., by Assistants R. S. Woodward and O. H. Tittmann, between July 6 and July 11, 1891.‡ Six micrometer microscopes§ were mounted on the iron beam in the vault, approximately 1 metre apart, and the distance between the terminal microscopes was repeatedly measured by means of P_{21}, successively placed, as well as by B_{17}, both bars being packed in ice. The result from ten sets of complete comparisons was

$$B_{17} = 5^{m} - 11{\cdot}0\ \mu \pm 1{\cdot}4\ \mu$$

(*b*) A more elaborate series of observations was made in the same place and by the same means between February 4 and March 12, 1892; the observers were R. S. Woodward and J. S. Siebert.‖ The resulting value from thirty-nine determinations, arranged in four groups, depending on special arrangement of bars and method of observing, is

$$B_{17} = 5^{m} - 15{\cdot}4\ \mu \pm 0{\cdot}7\ \mu$$

(*c*) In consequence of a want of perfect stability in the microscopes during the times of comparison which the preceding methods brought to light, Assistant Woodward determined on a

* Page 330 and following.

† Appendix No. 18, 1890, page 746.

‡ Appendix No. 8, 1892, pages 351–357.

§ Magnifying power of terminal microscopes, 50; of the intermediate ones, 27.

‖ Appendix No. 8, 1892, pages 357–359.

method* which should diminish the interval during which dependence upon their stability must be had. A second steel bar, B_{18}, of the same dimensions as B_{17}, was provided in 1892. It was subdivided into metre spaces, and platinum and iridium plugs were placed in the neutral plane and marked with the usual fiducial lines. The method consisted essentially in comparing each subspace or metre space of B_{18} directly with P_{21}, and, having got the whole length, to compare B_{17} with B_{18}—all bars, as in preceding cases, being immersed in melting ice during the operations. The observations were made in the vault, as before, by Woodward and Siebert, and cover the time from April 25 to May 10, 1892. The program with respect to orientation and position of the bars and the observers was an elaborate one. There were ninety measures of the five subspaces, and from eighteen determinations, arranged in three groups. From these resulted the value $B_{18} = 5\ P_{21} - 54{\cdot}3\ \mu \pm 1{\cdot}5\ \mu = 5^{m} - 41{\cdot}8\ \mu \pm 1{\cdot}7\ \mu$; further, from six sets the difference of the two bars was found to be $B_{17} - B_{18} = 30{\cdot}1\ \mu \pm 0{\cdot}6\ \mu$, whence we get the value

$$B_{17} = 5^{m} - 11{\cdot}7\ \mu \pm 1{\cdot}8\ \mu$$

(*d*) The preceding results were not considered by the observer as of quite a satisfactory quality and were primarily traceable to instability of microscopes. In June, 1892, it was determined to build a new comparator,† as free as may be of this and other defects. Six brick piers, one metre apart, resting on one heavy foundation, were constructed to support the microscopes, and a track was supplied, but isolated from the piers, used for shifting and placing the bars in position. The length of 5^{m} was first built up by successive additions of P_{21} and then by suitable arrangement compared with B_{17}, the bars being surrounded with melting ice. The shed covering this field comparator was open to the north, and was placed in the level ground south of the office. The observations cover the period from July 20 to August 9, 1892, and were made by Woodward and Siebert. The observed differences of 5 P_{21} and B_{17} were as follows:

Position: *A* end of bar 17, west.				Position: *A* end of bar 17, east.			
Date.		Diff.	Weight.	Date.		Diff.	Weight.
		μ				μ	
1892.	July 20	25·7	3	1892.	Aug. 4	29·4	2
	21	28·1	4		5	30·7	4
	22	27·0	4		6	33·0	4
	27	27·3	3		8	29·5	4
	28	25·8	3		9	32·5	6
	Aug. 10	27·0	3				
	Weighted mean	26·9 ± 0·4			Weighted mean	31·3 ± 0·4	

Resulting difference, 29·1μ; hence $B_{17} = 5^{m} - 16{\cdot}6\mu$, but with the specific difference designated conventionally by *A* end west and east, viz:

$$\left\{\begin{array}{l} B_{17} = 5^{m} - 14{\cdot}4\mu \pm 0{\cdot}4\mu \text{ for } A \text{ end west, or left} \\ B_{17} = 5^{m} - 18{\cdot}8\mu \pm 0{\cdot}4\mu \text{ for } A \text{ end east, or right} \end{array}\right\} \text{referring to the field comparator.}$$

The two values deduced are ascribed to personal equations or to a different aspect of the graduation marks for the two observers, which transverse lines are not of the same width.

Collecting the preceding results for length of B_{17}, we have the following summary:

Date.	Length of B_{17} at 0° C.
July, 1891	$5^{m} - 11{\cdot}5\ \mu \pm 1{\cdot}4\ \mu$
February and March, 1892	$5^{m} - 15{\cdot}4\ \mu \pm 0{\cdot}7\ \mu$
April to May, 1892	$5^{m} - 11{\cdot}7\ \mu \pm 1{\cdot}8\ \mu$
July and August, 1892	$5^{m} - 16{\cdot}6\ \mu \pm 0{\cdot}4\ \mu$
Weighted mean	$5^{m} - 16{\cdot}2\ \mu \pm 0{\cdot}4\ \mu$

* Appendix No. 8, 1892, pages 359-369.
† Ibid., page 369.

In accordance with the conclusions reached by the observer, we shall adopt for the length of B_{17} the value $5^m - 16{\cdot}2\,\mu \pm 1{\cdot}1\,\mu$, where the increased probable error is due to the introduction of the probable error $\pm\ {\cdot}2\,\mu$ for P_{21}; but in case the same observers (Woodward and Siebert) determine the length by the same method, as they have done at the Holton base, the special value (for A end right) $5^m - 18{\cdot}0\,\mu \pm 1{\cdot}3\,\mu$ is to be used.*

Determination of the coefficient of expansion of contact-slide rods Nos. 13 and 14.—The observations for the coefficient of expansion were made in the comparing vault of the office in May, 1891, by Assistant O. H. Tittmann and L. A. Fischer, adjuster W. and M. For this purpose the ends of the steel rods (subsequently numbered 13 and 14)† were cut down to the medial plane and platinum-iridium plugs, 5·02 metres apart, were inserted. Two lines on the left-hand and three on the right-hand plug served for making the micrometric measures when the rods were under observation. The general plan of operation was to compare the two rods through a large range of temperature alternately, as well as at high temperatures and at freezing temperatures. This was done by mounting the two rods in a zinc-lined trough, side by side, and by immersion in a solution of borax water, or packed in melting ice, as required. A second trough was provided for the case of one rod in ice and the other at a high temperature. The thermometers Tonnelot Nos. 4654, 4655, 4656 were compared with the standards 4623 and 4624; hence the following table of corrections:

Temp.	4623	4654	4655	4656	4624
° C.	°	°	°	°	°
0	+·02	—·04	—·05	—·04	·00
21	—·02	+·13	+·13	+·12	+·02
38	—·03	+·11	·00	—·05	+·03

For horizontal position of stem add $+0^{c}{\cdot}01$.
Value of 1 revolution of micrometer at 18° C.:
Of micrometer No. 5, $74{\cdot}615\,\mu$
" " No. 6, $75{\cdot}831\,\mu$
As determined May 16, 1891.

Abstract of results of comparison of lengths at various temperatures.

Date.	Time of Beg.	Time of End.	Temperature of Rod 13.	Temperature of Rod 14.	No. of sets.	Differences rod 14 — rod 13.
1891.	*h. m.*	*h. m.*	°	°		μ
May 18	11 52 to	3 02	15·36	15·36	4	+ 0·2
20	*p. m.*		34·21	34·21	2	— 17·6
21	10 30	10 42	27·10	27·10	2	— 15·7
22	9 16	9 25	20·43	20·43	2	— 12·0
22	11 04	11 10	0·00	0·00	2	— 13·6
22	3 17	3 24	20·38	0·00	2	—1193·9
23	2 45	3 15	37·90	0·00	4	—2248·4
25	12 33	12 55	0·00	20·74	4	+1202·3
25	$2^h\ 50^m$		0·00	0·00	2	— 6·8
26	12 51	1 08	0·00	36·11	4	+2104·3

Observation equations.

			μ	Weight.
$15{\cdot}36\,a_{14}$	$-15{\cdot}36\,a_{13}$	$+c=+$	0·2	2
34·21	—34·21	$+c=-$	17·6	1
27·10	—27·10	$+c=-$	15·7	1
20·43	—20·43	$+c=-$	12·0	1
		$+c=-$	13·6	1
	—20·38	$+c=-$	1193·9	1
	—37·90	$+c=-$	2248·4	2
20·74		$+c=+$	1202·3	2
		$+c=-$	6·8	1
36·11		$+c=+$	2104·3	2

and the normal equations

$$\begin{aligned} 6262{\cdot}14\,a_{14} - 2793{\cdot}98\,a_{13} + 226{\cdot}16\,c - 200\,577{\cdot}37 &= 0 \\ + 6082{\cdot}14 \quad - 208{\cdot}64 \quad - 196\,026{\cdot}98 &= 0 \\ + 14{\cdot}00 \quad - \quad 857{\cdot}20 &= 0 \end{aligned}$$

*Appendix No. 8, 1892, pages 391 and 491. The probable error assigned includes suspected variability in personal equation.

† The contact slides and agate ends were supplied afterwards; the whole apparatus was completed in July, 1891.

solving we get

$$a_{14} = +58{\cdot}571 \pm 0{\cdot}144 \quad (\mu)$$
$$a_{13} = +58{\cdot}879 \pm 0{\cdot}133 \quad (\mu)$$
$$c = -7{\cdot}5$$

hence the coefficient of expansion of Rod No. 14 $0.000\,011\,714 \pm 29$
" " " " " " Rod No. 13 $0{\cdot}000\,011\,776 \pm 27$ } for the centigrade scale.

Determination of the length of contact-slide rods Nos. 13 and 14.—There were four different determinations, two or three of which were of a confirmatory character only.

(*a*) Comparison of length of rods 13 and 14 at 22°·2 C with B_{17} in ice, in the office vault at Washington, July 15, 16, 17, 1891. Observers, Woodward and Tittmann. Four thermometers were attached to the rods (Green Nos. 5609 and 5604 to No. 13, and 5606 and 5607 to No. 14). Their indications were referred to the hydrogen scale as determined in August, 1890.

1891.	Length of rod No. 13.	Length of rod No. 14.
	μ	μ
July 15	$5^m + 1277$	$5^m + 1281$
16	1290	1297
16	1291	1296
17	1272	1306
17	1260	1306
Mean	$5^m + 1278 \pm 4$	$5^m + 1297 \pm 3$

These results refer to the temperature 22°·2 C and depend on $B_{17} = 5^m - 18\,\mu$ (in ice).* ± 1

(*b*) A second value for the combined length of the rods is obtained by the measure of the Holton camp comparator of 100 metres by means of Nos. 13 and 14 and comparing the result with the accepted length of the hectometre† as found by the measure with the bar-in-ice apparatus. The camp comparator was covered with a wooden shed open to the north. The termini were hemispheric copper bolts sunk in stones for use in connection with the Repsold cut-off cylinder. The hectometre was measured twelve times by Woodward and Siebert, with the following results:

		mm.
For the period July 30–Aug. 7, 1891	Length of comparator $20\,B_{17} + 39{\cdot}518\,\mu$	$= 100\,039{\cdot}158 \pm .030$
" " " Sept. 24–Oct. 6, 1891	" " " $20\,B_{17} + 39{\cdot}373^{mm}$	$= 100\,039{\cdot}013 \pm {\cdot}038$

where $B_{17} = 5^m - 18{\cdot}0\mu \pm 1{\cdot}3\mu$. The separate values from which the probable errors were in part derived are as follows:

	mm.	
July 30, 1891	100 039·172	
30	·214	
30	·300	
31	·182	Weighted mean, mm. 100 039·196 ± ·016 or mm. 100 039·158 ± ·026, as preferred by the observer when discussing personal equation and measures in opposite directions.
Aug. 3	·283	
4	·190 ($w=2$)	
7	·116 ($w=2$)	
Sept. 24	100 038·871	
Oct. 2	8·997	
2	9·040	Mean, mm. 100 039·013 ± ·028 ± ·026
6	9·036	
6	9·121	

But if the observer's supposition of a change in the position of the end marks, due to effect of moisture, be not entertained, the length of the camp hectometre may be taken as 100 039·09mm. $\pm {\cdot}04$

According to the supposition of an unchanged distance of the end stones, the probable error of

* Appendix No. 8, 1892, page 491. † Ibid., pages 396–401.

a single measure of a hectometre by means of a bar-in-ice apparatus becomes $\pm$·084^{mm}, or $\pm$·088^{mm} if the probable error of B_{17} is taken into consideration; thus it may be said that with the bar-in-ice apparatus a probable error not greater than one part in one million of the length may be reached by a single measure.

Soon after the measure of the Holton base was completed this standard distance was also measured twenty-one times with the rods 13 and 14 under a variety of conditions.* The results of these measures by Assistant Tittmann when reduced to a uniform temperature (on the hydrogen centigrade scale), and employing the value H_c=100 039·09^{mm} for length of camp hectometre, we have the following values:†

		mm.			*mm.*
1891 Aug. 17	10 Σ (13 and 14) = 100^m + 26·08 at 22°·2 C.		1891 Aug. 25	10 Σ (13 and 14) = 100^m + 26·30 at 22°·2 C.	
17		25·87	25		25·39
18		25·87	25		25·39
18		25·85	26		26·15
18		26·13	26		26·19
22		26·15	26		26·35
22		26·12	26		26·35
24		26·15	26		26·47
24		26·10	26		26·28
25		26·30	26		25·62
25		26·54			
				Mean	26·08
					$\pm$ ·05

hence Σ (13 and 14) at 22°·2C = 10^m + 2·608^{mm}.
$\pm$ 5

(*c*) A third value for the combined length of the rods is had by comparison of the length of the north end hectometre of the Holton base kilometre as measured by the bar-in-ice apparatus and again with the rods. With the bar-in-ice we have the following four measures:‡

			mm.	*mm.*
1891 Sept. 15	South to north		H_b = 100^m — 6·169	—6·202
15	N.	S.	— 6·235	$\pm$ 50
26	"	"	— 5·827	—5·893
26	S.	N.	— 5·960	$\pm$ 50

The observer uses two values for H_b supposing that a change in the ground-marks took place; supposing no change we would have H_b = 99 993·952^{mm}.

$\pm$ ·063

The same line was measured thirteen times with Σ (13 and 14) on September 21 and 22, 1891. The table of results is as below, and is based upon the mean value of H_b and the temperature of the rods reduced to 22°·2 C_h.

Resulting length for ten combined rods or value of 10 Σ (13 and 14):

		mm.	
Sept. 21 (N. to S.)	100^m +	26·25	
		26·20	
		26·17	
		26·08	
		[25·57]	rejected by observer
Sept. 22 (S. to N.)	100^m +	26·20	
		26·15	
		26·28	
		26·01	
		26·21	
		26·10	
		25·96	
		25·97	

Mean of 13 values 26·09^{mm}
Mean of 12 values 26·13 $\pm$ 0·02^{mm}
Hence Σ (13 and 14) = 10^m + 2·613 $\mp$ 2
If no rejection is made we have
Σ (13 and 14) = 10^m + 2·609^{mm} $\pm$ 4

* Appendix No. 8, 1892, pages 492–493.
† With respect to the individual values the observer's report may be consulted.
‡ Appendix No. 8, 1892, page 493.

The probable error of a single measure of the hectometre line by the two combined rods is $\pm$ 0·13^{mm} if no rejection is made, and $\pm$ 0·07^{mm} if one value is rejected. This points to a probable error of between $\frac{1}{770\,000}$ and $\frac{1}{1\,430\,000}$ part of the length, which is about the same as was shown to hold for a single bar-in-ice apparatus measure.

(*d*) The fourth and finally accepted determination depends on the comparison of the results for length of the Holton base kilometre (between section stones 3900 and 4900 metres from the south end). This distance was measured four times by Messrs. Woodward and Siebert with the bar-in-ice apparatus. The Repsold microscopes Nos. 1, 2, 3, and 4 were used in the order of enumeration when placed on the microscope posts. The bar B_{17} was mounted in a trough filled with pounded ice and resting on a movable track. The Repsold cut-off cylinder was used to measure all cut-offs on this kilometre; it was subdivided into four parts and measured as follows:

First measure	of	kilometre	from	north	to	south	made	between	Sept. 9–11, 1891.
Second	"	"	"	"	south	to north	"	"	" 14–15 "
Third	"	"	"	"	north	to south	"	"	" 26–28 "
Fourth	"	"	"	"	south	to north	"	"	" 29–30 "

In the following table of resulting length of the quarter sections and of the whole kilometre the old value for $B_{17} = 5^m - 11\,\mu$ was retained from the second revised computation, and the required correction for $B_{17} = 5^m - 18\,\mu$ is stated below:

Metre marks.	{ 3900 4150	4150 4400	4400 4650	4650 4900	3900 4900	
	m.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	
First measure	250	—21·114	+18·526	—5·980	+5·871	—2·697	
Second "	"	—19·829	+18·816	—5·103	+5·970	—0·146	
Third "	"	—21·833	+19·119	—6·045	+6·424	—2·335	The observer attaches double weight to these measures.
Fourth "	"	—21·743	+19·216	—6·151	+6·516	—2·162	
Mean	250	—21·130	+18·919	—5·820	+6·195	—1·835	
Giving double weight to the third and fourth measures						—1·973	
And introducing the proper length for B_{17} to be used *						—3·373	

* $B_{17} = 5^m - 18\,\mu$ for observers W. and S.

Hence we have for the length of the base kilometre $K = 1000^m - 3{\cdot}37^{mm} \pm 0{\cdot}37^{mm}$ as measured with the bar-in-ice apparatus.* We have also probable error of a single measure of 1 km. $\pm$ ·77^{mm}.

Six measures of this kilometre were made with rods Nos. 13 and 14, and computing the distance between the marks at 3900^m and 4900^m from the south end of the base, and assuming the approximate value Σ (13 and 14) = 10^m + 2·620^{mm} corresponding to the temperature 22°·2 C$_h$, we get the following measures in September, when the ground was in a favorable condition:

1891.	No. of bars.		Result. *m.*	*mm.*	*mm.*
Sept. 24	980th	to 930th	250	+ 5·85	+ 6·16
" 25	930	980		+ 6·48	
" 24	930	880	250	— 5·75	— 5·66
" 25	880	930		— 5·56	
" 24	880	830	250	+20·19	+19·82
" 25	830	880		+19·44	
" 24	830	780	250	—22·83	—23·48
" 25	780	830		—24·14	

During the four measures of the kilometre in August, 1891, the ground was very wet and springy over 0·6 of its length.† The September measures were made over dry ground. Total

* Appendix No. 8, 1892, page 496.

† The following table for all measures is given by the observer on page 496 of Appendix No. 8:

	m. *mm.*
Aug. 4 to 10	1000—0·6
" "	—5·2
" "	—9·2
" "	—5·5
Sept. 24	—3·9
" 25	—5·2
Mean	1000—4·9 $\pm$ 0·8

Another measure was taken October 5 and 6 with *falling* temperature. It gave 1000^m + 3·4^{mm}, from which the observer infers a lag in the thermometer indications of °·47 for *falling* temperature. (See remark further on in connection with the probable error assigned to the base.)

length, $1000^m - 3{\cdot}16^{mm} = 999{\cdot}99684^m$. The same distance as measured with bar-in-ice came out $999{\cdot}99663^m$, showing the small difference $0{\cdot}21^{mm}$. To make this disappear the value $10^m + 2{\cdot}618^{mm}$ would be required.

Summary of results for Σ (13 and 14) when at 22°·2 C_h.

			mm.	
(*a*) July,	1891, from comparisons with B_{17} in vault		$10^m + 2{\cdot}575 \pm 5\mu$	To the first result the observer applies a correction of $+{\cdot}030^{mm}$ for slant of knife-edges.
(*b*) July–Oct.,	1891, " "	on *H* in camp	$+ 2{\cdot}608 \pm 5$	
(*c*) Sept.,	1891, " "	" *H* on base	$+ 2{\cdot}609 \pm 4$	
(*d*) Sept.,	1891, " "	" *K* on base	$+ 2{\cdot}618 \pm 5(?)$	

The value $10^m + 2{\cdot}610^{mm} \pm 5$ has been adopted, i. e., for the average rod $5^m + 1{\cdot}305^{mm}$, as the best value deducible; for any other temperature t (C_h) we have $5^m + 1{\cdot}305^{mm} \pm 3 + 58{\cdot}7\mu \pm 2\ (t - 22°{\cdot}2)$.

The measure of the Holton base proper.—The base was measured throughout with contact-slide rods Nos. 13 and 14, once forward and once backward, with two additional measures over a small part of it. During all these measures the temperature was rising, as indicated by the thermometers in direct contact with the steel rods, and much the greater part of the work was done during bright sunshine. Appendix No. 8, 1892, page 499 and following, contains particulars respecting the construction of this new and improved secondary (so called) apparatus, referring to the agate ends, the contact slides, index lines, wooden casings, thermometers, covers, sectors, aligning telescopes, trestles, etc. The thermometers Green Nos. 5609 and 5604 (near rear and front end), were attached to bar No. 13 on opposite sides, and thermometers Green Nos. 5606 and 5616 (near rear and front end) were similarly attached to No. 14. On August 28 thermometer No. 5616 was accidentally broken and Green No. 5613 was substituted. The following table contains the corrections to the indications of these thermometers as determined from comparisons with Tonnelot thermometers Nos. 4655 and 4656; the numbers refer to the centigrade hydrogen scale:

Scale.	Green thermometers.				Mean.	G. Ther. 5613.	New mean.
	5609	5604	5606	5616			
°	°	°	°	°	°	°	°
0	—·10	+·05	—·15	—·10	—·08	—·08	—·07
3	·16	—·24	·25	·23	·22	·25	·22
6	·11	·19	·31	·19	·20	·19	·20
11	·13	·18	·33	·21	·21	·18	·21
16	·17	·17	·34	·17	·21	·19	·22
21	·26	·21	·23	·21	·23	·21	·23
25	·16	·16	·36	·26	·24	·26	·24
32	·21	·21	·36	·26	·26	·28	·26
34	·22	·22	·32	·22	·25	·32	·27
37	—·26	—·28	—·28	—·28	—·28	—·28	—·28

The stems are graduated into half degrees. The corrections were determined in June, 1891, but in August, 1891, the zero corrections were observed to have changed. On August 28 they were found in the order of the table, —0°·22, —0°·16, —0°·27, —0°·22; mean, —0°·22; also for 5613, —0°·09. The difference of the two results or the value —0°·14 was applied as an additional correction to each of the numbers of column "mean" and the value —0°·11 to each of the numbers in column "new mean." The work in connection with the Holton base was under the general direction of Assistant Mosman. When measured with the contact-slide apparatus contacts were made by Assistant Tittmann, who in these measures was aided by Mr. Hayford, Professor Gore (part of the time), Mr. Pennington, and Mr. Gjertsen for alignment, for reading of thermometers and sectors, and for recording.

Summary of results of the measures of the Holton base and its subdivisions with the new contact-slide apparatus, rods Nos. 13 and 14.

[The tabular quantities are based upon the relation Σ (13 and 14) = $10^{m} + 2{\cdot}620^{mm}$ at 22°·2.]

Date.	No. of bars From	To	Diff.	Temperature Obs'd.	Corr d.	Cor. for inclination.	Scale or cut-off measures.	Resulting length.	Mean length.	
1891.				°	°	*mm.*	*mm.*	*m.* *mm.*	*m.*	
July 28	South base.	66	66	22·14	21·77	82·39	0·0	330 + 2·4	330·0021	
Aug. 13	66	S. B.		31·03	30·64	65·07	−159·3, +107·0	+ 1·8		
July 28, 29	66	139	73	25·30	24·92	161·06	0·0	365 — 53·8	364·9450	
Aug. 13	139	66		24·58	24·20	83·88	−107·0, + 30·5	— 56·1		
July 29	139	240	101	30·58	30·18	22·75	— 81·0	505 + 75·8	505·0765	
Aug. 13	240	139		19·49	19·14	6·50	— 30·5	+ 77·2		
July 30	240	420	180	27·19	26·80	38·57	−281·3	900 — 35·5	899·9664	
Aug. 12	420	240		27·26	26·88	9·57	−307·3	— 31·6		
July 31	420	600	180	26·00	25·62	51·64	−156·5	900 + 63·9	900·0638	
Aug. 11	600	420		27·87	27·49	36·52	−191·6	+ 63·6		
Aug. 1, 4	600	780	180	22·55	22·18	296·15	— 22·0, +101·2	900 + 18·7	900·0200	
Aug. 11	780	600		28·38	27·99	185·89	— 89·7	+ 21·4		
Aug. 4	780	800	20	27·46	27·08	8·07	+ 22·0, — 49·98 — ·02	100 — 4·1	99·9950	99·9938
" 8	800	780		30·05	29·66	6·69	−269·5, +235·4	— 5·8	Mean	
" 8	780	800		31·50	31·10	7·54	— 35·7	— 6·6	99·9928	
" 10	800	780		30·00	29·61	7·68	−261·5, +226·0	— 8·3		
Aug. 10	800	875	75	23·69	23·31	17·41	−211·0	375 −125·3	374·8749	*900·0017
Aug. 10	875	800		27·40	27·01	18·33	−226·0	−124·9	Sum	
Aug. 7	875	980	105	28·77	28·38	7·41	— 40·2	525 +128·1	525·1268	
Aug. 7	980	875		22·14	21·77	9·55	0·0	+125·4		
Aug. 5	800	980	180	23·87	23·49	30·82	−236·9, + 23·2	900 + 4·9	*900·0033	Mean *900·0025
Aug. 8	980	800		25·28	24·89	27·08	−235·4	+ 1·7		
Aug. 5	980	1000	20	28·43	28·04	2·96	−298·7 +236·9, — 23·2	100 — 54·9	99·9456	
Aug. 6	1000	980		32·78	32·38	2·14	+ 30·5, −120·5	— 54·0		
Aug. 6	1000	N. B.	100	21·95	21·58	31·05	+703·34	500 +799·4	500·7994	
Aug. 6	North base.	1000		31·64	31·24	27·73	+673·6, — 30·5	+799·4		
	South base to north base								Total	5500·8151 m

For the purpose of presenting the data required for the computation of the probable error of the measure of the base, the following comparative table of the forward and backward measures has been prepared:

Section of base.			Forward measure.	Backward measure.	Diff.
			m.	*m.*	*mm.*
South base to 66th bar			330·0024	330·0018	+0·6
66	139		364·9462	364·9439	+2·3
139	240		505·0758	505·0772	−1·4
240	420		899·9645	899·9684	−3·9
420	600		900·0639	900·0636	+0·3
600	780		900·0187	900·0214	−2·7
780	800		99·9959	99·9942	
"	"		·9934	·9917	
		Mean	·9946	·9930	+1·6
(800	875)		(374·8747	374·8751)	(−0·4)
(875	980)		(525·1281	525·1254)	(+2·7)
		Sum	900·0028	900·0005	+2·3
800	980		900·0049	900·0017	+3·2
		Mean	900·0038	900·0011	+2·7
980	1000		99·9451	99·9460	−0·9
1000		N. base.	500·7994	500·7994	0·0
		Σ =	5500·8144	5500·8158	−1·4
		Mean	5500·8151m		

The above table has been condensed for further use as follows:

Bar No.		No. of bars.	Length.	Diff. Δ
			m. *mm.*	*mm.*
South B. to	240	240	1200+ 24·4 + 22·9	+1·5
240	420	180	900− 35·5 − 31·6	−3·9
420	600	180	900+ 63·9 + 63·6	+0·3
600	780	180	900+ 18·7 + 21·4	−2·7
780	980	200	1000− 1·5 − 6·0	+4·5
980 to North B.		120	600+744·5 +745·4	−0·9

The difference + 4·5mm for the space 780 to 980 is derived from the several measures involved

Probable error of the measure of the base.

Let s_1 = length of 1st section and d_1 = diff. of for. and back. measures.

s_2 2d d_2

. . .

. . .

. . .

. . .

s_n n d_n

Then the mean error of a single measure of the unit of length, here assumed 1 kilometre, $m_1 = \sqrt{\frac{1}{2n}\left[\frac{dd}{s}\right]}$, and the mean error of a double measure, $m_{11} = \frac{1}{2}\sqrt{\frac{1}{n}\left[\frac{dd}{s}\right]}$, and the probable error of a double measure of a length L becomes

$$r = 0{\cdot}6745\, m_{11}\, \sqrt{L} = 0{\cdot}6745 \sqrt{\frac{L}{4n}\left[\frac{dd}{s}\right]}$$

For the Holton base we get $m_1 = \pm\ 2{\cdot}01^{mm}$ and $r = \pm\ 2{\cdot}24^{mm}$ . . . . . (a)

The probable error of the joint bars has been estimated at $\pm\ {\cdot}005^{mm}$, and since there are 550 double bars the probable error of the base arising from this source is $\pm\ 2{\cdot}75^{mm}$ . . . . . (b)

Respecting any uncertainty due to imperfect data of the temperature relations of the rods, the thermometers, and the assigned length of the rods, it may first be noted that the coefficient of expansion of the rods appears to have been well ascertained, as is shown by the good accord of the two measures of the same length, made with an average difference of temperature of 11° for

the 101 bars 139 to 240, and with an average difference of $9\frac{3}{4}^{\circ}$ for the 100 bars 1000 to N. B., in which last case the difference in length amounted to zero.

The question of the relative temperatures of the rods and thermometers* was inquired into and from experiments made on August 26, 1891, when the length of the camp hectometre was measured seven times, it would appear that the rods take up changes of temperature faster than the thermometers; in other words, the thermometer indications lag about 0°·3 C. To test the behavior of the apparatus under bright sunshine† the base hectometre was measured five times on September 21 and eight times on September 22, with the result that the lag was practically insensible during bright sunshine, being only 0°·07. Respecting any uncertainty in the length of the base that might arise through lag of thermometers (with respect to the rods), it should be remembered that the rods were *standardized* under the *same* condition of rising temperature as obtained when the base was measured; hence the assigned length of Σ (13 and 14) refers to this (rising temperature) condition and no correction to the deduced length‡ of the base is needed. On October 5 and 6, 1891, some special observations were made for testing the length of the apparatus when used during falling temperature, in which case the thermometers show too high. The amount of lag deduced (nearly $\frac{1}{2}^{\circ}$) seems quite uncertain on account of the short distance measured and the small change of temperature, only about 2° on the 5th and no sensible change on the 6th. The variations in the deduced length of Σ (13 and 14), as found by means of measures of a known distance (as found by the bar-in-ice apparatus), appear quite large, as may be seen from the tabular values given on pages 492, 494, and 495 of Appendix No. 8. These variations are supposed due mainly to the varying *rates* of temperature changes. The effect of this on the base measure is supposed to be included in the above probable error of the measure. Any uncertainty in the zero correction of the thermometers would be felt as a constant error, and estimating it as $\pm$ 0°·03 C. we would have for one bar $\pm$ ·05872^{mm} × ·03 and for 1100 bars $\pm$ 1·94^{mm}. . . . . (c)

In the reduction of the base line to the sea level an uncertainty of $\pm$0·6^{m} in the measured elevation will correspond to $\pm$0·53^{mm} . . . . . (d)

Putting together the preceding values of probable errors that of the base becomes

$$\sqrt{(2\cdot24)^2 + (2\cdot75)^2 + (1\cdot94)^2 + (0\cdot53)^2} = \pm\ 4\cdot08^{mm}$$

which is about $\frac{1}{1\,348\,000}$ part of its length.

The length assigned to the base is yet to be corrected for the small change made, in computing the base and its parts, in the length of the combined bars, viz, — 550 × ·01^{mm} or by — 5·5^{mm}; further, we may substitute the length of the kilometre measured with the bar-in-ice apparatus (999·9966^{m}) for the length derived from the contact-slide apparatus (999·9968^{m}), but the correction is uncertain. The length of the base becomes 550·809^{m}.

Reduction of the length of the base to sea level.—No great elevations or depressions occur on the line. The range in height is but 21½ feet, and in general the ground rises in proceeding from south to north. The north end of the base is 9·0 feet, or 2·743^{m}, above its southern end. The average elevation of the line above its south end is 14·44 feet, or 4·401^{m}. Bench mark LXVII of the transcontinental line of spirit levels§ was connected with the north end of the base by leveling. This operation was performed by Mr. J. S. Siebert, who measured forward between June 15 and June 22 and backward between June 23 and 27, 1891. He found difference B. M. LXVII and north base = 429·77 feet, and north base and B. M. LXVII = 430·03 feet, respectively; mean difference, 429·90 feet, or 131·04 metres; hence height of north base 150·61^{m} + 131·04^{m}, and of average base 283·31^{m}. Adding to this 3·80 feet or 1·16 metres for height of bars above ground and subtracting 2 feet, or 0·61 metres, for correction to height of bench mark LXVII, we get for height of base above the sea 283·86^{m}; hence reduction to sea level — 0·2455^{m}, and the final result for length of base becomes 5500·564^{m}, and its logarithm 3·740 4073.

$\pm$ 4 $\pm$ 3

* Appendix No. 8, 1892, pages 492, 493.

† Ibid., pages 493, 494.

‡ Appendix No. 8, 1892, page 497, where the observer proposes a correction of 7·7^{mm}.

§ Appendix No. 11, Report for 1882, pages 547, 549.

This is the length of the base as marked by the base monuments, but the triangulation station "south base" was 6^{mm} inside the line; hence length of base for introduction to the triangulation

$$5500{\cdot}558^{m} \text{ and its logarithm } 3{\cdot}740\ 4068$$
$$\pm 4 \qquad\qquad \pm 3$$

The steel tape measures of the Holton base.—During part of August, September, and October, 1891, certain experimental work was undertaken at the Holton base, having for its object the inquiry into the practicability of the application of long metallic tapes for the measure of base lines of precision. These researches were conducted by Assistant Woodward, whose report on the results reached will be found in Appendix No. 8, 1892, pages 413–434. Briefly stated, the operations consisted in standardizing two 100-metre steel tapes, under given tension and temperature, on the camp hectometre, and these were in turn used for the measure of the Holton base.

The six sections of the base were measured from six to thirty times each, under various circumstances, as to temperature, state of weather, day or night, etc., and the behavior of the tapes was especially shown by the numerous measures of the base kilometre. Here the advantage a tape measure has over a bar measure could be fully realized—that is, the tape could be standardized at its *total length* and the measures of the base could be multiplied to a great extent without much cost when *once* the line had been prepared for tape measure. Thus the probable error of the *long* unit could be made extremely small and the mere error of measure of the base could be reduced to a minimum. The presence of constant errors are therefore those most to be feared with tape measures.

Assistant Woodward adopts the length of the camp hectometre as follows (page 423 of Appendix 8):

	mm.	*m.*
Aug. 1–8, 1891	$H_c = 20\ B_{17} + 39{\cdot}52$ and with B_{17} at 0° C. $= 5^{m} - 18\ \mu$	$H_c = 100{\cdot}03916$
Aug. 30–Sept. 5	$+ 39{\cdot}44$	3908
Oct. 3–9	$+ 39{\cdot}37$	3901

Between August 6 and October 9, 1891, the distance H_c was recorded seventy-seven times with tape No. 85, and between August 1 and October 9, 1891, the distance was recorded eighty-five times with tape No. 88. When these measures were made the temperature ranged between 32°·1 C. and 3°·5 C.

From these comparisons it follows that the probable error of a single measure of the length of tape No. 85 is $\pm\ 0{\cdot}17^{mm}$, and for tape No. 88 $\pm\ 0{\cdot}22^{mm}$. For the standard temperature 16°·89 C_h the resulting excess of tape T_{85} over the length 20 B_{17} was found to equal $22{\cdot}35^{mm}$, and the same equations made the expansion of the tape $1{\cdot}0947^{mm}$ for 1° C.; hence the length of T_{85} supported at intervals of 10 metres and at a tension of 25 pounds and 9 ounces:

$$T_{85} = 20\ B_{17} + 22{\cdot}35^{mm} + 1{\cdot}0947^{mm}\ (t - 16°{\cdot}89) \text{ and similarly for the other tape}$$
$$\pm{\cdot}02 \qquad \pm\ 21$$
$$T_{88} = 20\ B_{17} + 23{\cdot}47^{mm} + 1{\cdot}0914^{mm}\ (t - 15°{\cdot}72)\ *$$
$$\pm{\cdot}02 \qquad \pm\ 32$$

or $T_{85} = 100{\cdot}02199^{m} + 1{\cdot}0947^{mm}\ (t - 16°{\cdot}89)$ here the probable error assigned includes all

$$\pm\ 4 \qquad \pm\ 26$$
$$T_{88} = 100{\cdot}02311 + 1{\cdot}0914 \quad (t - 15°{\cdot}72) \qquad \text{known sources } \dagger$$
$$\pm\ 4 \qquad \pm\ 26$$

and for any temperature t: $T_{85} = 100\ 003{\cdot}50^{mm} + 1{\cdot}0947^{mm}\ t$

$$T_{88} = 100\ 005{\cdot}95 + 1{\cdot}0914\ t$$

With these values the various measures with the tapes of the Holton base and of its parts were computed; hence the results reached by the tapes can be directly compared with the results deduced from the bar measures. The thirty tape measures of the base kilometre afford an excellent means for judging of the practical outcome of such measures. Part of the following table is transferred from page 445 of Appendix No. 8. The last column gives the error of measure as compared with the true length $K = 1000^{m} - 3{\cdot}4^{mm} \pm 0{\cdot}4^{mm}$, in the sense of observed — true, and a negative sign indicates tape measure too short.

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* See Appendix No. 8, 1892, page 430.

† Ibid, page 433.

Summary of results of tape measures of the base kilometre.

Date.	Time of day, p. m. [a. m.].				No. of measures.	Error of measure.
1891.	*h.*	*m.*	*h.*	*m.*		*mm.*
Sept. 8	5	25—	7	12	3	+ 3·2
" 23	6	27	9	32	4	— 3·0
" 30	6	33	7	55	2	— 0·4
Oct. 1	6	50	8	07	2	— 0·6
" 2	6	48	7	55	2	+ 2·0
" 3	2	56	4	38	4	— 4·6
" 7	[10	02	11	31]	5	—10·0
" 8	7	44	9	58	8	— 0·4

It will be noted that the day measures of October 3 and 7 give results largely in error, whereas the mean of the night (evening) measures is fairly correct. Further attention may be called to the substantial agreement with each other and with the true value of the measures of the base kilometre from the two tapes, their disagreement being less than the millionth part of the length of the line.

Assistant Woodward concludes from the measures of the standard kilometre that the temperatures of the tapes when used at night in the open air were substantially as well defined by the mercurial thermometers as when the tapes were used under the shed of the 100-metre camp comparator, and he further points out that as a rule the day measures give results relatively too short.

Such measures can nevertheless be used, though with less confidence, if we adopt the equation of the tape to the special condition of day (sunshine) measures. When this is done the results may be combined with the results of the night or after-sundown measures. To effect this the length of the tape, to make it suitable for day measure, must be taken $0{\cdot}74^{mm}$ longer than its value adopted for night measures.

The following table exhibits a comparison between the results by the bar and tape measures of the length of the several sections of the base. Two sets of results are given for the tape measures, one depending solely on the night (after sundown) measures, the other depending on the night and day measures after the standard length of the tapes had been changed to correspond to the case of insolation. Certain results of August 27 and 28 were rejected as being untrustworthy, and all measures of September 4 were omitted as affected by a strong breeze, rising to a gale at intervals.

Comparison of results for length of sections of the Holton base by the contact-slide apparatus and the tape apparatus, both being standardized on the hectometre camp comparator and verified on the base kilometre.

Section of base.	Length* by rods Nos. 13 and 14.	Length by tapes by—		Total No. of measures.	Δ bar minus night measures.
		Night measures.	Night and corrected day measures.		
	m. *mm.*	*m.* *mm.*	*m.* *mm.*		*mm.*
South base to 1·2 km	1200+ 23·6	1200+ 30·0	1200+ 30·0	7	—6·4
1·2 km 2·1 km	900— 33·6	900— 30·0	900— 30·2	8	— 3·6
2·1 km 3·0 km	900+ 63·8	900+ 67·7	900+ 65·4	7	— 3·9
3·0 km 3·9 km	900+ 20·0	900+ 17·0	900+ 16·4	6	+ 3·0
3·9 km 4·9 km	1000— 3·8	1000— 3·6	1000— 3·2	30	— 0·2
4·9 km to north base	600+745·0	600+750·9	600+750·0	12 7	— 5·9
Sum	5500+815·0	5500+832·0	5500+828·4		—17·0

*The length of the bars is assumed the same as in the summary of results.

Taking the night measures alone and forming the differences of each single measure from the mean value of the respective sections, the observer deduces from forty-six measures covering the six sections (excluding a seventh section of 100 metres) the probable error of a measure of a single tape $\pm 0{\cdot}55^{mm}$ and the probable error of a single measure by the tape of a kilometre $\pm 1{\cdot}74^{mm}$, which equals nearly $\frac{1}{576\,000}$ part of the length. The probable error of his adopted length of the whole base ($5500{\cdot}832^{m}$) is given on page 454 of Appendix No. 8 as $\pm 3{\cdot}68^{mm}$, which nearly equals $\frac{1}{1\,495\,000}$ part of the length.

According to the probable errors assigned to the resultant values of the length of the base by the measures with the contact-slide apparatus and with the tape apparatus it would appear that the two measures are of about equal value and each subject to a probable error of about $\frac{1}{1\,420\,000}$ part of the length, whereas they differ by 17^{mm}, or about $\frac{1}{324\,000}$ part of the length.* This shows that the assigned probable errors can not be depended upon, and the prevalence of minus differences in the above table would indicate the presence of some constant error or errors not taken into account. So far as triangulation is concerned, even an uncertainty of one three-hundred-thousandth part would not be considered excessive. The great difference in the measures of the last 600 metres, which amounts to $\frac{1}{100\,000}$ part, nearly, is remarkable, especially since the separate measures agree well among themselves.

It would seem quite plain that the great accuracy apparently reached with the tape apparatus must in any case depend on the close attention paid by the observer to the minutest detail involved in the operation as well as upon favorable atmospheric conditions during the night measures. There appears to be no good reason why the results obtained by the bars and tape should not be united to a final result for the length of the Holton base. The difference in the results, however, indicates the presence of constant errors; hence the taking of the simple mean value is indicated. The two measures were not made at the same level. In the case of the tape measures we have their average elevation above south base about $4{\cdot}9^{m}$, and with north base $2{\cdot}61^{m}$ above south base, and allowing $-0{\cdot}61^{m}$ for the correction of the line of spirit levels, we obtain the average height of the tape, $283{\cdot}33^{m}$; hence the reduction to sea level, $-0{\cdot}2450^{m}$, and the length of the base, $5500{\cdot}587^{m}$. The mean length, $\frac{1}{2}$ ($5500{\cdot}564 + 5500{\cdot}587$), equals $5500{\cdot}576^{m} \pm 8{\cdot}4^{mm}$. The probable error is of course very uncertain, but may be taken as $\frac{1}{650\,000}$ part of the length. The base to be introduced in the triangulation is therefore $5500{\cdot}570^{m}$, and its logarithm 3·740 4077 0.

$\pm$ 8 $\pm$ 6 6

* The difference amounts to 23^{mm} as finally given.

APPENDIX No. 6—1894.

THE LENGTH OF THE ST. ALBANS BASE LINE, WEST VIRGINIA, MEASURED IN OCTOBER, 1892, R. S. WOODWARD, ASSISTANT, COAST AND GEODETIC SURVEY, IN CHARGE OF THE PARTY.

Reported by CHARLES A. SCHOTT, Assistant.

Submitted for publication September 26, 1894.

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Reported by CHARLES A. SCHOTT, Assistant.
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Introduction.—The St. Albans base line forms part of the transcontinental triangulation near the thirty-ninth parallel of latitude. It is situated in the valley of the Great Kanawha River, near the village of St. Albans, in Kanawha County, W. Va. The nearest base in this triangulation, to the eastward of it, is the Kent Island base, Maryland, distant from it about 545 kilometres as measured in the axis of the triangulation, and to the westward we have the Holton base, Indiana, about 330 kilometres distant. The middle point of the base is in latitude 38° 23′·0, and in longitude 81° 48′·9 west of Greenwich; the azimuth, east end to west end, is 108° 03′·9 (counted from the south westward). The length of the base is nearly 3·870 kilometres, and it lies about 180 metres above the average surface of the ocean. The line between the end points is nearly level throughout.

This is the second base of precision the measure of which was effected by means of metallic tapes, and the first one where the tape measures were employed exclusive of other means. The experimental work at the Holton base, Indiana, in the preceding year, involved the question of the comparative merits of the contact-slide apparatus and of the tape apparatus, when used for precise measures, and it was concluded that results by the latter could be fully trusted in those cases in which the requisite minute attention is paid to all circumstances which have or may have influence on the result. Among these influences the condition of the atmosphere is the most potent, and measures made after sundown or during night time were considered as made under more favorable circumstances than day measures. For a complete understanding of the use of metallic tapes for the above purpose no better reference can be given than the report of Assistant R. S. Woodward, by whom the method was developed on the Survey. (See Appendix No. 8, Report for 1892.)

The base was located in the summer of 1891, by Subassistant W. B. Fairfield. The terminal stones were set and the profile of the line and its connection with the height of the triangulation were ascertained under the direction of Assistant A. T. Mosman. The ground at west base is 0·5 metre below the top of the stake at east base.

In October, 1892, the base was measured by the party in charge of Assistant R. S. Woodward. The line had been cleared of obstacles, and the marking and supporting stakes for the tapes had

* For a full account of the measurement and results, see the observer's report, Appendix No. 8, Report for 1892, pages 455–474, and for the theory of metallic tape measures, pages 480–489.

been placed throughout its length. These stakes were set 10 metres apart, aligned and cut to slope for each tape length. All measures were made between October 10 and October 14; of these, one was merely experimental for training the party to the manipulation. Four were made at night and one during bright sunshine, but this latter was not employed for determining the length of the base. Of the four effective measures two were forward and two were backward measures by means of the steel tapes Nos. 85 and 88, previously employed, and standardized at the Holton camp and base, Indiana. The dimensions of these tapes are, length, 101·01 metres; cross section, 6·34 by 0·47 millimetre; their weight is 22·3 grammes per metre of length. The end graduations fall about half a metre from the tape ends; when not in use the tapes are rolled up on reels. As stated in Appendix No. 8, Report for 1892, and in my report on the length of the Holton base, Indiana (of August 23, 1894), the standard lengths of the tapes were found by repeated measures of the hectometre standard at the Holton camp, which length was laid down by means of the bar-in-ice apparatus. The length of this bar, known as B_{17}, was found to be 5 metres $-$ 18·0 microns in $\pm$ 1·1 terms of the international metre and when at the temperature of melting ice, as determined by Assistant Woodward and Mr. Siebert; and the lengths of the tapes are given as*

$$T_{85} = 20\,B_{17} + 3{\cdot}86\,\text{mm.} + 1{\cdot}0947\,t\,\text{mm.} \quad \text{or} \quad T_{85} = 100\,\text{m.} + 3{\cdot}50\,\text{mm.} + 1{\cdot}0947\,t\,\text{mm.}$$
$$T_{88} = 20\,B_{17} + 6{\cdot}31\,\text{mm.} + 1{\cdot}0914\,t\,\text{mm.} \quad\quad T_{88} = 100\,\text{m.} + 5{\cdot}95\,\text{mm.} + 1{\cdot}0914\,t\,\text{mm.}$$

This is for the standard temperature of 25 pounds 9 ounces and for the temperature t of the centigrade scale (referred to hydrogen). During the measure of the base the actual tension applied was but 25 pounds 6 ounces, which shortens the length of each by 0·14^{mm}. In all measures Assistant Woodward was the observer at the front end, and Assistant Haskell at the rear end, and the thermometers from which the tape temperature was inferred were read by these observers. The base was divided into four sections, representing approximately kilometres excepting one section of about 869 metres. The fractional part of a tape was obtained directly from the 20-metre subspaces of the tapes, and a remaining portion of 9 metres was measured by means of an auxiliary 15-metre steel tape, divided to millimetres. The several positions of the tapes were marked on zinc plates left in position throughout the measures, the marks on which form part of the record. Respecting grades, the greatest difference in height of the plates for any tape length was 3·571 metres. The corrections to the thermometer readings during the base measures are as follows:

Temperature.	Thermometer, Green.		
	5598	5620	5621
°	°	°	°
0	—0·10	—0·20	—0·25
5	·12	·15	·20
10	·09	·21	·26
15	·08	·25	·32
20	·08	·27	·34
25	·07	·25	·32
30	·04	·25	·25
35	—·09	—·23	—·28

These thermometers were provided with sheaths of thin steel tape slipped over their bulbs, in the hope of securing thereby a close approximation to the actual temperature of the tapes. Two thermometers were read when placed at a distance of 10 metres from the ends of the tape; the third was placed at the middle. The index correction to the spring balance measuring the tension of the tapes was ascertained on five days between October 10 and 21.

*Appendix No. 8, Report for 1892, pages 433, 434.

The results of the several measures* of the base and of its subdivisions are given in the following table:

	Date.	Time of day, p. m.	Direction of measure.	No. of tape.	Mean temperature.	Temperature rising or falling.		Grade corr'n.
Section I.	1892.	*h. m. h. m.*			° *C.*		Distance west base to stake 10: *mm.*	*mm.*
	Oct. 11	7 20— 8 02	Westward	88	9·04	F	200 B_{17}+258·2	—8·52
	12	9 03 9 44	Eastward	88	7·62	R	244·5	
	13	7 06 7 40	W	85	13·30	F	252·6	
	13	10 49 11 21	E	85	9·56	R	251·5	
	14	2 53 3 16	W	88	32·11	R, F	248·1	
Section II.							Distance stake 10 to stake 20:	
	Oct. 11	8 02— 8 44	W	88	5·92	F, R	200 B_{17}+534·8	—93·58
	12	9 44 10 25	E	88	6·39	F, R	535·5	
	13	7 40 8 12	W	85	10·38	F, R	533·0	
	13	11 21 11 53	E	85	9·05	F, R, F	536·0	
	14	3 16 3 49	W	88	30·47	F, R	536·0	
Section III.							Distance stake 20 to stake 30:	
	Oct. 11	8 44— 9 26	W	88	6·23	R, F, R	200 B_{17}+527·0	7·20
	12	7 40 8 22	E	88	7·84	R, F	524·0	
	13	8 12 8 44	W	85	9·92	F, R, F	527·8	
	13	9 45 10 17	E	85	8·75	R, F, R	528·9	
	14	3 49 4 02	W	88	30·08	R, F, R	534·0	
Section IV.							Distance stake 30 to east base:	
	Oct. 11	9 26—10 08	W	88	4·80	F, R	172 B_{17}+9325·5	—3·40
	12	8 22 9 03	E	88	7·92	F, R	9323·0	
	13	8 44 9 16	W	85	9·24	F, R	9321·4	
	13	10 17 10 49	E	85	8·57	F, R, F	9328·6	
	14	4 02 4 26	W	88	29·80	R, F, R	9333·0	

Summary of resulting lengths of each section and by each tape, omitting the fifth or daylight measure.

Section.		Tape No. 88.	Tape No. 85.	Mean.	Corr'n for slope.	Resulting length.
		mm.	*mm.*	*mm.*	*mm.*	*m.*
I	200 B_{17}	+ 251·35	+ 252·05	+ 251·70	— 8·52	1000·239 6
II	200	+ 535·15	+ 534·50	+ 534·82	— 93·58	1000·437 6
III	200	+ 525·50	+ 528·35	+ 526·93	— 7·20	1000·516 1
IV	172	+ 9324·25	+ 9325·00	+ 9324·62	— 3·40	869·318 1
Total	772 B_{17}	+10636·25	+10639·90	+10638·07	—112·70	3870·511 4

Difference between the two tape measures, 3·65mm. The results for length of base by the westward and eastward measures are:

Section.		Westward.	Eastward.	Diff.
		mm.	*mm.*	*mm.*
I	200 B_{17}	+ 246·9	+ 239·5	+7·4
II	200	+ 440·3	+ 442·1	—1·8
III	200	+ 520·2	+ 519·2	+1·0
IV	172	+ 9320·0	+ 9322·4	—2·4
Total	772 B_{17}	+10527·4	+10523·2	+4·2

Length of base:	*m.*
From 2 westward measures	3870·513 5
From 2 eastward measures	·509 3
Mean	·511 4

For deducing the probable error of the measure of the base the night measures alone are used. Supposing each segment of a base measured n times, let Σd^2 represent the sum of the

* Unreduced to the sea level.

squares of the differences of each of its measures from the mean, then for i sections, the probable error of the adopted length of the base is $0{\cdot}674\left[\frac{\Sigma d_1^2 + \Sigma d_2^2 + \Sigma d_3^2 \cdots\cdots \Sigma_i^2}{n(n-1)}\right]^{\frac{1}{2}}$ whence we get for the St. Albans base $0{\cdot}674\sqrt{\frac{142{\cdot}7}{12}} = \pm 2{\cdot}32^{mm}$. This represents also the probable error of the result of a single measure of 1 km., since the base of four segments may be taken as about 4 km. in length.

A corresponding value, $\pm 1{\cdot}74^{mm}$, for the measure of 1 km. at the Holton base is given by the observer, page 449 of his report. (Appendix 8, 1892.)

The probable error, $\pm 2{\cdot}32^{mm}$, of measure of the base is equivalent to one part in 1 660 000. It may also be deduced from the four differences of the forward and backward measures. In this case we have for the p. e. of the length of the base, regarded as two double measures, $0{\cdot}674\sqrt{\frac{l}{4n}\left[\frac{dd}{s}\right]}$ where s = length of a section and l = length of the base expressed in kilometres, the unit of length adopted; we get for four sections and $s = 1$, $0{\cdot}674\sqrt{\frac{3{\cdot}87}{16} \times 64{\cdot}76} = \pm 2{\cdot}67^{mm}$, a value slightly larger than that deduced above.

The p. e. in the length of the base, due to uncertainty in the length of the tape, is given by the observer (page 470 of his report) as $\pm 2{\cdot}32^{mm}$. To this must yet be added the p. e. due to uncertainty in the reduction to the sea level given below as $\pm 1{\cdot}1^{mm}$; hence we have the p. e. of the length of the St. Albans base $\sqrt{(2{\cdot}32)^2 + (2{\cdot}67)^2 + (1{\cdot}1)^2} = \pm 3{\cdot}70^{mm}$, which equals about $\frac{1}{1\,040\,000}$ part of the length.*

For the reduction of the length of the base to the average height of the sea level we have the following data: Average distance of tape below stone at west base, 2·66 feet; stone at west base, 1·29 feet below bench mark at St. Albans. Result of spirit leveling in November, 1891, by Subassistant Fairfield from forward and backward measures, bench mark at St. Albans below triangulation station Big Rocks, top of pier, 576·66 and 575·43 feet; mean, 576·05 feet $\pm$ 0·06 of a foot, and top of pier above ground at Big Rocks, 3·40 feet. Hence, average height of tape below Big Rocks, ground, 576·60 feet = 175·75^m. The height of Big Rocks station was determined by means of zenith distances carried through the triangulation from the District of Columbia and the Chesapeake Bay. From sixty-four cases of reciprocal zenith distances the value for the coefficient of refraction for this region was found to be 0·067 $\pm$ 0·0005. From zenith distances of Big Rocks observed at Table Rock, at Holmes, and at Piney, we get for the height of the station 357·04^m, 357·46^m, and 356·03^m, respectively; weighted mean, 356·23^m $\pm$ 0·23^m. To this p. e. must be added that due to the height of the given stations, which was found to be $\pm 1{\cdot}74^m$ $\pm$ uncertainty of *starting* height of Peach Grove, Va., and Stabler, Md.; for the latter we take $\pm 0{\cdot}1^m$. With these data we have the height of the base $180{\cdot}48^m \pm 1{\cdot}76^m$, and the corresponding reduction to sea level $-0{\cdot}1096^m \pm 0{\cdot}0011^m$. The base, reduced to sea level, is therefore 3870·4018^m. This result still requires a small correction, due to imperfect allowance for thermometer scale correction,† which on the average for the base is 0°·023 C. The corresponding correction to the length of the base is + 0·97^{mm}; hence we have the final value for length of St. Albans base

3870·4028^m	and its logarithm 3·587 756 17
$\pm$ 37	$\pm$ 42

After the completion of the base measurement the observer made some special experiments supplementary to those made at the preceding base measure. The results of these special inquiries are given on pages 470–474 of his report.

* This p. e. might be slightly increased in consideration that the alignment as well as the grades, respectively, are the same for every tape measure, which may give rise to a constant error.

† Pages 468, 469, Appendix No. 8, Report 1892.

APPENDIX TO ABOVE REPORT.

It will now be pertinent to inquire into the degree of accord of the Holton and the St. Albans base lines when referred from one to the other through the adjusted intervening triangulation, a distance of about 330 km. We have:

Holton base:	log. length in computation of base figure adjustment	3·740 393 5
	log. true length as measured	3·740 407 7
	log. length of side Reizin to Culbertson in base figure	4·387 778 1
	log. true length	4·387 792 3
St. Albans base:	log. length in computation of base figure adjustment	3·587 748 7
	log. true length as measured	3·587 756 2
	log. length of side Piney to Pigeon in base figure	4·378 835 0
	log. true length	4·378 842 5

hence ratio of length of sides, through the triangulation.

		True value.	
Reizin to Culbertson	4·387 778 1	4·387 792 3	
Piney to Pigeon	4·378 835 0	4·378 842 5	
Difference	0·008 943 1	0·008 949 8	*Difference.* 0·000 006 7

This logarithmic difference amounts to about $\frac{1}{64\,900}$ part of the length, which accord is satisfactory enough and falls in well with the fraction derived from the angular measures (through the closing of the triangles) which was $\frac{1}{60\,500}$ as computed in connection with my report of January 31, 1891.

The accord of the Kent Island and St. Albans bases can also be presented, viz:

St. Albans base:	log. length of side Somerville to Joy in base figure and as derived from Kent Island	4·888 941 2
	log. true value (from St. Albans base)	4·888 948 7

Discrepancy in log's., 75. This corresponds to $\frac{1}{57\,700}$ part of the length, which is of a tolerable though not of a great degree of accuracy. But here the remarks in the above report (of 1891) should be considered.

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APPENDIX No. 7—1894.

MANUAL OF TIDES.

PART III.

SOME CONNECTIONS BETWEEN HARMONIC AND NONHARMONIC QUANTITIES, INCLUDING APPLICATIONS TO THE REDUCTION AND PREDICTION OF TIDES.

By ROLLIN A. HARRIS.

Submitted for publication December 22, 1894.

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PREFACE TO PART III.

The following pages have been prepared for the purpose of supplying some of the immediate wants of the Tidal Division. They constitute Part III of a proposed manual of tides, the plan of which may be outlined thus:

Part I. History of tides, including old methods of treatment.

Part II. Tidal observation, equilibrium theory, and harmonic analysis.

Part III. Connections between harmonic and nonharmonic quantities.

Part IV. Tidal theory and astronomical quantities deduced from tidal observations.

Part V. Tidal currents.

Tables. Auxiliary tables and a collection of tidal constants, including cotidal charts.

As no considerable portion of the material constituting Part III is elsewhere available, it has seemed desirable to publish it in advance of Parts I and II, whose subject-matter has been largely treated in various publications.

The object of this paper is, in a general way, indicated by its title; but it may not be out of place to comment here upon certain of its aims and features.

Owing to a lack of reasonably precise definitions and adequate modes of reduction, the nonharmonic constants (i. e. those referring to high and low water) have too often been of little service where an accurate and satisfactory knowledge of the tide was desired. It is true that quite accurate predictions have been made, based upon the tables resulting from nonharmonic discussions; but it is to be observed (1) that the tables so used were designed chiefly for particular stations and so were of little or no use generally; (2) that long series of observations were necessary for the construction of such tables; (3) that most nonharmonic discussions have been confined to stations where the diurnal inequality is so small as to give no serious trouble. The present attempt to overcome these objections provides an approximate method of analyzing a single month's observations upon high and low water for obtaining both the harmonic and the nonharmonic constants, regardless of the amount of diurnal inequality, and without difficult computations. It also provides tables for the analysis and prediction of tides, designed for general use, regardless of the location of the station.

Little attention has heretofore been given to the classification of tides for the purpose of selecting the best possible port of reference for a given subordinate station, proximity in geographic position having been the sole criterion with few exceptions. Now, it is believed, are given for the first time such harmonic and nonharmonic criteria as will readily show how the types of tide at different stations compare. In this connection are given rules for referring one station to another.

The chapter entitled "Prediction of Tides" describes a proposed tide-predicting machine combining the merits of the Thomson and the Ferrel machines; a general graphic process enabling one (by means of a set of curves constructed once for all from the harmonic constants of the given station) to predict tides without a machine and without computation, the amount of work involved depending upon the accuracy desired; also an approximate arithmetical method for predicting high and low waters from certain tidal constants.

By correlating harmonic and nonharmonic quantities a better insight into tides is obtained than from the consideration of either alone. In this way observable phenomena may be inferred from harmonic constants, inconsistencies may be detected, and missing quantities supplied; also particular values of nonharmonic quantities may be reduced to their mean values, and conversely.

§§ 46, 47 are given mainly for the purpose of furnishing a key to the study of Ferrel's nonharmonic analyses. These discussions, covering years of observations, throw much light upon the nature of tidal inequalities.

The appended tables, already alluded to, are based principally upon those of Baird and Darwin. The considerable computation involved in their preparation has been performed by members of the Tidal Division. Their scope differs somewhat from that of the paper accompanying them. This remark applies especially to Tables 1 to 13, which are designed for the harmonic analysis of tides from hourly ordinates, a subject to be treated in Part II.

I have to acknowledge much assistance from Mr. L. P. Shidy, whose long experience in tidal work has rendered his advice particularly valuable, and whose cooperation has enabled the work to go on.

CONTENTS OF PART III.

CHAPTER I.

PROPERTIES OF COMPOUND WAVE HAVING A PREDOMINATING COMPONENT.

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CHAPTER I.

PROPERTIES OF A COMPOUND WAVE HAVING A PREDOMINATING COMPONENT.

1. The equation of a compound wave may be written

$$y = A\cos(at+\alpha) + B\cos(bt+\beta) + C\cos(ct+\gamma) + \quad . \quad . \quad . \tag{1}$$

where A, a, α refer to the predominating component (i. e. the one which determines the number and approximate times of the maximum and minimum values of y) and where B, b, β; C, c, γ; . . . refer to the subordinate components.

The values of t rendering y a maximum or a minimum are roots of the derived equation

$$Aa\sin(at+\alpha) + Bb\sin(bt+\beta) + Cc\sin(ct+\gamma) + \quad . \quad . \quad . \quad = 0. \tag{2}$$

Any root of (2) which causes y to become a maximum may be written

$$t = \frac{2n\pi}{a} - \frac{v}{a} - \frac{\alpha}{a}, \tag{3}$$

and a minimum

$$t = \frac{(2n+1)\pi}{a} - \frac{w}{a} - \frac{\alpha}{a}, \tag{4}$$

where n is an integer or zero and v, w, quantities usually small in comparison with π. v/a (or w/a) is the amount by which the time of any maximum (or minimum) of the compound wave precedes the corresponding time of the predominating component.

2. *Approximate expressions for v, w, and y.*

When v is small and b not many times greater than a, we may assume

$$\cos\frac{b}{a}v = \cos v \tag{5}$$

$$\sin\frac{b}{a}v = \frac{b}{a}\sin v, \tag{6}$$

and so for $\cos\frac{c}{a}v$ and $\sin\frac{c}{a}v$. When b differs little from a these are approximations even if v be not so small. Of course the same approximations are true when w replaces v.

From equations (2), (3), and (4) we have

$$\tan v = a\,\frac{Aa\sin 2n\pi + Bb\sin\frac{b}{a}\left(2n\pi+\frac{a}{b}\beta-\alpha\right) + Cc\sin\frac{c}{a}\left(2n\pi+\frac{a}{c}\gamma-\alpha\right) + \quad . \quad . \quad .}{Aa^2\cos 2n\pi + Bb^2\cos\frac{b}{a}\left(2n\pi+\frac{a}{b}\beta-\alpha\right) + Cc^2\cos\frac{c}{a}\left(2n\pi+\frac{a}{c}\gamma-\alpha\right) + \quad . \quad . \quad .}, \tag{7}$$

$$\tan w = a\,\frac{Aa\sin\overline{2n+1}\pi + Bb\sin\frac{b}{a}\left(\overline{2n+1}\pi+\frac{a}{b}\beta-\alpha\right) + Cc\sin\frac{c}{a}\left(\overline{2n+1}\pi+\frac{a}{c}\gamma-\alpha\right) + \quad . \quad . \quad .}{Aa^2\cos\overline{2n+1}\pi + Bb^2\cos\frac{b}{a}\left(\overline{2n+1}\pi+\frac{a}{b}\beta-\alpha\right) + Cc^2\cos\frac{c}{a}\left(\overline{2n+1}\pi+\frac{a}{c}\beta-\alpha\right) + \quad . \quad . \quad .}, \tag{8}$$

and the corresponding maximum and minimum values of y are

$$y = \left[A\cos 2n\pi + B\cos\frac{b}{a}\left(2n\pi + \frac{a}{b}\beta - \alpha\right) + C\cos\frac{c}{a}\left(2n\pi + \frac{a}{c}\gamma - \alpha\right) + \ . \ . \ .\right]\cos v$$
$$+ \left[A\sin 2n\pi + B\frac{b}{a}\sin\frac{b}{a}\left(2n\pi + \frac{a}{b}\beta - \alpha\right) + C\frac{c}{a}\sin\frac{c}{a}\left(2n\pi + \frac{a}{c}\gamma - \alpha\right) + \ . \ . \ .\right]\sin v, \quad (9)$$

$$y = \left[A\cos\overline{2n+1}\pi + B\cos\frac{b}{a}\left(\overline{2n+1}\pi + \frac{a}{b}\beta - \alpha\right) + C\cos\frac{c}{a}\left(\overline{2n+1}\pi + \frac{a}{c}\gamma - \alpha\right) + \ . \ . \ .\right]\cos w$$
$$+ \left[A\sin\overline{2n+1}\pi + B\frac{b}{a}\sin\frac{b}{a}\left(\overline{2n+1}\pi + \frac{a}{b}\beta - \alpha\right) + C\frac{c}{a}\cos\frac{c}{a}\left(\overline{2n+1}\pi + \frac{a}{c}\gamma - \alpha\right) + \ . \ . \ .\right]\sin w. \quad (10)$$

3. *To find the approximate average value of the maxima of a compound wave when the speeds of the components are independent of one another.*

Since

$$\cos v = 1 - \frac{\tan^2 v}{2} + \frac{3}{2\cdot 4}\tan^4 v - \ . \ . \ . \ , \quad (11)$$

equation (9) may be written

$$y = \left[1 - \frac{\tan^2 v}{2} + \ . \ . \ .\right]\left[A\cos 2n\pi + B\cos\frac{b}{a}\left(2n\pi + \frac{a}{b}\beta - \alpha\right)\right.$$
$$\left. + C\cos\frac{c}{a}\left(2n\pi + \frac{a}{c}\gamma - \alpha\right) + \ . \ . \ .\right] + \tan v\left[1 - \frac{\tan^2 v}{2} + \ . \ . \ .\right]$$
$$\left[A\sin 2n\pi + B\frac{b}{a}\sin\frac{b}{a}\left(2n\pi + \frac{a}{b}\beta - \alpha\right) + C\frac{c}{a}\sin\frac{c}{a}\left(2n\pi + \frac{a}{c}\gamma - \alpha\right) + \ . \ . \ .\right]. \quad (12)$$

It is required to find an expression for the average value of y; that is, the value of

$$\frac{1}{\infty}\sum_{n=o}^{\infty} y_n, \quad (13)$$

$a, b, c, \ . \ . \ .$ being independent of one another.

The part of (13) which is independent of v reduces to A. The part of (13) which contains $\tan v$ to first power is

$$\frac{1}{\infty}\sum_{n=o}^{\infty}\frac{\left[Aa\sin 2n\pi + Bb\sin\frac{b}{a}\left(2n\pi + \frac{a}{b}\beta - \alpha\right) + Cc\sin\frac{c}{a}\left(2n\pi + \frac{a}{c}\gamma - \alpha\right) \ . \ . \ .\right]^2}{Aa^2\cos 2n\pi + Bb^2\cos\frac{b}{a}\left(2n\pi + \frac{a}{b}\beta - \alpha\right) + Cc^2\cos\frac{c}{a}\left(2n\pi + \frac{a}{c}\gamma - \alpha\right) + \ . \ . \ .}. \quad (14)$$

The approximate value of the denominator of (14) is Aa^2. The numerator consists of products and squares of its terms; the average value of any such product is zero, while for the squares we have, since the average value of $(\text{sine})^2 = \frac{1}{2}$,

$$\tfrac{1}{2}\left[B^2b^2 + C^2c^2 + \ . \ . \ .\right].$$

Thus (14) is approximately equal to

$$\frac{1}{2Aa^2}\left[B^2b^2 + C^2c^2 + \ . \ . \ .\right]. \quad (15)$$

In like manner the part of (13) containing $\tan v$ to the second power is approximately equal to

$$-\frac{1}{4Aa^2}\left[B^2b^2 + C^2c^2 + \ . \ . \ .\right]. \quad (16)$$

The sum of (15) and (16) being

$$\frac{1}{4Aa^2}[B^2b^2 + C^2c^2 + \ . \ . \ .], \tag{17}$$

it follows that

The average value of the maxima of a compound wave is, approximately,

$$A + \frac{1}{4Aa^2}[B^2b^2 + C^2c^2 + \ . \ . \ . \ ] \tag{18}$$

provided $a, b, c, \ . \ . \ .$ are each incapable of expression in terms of the others, and the quantity added to A is relatively small.

This also represents the average depression of the minima; or, it is the average amplitude or semirange of the compound wave.

When there are fixed relations between the speeds of the components, the speeds of no two being commensurable with each other, formula (18) may still give the semirange of the compound wave, while the average elevation of the maxima or depression of the minima may not be given with sufficient accuracy. For, any alteration in the average range on account of such a relation implies an alteration in the average of the maxima or minima or both, while the average of the maxima or minima may be altered without necessitating an alteration in the average range.

4. *A wave composed of two simple waves of equal periods.*

Let its equation be

$$y = A\cos at + B\cos(at + \beta). \tag{19}$$

$$\therefore -\tan at = \tan v = \tan w = \frac{B\sin\beta}{A + B\cos\beta}. \tag{20}$$

$$y = \pm\sqrt{A^2 + B^2 + 2AB\cos\beta}. \tag{21}$$

The average value of this radical, supposing β to take all values from zero to π*, is

$$\frac{1}{\pi}\int_0^\pi \sqrt{A^2 + B^2 + 2AB\cos\beta}\, d\beta. \tag{22}$$

This integral represents the average value of the third side of a triangle two of whose sides are the fixed lengths A, B, while the included angle (or its supplement β) varies uniformly.

The integral

$$\int_0^\pi \sqrt{A^2+B^2+2AB\cos\beta}\, d\beta \tag{23}$$

represents one-half the periphery of an ellipse whose semiaxis major is $A + B$, and whose semiaxis minor is $A - B$.

By writing 2φ for β and $\sin\theta$ for $2\sqrt{\frac{AB}{A+B}}$, this integral becomes $2(A+B)$ times the integral

$$E(\sin\theta, \varphi)$$

which is tabulated by Legendre in his Traité des Fonctions Elliptiques, Table IX. However the average value of y be computed, the result will serve as a test of the accuracy of formula (18) for this special case, even when B is not small in comparison with A. Compare the values in the last column of Table 16 with column 9, Table 21, where the special form of (18),

$$A + \frac{1}{4Aa^2}[B^2b^2] \text{ or } A + \frac{B^2}{4A}, \tag{24}$$

has been tabulated.

* So far as obtaining an average value is concerned, it is indifferent whether we regard the speeds as equal and vary β, or regard the speeds as differing by an infinitesimal and make β constant or zero. In the latter case the radical may be written

$$\sqrt{A^2 + B^2 + 2AB\cos\omega}$$

where

$$\omega = (a \sim b)\, t.$$

It will be seen that the agreement is very close when B is comparatively small; when $B = A$ the discrepancy amounts to a trifle over 2 per cent of A or B.

It follows from this that if a and b denote the semiaxes of an ellipse, the periphery of the same is, as is well known, approximately

$$\pi\left[(a+b)+\frac{(a-b)^2}{4(a+b)}\right].$$

To find

$$\frac{1}{\beta'}\int_0^{\beta'}\sqrt{A^2+B^2+2AB\cos\beta}\,d\beta$$

when β' is small.

Upon replacing $\cos\beta$ by $1-2\sin^2\frac{\beta}{2}$, the radical may be written

$$A+B-\frac{2AB\sin^2\frac{\beta}{2}}{A+B}\quad\cdots,$$

which becomes

$$A+B-\frac{\beta^2}{2}\frac{AB}{A+B}$$

when β is small. The average value of β^2 when β varies from 0 to β' is $\frac{\beta'^2}{3}$; this gives for the required result

$$A+B-\frac{\beta'^2}{6}\frac{AB}{A+B}. \tag{25}$$

In like manner the value of

$$\frac{1}{\beta'}\int^{\pi+\beta'}\sqrt{A^2+B^2+2AB\cos\beta}\,d\beta,$$

which is the average value of the radical between $\beta=\pi$ and $\beta=\pi+\beta'$, becomes, when β' is small

$$A-B+\frac{\beta'^2}{6}\frac{AB}{A-B}. \tag{26}$$

5. *A wave composed of two simple waves, the period of one being twice that of the other.*

Let its equation be

$$y = A\cos at + B\cos(bt+\beta). \tag{27}$$

$$\therefore\ 4A\sin\tfrac{1}{2}v + B\tan\tfrac{1}{2}v\cos\beta - B\sin\beta = 0 \tag{28}$$

where $v = -at$ and $b = \frac{1}{2}a$. The angle $\frac{1}{2}v$ can be found by the following graphic process:

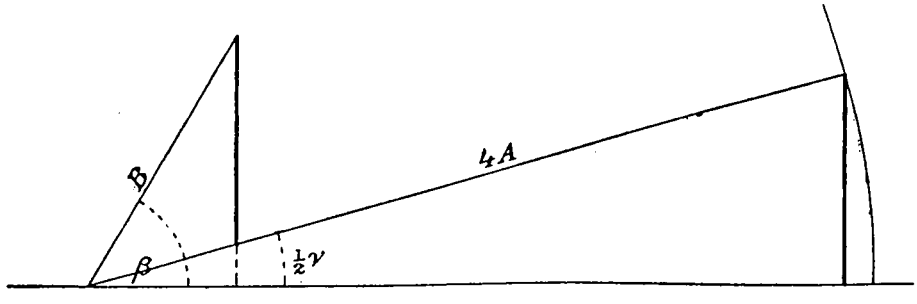

Fig. 1

Lay off β from the horizontal line, figure 1, and let B be laid off in the direction thus determined. Draw an arc to the radius $4A$; move this radius until the heavy lines are equal. The angle so determined is $\frac{1}{2}v$. It is convenient to work upon cross-section paper, using a thread for the radius $4A$.

The values of v are shown on Plate I (Table 17) for each value of β. The corresponding values of y are given on Plate II (Table 18). Formula (18) now becomes

$$A + \frac{1}{4Aa^2}[B^2 b^2] \text{ or } A + \frac{B^2}{16A} \tag{29}$$

whose values are given in column 15, Table 21. The values in this column, compared with those obtainable from Table 18, afford a means of testing formula (18) for the special case here considered, even when B is greater than A.

6. If the formula

$$A + \frac{1}{4Aa^2}[B^2 b^2] \tag{30}$$

expresses the average amplitude of a wave composed of the simple waves A and B, even when B is not small in comparison with A, then the formula

$$A + \frac{1}{4Aa^2}[B^2 b^2 + C^2 c^2] \tag{31}$$

expresses the average amplitude of a wave composed of the simple waves A, B, and C, provided c differs from b by an infinitesimal and $B^2 + C^2$ of (31) is not greater than B^2 of (30).

The amplitude of B and C combined is

$$\sqrt{B^2 + C^2 + 2BC\cos(b \sim c)t}. \tag{32}$$

Replacing B^2 of (30) by the square of this expression, the average value of B^2 becomes

$$B^2 + C^2.$$

In like manner, if formula (31) apply to three waves, the formula

$$A + \frac{1}{4Aa^2}[B^2 b^2 + C^2 c^2 + D^2 d^2] \tag{33}$$

will apply to four waves, provided c and d differ from b, and so from each other, by an infinitesimal and $B^2 + C^2 + D^2$ of (33) is not greater than $B^2 + C^2$ of (31) or B^2 of (30). So one can proceed for any number of simple waves.

Tables 16, 18, and 21 show that (30) is nearly true when a differs from b or from $2b$ by an infinitesimal, even if B is not small in comparison with A. In the former case B may be equal to A and in the latter it may be equal to $2A$ without sensibly affecting the truth of (30).

7. *The effect of a subordinate wave having a variable amplitude of the form*

$$B'\cos(b't + \beta') + B'', \tag{34}$$

where $B'' \gtreqless B'$, *in increasing the average amplitude of a given wave.*

In deriving formula (18) all amplitudes were assumed to be essentially positive; therefore in applying it to the present case the variable amplitude must not become negative.

Since $B'' \gtreqless B'$, all values of $\cos(b't + \beta')$ from $+1$ to -1 are to be used, and the average value of B^2, or

$$[B'\cos(b't + \beta') + B'']^2, \tag{35}$$

becomes

$$\tfrac{1}{2}B'^2 + B''^2. \tag{36}$$

When $B'' = 0$, this becomes

$$\tfrac{1}{2}B'^2; \tag{37}$$

i. e. the effect is one-half as much as it would have been had the amplitude of the subordinate wave been constantly equal to B'. (It may be noted here that the average numerical value of $B'\cos(b't + \beta')$ is $2B'/\pi$, the square of which is about $\frac{2}{5}B'^2$ instead of $\frac{1}{2}B'^2$.)

8. *To find the speed of a wave composed of two simple waves having approximately equal but not commensurable speeds.*

If n' be such a value of n that

$$\frac{b}{a}\left(2n'\pi + \frac{a}{b}\beta - \alpha\right) = 0,$$

then there is no displacement of the maximum of A due to B; i. e., A and B conspire at this common maximum. For the following minimum,

$$\frac{b}{a}\left(\overline{2n'+1}\,\pi + \frac{a}{b}\beta - \alpha\right) = \frac{b}{a}\pi.$$

At this maximum of A the phase of B is zero, at the minimum it is $\frac{b}{a}\pi$; the phase of B at a time midway between this maximum and minimum of A is equal to $\frac{b}{2a}\pi$. At the rth subsequent maximum, minimum, and midtime the phases of B are

$$\frac{b}{a}2r\,\pi,\ \frac{b}{a}\overline{2r+1}\,\pi,\ \frac{b}{2a}\overline{4r+1}\,\pi,$$

respectively. If

$$\frac{b}{2a}\overline{4r+1}\,\pi = z,$$

then

$$\frac{b}{a}\,2r\pi = z - \frac{b}{a}\frac{\pi}{2}$$

and

$$\frac{b}{a}\,2r+1\,\pi = z + \frac{b}{a}\frac{\pi}{2}.$$

By means of § 2 we obtain for the length of a half period expressed in hours, say, corresponding to a phase of B equal to z,

$$\tfrac{1}{2}P_z = \frac{180^\circ}{a} + 57{\cdot}3\,\frac{Bb\,\sin\left(z + \frac{b}{a}90^\circ\right)}{Aa^2 - Bb^2\cos\left(z + \frac{b}{a}90^\circ\right)} + 57{\cdot}3\,\frac{Bb\,\sin\left(z - \frac{b}{a}90^\circ\right)}{Aa^2 + Bb^2\cos\left(z - \frac{b}{a}90^\circ\right)}. \qquad (39)$$

If t denote the number of hours between the time of conspiring of A and B, and the given time for which the length of a half period is required, we have

$$z = (b - a)\,t. \qquad (40)$$

Finally, the speed for this time is equal to

$$\frac{360^\circ}{P_z}. \qquad (41)$$

At the time of conspiring the speed is approximately equal to

$$a + a\,\frac{Bb\,(b-a)}{Aa^2 + Bb^2}, \qquad (42)$$

and, at the time of interfering,

$$a - a\,\frac{Bb\,(b-a)}{Aa^2 - Bb^2}. \qquad (43)$$

9. *Small components having speeds commensurable with the speed of the predominating one.* Suppose now that in equation (1) there are terms of the form

$$A_i\cos\,(i\,at + \alpha_i) \qquad (44)$$

where i is an integer greater than unity.

So long as all speeds are independent of one another the average value of v or w will be zero. When the harmonics of A are included, the average values of (7) and (8) become

$$\tan v = a \frac{\sum_i A_i\, ai \sin i\left(\frac{\alpha_i}{i} - \alpha\right)}{Aa^2 + \sum_i A_i\,(ia)^2 \cos i\left(\frac{\alpha_i}{i} - \alpha\right)}, \tag{45}$$

and

$$\tan w = a \frac{\sum_i A_i\, ai \sin i\left(\pi + \frac{\alpha_i}{i} - \alpha\right)}{Aa^2 + \sum_i A_i\,(ia)^2 \cos i\left(\pi + \frac{\alpha_i}{i} - \alpha\right)}, \tag{46}$$

where

$$i = 2, 3, \text{etc.}$$

The respective values of each maximum and minimum of a wave *composed of A and its harmonic only* are

$$y = A \cos v + \sum_i A_i \cos i\left(\frac{\alpha_i}{i} - \alpha - v\right) \tag{47}$$

and

$$y = -A \cos w + \sum_i A_i \cos i\left(\pi + \frac{\alpha_i}{i} - \alpha - w\right). \tag{48}$$

These individual values are equivalent to average values, because they recur at each period of A.

If there are also very small components of the form

$$A_j \cos(j\, at + \alpha_j) \tag{49}$$

where j is a vulgar fraction, the effects of one such term upon the average value of the maxima and minima are

$$\frac{A_j}{m} \sum_{n=0}^{n=m-1} \cos j\left(2n\pi + \frac{\alpha_j}{j} - \alpha\right), \tag{50}$$

and

$$\frac{A_j}{m} \sum_{n=0}^{n=m-1} \cos j\left(\overline{2n+1}\,\pi + \frac{\alpha_j}{j} - \alpha\right), \tag{51}$$

where m is the denominator of the fraction j. Special case: When $j = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}$ . . . . . each of these expressions reduces to zero.

10. *Conditions for a predominating component.*

In order to have a simple wave determine the number of maxima and minima when combined with a series of other simple waves, it is necessary that its greatest slope be greater than the greatest possible slope of the series. For the two steepest parts of the predominating wave fall somewhere upon the serial wave; and the upward and downward slopes at these points cause the resultant curve to slope upward or downward at these points. But a maximum or a minimum implies the existence of both an upward and a downward slope.

Since the greatest slope of any simple wave is proportional to amplitude ÷ wave-length, the necessary condition for a predominating wave is

$$Aa > Bb + Cc + \text{ . . . . . } \tag{52}$$

This condition is also sufficient provided the greatest curvature of the predominating component be not less than the greatest possible curvature of the serial wave. Now, the greatest curvature of any component is at a maximum or minimum point; consequently the greatest possible

curvature of a series of waves would be the curvature at a time when all the maxima or the minima fall together. Writing the serial wave, we have

$$y = B\cos(bt+\beta) + C\cos(ct+\gamma) + \quad . \quad . \quad . \quad , \tag{53}$$

$$-\frac{dy}{dt} = +Bb\sin(bt+\beta) + Cc\sin(ct+\gamma) + \quad . \quad . \quad . \quad ,$$

$$-\frac{d^2y}{dt^2} = +Bb^2\cos(bt+\beta) + Cc^2\cos(ct+\gamma) + \quad . \quad . \quad . \quad .$$

Let the origin of time be taken at this common maximum, say; then

$$-\frac{dy}{dt} = 0$$

$$-\left(\frac{d^2y}{dt^2}\right)_0 = Bb^2 + Cc^2 + \quad . \quad . \quad . \quad .$$

These values substituted in the expression for the radius of curvature,

$$\left[1+\left(\frac{dy}{dt}\right)^2\right]^{\frac{3}{2}} \div \frac{d^2y}{dt^2},$$

gives at this point

$$\rho_0 = \frac{1}{Bb^2 + Cc^2 + \quad . \quad . \quad .};$$

or

$$\text{curvature} = Bb^2 + Cc^2 + \quad . \quad . \quad . \quad .$$

In like manner the greatest curvature of the predominating component is Aa^2 . . ∴ the remaining and, with (52), sufficient condition for a predominating component is

$$Aa^2 \overline{\gtrless} Bb^2 + Cc^2 + \quad . \quad . \quad . \quad . \tag{54}$$

CHAPTER II.

COMPUTATION OF NONHARMONIC QUANTITIES FROM HARMONIC TIDAL CONSTANTS.

11. In the preceding chapter on waves nothing has been said concerning the cause producing them. It will now be assumed that the maximum of a component follows its apparent cause, or fictitious moon, by a certain angle called the epoch of the component, and whose value is such that if it be divided by the speed of the component, the quotient is the time elapsing between the transit of the fictitious moon and the occurrence of the maximum value of the component. For this reason the terms which have been written in the form

$$A \cos (at + \alpha)$$

will now be written in the form

$$A \cos (at + \arg_0 A - A^\circ).$$

A may be used to denote either the component A itself or its amplitude;

a is the speed of the component expressed in degrees per mean solar hour;

α is the initial argument or phase of the component A; i. e. its phase when $t = 0$;

$\arg_0 A$ denotes the initial argument or hour angle of the fictitious moon producing A; for brevity it is usually called the initial argument or initial equilibrium argument of the component A. To avoid misunderstanding $at + \alpha$ will be spoken of as the *phase* rather than as the *argument* of the component.

A° denotes the epoch or lag of the component A behind its fictitious moon;

$$\therefore \alpha = \arg_0 A - A^\circ.$$

A°/a is the epoch expressed in time and may then be called the interval of the component.

For harmonics of A we always have

$$a_i = ia_1,$$

and usually

$$\arg_0 A_i = i \arg_0 A_1. \tag{55}$$

The mean range, the spring range, etc., and the high or low water inequality in height.

For some purposes it is convenient to give names to various ranges of tide.

Mean range is the average value of the semidaily range of tide.

Spring range is the greatest periodic semidaily range, occurring usually one or two days after new and full moon.

Neap range is the smallest periodic semidaily range, occurring usually one or two days after the moon is in quadrature, that is, after the first and third quarters.

Perigean range is the greatest periodic semidaily range of tide, occurring usually from one to three days after the moon is in perigee.

Apogean range is the smallest periodic semidaily range, occurring usually from one to three days after the moon is in apogee.

Great diurnal range is the difference between the mean of all the higher high waters and the mean of all the lower low waters of each day during one or more half tropical or declinational months.

Small diurnal range is the difference between the mean of all the lower high waters and the mean of all the higher low waters of each day during one or more half tropical or declinational months.

Great tropic range is the greatest periodic daily range of tide, usually occurring soon after the moon is farthest north or south from the equator and therefore near one of the tropics.

Small tropic range is the smallest periodic daily range of tide, usually occurring soon after the moon is farthest north or south from the equator and therefore near one of the tropics.

Tides determining these ranges, or of simultaneous occurrence, may be referred to as *spring, neap, perigean, tropic*, etc.; a like remark is applicable to lunitidal intervals, and occasionally to other quantities.

Diurnal inequality as here used generally denotes the greatest periodic difference in height between two consecutive high waters or low waters, usually occurring soon after the moon is farthest north or south from the equator; this inequality is therefore determined by the tropic tides.

12. *To compute the mean lunitidal interval or corrected establishment.*

When the tide contains no components whose speeds are commensurable with that of M_2, one can assume that the high water establishment is, in hours,

$$\frac{M_2^\circ}{28^\circ\cdot 9841}, \text{ or } \frac{M_2^\circ}{m_2}, \tag{56}$$

and the low-water establishment is the same increased, say, by one-fourth of a mean lunar day, that is

$$\frac{M_2^\circ}{m_2} + 6^h\cdot 2103\ (= 6^h\ 12^m\cdot 62). \tag{57}$$

When M_2 has harmonics, which are denoted by M_4, M_6, etc., the high water establishment is

$$\frac{M_2^\circ - v}{m_2} \tag{58}$$

and the low water

$$\frac{M_2^\circ - w}{m_2} + 6^h\cdot 2103 \tag{59}$$

where from § 9, since $\alpha_i = i \arg_0 A_1 - A_i^\circ$,

$$\tan v = \frac{2\,M_4 \sin(2\,M_2^\circ - M_4^\circ) + 3\,M_6 \sin(3\,M_2^\circ - M_6^\circ) + \ldots}{1^2\,M_2 + 2^2\,M_4 \cos(2\,M_2^\circ - M_4^\circ) + 3^2\,M_6 \cos(3\,M_2^\circ - M_6^\circ) + \ldots}, \tag{60}$$

$$\tan w = \frac{2\,M_4 \sin(2\,M_2^\circ - M_4^\circ) - 3\,M_6 \sin(3\,M_2^\circ - M_6^\circ) + \ldots}{-1^2\,M_2 + 2^2\,M_4 \cos(2\,M_2^\circ - M_4^\circ) - 3^2\,M_6 \cos(3\,M_2^\circ - M_6^\circ) + \ldots}. \tag{61}$$

Less accurate formulæ for v and w are

$$\tan v = \frac{2\,M_4 \sin(2\,M_2^\circ - M_4^\circ) + 3\,M_6 \sin(3\,M_2^\circ - M_6^\circ)}{M_2}, \tag{62}$$

$$\tan w = \frac{2\,M_4 \sin(2\,M_2^\circ - M_4^\circ) - 3\,M_6 \sin(3\,M_2^\circ - M_6^\circ)}{-M_2}. \tag{63}$$

13. *To compute the mean range of tide from given harmonic constants.*

In formula (18) substitute M_2 for A, and other components whose speeds are incommensurable with m_2 for B, C, etc. Multiply the result by 2. This should be increased by the excess of (47) − (48) over 2 M_2, which is

$$\begin{aligned} &M_2(\cos v + \cos w) \\ &+ M_4[\cos(2\,M_2^\circ - M_4^\circ - 2v) - \cos(2\,M_2^\circ - M_4^\circ - 2w)] \\ &+ M_6[\cos(3\,M_2^\circ - M_6^\circ - 3v) + \cos(3\,M_2^\circ - M_6^\circ - 3w)] \\ &+ \ldots\ldots\ldots\ldots \\ &\qquad - 2\,M_2 \end{aligned} \tag{64}$$

where v and w have the values given in § 12.

Since v and w are assumed to be comparatively small, and as v is often approximately equal to $-w$, the above may be written

$$M_2 (\cos v + \cos w) + 0{\cdot}035\, M_4 (v - w) \sin (2\, M_2{}^\circ - M_4{}^\circ) + 2\, M_6 \cos (3\, M_2{}^\circ - M_6{}^\circ) - 2\, M_2$$

where v and w are expressed in degrees.

The complete formula now becomes

$$2\, M_2 + \frac{1}{2\, M_2\, m_2{}^2} [S_2{}^2 s_2{}^2 + N_2{}^2 n_2{}^2 + \ . \ . \ . \ + K_1{}^2 k_1{}^2 + O_1{}^2 o_1{}^2 + \ . \ . \ .],$$

$$+ M_2 (\cos v + \cos w) + 0{\cdot}035\, M_4 (v - w) \sin (2\, M_2{}^\circ - M_4{}^\circ) + 2\, M_6 \cos (3\, M_2{}^\circ - M_6{}^\circ) - 2\, M_2 \quad (65)$$

where the second part is due to the harmonics of M_2 and is usually small except at river stations. Table 21 has been prepared for the purpose of avoiding the labor of each time computing the residual effects of S_2, N_2, etc., upon the range of tide, as indicated in (65). See also Table 22.

The above formula for computing the range of tide is not vitiated because of certain fixed relations between the speeds of some of the components.

Let the parallax wave, where $n_2 + l_2 = 2\, m_2$, $m_2 + 2\, n = 2\, n_2$, be first considered. Its amplitude at any particular time is approximately of the form

$$N_2 - L_2 \cos 2x + 2\, N \cos x, \quad (66)$$

the average value of which is N_2. But in reality the residual effect of L_2 and $2\, N$ upon N_2 is

$$\frac{L_2{}^2\, l_2{}^2}{4\, N_2\, n_2{}^2} + \frac{(2\, N)^2 (2\, n)^2}{4\, N_2\, n_2{}^2}$$

instead of zero. Therefore in finding the residual effect of the parallax wave upon M_2, the amplitude to be used would be approximately

$$N_2 + \frac{L_2{}^2\, l_2{}^2}{4\, N_2 n_2{}^2} + \frac{(2\, N)^2\, (2\, n)^2}{4\, N_2\, n_2{}^2} - L_2 \cos 2\, x + 2\, N \cos (-x)$$

The average value of the square of this expression (see § 7) multiplied by $n_2{}^2$ is, very nearly,

$$N_2{}^2\, n_2{}^2 + L_2{}^2\, l_2{}^2 + (2\, N)^2\, (2\, n)^2.$$

The theoretical values of N_2, L_2, $2\, N$, give, for each value of x, an amplitude with which to enter Table 16. From Table 15 a correction to the phase $(-x)$ is obtained. The mean of the corresponding tabular values shows that the fixed speed relations do not sensibly increase the range of tide.

For the declinational wave the fixed relations are $k_1 + o_1 = m_2$, $k_1 + p_1 = s_2$; the amplitude at any given time is approximately of the form

$$K_1 + O_1 \cos y + P_1 \cos z. \quad (67)$$

Now increase K_1 by the residual effects of O_1 and P_1 upon it, and (§ 16, remark based upon Table 18) multiply the average value of the square of the amplitude so altered by the square of the speed. When the amplitude of the declinational wave is great, the speed is a trifle greater than m_1; when the amplitude is small, the speed exceeds k_1.* For the present purpose the speed should be between m_1 and k_1, but nearer to m_1. The result indicated above becomes nearly equal to

$$K_1{}^2\, k_1{}^2 + O_1{}^2\, o_1{}^2 + P_1{}^2\, p_1{}^2.$$

Having regard to the derivation of (15) and (16), it is not difficult to convince one's self that small components like K_2 and S_1, S_4, S_6, require no special treatment because of their speed relations to K_1 and S_2, respectively.

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*By means of Table 27, the speed of the K_1 O_1 wave may be ascertained for any given time; it is approximately equal to

$$14{\cdot}6 + \frac{(2.8)^\delta}{400}$$

where δ is the number of days before or after the nearest extreme declination of the moon, or rather maximum declinational effect. See also § 8.

14. *The mean range of tide as determined from the tidal components is invariably less than the mean range of tide determined from observed high and low waters. The difference between the two determinations is constant from year to year at a given station.*

In summing for any component, the curve is read at *fixed times* (which are determined in advance) depending in no way upon the height of the sea. In summing for high and low waters the tidal curve is actually read at times which could be only approximately determined in advance, and which times depend to a considerable extent upon the height of the sea. In the former case the elevations and depressions other than those due to the component (with its harmonics) sought will eventually become eliminated. In the latter case we have the liberty of selecting readings at *about* the fixed times of maxima of the wave got by combining all the tidal components. The mean range of the observed tide will always be greater than that of the theoretical tide. For, in order to get this observed range of tide to agree with that of the theoretical tide, we would have to observe the height of the sea *at the theoretical* or *predictable times of high and low water.*

The magnitude of the discrepancy just pointed out will depend largely upon who observes the tides, and whether the high and low waters are observed upon a staff or are obtained from the record of an automatic tide gauge.

Let it be assumed that what is meant by high and low water heights are heights obtained from a continuous curve by a tabulator who reads, as nearly as his judgment will permit, a curve which will eliminate such irregularities as are obviously not predictable. With this definition of high and low waters, and in want of definite information, the discrepancy may be assumed to be perhaps 1 per cent of the computed range. For high and low waters as ordinarily tabulated this discrepancy probably amounts to about 2 per cent.

15. *To compute the hourly heights of the* M *tide.*

The height of the M tide h hours after high water is

$$\begin{aligned} &M_2 \cos\{28^\circ 59' h - v\} + M_4 \cos\{57^\circ 58' h + 2M_2{}^\circ - M_4{}^\circ - 2v\} \\ &\quad + M_6 \cos\{86^\circ 57' h + 3M_2{}^\circ - M_6{}^\circ - 3v\}; \end{aligned} \tag{68}$$

and h hours after low water

$$\begin{aligned} &-M_2 \cos\{28^\circ 59' h - w\} + M_4 \cos\{57^\circ 58' h + 2M_2{}^\circ - M_4{}^\circ - 2w\} \\ &\quad - M_6 \cos\{86^\circ 57' h + 3M_2{}^\circ - M_6{}^\circ - 3w\}. \end{aligned} \tag{69}$$

16. *To compute the speed and range of the diurnal wave when the moon is far from the equator; also the mean range of tide at these times.*

At the conspiring of K_1 and O_1 the speed of the combined wave is, by § 8,

$$k_1 - \frac{k_1 O_1 o_1 (k_1 - o_1)}{K_1 k_1{}^2 + O_1 o_1{}^2}; = 14^\circ.6 \tag{70}$$

when the value of K_1/O_1 is assumed to be 1·4066. In other words, it is very nearly 0°·1 greater than m_1.

Calling this speed d_1, it follows that the mean semirange of the diurnal wave when the moon is far from the equator is

$$K_1 + O_1 + \frac{1}{4} \frac{1}{(K_1 + O_1)\, d_1{}^2} [P_1{}^2 p_1{}^2 + Q_1{}^2 q_1{}^2 + \ . \ . \ .]; \tag{71}$$

$$= (1.0236)\ (K_1 + O_1) \tag{72}$$

when P_1 and Q_1 are given their theoretical values. Since K_1 and O_1 separate 13° 32′ in one-half of a D_1 day (i. e. in 12ʰ·33), $K_1 + O_1$ should be multiplied by 0·9977, formula (25), thus making the required range

$$2\ (1.021)\ (K_1 + O_1). \tag{73}$$

In computing the mean range of tides at these times it should be noted: First, that the K_2 moon is approximately 180° from the M_2 moon; second, the large wave whose amplitude is $K_1 + O_1$ has a fixed phase with respect to M_2; third, from Table 18 it is seen that the mean range of a wave composed of a semidiurnal and a diurnal component is not sensibly affected by the phase of the latter with respect to the former.

The mean range of tide at these times, which it is convenient to denote by Mc, differs from Mn, formula (65), by the substitution of $(K_1 + O_1)^2\, d_1^2$ in place of $K_1^2\, k_1^2 + O_1^2\, o_1^2$ and by the subtraction of 2 K_2 and the residual effect of K_2. That is

$$Mc = M\,n + \frac{(K_1 + O_1)^2\, d_1^2 - K_1^2\, k_1^2 - O_1^2\, o_1^2 - K_2^2 k_2^2}{2\, M_2\, m_2^2} - 2\, K_2, \tag{74}$$

$$= Mn + \frac{0{\cdot}127\,(K_1 + O_1)^2 - 0{\cdot}135\, K_1^2 - 0.116\, O_1^2 - 0.540\, K_2^2}{M_2} - 2\, K_2.$$

Mc will exceed Mn whenever

$$(K_1 + O_1)^2\, d_1^2 - K_1^2\, k_1^2 - O_1^2\, o_1^2 > 4\, M_2\, K_2\, m_2^2 - K_2^2 k_2^2; \tag{75}$$

or, roughly, whenever

$$K_1\, O_1 > 8\, M_2\, K_2; \tag{76}$$

which is about equivalent to saying whenever

$$D_1 > 2\, \triangle_2, \tag{77}$$

D_1 being the tropic amplitude of the diurnal wave and $\triangle_2$ the mean amplitude of the semidiurnal wave.

17. *Given the epochs of two components whose speeds are nearly equal, to find how much the time of their conspiring lags behind the time of conjunction of their fictitious moons.*

When the moons are in conjunction the angle between the crests of the component tides is

$$B° - A°.$$

The time required for the crests to come together will be

$$\tau = \frac{B° - A°}{b - a} \tag{78}$$

where a mean solar hour is taken for the time unit. Whenever $A°$ and $B°$ appear to differ by more than 180°, ± 360° should be applied to one of them.

τ also represents the amount of lagging of the interference behind the time of opposition of the fictitious moons.

For the components M_2 and S_2

$$\tau = \frac{S_2° - M_2°}{1{\cdot}0159} = 0{\cdot}984\,(S_2° - M_2°). \tag{79}$$

This may be written $\tau\,(S_2;\ M_2)$, meaning the *age*, or *retard*, *of* S_2 *relative to* M_2, expressed in hours. Assuming that $\begin{matrix}\text{spring}\\ \text{neap}\end{matrix}$ tides occur when M_2 and S_2 have $\begin{matrix}\text{like}\\ \text{opposite}\end{matrix}$ phases, this is the interval between $\begin{matrix}\text{new or full moon}\\ \text{moon in quadrature}\end{matrix}$ and $\begin{matrix}\text{spring}\\ \text{neap}\end{matrix}$ tides.

In like manner

$$\tau\,(N_2;\ M_2) = \frac{N_2° - M_2°}{-0{\cdot}5444} = \frac{M_2° - N_2°}{0{\cdot}5444} = 1.837\,(M_2° - N_2°). \tag{80}$$

Assuming that the parallax wave $\begin{matrix}\text{conspires}\\ \text{interferes}\end{matrix}$ with M_2 when M_2 and N_2 have $\begin{matrix}\text{like}\\ \text{opposite}\end{matrix}$ phases, this is the interval between $\begin{matrix}\text{moon in perigee}\\ \text{moon in apogee}\end{matrix}$ and the greatest $\begin{matrix}\text{increase}\\ \text{decrease}\end{matrix}$ of range of tide due to parallax.

Similarly

$$\tau\,(O_1;\ K_1) = \frac{O_1° - K_1°}{-1{\cdot}0980} = \frac{K_1° - O_1°}{1{\cdot}0980} = 0{\cdot}911\,(K_1° - O_1°) \tag{81}$$

is the number of hours between the time $\begin{matrix}\text{of the moon's extreme north or south declination}\\ \text{when the moon crosses the equator}\end{matrix}$ and the time of the $\begin{matrix}\text{greatest}\\ \text{least}\end{matrix}$ range of the diurnal wave. $\tau(S_2;\ M_2)$, $\tau(N_2;\ M_2)$, and $\tau(O_1;\ K_1)$ may be referred to as the ages of the phase, parallax, and diurnal inequalities, respectively.

18. *To compute spring and neap ranges.*

The phase wave consists of S_2 and μ_2. S_2 conspires with M_2 at spring tide and interferes at neap tide. The argument of the μ_2 moon exceeds that of the S_2 moon by four times the mean longitude of the sun less that of the moon. Therefore, whenever the moon is new, full, or in quadrature, the S_2 moon and that of μ_2 are in conjunction. For this reason, and assuming that the epochs of S_2 and μ_2 are equal, S_2 and μ_2 conspire at the times of spring or neap tides.

The mean range of tide with the residual effect of S_2 excluded is

$$\text{Mn} - \tfrac{1}{2}\frac{S_2^2\, s_2^2}{M_2\, m_2^2}. \tag{82}$$

Disregarding the time perturbations other than those due to phase, also the slight separation of M_2 and S_2 during a quarter lunar day, the $\begin{matrix}\text{spring}\\ \text{neap}\end{matrix}$ range ought to be expression (82) $\begin{matrix}\text{increased}\\ \text{decreased}\end{matrix}$ by $2(S_2 + \mu_2)$.

The perturbations just referred to diminish the direct effect of S_2 and μ_2 by about

$$0{\cdot}02 + 0{\cdot}04\left(\frac{K_1 + O_1}{M_2}\right)^2$$

part of their value; see formula (18). The diminution in S_2 due to the separation in a quarter lunar day is by formulæ (25) and (26) very small. Approximate values of the required ranges are

$$\text{Sg} = \text{Mn} + 1{\cdot}96\,(S_2 + \mu_2) - 0{\cdot}08\left(\frac{K_1 + O_1}{M_2}\right)^2 (S_2 + \mu_2) - \frac{S_2^2}{2\,M_2}, \tag{83}$$

$$\text{Np} = \text{Mn} - 1{\cdot}96\,(S_2 + \mu_2) + 0{\cdot}08\left(\frac{K_1 + O_1}{M_2}\right)^2 (S_2 + \mu_2) - \frac{S_2^2}{2\,M_2}; \tag{84}$$

$$\therefore\ \text{Sp} + \text{Np} = 2\,\text{Mn} - \frac{S_2^2}{M_2}. \tag{85}$$

19. *To compute perigean and apogean ranges.*

These terms are here used to denote ranges analogous to the spring and neap, but referring to perigee and apogee instead of syzygy and quadrature.

The parallax wave consists chiefly of N_2, L_2, and $2\,N$. The argument of M_2 (i. e. of its fictitious moon) exceeds that of $2\,N$ $\begin{matrix}N_2 \text{ by the}\\ \text{by twice the}\end{matrix}$ mean longitude of the moon from its perigee; in other words, $\begin{matrix}\text{by the}\\ \text{by twice the}\end{matrix}$ moon's mean anomaly.

The argument of L_2 (simple) is greater than that of M_2 by the mean longitude of the moon from its perigee + 180°. From this it follows that when the moon is in mean perigee the fictitious N_2 moon is in conjunction with the fictitious M_2 moon while that of L_2 is in opposition. If conspiring and interference took place immediately, the amplitude of the parallax wave when the moon is in mean perigee or apogee would be, approximately,

$$N_2 - L_2 \pm 2\,N.$$

Proceeding as in the case of spring and neap ranges, but remembering that true and mean perigee differ considerably, we obtain for the required ranges the approximate values

$$\text{Pn} = \text{Mn} + \left[2{\cdot}1 - \tfrac{1}{2}\left(\frac{S_2}{M_2}\right)^2\right](N_2 - L_2 + 2\,N) - 0{\cdot}08\,\frac{(K_1 + O_1)^2}{M_2^2}(N_2 - L_2 + 2\,N) - \frac{N_2^2}{2\,M_2}, \tag{86}$$

$$\text{An} = \text{Mn} - \left[2{\cdot}1 - \tfrac{1}{2}\left(\frac{S_2}{M_2}\right)^2\right](N_2 - L_2 - 2\,N) + 0{\cdot}08\,\frac{(K_1 + O_1)^2}{M_2^2}(N_2 - L_2 - 2\,N) - \frac{N_2^2}{2\,M_2}; \tag{87}$$

$$\therefore\ \text{Pn} + \text{An} = 2\,\text{Mn} - \frac{N_2^2}{M_2} + 4\,[2\,N]. \tag{88}$$

20. *To find the heights and lunitidal intervals of the tropic tides which have a fixed order of occurrence.*

Compute the semirange of the tide by formula (65), omitting the diurnal components, and diminish the result by K_2. The theoretical value of this is

$$1{\cdot}064\ M_2 - K_2,$$

or, more accurately,

$$1{\cdot}006\ M_2 + 0{\cdot}27\ \frac{S_2^2}{M_2} - K_2. \tag{89}$$

Where K_2 is not known it may be taken equal to $0{\cdot}272\ S_2$.

The semirange of the diurnal wave when K_1 and O_1 conspire is, formula (73),

$$1{\cdot}021\ (K_1 + O_1). \tag{90}$$

(90) divided by (89) gives the ratio with which to enter Tables 17 and 18.

By § 2 we see that for finding the acceleration in the times of maxima or minima, or the resultant heights, certain angles are involved which are of the forms

$$\frac{b}{a}\left(2n\pi + \frac{a}{b}\beta - \alpha\right), \frac{b}{a}\left(\overline{2n+1}\,\pi + \frac{a}{b}\beta - \alpha\right). \tag{91}$$

It will be convenient to refer to these as the *high water* and *low water phases*, respectively; and when no value of n is specified it is assumed to be zero.

The argument of the O_1 moon added to the argument of the K_1 moon is equal to that of the M_2 moon. When K_1 and O_1 conspire, the argument of either component or the half sum of these arguments is the argument of the diurnal wave. Putting $b = \frac{1}{2}\,a$, § 16, the high and low water phases become

$$\tfrac{1}{2}\,(2n\pi + M_2{}^\circ - K_1{}^\circ - O_1{}^\circ),\ \tfrac{1}{2}\,(\overline{2n+1}\,\pi + M_2{}^\circ - K_1{}^\circ - O_1{}^\circ). \tag{92}$$

Making $n = 0$ and 1, or any other even and odd integers, these phases become, after rejecting multiples of 360°,

High water phase.	*Low water phase.*
$\frac{1}{2}\,(M_2{}^\circ - K_1{}^\circ - O_1{}^\circ)$,	$\frac{1}{2}\,(M_2{}^\circ - K_1{}^\circ - O_1{}^\circ) + 90^\circ$,
$\frac{1}{2}\,(M_2{}^\circ - K_1{}^\circ - O_1{}^\circ) + 180^\circ$,	$\frac{1}{2}\,(M_2{}^\circ - K_1{}^\circ - O_1{}^\circ) + 270^\circ$.

(93)

These are the phases with which to enter Tables 17 and 18.

The heights of Table 18 are given in terms of the amplitude of the semidiurnal wave (89). The tropic lunitidal intervals are obtained from the mean values of the high and low water intervals, § 12, by subtracting from them the tabular values, Table 17, divided by 28·984.

When the harmonics of M_2 are large, $M_2{}^\circ$ should be replaced by $M_2{}^\circ - v$ in the above expressions which refer to the maxima of M_2, and by $M_2{}^\circ - w$ in those referring to its minima.

Having now determined the amplitude and phase arguments, the required quantities are readily obtained from the values in Tables 17 and 18.*

21. *To find the height inequalities.*

When the order of the tides determining a height inequality is fixed its value becomes known by the preceding paragraph. Here it is proposed to find an expression for a height inequality when the sequence of the tides upon which it depends is subject to alteration. Suppose that we are here concerned with the high water inequality, HWQ, and let the value from the table be denoted by $\overline{\text{HWQ}}$.

For that portion of the time during which the change of order is not possible because the effect of the P_1 wave in producing inequality in the heights of the high waters is less than $\overline{\text{HWQ}}$, we have

$$\text{HWQ} = \overline{\text{HWQ}}. \tag{94}$$

*Having thus obtained the heights of the tropic tides, each should be diminished by $Mf \cos Mf^\circ$. This is of importance when tropic LLW is required for the plane of reference. See also § 14.

Let x denote the distance in degrees of the maximum or minimum of P_1 from the maximum of M_2; then $2\,P_1 \cos x$ is the inequality in heights of the high waters which P_1 tends to introduce. Suppose that for the other portion of the time $2\,P_1 \cos x \gtrless \overline{HWQ}$. During this time one half of the inequalities will be in their normal condition and the other half will have their condition altered. The values of the former are represented by

$$2\,P_1 \cos x + \overline{HWQ}, \tag{95}$$

and of the latter by

$$2\,P_1 \cos x - \overline{HWQ}, \tag{96}$$

where

$$1 \gtrless \cos x \lessgtr \frac{\overline{HWQ}}{2\,P_1} = l, \text{ say.} \tag{97}$$

The average value of $\cos x$ between the limits $\cos x = 1$ and $\cos x = l$, or x between 0 and $\cos^{-1} l$, is

$$\frac{\sqrt{1 - l^2}}{\cos^{-1} l};$$

this substituted for $\cos x$ in (95) and (96) will give the required average values. The respective weights to be given to (94), (95), and (96) are

$$\frac{\pi}{2} - \cos^{-1} l,\ \frac{1}{2}\cos^{-1} l, \text{ and } \frac{1}{2}\cos^{-1} l.$$

The value of the required inequality is

$$\begin{aligned} HWQ &= \left(1 - \frac{2\cos^{-1} l}{\pi}\right)\overline{HWQ} + \frac{4\,P_1}{\pi}\sqrt{1 - l^2} \\ &= \left[1 - \frac{(\cos^{-1} l)^\circ}{90^\circ}\right]\overline{HWQ} + \frac{4\,P_1}{3{\cdot}1416}\sqrt{1 - l^2}. \end{aligned} \tag{98}$$

The fraction representing the percentage of (tropic) high water inequalities which have the order of their tides changed is

$$\frac{\cos^{-1} l}{\pi}$$

$$= \frac{1}{\pi}\cos^{-1}\frac{(\overline{HWQ})}{2\,P_1} = X, \text{ say.} \tag{99}$$

(If quite limited periods be considered, for example, particular years, P_1 will remain constant from year to year, but $\overline{HWQ}$ will vary; see § 48. Consequently values must be given to $\overline{HWQ}$ suited to the particular years in order to ascertain the number of high water inequalities such that the high waters upon which they depend will have their order reversed.)

22. *To compute the great and small tropic ranges, and the heights of the tides between which they occur.*

These are the greatest and least ranges of the tide upon a day when K_1 and O_1 conspire. Denoting them by Gc and Sc, respectively, we have

$$Gc + Sc = 2\,Mc, \tag{100}$$

$$Gc - Sc = HWQ + LWQ; \tag{101}$$

$$Gc = Mc + \tfrac{1}{2}(HWQ + LWQ), \tag{102}$$

$$Sc = Mc - \tfrac{1}{2}(HWQ + LWQ). \tag{103}$$

Suppose the inequality in low water to be the more pronounced; Table 18 gives the values of tropic low waters, § 20. The tropic high waters are then obtained by the equations

$$\text{Tropic HHW} = \text{tropic LLW} + Gc, \tag{104}$$

$$\text{Tropic LHW} = \text{tropic HLW} + Sc. \tag{105}$$

23. *To find the average range of the diurnal wave; also, roughly, the great and small diurnal ranges of tide.*

The average semirange of the diurnal wave is, formula (18),

$$K_1 + \frac{1}{4\,K_1\,k_1^2}\,[O_1^2\,o_1^2 + P_1^2\,p_1^2 + \ .\ .\ .]. \tag{106}$$

The theoretical value of this is 1·14 K_1, or 1·61 O_1. If this wave had a fixed position with respect to M_2, the difference between the great and small diurnal ranges of tide would be almost directly proportional to the range of the diurnal wave. This can be seen by referring to Table 18. When the moon is far from the equator—i. e. when the diurnal wave is large—the position is nearly fixed. Assuming the fixed position to hold true for all declinations of the moon, the above statement may be written

$$\frac{Gt - Sl}{Gc - Sc} = \frac{Gt - Mn}{Gc - Mc} = \frac{\text{range of diurnal wave}}{\text{tropic range of diurnal wave}} \tag{107}$$

since

$$Gt + Sl = 2\,Mn, \tag{108}$$

$$Gc + Sc = 2\,Mc. \tag{109}$$

(107) is theoretically equal to

$$\frac{1{\cdot}14\,K_1}{1{\cdot}02\,(K_1 + O_1)} = 0{\cdot}65. \tag{110}$$

Since the above assumption is not correct when the declination of the moon is small, and more especially since one is supposed to choose the greater range regardless of the sequence of the tides (see § 21), the above ratio ought to be increased by the positive quantity ζ representing these effects. For stations where there are usually two tides daily, ζ may be taken equal to 0·10, and for the present purpose Mc may be taken equal to Mn. Instead of (110) one may write

$$\frac{Gt - Mn}{Gc - Mn} = \frac{3}{4}; \tag{111}$$

$$\therefore\ Gt = \frac{3}{4}\,Gc + \frac{1}{4}\,Mn. \tag{112}$$

If the tide had no semidiurnal components Mn would be zero, and the sequence of tides would not enter into the question. In such a case

$$\frac{Gt}{Gc} = 0{\cdot}65. \tag{113}$$

For stations where there is usually but one tide a day, ζ must be very small. Mn can not be obtained from observation; but it may be replaced by a rough value 2 (1·2) M_2, while the ratio

$$\frac{Gt - Mn}{Gc - Mn}$$

may be put equal to $\frac{2}{3}$; consequently

$$Gt = \frac{2}{3}\,Gc + \frac{4}{5}\,M_2. \tag{114}$$

At stations having tides of this character, the diurnal range, Gt, is often called the mean range of tide.

24. *To compute roughly the average values of the height inequalities; application to planes of reference.*

If the sequence of tides remained fixed for all declinations of the moon, the average values of the height inequalities would be to their maximum values (HWQ, LWQ) as the amplitude of the diurnal wave is to its tropic amplitude, or as 0·65 is to 1·00, §§ 21, 23.

Considering now the more pronounced inequality, low water, say, the average value ought to be

0·65 LWQ + a fraction of (Gc − Mn), say.

This assumed, the fraction must be such that it vary directly as Gc — Mn and inversely as LWQ. The expression now becomes

$$0{\cdot}65\ \mathrm{LWQ} + \varepsilon \frac{\mathrm{Gc} - \mathrm{Mn}}{\mathrm{LWQ}} (\mathrm{Gc} - \mathrm{Mn}) \qquad (115)$$

where ε is supposed to be constant. The special case LWQ = HWQ gives, making use of (111), $\varepsilon = 0{\cdot}10$.

Assuming that the mean of the two tropic low waters is the same as mean low water, it follows that the depression of the lower low waters below mean low water is

$$\frac{\mathrm{LWQ}}{3} + \frac{1}{\mathrm{LWQ}} \left[\frac{\mathrm{Gc} - \mathrm{Mn}}{5}\right]^2. \qquad (116)$$

The average value of the other and less pronounced inequality is obtained by subtracting the one already obtained from the quantity Gt — Mn.

The following equations are obtained from Table 18 and show how the sum of the two tropic high or low waters differs from Mc, the mean tropic range of tide:

$$\text{Tropic HHW} + \text{tropic LHW} = \mathrm{Mc} - 0{\cdot}126 \frac{(\mathrm{K_1} + \mathrm{O_1})^2}{\mathrm{M_2}} \cos (\mathrm{M_2}^\circ - \mathrm{K_1}^\circ - \mathrm{O_1}^\circ); \qquad (117)$$

$$\text{Tropic LLW} + \text{tropic HLW} = -\mathrm{Mc} - 0{\cdot}126 \frac{(\mathrm{K_1} + \mathrm{O_1})^2}{\mathrm{M_2}} \cos (\mathrm{M_2}^\circ - \mathrm{K_1}^\circ - \mathrm{O_1}^\circ). \qquad (118)$$

Less accurately we have

$$\text{Mean HHW} + \text{mean LHW} = \mathrm{Mn} - 0{\cdot}08 \frac{(\mathrm{K_1} + \mathrm{O_1})^2}{\mathrm{M_2}} \cos (\mathrm{M_2}^\circ - \mathrm{K_1}^\circ - \mathrm{O_1}^\circ); \qquad (119)$$

$$\text{Mean LLW} + \text{mean HLW} = \mathrm{Mn} - 0{\cdot}08 \frac{(\mathrm{K_1} + \mathrm{O_1})^2}{\mathrm{M_2}} \cos (\mathrm{M_2}^\circ - \mathrm{K_1}^\circ - \mathrm{O_1}^\circ). \qquad (120)$$

The mean of both high and low water heights is the height of mean sea level, or rather half tide level (HTL), above the line about which the components are supposed to oscillate; that is, above mean sea level as determined from hourly ordinates (MSL). From § 13 the mean of high and low water gives the elevation of mean sea level due to the harmonics of $\mathrm{M_2}$.

$$\therefore \mathrm{HTL} = \mathrm{MSL} + \mathrm{M_4} \cos (2\,\mathrm{M_2}^\circ - \mathrm{M_4}^\circ) - 0{\cdot}04 \frac{(\mathrm{K_1} + \mathrm{O_1})^2}{\mathrm{M_2}} \cos (\mathrm{M_2}^\circ - \mathrm{K_1}^\circ - \mathrm{MO_1}^\circ). \qquad (121)$$

25. *Stations where the tide is usually diurnal.*

The tropic lunitidal intervals may be found by means of formulæ (58)–(61) after replacing $6^h{\cdot}2103$ by $12^h{\cdot}33$, $\mathrm{M_2}$, $\mathrm{M_2}^\circ$, $\mathrm{m_2}$ by $\mathrm{K_1} + \mathrm{O_1}$, $\frac{1}{2}(\mathrm{K_1}^\circ + \mathrm{O_1}^\circ)$, $\mathrm{d_1}$; and $\mathrm{M_4}$, $\mathrm{M_4}^\circ$, $\mathrm{m_4}$ by $\mathrm{M_2}$, $\mathrm{M_2}^\circ$ $\mathrm{m_2}$, respectively, omitting the higher harmonics.

The (great) tropic range of tide is by formulæ (65) and (73)

$$2\,(1{\cdot}021)\,(\mathrm{K_1}+\mathrm{O_1})+(\mathrm{K_1}+\mathrm{O_1})\,(\cos v+\cos w)-0{\cdot}035\,\mathrm{M_2}\,(v-w)\sin(\mathrm{M_2}^\circ-\mathrm{K_1}^\circ-\mathrm{O_1}^\circ)-2\,(\mathrm{K_1}+\mathrm{O_1}), \qquad (122)$$

the corresponding high and low water heights being

$$(\cos v + 0.021)\,(\mathrm{K_1} + \mathrm{O_1}) + \mathrm{M_2} \cos (\mathrm{M_2}^\circ - \mathrm{K_1}^\circ - \mathrm{O_1}^\circ) - 0.035\,\mathrm{M_2}\, v \sin (\mathrm{M_2}^\circ - \mathrm{K_1}^\circ - \mathrm{O_1}^\circ),$$

and

$$-(\cos w + 0.021)\,(\mathrm{K_1} + \mathrm{O_1}) + \mathrm{M_2} \cos (\mathrm{M_2}^\circ - \mathrm{K_1}^\circ - \mathrm{O_1}^\circ) - 0.035\,\mathrm{M_2}\, w \sin (\mathrm{M_2}^\circ - \mathrm{K_1}^\circ - \mathrm{O_1}^\circ),$$

where v and w are expressed in degrees.

When $\mathrm{M_2}$ is small, this range is nearly equal to

$$2\,(1{\cdot}021)\,(\mathrm{K_1}+\mathrm{O_1}). \qquad (123)$$

Mean daily low water is then about

$$\frac{2}{3}(\mathrm{K_1} + \mathrm{O_1})$$

below MSL.

CHAPTER III.

REDUCTIONS OF OBSERVATIONS MADE UPON HIGH AND LOW WATERS.

26. The main object of this chapter is to determine, from a series of observed high and low waters, certain harmonic and nonharmonic quantities which are of special importance in determining the best port of reference for a given station. In so far as the amplitudes and epochs of various components are determined, the reductions constitute a rude harmonic analysis.* The nonharmonic quantities obtained are of interest because of their obvious connection with observed tidal phenomena. The astronomical items used (transits, phases, etc.) are taken directly from the Greenwich ephemeris; the only change consists in using civil time.

The tables given at the close of this paper would, by some alterations and extensions, enable one to use mean motions throughout, thus doing away with some of the inaccuracies which attend the process of reduction as carried out below. It is believed, however, that such errors are too small to be of much consequence in an analysis of the kind proposed. There are some advantages, especially when the series is short, in using the real motions of the bodies.

For instance, the epoch of S_2 obtained from observing a few tides and referring them (without correction) to the mean sun will be much more in error than would have been the case had the true sun been used. But it will be seen from Table 31 that the correction to be applied to the epoch of S_2 because of T_2 and the solar part of K_2 is practically the equation of time.

FIRST REDUCTION.†

27. In this reduction the first process consists in tabulating the times and heights of high and low water, together with the times of transit of the moon across some known meridian. The next step is the subtraction of the transits from the times of the tides, usually selecting such transits as will give the smallest possible interval without introducing too many negative values. Before taking means of the intervals and heights, the length of series to be used must be decided upon.

Length of series suitable for finding the semidiurnal range of tide and the mean lunitidal interval.—Since the variation in range, from day to day depends chiefly upon the manner in which the semidiurnal components fall upon M_2, the required length of series should be, as nearly as possible, a multiple of the synodic periods of S_2, N_2, L_2, K_2, . . . with M_2; i. e. of the form

$$\frac{a\,S_2\,14{\cdot}765 + b\,(N_2 + L_2)\,27{\cdot}555 + c\,K_2\,13{\cdot}661 + \ldots}{S_2 + N_2 + L_2 + K_2 + \ldots} \tag{124}$$

where a, b, c, . . . are integers. The weights S_2, $N_2 + L_2$, K_2, . . . are given to the synodic periods because the *direct* effect of any component in altering the range of the tide is nearly proportional to its amplitude.

For the purpose of eliminating the diurnal inequality as far as possible, the $\frac{\text{high}}{\text{low}}$ water which ends the series should be of the opposite kind from the $\frac{\text{high}}{\text{low}}$ water beginning it. As a length of

* For a more elaborate mode of analysis, see a paper by Prof. G. H. Darwin entitled "On the harmonic analysis of tidal observations of high and low water," Roy. Soc. Proc., Vol. 48 (1890), pages 278–340, see also a correction to this paper, ibid., Vol. 52 (1892), pages 388, 389.

† For an example see § 30.

series suited to the high waters is generally also suited to the low waters, one should solve the above equation to the nearest lunar half day. This having been done, the results expressed in mean solar days are as follows:

29, 58, 87, 105, 134, 163, 192, 221, 250, 279, 297, 326, 355, 384.

It is often convenient to divide the series, whatever its length, into periods of 29 days each.

Since the transits of the true (not the mean) moon are used, the lunar semidiurnal components N_2, L_2, lunar K_2, . . . have little effect upon the interval. Consequently the synodic month of $29\frac{1}{2}$ days might seem to be a better length of series for the determination of the interval. But on account of the diurnal inequality in interval it is probable that even for this purpose 29 days would usually be preferable to $29\frac{1}{2}$.

Having fixed upon the length of series to be used, the sums and means of the intervals and the heights on staff are then taken. The resulting intervals are reduced to a value which would have been obtained had local transits been used by adding

$$S - L + 0{\cdot}035\,(E - L) \tag{125}$$

where E, S, and L are the west longitude in time of the meridian of the transits, i. e. of the ephemeris used, of the (standard) time meridian, and of the meridian of the station, respectively.

Using now the corrected intervals or establishments (HWI, LWI) expressed in hours, the epoch of M_2 is (unless M_6 be large)

$$14{\cdot}4921\,(\mathrm{HWI} + \mathrm{LWI} \mp 6{\cdot}2103) = \mathrm{M_2}^\circ. \tag{126}$$

The $\begin{matrix}\text{upper}\\ \text{lower}\end{matrix}$ sign is used when the low water interval is taken $\begin{matrix}\text{greater}\\ \text{less}\end{matrix}$ than the high water.

The resulting LW height subtracted from the HW height gives the range of tide for the period of the observations.

The intervals and ranges just considered refer to tides occurring twice daily. For this reason when evanescent tides occur such days' observations should be omitted in the summations. If only a few occur they may be interpolated, or if a continuous record be available the points of maximum curvature may be selected for the missing high and low waters.*

For some purposes the average height of the higher high and lower low water may be useful, particularly for determining the great diurnal range of tide and the plane of reference defined by lower low water. These heights are always obtainable, as one high water and one low water occur each day, even when there are evanescent tides. In the first reduction, mark such heights and take the mean of the quantities so marked. The length of series used for this purpose should be an integral number of tropical months, or, less accurately, of half tropical months.

The following numbers represent such periods expressed in mean solar days:

(14), 27, (41), 55, (68), 82, (96), 109, (123), 137, (150), 164, (178), 191, (205), 219, (232), 246, (260), 273, (287), 301, (314), 328, (342), 355, (369), 382.

28. *Determination of mean sea level and long-period tides.*

Where hourly heights of the tide are given, it is obvious that a suitable period of time for determining mean sea level would be one in which each of the principal tidal components makes an integral number of oscillations.

By taking multiples of the hourly speed of each component, it is readily seen that the period of 29 mean solar days and zero hours is the best value obtainable unless the given heights of the tide are taken at intervals of less than one hour. The same period may be adopted for the determination of mean sea level (half-tide level, § 24) from observations of high and low waters. This mean sea level is the half sum of the heights of mean high and low water for the 29-day period or group.

For long series of observations, it is desirable to have the periods conform to certain dates made out in advance. These dates should be the same for all stations in order that the fluctuations

* This implies, as it should, that the small tropic range becomes negative.

of mean sea level at various places may be more readily compared. The following dates are supposed to refer to any year; the dates marking the middle of each group divide the average year into twelve equal parts; the length of group is 29 days, as is shown by the terminal dates:

Groups for mean sea level.		
Beginning (midnight preceding).	Middle (noon).	End (midnight following).
Jan. 2	Jan. 16	Jan. 30
Feb. 1	Feb. 15	Feb. 29
Mar. 3	Mar. 17	Mar. 31
Apr. 3	Apr. 17	May 1
May 3	May 17	May 31
June 3	June 17	July 1
July 3	July 17	July 31
Aug. 3	Aug. 17	Aug. 31
Sept. 2	Sept. 16	Sept. 30
Oct. 2	Oct. 16	Oct. 30
Nov. 2	Nov. 16	Nov. 30
Dec. 2	Dec. 16	Dec. 30

For all spring and summer months the groups begin on the 3d of each month, while for all fall and winter months (except February) they begin on the 2d.

In harmonically analyzing the twelve ordinates thus obtained, it should be borne in mind that the first ordinate is 15·218 days after 0^h (midnight preceding) January 1; this increases the $V_0 + u$ of Sa, Table 3, by 15°. If $V_0 + u$ be found for date of beginning of series used in analyzing short-period tides, then it must be increased by the number of days from this date to the middle of the first 29-day group used, multiplied by 0·9856. Supposing the groups to be so taken as to conform to the above scheme, then it is clear that the values of Table 3 are simply increased by the amount

$$30° \times m - 15°$$

where m is the number of the calendar month approximately covered by the group.

Besides the yearly change in sea level, a small change having a period of about 428 days may be considered here. This depends upon the 428-day component of the variation of latitude. The annual and 428-day tidal components may be nearly separated by combining 7 years' observations. If the annual inequality in sea level has been determined from analyzing the monthly heights just considered for 7 years, it may be taken away from the sea-level curve and the residual curve read for the 428-day tide, using the true lengths of period for the particular years.

The fictitious moon has the longitude of the instantaneous minimum north latitude of the place so far as the latitude depends upon the 428-day component; this moon goes around the earth once in 428 days from west to east. Suppose the time of minimum north latitude to be given for Greenwich, i. e. the time when the north pole of the earth's figure passes the instantaneous meridian of Greenwich; the time for a place L hours west is

$$\text{Time of Greenwich min. lat.} - \frac{15\,L}{\text{daily speed}} \text{ days.}$$

The average value of the daily speed is 0°·840. Formulæ for more accurate values, together with a table of times of minimum north latitude or of high water of 428-day tide, are given below:

No. of periods from 1865. E	Time of high water at Greenwich of 428-day component tide. T_1	Amplitude of 428-day component of the latitude variation.	Amplitude of 428-day tide for latitude 45°.
	Civil date.	″	*Feet.*
−40	1818, June 16	0·184	0·062
−35	1824, Apr. 13	·170	·057
−30	1830, Jan. 28	·146	·049
−25	1835, Nov. 11	·118	·040
−20	1841, Aug. 29	·096	·032
−15	1847, July 1	·085	·029
−10	1853, May 18	·090	·030
− 5	1859, Apr. 20	·108	·037
0	1865, Mar. 31	·135	·046
+ 5	1871, Mar. 13	·162	·055
+10	1877, Feb. 12	·180	·061
+15	1882, Dec. 31	·185	·063
+20	1888, Nov. 1	·174	·059
+25	1894, Aug. 20	·152	·051
+30	1900, June 3	0·124	0·042

$$\text{Amplitude} = 0''\cdot135 + 0''\cdot05 \sin \Psi,$$
$$\text{Period} = 428^{d}\cdot6 + 5^{d}\cdot26 \cos \Psi,$$
$$T_1 = 1865\cdot25 + 428\cdot6\, E + 55 \sin \Psi,$$

where

$$\Psi = (t - 1865\cdot25)\, 5°\cdot48,$$

denoting the year.

[These values are taken from Dr. S. C. Chandler's paper on latitude variation in No. 322 (July 10, 1894) of the Astronomical Journal.]

At the times of local upper transit of the fictitious moon,

$$\text{Height of } 428^{d} \text{ tide} = \frac{\sin 2\lambda}{3} \times \text{change in latitude}^{*} \qquad (127)$$

where the height is reckoned in feet from mean sea level, the (north) latitude, λ, is expressed in degrees, and the change in latitude, column 3, is expressed in seconds.†

This fluctuation or tide is of little or no practical importance. It is noticed here because, like the annual tide, it may be determined from a sufficient number of observations upon high and low water.

In the special reductions which follow, the length of the series will usually be about one month. Certain modifications will be found necessary if, for any reason, other lengths be used.

* The rounded value $\frac{1}{3}$ is written for 0·338.

† A ready means of comparing theory and observation is to tabulate the times of local transits of the fictitious moon, as the times of high and low waters of the 428-day tide, and to find the reading of mean sea level, at such times using a 29-day group on each occasion. The sea level is then corrected for the annual component, and finally 6 high water or 6 low water groups (approximately 7 years) are combined and the mean taken.

From hourly readings (1870–1887) at Pulpit Harbor, Maine, (lat. 44° 09′ N., long. 68° 53′ W.), the mean for the component high water was 10·495 feet, and for low water 10·357, showing, upon application of the group factor 1·007, an amplitude of 0·069 feet. The theoretical value of this, formula (127), is about 0.059 feet.

From hourly readings (1869–1887) at San Francisco, Cal., (lat. 37° 50′ N., long. 122° 24′ W.), the corresponding observed quantities were 8·285, 8·206, giving an amplitude of 0·040 feet, the theoretical value being 0·057.

REDUCTION OF SPRING AND NEAP TIDES.

29. In one column of the sheet headed "Ephemeris" will be found the times of the moon's phases expressed in the kind of time used in making the observations. Select from the first reduction, groups of observations, each group beginning about a day and a half before the times of new moon, full moon, or quadrature; then fill out the forms for spring and neap tides. The correction for parallax is taken from Table 25, using for the amplitude of N_2 the value $\frac{1}{11}$ Mn, and for its relative age the value at a neighboring station taken as 1·837 ($M_2° - N_2°$). For a series about 220 days in length the parallax correction becomes zero. Since transits of the true (not the mean) moon are used, the lunitidal intervals need not be corrected for parallax, especially when the springs or neaps are taken in pairs.

The age of the solar tide.—The lunitidal intervals found in the column headed "Average" are plotted one-half lunar day apart, at times found in the average time column. The plotted values of each group are then connected, as nearly as possible, with a straight line. The values most distant from the time of spring or neap tide, as the case may be, will, theoretically, depart most widely from the straight line when the latter is properly drawn. The time of spring or neap tide is found by noting where the mean value of the interval (as determined from the first reduction before (125) has been applied) falls upon the straight line. Each such time is then diminished by the time of the appropriate phase of the moon. The mean of these differences is the age of the solar tide relative to the lunar.

Spring and neap ranges.—One range is obtained from the reduction of spring tides, and one from that of neap tides. The age applied to the times of one or more phases of the moon will show what group factors must be used in reducing the amplitude of the solar wave as brought out from the spring and neap ranges. The group used in determining the ranges need not be as extensive as the group used in determining the age.

According to § 18, the amplitude of the solar wave should be further increased by the factor

$$1·02 + 0·04 \frac{HWQ^2 + LWQ^2}{Mn^2} \qquad (128)$$

HWQ and LWQ may be taken from the first reduction with sufficient accuracy. This will be referred to as the *inequality factor.*

30. *Example.*

The following tabulations, relating to a month's observations at Sitka, Alaska, show how these reductions are carried out:

Sitka, Alaska.

First reduction.

Date.	Moon's transits.	Time of— HW	Time of— LW	Lunitidal interval. HW	Lunitidal interval. LW	Height of— HW	Height of— LW
1893.	h. m.	h. m.	h. m.	h. m.	h. m.	Feet.	Feet.
	(13 08)						
July 1	1 34	1 08	8 09	(12 00)	6 35	14·6	3·4
	(13 59)	14 51	19 54	13 17	(5 55)	12·8	8·4
2	2 24	2 01	8 42	(12 02)	6 18	14·4	3·9
	(14 48)	15 25	20 50	13 01	(6 02)	13·0	8·3
3	3 11	2 30	9 25	(11 42)	6 14	14·0	4·0
	(15 34)	15 58	21 14	12 47	(5 40)	12·8	7·8
4	3 37	3 12	9 54	(11 38)	5 57	13·2	4·3
	(16 19)	16 37	22 10	12 40	(5 51)	12·9	7·6
5	4 41	4 05	10 27	(11 46)	5 46	12·5	5·0
	(17 04)	17 23	23 23	12 42	(6 19)	13·2	7·2
6	5 26	5 09	11 14	(12 05)	5 48	12·0	5·9
	(17 48)	18 03	------	12 37	------	13·6	---
7	6 11	6 22	0 32	(12 34)	(6 44)	11·4	6·6
	(18 36)	18 46	12 18	12 35	6 07	14·0	6·7
8	7 00	7 49	1 49	(13 13)	(7 13)	11·2	5·8
	(19 26)	19 44	13 03	12 44	6 03	14·6	7·6
9	7 53	9 02	2 52	(13 36)	(7 26)	11·5	5·0
	(20 22)	20 37	14 15	12 44	6 22	15·0	8·3
10	8 51	10 28	3 50	(14 06)	(7 28)	11·9	3·9
	(21 23)	21 30	15 25	12 39	6 34	15·5	8·6
11	9 55	11 31	4 50	(14 08)	(7 27)	12·5	2·9
[11d 23h·5]	(22 28)	22 29	16 36	12 34	6 41	15·7	8·4
P 12	11 01	12 17	5 40	(13 49)	(7 12)	12·9	2·1
	(23 34)	23 26	17 29	12 25	6 28	16·1	8·0
13	------	------	6 28	------	(6 54)	----	1·9
	12 07	13 09	18 21	(13 35)	6 14	13·5	7·8
14	(0 38)	0 22	7 18	12 15	(6 40)	16·3	1·8
	13 09	13 55	19 19	(13 17)	6 10	13·9	7·6
15	(1 38)	1 11	8 01	12 02	(6 23)	16·2	2·4
	14 06	14 50	20 13	(13 12)	6 07	14·6	7·8
16	(2 32)	1 56	8 46	11 50	(6 14)	16·3	3·6
	14 57	15 19	21 04	(12 47)	6 07	15·1	7·9
17	(3 20)	2 50	9 31	11 53	(6 11)	15·7	4·3
	15 43	15 59	21 47	(12 39)	6 04	14·7	7·3
18	(4 05)	3 47	9 56	12 04	(5 51)	14·0	5·0
	16 27	16 38	22 50	(12 33)	6 23	14·2	7·0
19	(4 48)	4 40	10 35	12 13	(5 47)	12·7	5·9
	17 09	17 22	------	(12 34)	------	13·8	---
20	(5 30)	5 40	0 00	12 31	6 51	11·6	6·8
	17 51	18 08	11 21	(12 38)	(5 51)	13·7	7·1
21	(6 12)	6 52	0 48	13 01	6 57	11·2	6·9
	18 33	18 46	12 10	(12 34)	(5 58)	13·8	8·3
22	(6 55)	8 12	2 00	13 39	7 27	11·0	6·8
	19 17	19 34	13 08	(12 39)	(6 13)	13·4	9·0
23	(7 40)	9 30	3 18	14 13	8 01	11·0	6·0
[24d 2h·2]	20 04	20 28	14 41	(12 48)	(7 01)	13·4	9·2
A 24	(8 28)	11 11	4 07	15 07	8 03	11·3	5·3
	20 53	21 34	15 21	(13 06)	(6 53)	13·5	9·3
25	(9 19)	11 40	4 47	14 47	7 54	11·8	4·8
	21 45	22 20	16 34	(13 01)	(7 15)	14·1	9·2
26	(10 11)	12 08	5 27	14 23	7 42	12·7	4·6
	22 37	23 02	17 04	(12 51)	(6 53)	15·3	9·6
27	(11 03)	12 45	6 11	14 08	7 34	13·2	4·7
	23 29	23 43	17 54	(12 40)	(6 51)	15·1	9·1
28	(11 54)	------	6 40	------	7 11	----	4·0
	------	13 14	18 30	13 45	(6 36)	13·2	8·5
29	0 20	0 25	7 16	(12 31)	6 56	15·1	3·8
	(12 44)	13 44	19 00	13 24	(6 16)	13·5	8·2
30	1 08	0 57	7 46	(12 13)	6 38	15·4	3·8
	(13 32)	14 16	19 47	13 08	(6 15)	14·0	7·9
31	1 55	1 38	8 22	(12 06)	6 27	15·3	4·1
	(14 18)	14 38	20 28	12 43	(6 10)	15·0	7·3

Remarks.

Lat. = 57° 03′ N.
Long. = 125 18 = 9h 01m W.

Observations in mean local civil time.

Greenwich transits.

To convert Greenwich transits to local transits, observation time, add $L - S + 0.035\,(L - E) = 18^m.9$.

Greenwich civil time of perigee, *P*, and apogee, *A*.

P and *A* hour of transit = $9\frac{1}{2}$.

	HWQ	LWQ
	Feet.	Feet.
July 11, 12	3·2	6·3
" 26	2·6	5·0
Mean	2·9	5·6

Sequence HHW to LLW.

July 1–29, 1893.

	HWI 56	LWI 56	HW 56	LW 56
	h. m.	h. m.	Feet	Feet.
Sum	722 04	369 38	760·2	351·2
Mean	12 53·6	6 36·0	13·58	6·27

Interval = 9h 44m·8. Mn = 7·31 feet.
To correct for transits subtract 18m·9.
HWI = 12h 34m·7. LWI = 6h 17m·1.
HWI = 12h 34m·7 − 12h 25m·2 = 0h 9m·5.
HWI − LWI = 6h 26m·6 = 6h·443.
6h·443 − 6h·210 = 0h·233.
14°·492 × 0·233 = 3°·4 = M_2°.
Duration of fall = 6h 07m·6.

July 1–27, 1893.

HHW 26	LLW 25	Gt
Feet.	Feet.	Feet.
376·5	110·2	
14·48	4·41	10·07

Sitka, Alaska, 1893.

Ephemeris.

		h.	m.	
Longitude of ephemeris	(*E*)	0	00	W.
Longitude of time meridian	(*S*)	9	01	"
	E − *S* =	−9	01	

Moon.	Greenwich civil time.		Observation time. Gr. civ. time + *E* − *S*.		Observation time increased by assumed age.		Observation time increased by uncorrected age.	
	d.	*h.*	*d.*	*h.*	*d.*	*h.*	*d.*	*h.*
○ Full moon	June 29	6·4	28	21·4			29	23·9
☾ Last quarter	July 6	22·1	6	13·1			7	15·6
● New moon	" 13	12·8	13	3·8			14	6·3
☽ First quarter	" 20	17·0	20	8·0			21	10·5
○ Full moon	" 28	20·2	28	11·2			29	13·7
Apogee	June 26	13·7	26	4·7	28	3·7	28	1·7
(Mid-time)	July 4	6·6	3	21·6	5	20·6	5	18·6
Perigee	" 11	23·5	11	14·5	13	13·5	13	11·5
(Mid-time)	" 18	0·8	17	15·8	19	14·8	19	12·8
Apogee	" 24	2·2	23	17·2	25	16·2	25	14·2
(Mid-time)	Aug. 1	0·0	31	15·0	2	14·0	2	12·0
Perigee	" 8	21·7	8	12·7	10	11·7	10	9·7
On equator	July 6	2·9	5	17·9			6	11·4
Farthest N.	" 12	8·9	11	23·9			12	17·4
On equator	" 18	18·3	18	9·3			19	2·8
Farthest S.	" 26	5·2	25	20·2			26	13·7

Sitka, Alaska, 1893.

Spring tides.

		h.	m.	
Longitude of ephemeris	(*E*)	0	00	W.
Longitude of time meridian	(*S*)	9	01	"
	E − *S* =	−9	01	

From first reduction, July 1–29, 1893: Mean (uncorrected) interval = $9^h\ 44^m{\cdot}8$; Mn = 7·31 ft.
Assumed: $N_2 = \frac{1}{11}$ Mn = 0·665 ft.; τ (N_2; M_2) = 47^h, from analysis at St. Paul, Kadiak Id.

Moon new and full + *E* − *S*.		Time. H W			Time. L W			Average.	Lunitidal interval. H W		Lunitidal interval. L W		Average.		Height. H W	Height. L W
d.	*h.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*	*d.* *h.* *m.*	*h.*	*m.*	*h.*	*m.*	*h.*	*m.*	*Feet.*	*Feet.*
		11	22	29	11	16	36		12	34	6	41	10	04·0	15·7	8·4
		12	12	17	12	5	40		13	49	7	12	9	58·5	12·9	2·1
July 13	3·8	12	23	26	12	17	29	13 3 08	12	25	6	28	9	50·5	16·1	8·0
		13	13	09	13	6	28		13	35	6	54	9	44·5	13·5	1·9
		14	0	22	13	18	21		12	15	6	14	9	36·5	16·3	7·8
		14	13	55	14	7	18		13	17	6	40	9	32·2	13·9	1·8
		15	1	11	14	19	19		12	02	6	10	9	26·8	16·2	7·6
		15	14	50	15	8	01		13	12	6	23			14·6	2·4
															8	8
															119·2	40·0
															14·90	5·00
Group $0^d\ 2^h$ after perigean tides. Correction in terms of N_2															— ·90	+ ·90
" " feet															— ·60	+ ·60
															14·30	5·60
		26	23	02	27	6	11		12	51	7	34	10	21·0	15·3	4·7
		27	12	45	27	17	54		14	08	6	51	10	12·5	13·2	9·1
July 28	11·2	27	23	43	28	6	40	28 9 32	12	40	7	11	10	03·0	15·1	4·0
		28	13	14	28	18	30		13	45	6	36	9	57·0	13·2	8·5
		29	0	25	29	7	16		12	31	6	56	9	46·8	15·1	3·8
		29	13	44	29	19	00		13	24	6	16	9	37·8	13·5	8·2
		30	0	57	30	7	46		12	13	6	38	9	33·5	15·4	3·8
		30	14	16	30	19	47		13	08	6	15			14·0	7·9
															8	8
															114·8	50·0
															14·35	6·25
Group $3^d\ 6^h$ after apogean tides. Correction in terms of N_2															+ ·60	·60
" " feet															+ ·40	·40
															14·75	5·85

Age = ½ (12 + 29) = 20·5
Spring range = 8·80

Sitka, Alaska, 1893.

Neap tides.

	h.	m.	
Longitude of ephemeris	(*E*)	0	00 W.
Longitude of time meridian	(*S*)	9	01 "
$E - S = -9$		01	

Moon in quadrature $\frac{1}{4}$ *E* − *S*.		Time. H W			Time. L W			Time. Average.	Lunitidal interval. H W		Lunitidal interval. L W		Lunitidal interval. Average.		Height. H W	Height. L W
d.	*h.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*	*d. h. m.*	*h.*	*m.*	*h.*	*m.*	*h.*	*m.*	*Feet.*	*Feet.*
		5	4	05	5	10	27		11	46	5	46	9	08·2	12·5	5·0
		5	17	23	5	23	23		12	42	6	19	9	13·5	13·2	7·2
July 6	13·1	6	5	09	6	11	14	6 14 44	12	05	5	48	9	18·5	12·0	5·9
		6	18	03	7	0	32		12	37	6	44	9	30·5	13·6	6·6
		7	6	22	7	12	18		12	34	6	07	9	37·2	11·4	6·7
		7	18	46	8	1	49		12	35	7	13	9	46·0	14·0	5·8
		8	7	49	8	13	03		13	13	6	03	9	51·5	11·2	7·6
		8	19	44	9	2	52		12	44	7	26			14·6	5·0
															8	8
															102·5	49·8
															12·81	6·22
		Group 1d 7h after mid. tides (*A* to *P*). Correction in terms of N_2													− ·20	+ ·20
		" " feet													− ·13	+ ·13
															12·68	6·35
		19	4	40	18	22	50		12	13	6	23	9	14·2	12·7	7·0
		19	17	22	19	10	35		12	34	5	47	9	25·8	13·8	5·9
July 20	8·0	20	5	40	20	0	00	20 8 47	12	31	6	51	9	27·8	11·6	6·8
		20	18	08	20	11	21		12	38	5	51	9	36·8	13·7	7·1
		21	6	52	21	0	48		13	01	6	57	9	37·5	11·2	6·9
		21	18	46	21	12	10		12	34	5	58	9	54·5	13·8	8·3
		22	8	12	22	2	00		13	39	7	27	9	59·5	11·0	6·8
		22	19	34	22	13	08		12	39	6	13			13·4	9·0
															8	8
															101·2	57·8
															12·65	7·22
		Group 1d 6h after mid. tides (*P* to *A*). Correction in terms of N_2													+ ·28	− ·28
		" " feet													+ ·19	− ·19
															12·84	7·03

Age = $\frac{1}{2}$ (36 + 29) = 32·5

Age from springs and neaps = $\frac{1}{2}$ (20·5 + 32·5) = 26·5

Average date of phases + age = July 18

No. of tides before springs or neaps = $6 + \frac{26·5}{6·2} = 10·3$

" " " after " " " = 16 − 10·3 = 5·7

Spring range = 8·80

Neap " = 6·07

31. *Treatment of phase reduction results.*

STATION.	SITKA, ALASKA, 1893.
Spring and neap tides.	*Spring and neap tides, July 18, 1893.*
Amplitude relations.	Amplitude relations.
(1) Spring range from reduction.	(1) 8·80.
(2) Neap range from reduction.	(2) 6·07.
(3) ½ [(1) − (2)] = approx. S_2.	(3) ½ [8·80 − 6·07] = 0·682.
(4) (3) × group factor, Table 35.	(4) 0·682 × 1·17 = 0·798.
(5) (4) × inequality factor.	(5) 0·798 × 1·070 = 0·854.
(6) (5) × F_2, Table 33.	(6) 0·854 × 1·318 = 1·126.
(7) (6) − 0·01 Mn = S_2.	(7) 1·126 − 0·073 = 1·053 = S_2.
$(1)+2\left\{(6)-(5)+\frac{Mn-2(6)}{2\,Mn}[(4)-(3)]\right\}$ = spring range, Sg.	8·80 + 2{0·272 + 0·347 [0·115]} = 9·43 = Sg.
$(2)-2\left\{(6)-(5)+\frac{Mn+2(6)}{2\,Mn}[(4)-(3)]\right\}$ = neap range, Np.	6·07 − 2{0·272 + 0·653 [0·115]} = 5·36 = Np.
Sg and Np are reduced to their mean values by Chapter IV, as soon as K_1+O_1 becomes approximately known by § 39 or 44.	
Epoch relations.	Epoch relations.
(8) Age from reduction (hours).	(8) 26·5 = τ(S_2; M_2).
(9) $M_2°+(8)\times 1·016 = S_2°$.	(9) 3·4 + 26·5 × 1·016 = 3·4 + 26·9 = 30·3 = $S_2°$.

REDUCTION OF PERIGEAN, APOGEAN, AND MIDTIME TIDES.

32. *Midtime tides.*

A number of tides occurring between perigee and apogee, also between apogee and perigee, are tabulated in the form headed "Midtime tides" for the purpose of ascertaining the relative age of the parallax wave. It is generally sufficient to begin the tabulation about a day and a half before the midtimes and to use on each occasion, say, 24 tides, thus covering nearly 6 lunar days. It is necessary to take pairs of midtimes because the age as determined from the one following perigee may differ a day or two from the age as determined from the one following apogee. The phase correction employed in this reduction is obtained from Table 24, column headed "0 tides," using the amplitude of S_2 uncorrected for K_2 and T_2. The phase correction becomes zero for a series about 220 days in length; i. e. when 8 midtime groups of the same kind are combined into one. The last column shows the corrected range of tide for the times given in the column headed "Average."

The next step is to plot these ranges at the proper times—which times are one-half lunar day apart, very nearly—and to draw a curve fitting the plotted values. Since these values usually appear as a double row of points, a third row should be obtained lying midway between the other two. It may be seen by aid of Table 16 that a parallax inequality whose age is zero and which is due to N_2, L_2, and νN should cause the range of tide at midtime to be about equal to its mean value. Consequently one should mark upon each curve the time when the range becomes equal to its mean value taken from the first reduction. The times of occurrence of these ranges, diminished by the appropriate midtimes, give, in the mean, the age of the parallax inequality.

33. *Perigean and apogean tides.*

The age of the parallax inequality, when added to the observation times of perigee and apogee, gives the times of greatest and least parallax effect upon the range of tide. Before and after each of these times copy down, say, 6 tides, and determine the perigean and apogean ranges. Table 24, column headed "6 tides," is employed in making the correction for phase. The high and low water diurnal inequalities are taken at the times of greatest and least parallax effect.

The inequality factor for a short series is approximately equal to

$$0{\cdot}95 + \left(\frac{S_2}{Mn}\right)^2 + 0{\cdot}08\,\frac{\Sigma_n\,(\text{HW inequality})^2 + \Sigma_n\,(\text{LW inequality})^2}{n\qquad\qquad Mn^2} \tag{129}$$

where n is the number of perigees and apogees taken. For a long series the factor becomes

$$0{\cdot}95 + \left(\frac{S_2}{Mn}\right)^2 + 0{\cdot}04\,\frac{HWQ^2 + LWQ^2}{Mn^2}. \tag{130}$$

34. *Example.*

A month's observations at Sitka, Alaska, will illustrate what has been said concerning the reduction of parallax tides.

Sitka, Alaska, 1893.

Midtime tides.

		h.	m.	
Longitude of ephemeris	(E)	0	00	W.
Longitude of time meridian	(S)	9	01	"
$E - S =$		-9	01	

From first reduction, July 1–29, 1893: Mn = 7·31 feet.
From phase reduction: $S_2 = (5) - 0{\cdot}01\ \text{Mn} = 0{\cdot}781$ foot; $\tau\,(S_2;\ M_3) = 26^h{\cdot}5$.

Midtime + $E - S$.		Time.								Range.				
		H W			L W			Average.						
										Observed.	Average.	½ Correction.	Correction.	Corrected.
d.	*h.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*	*d.*	*h.*	*Feet.*	*Feet.*		*Feet.*	*Feet.*
		2	15	25	2	20	50			4·7				
		3	2	30	3	9	45			10·0	7·35	$-0{\cdot}47\ S_2$	−0·73	6·62
		3	15	58	3	21	14			5·0	7·50	−0·29	−0·45	7·05
July 3	21·6	4	3	12	4	9	54	4	00	8·9	6·95	−0·08	−0·12	6·83
A to *P*		4	16	37	4	22	10			5·3	7·10	+0·13	+0·22	7·32
		5	4	05	5	10	27			7·5	6·40	+0·37	+0·58	6·98
		5	17	23	5	23	23			6·0	6·75	+0·60	+0·94	7·69
		6	5	09	6	11	14			6·1	6·05	+0·83	+1·30	7·35
		6	18	03	7	0	32			7·0	6·55	+1·00	+1·56	8·11
		7	6	22	7	12	18	7	3	19	4·7	5·85	+1·13	+1·77
		7	18	46	8	1	49			8·2	6·45	+1·18	+1·84	8·29
		8	7	49	8	13	03			3·6	5·90	+1·13	+1·77	7·67
		16	1	56	16	8	46			12·7				
		16	15	19	16	21	04			7·2	9·95	−0·61	−0·95	9·00
		17	2	50	17	9	31			11·4	9·30	−0·45	−0·70	8·60
July 17	15·8	17	15	59	17	21	47	17	12	32	7·4	9·40	−0·29	−0·42	8·98
P to *A*		18	3	47	18	9	56			9·0	8·20	0·00	0·00	8·20
		18	16	38	18	22	50			7·2	8·10	+0·26	+0·41	8·51
		19	4	40	19	10	35			6·8	7·00	+0·48	+0·75	7·75
		19	17	22	20	0	00			7·0	6·90	+0·70	+1·09	7·99
		20	5	40	20	11	21			4·5	5·75	+0·90	+1·41	7·16
		20	18	08	21	0	48	20	14	59	6·8	5·65	+1·05	+1·64	7·29
		21	6	52	21	12	10			2·9	4·85	+1·15	+1·80	6·65
		21	18	46	22	2	00			7·0	4·95	+1·16	+1·81	6·76
												Age = ½ (20 + 70) = 45		

Sitka, Alaska, 1893.

Perigean and apogean tides.

	h.	m.	
Longitude of ephemeris	(*E*)	0 00	W.
Longitude of time meridian	(*S*)	9 01	"
E − *S* =		− 9 0	

Perigee, apogee, $+E-S+45^h$.		Time. H W			Time. L W			Time. Average.			Height. H W	Height. L W
d.	*h.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*	*Feet.*	*Feet.*
		11	22	29	12	5	40				15·7	2·1
		12	12	17	12	17	29				12·9	8·0
July 13	11·5	12	23	26	13	6	28	13	9	20	16·1	1·9
		13	13	09	13	18	21				13·5	7·8
		14	0	22	14	7	18				16·3	1·8
		14	13	55	14	19	19				13·9	7·6
											6	6
											88·4.	29·2
											14·73	4·87
											− 0·87	+ 0·87
Group 0d 21h before springs. Correction in terms of S_2											− 0·68	+ 0·68
" " feet											14·05	5·55
											Perigean range	= 8·50
											H W ineq. = 2·6	L W ineq. = 5·9
		24	11	11	24	4	07				11·3	5·3
		24	21	34	24	15	21				13·5	9·3
July 25	14·2	25	11	40	25	4	47	25	13	46	11·8	4·8
		25	22	20	25	16	34				14·1	9·2
		26	12	08	26	5	27				12·7	4·6
		26	23	02	26	17	04				15·3	9·6
											6	6
											78·7	42·8
											13·12	7·13
											− 0·17	+ 0·17
Group 4d 00h before springs. Correction in terms of S_2											− 0·13	+ 0·13
" " feet											12·99	7·26
											Apogean range	= 5·73
											H W ineq. = 2·3	L W ineq. = 4·4

35. *Treatment of parallax reduction results.*

STATION.

Parallax tides.

Amplitude relations.

(1) Perigean range from reduction.
(2) Apogean range from reduction.
(3) $\frac{1}{2}[(1)-(2)]$ = approx. $(N_2 - L_2)$.
(4) (3) × group factor, Table 35.
(5) (4) × inequality factor.
(6) $f(N_2)$, $f(L_2)$, Table 10; c, Table 34.
(7) $\frac{(5)}{cf(N_2)-\frac{1}{4}f(L_2)} = N_2$.
$(1)+2\{N_2(1-c)+0{\cdot}4[(4)-(3)]\}$ = perigean range, Pn.
$(2)-2\{N_2(1-c)+0{\cdot}6[(4)-(3)]\}$ = apogean range, An.
Pn and An are reduced to their mean values by Chapter IV.

Epoch relations.

(8) Age from reduction (hours).
(9) $M_2° - (8) \times 0{\cdot}544 = N_2°$.

SITKA, ALASKA, 1893.

Parallax tides July 19, 1893.

Amplitude relations.

(1) 8·50.
(2) 5·73.
(3) $\frac{1}{2}[8{\cdot}50 - 5{\cdot}73] = 0{\cdot}692$.
(4) $0{\cdot}692 \times 1{\cdot}02 = 0{\cdot}706$.
(5) $0{\cdot}706 \times 1{\cdot}041 = 0{\cdot}735$.
(6) $f(N_2) = 0{\cdot}967$, $f(L_2) = 0{\cdot}64$, $c = 1{\cdot}05$.
(7) $\frac{0{\cdot}735}{1{\cdot}05 \times 0{\cdot}967 - \frac{1}{4}0{\cdot}68} = \frac{0{\cdot}735}{0{\cdot}918} = 0{\cdot}801 = N_2$.
$8{\cdot}50 + 2\{0{\cdot}801 \times (-0{\cdot}05) + 0{\cdot}4[0{\cdot}014]\} = 8{\cdot}53 = Pn$.
$5{\cdot}73 - 2\{0{\cdot}801 \times (-0{\cdot}05) + 0{\cdot}6[0{\cdot}014]\} = 5{\cdot}65 = An$.

Epoch relations.

(8) $5{\cdot}45 = \tau(N_2; M_2)$.
(9) $M_2° - 24{\cdot}5 = -21{\cdot}1 = 338{\cdot}9 = N_2°$.

REDUCTION OF DECLINATIONAL TIDES.

36. *Moon near the equator.*

Whenever the amplitude of the diurnal wave is small in comparison with that of the semidiurnal, we have

$$\text{Range of diurnal wave} = \sqrt{(\text{HW inequality})^2 + (\text{LW inequality})^2} \tag{131}$$

The minimum value of this range and the time of its occurrence are found by means of the reduction headed "Minimum diurnal tides." The time of this event diminished by the observation time of moon on equator is the uncorrected age of the diurnal inequality, or of O_1 relative to K_1.

In determining the minimum diurnal tide, several days' observations should be used, beginning shortly before the moon crosses the equator. The HW inequality or LW inequality should be made to change sign whenever either passes through zero. The following process may be employed:

Plot the numerically greater inequality, and thus determine when it becomes zero. The equation of this straight line may be written

$$y = mt \tag{132}$$

The lesser inequality when plotted will approximately follow a straight line whose equation is

$$\frac{t}{a} + \frac{y}{b} = 1 \tag{133}$$

The sum of the squares of the two y's becomes a minimum when

$$t = \frac{b^2\, a}{a^2 m^2 + b^2} \tag{134}$$

If the speed of the diurnal wave is less than m_1, prefix the minus sign to the minimum range.

The minimum ranges should be taken in pairs in order to eliminate Q_1 from O_1.

37. *Moon far north or south.*

The uncorrected age of the diurnal inequality having been found, increase the times of extreme declination thereby, thus obtaining the times when the amplitude of the diurnal wave becomes a maximum. At these times tropic tides occur; in the reduction, one or two or more high waters and as many low waters are taken on either side of each time. It may be noted that for any one determination of the quantities directly connected with the tropic tides, the lunitidal intervals having approximately equal values should be written in the same column. From a reduction of the high waters and of the low waters, according to the accompanying form, the following uncorrected quantities are obtained:

Intervals, heights, Gc, Sc, Mc, $\overline{\text{HWQ}}$*, LWQ.

Both heights and intervals of the great tropic tides can always be obtained from the reductions; but the small tropic tides can not be so obtained where evanescent tides occur. At such places Sc may be roughly inferred from the equation

$$\text{Gc} + \text{Sc} = 2\ \text{Mn}.$$

The tropic range of the diurnal wave for a given time becomes approximately known by the formula

$$2\,D_1 = \sqrt{\overline{\text{HWQ}}^2 + \overline{\text{LWQ}}^2}. \tag{137}$$

The amplitude D_2 of the semidiurnal wave when the moon is far from the equator is approximately equal to

$$\tfrac{1}{2}\,\text{Mc} - \tfrac{1}{8}\,\frac{D_1^2}{\text{Mc}} \tag{138}$$

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* It is here supposed that LWQ > HWQ. $\overline{\text{HWQ}}$ indicates merely that the order of taking the tropic higher high and lower high water, has remained the same throughout the series.

At stations where the order of the high waters, say, is sometimes reversed, even when the moon is far from the equator, a period of six months, or some multiple thereof, should be used in finding HWQ and X, § 21. These quantities are reduced to their mean values by Chapter IV.

When a short series is used, X and HWQ should be computed from $P_1 = 0.331\ K_1$, §§ 39, 40, and the corrected $\overline{\text{HWQ}}$, by means of the formulæ

$$\text{Cos X } 180^\circ = \frac{\overline{\text{HWQ}}}{2\,P_1}, \tag{135}$$

$$\text{HWQ} = 2\,P_1\,[(1-2\,\text{X})\cos \text{X } 180^\circ + \frac{2}{\pi}\sin \text{X } 180^\circ] \tag{136}$$

where Mc is the mean of Gc and Sc. If Mc is poorly determined, the formula

$$D_2 = 0{\cdot}44\ Mn - 0{\cdot}06\ \frac{D_1^2}{Mn} \qquad (139)$$

should be used.

Having found D_2, two ratios are obtained by dividing $\overline{HWQ}$ and LWQ by 2 D_2. The intersection of two curves upon Plate III which correspond to these ratios gives an amplitude (in terms of D_2) and a HW phase.

Stations where the tide is usually diurnal.—The quantities to be obtained from the reduction are the intervals (properly distinguished) and the heights of the tropic tides; also, approximately, mean sea level and the mean semidaily range of tide. For most stations, the two latter quantities can be found whenever the moon is near the equator, and especially about the times of the equinoxes. From these results are determined the ratio Gc ÷ Mn, the duration of the great tropic range (always taken to be less than a half lunar day), and whether the tropic high or tropic low water, departs farther from mean sea level. By means of Table 20 an amplitude and HW phase become known.

Rule for distinguishing between the qurdrants:

Sequence HHW to LLW	Interval (HW or LW) marked (*a*)	HW phase falls in	1st quadrant.
	" " " (*b*)	"	" " 3d "
Sequence LLW to HHW	HW interval marked (*a*)	"	" " 4th "
	LW (*b*)	"	" " " "
	HW interval marked (*b*)	"	" " 2d "
	LW (*a*)	"	" " " "

It is assumed that the HW interval is taken approximately equal to $M_2°/29$ and the LW interval, to $M_2°/29 + 6^h$; also that the mean intervals have the marks (*a*, *b*) belonging to the intervals of the great tropic tides, § 53.

38. *Example.*

Declinational reductions for a month's observations at Sitka, Alaska, are given below:

Sitka, Alaska, 1893.

Minimum diurnal tide.

	h.	m.
Longitude of ephemeris (*E*)	0	00 W.
Longitude of time meridian (*S*)	9	01 "
E − *S* =	− 9	01

Moon on equator $+E-S$.		Time. HW			Average.			Time. LW			Average.			Height. HW	Height. LW	Inequality. HW	Inequality. LW	Time and value of minimum range.
d.	*h.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*	*d.*	*h.*	*m.*	*Feet.*	*Feet.*			
		3	15	58				3	9	25				12·8	4·0			
		4	3	12				3	21	14				13·2	7·8	+0·4	−3·8	
		4	16	37				4	9	54				12·9	4·3	+0·3	−3·5	
		5	4	05				4	22	10				12·5	7·6	−0·4	−3·3	
		5	17	23				5	10	27				13·2	5·0	−0·7	−2·6	
July 5	17·9	6	5	09	5	23	16	5	23	23	5	16	55	12·0	7·2	−1·2	−2·2	
		6	18	03				6	11	14				13·6	5·9	−1·6	−1·3	July 6, 8h
		7	6	22				7	0	32				11·4	6·6	−2·2	−0·7	" 5, 18
		7	18	46				7	12	18				14·0	6·7	−2·6	+0·1	14 = age.
		8	7	49				8	1	49				11·2	5·8	−2·8	+0·9	Range = 2·20
		16	1	56				15	20	13				16·3	7·8			
		16	15	19				16	8	46				15·1	3·6	+1·2	−4·2	
		17	2	50				16	21	04				15·7	7·9	+0·6	−4·3	
		17	15	59				17	9	31				14·7	4·3	+1·0	−3·6	
		18	3	47				17	21	47				14·0	7·3	−0·7	−3·0	
July 18	9·3	18	16	38	18	10	12	18	9	56	18	3	52	14·2	5·0	−0·2	−2·3	July 19, 6h
		19	4	40				18	22	50				12·7	7·0	−1·5	−2·0	" 18, 9
		19	17	22				19	10	35				13·8	5·9	−1·1	−1·1	21 = age.
		20	5	40				20	0	00				11·6	6·8	−2·2	−0·9	Range = 1·60
		20	18	08				20	11	21				13·7	7·1	−2·1	+0·3	

Uncorrected age = ½ (14 + 21) = 17·5
Average date of moon on equator + age = July 12
Minimum range = 1·90

Sitka, Alaska, 1893.

Tropic high waters.

	h.	m.
Longitude of ephemeris (E)	0	00 W.
Longitude of time meridian (S)	9	01 "
$E - S =$	9	01

From first reduction, July 1–29, 1893: Mean interval = $9^h\ 45^m$.
From phase reduction: $S_2 = (5) - 0{\cdot}01\ Mn = 0{\cdot}781$ foot; $r\ (S_2;\ M_2) = 26^h{\cdot}5$.

Moon.						Time of high water.			Lunitidal interval.			Height.			
Extreme declination. $+ E - S + 17^h{\cdot}5$.			Transit.						u n, l s, or		l n, u s.		For H H W.	Corr'n.	For L H W.	Corr'n.
			Time.			Kind.										
	d.	h.	d.	h.	m.		d.	h.	m.	h.	m.	h.	m.	Feet.		Feet.	
			11	9	55	u n	11	22	29	12	34			15·7	— ·60 S_2		
July	12 N.	17·4	11	22	28	l n	12	12	17			13	49			12·9	— ·75 S_2
			12	11	01	u n	12	23	26	12	25			16·1	— ·83		
			12	23	34	l n	13	13	09			13	35			13·5	— ·90
			25	9	19	l s	25	22	20	13	01			14·1	— ·15		
July	26 S.	13·7	25	21	45	u s	26	12	08			14	23			12·7	— ·36
			26	10	11	l s	26	23	02	12	51			15·3	— ·52		
			26	22	37	u s	27	12	45			14	08			13·2	— ·68
										4		4		4	4	4	4
										49	111	54	115	61·2	—2·10	52·3	—2·69
						Mean				12	43	13	59	15·30	— ·52	13·08	— ·67
						Corrected for phase				12	15	13	31	14·89		12·56	

Sitka, Alaska, 1893.

Tropic low waters.

	h.	m.	
Longitude of ephemeris	(E)	0	00 W
Longitude of time meridian	(S)	9	01 "
$E - S =$		-9	01

Moon.					Time of low water.			Lunitidal interval.			Height.			
Extreme declination $+E-S+17^{\circ}5^{b}$.		Transit.						u n, l s, or	l n, u s.		For L L W.	Corr'n.	For H L W.	Corr'n.
		Time.			Kind.									
d.	*h.*	*d.*	*h.*	*m.*		*d.*	*h.*	*m.*	*h.* *m.*	*h.* *m.*	*Feet.*		*Feet.*	
		11	9	55	u n	11	16	36		6 41			8·4	+ ·53 S_2
July 12 N.	17·4	11	22	28	l n	12	5	40	7 12		2·1	+ ·69 S_2		
		12	11	01	u n	12	17	29		6 28			8·0	+ ·79
		12	23	26	l n	13	6	28	6 54		1·9	+ ·87		
		25	9	19	l s	25	16	34		7 15			9·2	+ ·05
July 26 S.	13·7	25	21	45	u s	26	5	27	7 42		4·6	+ ·27		
		26	10	11	l s	26	17	04		6 53			9·6	+ ·44
		26	22	37	u s	27	6	11	7 34		4·7	+ ·60		
									h m	h m	ft		ft	
									27 142	25 137	13·3	+2·43	35·2	+1·81
					Mean				7 20	6 49	3·32	+ ·61	8·80	+ ·45
					Corrected for phase				6 52	6 21	3·80		9·15	
					Mean of tropic ints. =				10 13					
					" int. first red'n =				9 45					
					Diff. =				28					

Average date of extreme declination + age = July 20
Great tropic range = 11·09
Small tropic " = 3·41
High water inequality = 2·33
Low " " = 5·35

39. *Treatment of declinational reduction results.*

STATION.

Declnational tides.

Amplitude relations.

(1) Minimum semirange of diurnal wave from reduction.
(2) $F(K_1)$, Table 10; c_1, Table 31. For av. time of min. diurnal tides.
(3) $\overline{HWQ}$ from reduction.
(4) LWQ " "
(5) (3) × group factor.
(6) (4) × " "
(6′) Gc from reduction $+ \frac{1}{2}[(5) + (6) - (3) - (4)]$.
(6″) Sc " " $- \frac{1}{2}[(5) + (6) - (3) - (4)]$.
(6‴) Tropic LLW from reduction $- \frac{1}{2}[(6) - (4)]$.
(7) $\sqrt{(5)^2 + (6)^2} =$ approx. $2\,D_1$.
(8) $0{\cdot}88\,Mn - 0{\cdot}03\frac{(7)^2}{Mn} = 2\,D_2$.
(9) $\frac{(5)}{(8)} = \frac{\overline{HWQ}}{2\,D_2}$.
(10) $\frac{(6)}{(8)} = \frac{LWQ}{2\,D_2}$.
(11) Amplitude and HW phase from Table 19.
(12) $F(K_1)$, $F(O_1)$, Table 10; c_{11}, Table 31. For av. time of tropic tides.
(13) $\frac{(1) + (11)}{c_1 + c_{11}} = K_1'$
(14) $\frac{c_1(11) - c_{11}(1)}{c_1 + c_{11}} = O_1'$
(15) $K_1' \times F(K_1) = K_1$.
(16) $O_1' \times F(O_1) = O_1$.
(17) I and $F(Mn)$ for middle of series, Tables 6, 14.
(18) Mn from first reduction.
(19) (18) × $F(Mn) = Mn$
(20) $\frac{S_2}{\frac{1}{3}Mn}, \frac{K_1 + O_1}{\frac{1}{3}Mn}$.
(21) Tabular value, Table 23.
(22) $\frac{1}{2}$ (19) × (21) $= (1 + \varepsilon)\,M_2$.

Nonharmonic quantities (see Chapter IV).

$$\frac{1{\cdot}02\,(K_1 + O_1)}{c_{11}\,K_1{}^1 + O_1{}^1} = 1{\cdot}02\,F_1$$

(5) × $1{\cdot}02\,F_1 = \overline{HWQ}$. (6) × $1{\cdot}02\,F_1 =$ LWQ

[tropic HHWI from reduction — HWI*] × $1{\cdot}02\,F_1$ + HWI† = tropic HHWI.
[tropic LHWI from reduction — HWI] " " = tropic LHWI.
[tropic LLWI from reduction — LWI] " LWI = tropic LLWI.
[tropic HLWI from reduction — LWI] " " = tropic HLWI.
$[(6') - (18)] \times 1{\cdot}02\,F_1 + (19) =$ Gc.
$[(6'') - (18)]$ " " = Sc.
[Gt from first reduction — (18)] × $1{\cdot}02\,F_1$ + (19) = Gt.
2 (19) — Gt = Sl.
Mean LW from first reduction $- \frac{1}{2}[(19) - (18)] =$ LW.
[(6‴) — mean LW from first reduction] × $1{\cdot}02\,F_1$ + LW = tropic LLW.
[LLW from first reduction — mean LW from first reduction] × $1{\cdot}02\,F_1$ + LW = LLW.

Epoch relations.

(23) Age from reduction (hours).
(24) (23) × 1·098 = approx. $(K_1° - O_1°)$.
(25) (24) + acc. in K_1 due to P_1, Table 31, $= K_1° - O_1°$.
0·911 $(K_1° - O_1° = \tau\,(O_1; K_1))$.
(26) Mean lunitidal interval exceeds mean tropic interval (minutes).
(27) (26) × 0·483.
(28) 2 HW phase from amplitude relations.
(29) (27) + (28) — acc. in K_1 due to P_1, Table 31, $= M_2° - K_1° - O_1°$.
(30) $\frac{M_2° + (25) - (29)}{2} = K_1°$.
(31) $\frac{M_2° - (25) - (29)}{2} = O_1°$

* Not corrected by (125). † Corrected by (125).

SITKA, ALASKA, 1893.

Declinational tides, July, 1893.

Amplitude relations.

(1) 0·95.

(2) $F(K_1) = 0{\cdot}905$, $c_1 = 1.243$; July 12.

(3) 2·33.

(4) 5·35.

(5) $2{\cdot}33 \times 1{\cdot}01 = 2{\cdot}353$.

(6) $5{\cdot}35 \times 1{\cdot}01 = 5{\cdot}404$.

(6′) $11{\cdot}09 + \frac{1}{3}[0{\cdot}077] = 11{\cdot}13$.

(6″) $3{\cdot}41 - \frac{1}{3}[0{\cdot}077] = 3{\cdot}37$.

(6‴) $3{\cdot}81 - \frac{1}{3}[0{\cdot}054] = 3{\cdot}783$.

(7) $\sqrt{2{\cdot}353^2 + 5{\cdot}404^2} = \sqrt{34{\cdot}740} = 5{\cdot}894$.

(8) $0{\cdot}88 \times 7{\cdot}31 - 0{\cdot}03\,\frac{34{\cdot}740}{7{\cdot}31} = 6{\cdot}433 - 0{\cdot}143 = 6{\cdot}290 = 2\,D_2$.

(9) $\frac{2{\cdot}353}{6{\cdot}290} = 0{\cdot}374$.

(10) $\frac{5{\cdot}404}{6{\cdot}290} = 0{\cdot}859$.

(11) $D_1 = 0{\cdot}945\,D_2 = 2{\cdot}972$, HW phase $= 246{\cdot}1$.

(12) $F(K_1) = 0{\cdot}905$, $F(O_1) = 0{\cdot}854$, $c_{11} = 1{\cdot}196$; July 20.

(13) $\frac{3{\cdot}922}{2{\cdot}439} = 1{\cdot}608 = K_1'$

(14) $\frac{2{\cdot}558}{2{\cdot}439} = 1{\cdot}049 = O_1'$

(15) $1{\cdot}608 \times 0{\cdot}905 = 1{\cdot}455 = K_1$.

(16) $1{\cdot}049 \times 0{\cdot}854 = 0{\cdot}896 = O_1$.

(17) $I = 28{\cdot}23$, $F(Mn) = 1{\cdot}022$; July 15.

(18) 7·31.

(19) $7{\cdot}31 \times 1{\cdot}022 = 7{\cdot}471 = Mn$.

(20) $\frac{1{\cdot}053}{3{\cdot}736} = 0{\cdot}28$, $\frac{2{\cdot}351}{3{\cdot}736} = 0{\cdot}63$.

(21) 0·949.

(22) $3{\cdot}736 \times 0{\cdot}949 = 3{\cdot}545 = (1 + \varepsilon)\,M_2 = 1{\cdot}02\,M_2$; $\therefore 3{\cdot}476 = M_2$.

Nonharmonic quantities.

$$\frac{1{\cdot}02\,(1{\cdot}455 + 0{\cdot}896)}{1{\cdot}196 \times 1{\cdot}608 + 1{\cdot}049} = 1{\cdot}02\left(\frac{2{\cdot}351}{2{\cdot}972}\right) = 1{\cdot}02 \times 0{\cdot}791 = 0{\cdot}807.$$

$2{\cdot}353 \times 0{\cdot}807 = 1{\cdot}899 = HWQ$. $5{\cdot}404 \times 0{\cdot}807 = 4{\cdot}361 = LWQ$.

[12 15 — 12 54] × 0·807 = — 31. — 31 + 12 35 = 12 04 = tropic HHWI.

[13 31 — 12 54] × 0·807 = + 30. + 30 + 12 35 = 13 05 = tropic LHWI.

[6 52 — 6 36] × 0·807 = + 13. + 13 + 6 17 = 6 30 = tropic LLWI.

[6 21 — 6 36] × 0·807 = — 12. — 12 + 6 17 = 6 05 = tropic HLWI.

[11·13 — 7·31] × 0·807 = + 3·083. + 3·083 + 7·471 = 10·55 = Gc.

[3·37 — 7·31] × 0·807 = — 3·180. — 3·180 + 7·471 = 4·29 = Sc.

[10·07 — 7·31] × 0·807 = + 2·227. + 2·227 + 7·471 = 9·70 = Gt.

14·94 — 9·70 = 5·24 = Sl.

$6{\cdot}27 - \frac{1}{3}[7{\cdot}47 - 7{\cdot}31] = 6{\cdot}19 = LW$.

[3·783 — 6·27] × 0·807 = — 2·007. — 2·01 + 6·19 = 4·18 = tropic LLW.

[4·41 — 6·27] × 0·807 = — 1·501. — 1·50 + 6·19 = 4·69 = LLW.

Epoch relations.

(23) 17·5.

(24) $17{\cdot}5 \times 1{\cdot}098 = 19{\cdot}2$.

(25) $19{\cdot}2 + (-8{\cdot}6) = 10{\cdot}6$, July 12.

$0{\cdot}911 \times 10{\cdot}6 = 9{\cdot}7 = \tau\,(O_1; K_1)$.

(26) — 28.

(27) $-28 \times 0{\cdot}483 = -13{\cdot}5$.

(28) $2 \times 246{\cdot}0 = 492{\cdot}0$.

(29) $-13{\cdot}5 + 492{\cdot}0 - (-11{\cdot}6) = 490{\cdot}1$, July 20.

(30) $\frac{3{\cdot}4 + 10{\cdot}6 - 490{\cdot}1}{2} = -238{\cdot}0 = 122{\cdot}0 = K_1{}^0$.

(31) $\frac{3{\cdot}4 - 10{\cdot}6 - 490{\cdot}1}{2} = --248{\cdot}6 = 111{\cdot}4 = O_1{}^0$.

40. *Inferred amplitudes and epochs of components.*

Component.	Amplitude.	Epoch.
K_2	0·272 S_2	$M_2° + 1·098\,\tau\,(S_2;\ M_2)$
L_2	0·145 N_2	$M_2° + 0·544\,\tau\,(N_2;\ M_2)$
ν_2	0·194 N_2	$M_2° - 0·472\,\tau\,(N_2;\ M_2)$
2N	0·133 N_2	$M_2° - 1·089\,\tau\,(N_2;\ M_2)$
P_1	0·331 K_1	$K_1° - 0·082\,\tau\,(O_1;\ K_1)$
Q_1	0·194 O_1	$K_1° - 1·642\,\tau\,(O_1;\ K_1)$
T_2	0·059 S_2	$M_2° + 975\,\tau\,(S_2;\ M_2)$
M_4	$\frac{1}{8}$ M_2 (duration fall $\sim 6^h·21$)	$2\,M_2° \mp 90°$ *
$(MS)_4$	$M_4 \times \frac{2\,S_2}{M_2}$	$M_4° + S_2° - M_2°$

$$K_2° = M_2° + 1·081\ (S_2° - M_2°)$$
$$L_2° = 2\,M_2° - N_2°$$
$$\nu_2° = M_2° - 0·868\,(M_2° - N_2°)$$
$$(2N)° = 2\,N_2° - M_2°$$
$$P_1° = K_1° - 0·075\,(K_1° - O_1°)$$
$$Q_1° = K_1° - 1·495\,(K_1° - O_1°)$$
$$T_2° = M_2° + 0·960\ (S_2° - M_2°)$$
$$M_4° = 2\,M_2° \mp 90°\ *$$
$$(MS)_4° = M_4° + S_2° - M_2°$$

41. *Collection of results, Sitka, Alaska.*

	From 29 days' high and low water, July 1–29, 1893.		From harmonic analysis of hourly ordinates 1 year, 1893–94.	
	Amplitude.	Epoch.	Amplitude.	Epoch.
	Feet.	°	*Feet.*	°
K_1	1·46	122	1·51	125
K_2	0·29	32	0·32	20
L_2	0·12	28	0·31	35
M_2	3·48	3·4	3·58	2·6
N_2	0·80	339	0·69	338
2N	0·11	314		
O_1	0·90	111	0·91	106
P_1	0·48	121	0·46	123
Q_1	0·17	106	0·14	106
S_2	1·05	30	1·14	34
ν_2	0·16	342	0·06	295

From 29 days' high and low water, July 1–29, 1893.

	h.	*m.*		*Feet.*
HWI	0	10	Mn	7·47
LWI	6	17	Gc	10·55
Tropic HHWI	—0	21 *b*	Sc	4·29
Tropic LHWI	0	40 *a*	Gt	9·70
Tropic LLWI	6	30 *b*	Sl	5·24
Tropic HLWI	6	05 *a*	Sg	9·59
Age of phase inequality	26		Np	5·52
Age of parallax inequality	45		Pn	8·67
Age of diurnal inequality	10		An	5·83
			HWQ	1·90
			LWQ	4·36
			LW (on staff)	6·19
			Tropic LLW (on staff)	4·18
			Mean LLW (on staff)	4·69

* Use $\overset{\text{upper}}{\text{lower}}$ sign when duration of fall $\gtrless 6^h·21$. The determination of M_4 in this manner is necessarily rough.

DATUM PLANES.

42. *To determine a plane of reference, having a given definition with respect to the tide, when only a few observations are available.*

It is here supposed that observations, or more likely predictions, simultaneous with the observations in question are given for a neighboring principal station having a similar type of tide; it is also supposed that the observations or predictions at the principal station have been reduced to a plane of reference having the required definition.

Determine from the observed heights at the subordinate station a plane approaching the one which definition would require. Call this the approximate plane and let h denote its height above the required plane. Find a range of tide by taking the mean of all observed low waters from the mean of all observed high waters.

Let H denote the height of the tides at the principal station which correspond to the tides used in determining the approximate plane at the subordinate station. Let

$$r = \frac{\text{observed range at subordinate station}}{\text{corresponding range at principal station}}; \tag{140}$$

then

$$h = r\,H. \tag{141}$$

The more nearly r remains constant, the better the selection of the neighboring principal station.

As a general rule field parties are supplied with tide tables giving predictions for the time in question. Now, unless the predicted heights are referred to a plane of reference having the same tidal definition as the one to be determined, they must be reduced to such a plane by adding a constant which we must suppose to be given in the tide tables. To dispense with this labor, predictions and soundings should be referred to planes having uniform definitions over a considerable area. To avoid confusion, which is sure to result near the limits of each such area, one definition should be used the world over.

43.* *To determine mean sea level from one month's observations.*—Use the period of 29 solar days. Take the mean of average high and average low water, or the mean of the hourly ordinates if a continuous record be available.

To determine mean low water from one month's observations.—Use the period of 29 solar days. Find the mean range of tide and mean low water for this period. Reduce this range by the factor F (Mn), Table 14. Depress the observed mean low water by

$$\tfrac{1}{2}\,(\text{mean range} - \text{observed mean range}). \tag{143}$$

The value of $(K_1 + O_1)/M_2$ which is needed in Table 14 may be inferred from some neighboring station with sufficient accuracy for the present purpose, or it may be found by means of § 44.

To determine mean lower low water from one month's observations.—Use the period of 27 solar days, i. e. a declinational month. Mark the lower low water of each day, and take the mean of the values so marked. Subtract this value from mean low water as determined from the 29-day period, and multiply the result by the factor 1·02 F_1, Table 32. Depress the corrected mean low water by the quantity just obtained, and the result will be mean lower low water.

This plane of reference is unsatisfactory in accurate work, because no one reducing factor, like F_1, applies well to all stations. This is especially true where the low water inequality (LWQ) is small in comparison with the high water inequality (HWQ).

44. *To determine the harmonic or Indian tide plane.*

This plane is, by definition,

$$M_2 + S_2 + K_1 + O_1 \tag{144}$$

*To correct the planes of reference mentioned in this paragraph for the annual and semiannual components, depress the observation result by

$$Sa\cos(h - Sa^\circ) + Ssa\cos(2h - Ssa^\circ) \tag{142}$$

where h is the mean longitude of the sun, Table 29. The amplitudes and epochs of these components may be taken from a neighboring station.

feet below mean sea level as determined from hourly ordinates. Usually it nearly coincides with what might be called the tropic lower low water springs. At stations where harmonic analyses are available the depression of this plane below mean sea level becomes known at once.

Where harmonic analyses are not available a month's observations upon high and low water may be used, as indicated below, for determining the required plane:

Select a time near each extreme declination of the moon when the sum of the high and low water inequalities is a maximum. Denoting these inequalities by HWQ and LWQ, the tropic range of the diurnal wave for the series is, approximately,

$$2\,D_1 = \sqrt{HWQ^2 + LWQ^2}\ ; \tag{145}$$

$$\therefore\ K_1 + O_1 = D_1 \times F_1\ , \tag{146}$$

Table 32.

From the observations determine spring and neap ranges, denoting them by Sg and Np; then

$$S_2 = \tfrac{1}{4}\,(Sg - Np)\left(1{\cdot}02 + 0{\cdot}04\,\frac{HWQ^2 + LWQ^2}{Mn^2}\right) F_2 - 0{\cdot}01\ Mn\ . \tag{147}$$

M_2 is obtained directly from Mn; i. e. the mean range from first reduction $\times\ F$ (Mn), Table 23. The quantities M_2, S_2, and $K_1 + O_1$, taken in connection with mean sea level as determined by the preceding paragraph, determine the required plane. This plane is in quite extensive use under the name of low water springs or Indian low water springs. It has the convenience of being so low that comparatively few low water heights are negative.

45. *Stations where the tides are usually diurnal.*

When possible, mean sea level should be determined from hourly ordinates. If determined from high and low waters, they should be taken in pairs, so that each high water taken shall be accompanied by an adjacent low water having approximately the same displacement from mean sea level. Mean low water (semidiurnal) is here of no consequence as a plane of reference. The correction for annual and semiannual components is made as in § 43.

The semidaily amplitude of tide when the moon is near the equator is, approximately,

$$1{\cdot}1\ M_2 + \text{correction for phase, Table 24.} \tag{148}$$

S_2 may be assumed to be

$$M_2\,\frac{S_2 \text{ at neighboring station}}{M_2 \text{ at neighboring station}}\ . \tag{149}$$

From the observed tropic range we have

$$K_1 + O_1 = \left[\frac{Gc}{2} - 2\,\frac{(M_2^2 + S_2^2)}{Gc}\right] \times F_1 \tag{150}$$

[obtained by aid of formulæ (65), (73), and (122)].

Having in this manner found M_2, S_2, and $K_1 + O_1$ from, say, one month's observations, the Indian tide plane becomes approximately known.

FERREL'S EXPRESSIONS FOR INEQUALITIES IN THE TIDE.

46. If the lunitidal intervals and heights be classified according to an argument x whose period is that of some tidal inequality, the resulting interval and amplitude may, according to Fourier's theorem, be written

$$B_0 + M_i' \sin x + N_i' \cos x + M_{ii}' \sin 2\,x + N_{ii}' \cos 2\,x + \ .\ .\ . \tag{7) (151}$$

$$\tfrac{1}{2}\,Mn + M_i \cos x + N_i \sin x + M_{ii} \cos 2\,x + N_{ii} \sin 2\,x + \ .\ .\ . \tag{4) (152}$$

where B_0 denotes the mean lunitidal interval, Mn the mean range of tide, and i the characteristic of the inequality. These expressions may be written in the form

$$B_0 + B_i \sin (x - \epsilon_i) + B_{ii} \sin (2\,x - \epsilon_{ii}) + \ .\ .\ . \tag{7) (153}$$

$$\tfrac{1}{2}\,Mn\,[1 + R_i \cos (x - \alpha_i) + R_{ii} \cos (2\,x - \alpha_{ii}) + \ .\ .\ .] \tag{1) (154}$$

where

$$B_i = \pm\sqrt{M_i'^2 + N_i'^2} = \frac{M_i'}{\cos\varepsilon_i},\quad B_{ii} = \pm\sqrt{M_{ii}'^2 + N_{ii}'^2} = \frac{M_{ii}'}{\cos\varepsilon_{ii}},\quad \ldots,$$
$$\tan\varepsilon_i = -\frac{N_i'}{M_i'},\qquad \tan\varepsilon_{ii} = -\frac{N_{ii}'}{M_{ii}'},\qquad \ldots; \qquad (8)\ (155)$$

$$\tfrac{1}{2}\,\mathrm{Mn}\,R_i = \pm\sqrt{M_i^2 + N_i^2} = \frac{M_i}{\cos\alpha_i},\quad \tfrac{1}{2}\,\mathrm{Mn}\,R_{ii} = \pm\sqrt{M_{ii}^2 + N_{ii}^2} = \frac{M_{ii}}{\cos\alpha_{ii}},\quad \ldots,$$
$$\tan\alpha_i = \frac{N_i}{M_i},\qquad \tan\alpha_{ii} = \frac{N_{ii}}{M_{ii}}\qquad \ldots. \qquad (5)\ (156)$$

In reducing tides, the observations are taken in groups. For this reason the coefficients B_i, R_i, and B_{ii}, R_{ii} as determined above should be multiplied by the factors (a little greater than unity,)

$$\frac{x_q - x_p}{2\sin\frac{1}{2}(x_q - x_p)} \text{ and } \frac{x_q - x_p}{\sin(x_q - x_p)}$$

where x_p and x_q are the values of x at the two limits of the group of observations.

ε_i and α_i denote the epoch or lag of the principal term in the expression for any inequality. These divided by the "speed" of the inequality (i. e. the change in x per mean solar hour, say) give the "age of the tide" from times and heights, respectively. In all cases we shall assume that x corresponds to the hour of (local) transit of the moon, or to the moon's anomaly, longitude, etc., as the case may be, and not to the time of high water, low water, or a mean of these times; otherwise the value of x would correspond to a time a constant amount in advance or in retard of the moon's transit or other astronomical argument. Ferrel adopted this assumption in his "Discussion of tides in New York Harbor."* In earlier papers, notably in his "Discussion of tides in Boston Harbor"† and in his "Tidal researches,"‡ he has not corrected the ε's and α's for the lunitidal interval. To make this correction, add the value of the lunitidal interval multiplied by the speed of the inequality when the ε's and α's are affected with one subscript; use twice this speed when there are two subscripts, and so on.

47. *To express Ferrel's constants in the harmonic notation.*

For most inequalities this is not an easy matter, especially if much accuracy is required. The chief difficulties are, first, the inequality may be due to several components; second, the argument x may not vary uniformly with the time. The work given below will illustrate some simple cases.

Inequality due to a single component B.—From § 2 we have

$$\tan v = \frac{a}{b}\,\frac{\frac{B\,b^2}{A\,a^2}\sin(x-\theta)}{1 + \frac{B\,b^2}{A\,a^2}\cos(x-\theta)} \qquad (157)$$

where

$$\theta = B^\circ - A^\circ,$$
$$x = (b-a)\,t,$$
$$t = \frac{2\,n\,\pi}{a} - \frac{\alpha}{a} = \text{the time of a high water of } A \text{ reckoned}$$

from the conjunction of the fictitious moons of A and B, expressed in hours.

If

$$\tan v' = \frac{e\sin(x-\theta)}{1 + e\cos(x-\theta)}$$

where e is a constant less than unity, then

$$v' = e\sin(x-\theta) - \tfrac{1}{2}e^2\sin 2(x-\theta) + \tfrac{3}{8}e^3\sin 3(x-\theta) - \ldots$$
$$= e\cos\theta\sin x - e\sin\theta\cos x - \frac{e^2}{2}\cos 2\theta\sin 2x + \frac{e^2}{2}\sin 2\theta\cos 2x + \ldots \qquad (158)$$

* United States Coast Survey Report for 1875. This discussion, because of its comparative clearness and consistency, will be referred to in preference to his other works. The left-hand numbers in the above expressions refer to corresponding expressions in the "Discussion of tides in New York Harbor."

† United States Coast Survey Report, 1868.

‡ Ibid., 1874, Appendix.

when v is small, and especially when a is nearly equal to b,

$$\frac{v}{a} = \frac{1}{b}\left[e\cos\theta\sin x - e\sin\theta\cos x - \frac{e^2}{2}\cos 2\theta\sin 2x + \frac{e^2}{2}\sin 2\theta\cos 2x + \ . \ . \ . \right] \quad (159)$$

$$= -\left[M_i'\sin x + N_i'\cos x + M_{ii}'\sin 2x + N_{ii}'\cos 2x + \ . \ . \ . \right] \quad (160)$$

where

$$M_i' = -\frac{e}{b}\cos\theta = -\frac{B\,b}{A\,a^2}\cos(B^\circ - A^\circ),$$

$$N_i' = \frac{e}{b}\sin\theta = \frac{B\,b}{A\,a^2}\sin(B^\circ - A^\circ),$$

$$M_{ii}' = \frac{e^2}{2\,b}\cos 2\theta = \frac{B^2\,b^3}{2\,A^2\,a^4}\cos 2(B^\circ - A^\circ),$$

$$N_{ii}' = -\frac{e^2}{2\,b}\sin 2\theta = -\frac{B^2\,b^3}{2\,A^2\,a^4}\sin 2(B^\circ - A^\circ),$$

. . . . . .

Assuming the decrease of interval to be

$$\frac{v}{a} = -\left[B_i\sin(x - \varepsilon_i) + B_{ii}\sin(2x - \varepsilon_{ii}) + \ . \ . \ . \right], \quad (161)$$

then

$$B_i = \pm\sqrt{M_i'^2 + N_i'^2} = \frac{M_i'}{\cos\varepsilon_i} = -57{\cdot}3\,\frac{B\,b}{A\,a^2}\text{ hours},$$

$$B_{ii} = \pm\sqrt{M_{ii}'^2 + N_{ii}'^2} = \frac{M_{ii}'}{\cos\varepsilon_{ii}} = 57{\cdot}3\,\frac{B^2\,b^3}{2\,A^2\,a^4}\text{ hours}, \quad (162)$$

. . . . . .

$$\tan\varepsilon_i = -\frac{N_i'}{M_i'};\ \varepsilon_i = \theta = B^\circ - A^\circ, \text{ a small angle},$$

$$\tan\varepsilon_{ii} = -\frac{N_{ii}'}{M_{ii}'};\ \varepsilon_{ii} = 2\theta = 2(B^\circ - A^\circ), \text{ a small angle}, \quad (163)$$

. . . . . .

For a case as simple as this, the auxiliary quantities M_i', N_i', . . . are introduced merely for the purpose of illustration.

From § 3 we have

$$y = A + B\cos(x - \theta) + B\,\frac{b}{a}\tan v\sin(x - \theta) - \tfrac{1}{2}A\tan^2 v + \ . \ . \ .$$
$$+ \text{residual effects of components not involved in the inequality.} \quad (164)$$

This may be written, without introducing M_i, N_i, . . . ,

$$y = \tfrac{1}{2}\,\mathrm{Mn}\left[1 + R_i\cos(x - \alpha_i) + R_{ii}\cos(2x - \alpha_{ii}) + \ . \ . \ .\right] \quad (165)$$

where

$$R_i = \frac{2\,B}{\mathrm{Mn}},\ R_{ii} = -\frac{B^2\,b^2}{2\,A\,a^2\,\mathrm{Mn}},\ \ . \ . \ .; \quad (166)$$

$$\alpha_i = \theta = B^\circ - A^\circ,\ \alpha_{ii} = 2\theta = 2(B^\circ - A^\circ),\ \ . \ . \ . \quad (167)$$

When an inequality is due to more than one component, the harmonic expressions for B_i, ε_i, R_{ii}, α_i, B_{ii}, . . . become more complicated than those just given. Forms (151) and (152) are, however, sufficiently general to include such cases.

The phase inequality. If A, B denote the components M_2, S_2, and if there be no tide whose speed is a linear function of m_2 and s_2, we have

$$B_1 = -57{\cdot}3\,\frac{S_2\,s_2}{M_2\,m_2^2}\text{hours},\quad B_{11} = 57{\cdot}3\,\frac{S_2^2\,s_2^3}{2\,M_2^2\,m_2^4}\text{ hours},\quad \ldots,$$

$$\varepsilon_1 = S_2^\circ - M_2^\circ\ ,\qquad \varepsilon_{11} = 2\,(S_2^\circ - M_2^\circ),\quad \ldots; \tag{168}$$

$$R_1 = \frac{2\,S_2}{Mn}\ ,\qquad R_{11} = -\frac{S_2^2\,s_2^2}{2\,M_2\,m_2^2\,Mn},\quad \ldots,$$

$$\alpha_1 = S_2^\circ - M_2^\circ\qquad \alpha_{11} = 2\,(S_2^\circ - M_2^\circ),\quad \ldots \tag{169}$$

When μ_2 is taken into account, R_1 becomes

$$\frac{2\,(S_2 + \mu_2)}{Mn}$$

This should be divided by the inequality factor belonging to the phase reduction, § 29.

The parallax inequality. Whatever parallax inequality in time there may be is due chiefly to the transit selected in taking the intervals. The time coefficients B_2, B_{22}, . . . of this inequality ought to be small, and so will not be considered here. In regard to the constants R_2, α_2 it may be noted that an approximate value for y is, § 3,

$$y = A + B\cos(x - \theta) + C\cos(x - \varkappa) + \ldots, \tag{170}$$

and so

$$M_2^* = B\cos\theta + C\cos\varkappa$$

$$N_2^* = B\sin\theta + C\sin\varkappa$$

. . . . . .

$$(\tfrac{1}{2}\,Mn)^2\,R_2^2 = M_2^{2*} + N_2^{2*} = B^2 + C^2 + 2\,B\,C\cos(\theta \sim \varkappa)$$

$$\tan\alpha_2 = \frac{B\sin\theta + C\sin\varkappa}{B\cos\theta + C\cos\varkappa}. \tag{171}$$

When $\theta = \varkappa$ or $\theta = \varkappa \pm 180^\circ$, $R_2 = 2\,(B + C)\,/\,Mn$ or $R_2 = 2\,(B - C)/\,Mn$, respectively. Here N_2, L_2 replace B, C, and θ differs from $\varkappa$ by about 180°.

$$R_2 = \frac{2\,(N_2 - L_2)}{Mn}, \tag{172}$$

$$\theta = M_2^\circ - N_2^\circ,$$

$$\varkappa = L_2^\circ - M_2^\circ \pm 180^\circ.$$

α_2 is found from the above expression for tan α_2. The value of R_2 should be divided by an inequality factor belonging to a parallax reduction where the mean, not the true, perigee is used.

The declinational inequality. The time inequality whose period is a half tropical month, is due to the transit selected and to the sun's declination; it is usually small. The height constants R_3, α_3 have for their approximate values (see § 16)

$$R_3 = \frac{2\,K_2}{Mn} - \frac{K_1\,O_1}{2\,Mn^2}, \tag{173}$$

$$\alpha_3 = K_2^\circ - M_2^\circ.$$

Diurnal tides.—In what has preceded no distinction has been made between the two high waters of a day, or between the two low waters. Let it now be supposed that the differences

* This is an auxiliary quantity, not a harmonic component.

between the high water heights and also between the low water heights have been found for each day. The amplitude of the diurnal wave for any particular day is approximately equal to

$$\tfrac{1}{2}\,[\,(\text{HW inequality})^2 + (\text{LW inequality})^2\,]^{\frac{1}{2}} \qquad (174)$$

Having found this amplitude for each value of the moon's longitude (λ), the constants involved in its expression may be determined. Let us assume the amplitude to be (see Ferrel's New York tides, § 22, l. c.)

$$K_1 + O_1 \sin (2\lambda - \alpha_1') + O_{11} \sin (4\lambda - \alpha_{11}'). \qquad (175)$$

The number of hours by which the maximum amplitude of the diurnal wave follows an extreme declination of the moon is

$$\alpha_1' - 90^\circ, = K_1^\circ - O_1^\circ,$$

divided by $k_1 - o_1$ or 1·098. This is the age of the diurnal inequality.

CHAPTER IV.

TO REDUCE RESULTS TO THEIR MEAN VALUES.

48. All tidal components which depend upon the moon are assumed to have slightly variable amplitudes in order to better adapt them to each year of the luni-solar cycle. The reason for this is that if they had fixed amplitudes many additional components would be necessary to take into account this irregularity of the tide; moreover, these additional components would have periods differing so little from the periods of the components with which they are now combined that a long series of observations would be necessary for their independent determination. Besides accounting for the small components due to the regression of the moon's node, the variation in the amplitudes may be made to take into account still other components whose speeds are nearly equal to the speeds of those components with which they are combined.

The factors F and f, for reducing the amplitudes of the components obtained from a particular series to their mean values and vice versa, are given in Tables 10 and 13, which are based upon, or copied from, the tables given in Baird's Manual for Tidal Observations. In Table 14 are given F for the mean range of tide, for $K_1 + O_1$, and X, based upon the factors of Baird's manual and the mean values of the coefficients as given in Darwin's report (1883). Table 14, for reducing the mean range of tide, may be tested by means of the observed ranges at Boston for the years 1848 to 1865, United States Coast Survey Report, 1868, page 81, Table VIII, last column; also at New York for the years 1856 to 1874, United States Coast Survey Report, 1875, page 198, Table V, eighth column. The ratio $(K_1 + O_1)/M_2$ is about 0·2 at Boston and 0·3 at New York.

49. The following approximate relations will suffice for reducing reduction results to their mean values. In fact, a consideration of the nature of these relations, together with the nature of the F's of the components, of Mn, $K_1 + O_1$, and X, shows that the left-hand part of these relations lies very near to its mean value when the quantities composing the right-hand part have their respective mean values. To reduce a quantity represented by the left-hand part to its mean value, observe the corresponding increase, say, in the right-hand part and apply it to the given quantity, adding or multiplying as the case may be.

$$Sg = Mn + 2S_2. \tag{176}$$

$$Np = Mn - 2S_2. \tag{177}$$

$$Pn = Mn + 2(N_2 - L_2). \tag{178}$$

$$An = Mn - 2(N_2 - L_2). \tag{179}$$

$\overline{HWQ}$, $\overline{LWQ}$, proportional to $K_1 + O_1$. (180)

$$HWQ^* = 2P_1\left[(1 - 2X)\cos X\,180^\circ + \frac{2}{\pi}\sin X\,180^\circ\right] \tag{181}$$

where

$$\cos X\,180^\circ = \frac{\overline{HWQ}}{2P_1}.$$

Mean duration of rise or fall $\sim 6^h.21$, proportional to M_4. (182)

Lunitidal interval for the great or small tropic tides $\sim$ mean lunitidal interval, proportional to $K_1 + O_1$. (183)

Duration of rise or fall for the great or small tropic tides $\sim$ mean duration of rise or fall, proportional to $K_1 + O_1$. (184)

$$Gc = Mn + \tfrac{1}{2}HWQ + \tfrac{1}{2}LWQ. \tag{185}$$

$$Sc = 2Mn - \tfrac{1}{2}HWQ - \tfrac{1}{2}LWQ. \tag{186}$$

$$Gt = \tfrac{3}{4}Gc + \tfrac{1}{4}Mn. \tag{187}$$

$$Sl = \tfrac{7}{4}Mn - \tfrac{3}{4}Gc. \tag{188}$$

Depression of tropic LLW or mean LLW below mean LW, proportional to LWQ. (189)

* This supposes HWQ < LWQ; when LWQ < HWQ, the low water values should replace the high water.

If K_1 and O_1 are each known, the variation in $K_1 + O_1$ should be found by means of Table 10 instead of Table 14. Quantities proportional to $K_1 + O_1$ are obviously reduced to their mean values by the factor

$$\frac{K_1 + O_1}{K_1' + O_1'} \tag{190}$$

where the primes indicate values at a particular time as distinguished from mean values. For a short series P_1 combines with K_1, and the factor becomes

$$\frac{1{\cdot}02\ (K_1 + O_1)}{c_{11}\ K_1' + O_1'} \tag{191}$$

to be computed by aid of Tables 10 and 31, when K_1 and O_1 are known; otherwise it may be taken equal to $1{\cdot}02\ F_1$, Table 32.

CHAPTER V.

ON THE CLASSIFICATION OF TIDES.

50. For places where continuous records of the tides have been obtained for any considerable length of time, it is usually possible to make predictions based upon the analysis of such observations. But any tide table would soon become too bulky and expensive if predictions were to be given in detail for every place where forecasts are desired. It therefore becomes important to find a classification of tides, with the object of referring all stations having similar tides to one principal station where full predictions are given.

The following assumptions implied in the proposed classification hold true, as regards the principal components, for nearly every station where an analysis has been made:

First. The intervals of the $\frac{\text{semidiurnal}}{\text{diurnal}}$ components are approximately equal to one another at any particular station.

Second. The amplitudes of the $\frac{\text{lunar or solar semidiurnal}}{\text{diurnal}}$ components bear approximately the same ratios to one another at all stations.

Granting the truth of these assumptions, the form of the tidal wave depends almost wholly upon

(a) The form of the wave composed of the tropic diurnal wave and the principal lunar semidiurnal component; that is, upon $(K_1 + O_1) / M_2$ and $M_2^\circ - K_1^\circ - O_1^\circ$.

(b) The ratio of the amplitudes of the principal solar and lunar semidiurnal component; that is, upon S_2/M_2.

(c) The form of the lunar semidiurnal wave; that is, upon M_4/M_2, $2\,M_2^\circ - M_4^\circ$, M_6/M_2, $3\,M_2^\circ - M_6^\circ$, where, as is nearly always the case, M_4 and M_6 are the principal harmonics of M_2.

These quantities being equal at two stations, the tides at the one may be inferred from those at the other. Not only are the times and heights of high and low water comparable, but also the height of the sea or tide at any intermediate hour. When only high and low waters are to be compared, the quantities in (c) need not be alike at both stations unless $(K + O_1)/M_2$ is a comparatively large quantity; in which case the form of the lunar semidiurnal wave should be approximately the same at both stations.

51. If nonharmonic constants are used the quantities upon which the form of the tide wave depends are

(a′) The ratios of the high and low water inequalities in height to the mean range of tide, together with the sequence of the four tides of a day; that is, upon HWQ/Mn, LWQ/Mn, and whether the order of the tides is from higher high to lower low, or from lower low to higher high, the moon being far from the equator.

(b′) The ratio of the semimensual height inequality to the mean range of tide; that is, $(Sg - Np)/2\,Mn$.

(c′) The form of the lunar semidiurnal wave. The quantities here selected for determining this are the duration of fall and the heights of the sea referred to high and low waters expressed in terms of the mean range; that is, LWI — HWI, and heights of the sea or tide at various hours before and after high and low water expressed in terms of Mn, when the range has its mean value.

It will be observed that (a′), (b′), and (c′) are nearly equivalent to (a), (b), and (c), respectively, in fixing the form of the tide wave. Whenever the quantities in (a′), (b′), and (c′) are equal at two stations the tides are comparable throughout. If only high and low waters are to be com-

pared, the quantities in (c′) need not to be alike at both stations unless HWQ/Mn or LWQ/Mn is a comparatively large quantity; in which case the form of the lunar semidiurnal wave should be approximately the same at both stations.

At stations where the tide is usually diurnal the height inequalities are not easily determined. The form of tide may be determined from the duration of the (great) tropic range, together with the rise of tropic HHW and the fall of tropic LLW reckoned from mean sea level. The amount of rise compared with the amount of fall shows whether HWQ $\gtrless$ LWQ.

52. The *sequence of the tides* is determined by the following rule:

If the HW phase, i. e. $\frac{1}{2}(M_2° - K_1° - O_1°)$, lie in the first or third quadrant, higher high precedes lower low; if in the second or fourth quadrant, higher high follows lower low. If twice the HW phase is used, it will lie in the first or second semicircle according as higher high precedes or follows lower low.

Having found that the tides at two stations are comparable, the next step is to give rules for referring the one to the other.

The times.—The quantities which must be applied to the times of the tides at the first station to obtain the times of the tides at the second station may be expressed thus:

$$\begin{aligned}\text{Difference for HW} &= (\text{HW})_{,,} - (\text{HW})_{,} = (\text{HWI})_{,,} - (\text{HWI})_{,} + S_{,} - S_{,,} \\ &\quad + 1\tfrac{1}{3\,0}\,(L_{,,} - L_{,}) + n\,(12^h\ 25^m), \\ \text{Difference for LW} &= (\text{LW})_{,,} - (\text{LW})_{,} = (\text{LWI})_{,,} - (\text{LWI})_{,} + S_{,} - S_{,,} \\ &\quad + 1\tfrac{1}{3\,0}\,(L_{,,} - L_{,}) + n\,(12^h\ 25^m);\end{aligned} \tag{192}$$

where $L_{,}$, $L_{,,}$ are the longitudes of the stations and $S_{,}$, $S_{,,}$ the longitudes of the time meridians, all expressed in time and reckoned westward from Greenwich. n ($12^h\ 25^m$) is such a multiple of a half lunar day as will cause the diurnal inequality at the first station to properly reappear at the second. As the form of the tide wave changes slowly from one day to another, n can be so taken as to allow for the change in date which occurs in crossing the Pacific Ocean, at the same time keeping the tidal differences between the limits $-12^h\ 25^m$ and $+12^h\ 25^m$.

When the tidal waves at the two stations are of the same form, the time "difference for HW" is equal to the "difference for LW;" in fact, all like phases of the tide at the two stations are directly comparable by means of this time difference.

The transit.—Rules for computing the high and low water establishments and for determining the sequence of the tides from harmonic constants alone have already been given. The question which now arises is, To which transit must a highwater interval (whose value is nearer $M_2°/28{\cdot}98$ than to $M_2°/28{\cdot}98 \pm 12^h\ 25^m$) be applied in order to obtain a higher high water when the moon's declination is $\begin{matrix}\text{north?}\\ \text{south?}\end{matrix}$ The answer is, $\begin{matrix}\text{an upper}\\ \text{a lower}\end{matrix}$ transit must be used if the HW phase lies in the first or fourth quadrant, and $\begin{matrix}\text{a lower}\\ \text{an upper}\end{matrix}$ if in the second or third quadrant. In order to obtain a lower low water when the moon's declination is $\begin{matrix}\text{north, an upper}\\ \text{south, a lower}\end{matrix}$ transit must be used if the HW phase lies in the first or second quadrant, and $\begin{matrix}\text{a lower}\\ \text{an upper}\end{matrix}$ if in the third or fourth quadrant (supposing the low water interval to be nearer $M_2°/28{\cdot}98 + 6^h\ 13^m$ than to $M_2°/28{\cdot}98 + 6^h\ 13^m \pm 12^h\ 25^m$).

These statements enable one to decide whether n in the above equations is odd or even.

If the intervals at the two stations refer to the same transit, then n = o or some even integer, as -2 or $+2$; if to opposite transits, n = some odd integer, as -1 or $+1$.

53. The following rules are here collected together for convenience of reference:

Sequence of tides.

$0° < M_2° - K_1° - O_1° < 180°$, HHW precedes LLW;
$180° < M_2° - K_1° - O°_1 < 360°$, LLW precedes HHW.

Greater height inequality.

$-90° < M_2° - K_1° - O_1° < 90°$, HWQ > LWQ;
$90° < M_2° - K_1° - O_1° < 270°$, LWQ $\lesssim$ HWQ.

The transit.

		For HHW use	For LHW use
HWI taken approximately equal to $M_2°/29$ hours.	$-90° < \frac{1}{2}(M_2° - K_1° - O_1°) < 90°$	upper north, or lower south;	lower north, or upper south;
	$90° < \frac{1}{2}(M_2° - K_1° - O_1°) < 270°$	lower north, or upper south.	upper north, or lower south.
		For LLW use	or HLW use
LWI taken approximately equal to HWI + $6^h\ 13^m$.	$0° < \frac{1}{2}(M_2° - K_1° - O_1°) < 180°$	upper north, or lower south;	lower north, or upper south;
	$180° < \frac{1}{2}(M_2° - K_1° - O_1°) < 360°$	lower north, or upper south.	upper north, or lower south.

Intervals applied to $\begin{matrix}\text{an upper north or a lower south}\\ \text{a lower north or an upper south}\end{matrix}$ transit, may be marked $\frac{a}{b}$. At stations where $\begin{matrix}\text{HWQ} < 2\ \text{P}_{,,}\\ \text{LWQ} < 2\ \text{P}_{,,}\end{matrix}$ the order of $\begin{matrix}\text{high}\\ \text{low}\end{matrix}$ waters may be reversed even when the moon is farthest from the equator. See § 21.

The heights.—If the planes of reference at the two stations have the same definition with respect to the tide, corresponding heights at the two stations differ only by a constant factor. This factor is usually taken as the ratio of the mean ranges. Where evanescent tides frequently occur, the ratio of the (great) tropic ranges or of the great diurnal ranges, should be used instead. If the planes of reference have different definitions at the two stations, the heights at one of the stations must be properly reduced before applying the factor.

The height differences are

$$\begin{aligned}&\text{Difference for HW} = C\frac{(\text{Mn})_{,,}}{(\text{Mn})_{,}} - D + (\text{Mn})_{,,} - (\text{Mn})_{,,}\\ &\text{Difference for LW} = C\frac{(\text{Mn})_{,,}}{(\text{Mn})_{,}} - D,\end{aligned} \tag{193}$$

where D is the depression of the plane of reference below mean low water at the principal station and C the depression below mean low water at the principal station of a plane there having the same definition as the plane of reference at the subordinate station.

When the two stations are far apart, it will generally be necessary to allow for the long period components if *absolute* heights of the tide are required.

54. *Tides comparable by inversion.*

When the tide at a subordinate station is similar to the one at the principal station inverted, the $\frac{\text{HW}}{\text{LW}}$ at the subordinate station is proportional to the $\frac{\text{LW}}{\text{HW}}$ at the principal station, the plane of reference being mean sea level. To ascertain if such a comparison can be made, find the quantities in (a), (b), and (c). The procedure is as in the case of tides *directly* comparable, except that $M_2° - K_1° - O_1°$ and $2\,M_2° - M_4°$ should no longer have the same values at the two stations, but each should be 180° greater or less at the one station than at the other. Using nonharmonic criteria, LWQ at the one station should be proportional to HWQ at the other. The duration of fall at the one should equal the duration of rise at the other.

55. *To infer harmonic constants through the comparison of nonharmonic constants, and conversely.*

Supposing the tides to be similar at two stations, we have for any short period component C

$$(C°)_{,,} = (C°)_{,} + c\frac{(\text{HWI})_{,,} + (\text{LWI})_{,,} - (\text{HWI})_{,} - (\text{LWI})_{,}}{2}, \tag{194}$$

$$(C)_{,,} = (C)_{,} \times \frac{(\text{Mn})_{,,}}{(\text{Mn})_{,}}. \tag{195}$$

If the tides are not exactly similar, i. e. if the quantities (a'), (b'), and (c'), § 51, differ slightly at the two stations, then, instead of equation (195), we have

$$(C_2)_{,,} = (C_2)_{,} \times \frac{(\mathrm{Mn})_{,,}}{(\mathrm{Mn})_{,}} \tag{196}$$

where C_2 denotes any lunar semidiurnal component;

$$(C_2)_{,,} = (C_2)_{,} \times \frac{(\mathrm{Sg})_{,,} - (\mathrm{Np})_{,,}}{(\mathrm{Sg})_{,} - (\mathrm{Np})_{,}} \tag{197}$$

where C_2 denotes any solar semidiurnal component, including lunisolar K_2;

$$(C_1)_{,,} = (C_1)_{,} \times \frac{(\mathrm{HWQ})_{,,} + (\mathrm{LWQ})_{,,}}{(\mathrm{HWQ})_{,} + (\mathrm{LWQ})_{,}} \tag{198}$$

where C_1 denotes any diurnal component;

$$(C_4)_{,,} = (C_4)_{,} \times \frac{(\mathrm{LWI})_{,,} - (\mathrm{HWI})_{,,} \mp 6^{\mathrm{h}}\,13^{\mathrm{m}}}{(\mathrm{LWI})_{,} - (\mathrm{HWI})_{,} \mp 6^{\mathrm{h}}\,13^{\mathrm{m}}} \tag{199}$$

where C_4 denotes any quarter diurnal component; and where the upper or lower sign is used according as LWI is taken greater or less than HWI.

For inferring nonharmonic constants through the harmonic, we have

$$(\mathrm{HWI})_{,,} = (\mathrm{HWI})_{,} + \frac{(\mathrm{M_2O})_{,,} - (\mathrm{M_2O})_{,}}{\mathrm{m_2}}, \tag{200}$$

$$(\mathrm{LWI})_{,,} = (\mathrm{LWI})_{,} + \frac{(\mathrm{M_2O})_{,,} - (\mathrm{M_2O})_{,}}{\mathrm{m_2}}, \tag{201}$$

$$(\mathrm{Mn})_{,,} = (\mathrm{Mn})_{,} \times \frac{(\mathrm{M_2})_{,,}}{(\mathrm{M_2})_{,}}. \tag{202}$$

If the tides are exactly similar, Mn in the equation last written may be replaced by any other quantity measurable in feet, as HWQ, Sg, etc. If, on the other hand, (a), (b), and (c), § 50, differ somewhat at the two stations, then the following equations should be used:

$$(\mathrm{HWQ})_{,,} = (\mathrm{HWQ})_{,} \times \frac{(\mathrm{K_1 + O_1})_{,,}}{(\mathrm{K_1 + O_1})_{,}}, \tag{203}$$

$$(\mathrm{LWQ})_{,,} = (\mathrm{LWQ})_{,} \times \frac{(\mathrm{K_1 + O_1})_{,,}}{(\mathrm{K_1 + O_1})_{,}}, \tag{204}$$

$$(\mathrm{Sg})_{,,} = (\mathrm{Sg})_{,} \times \frac{(\mathrm{M_2 + S_2})_{,,}}{(\mathrm{M_2 + S})_{,}}, \tag{205}$$

$$(\mathrm{Np})_{,,} = (\mathrm{Np})_{,} \times \frac{(\mathrm{M_2 - S_2})_{,,}}{(\mathrm{M_2 - S_2})_{,}}. \tag{206}$$

The deviation of a tropic interval from the mean is obtained by multiplying the value of this deviation at the first station by $\frac{(\mathrm{K_1 + O_1})_{,,}}{(\mathrm{K_1 + O_1})_{,}}$. In this connection see § 49.

Long period components are taken from a neighboring station and without alteration.

If the nonharmonic quantities at the second station are not properly corrected for the effect of tidal (not accidental) inequalities, they should be used along with the same quantities obtained simultaneously and in like manner, at the first station, using either observations or predictions. If the nonharmonic quantities are affected with accidental inequalities, it is important that the two stations be situated near each other, and that simultaneous observations be used in making inferences.

56. *Cotidal lines.*

A cotidal line is an assemblage of points on the earth's surface where tides occur at the same absolute time.

The number of each such line is usually taken as the lunar time (i. e. the lunar hour after upper or lower transit) at Greenwich when HW occurs at stations along the cotidal line. If solar hours are used, reckoned, of course, from the time of the moon's transits, each period of cotidal lines will consist of 12·42 hour-lines instead of 12.

The cotidal lunar hour of a place whose west longitude in time equals L is

$$0{\cdot}966\ \mathrm{HWI} + L,$$

or more exactly,

$$0{\cdot}483\ (\mathrm{HWI} + \mathrm{LWI} \mp 6{\cdot}210) + L; \tag{207}$$

while the cotidal solar hour is

$$\mathrm{HWI} + 1{\cdot}035\ L,$$

or more exactly,

$$\frac{\mathrm{HWI} + \mathrm{LWI} \mp 6{\cdot}^{\mathrm{h}}210}{2} + 1{\cdot}035\ L. \tag{208}$$

The $\begin{matrix}\text{upper}\\ \text{lower}\end{matrix}$ sign is used when the low water interval is taken $\begin{matrix}\text{greater}\\ \text{less}\end{matrix}$ than the high water.

The cotidal lines relating to the semidiurnal portion of the tide are quite distinct from those relating to the diurnal.

The tropic high and low water intervals of the diurnal wave are obtained thus (see § 16):

$$\mathrm{HWI}\ (a) = \frac{\mathrm{K_1}^\circ + \mathrm{O_1}^\circ}{29{\cdot}2} \tag{209}$$

$$\mathrm{LWI}\ (a) = \mathrm{HWI}\ (a) \pm 12^{\mathrm{h}}\ 20^{\mathrm{m}}. \tag{210}$$

To change the transits add or subtract $12^{\mathrm{h}}\ 25^{\mathrm{m}}$.

The cotidal lunar and solar hours for the diurnal wave become

$$0{\cdot}966\ \mathrm{HWI}\ (a) + L \tag{211}$$

and

$$\mathrm{HWI}\ (a) + 1{\cdot}035\ L, \tag{212}$$

respectively.

CHAPTER VI.

PREDICTION OF TIDES.

TIDE-PREDICTING MACHINES.

57. *British tide-predicting machines.**

The object of these machines is to continuously sum the series

$$H_o + A \cos (at + \alpha) + B \cos (bt + \beta) + \quad . \quad . \quad . \quad , \tag{213}$$

or to trace the curve

$$y = H_o + A \cos (at + \alpha) + B \cos (bt + \beta) + \quad . \quad . \quad . \quad , \tag{214}$$

thus giving the height of the sea or tide at any particular time.

Among the earlier mechanical devices for summing a series of cosine or sine terms, where the angles vary uniformly with the time t, or with the angle θ, may be mentioned the following:†

In the British Association for the Advancement of Science Report for 1845, Cambridge Meeting, Rev. F. Bashforth mentions a machine for describing the curve

$$\rho = A \cos (a\,\theta + \alpha) + B \cos (b\,\theta + \beta) + \quad . \quad . \quad . \tag{215}$$

where $A, B, C, \ . \ . \ .$ $a, b, c, \ . \ . \ .$ are real quantities, integral or fractional. He applies it to the finding of *real* roots of the algebraic equation

$$p_o x^n + p_1 x^{n-1} + \quad . \quad . \quad . \quad + p_n = 0 \tag{216}$$

where n is a positive integer. By writing $x = \cos \theta$ this equation becomes of the form

$$q_o \cos n\,\theta + q_1 \cos \overline{n-1}\,\theta + \quad . \quad . \quad . \quad + q_n = 0. \tag{217}$$

The values of $\cos \theta$ at the intersections of

$$\rho = k + q_o \cos n\,\theta + q_1 \cos \overline{n-1}\,\theta + \quad . \quad . \quad + q_n$$

and

$$\rho = k$$

are, obviously, the roots required.

In the Proceedings of the Royal Society of London, Vol. 18 (1869), pages 72, 73, Mr. W. H. L. Russell shows how the curve

$$y = A \cos (at + \alpha) + B \cos (bt + \beta) + \quad . \quad . \quad . \tag{218}$$

may be described mechanically. From his diagram it will be noticed that the mechanism is "substantially the same as that of the tide predictor" (No. 2 or 3).

In the Minutes of Proceedings of the Institution of Civil Engineers (London), Vol. 65, page 16, a description is given of a wooden model designed by Sir William Thomson and constructed for him in 1872–73. This model made provision for eight components, and its plan was very like tide predictor No. 1.

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*For an account of these machines see the Minutes of Proceedings of the Institution of Civil Engineers (London), Vol. 65 (1881), pages 15–72.

For "predictor No. 1" see Thomson and Tait's Natural Philosophy.

For the Indian predictor see also Proceedings of the Royal Society of London, Vol. 29 (1879), pages 198–201, and especially The Engineer (London) of December 19, 1879, where drawings of the machine are given.

†See Popular Lectures and Addresses by Sir William Thomson, Vol. III, page 185.

Tide predictor No. 1.—This predictor, designed by Thomson, was constructed in about 1876. It contains ten components and is described in Thomson and Tait's Natural Philosophy, Part I. It differs from Nos. 2 and 3 in the number of components represented and in having cranks carrying pulleys instead of pins working in slots. This machine is now kept at the South Kensington Museum.

Tide predictor No. 2.—This machine was designed by Mr. E. Roberts and is now worked under his direction in preparing the "Tide tables for Indian ports." The number of components is twenty.

Tide predictor No. 3.—This predictor, designed by Thomson, differs from No. 2 in the number of components, which is fifteen or sixteen instead of twenty, and in the direct character of the gearing. It was constructed in about 1881.

General description.—Upon one or more shafts, driven by hand or by clockwork, are fixed a number of wheels which mesh into other wheels, causing the latter (or wheels moved by them) to revolve with angular velocities having given ratios to the angular velocities of the shafts. These ratios are taken, as nearly as possible, proportional to the speeds of particular tidal components. Rigidly connected to these wheels are cranks carrying pulleys, or pins working in slots, imparting to rods carrying pulleys rectilineal harmonic motions. At one end of the predictor a chain or flexible wire is made fast; thence it is laid alternately over and under the pulleys. To the free end of the wire is attached a marking point, which when moved transversely to the line of motion of the paper roll traces the tidal curve. This machine evidently sums the series (213) or traces the curve (214).

58. *Maxima and minima tide-predicting machine.*

This machine, designed by the late Prof. William Ferrel, of the United States Coast and Geodetic Survey, was constructed in the years 1881–82. A description is given in the Report for 1883, pages 253–272. Most of the predictions published by the Survey since 1885 have been made upon it. The machine provides for nineteen components. The amplitude of the principal lunar component is introduced into the predictor by shortening one of the summation chains about to be mentioned. Its argument is indicated by a hand on the face of the machine making two revolutions for each lunar day. Generally speaking, the speed ratios in the machine are not those of the components themselves, but are the differences between such ratios and the speed ratio of the principal lunar component. The smaller short-period components are each provided with two cranks fixed at right angles to each other, one for cosine terms and one for sine terms. Each set of cranks carries pulleys, and the resultant effects are obtained by means of two summation chains. One chain is made to impart a vertical motion to a slotted horizontal strip of steel, while the other imparts a horizontal motion to a slotted vertical strip. These slots intersect at the center of the machine when all short-period components are set at zero amplitude. In general, two settings of the machine are required, one for times and one for heights. When set for times, the direction of the intersection of the slots from the center of the machine shows (by aid of an oscillating needle) how the lunar hand must be directed * at the time of a high or low water. When set for heights the distance of the intersection from the center † is, when multiplied by the cosine of the angle between the lunar hand and the oscillating needle,‡ the elevation or depression of the sea or tide from mean sea level.

The machine gives the times of high and low water directly; no tidal curve is traced, nor is any computation required. Approximate values of the heights are also given directly, but the determination of their exact values or of the height of the sea at any intermediate time requires a little additional labor, viz., the setting and reading of an extensible cosine scale.

59. *A proposed tide predictor.*

The machine briefly described below will carry on simultaneously four operations, viz.:

1. The tracing of the tidal curve.

2. The marking upon the axis of the curve the times of the maxima and minima.

* This angle reckoned counterclockwise from the vertical is the u of § 60.

† This distance is the R of § 60.

‡ This angle is $at + \alpha + z$ of § 60; at times of high or low water it becomes $z - u$. z is always the angle made by the oscillating needle with the vertical reckoned counterclockwise, the machine being set for heights; $at + \alpha$ is the argument or angle of the lunar hand reckoned clockwise, as on the face of the machine.

3. The exhibiting upon the face of the machine the times of high and low water.

4. The exhibiting upon the face of the machine the heights of high and low water, and the height of the sea at any given time.

(1) In regard to the accomplishment of the first of these objects nothing further need be said, for a mechanism similar to that used in the British machines seems quite satisfactory.

(2) Now let there be a set of cranks at right angles to the set used in producing the tide curve; for distinction the former may be called the time cranks and the latter height cranks. Each set has its resultant effect shown by the movement of the free end (or of a mark a constant distance therefrom) of a wire or slender chain. In each case the result might be shown in the form of a continuous curve. This, however, is not ordinarily wanted in the case of the time cranks. A projection upon the wire uniting their effects comes into contact with a pencil placed at mean sea level, causing a short mark to be made every time high or low water occurs.

(3) A mark on the wire at a fixed distance from the projection just referred to passes before an opening in the face of the machine, and is so adjusted that when it crosses a given line or mark the time shown on the face is the time of high or low water according to the direction of the wire's movement.

(4) The heights may be conveniently shown by means of a pointer moving along a circular row of figures outside the time dial.

A clear mode of indicating the time would be to have the day of the month and the hour of the day show through two small openings, while a single hand points out the minutes.

In order to warn the operator that a high or low water is close at hand, a bell may be made to ring just before each tide.*

Imaginary roots of equations, etc.†—A purely mathematical use for a machine of this kind is the finding of imaginary roots of equations.

Let

$$Z = A\,z^{a} + B\,z^{b} + \quad . \quad . \quad . \quad = 0 \tag{219}$$

where the coefficients are general but the exponents are real quantities. Now, as z describes a circle whose radius is k, Z will for each value of arg z or θ have a certain affix

$$\begin{aligned} & \text{mod } A\,k^{a}\,[\cos(a\,\theta+\alpha)+i\sin(a\,\theta+\alpha)] \\ + \quad & \text{mod } B\,k^{b}\,[\cos(b\,\theta+\beta)+i\sin(b\,\theta+\beta)] \\ + \quad & \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \end{aligned} \tag{220}$$

The locus of Z will be mechanically described by a point whose ordinate and abscissa represent the resultant effects of the height and time cranks each set to the same amplitudes.

Such values of k and θ as will make both sums zero give roots of the equation.

60. *Equations relating to tide-predicting machines.*

The height of the sea or tide at any given time t may be expressed in various ways:

$$y = H_0 + A\cos(at+\alpha) + B\cos(bt+\beta) + \quad . \quad . \quad . \tag{221}$$

$$= H_0 + \bar{A}\cos at + \bar{B}\cos bt + \quad . \quad . \quad . \\ + \bar{\bar{A}}\sin at + \bar{\bar{B}}\sin bt + \quad . \quad . \quad . \tag{222}$$

where

$$\bar{A} = A\cos\alpha\,,\ \bar{\bar{A}} = -A\sin\alpha\,; \\ \therefore A = (\bar{A}^2 + \bar{\bar{A}}^2)^{\frac{1}{2}},\ \tan\alpha = -\frac{\bar{\bar{A}}}{\bar{A}}. \tag{223}$$

$$y = H_0 + M\cos(at+\alpha) - N\sin(at+\alpha) \tag{224}$$

where

$$M = A + B\cos(\overline{b-a}t+\beta-\alpha) + C\cos(\overline{c-a}t+\gamma-\alpha) + \quad . \quad . \quad . \quad , \tag{225}$$

$$N = 0 + B\sin(\overline{b-a}t+\beta-\alpha) + C\sin(\overline{c-a}t+\gamma-\alpha) + \quad . \quad . \quad . \quad ; \tag{226}$$

$$y = H_0 + R\cos(at+\alpha+z) \tag{227}$$

where

$$R = (M^2+N^2)^{\frac{1}{2}},\ \tan z = \frac{N}{M}. \tag{228}$$

z is evidently the angle of a right-angled triangle, whose sides are M, N, lying opposite N.

[*This survey has undertaken the designing and construction of a machine which will carry on the above operations. When completed, a full description of the machine will be published.—July, 1895.]

†The notation here employed is independent of the notation used elsewhere in this paper.

The times of high and low water are roots of the derived equation

$$-\frac{dy}{dt} = A\,a\sin(at+\alpha) + B\,b\sin(bt+\beta) + \ldots = 0 \tag{229}$$

$$= \bar{A}\,a\sin at + \bar{B}\,b\sin bt + \ldots$$
$$-(\bar{\bar{A}}\,a\cos at + \bar{\bar{B}}\,b\cos bt + \ldots) \tag{230}$$

where

$$\bar{A} = A\cos\alpha,\ \bar{\bar{A}} = -A\sin\alpha;$$
$$\therefore A = (\bar{A}^2 + \bar{\bar{A}}^2)^{\frac{1}{2}},\ \tan\alpha = -\frac{\bar{\bar{A}}}{\bar{A}}. \tag{231}$$

$$-\frac{dy}{dt} = a\,M'\sin(at+\alpha) + a\,N'\cos at+\alpha) = 0 \tag{232}$$

where

$$M' = A + \frac{B\,b}{a}\cos(\overline{b-a}t+\beta-\alpha) + \frac{C\,c}{a}\cos(\overline{c-a}t+\gamma-\alpha) + \ldots, \tag{233}$$

$$N' = 0 + \frac{B\,b}{a}\sin(\overline{b-a}t+\beta-\alpha) + \frac{C\,c}{a}\sin(\overline{c-a}t+\gamma-\alpha) + \ldots; \tag{234}$$

$$-\frac{dy}{dt} = R'\sin(at+\alpha+u) = 0 \tag{235}$$

where

$$R' = (M'^2 + N'^2)^{\frac{1}{2}},\ \tan u = \frac{N'}{M'}. \tag{236}$$

The angle u shows how much (in A degrees) the high or low water is accelerated because of components other than A. The times of the tide are therefore

$$t' = \frac{n\,\pi - \alpha - u}{a} \tag{237}$$

where n is any integer, even for a high and odd for a low water. v and w of § 1 are values of u for these two cases.

A GRAPHIC METHOD OF PREDICTING TIDES FROM HARMONIC CONSTANTS.

61. The prediction of tides, as already stated, implies the combining of a series of waves into one for the purpose of ascertaining the height of the tide at a given time or of determining the times and heights of high and low water. The computation of these quantities, while not difficult, is extremely laborious; on this account mechanical tide predictors have been constructed. As these instruments are too expensive for general use, a method is here proposed whereby predictions may be made, without computation, from the constants used in setting a machine—in other words, from the harmonic tidal constants, the initial equilibrium arguments, and certain factors (f of Table 10).

The apparatus consists, first, of a smooth board (about 3 by 4 feet), one section of which is divided into twenty-four equal spaces, representing the hours of the day; second, of a set of pairs of movable curves, drawn once for all for a given station, each pair provided with a "calendar" good for all stations and all time; and third, of two stationary cleats for holding the curves in place, and a number of movable cleats for indices—one for each pair of curves.

62. The equation of any component with its harmonics may be written

$$\begin{aligned} y = {} & A_1\cos(a_1 t + \arg_0 A_1 - A_1{}^\circ) \\ & + A_2\cos(2\,a_1 t + \arg_0 A_2 - A_2{}^\circ) \\ & + A_3\cos(3\,a_1 t + \arg_0 A_3 - A_3{}^\circ) \\ & + \ldots \end{aligned} \tag{238}$$

where A_1 is the oscillation of longest period, or the fundamental, not necessarily a diurnal component. Of course, a curve representing this compound wave can always be replaced by as many simple cosine curves as there are terms in y. In fact, the only instances where it is generally

advantageous to use other than simple curves are M_2 and S_1, with their respective harmonics. Strictly speaking, the amplitude of the harmonics of M_2 vary faster on account of the change in the inclination of the lunar orbit to the earth's equator than does the amplitude of M_2; but as the amount of this change is small in small quantities, no great inaccuracy will be introduced by making the whole M wave vary as M_2 varies.

It is customary to put

$$\begin{aligned} &\arg_0 A_2 = 2 \arg_0 A_1 \\ &\arg_0 A_3 = 3 \arg_0 A_1 \\ &\quad . \quad . \quad . \quad . \quad . \end{aligned} \tag{239}$$

The above equation assumes that one has the value of the initial arguments at the time $t = 0$, local time, midnight, say. In practice it is convenient to take the origin of time at the instant of midnight on a certain standard time meridian, S, and to have the initial arguments made out for the meridian of Greenwich; then one might alter the arguments in such a way as to adapt them to the longitude of the locality, L, and to the standard time midnight. But if, instead of altering the Greenwich arguments, one alter the epochs by the same amounts, with opposite signs, the same results will be attained and with the great advantage of being done once for all. The epoch of any component A_p thus modified is

$$\mathfrak{A}_p^\circ = A_p^\circ + (15\,p - a_p)\,L + a_p\,(L - S), = A_p^\circ + 15\,pL - apS \tag{240}$$

where p is such an integer that $15\,p$ is nearly equal to a_1. When A_1 denotes a diurnal component, then $p = 1, 2, \ . \ . \ .$ according as A_p is diurnal, semidiurnal, etc.

63. *Construction of a height curve.*—For convenience in drawing the curve, suppose $\arg_0 A_1$ to be zero; then its equation with modified epochs becomes

$$y = A_1 \cos(a_1 t - \mathfrak{A}_1^\circ) + A_2 \cos(2\,a_1 t - \mathfrak{A}_2^\circ) + A_3 \cos(3\,a_1 t - \mathfrak{A}_3^\circ) + \ . \ . \ . \ . \tag{241}$$

The position of the maxima of A_1 are given by the equation

$$t = \frac{\mathfrak{A}_1^\circ}{a_1} + \frac{2\,n\,\pi}{a_1} \tag{242}$$

where n is zero or a positive or negative integer. At this time the phases of the harmonics are

$$2\,\mathfrak{A}_1^\circ - \mathfrak{A}_2^\circ,\ 3\,\mathfrak{A}_1^\circ - \mathfrak{A}_3^\circ,\ \ . \ . \ . \ , \tag{243}$$

while the positions of their respective maxima are given by the equations

$$t = \frac{\mathfrak{A}_2^\circ}{2\,a_1} + \frac{2\,n\,\pi}{2\,a_1},\quad t = \frac{\mathfrak{A}_3^\circ}{3\,a_1} + \frac{2\,n\,\pi}{3\,a_1},\ \ . \ . \ . \ . \ . \tag{244}$$

The beginning of the curve should be $\mathfrak{A}_1^\circ$ degrees or $\mathfrak{A}_1^\circ/a_1$ hours before the first maximum. It should extend over a trifle more than two or three days according as A_1 is a semidiurnal or a diurnal component. From the beginning and along the axis, generally lay off two periods, leaving the first blank and dividing the second into degrees from zero to 360. The number equivalent to $\arg_0 A_1$ when brought over the stationary zero hour line fixes the position of the curve for the day.

Construction of a time curve.—The equation of the derived curve corresponding to (241) is

$$-y = A_1 a_1 \sin(a_1 t - \mathfrak{A}_1^\circ) + 2\,A_2 a_1 \sin(2\,a_1 - \mathfrak{A}_2^\circ) + 3\,A_3\,a_1 \sin(3\,a_1 - \mathfrak{A}_3^\circ) + \ . \ . \ . \ . \tag{245}$$

It will be noticed that the $\begin{matrix}\text{descending}\\ \text{ascending}\end{matrix}$ nodes of the derived curve will coincide in time with the $\begin{matrix}\text{maxima}\\ \text{minima}\end{matrix}$ of the height curve. This is of course equally true for each element or component of the curve.

In ascertaining the magnitude of the coefficients $A_1\,a_1$, $2\,A_2\,a_1$, $3\,A_3\,a_1$ . . . relative to $A_1, A_2, A_3, \ . \ . \ .$, it is usually convenient to take the speed of M_2 as unity, expressing other speeds in term of this unit. The derived curve is used in ascertaining the times of tide, and is drawn in a broken line upon the movable strip upon which the height curve has already been drawn.

Construction of a "calendar."—It will now be supposed that $\arg_0 A_2$ is given for only one day of each year, January 1. The change in the given $\arg_0 A_2$ necessary to adapt it to any other

day of the year may be assumed to be uniform, and the same for all years. This change is introduced by means of a "calendar" peculiar to the component and its harmonics.

Anywhere at the left of the curves, a section of the strip one period in length is set apart for the days of the year. The positions of the dates are given by Table 4. January 1 will be located at the right or left edge of the period according as the speed of the component is less or greater than that of the solar component of approximately the same speed.

It is sometimes more convenient to set apart two or more periods for the calendar. This will necessitate two or more blank periods of the curve, instead of one, before the period used in laying down $\arg_0 A_1$. This means, of course, an increase in the length of the curve.

Lunar nodal components, etc.—In order to avoid numerous small components, especially those dependent upon the longitude of the moon's node, the lunar tides are made to undergo small changes in argument which are not directly proportional to the time, and also small changes of amplitude. The former have been accounted for in Table 3 by the u of $V_0 + u$, or $\arg_0$, where u has an irregular variation, but so slow that for the purpose of prediction it may be regarded as constant during a year.

The variations of amplitude are given by the f's of Table 10, and can be shown upon the curves by means of a scale of proportional parts of the mean values of the amplitude and ordinates of each component. But as the f's vary quite uniformly with I (the inclination of the lunar orbit to the equator, Tables 1 and 13) it is generally sufficient to mark upon certain ordinates of the curve their increased or decreased values corresponding to changes in I.

The time scale.—This scale consists of twenty-five equidistant lines drawn upon the stationary board underneath all of the curves. The strips upon which the curves are drawn should be separated from one another by narrow spaces, so that the time scale, or rather the hour lines, may be seen between them.

64. *Directions for predicting.*

Find in Table 3 the value of $V_0 + u$ of each component for the given year and bring this number of the degree scale over the zero hour line. Set the various indices over the date January 1. For any other day move the scales until the indices, as already set, come over the required date upon each scale.

Suppose, in the first instance, that the height of the sea or tide is required at any particular hour of this day.

Along the edge of a piece of paper made to coincide with the given hour line, mark the positive ordinates of the full curves (slightly modified to account for the varying obliquity of the moon's orbit to the equator) so that all such ordinates shall be added together. Along the same edge, but on the opposite surface of the paper, mark the negative ordinates, beginning at the height upon the paper slip reached by the positive ordinates and going in an opposite direction. The resulting difference is the height of the tide above or below mean sea level at the stated hour. If a lower plane of reference be preferred, its depression below mean sea level should be laid off upon the paper slip before marking the ordinates upon it.

To find the time of high or low water.—By glancing at the dotted curves of the principal components one can usually tell roughly where the algebraic sum of their ordinates approach zero. If a high water time is sought, select a descending node; if a low water, an ascending.

At two adjacent hours near the high or low water, lay off upon a slip of paper the positive and negative ordinates of the dotted curves, properly modified for the varying obliquity of the moon's orbit to the equator.

Now take any scale about three hours in length, divided to single minutes. From this lay off the two resulting heights, one hour apart. A straightedge will show where a line joining the two points just laid down will cut the time scale. The time thus determined is the time of high or low water with reference to either hour line.

65. It is obvious that the foregoing method is applicable to periodic phenomena, although the constituent periodic curves may have no resemblance to simple cosine curves. Such curves are constructed by means of component hourly ordinates obtained from the observations. These remarks have special reference to the prediction of tidal currents.

APPROXIMATE PREDICTION OF HIGH AND LOW WATER.*

66. By means of the following method predictions can be made without resorting to graphic processes, and without access to a tide-predicting machine.

Moon's transits, phases, etc.—If the transits used are for the meridian of Greenwich (E) and expressed in civil time, they may be adapted to another meridian (L) and expressed in standard or prediction time (S) by adding

$$L - S + 0{\cdot}035\ (L - E) \tag{246}$$

§ 27. The times of the moon's phases, distances, and declinations are expressed in standard time by adding

$$E - S$$

to their Greenwich civil times. A further increase of τ hours, the age of the particular inequality, gives the standard or prediction time of the conspiring or interfering to which the inequality is due. See sheet headed "Ephemeris."

The tidal constants.—The constants are as follows:

$$\text{HWI, LWI, } \triangle_2,\ M_2,\ S_2,\ \tau\ (S_2;\ M_2),\ N_2,\ \tau\ (N_2;\ M_2)\ K_1,\ \mathfrak{K}_1{}^\circ,\ O_1,\ \tau\ (O_1;\ K_1),$$
$$\tau_2 = \frac{12\ \tau\ (N_2;\ M_2) + 5\ \tau\ (S_2;\ M_2)}{17 \times 24{\cdot}84\ (= 422{\cdot}3)}. \tag{247}$$

$\triangle_2$ is the mean amplitude of the tide with the effects of the diurnal components excluded. $\mathfrak{K}_1{}^\circ$ is the modified form of $K_1{}^\circ$, defined in § 62. HWI and LWI are so taken that their sum is zero, as nearly as possible. $\triangle_2$, M_2, S_2, N_2, K_1, O_1 are reduced to their values for the year of the predictions by the factors $f\,(M_2)$, $f\,(M_2)$, 1, $f\,(M_2)$, $f\,(K_1)$, $f\,(O_1)$, respectively, found in Table 10.

67. The "Ephemeris" and the sheet following it indicate the work preparatory to making predictions. The process of prediction indicated below consists of three steps, the determination of the semidiurnal wave, of the diurnal, and of combining the two thus determined. Port Townsend, Washington, is taken as an illustration because of its large diurnal components.

Ephemeris.

Port Townsend, Wash., 1895.

	h.	m.
Longitude of ephemeris (E)	0	00
Longitude of time meridian (S)	8	00
$E-S=$	−8	00

Moon.	Greenwich civil time.		$E-S+\tau$	Prediction time of conspiring or interfering.		
		d. h.	h. h. h.		d. h.	
☾ Last quarter	February	16 13	−8+21=13	Feb. 17	2	
● New moon	"	24 17	"	" 25	6	
☽ First quarter	March	4 13	"	Mar. 5	2	
Apogee	February	22 19	−8+51=43	Feb. 24	14	
(Midtime)	March	2 10	"	Mar. 4	5	
Perigee	"	10 1	"			
				(for P_1.)		
				h.	d.	h.
Farthest S.	February	19 1	−8+16= 8	Feb. 19	9+15=20	0
On equator	"	26 14	"	" 26	22+14=27	12
Farthest N.	March	5 15	"	Mar. 5	23+12= 6	11

* For other modes of predicting high and low water from harmonic constants, see an article entitled "On tidal prediction," by Prof. G. H. Darwin, Phil. Trans., Vol. 182 (1891), A, pages 159-229; and, by the same author, a portion of the article on "Tides" in the Manual of Scientific Enquiry (fifth edition), pages 75-90. See also Gezeitentafeln (Berlin), 1894. The equations for passing from the $\triangle$'s of the components in these tables to their epochs are

$$B_2{}^\circ = M_2{}^\circ - \triangle\ B_2{}^\circ + (b_2 - m_2)\ (0{\cdot}0345\ M_2{}^\circ + L).$$
$$K_1{}^\circ = -\triangle\ K_1{}^\circ + (k_1 - m_1)\ (0{\cdot}345\ M_2{}^\circ + L),$$
$$B_1{}^\circ = K_1{}^\circ - \triangle\ B_1{}^\circ + (b_1 - k_1)\ (0{\cdot}0345\ M_2{}^\circ + L),$$

where the small letters denote speeds, and $\triangle\ B^\circ$, $\triangle\ K_1{}^\circ$ are written instead of $\triangle\ b$, $\triangle\ k_1$ of the Gezeitentafeln.

The standard time (120° W.) of the moon's transits across the meridian of Port Townsend (122° 45′) can be obtained from the table of transits, Pacific Coast Tide Tables, by adding 11m.

PORT TOWNSEND, WASHINGTON, 1895.

CONSTANTS.

HWI	LWI	$\triangle_2$,	M_2,	S_2,	$\tau(S_2; M_2)$,	N_2,	$\tau(N_2; M_2)$,	K_1,	$\mathfrak{K}_1°$,	O_1,	$\tau(O_1; K_1)$.	τ_2
3 53 (*a*)	−2 44 (*a*)	2·40	2·24	0·55	21h	0ft·46	51h	2ft·47	151°·5	1ft·41	16	1·70 lunar days.

Factors for the year 1895.

$f(K_2)$,	$f(M_2)$,	$F(K_1)$,	$f(K_1)$,	$f(O_1)$.
1·308	0·964	0·901	1·110	1·179.

CONSTANTS.

Amplitudes for the year 1895.

$\triangle_2$,	M_2,	S_2,	N_2,	K_1,	O_1.
2·31	2·16	0·55	0·44	2·74	1·66

Amplitudes for obtaining height corrections.

February 20	S_2 (with K_2 and T_2)	1·25 × 0·55 = 0·69, Table 31 or 33
March 2	"	1·32 × 0·55 = 0·73
February 22	N_2 (with ν_2)	1·16 × 0·44 = 0·51, Table 34
March 10	"	1·17 × 0·44 = 0·51
February 20	K_1 (with P_1)	0·90 × 2·74 = 2·47, Table 31
March 2	"	0·80 × 2·74 = 2·19
February 21	O_1 (with Q_1)	0·81 × 1·66 = 1·34, Table 26
22	"	0·81 × " = 1·34
23	"	0·81 × " = 1·34
24	"	0·83 × " = 1·38
25	"	0·86 × " = 1·43
26	"	0·88 × " = 1·46
27	"	0·89 × " = 1·48
28	"	0·93 × " = 1·54

Amplitude for obtaining time corrections.

February 20	S_2 (with T_2 and solar K_2)	1·09 × 0·55 = 0·60.	S_2/M_2 = 0·27, Table 31
March 2	"	1·10 × " = 0·61.	" = 0·28

Acceleration.

				$\tau(O_1; K_1)$ increased.
February 20	K_1 by P_1	−17° = −68m.	−17 (−4♀) = +15h,	Table 31
March 2	"	−14 = −56.	−14 (−4♀) = +13	"

Time of K_1 tides.

Arg_0 K_1 (Feb. 21) =	62°·55 = 4h 09m	Table 3
$\mathfrak{K}_1° = 151 \cdot 5 =$	10 04	
$-[arg_0 K_1 - \mathfrak{K}_1°] =$	5 55	Feb. 21 = K_1 HW
½ of a K_1 day =	11 58	
	17 53	Feb. 21 = K_1 LW

General form.

Computation of high and low water, Port Townsend, Wash., February 21–28, 1895.

		Feb. 21			22			23			24			25			26			27			28		
(1)	Time of moon's transit. [8:43, 21:09, 9:34, 21:59, preceding transits.]			10:23			22:46			11:08			23:30			11:51			0:12			12:32			0:52
(2)	(1) diminished by second preceding.			24:49			47			45			44			43			42			41			40
(3)	(2) first following subtracted from second preceding.			04			05			05			04			03			03			03			03
(4)	(3) × ⅓ τ_2, correction for moon's declination and parallax on account of transit.			05			06			06			05			03			03			03			02
(5)	HWI, LWI.			−2:44			+3:53																		
(6)	(1) + (5).			7:39			14:16			20:02			2:39			8:24			15:01			20:46			3:23
(7)	Tabular correction for phase, Table 24.			+119×0·27			+114			+109			+102			+96			+88			+81			+72
(8)	Do. expressed in minutes.			32			31			29			28			26			24			22			19
(9)	(8) × (15).			37			36			34			33			31			28			26			23
				LW			HW			LW			HW			LW			HW			LW			HW
(10)	(4) + (6) + (9), time of HW, LW of semidiurnal wave.			8:21			14:57			20:42			3:18			9:01			15:35			21:17			3:51
(11)	Amplitude of semidiurnal wave, Δ_2.			2·31																					
(12)	Tabular correction for parallax, Table 25.			−0·61			−0·63			−0·66			−0·68			−0·69			−0·71			−0·73			−0·74
(13)	Do. expressed in feet.			−0·31			−0·32			−0·34			−0·35			−0·35			−0·36			−0·37			−0·38
(14)	(11) + (13).			2·00			1·99			1·97			1·96			1·96			1·95			1·94			1·93
(15)	(11) ÷ (14).			1·16			1·16			1·17			1·18			1·18			1·18			1·19			1·20
(16)	Tabular correction for phase, Table 24.			·00×·69			+·12			+·21			+·31			+·40			+·49			+·56×·70			+·64
(17)	Do. expressed in feet.			·00			+ ·08			+ ·14			+ ·21			+ ·28			+ ·34			+ ·39			+ ·45
(18)	(14) + (17), amplitude of semidiurnal wave.			2·00			2·07			2·11			2·17			2·24			2·29			2·33			2·38

		Feb. 21		22		23		24		25		26		27		28	
(19)	Time of HW, LW of K_1.		5:55		17:53		5:51		17:49		5:47		17:45		5:43		17:41
(20)	Add 4^m to (19) for each preceding day; subtract 4^m for each following.		5:55		17:53		5:51		17:49		5:47		17:45		5:43		17:41
(21)	Acceleration in K_1 due to P_1, expressed in time.		− 1:06		− 1:06		−1:05		− 1:05		−1:04		− 1:04		−1:03		− 1:03
(22)	(20) − (21), time of K_1 (with P_1) tides.		7:01		18:59		6:56		18:54		6:51		18:49		6:46		18:44
(23)	Tabular correction for O_1, using (22), Table 27.		+ 1:13		+ 1:41		+2:08		+ 2:34		+2:59		+ 3:05		+3:13		+ 3:33
(24)	Do. expressed in time, using (33).		+ 0:40		+ 0:56		+1:12		+ 1:26		+1:40		+ 1:45		+1:52		+ 2:08
(10)			8:21	14:57	20:42	3:18	9:01	15:35	21:17	3:51	9:32	16:05	21:47	4:20	10:01	16:34	22:14
(25)	(22) + (24), time of HW, LW of diurnal wave. Between each time write the half length of the diurnal wave.		7:41	(12:14)	19:55	(12:13)	8:08	(12:12)	20:20	(12:11)	8:31	(12:03)	20:34	(12:04)	8:38	(12:14)	20:52
(26)	(10) − (25), always subtracting a diurnal tide from the times of two semidiurnal tides which include it. Bracket the values obtained from LW of diurnal wave.			0:40	[−4:58]	[0:47]	−4:50	0:53	[−4:45]	[0:57]	−4:40	1:01	[−4:29]	[1:13]	−4:18	1:23	[−4:18]
(27)	(26) converted into degrees. Change name of phase when inclosed in brackets; otherwise the name of (10), Table 28.			10° L	−73° L	12° H	−71° H	13° L	−70° L	14° H	−69° H	15° L	−67° L	18° H	−64° H	20° L	−63° L
(28)	Tabular value of acceleration, using (27) and (37), Table 17.			−16°·5	+57°·2	+7°·0	−37°·9	−14°·8	+44°·0	+7°·0	−29°·9	−12°·4	+34°·4	+7°·9	−24°·5	−13°·4	+28°·1
(29)	Do. converted into time.			−0 34	+1 58	+0 14	−1 18	−0 31	1 31	0 14	−1 02	−0 26	+1 11	+0 16	−0 51	−0 28	+0 58
			LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW
(30)	(10) − (29), time of HW, LW.		8:55	12:59	20:28	4:36	9:32	14:04	21:03	4:53	9:58	14:54	21:31	5:11	10:29	15:36	21:59
			−30	−4	−10	−11	+2	−5	−12	+9	+21	−3	−6	−13	−11	+4	+2
	Date		Feb. 21		22		23		24		25		26		27		
(31)	Amplitude of K_1 (with P_1), using times of (10).		2·44	2·44	2·43	2·42	2·41	2·41	2·40	2·39	2·39	2·38	2·37	2·36	2·36	2·35	2·34
(32)	Amplitude of O_1 (with Q_1), using times of (10).		1·34	1·34	1·34	1·34	1·34	1·34	1·34	1·34	1·34	1·34	1·35	1·36	1·38	1·39	1·41
(33)	(32) ÷ (31).		0·55	0·55	0·55	0·55	0·56	0·56	0·56	0·56	0·56	0·56	0·57	0·58	0·58	0·59	0·60
(34)	Tabular correction for O_1, using times of (10), Table 27.		0·89 O_1	0·84	0·78	0·72	0·66	0·58	0·50	0·40	0·36	0·31	0·27	0·23	0·18	0·08	−0·02
(35)	Do. expressed in feet, [(32) × (34)].		1·19	1·13	1·05	0·96	0·88	0·78	0·67	0·54	0·48	0·42	0·36	0·31	0·25	0·11	−0·03
(36)	(31) + (35), amplitude of diurnal wave.		3·63	3·57	3·48	3·38	3·29	3·19	3·07	2·93	2·87	2·80	2·73	2·67	2·61	2·46	2·31
(37)	(36) − (18).		1·82	1·72	1·65	1·56	1·47	1·39	1·32	1·23	1·19	1·14	1·10	1·06	1·03	0·96	0·90
(38)	Tabular height of HW, LW, using (27) and (37) in connection with (10), Table 18.		+ ·77	+ ·89	−2·62	+1·75	+0·40	+ ·77	−2·29	+1·59	+0·13	+0·71	−2·06	+1·56	−0·05	+0·73	−1·86
(39)	Do. expressed in feet, [(18) × (38)].		+1·54	+1·84	−5·53	+3·80	+0·90	+1·76	−5·34	+3·78	+0·31	+1·74	−5·11	+3·93	−0·13	+1·86	−4·78
(40)	(39) + height of mean sea level (for date of tide) above plane of reference.		8·30	8·60	1·23	10·56	7·66	8·52	1·42	10·54	7·07	8·50	1·65	10·69	6·63	8·62	1·98
			+0·6	+0·1	+0·3	−0·4	+0·6	+0·1	+0·4	−0·2	+0·3	+0·1	+0·4	−0·5	+0·2	−0·1	+0·5

		27			28		
(1)	Time of moon's transit. [8:43, 21:09, 9:34, 21:59, preceding transits.]	1:32	13:52	2:12	14:32	2:53	15:14
(2)	(1) diminished by second preceding.	40	40	40	40	41	42
(3)	(2) first following subtracted from second preceding.	00	00	00	−01	−02	−03
(4)	(3) × ⅓ τ_2, correction for moon's declination and parallax on account of transit.	00	00	00	−01	−02	−03
(5)	HWI, LWI.						
(6)	(1) + (5).	11:48	18:25	0:09	6:46	12:30	19:07
(7)	Tabular correction for phase, Table 24.	−84	−92	−99	−105	−112	
(8)	Do. expressed in minutes.	−24	−26	−28	−29	−31	
(9)	(8) × (15).	−30	−32	−33	−36		
		LW	HW	LW	HW		
(10)	(4) + (6) + (9), time of HW, LW of semidiurnal wave.	5:43	11:21	17:56	23:37	6:12	11:54	18:28
(11)	Amplitude of semidiurnal wave, Δ_2.						
(12)	Tabular correction for parallax, Table 25.	−0·74	−0·75	−0·76	−0·77	−0·77	−0·77	−0·77
(13)	Do. expressed in feet.	−0·38	−0·38	−0·38	−0·39	−0·39	−0·39	−0·39
(14)	(11) + (13).	1·93	1·93	1·92	1·92	1·92	1·92	1·92
(15)	(11) ÷ (14).	1·20	1·20	1·20	1·20	1·20	1·20	1·20
(16)	Tabular correction for phase, Table 24.	+·85	+·88	+·90	+·92×·71	+·93	+·92	+·91
(17)	Do. expressed in feet.	+ ·60	+ ·62	+ ·63	+·65	+ ·66	+ ·65	+ ·65
(18)	(14) + (17), amplitude of semidiurnal wave.	2·53	2·55	2·57	2·58	2·57	2·58	2·57

		27			28		
(19)	Time of HW, LW of K_1.		17:37		5:31		17:29
(20)	Add 4^m to (19) for each preceding day; subtract 4^m for each following.		17:37		5:31		17:29
(21)	Acceleration in K_1 due to P_1, expressed in time.		−1:02		−1:01		−1:00
(22)	(20) − (21), time of K_1 (with P_1) tides.		18:39		6:36		18:34
(23)	Tabular correction for O_1, using (22), Table 27.		+3:48		+3:43		+ 2:59
(24)	Do. expressed in time, using (33).		+2:19		+2:20		+1:55
(10)		17:00	22:40	5:13	10:54	17:27	23:08	5:43	11:21	17:56	23:37
(25)	(22) + (24), time of HW, LW of diurnal wave. Between each time write the half length of the diurnal wave.	21:04	(11:52)	8:56	(11:33)	20:29	(10:46)	7:15	(10:22)	17:37	(10:43)	4:20	(11:30)
(26)	(10) − (25), always subtracting a diurnal tide from the times of two semidiurnal tides which include it. Bracket the values obtained from LW of diurnal wave.	[−4:04]	[1:36]	−3:43	1:58	[−3:02]	[2:39]	−1:32	4:06	[−6:16]	[0:19]	−4:43	1:52
(27)	(26) converted into degrees. Change name of phase when inclosed in brackets; otherwise the name of (10), Table 28.	22° L	−61° L	24° H	−56° H	31° L	−47° L	44° H	−26° H	71° L	−109° H	5° L	−79° L	29° H
(28)	Tabular value of acceleration, using (27) and (37), Table 17.	+18°·9	+6°·4	−12°·3	− 8°·3	+10°·0	+ 7°·2	− 4°·0	− 9°·2	− 9°·2	−0°·9	+ 10°·9	+5°·6
(29)	Do. converted into time.	+0 39	+0 13	− 0 25	− 0 17	+ 0 21	+ 0·15	− 0 08	− 0 19	− 0 19	−0 02	+ 0 23	+0 11
		HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	
(30)	(10) − (29), time of HW, LW.	22:27	5:38	11:11	17:06	22:53	5:51	11:40	17:58	23:14	6:01		
		+10	−12	+14	+8	+16	−9	+15	−3	+28	+1		Predictions of Tide Tables — (30)
	Date	26		27									
(31)	Amplitude of K_1 (with P_1), using times of (10).	2·31	2·30	2·30	2·29	2·28	2·27	2·27	2·26	2·25	2·25	2·24	
(32)	Amplitude of O_1 (with Q_1), using times of (10).	1·44	1·45	1·46	1·46	1·47	1·47	1·48	1·49	1·50	1·52	1·54	1·55
(33)	(32) ÷ (31).	0·62	0·63	0·64	0·64	0·64	0·64	0·65	0·66	0·66	0·68	0·68	0·69
(34)	Tabular correction for O_1, using times of (10), Table 27.	−0·38	−0·49	−0·61	−0·71	−0·82	−0·90	−0·97	−1·00	−0·97	−0·92	−0·83	−0·73	−0·62
(35)	Do. expressed in feet, [(32) × (34)].	−0·36	−0·54	−0·71	−0·88	−1·04	−1·20	−1·32	−1·43	−1·48	−1·45	−1·38	−1·26	−1·12	−0·96
(36)	(31) + (35), amplitude of diurnal wave.	1·97	1·78	1·61	1·43	1·26	1·10	0·97	0·85	0·79	0·82	0·88	0·99	1·13	1·28
(37)	(36) − (18).	0·77	0·69	0·63	0·56	0·50	0·41	0·39	0·35	0·33	0·34	0·38	0·44	0·51	0·60
(38)	Tabular height of HW, LW, using (27) and (37) in connection with (10), Table 18.	−0·34	+0·72	−1·58	+1·34	−0·58	+0·71	−1·29	+1·32	−0·91	+0·66	−0·94	+1·39		
(39)	Do. expressed in feet, [(18) × (38)].	−0·87	+1·86	−4·06	+3·40	−1·46	+1·78	−3·21	+3·23	−2·19	+1·57	−2·20	+3·14		
(40)	(39) + height of mean sea level (for date of tide) above plane of reference.	5·89	8·62	2·70	10·16	5·30	8·54	3·55	9·99	4·57	8·33	4·56	9·90		
		+0·2	−0·2	+0·5	0·0	0·0	−0·2	+0·4	+0·2	−0·4	0·0	−0·2	+0·3		Predictions of Tide Tables — (40.

AUXILIARY TABLES

FOR THE

REDUCTION AND PREDICTION

OF

TIDES.

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TABLE 1.—*The principal harmonic components,*

Symbol.	Name of component, etc.	Speed per mean solar hour.		Speed ratios.				Synodic period.* $15/(m\sim c)$
		Formula.	c	$\frac{c}{s_1}$	$\frac{s_1}{c}$	$\frac{c}{m_2}$	$\frac{c}{k_1}$	
			°					*d.*
J_1	Smaller lunar elliptic diurnal	$\gamma+\sigma-\varpi$	15·5854433	1·03903	0·96244	0·53772	1·03619	13·71879
	Lunar elliptic diurnal, second order	$\gamma-4\sigma+2\varpi$	12·8542862	0·85695	1·16693	0·44349	0·85461	9·15882
	Larger lunar evectional diurnal	$\gamma-3\sigma-\varpi+2\eta$	13·4715144	0·89810	1·11346	0·46479	0·89565	14·69813
$[K_1]$	Lunar diurnal	γ	15·0410686	1·00274	0·99727	0·51894	1·00000	27·32158
$[K_1]$	Solar diurnal	γ	15·0410686	1·00274	0·99727	0·51894	1·00000	27·32158
K_1	Luni-solar diurnal	γ	15·0410686	1·00274	0·99727	0·51894	1·00000	27·32158
$[K_2]$	Lunar semidiurnal	2γ	30·0821372	2·00548	0·49863	1·03788	2·00000	13·66079
$[K_2]$	Solar semidiurnal	2γ	30·0821372	2·00548	0·49863	1·03788	2·00000	13·66079
K_2	Luni-solar semidiurnal	2γ	30·0821372	2·00548	0·49863	1·03788	2·00000	13·66079
L_2	Smaller lunar elliptic semidiurnal	$2\gamma-\sigma-\varpi$ and $2\gamma-\sigma+\varpi$	29·5284788	1·96857	0·50798	1·01878	1·96319	27·55456
$[L_2]$	[Ferrel's L_2]	$2\gamma-\sigma-\varpi$	29·5284788	1·96857	0·50798	1·01878	1·96319	27·55456
		$2\gamma+\sigma-\varpi$	30·6265120	2·04177	0·48977	1·05667	2·03619	9·13293
M_1	Smaller lunar elliptic diurnal	$\gamma-\sigma-\varpi$ and $\gamma-\sigma+\varpi$†	14·4920521	0·96614	1·03505	0·50000	0·96350	
$[M_1]$	[Ferrel's m_1 or Q_1']	$\gamma-\sigma+\varpi$	14·4966939	0·96645	1·03472	0·50016	0·96381	
M_2	Principal lunar series	$2(\gamma-\sigma)$	28·9841042	1·93227	0·51753	1·00000	1·92700	
M_3		$3(\gamma-\sigma)$	43·4761563	2·89841	0·34502	1·50000	2·89050	
M_4		$4(\gamma-\sigma)$	57·9682084	3·86455	0·25876	2·00000	3·85400	
M_6		$6(\gamma-\sigma)$	86·9523126	5·79682	0·17251	3·00000	5·78099	
M_8		$8(\gamma-\sigma)$	115·9364168	7·72909	0·12938	4·00000	7·70799	
N_2	Larger lunar elliptic, semidiurnal	$2\gamma-3\sigma+\varpi$	28·4397296	1·89598	0·52743	0·98122	1·89081	27·55456
2 N	Lunar elliptic semidiurnal, second order	$2\gamma-4\sigma+2\varpi$	27·8953548	1·85969	0·53772	0·96244	1·85461	13·77728
O_1	Lunar diurnal	$\gamma-2\sigma$	13·9430356	0·92954	1·07581	0·48106	0·92700	27·32158
OO	Lunar diurnal, second order	$\gamma+2\sigma$	16·139·016	1·07594	0·92942	0·55683	1·07300	9·10719
P_1	Solar diurnal	$\gamma-2\eta$	14·9589314	0·99726	1·00275	0·51611	0·99454	32·12822
Q_1	Larger lunar elliptic diurnal	$\gamma-3\sigma+\varpi$	13·3986609	0·89324	1·11951	0·46228	0·89081	13·71879
R_2	Smaller solar elliptic	$2\gamma-\eta$	30·0410686	2·00274	0·49932	1·03647	1·99727	14·19158
S_1	Principal solar series	$\gamma-\eta$	15·0000000	1·00000	1·00000	0·51753	0·99727	29·53059
S_2		$2(\gamma-\eta)$	30·0000000	2·00000	0·50000	1·03505	1·99454	14·76529
S_3		$3(\gamma-\eta)$	45·0000000	3·00000	0·33333	1·55257	2·99181	
S_4		$4(\gamma-\eta)$	60·0000000	4·00000	0·25000	2·07010	3·98908	
T_2	Larger solar elliptic	$2\gamma-3\eta$	29·9589314	1·99726	0.50069	1·03363	1·99181	15·38734
λ_2	Smaller lunar evectional	$2\gamma-\sigma+\varpi-2\eta$	29·4556254	1·96371	0·50924	1·01627	1·95835	31·81193
μ_2	Variational	$2\gamma-4\sigma+2\eta$	27·9682084	1·86455	0·53632	0·96495	1·85946	14·76529
ν_2	Larger lunar evectional	$2\gamma-3\sigma-\varpi+2\eta$	28·5125830	1·90084	0·52608	0·98373	1·89565	31·81193

*The diurnal components are synodic with M_1, and the semidiurnal components with M_2.
† The first of these components is Ferrel's n_1; the second his m_1 or Q_1', and is the same as $[M_1]$. U. S. C. and G. S. Report, 1878, App. 11.

with their speeds, coefficients, etc.

Symbol.	Coefficients. Formula.	Mean value.	Coeff. ratios. $\frac{C}{M_2}$	Coeff. ratios. $\frac{C}{K_1}$	Factors for reduction. F	Equilibrium arguments. V	Equilibrium arguments. u
J_1	$\frac{2}{3} e \sin 2I$	·01485	0·03269	0·05600	$F(J_1) = \frac{0·72147}{\sin 2I}$	$t+h+s-p+90°$	$-\nu$
	$\frac{1}{4} e^2 \sin I \cos^2 \frac{1}{2} I$	·00487	0·01072	0·01836	$F = F(O_1)$	$t+h-4s+2p-90°$	$2\xi-\nu$
	$\frac{15}{32} me \sin I \cos^2 \frac{1}{2} I$	·00512* / ·00708	0·01127 / 0·01559	0·01930 / 0·02669	$F = F(O_1)$	$t+3h-3s-p-90°$	$2\xi-\nu$
$[K_1]$	$(\frac{1}{2}+\frac{3}{8} e^2) \sin 2I$	·18115	0·39878	0·68302	$F([K_1]) = \frac{0·72147}{\sin 2I} = F(J_1)$	$t+h+90°$	$-\nu$
$[K_1]$	$(\frac{1}{2}+\frac{3}{8} e_1) \frac{\tau_1}{\tau^2} \sin 2\omega$	·08407	0·18507	0·31698	$F([K_1]) =$ unity	$t+h+90°$	Zero
K_1	$(\frac{1}{2}+\frac{3}{8} e^2) \sin 2I + (\frac{1}{2}+\frac{3}{8} e_1^2) \frac{\tau_1}{\tau} \sin 2\omega$	·26522	0·58385	1·00000	$F(K_1) = \frac{1·05628}{(\sin^2 2I + 0·6696 \cos\nu \sin 2I + 0·11210)^{\frac{1}{2}}}$	$t+h+90°$	$-\nu'$
$[K_2]$	$(\frac{1}{2}+\frac{1}{8} e^2) \sin^2 I$	·03929	0·08649	0·14814	$F([K_2]) = \frac{0·15652}{\sin^2 I}$	$2t+2h$	-2ν
$[K_2]$	$(\frac{1}{2}+\frac{1}{8} e_1^2) \frac{\tau_1}{\tau} \sin^2 \omega$	·01823	0·04013	0·06874	$F([K_2]) =$ unity.	$2t+2h$	Zero
K_2	$(\frac{1}{2}-\frac{1}{8} e^2) \sin^2 I + (\frac{1}{2}+\frac{1}{8} e_1^2) \frac{\tau_1}{\tau} \sin^2 \omega$	·05752	0·12662	0·21688	$F(K_2) = \frac{0·22915}{(\sin^4 I + 0·14527 \cos 2\nu \sin^2 I + 0·00528)^{\frac{1}{2}}}$	$2t+2h$	$-2\nu''$
L_2	$\frac{1}{4} e \{1 - 12 \tan^2 \frac{1}{2} I \cos 2I\} \frac{1}{2} \cos^4 \frac{1}{2} I$ †	·01257	0·02767	0·04739	$F(L_2) = F(M_2) \times R'$	$2t+2h-s-p+180°$	$2\xi-2\nu-R$
$[L_2]$	$\frac{1}{4} e \cos^4 \frac{1}{2} I$	·01257	0·02767	0·04739	$F([L_2]) = \frac{0·91538}{\cos^4 \frac{1}{2} I} = F(M_2)$	$2t+2h-s-p+180°$	$2\xi-2\nu$
	$\frac{2}{3} e \sin^2 I$	·00323	0·00711	0·01218	$F = \frac{0·15652}{\sin^2 I}$	$2t+2h+s-p$	-2ν
M_1	$\frac{1}{2} e \{\frac{5}{3}+\frac{3}{2} \cos 2I\} \frac{1}{2} \sin I \cos^2 \frac{1}{2} I$ †	·00522‡ / ·01649	0·01149 / 0·03630	0·01968 / 0·06217	$F(M_1) = F(O_1) \times Q'$	$t+h-s+90°$	$\xi-\nu+Q$
$[M_1]$	$\frac{2}{3} e \sin 2I$	·01485	0·03269	0·05599	$F([M_1]) = \frac{0·72147}{\sin 2I} = F(J_1)$	$t+h-s+p+90°$	$-\nu$
M_2	$(\frac{1}{2}-\frac{1}{4} e^2) \cos^4 \frac{1}{2} I$	·45426	1·00000	1·71277	$F(M_2) = \frac{0·91538}{\cos^4 \frac{1}{2} I}$	$2t+2h-2s$	$2\xi-2\nu$
M_3	$\frac{9}{16} d \cos^6 \frac{1}{2} I$, (and shallow water)	·00599	0·01319	·02259	$F(M_3) = \frac{0·87579}{\cos^6 \frac{1}{2} I} = F^{\frac{3}{2}}(M_2)$	$3t+3h-3s+180°$	$3\xi-3\nu$
M_4	(Shallow water)				$F(M_4) = \frac{0·83792}{\cos^8 \frac{1}{2} I} = F^2(M_2)$	$4t+4h-4s$	$4\xi-4\nu$
M_6	(Shallow water)				$F(M_6) = \frac{0·76701}{\cos^{12} \frac{1}{2} I} = F^3(M_2)$	$6t+6h-6s$	$6\xi-6\nu$
M_8	(Shallow water)				$F(M_8) = \frac{0·70210}{\cos^{16} \frac{1}{2} I} = F^4(M_2)$	$8t+8h-8s$	$8\xi-8\nu$
N_2	$\frac{1}{4} e \cos^4 \frac{1}{2} I$	·08796	0·19363	0·33165	$F(N_2) = \frac{0·91538}{\cos^4 \frac{1}{2} I} = F(M_2)$	$2t+2h-3s+p$	$2\xi-2\nu$
$2N$	$\frac{1}{4} e^2 \cos^4 \frac{1}{2} I$	·01173	0·02582	0·04423	$F(2N) = \frac{0·91538}{\cos^4 \frac{1}{2} I} = F(M_2)$	$2t+2h-4s+2p$	$2\xi-2\nu$
O_1	$(\frac{1}{2}-\frac{1}{4} e^2) \sin I \cos^2 \frac{1}{2} I$	·18856	0·41509	0·71096	$F(O_1) = \frac{0·38005}{\sin 1 \cos^2 \frac{1}{2} I}$	$t+h-2s-90°$	$2\xi-\nu$
OO	$(\frac{3}{2}-\frac{5}{4} e^2) \sin I \sin^2 \frac{1}{2} I$	·00812	0·01788	0·03062	$F(OO) = \frac{0·01638}{\sin 1 \sin^2 \frac{1}{2} I}$	$t+h+2s+90°$	$-2\xi-\nu$
P_1	$(\frac{1}{2}-\frac{1}{2} e_1^2) \frac{\tau_1}{\tau} \sin \omega \cos^2 \frac{1}{2} \omega$	·08775	0·19317	0·33086	$F(P_1) =$ unity	$t-h-90°$	Zero
Q_1	$\frac{1}{4} e \sin I \cos^2 \frac{1}{2} I$	·03651	0·08037	0·13766	$F(Q_1) = \frac{0·38005}{\sin 1 \cos^2 \frac{1}{2} I} = F(O_1)$	$t+h-3s+p-90°$	$2\xi-\nu$
R_2	$\frac{1}{4} e_1 \frac{\tau_1}{\tau} \cos^4 \frac{1}{2} \omega$	·00178	0·00392	0·00671	$F(R_2) =$ unity	$2t+h-p_1$	Zero
S_1	(Chiefly meteorological)				$F(S_1) =$ unity	$t+180°$	Zero
S_2	$(\frac{1}{2}-\frac{5}{4} e_1^2) \frac{\tau_1}{\tau} \cos^4 \frac{1}{2} \omega$	·21137	0·46531	0·79696	$F(S_2) =$ unity	$2t$	Zero
S_3	(Chiefly shallow water)				$F(S_3) =$ unity	$3t+180°$	Zero
S_4	(Shallow water), $(S_2/M_2)^2 M_4$				$F(S_4) =$ unity	$4t$	Zero
T_2	$\frac{1}{4} e_1 \frac{\tau_1}{\tau} \cos^4 \frac{1}{2} \omega$	·01243	0·02736	0·04687	$F(T_2) =$ unity	$2t-h+p_1$	Zero
λ_2	$\frac{1}{36} me \cos^4 \frac{1}{2} I$	·00176* / ·00330	0·00387 / 0·00726	0·00664 / 0·01244	$F(\lambda_2) = \frac{0·91538}{\cos^4 \frac{1}{2} I} = F(M_2)$	$2t-s+p+180°$	$2\xi-2\nu$
μ_2	$\frac{9}{16} m^2 \cos^4 \frac{1}{2} I$	·00736* / ·01094	0·01620 / 0·02408	0·02775 / 0·04125	$F(\mu_2) = \frac{0·91538}{\cos^4 \frac{1}{2} I} = F(M_2)$	$2t+4h-4s$	$2\xi-2\nu$
ν_2	$\frac{1}{36} me \cos^4 \frac{1}{2} I$	·01234* / ·01706	0·02717 / 0·03756	0·04653 / 0·06432	$F(\nu_2) = \frac{0·91538}{\cos^4 \frac{1}{2} I} = F(M_2)$	$2t+4h-3s-p$	$2\xi-2\nu$

* The lower of these two figures gives the value when the coefficients in the evection and variation have their full values as derived from Lunar Theory.

† The coefficients of L_2 and M_1 are approximately expressed by the given formulæ; the true mean values are 0·01278 and 0·01531, respectively.

‡ The first of these two numbers is the mean value of the coefficients of the tide $\gamma-\sigma-\varpi$; the second applies to the tide M_1, compounded from $\gamma-\sigma-\varpi$ and $\gamma-c+\varpi$.

TABLE 1.—*The principal harmonic components,*

Symbol.	Name of component, etc.	Speed per mean solar hour.		Speed ratios.				Synod c period.* $15/(m \sim c)$
		Formula.	c	$\frac{c}{s_1}$	$\frac{s_1}{c}$	$\frac{c}{m_2}$	$\frac{c}{k_1}$	
			°					*d.*
MK	Compound tides	$3\gamma-2\sigma$	44·0251728	2·93501	0·34071	1·51894	2·92700	
2 MK		$3\gamma-4\sigma$	42·9271398	2·86181	0·34943	1·48106	2·85400	
MN		$4\gamma-5\sigma+\varpi$	57·4238338	3·82826	0·26122	1·98122	3·81780	
MS †		$4\gamma-2\sigma-2\eta$	58·9841042	3·93227	0·25431	2·03505	3·92154	
2 MS		$2\gamma-4\sigma+2\eta$	27·9682084	1·86455	0·53632	0·96495	1·85946	
2 SM		$2\gamma+2\sigma-4\eta$	31·0158958	2·06773	0·48362	1·07010	2·06208	
Mf	Lunar fortnightly	2σ	1·0980330	0·07320	13·66079	0·03788	0·07300	
MSf †	Luni-solar synodic fortnightly	$2(\sigma-\eta)$	1·0158958	0·06773	14·76529	0·03505	0·06754	
Mm	Lunar monthly	$\sigma-\varpi$	0·5443747	0·03629	27·55455	0·01878	0·03619	
Sa	Solar annual	η	0·0410686	0·00274	365·24219	0·00142	0·00273	
Ssa	Solar semiannual	2η	0·0821372	0·00548	182·62109	0·00283	0·00546	
	Right ascension of local meridian	γ	15·04106864	1·00274	0·99727	0·51894	1·00000	
h	Mean longitude of sun	η	0·04106864	0·00274	365·24219	0·00142	0·00273	
s	Mean longitude of moon	σ	0·54901653	0·03660	27·32158	0·01894	0·03650	
p	Mean longitude of lunar perigee	ϖ	0·00464183	0·00031	3231·48	0·00016	0·00031	
p_1	Mean longitude of solar perigee		0·00000196	0·00000	.....	0·00000	0·00000	
t	Time in hours after midnight, or do. multiplied by 15	$\gamma-\eta$	15·00000000	1·00000	1·00000	0·51753	0·99727	

c = speed of any component.
c_1 = speed of any diurnal component.
k_1 = speed of the diurnal component K_1.
m_1 = speed of the diurnal component M_1.
m_2 = speed of the semidiurnal component $M_2 = 2\,m_1$.
s_1 = speed of the diurnal component $S_1 = 15°$ per hour.

* The diurnal components are synodic with M_1, and the semidiurnal components with M_2.

† Suggested by Helmholtz's theory of compound sounds. B. A. A. S. Report 1869, p. 504. MS has been called the Helmholtz luni-solar tide. B. A. A. S. Report 1870, p. 149. Ferrel designated it by $(MS)_4$.

with their speeds, coefficients, etc.—Continued.

Symbol.	Coefficients. Formula.	Coefficients. Mean value.	Coeff. ratios. $\frac{C}{M_2}$	Coeff. ratios. $\frac{C}{K_1}$	Factors for reduction. F	Equilibrium arguments. V'	Equilibrium arguments. u
MK	(Shallow water)				$F(MK) = F(M_2) \times F(K_1)$	$3t+3h-2s+90°$	$2\xi-2\nu-\nu'$
2 MK	(Shallow water)				$F(2MK) = F(M_4) \times F(K_1)$	$3t+3h-4s-90°$	$4\xi-4\nu+\nu'$
MN	(Shallow water)				$F(MN) = \frac{0{\cdot}83792}{\cos^8 \frac{1}{2} I} = F(M_4)$	$4t+4h-5s+p$	$4\xi-4\nu$
MS	(Shallow water), 2 (S_2/M_2) M_4				$F(MS) = \frac{0{\cdot}91538}{\cos^4 \frac{1}{2} I} = F(M_2)$	$4t+2h-2s$	$2\xi-2\nu$
2 MS	(Shallow water)				$F(2MS) = \frac{0{\cdot}83792}{\cos^8 \frac{1}{2} I} = (F M_4)$	$2t+4h-4s$	$4\xi-4\nu$
2 SM	(Shallow water)				$F(2SM) = \frac{0{\cdot}91538}{\cos^4 \frac{1}{2} I} = F(M_2)$	$2t-2h+2s$	$-2\xi+2\nu$
Mf	$(\frac{2}{3}-\frac{4}{3} e^2) \sin^2 I$	·07827	·17230	0·29511	$F(Mf) = \frac{0{\cdot}15779}{\sin^2 I}$	$2s$	-2ξ
MSf	$m^2 (1-\frac{3}{2} \sin^2 I)$, (and shallow water)	{·00422* ·00621	·00929 ·01367	0·01591 0·02341	$F(MSf) = \frac{0{\cdot}91538}{\cos^4 \frac{1}{2} I} = F(M_2)$	$-2h+2s$	$-2\xi+2\nu$
Mm	$e (1-\frac{3}{2} \sin^2 I)$	·04136	·09105	0·15595	$F(Mm) = \frac{0{\cdot}75316}{1-1{\cdot}5 \sin^2 I}$	$s-p$	Zero
Sa	(Chiefly meteorological)				$F(Sa) = \text{unity}$	h	Zero
Ssa	$(\frac{2}{3}-\frac{4}{3} e_1^2) \frac{\tau_1}{\tau} \sin^2 \omega$	·03643	·08020	0·13736	$F(Ssa) = \text{unity}$	$2h$	Zero

C = Coefficient or theoretical amplitude of any component.
M_2 = Coefficient or theoretical amplitude of the component M_2.
K_1 = Coefficient or theoretical amplitude of the component K_1.

$m = \frac{\text{mean motion of sun}}{\text{mean motion of moon}} = 0{\cdot}07480 = \frac{1}{13{\cdot}369}$.

R is such that $\tan R = \frac{\sin 2P}{\frac{1}{6} \cot^2 \frac{1}{2} I - \cos 2P}$; see Table 8.

$K' = \left(\frac{1}{1-12 \tan^2 \frac{1}{2} I \cos 2P}\right)^{\frac{1}{2}}$; see Table 11.

ν' is such that $\tan \nu' = \frac{\sin \nu \sin 2I}{0{\cdot}334811 + \cos \nu \sin 2I}$; see Table 7.

e = eccentricity of moon's orbit = 0·0549.
e_1 = eccentricity of earth's orbit = 0·0168.
ω = obliquity of the ecliptic = 23° 27′·3.

$\frac{\tau_1}{\tau} = \frac{\text{mass of sun}}{\text{mass of moon}} \times \left(\frac{\text{mean dist. of moon}}{\text{mean dist. of sun}}\right)^3 = 0{\cdot}46035 = \frac{1}{2{\cdot}17225}$.

Q is such that $\tan Q = \frac{1}{3} \tan P$; see Table 9.

$Q' = \left(\frac{1}{2{\cdot}5 + 1{\cdot}5 \cos 2P}\right)^{\frac{1}{2}}$; see Table 12.

ν'' is such that $\tan 2\nu'' = \frac{\sin 2\nu \sin^2 I}{0{\cdot}072634 + \cos 2\nu \sin^2 I}$; see Table 7.

I = inclination of lunar orbit to the plane of the earth's equator; it varies between $\omega-5° 8'·8$ and $\omega+5° 8'·8$, i. e. from 18° 18′·5 to 28° 36′·1. See Tables 6 and 7.

P = mean longitude of lunar perigee measured from the intersection of moon's orbit with the plane of the earth's equator. See Table 6.

d = earth's radius divided by moon's mean distance, i. e. the lunar parallax expressed in radians = 0·01659 = $\frac{1}{60{\cdot}27}$.

ξ = longitude in moon's orbit of the intersection of the lunar orbit with the plane of the earth's equator. See Table 7.
ν = right ascension of the intersection of the lunar orbit with the plane of the earth's equator. See Table 7.

The semidiurnals have a general coefficient $\cos^2 \lambda$; the diurnals, $\sin 2\lambda$; those of long period, $\frac{1}{2}-\frac{3}{2} \sin^2 \lambda$; and M_3, $\cos^3 \lambda$. λ denotes the latitude.

*The lower of these two figures gives the value when the coefficients in the evection and variation have their full values as derived from Lunar Theory.

TABLE 2.—*Dependence of component speeds upon certain astronomical quantities (epoch 1900).*

	h.		°
Solar day	$= 24{\cdot}000\ 0000 = \frac{2 \times 360}{s_2}$;	$s_2 = \frac{2 \times 360}{\text{solar day}}$	$= 30{\cdot}000\ 0000$
Lunar day	$= 24{\cdot}841\ 2024 = \frac{2 \times 360}{m_2}$;	$m_2 = \frac{2 \times 360}{\text{lunar day}}$	$= 28{\cdot}984\ 1042$
Tropical day	$= 23{\cdot}934\ 4696 = \frac{2 \times 360}{k_2}$;	$k_2 = \frac{2 \times 360}{\text{tropical day}}$	$= 30{\cdot}082\ 1373$

If c denote the speed of any given component C, then a component whose speed is

$$c \pm \frac{360}{\Pi}$$

has with C a synodic period Π hours in length. If C be the principal one of the two components, then the effect of the other is to introduce an inequality into C of a period equal to Π. The known motions of the moon and sun suggest what tidal inequalities may exist corresponding to periodic irregularities in the motions of these bodies, or in the motions of the elements of their orbits. The following tabulation shows that it is often necessary to use more than one component to account for what may be regarded as an irregularity in the principal component:

	Π		Speed.		
			Formula.		Symbol.
	Name.	Value (hours, days).	$c + \frac{360}{\Pi}$	$c - \frac{360}{\Pi}$	
			°	°	
$c = m_2 = 28{\cdot}9841042$ °	Half synodic month	½ (708·734115) h. ½ (29·5305881) d.	30·0000000	27·9682084	s_2 μ_2
	Half tropical month	½ (655·717960) h. ½ (27·3215817) d.	30·0821373		k_2
	Anomalistic month	661·309206 h. 27·5545503 d.	29·5284789	28·4397295	l_2 n_2
	Half anomalistic month	½ (661·309206) h. ½ (27·5545503) d.		27·8953549	2 n
	Evectional period	763·486534 h. 31·8119389 d.	29·4556253	28·5125831	λ_2 ν_2
$c = s_2 = 30$ °	Half tropical year	½ (8765·812722) h. ½ (365·2421968) d.	30·0821373		k_2
	Tropical year *	8765·812722 h. 365·2421968 d.	30·0410686	29·9589314	r_2 t_2
$c = k_1 = 15{\cdot}0410686$ °	Half tropical month	½ (655·717960) h. ½ (27·3215817) d.	16·1391017	13·9430356	oo o_1
	Anomalistic month	661·309206 h. 27·5545503 d.	15·5854433		j_1
	Half tropical year	½ (8765·812722) h. ½ (365·2421968) d.		14·9589314	p_1
$c = 0$ °	Anomalistic month	661·309206 h. 27·5545503 d.		13·3986609	q_1
$c = l_2$ $c = n_2$	Half evectional period in moon's parallax	½ (9882·831893) h. ½ (411·7846622) d.	28·5125831	29·4556253	λ_2 ν_2

* The tropical year is taken for convenience instead of the anomalistic year (= 8766·2295 h. or 365·25956 d.).

This table is based in part upon values given in Harkness' paper on the solar parallax, App. III, Washington Observations for 1885.

TABLE 3.—*Equilibrium arguments (V_0+u) at the midnight preceding January 1 of each year from 1850 to 1950, for the meridian of Greenwich, together with the elements used in computing them.*

Component.	1850	1851	1852	1853	1854	1855	1856	1857	1858	1859
	°	°	°	°	°	°	°	°	°	°
J_1	29·66	116·00	204·03	307·53	38·07	129·39	221·21	327·32	59·40	151·25
K_1	3·47	1·64	0·92	2·20	3·31	5·03	7·13	10·45	12·78	14·92
K_2	187·75	183·76	181·83	183·99	186·04	189·52	193·95	200·87	205·84	210·36
L_2	155·70	350·62	161·48	330·94	177·72	26·05	194·57	353·33	204·19	54·37
$[L_2]$	149·54	338·59	167·84	346·01	175·74	5·69	195·78	14·65	204·84	34·96
M_1	6·83	273·54	165·21	50·56	346·93	274·81	170·80	55·36	347·23	281·70
$[M_1]$	330·16	239·05	149·63	49·56	322·66	236·54	150·91	53·45	328·08	242·49
M_2	299·79	40·11	140·64	217·03	318·04	59·26	160·63	237·71	339·18	80·58
M_3	269·69	240·17	210·96	145·54	117·05	88·89	60·95	356·57	328·78	300·86
M_4	239·58	80·22	281·28	74·06	276·07	118·52	321·26	115·43	318·37	161·15
M_6	179·38	120·34	61·93	291·08	234·11	177·77	121·89	353·14	297·55	241·73
M_8	119·17	160·45	202·57	148·11	192·14	237·03	282·52	230·86	276·74	322·30
N_2	270·04	281·64	293·45	268·05	280·33	292·83	305·48	280·78	293·52	306·19
2 N	240·29	163·17	86·25	319·06	242·63	166·40	90·33	323·84	247·86	171·81
O_1	299·88	42·59	143·81	218·48	317·67	56·29	154·57	227·33	325·45	63·71
OO	239·95	132·46	29·85	318·61	223·07	129·63	37·54	333·44	242·03	150·04
P_1	349·70	349·94	350·18	349·43	349·67	349·91	350·15	349·40	349·64	349·88
Q_1	270·13	284·11	296·62	269·50	279·96	289·87	299·42	270·39	279·79	289·32
R_2	359·93	359·67	359·42	0·15	359·89	359·63	359·38	0·11	359·85	359·60
$S_{1, 3}$	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00
$S_{2, 4, 6}$	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
T_2	0·07	0·33	0·58	359·85	0·11	0·37	0·62	359·89	0·15	0·40
λ_2	148·79	59·63	330·69	228·92	140·45	52·19	324·09	223·02	135·01	46·93
μ_2	241·04	82·12	283·40	76·16	277·92	119·89	322·02	115·47	317·70	159·84
ν_2	270·79	200·59	130·60	25·14	315·62	246·32	177·17	72·41	3·36	294·22
MK	303·26	41·75	141·56	219·23	321·35	64·29	167·77	248·16	351·96	95·49
2 MK	236·12	78·59	280·37	71·86	272·76	113·49	314·13	104·98	305·59	146·23
MN	209·83	321·75	74·09	125·07	238·37	352·09	106·11	158·49	272·71	26·77
MS	299·79	40·11	140·64	217·03	318·04	59·26	160·63	237·71	339·18	80·58
2 MS	239·58	80·22	281·28	74·06	276·07	118·52	321·26	115·43	318·37	161·15
2 SM	60·21	319·89	219·36	142·97	41·96	300·74	199·37	122·29	20 82	279·42
Mf	240·03	134·94	33·02	320·06	222·70	126·67	31·48	323·06	228·29	133·17
MSf	60·21	319·89	219·36	142·97	41·96	300·74	199·37	122·29	20·82	279·42
Mm	29·75	118·47	207·20	308·98	37·71	126·43	215·15	316·94	45·66	134·38
Sa	280·30	280·06	279·82	280·57	280·33	280·09	279·85	280·60	280·36	280·12
Ssa	200·60	200·12	199·64	201·13	200·66	200·18	199·70	201·20	200·72	200·24
Elements.	Values at Greenwich, midnight beginning each year.									
h	280·30	280·06	279·82	280·57	280·33	280·09	279·85	280·60	280·36	280·12
s	129·67	259·06	28·44	171·00	300·39	69·77	199·16	341·72	111·10	240·49
p	99·92	140·58	181·25	222·02	262·68	303·35	344·01	24·78	65·44	106·11
	Values at the middle of each year, or for July 2 at Greenwich mean noon for common years, and at preceding midnight for leap years.									
p_1	280·37	280·39	280·40	280·42	280·44	280·46	280·47	280·49	280·51	280·52
P	110·60	149·33	189·70	231·38	273·98	317·24	0·98	44·92	88·82	132·53
N	136·54	117·21	97·85	78·50	59·17	39·84	20·49	1·13	341·81	322·48
I	20·02	21·57	23·28	24·97	26·44	27·59	28·33	28·60	28·39	27·71
Q	126·93	163·48	184·89	212·04	277·91	335·19	0·49	26·51	87·63	151·41
R	353·84	347·96	6·36	15·08	358·02	339·64	1·21	21·32	0·66	345·41
ξ	9·65	11·59	11·93	10·97	9·04	6·44	3·42	0·19	356·96	353·91
ν	10·39	12·54	12·99	12·02	9·96	7·13	3·79	0·21	356·62	353·25
ν'	6·83	8·42	8·90	8·37	7·02	5·06	2·72	0·15	357·58	355·20
$2\nu''$	12·85	16·36	17·81	17·14	14·62	10·67	5·75	0·32	354·88	349·88

In making analyses or predictions it is not desirable to modify the values of V_0+u as here given either on account of the longitude of the station or the longitude of the time meridian. Such alteration should be made once for all in the epoch (C^0) of the particular component (C) as will adapt it to the tabular V_0+u.

TABLE 3.—*Equilibrium arguments (V_0+u) at the midnight preceding January 1 of each year, from 1850 to 1950, for the meridian of Greenwich, together with the elements used in computing them*—Continued.

Component.	1860	1861	1862	1863	1864	1865	1866	1867	1868	1869
	°	°	°	°	°	°	°	°	°	°
J_1	242·65	347·35	76·95	165·17	251·71	350·55	74·00	157·03	240·76	340·06
K_1	16·70	18·88	19·28	18·69	16·99	15·22	11·71	7·97	4·62	3·11
K_2	213·98	218·19	218·62	216·95	213·19	209·68	203·16	196·37	190·05	186·95
L_2	229·00	26·04	228·97	72·20	259·39	62·53	249·41	86·02	283·89	100·40
$[L_2]$	224·92	43·36	232·88	62·16	251·23	68·81	257·60	86·37	275·18	92·79
M_1	178·86	61·04	340·98	280·05	179·71	56·79	311·75	235·51	162·59	47·19
$[M_1]$	156·44	57·57	329·72	240·49	149·59	44·86	310·86	216·44	122·73	18·46
M_2	181·82	258·47	359·27	99·83	200·17	275·96	16·03	116·07	216·16	291·99
M_3	272·72	207·70	178·90	149·74	120·25	53·94	24·05	354·11	324·25	257·99
M_4	3·63	156·94	358·53	199·65	40·33	191·92	32·06	232·15	72·33	223·99
M_6	185·45	55·40	357·80	299·48	240·50	107·88	48·10	348·22	288·49	155·98
M_8	7·26	313·87	357·06	39·30	80·66	23·84	64·13	104·30	144·66	87·98
N_2	318·71	293·58	305·65	317·49	329·11	303·11	314·46	325·78	337·15	311·19
2 N	95·61	328·68	252·04	175·15	98·05	330·27	252·89	175·49	98·14	330·39
O_1	162·27	236·01	335·93	77·00	179·52	258·25	3·60	109·34	214·42	292·74
OO	56·81	348·91	250·74	148·66	41·77	317·16	201·26	84·13	329·07	245·78
P_1	350·12	349·37	349·61	349·85	350·09	349·34	349·58	349·82	350·06	349·31
Q_1	299·17	271·12	282·32	294·66	308·46	285·41	302·03	319·05	335·40	311·93
R_2	359·34	0·07	359·82	359·56	359·30	0·03	359·78	359·52	359·27	359·99
$S_{1,3}$	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00
$S_{2,4,6}$	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
T_2	0·66	359·93	0·18	0·44	0·70	359·97	0·22	0·48	0·73	0·01
λ_2	318·69	217·19	128·51	39·59	310·46	208·10	118·69	29·26	299·87	197·55
μ_2	1·83	154·86	356·41	197·72	38·81	190·98	31·80	232·60	73·44	225·64
ν_2	224·94	119·75	50·02	340·06	269·87	163·82	93·37	22·89	312·45	206·44
MK	198·51	277·35	18·54	118·51	217·15	291·18	27·74	124·04	220·78	295·10
2 MK	346·93	138·06	339·25	180·96	23·34	176·70	20·36	224·18	67·71	220·88
MN	140·53	192·04	304·92	57·31	169·27	219·07	330·49	81·86	193·31	243·19
MS	181·82	258·47	359·27	99·83	200·17	275·96	16·03	116·07	216·16	291·99
2 MS	3·63	156·94	358·53	199·65	40·33	191·92	32·06	232·15	72·33	223·99
2 SM	178·18	101·53	0·73	260·17	159·83	84·04	343·97	243·93	143·84	68·01
Mf	37·27	326·45	227·40	125·83	21·13	299·45	188·83	77·40	327·33	246·52
MSf	178·18	101·53	0·73	260·17	159·83	84·04	343·97	243·93	143·84	68·01
Mm	223·11	324·00	53·61	142·34	231·06	332·85	61·57	150·29	239·01	340·80
Sa	279·88	280·63	280·39	280·15	279·91	280·66	280·42	280·18	279·94	280·69
Ssa	199·76	201·26	200·78	200·30	199·83	201·32	200·84	200·37	199·89	201·38
Elements.	Values at Greenwich, midnight beginning each year.									
h	279·88	280·63	280·39	280·15	279·91	280·66	280·42	280·18	279·94	280·69
s	9·87	152·43	281·82	51·21	180·59	323·15	92·54	221·92	351·31	133·87
p	146·77	187·54	228·21	268·87	309·53	350·31	30·97	71·63	112·29	153·07
	Values at the middle of each year, or for July 2, at Greenwich mean noon for common years and at preceding midnight for leap years.									
p_1	280·54	280·56	280·57	280·59	280·61	280·63	280·64	280·66	280·68	280·69
P	175·91	218·66	260·42	300·91	339·89	17·21	53·18	88·74	125·04	162·79
N	303·12	283·77	264·44	245·11	225·76	206·40	187·07	167·75	148·39	129·03
I	26·60	25·15	23·49	21·77	20·19	18·98	18·36	18·46	19·25	20·58
Q	177·95	201·80	251·35	320·13	349·62	8·81	33·73	87·48	144·51	171·19
R	355·92	17·32	3·91	349·96	351·83	6·27	8·19	0·34	351·29	352·39
ξ	351·24	349·21	348·12	348·29	350·03	353·43	358·12	3·22	7·64	10·61
ν	350·34	348·17	347·06	347·32	349·27	352·95	357·99	3·45	8·20	11·43
ν'	353·19	351·75	351·11	351·46	352·92	355·44	358·71	2·21	5·33	7·58
$2\nu''$	345·78	343·07	342·16	343·35	346·64	351·64	357·68	4·00	9·84	14·43

From §62 we have for the modified epoch ($\mathfrak{C}^o$)

$$\mathfrak{C}^o = C^o + 15\,p\,L - c\,S$$

where p is to be put equal 1, 2, . . . according as C is diurnal, semidiurnal, etc.; c is the hourly speed of C; L, S denote the west longitude in hours of the station and of the time meridian used. The values of L and S should always accompany the work of analysis or prediction, thus enabling one to pass from $\mathfrak{C}^o$ to C^o or C^o to $\mathfrak{C}^o$ as the case may be.

TABLE 3.—*Equilibrium arguments (V_0+u) at the midnight preceding January 1 of each year, from 1850 to 1950, for the meridian of Greenwich, together with the elements used in computing them*—Continued.

Component.	1870	1871	1872	1873	1874	1875	1876	1877	1878	1879
	°	°	°	°	°	°	°	°	°	°
J_1	67·07	155·69	245·61	350·54	82·08	174·02	266·11	12·19	103·89	195·03
K_1	1·71	1·41	2·04	4·40	6·29	8·51	10·86	14·12	16·15	17·73
K_2	183·73	182·64	183·58	188·21	192·12	196·81	201·81	208·64	212·86	216·00
L_2	270·95	100·60	307·85	139·35	296·92	121·83	334·74	170·64	331·40	151·77
$[L_2]$	281·92	111·26	300·85	119·34	309·36	139·50	329·70	148·55	338·61	168·50
M_1	297·71	201·00	145·32	47·99	301·76	202·48	145·46	55·40	309·99	207·85
$[M_1]$	288·03	199·20	111·67	13·03	287·13	201·62	116·27	18·77	293·03	206·72
M_2	32·39	133·02	233·88	310·59	51·88	153·30	254·77	331·84	73·18	174·35
M_3	228·59	199·52	170·81	105·88	77·82	49·95	22·16	317·76	289·77	261·52
M_4	64·79	266·03	107·75	261·18	103·76	306·60	149·55	303·68	146·36	348·70
M_6	97·18	39·05	341·63	211·76	155·63	99·90	44·32	275·53	219·55	163·04
M_8	129·58	172·06	215·50	162·35	207·51	253·20	299·10	247·37	292·73	337·39
N_2	322·87	334·77	346·91	321·82	334·40	347·10	359·85	335·13	347·75	0·19
2 N	253·35	176·52	99·94	333·08	256·92	180·90	104·93	338·42	262·32	186·04
O_1	34·84	135·57	235·24	308·80	47·27	145·48	243·58	316·37	54·72	153·47
OO	140·26	39·33	302·04	234·76	141·93	50·16	318·80	254·59	162·20	68·28
P_1	349·55	349·79	350·03	349·28	349·52	349·75	349·99	349·25	349·49	349·73
Q_1	325·32	337·32	348·27	320·05	329·80	339·28	348·66	319·65	329·29	339·32
R_2	359·74	359·49	359·23	359·96	359·70	359·45	359·19	359·92	359·67	359·41
$S_{1,3}$	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00
$S_{2,4,6}$	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
T_2	0·26	0·51	0·77	0·04	0·30	0·55	0·81	0·08	0·33	0·59
λ_2	108·47	19·62	291·00	189·56	101·37	13·32	285·32	184·23	96·09	7·78
μ_2	66·79	268·17	109·78	262·86	104·91	307·08	149·31	302·75	144·84	346·76
ν_2	136·32	66·42	356·75	251·62	182·39	113·28	44·23	299·46	230·27	160·91
MK	34·11	134·42	235·92	314·99	58·17	161·81	265·63	345·97	89·33	192·07
2 MK	63·07	264·62	105·71	256·78	97·46	298·09	138·69	289·56	130·21	330·97
MN	355·27	107·79	220·78	272·42	26·28	140·40	254·63	306·97	60·93	174·54
MS	32·39	133·02	233·88	310·59	51·88	153·30	254·77	331·84	73·18	174·35
2 MS	64·79	266·03	107·75	261·18	103·76	306·60	149·55	303·68	146·36	348·70
2 SM	327·61	226·98	126·12	49·41	308·12	206·70	105·23	28·16	286·82	185·65
Mf	142·71	41·88	303·40	232·98	137·33	42·34	307·61	239·11	143·74	47·41
MSf	327·61	226·98	126·12	49·41	308·12	206·70	105·23	28·16	286·82	185·65
Mm	69·52	158·25	246·97	348·75	77·48	166·20	254·92	356·71	85·43	174·15
Sa	280·45	280·21	279·97	280·72	280·48	280·25	280·01	280·75	280·51	280·27
Ssa	200·90	200·43	199·95	201·44	200·97	200·49	200·01	201·50	201·03	200·55
Elements.	Values at Greenwich, midnight beginning each year.									
h	280·45	280·21	279·97	280·72	280·48	280·25	280·01	280·75	280·51	280·27
s	263·25	32·64	162·02	304·58	73·97	203·35	332·74	115·30	244·68	14·07
p	193·73	234·39	275·05	315·83	356·49	37·15	77·81	118·59	159·25	199·91
	Values at the middle of each year, or for July 2, at Greenwich mean noon for common years and at preceding midnight for leap years.									
p_1	280·71	280·73	280·75	280·76	280·78	280·80	280·81	280·83	280·85	280·87
P	202·16	243·03	285·12	328·07	11·52	55·30	99·27	143·18	186·77	229·88
N	109·71	90·38	71·03	51·67	32·34	13·01	353·66	334·30	314·97	295·65
I	22·22	23·95	25·57	26·93	27·93	28·49	28·57	28·18	27·32	26·07
Q	191·51	224·49	298·38	342·69	5·82	35·83	108·07	159·48	183·40	210·68
R	10·97	10·66	353·00	339·99	12·44	17·67	354·95	337·91	7·22	16·73
ξ	11·90	11·70	10·32	8·09	5·30	2·18	358·93	355·74	352·81	350·37
ν	12·90	12·77	11·33	8·94	5·88	2·43	358·81	355·27	352·05	349·40
ν'	8·74	8·81	7·93	6·32	4·19	1·74	359·15	356·63	354·37	352·55
$2\nu''$	17·18	17·79	16·36	13·23	8·85	3·68	358·20	352·87	348·16	344·55

If the first day of the series to be analyzed be other than January 1, the change in the V_0+u as here tabulated is obtained from Tables 4, 6, 7, 8, and 9. In the case of prediction, only Table 4 is required, because u may be regarded as constant for any fraction of a year.

TABLE 3.—*Equilibrium arguments ($V_0 + u$) at the midnight preceding January 1 of each year, from 1850 to 1950, for the meridian of Greenwich, together with the elements used in computing them*—Continued.

Component.	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889
	°	°	°	°	°	°	°	°	°	°
J_1	285·32	28·47	116·06	201·92	286·12	23·31	106·49	190·75	276·68	18·39
K_1	18·64	19·66	18·65	16·53	13·43	10·74	7·07	4·01	1·94	1·96
K_2	217·59	219·20	216·70	212·21	206·24	201·48	194·79	188·87	184·45	184·02
L_2	359·19	189·85	8·80	184·51	17·70	204·53	38·89	219·81	35·38	219·58
$[L_2]$	358·17	176·28	5·47	194·47	23·31	200·77	29·54	218·40	47·40	225·28
M_1	142·24	58·16	312·82	203·44	108·15	31·14	301·37	192·56	83·72	344·54
$[M_1]$	119·56	19·14	289·29	197·71	104·45	358·07	263·80	170·62	79·11	337·25
M_2	275·29	351·62	92·08	192·36	292.48	8·15	108·20	208·33	308·61	24·71
M_3	232·94	167·42	138·13	108·54	78·72	12·22	342·30	312·50	282·91	217·06
M_4	190·58	343·23	184·17	24·72	224·96	16·30	216·40	5·67	257·22	49·42
M_6	105·88	334·85	276·25	217·07	157.44	24·44	324·61	265·00	205·83	72·12
M_8	21·17	326·46	8·34	49·43	89·92	32·59	72·81	113·34	154·44	98·83
N_2	12·41	346·95	358·70	10·25	21·65	355·53	6·86	18·27	29·82	4·13
2 N	109·54	342·29	265·31	188·14	110·82	342·91	265·52	188·21	111·04	343·56
O_7	252·85	327·81	69·41	172·54	277·19	357·46	103·06	207·65	310·72	26·89
OO	332·03	259·80	155·95	47·08	293·37	203·93	87·23	333·72	225·07	148·75
P_1	349·96	349·22	349·46	349·69	349·93	349·19	349·43	349·66	349·90	349·16
Q_1	349·97	323·15	336·02	350·43	6·36	344·84	1·72	17·59	31·93	6·31
R_2	359·15	359·88	359·63	359·37	359·11	359·84	359·59	359·33	359·08	359·81
$S_{1, 3}$	180·00	180·00	180.00	180·00	180·00	180·00	180.00	180·00	180·00	180·00
$S_{2, 4, 6}$	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
T_2	0·85	0·12	0·37	0·63	0·89	0·16	0·41	0·67	0·92	0·19
λ_2	279·25	177·42	88·41	359.21	269·85	167·37	77·94	348·60	259·40	157·34
μ_2	188·46	341·15	182·37	23·40	224·27	16·31	217·12	58·00	259·03	51·50
ν_2	91·33	345·82	275·76	205·51	135·11	28·93	318·46	248·07	177·82	72·08
MK	293·93	11·28	110.73	208·89	305·91	18·88	115·28	212·34	310·55	26·67
2MK	171·95	323·57	165·52	8·18	211·53	5·56	209·33	52·66	255·28	47·46
MN	287·71	338·57	90·78	202·61	314·13	3·68	115·06	226·60	338·43	28·84
MS	275·29	351·62	92·08	192·36	292·48	8·15	108·20	208·33	308·61	24·71
2MS	190·58	343·23	184·17	24·72	224·96	16·30	216·40	56·67	257·22	49·42
2SM	84·71	8·38	267·92	167·64	67·52	351·85	251·80	151·67	51·39	335·29
Mf	309·59	236·00	133·27	27·27	278·09	193·23	82·09	333·04	227·17	150·93
MSf	84·71	8·38	267·92	167·64	67·52	351·85	251·80	151·67	51·39	335·29
Mm	262·88	4·66	93·39	182·11	270·83	12·62	101·34	190·06	278·79	20·57
Sa	280·04	280·78	280·54	280·31	280·07	280·81	280·57	280·34	280·10	280·84
Ssa	200·07	201·57	201·09	200·61	200·13	201·63	201·15	200·67	200·20	201.69
Elements.	Values at Greenwich, midnight beginning each year.									
h	280·04	280·78	280·54	280·31	280·07	280·81	280·57	280·34	280·10	280·84
s	143·45	286·01	55·40	184·79	314·17	96·73	226·12	355·50	124·89	267·45
p	240·58	281·35	322·01	2·68	43·34	84·11	124·77	165·44	206·10	246·87
	Values at the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years.									
p_1	280·88	280·90	280·92	280·93	280·95	280·97	280·99	281·00	281·02	281·04
P	272·30	313·67	353·58	31·86	68·60	104·33	140·03	176·79	215·19	255·22
N	276·29	256·94	237·61	218·28	198·93	179·57	160·24	140·91	121·56	102·21
I	24·53	22·82	21·12	19·66	18·66	18·31	18·69	19·71	21·19	22·89
Q	274·60	332·35	356·78	17·26	51·91	117·06	157·27	178·39	199·42	242·19
R	358·98	346·43	356·67	9·96	5·61	356·24	350·65	358·58	12·01	5·71
ξ	348·66	348·02	348·77	351·15	355·13	0·11	5·07	8·98	11·30	11·98
ν	347·60	346·98	347·87	350·49	354·78	0·12	5·43	9·65	12·21	13·03
ν'	351·40	351·12	351·89	353·77	356·64	·08	3·50	6·33	8·16	8·89
$2\nu''$	342·48	342·37	344·39	348·40	353·90	0·14	6·36	11·80	15·74	17·67

TABLE 3.—*Equilibrium arguments ($V_0 + u$) at the midnight preceding January 1 of each year, from 1850 to 1950, for the meridian of Greenwich, together with the elements used in computing them*—Continued.

Component.	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899
	°	°	°	°	°	°	°	°	°	°
J_1	107·55	197·88	289·05	34·83	126·86	218·95	310·88	56·45	147·29	237·16
K_1	2·04	2·98	4·58	7·61	9·90	12·24	14·45	17·31	18·65	19·25
K_2	183·75	185·40	188·60	194·35	199·71	204·70	209·37	215·21	217·80	218·67
L_2	65·75	260·29	55·86	240·32	93·98	295·30	86·65	268·40	118·43	317·10
$[L_2]$	54·72	244·40	74·29	253·04	83·22	273·42	103·56	282·25	112·05	301·63
M_1	287·73	192·32	85·29	340·37	288·59	199·79	93·36	344·85	289·57	205·07
$[M_1]$	248·96	161·84	75·57	337·77	252·35	167·00	81·48	343·48	256·88	169·30
M_2	125·42	226·38	327·55	44·52	145·97	247·45	348·86	65·76	166·84	267·70
M_3	188·14	159·57	131·33	66·77	38·95	11·17	343·29	278·64	250·26	221·55
M_4	250·85	92·76	295·10	89·03	291·94	134·89	337·72	131·52	333·68	175·40
M_6	16·27	319·14	262·66	133·55	77·91	22·34	326·58	197·29	140·53	83·09
M_8	141·70	185·52	230·21	178·06	223·88	269·78	315·44	263·05	307·37	350·79
N_2	16·13	28·36	40·81	15·99	28·72	41·47	54·16	29·28	41·64	53·77
2 N	266·83	190·34	114·07	347·46	271·47	195·50	119·47	352·80	276·43	199·84
O_1	127·17	226·52	325·24	38·21	136·37	234·47	332·68	45·80	144·76	244·47
OO	49·35	313·21	219·38	154·39	62·85	331·47	239·68	174·14	79·41	341·99
P_1	349·39	349·63	349·87	349·13	349·36	349·60	349·84	349·09	349·33	349·57
Q_1	17·87	28·50	38·50	9·69	19·11	28·50	37·98	9·31	19·55	30·54
R_2	359·55	359·30	359·04	359·77	359·51	359·26	359·00	359·73	359·48	359·22
$S_{1, 3}$	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00
$S_{2, 4, 6}$	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
T_2	0·45	0·70	0·96	0·23	0·49	0·74	1·00	0·27	0·52	0·78
λ_2	68·58	340·06	251·76	150·56	62·54	334·54	246·48	145·23	56·83	328·21
μ_2	252·97	94·68	296·60	89·94	292·15	134·38	336·54	129·82	331·65	173·26
ν_2	2·27	292·70	223·35	118·47	49·40	340·35	271·24	166·30	96·85	27·19
MK	127·46	229·36	332·13	52·13	155·87	259·68	3·31	83·07	185·50	286·95
2MK	248·81	89·78	290·53	81·42	282·04	122·65	323·27	114·21	315·03	156·14
MN	141·55	254·74	8·36	60·50	174·69	288·92	43·02	95·04	208·48	321·47
MS	125·42	226·38	327·55	44·52	145·97	247·45	348·86	65·76	166·84	267·70
2MS	250·85	92·76	295·10	89·03	291·94	134·89	337·72	131·52	333·68	175·40
2SM	234·58	133·62	32·45	315·48	214·03	112·55	11·14	294·24	193·16	92·30
Mf	51·09	313·34	217·07	148·09	53·24	318·50	223·50	154·17	57·33	318·76
MSf	234·58	133·62	32·45	315·48	214·03	112·55	11·14	294·24	193·16	92·30
Mm	109·30	198·02	286·74	28·53	117·25	205·97	294·70	36·48	125·21	213·93
Sa	280·61	280·37	280·13	280·87	280·64	280·40	280·16	280·91	280·67	280·43
Ssa	201·21	200·74	200·26	201·75	201·27	200·80	200·32	201·82	201·33	200·86
Elements.	Values at Greenwich, midnight beginning each year.									
h	280·61	280·37	280·13	280·87	280·64	280·40	280·16	280·91	280·67	280·43
s	36·83	166·22	295·60	78·16	207·55	336·93	106·32	248·88	18·26	147·65
ϕ	287·54	328·20	8·86	49·63	90·30	130·96	171·62	212·40	253·06	293·72
	Values at the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years.									
p	281·05	281·07	281·09	281·11	281·12	281·14	281·16	281·17	281·19	281·21
P	296·58	338·99	22·18	65·85	109·70	153·61	197·44	240·93	283·79	325·79
N	82·88	63·55	44·19	24·84	5·51	346·18	326·83	307·47	288·15	268·82
I	24·60	26·13	27·37	28·20	28·58	28·48	27·90	26·88	25·50	23·88
Q	315·02	349·13	11·52	48·11	125·61	166·07	188·93	221·97	296·15	341·22
R	348·97	344·10	18·44	12·73	349·24	338·12	16·90	13·84	353·62	344·53
ξ	11·29	9·55	7·07	4·12	0·93	357·68	354·57	351·79	349·60	348·27
ν	12·35	10·51	7·82	4·57	1·03	357·43	353·98	350·94	348·58	347·20
ν'	8·57	7·39	5·55	3·26	0·74	358·16	355·71	353·59	352·01	351·18
$2\nu''$	17·47	15·33	11·66	6·91	1·57	356·10	350·95	346·60	343·54	342·19

TABLE 3.—*Equilibrium arguments ($V_o + u$) at the midnight preceding January 1 of each year, from 1850 to 1950, for the meridian of Greenwich, together with the elements used in computing them*—Continued.

Component.	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909
	°	°	°	°	°	°	°	°	°	°
J_1	325·72	52·66	137·84	221·53	304·55	42·08	126·95	213·56	301·84	45·54
K_1	18·90	17·46	14·93	11·56	7·81	5·30	2·59	0·93	0·39	1·81
K_2	217·49	214·18	209·05	202·71	195·90	191·37	185·96	182·27	180·69	183·17
L_2	127·09	309·02	147·11	345·00	174·12	339·64	162·47	1·20	204·78	17·54
$[L_2]$	130·96	320·07	149·00	337·81	166·58	344·05	172·95	2·03	191·32	9·53
M_1	97·46	351·64	271·67	203·30	101·59	338·11	232·12	158·08	90·59	336·18
$[M_1]$	80·41	349·91	257·65	163·90	69·47	323·42	230·85	140·02	50·85	310·97
M_2	8·31	108·70	208·90	309·00	49·04	124·72	224·90	325·26	65·83	142·25
M_3	192·46	163·04	133·35	103·49	73·55	7·09	337·36	307·89	278·74	213·37
M_4	16·62	217·39	57·80	257·99	98·07	249·45	89·81	290·52	131·65	284·50
M_6	24·92	326·09	266·71	206·99	147·11	14·17	314·71	255·77	197·48	66·74
M_8	33·23	74·78	115·61	155·98	196·14	138·90	179·62	221·03	263·30	208·99
N_2	65·66	77·32	88·81	100·18	111·50	85·40	96·85	108·49	120·33	94·97
2 N	123·01	45·95	328·71	251·36	173·96	46·07	328·81	251·72	174·84	47·69
O^1	345·24	87·41	191·16	296·28	42·03	121·97	226·01	328·47	69·48	143·99
OO	240·89	135·15	24·33	269·15	151·99	63·53	311·79	205·11	103·20	32·52
P_1	349·81	350·05	350·29	350·53	350·76	350·02	350·26	350·49	350·73	349·99
Q_1	42·59	56·04	71·06	87·46	104·49	82·65	97·96	111·70	123·99	96·71
R_2	358·97	358·71	358·45	358·20	357·94	358·67	358·41	358·16	357·90	358·63
$S_{1,3}$	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00
$S_{2,4,6}$	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
T_2	1·03	1·29	1·55	1·80	2·06	1·33	1·59	1·84	2·10	1·37
λ_2	239·35	150·26	60·99	331·61	242·17	139·70	50·41	321·9	232·38	130·64
μ_2	14·62	215·76	56·72	257·57	98·36	250·42	91·35	292·46	133·78	286·57
ν_2	317·27	247·13	176·81	106·39	35·90	289·75	219·40	149·23	79·27	333·85
MK	27·21	126·16	223·83	320·55	56·84	130·02	227·49	326·19	66·21	144·06
2 MK	357·71	199·93	42·87	246·44	90·26	244·15	87·22	289·58	131·27	282·69
MN	73·97	186·02	297·71	49·17	160·53	210·12	321·76	73·75	186·16	237·21
MS	8·31	108·70	208·90	309·00	49·04	124·72	224·90	325·26	65·83	142·25
2 MS	16·62	217·39	57·80	257·99	98·07	249·45	89·81	290·52	131·65	284·50
2 SM	351·69	251·30	151·10	51·00	310·96	235·28	135·10	34·74	294·17	217·75
Mf	217·82	113·87	6·59	256·44	144·98	60·78	312·89	208·32	106·86	34·26
MSf	351·69	251·30	151·10	51·00	310·96	235·28	135·10	34·74	294·17	217·75
Mm	302·65	31·37	120·09	208·82	297·54	39·33	128·05	216·77	305·49	47·28
Sa	280·19	279·95	279·71	279·47	279·24	279·98	279·74	279·51	279·27	280·01
Ssa	200·38	199·90	199·42	198·95	198·47	199·96	199·49	199·01	198·53	200·03
Elements.	Values at Greenwich, midnight beginning each year.									
h	280·19	279·95	279·71	279·47	279·24	279·98	279·74	279·51	279·27	280·01
s	277·03	46·42	175·80	305·19	74·57	217·13	346·52	115·90	245·29	27·85
p	334·38	15·05	55·71	96·37	137·03	177·81	218·47	259·13	299·80	340·57
	Values at the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years.									
p_1	281·23	281·24	281·26	281·28	281·29	281·31	281·33	281·35	281·36	281·38
P	6·59	45·89	83·53	119·73	155·34	191·39	228·73	267·72	308·32	350·18
N	249·49	230·16	210·83	191·51	172·15	152·80	133·47	114·14	94·79	75·43
I	22·15	20·52	19·21	18·44	18·37	19·01	20·24	21·83	23·56	25·22
Q	3·31	27·29	77·22	138·80	167·07	185·75	209·67	265·45	327·68	355·06
R	3·87	11·05	1·89	352·82	352·45	4·41	10·48	0·83	346·54	351·99
ξ	348·12	349·48	352·51	356·97	2·08	6·75	10·07	11·74	11·86	10·72
ν	347·13	348·67	351·97	356·76	2·23	7·23	10·85	12·72	12·92	11·76
ν'	351·29	352·49	354·78	357·92	1·43	4·68	7·16	8·57	8·88	8·21
$2\nu''$	342·89	345·72	350·37	356·24	2·57	8·59	13·53	16·73	17·84	16·85

TABLE 3.—*Equilibrium arguments* ($V_0 + u$) *at the midnight preceding January 1 of each year, from 1850 to 1950, for the meridian of Greenwich, together with the elements used in computing them*—Continued.

Component.	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
	°	°	°	°	°	°	°	°	°	°
J_1	136·22	227·63	319·51	65·64	157·69	249·49	340·79	85·35	174·75	262·72
K_1	3·03	4·82	6·99	10·30	12·61	14·72	16·41	18·49	18·74	17·98
K_2	185·47	189·13	193·69	200·64	205·56	209·97	213·40	217·36	217·46	215·46
L_2	179·69	22·00	235·00	55·42	206·55	48·99	260·18	81·51	245·33	75·84
$[L_2]$	199·29	29·27	219·39	38·26	228·44	58·54	248·48	66·88	256·36	85·61
M_1	229·57	146·18	92·11	343·35	237·05	149·20	96·33	350·12	242·01	142·58
$[M_1]$	224·21	138·19	52·61	315·17	229·78	144·14	57·99	318·97	230·93	141·45
M_2	243·29	344·54	85·94	163·03	264·49	5·86	107·07	183·69	284·45	24·97
M_3	184·94	156·81	128·91	64·54	36·73	8·79	340·61	275·53	246·67	217·46
M_4	126·58	329·08	171·88	326·06	168·97	11·72	214·15	7·38	208·89	49·94
M_6	9·88	313·63	257·82	129·08	73·46	17·59	321·22	191·07	133·34	74·92
M_8	253·17	298·17	343·76	292·11	337·94	23·45	68·30	14·76	57·78	99·89
N_2	107·29	119·82	132·49	107·79	120·53	133·18	145·67	120·50	132·53	144·34
2 N	331·29	255·09	179·04	52·56	336·57	260·50	184·27	57·31	340·62	263·71
O_1	243·07	341·63	79·88	152·62	250·75	349·05	87·69	161·53	261·61	2·89
OO	297·36	204·19	112·24	48·19	316·73	224·58	131·09	62·79	324·07	221·28
P_1	350·23	350·47	350·70	349·96	350·20	350·43	350·67	349·93	350·17	350·40
Q_1	107·07	116·91	126·43	97·39	106·79	116·37	126·28	98·34	109·70	122·26
R_2	358·38	358·12	357·87	358·60	358·34	358·08	357·83	358·56	358·30	358·05
$S_{1, 3}$	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00
$S_{2, 4, 6}$	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
T_2	1·62	1·88	2·13	1·40	1·66	1·92	2·17	1·44	1·70	1·95
λ_2	42·21	313·99	225·91	124·84	36·83	308·72	220·46	118·92	30·20	301·25
μ_2	128·37	330·37	172·52	325·98	168·19	10·32	212·29	5·27	206·78	48·06
ν_2	264·37	195·10	125·97	21·22	312·15	243·00	173·69	68·46	358·69	288·69
MK	246·32	349·37	92·93	173·33	277·10	20·58	123·49	202·17	303·18	42·95
2 MK	123·55	324·26	164·89	315·75	156·36	357·01	197·73	348·89	190·15	31·97
MN	350·58	104·36	218·43	270·82	25·01	139·05	252·75	304·19	56·98	169·31
MS	243·29	344·54	85·94	160·03	264·49	5·86	107·07	183·69	284·45	24·97
2 MS	126·58	329·08	171·88	326·06	168·97	11·72	214·15	7·38	208·89	49·94
2 SM	116·71	15·46	274·06	196·97	95·51	354·14	352·93	176·31	75·55	335·03
Mf	297·14	201·28	106·18	37·79	302·99	207·77	111·70	40·63	301·23	199·19
MSf	116·71	15·46	274·06	196·97	95·51	354·14	252·93	176·31	75·55	335·03
Mm	136·00	224·73	313·45	55·23	143·96	232·68	321·40	63·19	151·91	240·63
Sa	279·77	279·53	279·30	280·04	279·80	279·57	279·33	280·07	279·83	279·60
Ssa	199·55	199·07	198·59	200·09	199·61	199·13	198·66	200·15	199·67	199·19
Elements.	Values at Greenwich, midnight beginning each year.									
h	279·77	279·53	279·30	280·04	279·80	279·57	279·33	280·07	279·83	279·60
s	157·24	286·62	56·01	198·57	327·95	97·34	226·72	9·28	138·67	268·05
p	21·23	61·89	102·56	143·33	183·99	224·66	265·32	306·09	346·76	27·42
	Values at the middle of each year, or for July 2, at Greenwich mean noon for common years and at preceding midnight for leap years.									
p_1	281·40	281·41	281·43	281·45	281·47	281·48	281·50	281·52	281·53	281·55
P	72·90	76·25	120·03	163·99	207·87	251·54	294·84	337·46	19·03	59·29
N	56·10	36·77	17·42	358·06	338·74	319·41	300·05	280·70	261·37	242·04
I	26·65	27·74	28·40	28·60	28·31	27·55	26·39	24·90	23·21	21·50
Q	17·93	63·91	139·14	171·83	194·81	236·27	312·79	348·28	9·79	40·09
R	19·60	7·27	344·39	342·84	21·89	9·55	348·29	345·37	11·03	9·76
ξ	8.66	5·98	2·91	359·67	356·46	353·45	350·87	348·97	348·05	348·45
ν	9·56	6·63	3·24	359·64	356·07	352·75	349·94	347·91	347·00	347·51
ν'	6·75	4·71	2·31	359·74	357·19	354·85	352·91	351·59	351·10	351·62
$2\nu''$	14·08	9·94	4·90	359·45	354·05	349·16	345·25	342·79	342·21	343·74

TABLE 3.—*Equilibrium arguments ($V_0 + u$) at the midnight preceding January 1 of each year, from 1850 to 1950, for the meridian of Greenwich, together with the elements used in computing them*—Continued.

Component.	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
	°	°	°	°	°	°	°	°	°	°
J_1	348·98	87·57	170·87	253·94	337·87	77·45	164·74	253·58	343·67	88·73
K_1	16·11	14·19	10·60	6·88	3·63	2·29	1·08	0·93	1·70	4·15
K_2	211·39	207·66	201·05	194·28	188·11	185·27	182·37	181·62	182·87	187·73
L_2	277·13	101·57	284·24	101·71	291·23	119·89	319·09	133·44	306·72	141·37
$[L_2]$	274·64	92·19	280·98	109·75	298·58	116·22	305·37	134·75	324·38	142·91
M_1	78·36	344·03	235·99	124·59	25·11	309·86	226·49	119·97	15·31	292·00
$[M_1]$	50·27	305·28	211·14	116·77	23·25	279·26	189·10	100·50	13·15	274·63
M_2	125·28	201·05	301·11	41·16	141·27	217·12	317·55	58·21	159·11	235·86
M_3	187·93	121·58	91·67	61·74	31·90	325·68	296·33	267·32	238·67	173·79
M_4	250·57	42·10	242·22	82·32	282·53	74·24	275·10	116·42	318·23	111·72
M_6	15·85	243·16	183·33	123·48	63·80	291·37	232·65	174·64	117·34	347·57
M_8	141·14	84·21	124·44	164·64	205·06	148·49	190·20	232·85	276·46	223·43
N_2	155·93	129·91	141·24	152·57	163·96	138·02	149·73	161·67	173·85	148·81
2 N	186·57	58·77	341·38	263·99	186·65	58·93	341·91	265·13	188·59	61·75
O_1	105·66	184·63	290·10	35·81	140·70	218·77	320·63	61·17	160·71	234·18
OO	113·58	28·22	271·91	154·90	40·43	317·94	213·20	112·91	16·11	309·18
P_1	350·64	349·89	350·13	350·37	350·61	349·86	350·10	350·34	350·58	349·83
Q_1	136·31	113·49	130·24	147·22	163·39	139·67	152·81	164·63	175·44	147·13
R_2	357·79	358·52	358·26	358·01	357·75	358·48	358·23	357·97	357·72	358·45
$S_{1, 3}$	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00
$S_{2, 4, 6}$	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
T_2	2·21	1·48	1·74	1·99	2·25	1·52	1·77	2·03	2·28	1·55
λ_2	212·08	109·70	20·28	290·85	201·48	99·18	10·14	281·32	192·75	91·33
μ_2	249·13	41·26	242·07	82·88	283·74	65·96	277·14	118·56	320·22	113·33
ν_2	218·48	112·41	41·94	331·47	261·05	155·06	84·96	15·10	305·48	200·38
MK	141·39	215·24	311·71	48·04	144·90	219·42	318·63	59·15	160·81	240·01
2 MK	234·46	27·91	231·62	75·44	278·90	71·95	274·02	115·49	316·53	107·56
MN	281·21	330·96	82·35	193·73	305·22	355·15	107·28	219·88	332·96	24·66
MS	125·28	201·05	301·11	41·16	141·27	217·12	317·55	58·21	159·11	235·86
2 MS	250·57	42·10	242·22	82·32	282·53	74·24	275·10	116·42	318·23	111·72
2 SM	234·72	158·95	58·89	318·84	218·73	142·88	42·45	301·79	200·89	124·14
Mf	93·96	11·80	260·90	149·54	39·86	319·59	216·28	115·87	17·70	307·50
MSf	234·72	158·95	58·89	318·84	218·73	142·88	42·45	301·79	200·89	124·14
Mm	329·36	71·14	159·87	248·59	337·31	79·10	167·82	256·54	345·26	87·05
Sa	279·36	280·11	279·87	279·63	279·39	280·14	279·90	279·66	279·42	280·17
Ssa	198·72	200·21	199·73	199·26	198·78	200·27	199·79	199·32	198·84	200·33
Elements.	Values at Greenwich, midnight beginning each year.									
h	279·36	280·11	279·87	279·63	279·39	280·14	279·90	279·66	279·42	280·17
s	37·44	180·00	309·38	78·77	208·15	350·71	120·10	249·48	18·87	161·43
p	68·08	108·86	149·52	190·18	230·84	271·62	312·28	352·94	33·61	74·38
	Values at the middle of each year, or for July 2, at Greenwich, mean noon for common years and at preceding midnight for leap years.									
p_1	281·57	281·59	281·60	281·62	281·64	281·65	281·67	281·69	281·70	281·72
P	98·01	135·09	170·92	206·52	243·01	281·03	320·65	1·73	43·97	87·03
Λ	222·69	203·33	184·00	164·68	145·32	125·97	106·64	87·31	67·96	48·60
I	19·96	18·83	18·32	18·54	19·43	20·83	22·50	24·22	25·81	27·12
Q	105·72	153·50	175·43	194·01	224·47	291·29	337·71	0·87	25·75	84·07
R	357·51	350·62	356·73	8·04	7·35	356·33	346·28	1·32	17·66	1·54
ξ	350·46	354·10	358·93	4·00	8·22	10·92	11·96	11·55	10·02	7·68
ν	349·74	353·68	358·86	4·28	8·83	11·78	12·98	12·62	11·01	8·49
ν'	353·25	355·92	359·27	2·75	5·75	7·84	8·82	8·73	7·72	6·01
$2\nu''$	347·33	352·55	358·68	4·98	10·67	15·01	17·42	17·69	15·97	12·61

TABLE 3. - *Equilibrium arguments (V_0+u) at the midnight preceding January 1 of each year, from 1850 to 1950, for the meridian of Greenwich, together with the elements used in computing them*—Continued.

Component.	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939
	°	°	°	°	°	°	°	°	°	°
J_1	180·35	272·33	4·43	110·47	202·10	293·12	23·24	126·18	213·51	299·09
K_1	6·11	8·36	10·71	13·95	15·92	17·40	18·19	19·06	17·87	15·58
K_2	191·79	196·56	201·57	208·33	212·41	215·33	216·64	217·91	215·07	210·31
L_2	352·21	170·08	330·77	167·92	18·80	201·72	5·95	193·11	35·89	227·40
$[L_2]$	332·94	163·10	353·30	172·15	2·18	192·04	21·67	199·74	28·90	217·87
M_1	228·28	126·48	21·61	293·28	234·44	134·12	26·99	285·68	227·36	132·55
$[M_1]$	188·80	103·33	17·99	280·46	194·64	108·22	20·90	280·26	190·14	98·28
M_2	337·17	78·60	180·08	257·14	358·45	99·59	200·50	276·78	17·21	117·46
M_3	145·75	117·91	90·13	25·71	357·68	329·38	300·74	235·17	205·82	176·19
M_4	314·34	157·21	0·17	154·28	356·90	199·18	40·99	193·56	34·43	234·92
M_6	291·51	235·81	180·25	51·42	355·36	298·76	241·49	110·34	51·64	352·39
M	268·68	314·42	0·34	308·56	353·81	38·35	81·98	27·12	68·86	109·85
N_2	161·40	174·11	186·87	162·13	174·72	187·14	199·32	173·82	185·53	197·06
2 N	345·62	269·61	193·65	67·13	351·00	274·69	198·15	70·86	353·85	276·65
O_1	332·59	70·77	168·87	241·68	340·08	78·92	178·43	253·56	355·39	98·78
OO	216·56	124·89	33·55	329·25	236·66	142·43	45·71	332·87	228·26	118·58
P_1	350·07	350·31	350·55	349·80	350·04	350·28	350·52	349·77	350·01	350·25
Q_1	156·82	166·28	175·65	146·67	156·35	166·47	177·25	150·60	163·71	178·38
R_2	358·19	357·93	357·68	358·41	358·15	357·90	357·64	358·37	358·11	357·87
S_1,	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00
$S_{2,4,6}$	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
T_2	1·81	2·07	2·32	1·59	1·85	2·10	2·36	1·63	1·89	2·14
λ_2	3·17	275·13	187·13	86·03	357·87	269·53	180·96	79·09	350·05	260·82
μ_2	315·39	157·58	359·82	153·24	355·30	197·20	38·86	191·51	32·70	233·70
ν_2	131·17	62·08	353·03	248·25	179·03	109·65	40·03	294·47	224·38	154·10
MK	343·28	86·96	190·79	271·09	14·37	116·99	218·69	295·84	35·09	133·04
2 MK	308·23	148·85	349·46	140·33	340·99	181·77	22·80	174·50	16·56	219·35
MN	138·57	252·71	6·95	59·27	173·18	286·73	39·82	90·60	202·75	314·52
MS	337·17	78·60	180·08	257·14	358·45	99·59	200·50	276·78	17·21	117·46
2 MS	314·34	157·21	0·17	154·28	356·90	199·18	40·99	193·56	34·43	234·92
2 SM	22·83	281·40	179·92	102·86	1·55	260·41	159·50	83·22	342·79	242·54
Mf	211·98	117·06	22·34	313·78	218·29	121·76	23·64	309·66	206·43	99·90
MSf	22·83	281·40	179·92	102·86	1·55	260·41	159·50	83·22	342·79	242·54
Mm	175·77	264·49	353·22	95·01	183·73	272·45	1·17	102·96	191·68	280·40
Sa	279·93	279·69	279·45	280·20	279·96	279·72	279·48	280·23	279·99	279·75
Ssa	199·86	199·38	198·90	200·40	199·92	199·44	198·96	200·46	199·98	199·50
Elements.	Values at Greenwich, midnight beginning each year.									
h	279·93	279·69	279·45	280·20	279·96	279·72	279·48	280·23	279·99	279·75
s	290·82	60·20	189·59	332·15	101·53	230·92	0·30	142·86	272·25	41·63
p	115·04	155·70	196·37	237·14	277·80	318·47	359·13	39·90	80·57	121·23
	Values at the middle of each year, or for July 2, at Greenwich mean noon for common years and at preceding midnight for leap years.									
p_1	281·74	281·76	281·77	281·79	281·81	281·82	281·84	281·86	281·88	281·89
P	130·55	174·37	218·33	262·22	305·75	348·76	31·03	72·20	111·87	149·88
N	29·27	9·94	350·59	331·23	311·91	292·58	273·22	253·87	234·54	215·21
I	28·05	28·54	28·54	28·07	27·15	25·85	24·26	22·54	20·87	19·47
Q	149·70	177·18	201·57	254·71	325·22	354·33	16·75	57·29	128·75	163·82
R	340·73	353·02	22·54	4·23	343·38	350·32	15·72	6·63	353·01	350·47
ξ	4·83	1·67	358·42	355·25	352·39	350·04	348·48	348·04	349·03	351·68
ν	5·35	1·86	358·24	354·74	351·59	349·05	347·41	347·01	348·17	351·07
ν'	3·81	1·33	358·74	356·25	354·04	352·32	351·29	351·17	352·12	354·17
$2\nu''$	8·07	2·82	357·33	352·06	347·50	344·11	342·33	342·55	344·90	349·19

The values of the mean longitudes were obtained from formulæ given by Darwin in B. A. A. S. Report, 1883, p. 87:

$s = 150°·0419 + [13 \times 360° + 132°·67900]\,T + 13°·1764\,D + 0°·5490165\,H,$

$p = 240°·6322 + 40°·69035\,T + 0°·1114\,D + 0°·0046418\,H,$

$h = 280°·5287 + 360°·00769\,T + 0°·9856\,D + 0°·0410686\,H,$

$p_1 = 280°·8748 + 0°·01711\,T + 0°·000047\,D,$

$N = 285°·9569 - 19°·34146\,T - 0°·0529540\,D,$

TABLE 3.—*Equilibrium arguments* (V_0+u) *at the midnight preceding January 1 of each year, from 1850 to 1950, for the meridian of Greenwich, together with the elements used in computing them*—Continued.

Component.	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
	°	°	°	°	°	°	°	°	°	°	°
J_1	23·06	120·18	203·46	287·96	14·18	116·15	205·52	296·00	27·28	133·12	225·17
K_1	12·35	9·62	6·02	3·09	1·19	1·39	1·62	2·68	4·37	7·45	9·75
K_2	204·17	199·37	192·74	187·02	182·90	182·80	182·85	184·79	188·19	194·55	199·47
L_2	44·29	215·18	49·56	248·99	82·00	240·19	64·35	271·82	118·73	270·72	86·64
$[L_2]$	46·69	224·15	52·93	241·80	70·83	248·75	78·23	267·94	97·87	276·64	106·82
M_1	21·99	260·90	173·39	109·54	12·89	251·95	151·20	91·30	14·50	257·36	155·34
$[M_1]$	4·80	258·35	164·19	71·25	340·01	238·41	150·34	63·37	337·20	239·47	154·08
M_2	217·57	293·23	33·29	133·44	233·75	309·88	50·63	151·63	252·83	329·82	71·28
M_3	146·35	79·85	49·93	20·16	350·62	284·82	255·95	227·44	199·25	134·73	106·92
M_4	75·14	226·46	66·58	266·88	107·50	259·76	101·27	303·25	145·67	299·64	142·56
M_6	292·70	159·70	99·87	40·33	341·24	209·65	151·90	94·88	38·50	269·46	213·83
M_8	150·27	92·93	133·16	173·77	214·99	159·53	202·54	246·50	291·34	239·28	285·11
N_2	208·44	182·32	193·65	205·08	216·67	191·01	203·04	215·31	227·80	203·00	215·73
2 N	199·31	71·40	354·02	276·73	199·59	72·14	355·45	279·00	202·76	76·17	0·19
O_1	203·64	283·97	29·47	133·84	236·65	312·60	52·71	151·94	250·59	323·52	61·65
OO	4·22	274·55	158·19	45·38	297·54	221·96	123·15	27·42	293·89	229·07	137·59
P_1	350·49	349·74	349·98	350·22	350·46	349·71	349·95	350·19	350·43	349·68	349·92
Q_1	194·51	173·06	189·83	205·48	219·57	193·73	205·12	215·63	225·56	196·70	206·11
R_2	357·60	358·33	358·08	357·82	357·57	358·29	358·04	357·78	357·53	358·26	358·00
$S_{1,3}$	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00	180·00
$S_{2,4,6}$	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
T_2	2·40	1·67	1·92	2·18	2·43	1·71	1·96	2·22	2·47	1·74	2·00
λ_2	171·45	68·96	339·54	250·22	161·05	59·62	330·30	241·82	153·55	52·38	324·36
μ_2	74·56	226·59	67·40	268·31	109·37	261·87	103·38	305·12	147·08	300·44	142·65
ν_2	83·69	337·51	267·04	196·67	126·45	20·74	310·97	241·43	172·12	67·26	358·19
MK	229·92	302·85	39·31	136·53	234·94	311·27	52·25	154·31	257·20	337·27	81·03
2 MK	62·78	216·84	60·56	263·79	106·30	258·38	99·65	300·57	141·30	292·19	132·80
MN	66·01	115·55	226·94	338·53	90·41	140·89	253·68	6·94	120·63	272·82	287·01
MS	217·57	293·23	33·29	133·44	233·75	309·88	50·63	151·63	252·83	329·82	71·28
2 MS	75·14	226·46	66·58	266·88	107·50	259·76	101·27	303·25	145·67	299·64	142·56
2 SM	142·43	66·77	326·71	226·56	126·25	50·12	309·37	208·37	107·17	30·18	288·72
Mf	350·29	265·29	154·36	45·77	300·44	224·68	125·22	27·74	291·65	222·77	127·97
MSf	142·43	66·77	326·71	226·56	126·25	50·12	309·37	208·37	107·17	30·18	288·72
Mm	9·13	110·91	199·64	288·36	17·08	118·87	207·59	296·31	25·04	126·82	215·55
Sa	279·51	280·26	280·02	279·78	279·54	280·29	280·05	279·81	279·57	280·32	280·08
Ssa	199·02	200·52	200·04	199·56	199·09	200·58	200·10	199·62	199·15	200·64	200·16
Elements.	Values at Greenwich, midnight beginning each year.										
h	279·51	280·26	280·02	279·78	279·54	280·29	280·05	279·81	279·57	280·32	280·08
s	171·02	313·58	82·96	212·35	341·73	124·29	253·68	23·06	152·45	295·01	64·40
p	161·89	202·66	243·33	283·99	324·65	5·43	46·09	86·75	127·41	168·19	208·85
	Values at the middle of each year, or for July 2, at Greenwich mean noon for common years and at preceding midnight for leap years.										
p_1	281·91	281·93	281·94	281·96	281·98	281·99	282·01	282·03	282·05	282·06	282·08
P	186·41	222·06	257·87	294·86	333·53	13·80	55·35	97·89	141·17	184·89	228·77
N	195·86	176·50	157·17	137·85	118·49	99·14	79·81	60·48	41·13	21·77	2·44
I	18·55	18·32	18·81	19·92	21·45	23·17	24·86	26·35	27·53	28·29	28·60
Q	183·21	204·29	246·75	312·82	346·02	7·01	35·89	105·49	158·08	182·45	209·71
R	2·41	8·96	3·36	352·81	348·82	8·56	13·88	356·12	339·14	5·92	20·18
ξ	355·87	0·93	5·78	9·46	11·51	11·95	11·07	9·19	6·63	3·63	0·41
ν	355·58	1·00	6·19	10·17	12·45	13·01	12·12	10·13	7·33	4·03	0·46
ν'	357·16	0·64	4·00	6·69	8·35	8·90	8·43	7·13	5·21	2·87	0·33
$2\nu''$	354·85	1·15	7·30	12·54	16·19	17·78	17·25	14·84	10·96	6·09	0·70

where T is the number of Julian years of 365¼ mean solar days; D, the number of mean solar days; H, the number of mean solar hours after Greenwich mean noon, January 1, 1880. On account of the slowness of the secular changes in the coefficients of T, D, or H, the epoch of this table may be regarded as 1900. See Hansen's Tables de la Lune, p. 15, from which these formulæ may be obtained by putting $t = 80$. Newcomb's corrections (Washington Observations, Vol. 22 (1875), App. II, pp. 268, 274) are not of sufficient magnitude to affect the values in Table 3.

TABLE 4.—*For adapting the uniformly varying portion (V_0) of the equilibrium arguments of Table 3 to Greenwich midnight, beginning any day throughout the year.*

Months.		K_1	K_2	L_2	M_2	M_3	M_4	M_6	M_8	N_2	O_1	P_1	Q_1
		°	°	°	°	°	°	°	°	°	°	°	°
Jan. 1		0	0	0	0	0	0	0	0	0	0	0	0
Feb. 1		30·56	61·11	9·19	324·17	306·26	288·35	252·52	216·69	279·16	293·62	329·44	248·60
Mar. 1	Com. yr.	58·15	116·31	52·33	1·49	2·24	2·98	4·48	5·97	310·66	303·34	301·85	252·50
	Leap yr.	59·14	118·28	41·01	337·11	325·66	314·22	291·33	268·44	273·21	277·97	300·86	214·07
Apr. 1	Com. yr.	88·71	177·42	61·54	325·66	308·50	291·33	257·00	222·66	229·82	236·96	271·29	141·11
	Leap yr.	89·69	179·39	50·20	301·28	271·93	242·57	183·85	125·13	192·37	211·59	270·31	102·68
May 1	Com. yr.	118·28	236·56	82·02	314·22	291·33	268·44	222·66	176·88	186·42	195·94	241·72	68·14
	Leap yr.	119·26	238·53	70·70	289·84	254·76	219·68	149·52	79·36	148·98	170·58	240·74	29·71
June 1	Com. yr.	148·83	297·66	91·21	278·39	237·59	196·79	115·18	33·58	105·58	129·56	211·17	316·75
	Leap yr.	149·82	299·64	79·89	254·01	201·02	148·02	42·04	296·05	68·13	104·19	210·18	278·32
July 1	Com. yr.	178·40	356·80	111·71	266·95	220·42	173·90	80·85	347·80	62·18	88·55	181·60	243·78
	Leap yr.	179·39	358·78	100·40	242·57	183·85	125·14	7·70	250·27	24·74	63·18	180·61	205·35
Aug. 1	Com. yr.	208·96	57·91	120·90	231·12	166·68	102·24	333·37	204·49	341·34	22·16	151·04	132·39
	Leap yr.	209·94	59·89	109·58	206·74	130·11	53·48	260·22	106·96	303·90	356·80	150·06	93·96
Sept. 1	Com. yr.	239·51	119·02	130·09	195·30	112·94	30·59	225·89	61·18	260·50	315·78	120·49	20·99
	Leap yr.	240·50	121·00	118·77	170·92	76·37	341·83	152·74	323·66	223·06	290·42	119·50	342·56
Oct. 1	Com. yr.	269·08	178·16	150·59	183·85	95·78	7·70	191·55	15·40	217·11	274·77	90·92	308·03
	Leap yr.	270·07	180·13	139·28	159·47	59·20	318·94	118·41	277·88	179·66	249·40	89·93	269·59
Nov. 1	Com. yr.	299·64	239·27	159·78	148·02	42·04	296·05	84·07	232·10	136·27	208·39	60·36	196·63
	Leap yr.	300·62	241·24	148·47	123·64	5·46	247·29	10·93	134·57	98·82	183·02	59·38	158·20
Dec. 1	Com. yr.	329·21	298·41	180·29	136·58	24·87	273·16	49·74	186·32	92·87	167·37	30·79	123·67
	Leap yr.	330·19	300·38	168·97	112·20	348·30	224·40	336·59	88·79	55·43	142·01	29·81	85·23
Dec. 32	Com. yr.	359·76	359·52	189·48	100·75	331·13	201·51	302·26	43·01	12·03	100·99	0·24	12·27
	Leap yr.	0·75	1·49	178·16	76·37	294·56	152·74	229·11	305·49	334·58	75·62	359·25	333·84
Day of month													
1		0	0	0	0	0	0	0	0	0	0	0	0
2		0·99	1·97	348·68	335·62	323·43	311·24	286·86	262·47	322·55	334·63	— 0·99	321·57
3		1·97	3·94	337·37	311·24	286·86	262·47	213·71	164·95	285·11	309·27	— 1·97	283·14
4		2·96	5·91	326·05	286·86	250·28	213·71	140·57	67·42	247·66	283·90	— 2·96	244·70
5		3·94	7·88	314·73	262·47	213·71	164·95	67·42	329·90	210·21	258·53	— 3·94	206·27
6		4·93	9·86	303·42	238·09	177·14	116·18	354·28	232·37	172·77	233·16	— 4·93	167·84
7		5·91	11·83	292·10	213·71	140·57	67·42	281·13	134·84	135·32	207·80	— 5·91	129·41
8		6·90	13·80	280·78	189·33	103·99	18·66	207·99	37·32	97·88	182·43	— 6·90	90·98
9		7·88	15·77	269·47	164·95	67·42	329·90	134·84	299·79	60·43	157·06	— 7·88	52·54
10		8·87	17·74	258·15	140·57	30·85	281·13	61·70	202·27	22·98	131·70	— 8·87	14·11
11		9·86	19·71	246·84	116·18	354·28	232·37	348·56	104·74	345·54	106·33	— 9·86	335·68
12		10·84	21·68	235·52	91·80	317·70	183·61	275·41	7·21	308·09	80·96	—10·84	297·25
13		11·83	23·66	224·20	67·42	281·13	134·84	202·27	269·69	270·64	55·59	—11·83	258·81
14		12·81	25·63	212·88	43·04	244·56	86·08	129·12	172·16	233·20	30·23	—12·81	220·38
15		13·80	27·60	201·57	18·66	207·99	37·32	55·98	74·64	195·75	4·86	—13·80	181·95
16		14·78	29·57	190·25	354·28	171·42	348·56	342·83	337·11	158·30	339·49	—14·78	143·52
17		15·77	31·54	178·94	329·90	134·84	299·79	269·69	239·58	120·86	314·13	—15·77	105·09
18		16·76	33·51	167·62	305·52	98·27	251·03	196·54	142·06	83·41	288·76	—16·76	66·65
19		17·74	35·48	156·30	281·13	61·70	202·27	123·40	44·53	45·96	263·39	—17·74	28·22
20		18·73	37·46	144·99	256·75	25·13	153·50	50·26	307·01	8·52	238·02	—18·73	349·79
21		19·71	39·43	133·67	232·37	348·56	104·74	337·11	209·48	331·07	212·66	—19·71	311·36
22		20·70	41·40	122·35	207·99	311·98	55·98	263·97	111·95	293·62	187·29	—20·70	272·92
23		21·68	43·37	111·04	183·61	275·41	7·21	190·82	14·43	256·18	161·92	—21·68	234·49
24		22·67	45·34	99·72	159·23	238·84	318·45	117·68	276·90	218·73	136·56	—22·67	196·06
25		23·66	47·31	88·40	134·84	202·27	269·69	44·53	179·38	181·28	111·19	—23·66	157·63
26		24·64	49·28	77·09	110·46	165·69	220·92	331·39	81·85	143·84	85·82	—24·64	119·20
27		25·63	51·25	65·77	86·08	129·12	172·16	258·24	344·32	106·39	60·45	—25·63	80·76
28		26·61	53·22	54·45	61·70	92·55	123·40	185·10	246·80	68·94	35·09	—26·61	42·33
29		27·60	55·20	43·14	37·32	55·98	74·64	111·95	149·27	31·50	9·72	—27·60	3·90
30		28·58	57·17	31·82	12·94	19·40	25·87	38·81	51·75	354·05	344·35	—28·58	325·47
31		29·57	59·14	20·50	348·56	342·83	337·11	325·66	314·22	316·60	318·99	—29·57	287·04

The upper line for each month is for common years, and the lower line for leap years. For longitude corrections see Table 5, and for the portion (u) of the equilibrium arguments of Table 3, which depend upon the longitude of the moon's node, see Tables 6 and 7. The changes for other components may be found from those above, as follows:

$J_1 = L_2 - O_1$ | $S_{2,4,6} = 0$ | $[L_2] = L_2$ | $T_2 = P_1$ | $M_1 = h - s$ | $MN = M_2 + N_2$ | $[M_1] = K_1 + \lambda_2$ | $MS = M_2$ | $2N = N_2 + \lambda_2$ | $2MS = M_4$ | $OO = K_2 - O_1$ | $2SM = MSf$ | $R_2 = K_1$ | $Sa = K_1$ | $S_{1,3} = 0$ | $Ssa = K_2$

TABLE 4.—*For adapting the uniformly varying portion (V_0) of the equilibrium arguments of Table 3 to Greenwich midnight, beginning any day throughout the year*—Continued.

Months.	λ_2	μ_2	ν_2	MK	2MK	MSf	Mf	Mm	h	s	p	N'
	°	°	°	°	°	°	°	°	°	°	°	°
Jan. 1	0	0	0	0	0	0	0	0	0	0	0	C.+9·66 L.+9·69
Feb. 1	314·98	288·35	333·36	354·73	257·79	35·83	96·94	45·02	30·56	48·47	3·45	+8·02 +8·05
Mar. 1 Com. yr.	309·16	2·98	53·82	59·64	304·83	358·51	114·82	50·84	58·15	57·41	6·57	+6·54
Mar. 1 Leap yr.	296·10	314·22	18·12	36·25	255·08	22·89	141·17	63·90	59·14	70·58	6·68	+6·51
Apr. 1 Com. yr.	264·15	291·33	27·18	54·37	202·62	34·34	211·75	95·85	88·71	105·88	10·03	+4·90
Apr. 1 Leap yr.	251·09	242·57	351·48	30·98	152·87	58·72	238·10	108·91	89·69	119·05	10·14	+4·87
May 1 Com. yr.	232·20	268·44	36·24	72·50	150·16	45·78	282·34	127·80	118·28	141·17	13·37	+3·31
May 1 Leap yr.	219·14	219·68	0·54	49·10	100·41	70·16	308·69	140·86	119·26	154·34	13·48	+3·28
June 1 Com. yr.	187·19	196·79	9·60	67·23	47·96	81·61	19·27	172·81	148·83	189·64	16·82	+1·67
June 1 Leap yr.	174·12	148·02	333·90	45·83	358·21	105·99	45·62	185·88	149·82	202·81	16·93	+1·64
July 1 Com. yr.	155·24	173·90	18·66	85·35	355·50	93·05	89·86	204·76	178·40	224·93	20·16	+0·08
July 1 Leap yr.	142·17	125·14	342·96	61·96	305·75	117·43	116·21	217·83	179·39	238·10	20·28	+0·05
Aug. 1 Com. yr.	110·22	102·24	352·02	80·08	253·29	128·88	186·79	249·78	208·96	273·40	23·62	−1·56
Aug. 1 Leap yr.	97·16	53·48	316·32	56·68	203·54	153·26	213·14	262·84	209·94	286·57	23·73	−1·59
Sept. 1 Com. yr.	65·21	30·59	325·38	74·81	151·08	164·70	283·73	294·79	239·51	321·86	27·07	−3·20
Sept. 1 Leap yr.	52·14	341·83	289·69	51·41	101·33	189·08	310·08	307·86	240·50	335·04	27·18	−3·23
Oct. 1 Com. yr.	33·26	7·70	334·44	92·93	98·62	176·15	354·31	326·74	269·08	357·16	30·41	−4·79
Oct. 1 Leap yr.	20·19	318·94	298·75	69·54	48·88	200·53	20·66	339·81	270·07	10·33	30·52	−4·82
Nov. 1 Com. yr.	348·24	296·05	307·81	87·66	356·41	211·98	91·25	11·76	299·64	45·62	33·87	−6·43
Nov. 1 Leap yr.	335·18	247·29	272·11	64·26	306·66	236·36	117·60	24·82	300·62	58·80	33·98	−6·46
Dec. 1 Com. yr.	316·29	273·16	316·87	105·79	303·95	223·42	161·83	43·71	329·21	80·92	37·21	−8·02
Dec. 1 Leap yr.	303·23	224·40	281·17	82·39	254·20	247·80	188·19	56·77	330·19	94·09	37·32	−8·05
Dec. 32 Com. yr.	271·28	201·51	290·23	100·51	201·74	259·25	258·77	88·72	359·76	129·38	40·66	−9·66
Dec. 32 Leap yr.	258·21	152·74	254·53	77·12	152·00	283·63	285·12	101·79	0·75	142·56	40·77	−9·69
Day of month.												
1	0	0	0	0	0	0	0	0	0	0	0	0
2	346·93	311·24	324·30	336·60	310.25	24·38	26·35	13·07	0·99	13·18	0·11	−0·05
3	333·87	262·47	288·60	313·21	260·50	48·76	52·71	26·13	1·97	26·35	0·22	−0·11
4	320·80	213·71	252·91	289·81	210·75	73·14	79·06	39·20	2·96	39·53	0·33	−0·16
5	307·74	164·95	217·21	266·42	161·00	97·53	105·41	52·26	3·94	52·71	0·45	−0·21
6	294·68	116·18	181·51	243·02	111·26	121·91	131·76	65·32	4·93	65·88	0·56	−0·26
7	281·61	67·42	145·81	219·62	61·51	146·29	158·12	78·39	5·91	79·06	0·67	−0·32
8	268·54	18·66	110·11	196·23	11·76	170·67	184·47	91·46	6·90	92·23	0·78	−0·37
9	255·48	329·90	74·42	172·83	322·01	195·05	210·82	104·52	7·88	105·41	0·89	−0·42
10	242·42	281·13	38·72	149·44	272·26	219·43	237·18	117·58	8·87	118·59	1·00	−0·48
11	229·35	232·37	3·02	126·04	222·51	243·82	263·53	130·65	9·86	131·76	1·11	−0·53
12	216·28	183·61	327·32	102·65	172·76	268·20	289·88	143·72	10·84	144·94	1·23	−0·58
13	203·22	134·84	291·62	79·25	123·02	292·58	316·23	156·78	11·83	158·12	1·34	−0·64
14	190·16	86·08	255·93	55·85	73·27	316·96	342·59	169·84	12·81	171·29	1·45	−0·69
15	177·09	37·32	220·23	32·46	23·52	341·34	8·94	182·91	13·80	184·47	1·56	−0·74
16	164·02	348·56	184·53	9·06	333·77	5·72	35·29	195·98	14·78	197·65	1·67	−0·79
17	150·96	299·79	148·83	345·67	284·02	30·10	61·64	209·04	15·77	210·82	1·78	−0·85
18	137·90	251·03	113·13	322·27	234·27	54·48	88·00	222·10	16·76	224·00	1·89	−0·90
19	124·83	202·27	77·44	298·88	184·52	78·87	114·35	235·17	17·74	237·18	2·01	−0·95
20	111·76	153·50	41·74	275·48	134·78	103·25	140·70	248·24	18·73	250·35	2·12	−1·01
21	98·70	104·74	6·04	252·08	85·03	127·63	167·06	261·30	19·71	263·53	2·23	−1·06
22	85·64	55·98	330·34	228·69	35·28	152·01	193·41	274·36	20·70	276·70	2·34	−1·11
23	72·57	7·21	294·64	205·29	345·53	176·39	219·76	287·43	21·68	289·88	2·45	−1·16
24	59·50	318·45	258·95	181·90	295·78	200·77	246·11	300·50	22·67	303·06	2·56	−1·22
25	46·44	269·69	223·25	158·50	246·03	225·16	272·47	313·56	23·66	316·23	2·67	−1·27
26	33·38	220·92	187·55	135·10	196·28	249·54	298·82	326·62	24·64	329·41	2·79	−1·32
27	20·31	172·16	151·85	111·71	146·54	273·92	325·17	339·69	25·63	342·59	2·90	−1·38
28	7·24	123·40	116·15	88·31	96·79	298·30	351·52	352·76	26·61	355·76	3·01	−1·43
29	354·18	74·64	80·46	64·92	47·04	322·68	17·88	5·82	27·60	8·94	3·12	−1·48
30	341·12	25·87	44·76	41·52	357·29	347·06	44·23	18·88	28·58	22·12	3·23	−1·54
31	328·05	337·11	9·06	18·12	307·54	11·44	70·58	31·95	29·57	35·29	3·34	−1·59

*This column gives the longitude of the moon's ascending node for any day when applied to the N of Table 3.

The change in the dial reading of any component (except M_2 and Sa) on the Ferrel machine = ± (tabular value for component − tabular value for M_2), the $\frac{\text{upper}}{\text{lower}}$ sign being used when the speed of the component is $\frac{\text{greater}}{\text{less}}$ than that of M_2. The changes for M_2 and Sa are given directly by this table.

TABLE 5.—*For adapting the uniformly varying portion (V_0) of the equilibrium arguments of Table 3 to local midnight for any degree of west longitude.*

West longitude.	K_1	K_2	L_2	M_2	M_3	M_4	M_6	M_8	N_2	O_1	P_1	Q_1
	°	°	°	°	°	°	°	°	°	°	°	°
¼	0·00	0·00	— 0·01	— 0·02	— 0·03	— 0·03	— 0·05	— 0·07	— 0·03	— 0·02	0·00	— 0·03
½	0·00	0·00	— 0·02	— 0·03	— 0·05	— 0·07	— 0·10	— 0·14	— 0·05	— 0·04	0·00	— 0·05
¾	0·00	0·00	— 0·02	— 0·05	— 0·08	— 0·10	— 0·15	— 0·20	— 0·08	— 0·05	0·00	— 0·08
1	0·00	0·01	— 0·03	— 0·07	— 0·10	— 0·14	— 0·20	— 0·27	— 0·10	— 0·07	0·00	— 0·11
2	0·01	0·01	— 0·06	— 0·14	— 0·20	— 0·27	— 0·41	— 0·54	— 0·21	— 0·14	— 0·01	— 0·21
3	0·01	0·02	— 0·09	— 0·20	— 0·30	— 0·41	— 0·61	— 0·81	— 0·31	— 0·21	— 0·01	— 0·32
4	0·01	0·02	— 0·13	— 0·27	— 0·41	— 0·54	— 0·81	— 1·08	— 0·42	— 0·28	— 0·01	— 0·43
5	0·01	0·03	— 0·16	— 0·34	— 0·51	— 0·68	— 1·02	— 1·35	— 0·52	— 0·35	— 0·01	— 0·53
6	0·02	0·03	— 0·19	— 0·41	— 0·61	— 0·81	— 1·22	— 1·63	— 0·62	— 0·42	— 0·02	— 0·64
7	0·02	0·04	— 0·22	— 0·47	— 0·71	— 0·95	— 1·42	— 1·90	— 0·73	— 0·49	— 0·02	— 0·75
8	0·02	0·04	— 0·25	— 0·54	— 0·81	— 1·08	— 1·63	— 2·17	— 0·83	— 0·56	— 0·02	— 0·85
9	0·02	0·05	— 0·28	— 0·61	— 0·91	— 1·22	— 1·83	— 2·44	— 0·94	— 0·63	— 0·02	— 0·96
10	0·03	0·05	— 0·31	— 0·68	— 1·02	— 1·35	— 2·03	— 2·71	— 1·04	— 0·70	— 0·03	— 1·07
20	0·05	0·11	— 0·63	— 1·35	— 2·03	— 2·71	— 4·06	— 5·42	— 2·08	— 1·41	— 0·05	— 2·14
30	0·08	0·16	— 0·94	— 2·03	— 3·05	— 4·06	— 6·10	— 8·13	— 3·12	— 2·11	— 0·08	— 3·20
40	0·11	0·22	— 1·26	— 2·71	— 4·06	— 5·42	— 8·13	—10·84	— 4·16	— 2·82	— 0·11	— 4·27
50	0·14	0·27	— 1·57	— 3·39	— 5·08	— 6·77	—10·16	—13·55	— 5·20	— 3·52	— 0·14	— 5·34
60	0·16	0·33	— 1·89	— 4·06	— 6·10	— 8·13	—12·19	—16·25	— 6·24	— 4·23	— 0·16	— 6·41
70	0·19	0·38	— 2·20	— 4·74	— 7·11	— 9·48	—14·22	—18·96	— 7·28	— 4·93	— 0·19	— 7·47
80	0·22	0·44	— 2·51	— 5·42	— 8·13	—10·84	—16·25	—21·67	— 8·32	— 5·64	— 0·22	— 8·54
90	0·25	0·49	— 2·83	— 6·10	— 9·14	—12·19	—18·29	—24·38	— 9·36	— 6·34	— 0·25	— 9·61
100	0·27	0·55	— 3·14	— 6·77	—10·16	—13·55	—20·32	—27·09	—10·40	— 7·05	— 0·27	—10·68
110	0·30	0·60	— 3·46	— 7·45	—11·17	—14·90	—22·35	—29·80	—11·44	— 7·75	— 0·30	—11·74
120	0·33	0·66	— 3·77	— 8·13	—12·19	—16·25	—24·38	—32·51	—12·48	— 8·46	— 0·33	—12·81
130	0·36	0·71	— 4·09	— 8·80	—13·21	—17·61	—26·41	—35·22	—13·52	— 9·16	— 0·36	—13·88
140	0·38	0·77	— 4·40	— 9·48	—14·22	—18·96	—28·45	—37·93	—14·56	— 9·87	— 0·38	—14·95
150	0·41	0·82	— 4·72	—10·16	—15·24	—20·32	—30·48	—40·64	—15·60	—10·57	— 0·41	—16·01
160	0·44	0·88	— 5·03	—10·84	—16·25	—21·67	—32·51	—43·34	—16·64	—11·27	— 0·44	—17·08
170	0·47	0·93	— 5·34	—11·51	—17·27	—23·03	—34·54	—46·05	—17·68	—11·98	— 0·47	—18·15
180	0·49	0·99	— 5·66	—12·19	—18·29	—24·38	—36·57	—48·76	—18·72	—12·68	— 0·49	—19·22
190	0·52	1·04	— 5·97	—12·87	—19·30	—25·74	—38·60	—51·47	—19·76	—13·39	— 0·52	—20·28
200	0·55	1·10	— 6·29	—13·55	—20·32	—27·09	—40·64	—54·18	—20·80	—14·09	— 0·55	—21·35
210	0·57	1·15	— 6·60	—14·22	—21·33	—28·45	—42·67	—56·89	—21·84	—14·80	— 0·57	—22·42
220	0·60	1·20	— 6·92	—14·90	—22·35	—29·80	—44·70	—59·60	—22·88	—15·50	— 0·60	—23·49
230	0·63	1·26	— 7·23	—15·58	—23·37	—31·15	—46·73	—62·31	—23·92	—16·21	— 0·63	—24·55
240	0·66	1·31	— 7·54	—16·25	—24·38	—32·51	—48·76	—65·02	—24·96	—16·91	— 0·66	—25·62
250	0·68	1·37	— 7·86	—16·93	—25·40	—33·86	—50·79	—67·73	—26·00	—17·62	— 0·68	—26·69
260	0·71	1·42	— 8·17	—17·61	—26·41	—35·22	—52·83	—70·44	—27·04	—18·32	— 0·71	—27·76
270	0·74	1·48	— 8·49	—18·29	—27·43	—36·57	—54·86	—73·14	—28·08	—19·03	— 0·74	—28·82
280	0·77	1·53	— 8·80	—18·96	—28·45	—37·93	—56·89	—75·85	—29·13	—19·73	— 0·77	—29·89
290	0·79	1·59	— 9·12	—19·64	—29·46	—39·28	—58·92	—78·56	—30·17	—20·43	— 0·79	—30·96
300	0·82	1·64	— 9·43	—20·32	—30·48	—40·64	—60·95	—81·27	—31·21	—21·14	— 0·82	—32·03
310	0·85	1·70	— 9·74	—21·00	—31·49	—41·99	—62·99	—83·98	—32·25	—21·84	— 0·85	—33·09
320	0·88	1·75	—10·06	—21·67	—32·51	—43·34	—65·02	—86·69	—33·29	—22·55	— 0·88	—34·16
330	0·90	1·81	—10·37	—22·35	—33·52	—44·70	—67·05	—89·40	—34·33	—23·25	— 0·90	—35·23
340	0·93	1·86	—10·69	—23·03	—34·54	—46·05	—69·08	—92·11	—35·37	—23·96	— 0·93	—36·30
350	0·96	1·92	—11·00	—23·70	—35·56	—47·41	—71·11	—94·82	—36·41	—24·66	— 0·96	—37·36
360	0·99	1·97	—11·32	—24·38	—36·57	—48·76	—73·14	—97·53	—37·45	—25·37	— 0·99	—38·43

The changes for other components may be found from those above as follows:

$J_1 = L_2 - O_1$ | $S_{2,\,4,\,6} = 0$ | $[L_2] = L_2$ | $T_2 = P_1$ | $M_1 = k - s$ | $MN = M_2 + N_2$ | $[M_1] = K_1 + \lambda_2$ | $MS = M_3$ | $2N = N_2 + \lambda_2$ | $2MS = M_4$ | $OO = K_2 - O_1$ | $2SM = MSf$ | $R_2 = K_1$ | $Sa = K_1$ | $S_{1,\,3} = 0$ | $Ssa = K_2$

TABLE 5.—*For adapting the uniformly varying portion (V_0) of the equilibrium arguments of Table 3 to local midnight for any degree of west longitude*—Continued.

West longitude.	λ_2	μ_2	ν_2	MK	2MK	MSf	Mf	Mm	h	s	p	N
	°	°	°	°	°	°	°	°	°	°	°	°
¼	— 0·01	— 0·03	— 0·02	— 0·02	— 0·03	0·02	0·02	0·01	0·00	0·01	0·00	0·00
½	— 0·02	— 0·07	— 0·05	— 0·03	— 0·07	0·03	0·04	0·02	0·00	0·02	0·00	0·00
¾	— 0·03	— 0·10	— 0·07	— 0·05	— 0·10	0·05	0·05	0·03	0·00	0·03	0·00	0·00
1	— 0·04	— 0·14	— 0·10	— 0·06	— 0·14	0·07	0·07	0·04	0·00	0·04	0·00	0·00
2	— 0·07	— 0·27	— 0·20	— 0·13	— 0·28	0·14	0·15	0·07	0·01	0·07	0·00	0·00
3	— 0·11	— 0·41	— 0·30	— 0·19	— 0·41	0·20	0·22	0·11	0·01	0·11	0·00	0·00
4	— 0·15	— 0·54	— 0·40	— 0·26	— 0·55	0·27	0·29	0·15	0·01	0·15	0·00	0·00
5	— 0·18	— 0·68	— 0·50	— 0·32	— 0·69	0·34	0·37	0·18	0·01	0·18	0·00	0·00
6	— 0·22	— 0·81	— 0·59	— 0·39	— 0·83	0·41	0·44	0·22	0·02	0·22	0·00	0·00
7	— 0·25	— 0·95	— 0·69	— 0·45	— 0·97	0·47	0·51	0·25	0·02	0·26	0·00	0·00
8	— 0·29	— 1·08	— 0·79	— 0·52	— 1·11	0·54	0·59	0·29	0·02	0·29	0·00	0·00
9	— 0·33	— 1·22	— 0·89	— 0·58	— 1·24	0·61	0·66	0·33	0·02	0·33	0·00	0·00
10	— 0·36	— 1·35	— 0·99	— 0·65	— 1·38	0·68	0·73	0·36	0·03	0·37	0·00	0·00
20	— 0·73	— 2·71	— 1·98	— 1·30	— 2·76	1·35	1·46	0·73	0·05	0·73	0·01	0·00
30	— 1·09	— 4·06	— 2·97	— 1·95	— 4·15	2·03	2·20	1·09	0·08	1·10	0·01	0·00
40	— 1·45	— 5·42	— 3·97	— 2·60	— 5·53	2·71	2·93	1·45	0·11	1·46	0·01	— 0·01
50	— 1·81	— 6·77	— 4·96	— 3·25	— 6·91	3·39	3·66	1·81	0·14	1·83	0·02	— 0·01
60	— 2·18	— 8·13	— 5·95	— 3·90	— 8·29	4·06	4·39	2·18	0·16	2·20	0·02	— 0·01
70	— 2·54	— 9·48	— 6·94	— 4·55	— 9·67	4·74	5·12	2·54	0·19	2·56	0·02	— 0·01
80	— 2·90	—10·84	— 7·93	— 5·20	—11·06	5·42	5·86	2·90	0·22	2·93	0·02	— 0·01
90	— 3·27	—12·19	— 8·92	— 5·85	—12·44	6·10	6·59	3·27	0·25	3·29	0·03	— 0·01
100	— 3·63	—13·55	— 9·92	— 6·50	—13·82	6·77	7·32	3·63	0·27	3·66	0·03	— 0·01
110	— 3·99	—14·90	—10·91	— 7·15	—15·20	7·45	8·05	3·99	0·30	4·03	0·03	— 0·02
120	— 4·36	—16·25	—11·90	— 7·80	—16·58	8·13	8·78	4·36	0·33	4·39	0·04	— 0·02
130	— 4·72	—17·61	—12·89	— 8·45	—17·96	8·80	9·52	4·72	0·36	4·76	0·04	— 0·02
140	— 5·08	—18·96	—13·88	— 9·10	—19·35	9·48	10·25	5·08	0·38	5·12	0·04	— 0·02
150	— 5·44	—20·32	—14·87	— 9·75	—20·73	10·16	10·98	5·44	0·41	5·49	0·05	— 0·02
160	— 5·81	—21·67	—15·87	—10·40	—22·11	10·84	11·71	5·81	0·44	5·86	0·05	— 0·02
170	— 6·17	—23·03	—16·86	—11·05	—23·49	11·51	12·44	6·17	0·47	6·22	0·05	— 0·03
180	— 6·53	—24·38	—17·85	—11·70	—24·87	12·19	13·18	6·53	0·49	6·59	0·06	— 0·03
190	— 6·90	—25·74	—18·84	—12·35	—26·26	12·87	13·91	6·90	0·52	6·95	0·06	— 0·03
200	— 7·26	—27·09	—19·83	—13·00	—27·64	13·55	14·64	7·26	0·55	7·32	0·06	— 0·03
210	— 7·62	—28·45	—20·82	—13·65	—29·02	14·22	15·37	7·62	0·57	7·69	0·06	— 0·03
220	— 7·98	—29·80	—21·82	—14·30	—30·40	14·99	16·10	7·98	0·60	8·05	0·07	— 0·03
230	— 8·35	—31·15	—22·81	—14·95	—31·78	15·58	16·84	8·35	0·63	8·42	0·07	— 0·03
240	— 8·71	—32·51	—23·80	—15·60	—33·17	16·25	17·57	8·71	0·66	8·78	0·07	— 0·04
250	— 9·07	—33·86	—24·79	—16·25	—34·55	16·93	18·30	9·07	0·68	9·15	0·08	— 0·04
260	— 9·44	—35·22	—25·78	—16·90	—35·93	17·61	19·03	9·44	0·71	9·52	0·08	— 0·04
270	— 9·80	—36·57	—26·77	—17·55	—37·31	18·29	19·76	9·80	0·74	9·88	0·08	— 0·04
280	—10·16	—37·93	—27·77	—18·20	—38·69	18·96	20·50	10·16	0·77	10·25	0·09	— 0·04
290	—10·52	—39·28	—28·76	—18·85	—40·08	19·64	21·23	10·52	0·79	10·61	0·09	— 0·04
300	—10·89	—40·64	—29·75	—19·50	—41·46	20·32	21·96	10·89	0·82	10·98	0·09	— 0·04
310	—11·25	—41·99	—30·74	—20·15	—42·84	21·00	22·69	11·25	0·85	11·35	0·10	— 0·05
320	—11·61	—43·34	—31·73	—20·80	—44·22	21·67	23·42	11·61	0·88	11·71	0·10	— 0·05
330	—11·98	—44·70	—32·72	—21·45	—45·60	22·35	24·16	11·98	0·90	12·08	0·10	— 0·05
340	—12·34	—46·05	—33·71	—22·10	—46·98	23·03	24·89	12·34	0·93	12·44	0·11	— 0·05
350	—12·70	—47·41	—34·71	—22·75	—48·37	23·70	25·62	12·70	0·96	12·81	0·11	— 0·05
360	—13·07	—48·76	—35·70	—23·40	—49·75	24·38	26·35	13·07	0·99	13·18	0·11	— 0·05

TABLE 6.—*Values of N, I, and P for Greenwich midnight, beginning each month, from 1850 to 1949.*

Month.	*N*	*I*	*P*	*N*	*I*	*P*	*N*	*I*	*P*	*N*	*I*	*P*
	1850			1855			1860			1865		
	°	°	°	°	°	°	°	°	°	°	°	°
Jan. 1	146·201	19·379	91·861	49·506	27·066	295·540	312·812	27·201	154·257	216·065	19·518	358·775
Feb. 1	144·559	19·479	95·015	47·865	27·162	299·217	311·171	27·105	157·936	214·424	19·416	1·933
Mar. 1	143·076	19·572	97·875	46·382	27·247	302·542	309·635	27·014	161·374	212·941	19·329	4·777
Apr. 1	141·435	19·679	101·049	44·741	27·339	306·226	307·994	26·913	165·045	211·300	19·234	7·913
May 1	139·846	19·785	104·135	43·152	27·424	309·794	306·405	26·813	168·594	209·711	19·146	10·938
June 1	138·205	19·899	107·335	41·510	27·509	313·485	304·763	26·707	172·258	208·069	19·060	14·054
July 1	136·616	20·011	110·442	39·922	27·589	317·059	303·175	26·603	175·797	206·481	18·980	17·061
Aug. 1	134·974	20·130	113·664	38·280	27·669	320·756	301·533	26·491	179·452	204·839	18·902	20·157
Sept. 1	133·333	20·253	116·900	36·639	27·746	324·456	299·892	26·378	183·102	203·198	18·828	23·246
Oct. 1	131·744	20·373	120·041	35·050	27·817	328·038	298·303	26·266	186·629	201·609	18·761	26·223
Nov. 1	130·103	20·500	123·301	33·408	27·888	331·744	296·661	26·149	190·269	199·967	18·696	29·294
Dec. 1	128·514	20·625	126·468	31·820	27·952	335·331	295·073	26·032	193·787	198·379	18·638	32·258
	1851			1856			1861			1866		
Jan. 1	126·872	20·755	129·753	30·178	28·017	339·040	293·431	25·911	197·415	196·737	18·583	35·312
Feb. 1	125·231	20·889	133·047	28·537	28·078	342·752	291·790	25·787	201·038	195·096	18·532	38·360
Mar. 1	123·748	21·011	136·034	27·001	28·132	346·226	290·307	25·673	204·309	193·613	18·490	41·108
Apr. 1	122·107	21·148	139·353	25·360	28·187	349·941	288·666	25·545	207·919	191·972	18·449	44·144
May 1	120·518	21·281	142·575	23·771	28·237	353·539	287·077	25·419	211·410	190·383	18·415	47·078
June 1	118·876	21·421	145·918	22·129	28·285	357·258	285·435	25·288	215·011	188·741	18·383	50·106
July 1	117·288	21·558	149·164	20·541	28·329	0·858	283·847	25·159	218·489	187·153	18·359	53·031
Aug. 1	115·646	21·700	152·528	18·899	28·370	4·580	282·205	25·025	222·076	185·511	18·338	56·051
Sept. 1	114·005	21·845	155·905	17·258	28·408	8·303	280·564	24·888	225·656	183·870	18·323	59·070
Oct. 1	112·416	21·984	159·183	15·669	28·443	11·909	278·975	24·755	229·115	182·281	18·314	61·989
Nov. 1	110·774	22·129	162·582	14·027	28·474	15·633	277·333	24·617	232·682	180·639	18·309	65·004
Dec. 1	109·186	22·270	165·882	12·439	28·501	19·239	275·745	24·481	236·126	179·051	18·309	67·923
	1852			1857			1862			1867		
Jan. 1	107·544	22·416	169·301	10·797	28·526	22·968	274·103	24·340	239·678	177·409	18·315	70·939
Feb. 1	105·903	22·563	172·732	9·156	28·547	26·695	272·462	24·197	243·221	175·768	18·326	74·955
Mar. 1	104·367	22·701	175·951	7·673	28·563	30·064	270·979	24·068	246·415	174·285	18·341	76·682
Apr. 1	102·726	22·848	179·401	6·032	28·578	33·793	269·338	23·924	249·943	172·644	18·362	79·676
May 1	101·137	22·991	182·750	4·443	28·589	37·402	267·749	23·783	253·349	171·054	18·387	82·628
June 1	99·495	23·137	186·221	2·801	28·597	41·132	266·107	23·638	256·860	169·413	18·419	85·657
July 1	97·907	23·279	189·588	1·213	28·601	44·741	264·519	23·497	260·249	167·825	18·454	88·591
Aug. 1	96·265	23·426	193·076	359·571	28·602	48·471	262·877	23·350	263·742	166·183	18·496	91·628
Sept. 1	94·624	23·573	196·574	357·930	28·599	52·202	261·236	23·203	267·226	164·542	18·542	94·671
Oct. 1	93·035	23·714	199·968	356·341	28·593	55·842	259·647	23·060	270·589	162·953	18·592	97·623
Nov. 1	91·393	23·859	203·484	354·699	28·583	59·542	258·005	22·914	274·054	161·311	18·649	100·679
Dec. 1	89·805	23·999	206·895	353·111	28·571	63·150	256·417	22·771	277·398	159·723	18·707	103·644
	1853			1858			1863			1868		
Jan. 1	88·163	24·143	210·426	351·469	28·555	66·879	254·774	22·624	280·842	158·080	18·774	106·715
Feb. 1	86·522	24·285	213·966	349·828	28·535	70·607	253·133	22·477	284·277	156·439	18·844	109·795
Mar. 1	85·039	24·414	217·172	348·345	28·514	73·975	251·650	22·345	287·371	154·903	18·914	112·686
Apr. 1	83·397	24·555	220·727	346·704	28·487	77·701	250·009	22·199	290·785	153·262	18·992	115·783
May 1	81·809	24·689	224·174	345·115	28·458	81·307	248·420	22·058	294·079	151·673	19·073	118·791
June 1	80·167	24·827	227·746	343·473	28·424	85·032	246·778	21·913	297·473	150·031	19·160	121·908
July 1	78·578	24·960	231·207	341·885	28·389	88·636	245·190	21·774	300·746	148·443	19·248	124·935
Aug. 1	76·937	25·095	234·790	340·243	28·349	92·358	243·548	21·631	304·117	146·801	19·343	128·074
Sept. 1	75·295	25·229	238·382	338·602	28·306	96·079	241·907	21·489	307·476	145·160	19·442	131·224
Oct. 1	73·707	25·357	241·863	337·013	28·260	99·679	240·318	21·353	310·716	143·571	19·541	134·283
Nov. 1	72·065	25·488	245·467	335·371	28·211	103·398	238·676	21·214	314·052	141·929	19·647	137·456
Dec. 1	70·476	25·612	248·960	333·783	28·159	106·994	237·088	21·081	317·270	140·341	19·752	140·538
	1854			1859			1864			1869		
Jan. 1	68·834	25·746	252·587	332·140	28·102	110·709	235·446	20·945	320·582	138·699	19·864	143·733
Feb. 1	67·193	25·864	256·198	330·499	28·043	114·421	233·805	20·810	323·883	137·058	19·980	146·940
Mar. 1	65·710	25·974	259·475	329·016	27·986	117·773	232·269	20·687	326·960	135·575	20·087	149·848
Apr. 1	64·069	26·096	263·107	327·375	27·920	121·481	230·628	20·556	330·237	133·934	20·208	153·078
May 1	62·480	26·210	266·626	325·786	27·853	125·067	229·039	20·433	333·397	132·345	20·328	156·216
June 1	60·838	26·328	270·281	324·144	27·781	128·771	227·397	20·307	336·650	130·703	20·453	159·472
July 1	59·250	26·438	273·799	322·556	27·709	132·353	225·809	20·189	339·786	129·115	20·577	162·633
Aug. 1	57·608	26·550	277·451	320·914	27·629	136·050	224·167	20·068	343·015	127·473	20·707	165·911
Sept. 1	55·967	26·659	281·107	319·273	27·549	139·746	222·526	19·951	346·232	125·832	20·840	169·205
Oct. 1	54·378	26·763	284·651	317·684	27·468	143·319	220·937	19·840	349·332	124·243	20·970	172·399
Nov. 1	52·736	26·867	288·316	316·042	27·380	147·008	219·295	19·728	352·526	122·601	21·106	175·715
Dec. 1	51·148	26·966	291·867	314·454	27·293	150·575	217·707	19·623	355·605	121·013	21·240	178·934

N = the mean longitude of the moon's ascending node. *I* = the inclination of the lunar orbit to the plane of the earth's equator. *P* = the mean longitude of the lunar perigee measured from the intersection of moon's orbit with the plane of the earth's equator.

TABLE 6.—*Values of N, I, and P for Greenwich midnight, beginning each month, from 1850 to 1949*—Continued.

Month.	*N*	*I*	*P*	*N*	*I*	*P*	*N*	*I*	*P*	*N*	*I*	*P*
		1870			1875			1880			1885	
	°	°	°	°	°	°	°	°	°	°	°	°
Jan. 1	119·371	21·379	182·274	22·677	28·270	33·381	285·983	25·332	251·173	189·236	18·393	86·557
Feb. 1	117·730	21·520	185·623	21·036	28·316	37·100	284·342	25·200	254·770	187·595	18·366	89·582
Mar. 1	116·247	21·649	188·660	19·553	28·355	40·462	282·806	25·074	258·128	186·112	18·345	92·312
Apr. 1	114·606	21·793	192·032	17·912	28·394	44·184	281·165	24·939	261·710	184·471	18·327	95·329
May 1	113·017	21·930	195·306	16·323	28·429	47·788	279·576	24·806	265·171	182·882	18·317	98·249
June 1	111·375	22·076	198·703	14·681	28·462	51·514	277·934	24·667	268·741	181·240	18·309	101·265
July 1	109·787	22·217	201·997	13·093	28·490	55·120	276·346	24·532	272·188	179·652	18·309	104·183
Aug. 1	108·145	22·363	205·414	11·451	28·517	58·846	274·704	24·392	275·742	178·010	18·312	107·198
Sept. 1	106·504	22·510	208·839	9·810	28·539	62·574	273·063	24·249	279·289	176·369	18·321	110·214
Oct. 1	104·915	22·652	212·166	8·221	28·558	66·183	271·474	24·111	282·711	174·780	18·335	113·135
Nov. 1	103·273	22·798	215·613	6·579	28·573	69·913	269·832	23·967	286·244	173·138	18·355	116·155
Dec. 1	101·685	22·941	218·958	4·991	28·585	73·521	268·244	23·828	289·652	171·550	18·379	119·080
		1871			1876			1881			1886	
Jan. 1	100·043	23·088	222·425	3·349	28·595	77·249	266·602	23·682	293·166	169·908	18·409	122·107
Feb. 1	98·402	23·236	225·901	1·708	28·600	80·981	264·961	23·536	296·671	168·267	18·444	125·138
Mar. 1	96·919	23·368	229·050	0·172	28·602	84·471	263·478	23·403	299·829	166·784	18·480	128·881
Apr. 1	95·278	23·515	232·543	358·531	28·600	88·203	261·837	23·257	303·316	165·143	18·525	130·920
May 1	93·689	23·656	235·934	356·942	28·596	91·811	260·248	23·114	306·682	163·554	18·574	133·867
June 1	92·047	23·802	239·446	355·300	28·587	95·541	258·606	22·968	310·151	161·912	18·627	136·923
July 1	90·459	23·942	242·853	353·712	28·576	99·149	257·018	22·823	313·498	160·324	18·685	139·886
Aug. 1	88·817	24·086	246·382	352·070	28·561	102·878	255·376	22·678	316·946	158·682	18·749	142·954
Sept. 1	87·176	24·229	249·920	350·429	28·542	106·608	253·735	22·531	320·386	157·041	18·817	146·031
Oct. 1	85·587	24·367	253·350	348·840	28·521	110·215	252·146	22·389	323·704	155·452	18·888	149·017
Nov. 1	83·945	24·508	256·904	347·198	28·495	113·943	250·504	22·242	327·123	153·810	18·965	152·113
Dec. 1	82·357	24·643	260·349	345·610	28·467	117·549	248·916	22·102	330·419	152·222	19·044	155·116
		1872			1877			1882			1887	
Jan. 1	80·715	24·782	263·916	343·967	28·435	121·273	247·273	21·956	333·815	150·579	19·131	158·230
Feb. 1	79·074	24·919	267·492	342·326	28·399	124·997	245·632	21·813	337·200	148·938	19·220	161·355
Mar. 1	77·538	25·046	271·843	340·843	28·364	128·361	244·149	21·683	340·249	147·455	19·305	164·187
Apr. 1	75·897	25·180	274·431	339·202	28·322	132·082	242·508	21·541	343·612	145·814	19·463	167·332
May 1	74·308	25·309	277·910	337·613	28·278	135·682	240·919	21·404	346·856	144·225	19·500	170·387
June 1	72·666	25·440	281·512	335·971	28·229	139·401	239·277	21·264	350·197	142·583	19·604	173·554
July 1	71·078	25·565	285·003	334·383	28·179	142·998	237·089	21·131	353·418	140·995	19·708	176·631
Aug. 1	69·436	25·693	288·615	332·741	28·123	146·708	236·047	20·994	356·735	139·353	19·819	179·822
Sept. 1	67·795	25·819	292·236	331·100	28·065	150·426	234·406	20·859	0·040	137·712	19·934	183·025
Oct. 1	66·206	25·938	295·744	329·511	28·005	154·017	232·817	20·731	3·227	136·123	20·047	186·136
Nov. 1	64·564	26·059	299·375	327·869	27·940	157·727	231·175	20·600	6·509	134·481	20·167	189·363
Dec. 1	62·976	26·175	302·893	326·281	27·874	161·314	229·587	20·475	9·672	132·893	20·307	192·461
		1873			1878			1883			1888	
Jan. 1	61·333	26·292	305·534	324·639	27·803	165·019	227·945	20·349	12·930	131·251	20·411	195·747
Feb. 1	59·692	26·408	310·180	322·998	27·729	168·720	226·304	20·226	16·174	129·610	20·538	199·021
Mar. 1	58·209	26·509	313·478	321·515	27·659	172·062	224·821	20·116	19·095	128·074	20·660	202·075
Apr. 1	56·568	26·620	317·133	319·874	27·579	175·757	223·180	19·997	22·316	126·433	20·791	205·361
May 1	54·979	26·724	321·674	318·285	27·501	179·331	221·591	19·884	25·422	124·844	20·921	208·553
June 1	53·337	26·829	324·338	316·643	27·413	183·020	219·949	19·772	28·620	123·202	21·056	211·864
July 1	51·749	26·929	327·889	315·055	27·327	186·590	218·361	19·666	31·704	121·614	21·189	215·081
Aug. 1	50·107	27·030	331·560	313·413	27·235	190·273	216·719	19·559	34·878	119·972	21·328	218·413
Sept. 1	48·466	27·127	335·236	311·772	27·141	193·954	215·078	19·457	38·041	118·331	21·468	221·760
Oct. 1	46·877	27·219	338·796	310·183	27·047	197·511	213·489	19·360	41·091	116·742	21·606	225·009
Nov. 1	45·235	27·311	342·480	308·541	26·947	201·185	211·847	19·264	44·231	115·100	21·748	228·378
Dec. 1	43·647	27·397	346·047	306·953	26·848	204·735	210·259	19·176	47·261	113·512	21·887	231·649
		1874			1879			1884			1889	
Jan. 1	42·005	27·484	349·736	305·311	26·743	208·399	208·617	19·088	50·379	111·870	22·032	235·040
Feb. 1	40·364	27·567	353·429	303·670	26·635	212·059	206·976	19·004	53·489	110·229	22·177	238·442
Mar. 1	38·881	27·642	356·768	302·187	26·536	215·361	205·440	18·930	56·390	108·746	22·309	241·524
Apr. 1	37·240	27·718	0·465	300·546	26·424	219·012	203·799	18·854	59·480	107·105	22·455	244·947
May 1	35·651	27·790	4·047	298·957	26·313	222·542	202·210	18·786	62·462	105·516	22·598	248·269
June 1	34·009	27·862	7·752	297·315	26·196	226·184	200·568	18·719	65·535	103·874	22·744	251·713
July 1	32·421	27·928	11·338	295·727	26·081	229·703	198·980	18·659	68·501	102·286	22·887	255·055
Aug. 1	30·779	27·994	15·046	294·085	25·959	233·334	197·338	18·602	71·558	100·644	23·034	258·518
Sept. 1	29·138	28·056	18·757	292·444	25·837	236·961	195·697	18·548	74·610	99·003	23·182	261·991
Oct. 1	27·549	28·113	22·349	290·855	25·715	240·464	194·108	18·504	77·555	97·414	23·324	265·361
Nov. 1	25·907	28·169	26·066	289·213	25·588	244·080	192·474	18·461	80·594	95·772	23·470	268·853
Dec. 1	24·319	28·220	29·663	287·625	25·463	247·571	190·878	18·425	83·530	94·184	23·612	272·241

TABLE 6.—*Values of N, I, and P for Greenwich midnight, beginning each month, from 1850 to 1949*—Continued.

Month.	N	I	P	N	I	P	N	I	P	N	I	P
	1890			1895			1900			1905		
	°	°	°	°	°	°	°	°	°	°	°	°
Jan. 1	92·542	23·757	275·751	355·848	28·590	131·659	259·154	23·017	346·357	162·460	18·608	173·267
Feb. 1	90·901	23·903	279·267	354·207	28·580	135·388	257·513	22·869	349·819	160·819	18·666	176·328
Mar. 1	89·418	24·033	282·454	352·724	28·568	138·754	256·030	22·737	352·938	159·336	18·723	179·055
Apr. 1	87·777	24·176	285·988	351·083	28·550	142·486	254·389	22·589	356·380	157·695	18·790	182·168
May 1	86·188	24·314	289·415	349·494	28·530	146·104	252·800	22·447	359·702	156·106	18·858	185·151
June 1	84·546	24·456	292·966	347·852	28·506	149·822	251·158	22·301	3·124	154·464	18·935	188·242
July 1	82·958	24·593	296·409	346·264	28·479	153·428	249·570	22·159	6·426	152·876	19·011	191·243
Aug. 1	81·316	24·730	299·974	344·622	28·448	157·153	247·928	22·015	9·826	151·234	19·096	194·353
Sept. 1	79·675	24·868	303·547	342·981	28·414	160·878	246·287	21·869	13·217	149·593	19·184	197·474
Oct. 1	78·086	25·001	307·010	341·392	28·377	164·482	244·698	21·730	16·487	148·004	19·273	200·504
Nov. 1	76·444	25·136	310·597	339·750	28·337	168·204	243·056	21·588	19·854	146·362	19·369	203·645
Dec. 1	74·856	25·264	313·074	338·162	28·294	171·805	241·468	21·451	23·102	144·774	19·466	206·696
	1891			1896			1901			1906		
Jan. 1	73·214	25·396	317·673	336·519	28·246	175·523	239·825	21·311	26·447	143·131	19·568	209·861
Feb. 1	71·573	25·526	321·278	334·878	28·195	179·240	238·184	21·172	29·779	141·490	19·676	213·035
Mar. 1	70·090	25·642	324·540	333·342	28·144	182·717	236·701	21·048	32·780	140·007	19·775	215·915
Apr. 1	68·449	25·769	328·157	331·701	28·086	186·430	235·060	20·913	36·089	138·366	19·887	219·113
May 1	66·860	25·889	331·663	330·112	28·028	190·023	233·471	20·784	39·280	136·777	20·000	222·205
June 1	65·218	26·011	335·291	328·470	28·963	193·733	231·829	20·652	42·567	135·135	20·119	225·441
July 1	63·630	26·128	338·808	326·882	27·899	197·321	230·241	20·527	45·735	133·547	20·237	228·570
Aug. 1	61·988	26·246	342·446	325·240	27·830	201·026	228·599	20·400	49·007	131·905	20·360	231·815
Sept. 1	60·347	26·362	346·091	323·599	27·757	204·728	226·958	20·275	52·247	130·264	20·497	235·075
Oct. 1	58·758	26·471	349·622	322·010	27·682	208·309	225·369	20·156	55·380	128·675	20·612	238·239
Nov. 1	57·116	26·583	353·276	320·368	27·603	212·007	223·727	20·036	58·606	127·033	20·743	241·521
Dec. 1	55·528	26·688	356·815	318·780	27·524	215·582	222·139	19·923	61·716	125·445	20·872	244·709
	1892			1897			1902			1907		
Jan. 1	53·885	26·794	0·478	317·138	27·439	219·273	220·497	19·809	64·918	123·803	21·007	248·015
Feb. 1	52·244	26·898	4·145	315·497	27·351	222·960	218·856	19·698	68·107	122·162	21·143	251·333
Mar. 1	50·708	26·993	7·579	314·014	27·269	226·290	217·373	19·602	70·979	120·679	21·208	254·341
Apr. 1	49·067	27·091	11·253	312·373	27·176	229·970	215·732	19·497	74·146	119·038	21·408	257·682
May 1	47·478	27·185	14·812	310·784	27·081	233·529	214·143	19·400	77·200	117·449	21·544	260·926
June 1	45·836	27·277	18·494	309·142	26·984	237·204	212·501	19·302	80·345	115·807	21·687	264·290
July 1	44·248	27·365	22·061	307·554	26·885	240·756	210·913	19·212	83·379	114·219	21·826	267·557
Aug. 1	42·606	27·453	25·748	305·912	26·782	244·421	209·271	19·123	86·502	112·577	21·969	270·942
Sept. 1	40·965	27·537	29·440	304·271	26·675	248·084	207·630	19·037	89·616	110·936	22·115	274·340
Oct. 1	39·376	27·616	33·016	302·682	26·569	251·623	206·041	18·958	92·619	109·347	22·256	277·638
Nov. 1	37·734	27·695	36·714	301·040	26·458	255·276	204·399	18·881	95·714	107·705	22·402	281·058
Dec. 1	36·146	27·768	40·295	299·452	26·348	258·807	202·811	18·811	98·699	106·117	22·544	284·376
	1893			1898			1903			1908		
Jan. 1	34·504	27·841	43·998	297·810	26·231	262·450	201·169	18·743	101·774	104·475	22·691	287·816
Feb. 1	32·863	27·909	47·703	296·169	26·113	266·087	199·528	18·679	104·842	102·834	22·838	291·266
Mar. 1	31·380	27·970	51·054	294·686	25·004	269·370	198·045	18·626	107·607	101·298	22·976	294·503
Apr. 1	29·739	28·034	54·763	293·045	25·881	272·997	196·404	18·572	110·660	99·657	23·123	297.971
May 1	28·150	28·093	58·355	291·456	25·762	276·503	194·815	18·524	113·609	98·068	23·265	301·338
June 1	26·508	28·149	62·070	289·814	25·634	280·120	193·173	18·479	116·650	96·426	23·413	304·826
July 1	24·920	28·202	65·666	288·226	25·511	283·614	191·585	18·441	119·587	94·838	23·554	308·210
Aug. 1	23·278	28·252	69·383	286·584	25·381	287·218	189·943	18·406	122·617	93·196	23·700	311·715
Sept. 1	21·637	28·299	73·103	284·943	25·238	290·818	188·302	18·377	125·644	91·555	23·845	315·231
Oct. 1	20·048	28·342	76·703	283·354	25·119	294·294	186·713	18·353	128·569	89·966	23·985	318·640
Nov. 1	18·406	28·382	80·426	281·712	24·984	297·879	185·071	18·334	131·589	88·324	24·128	322·172
Dec. 1	16·818	28·418	84·030	280·124	24·851	301·342	183·483	18·320	134·509	86·736	24·267	325·597
	1894			1899			1904			1909		
Jan. 1	15·176	28·452	87·754	278·482	24·713	304·915	181·841	18·312	137·525	85·094	24·409	329·145
Feb. 1	13·535	28·482	91·479	276·841	24·574	308·478	180·200	18·308	140·540	83·453	24·549	332·700
Mar. 1	12·052	28·507	94·846	275·358	24·448	311·692	178·664	18·310	143·361	81·970	24·676	335·918
Apr. 1	10·411	28·531	98·573	273·717	24·306	315·241	177·023	18·317	146·376	80·329	24·814	339·488
May 1	8·822	28·551	102·181	272·128	24·168	318·668	175·434	18·329	149·296	78·740	24·946	342·949
June 1	7·180	28·568	105·915	270·486	24·025	322·203	173·792	18·346	152·315	77·098	25·082	346·532
July 1	5·592	28·582	109·520	268·898	23·885	325·614	172·204	18·369	155·239	75·510	25·212	350·007
Aug. 1	3·950	28·591	113·248	267·256	23·740	329·131	170·562	18·397	158·264	73·868	25·345	353·603
Sept. 1	2·309	28·598	116·979	265·615	23·594	332·639	168·921	18·430	161·296	72·227	25·475	357·206
Oct. 1	0·720	28·602	120·589	264·026	23·452	336·026	167·332	18·466	164·229	70·638	25·599	0·699
Nov. 1	359·078	28·601	124·320	262·384	23·306	339·517	165·690	18·510	167·269	68·996	25·726	4·314
Dec. 1	357·490	28·598	127·929	260·796	23·164	342·886	164·102	18·556	170·215	67·408	25·848	7·819

TABLE 6.—*Values of N, I, and P for Greenwich midnight, beginning each month, from 1850 to 1949*—Continued.

Month.	*N*	*I*	*P*	*N*	*I*	*P*	*N*	*I*	*P*	*N*	*I*	*P*
	1910			1915			1920			1925		
	°	°	°	°	°	°	°	°	°	°	°	°
Jan. 1	65·765	25·970	11·446	329·071	27·988	229·741	232·377	20·695	78·837	135·630	20·083	261·833
Feb. 1	64·124	26·092	15·077	327·430	27·922	233·449	230·736	20·565	82·115	133·989	20·204	265·064
Mar. 1	62·641	26·199	18·363	325·947	27·860	236·797	229·200	20·446	85·171	132·506	20·315	267·992
Apr. 1	61·000	26·316	22·004	324·306	27·788	240·500	227·559	20·318	88·425	130·865	20·441	271·245
May 1	59·411	26·427	25·534	322·717	27·716	244·082	225·970	20·201	91·562	129·276	20·564	274·406
June 1	57·769	26·539	29·186	321·075	27·638	247·781	224·328	20·080	94·793	127·634	20·695	277·684
July 1	56·181	26·645	32·723	319·487	27·559	251·357	222·740	19·966	97·907	126·046	20·822	280·868
Aug. 1	54·539	26·753	36·384	317·845	27·476	255·049	221·098	19·851	101·112	124·404	20·957	284·169
Sept. 1	52·898	26·865	40·049	316·204	27·389	258·739	219·457	19·739	104·307	122·763	21·093	287·483
Oct. 1	51·309	26·956	43·600	314·615	27·302	262·307	217·868	19·634	107·387	121·174	21·226	290·701
Nov. 1	49·667	27·056	47·273	312·973	27·210	265·990	216·226	19·528	110·558	119·532	21·365	294·039
Dec. 1	48·079	27·149	50·831	311·385	27·118	269·550	214·638	19·430	113·616	117·944	21·502	297·280
	1911			1916			1921			1926		
Jan. 1	46·437	27·244	54·512	309·743	27·021	273·224	212·996	19·332	116·765	116·302	21·644	300·641
Feb. 1	44·796	27·335	58·195	308·102	26·919	276·897	211·355	19·237	119·902	114·661	21·787	304·012
Mar. 1	43·313	27·415	61·526	306·566	26·823	280·328	209·872	19·155	122·727	113·178	21·916	307·068
Apr. 1	41·672	27·501	65·216	304·925	26·718	283·991	208·231	19·068	125·843	111·537	22·062	310·461
May 1	40·083	27·581	68·790	303·336	26·613	287·532	206·642	18·988	128·850	109·948	22·203	313·756
June 1	38·441	27·661	72·487	301·694	26·502	291·187	205·000	18·909	131·948	108·306	22·348	317·171
July 1	36·853	27·736	76·066	300·106	26·393	294·719	203·412	18·837	134·937	106·718	22·490	320·486
Aug. 1	35·211	27·810	79·768	298·464	26·277	298·365	201·770	18·767	138·016	105·076	22·637	323·922
Sept. 1	33·570	27·881	83·473	296·823	26·160	302·005	200·129	18·702	141·087	103·435	22·784	327·368
Oct. 1	31·981	27·946	87·060	295·234	26·044	305·523	198·540	18·643	144·052	101·846	22·927	330·712
Nov. 1	30·339	28·011	90·770	293·592	25·923	309·153	196·898	18·588	147·107	100·204	23·074	334·179
Dec. 1	28·751	28·070	94·362	292·004	25·803	312·661	195·310	18·538	150·058	98·616	23·217	337·541
	1912			1917			1922			1927		
Jan. 1	27·109	28·128	98·074	290·362	25·677	316·280	193·668	18·492	153·099	96·974	23·363	341·028
Feb. 1	25·468	28·184	101·790	288·721	25·549	319·892	192·027	18·451	156·136	95·333	23·510	344·521
Mar. 1	23·932	28·232	105·268	287·238	25·432	323·151	190·544	18·418	158·875	93·850	23·641	347·686
Apr. 1	22·291	28·281	108·986	285·597	25·301	326·751	188·903	18·386	161·903	92·209	23·787	351·196
May 1	20·702	28·325	112·586	284·008	25·173	330·230	187·314	18·361	164·829	90·620	23·927	354·602
June 1	19·060	28·367	116·308	282·366	25·038	333·819	185·672	18·340	167·850	88·978	24·072	358·131
July 1	17·472	28·404	119·911	280·778	24·906	337·284	184·084	18·325	170·771	87·390	24·210	1·553
Aug. 1	15·830	28·439	123·635	279·136	24·769	340·858	182·442	18·315	173·787	85·748	24·353	5·096
Sept. 1	14·189	28·471	127·361	277·495	24·631	344·426	180·801	18·309	176·803	84·107	24·494	8·649
Oct. 1	12·600	28·498	130·966	275·906	24·495	347·871	179·212	18·309	179·721	82·518	24·629	12·094
Nov. 1	10·958	28·524	134·695	274·264	24·354	351·424	177·570	18·315	182·737	80·876	24·768	15·662
Dec. 1	9.370	28·545	138·302	272·676	24·215	354·853	175·982	18·324	185·655	79·288	24·902	19·121
	1913			1918			1923			1928		
Jan. 1	7·728	28·563	142·032	271·034	24·073	358·389	174·340	18·340	188·674	77·646	25·037	22·701
Feb. 1	6·087	28·578	145·760	269·393	23·929	1·917	172·699	18·361	190·695	76·005	25·172	26·290
Mar. 1	4·604	28·588	149·130	267·910	23·798	5·097	171·216	18·385	194·426	74·469	25·296	29·653
Apr. 1	2·963	28·596	152·858	266·269	23·652	8·608	169·575	18·415	197·453	72·828	25·427	33·253
May 1	1·374	28·600	156·468	264·680	23·510	11·999	167·986	18·450	200·387	71·239	25·552	36·744
June 1	359·732	28·602	160·199	263·038	23·364	15·493	166·344	18·491	203·425	69·597	25·680	40·356
July 1	358·144	28·599	163·809	261·450	23·223	18·866	164·756	18·534	206·368	68·009	25·802	43·859
Aug. 1	356·502	28·594	167·539	259·808	23·075	22·341	163·114	18·587	209·417	66·367	25·926	47·483
Sept. 1	354·861	28·584	171·268	258·167	22·929	25·807	161·473	18·643	212·473	64·726	26·047	51·113
Oct. 1	353·272	28·572	174·877	256·578	22·785	29·152	159·884	18·701	215·437	63·137	26·163	54·631
Nov. 1	351·630	28·557	178·607	254·936	22·638	32·599	158·242	18·772	218·508	61·495	26·280	58·272
Dec. 1	350·042	28·537	182·215	453·348	22·496	35·924	156·654	18·834	221·488	59·907	26·393	61·800
	1914			1919			1924			1929		
Jan. 1	348·400	28·514	185·944	251·706	22·350	39·350	155·011	18·908	224·575	58·264	26·505	65·450
Feb. 1	346·759	28·488	189·670	250·065	22·204	42·765	153·370	18·987	227·673	56·623	26·616	69·104
Mar. 1	345·276	28·461	193·036	248·582	22·072	45·841	151·834	19·065	230·580	55·140	26·714	72·409
Apr. 1	343·635	28·428	196·761	246·941	21·927	49·235	150·193	19·152	233·696	53·499	26·819	76·072
May 1	342·046	28·393	200·364	245·352	21·788	52·508	148·604	19·239	236·714	51·910	26·919	79·622
June 1	340·404	28·354	204·088	243·710	21·645	55·881	146·962	19·334	239·860	50·268	27·020	83·294
July 1	338·816	28·312	207·689	242·122	21·507	59·133	145·374	19·429	242·907	48·680	27·114	86·851
Aug. 1	337·174	28·265	211·408	240·480	21·366	62·482	143·732	19·531	246·067	47·038	27·210	90·529
Sept. 1	335·533	28·216	215·127	238·839	21·228	65·820	142·091	19·636	249·238	45·397	27·302	94·212
Oct. 1	333·944	28·164	218·723	237·250	21·094	69·038	140·502	19·742	252·318	43·808	27·388	97·779
Nov. 1	332·302	28·108	222·438	235·608	20·958	72·353	138·860	19·854	255·513	42·166	27·475	101·469
Dec. 1	330·714	28·051	226·031	234·020	20·828	75·548	137·272	19·965	258·616	40·578	27·556	105·042

TABLE 6.—*Values of N, I, and P for Greenwich midnight, beginning each month, from 1850 to 1949*—Continued.

Month.	*N*	*I*	*P*	*N*	*I*	*P*	*N*	*I*	*P*	*N*	*I*	*P*
		1930			1935			1940			1945	
	°	°	°	°	°	°	°	°	°	°	°	°
Jan. 1	38·936	27·637	108·738	302·242	26·539	327·333	205·548	18·935	168·280	108·801	22·305	353·506
Feb. 1	37·295	27·715	112·436	300·601	26·428	330·985	203·907	18·859	171·372	107·160	22·451	356·928
Mar. 1	35·812	27·783	115·780	299·118	26·324	334·280	202·371	18·793	174·256	105·677	22·583	0·029
Apr. 1	34·171	27·855	119·483	297·477	26·207	337·922	200·730	18·725	177·329	104·036	22·731	3·470
May 1	32·582	27·922	123·069	295·888	26·093	341·441	199·141	18·665	180·296	102·447	22·873	6·811
June 1	30·940	28·003	126·778	294·246	25·971	345·074	197·499	18·607	183·355	100·805	23·020	10·275
July 1	29·352	28·048	130·368	292·658	25·853	348·584	195·911	18·556	186·308	99·217	23·162	13·634
Aug. 1	27·710	28·107	134·081	291·016	25·727	352·204	194·269	18·509	189·352	97·575	23·309	17·115
Sept. 1	26·069	28·164	137·796	289·375	25·600	355·820	192·628	18·465	192·392	95·934	23·456	20·606
Oct. 1	24·480	28·216	141·392	287·786	25·476	359·313	191·039	18·429	195·327	94·345	23·598	23·993
Nov. 1	22·838	28·265	145·111	286·144	25·346	2·916	189·397	18·396	198·356	92·703	23·743	27·502
Dec. 1	21·250	28·310	148·710	284·556	25·217	6·396	187·809	18·369	201·284	91·115	23·884	30·905
		1931			1936			1941			1946	
Jan. 1	19·608	28·353	152·432	282·914	25·083	9·987	186·167	18·346	204·306	89·473	24·028	34·431
Feb. 1	17·967	28·393	156·154	281·273	24·947	13·570	184·526	18·328	207·324	87·832	24·171	37·965
Mar. 1	16·484	28·425	159·519	279.737	24·819	16·916	183·043	18·317	210·050	86·349	24·300	41·164
Apr. 1	14·843	28·459	163·243	278·096	24·681	20·486	181·402	18·311	213·066	84·708	24·442	44·714
May 1	13·254	28·487	166·849	276·507	24·546	23·934	179·813	18·308	215·983	83·119	24·578	48·155
June 1	11·612	28·514	170·576	274·865	24·405	27·489	178·171	18·312	218·998	81·477	24·717	51·721
July 1	10·024	28·537	174·184	273·277	24·268	30·922	176·583	18·320	221·917	79·889	24·850	55·177
Aug. 1	8·382	28·556	177·912	271·635	24·125	34·462	174·941	18·333	224·934	78·247	24·987	58·755
Sept. 1	6·741	28·572	181·642	269·994	23·981	37·992	173·300	18·353	227·955	76·606	25·122	62·340
Oct. 1	5·152	28·584	185·250	268·405	23·842	41·402	171·711	18·377	230·879	75·017	25·252	65·817
Nov. 1	3·510	28·594	188·980	266·763	23·696	44·917	170·069	18·406	233·906	73·375	25·384	68·416
Dec. 1	1·922	28·599	192·674	265·175	23·555	48·310	168·481	18·440	236·839	71·787	25·511	72·904
		1932			1937			1942			1947	
Jan. 1	0·280	28·602	196·319	263·533	23·409	51·807	166·839	18·479	239·873	70·145	25·638	76·515
Feb. 1	358·639	28·600	200·050	261·892	23·261	55·294	165·198	18·523	242·914	68·504	25·765	80·132
Mar. 1	357·103	28·596	203·539	260·409	23·130	58·437	163·715	18·568	245·666	67·021	25·876	83·404
Apr. 1	355·462	28·589	207·268	258·768	22·983	61·906	162·074	18·621	248·719	65·380	25·999	87·031
May 1	353·873	28·577	210·877	257·179	22·839	65·254	160·485	18·679	251·680	63·791	26·117	90·547
June 1	352·231	28·562	214·607	255·537	22·692	68·704	158·843	18·742	254·749	62·149	26·234	94·186
July 1	350·643	28·545	218·216	253·949	22·550	72·033	157·255	18·808	257·725	60·561	26·347	97·712
Aug. 1	349·001	28·523	221·943	252·307	22·403	75·463	155·613	18·881	260·809	58·919	26.461	101·360
Sept. 1	347·360	28·498	225·671	250·666	22·257	78·882	153·972	18·958	263·904	57·278	26·570	105·013
Oct. 1	345·771	28·470	229·277	249·077	22·116	82·180	152·383	19·036	266·907	55·689	26·678	108·552
Nov. 1	344·129	28·439	233·003	247·435	21·970	85·579	150·741	19·122	270·021	54·047	26·784	112·215
Dec. 1	342·541	28·404	236·607	245·847	21·832	88·855	149·153	19·208	273·043	52·459	26·885	115·762
		1933			1938			1943			1948	
Jan. 1	340·899	28·366	240·330	244·205	21·688	92·231	147·510	19·302	276·178	50·816	26·986	119·433
Feb. 1	339·258	28·324	244·052	242·564	21·546	95·594	145·869	19·399	279·322	49·175	27·085	123·107
Mar. 1	337·775	28·283	247·412	241·081	21·418	98·623	144·386	19·490	282·173	47·639	27·175	126·548
Apr. 1	336·134	28·234	251·131	239·440	21·278	101·965	142·745	19·594	285·339	45·998	27·268	130·228
May 1	334·545	28·184	254·728	237·851	21·144	105·187	141·156	19·698	288·415	44·409	27·356	133·795
June 1	332·903	28·129	258·444	236·209	21·008	108·506	139·514	19·808	291·605	42·767	27·444	137·494
July 1	331·315	28·072	262·037	234·621	20·877	111·705	137·926	19·920	294·703	41·179	27·526	141·055
Aug. 1	329·673	28·012	265·748	232·979	20·744	115·000	136·284	20·036	297·916	39·537	27·608	144·750
Sept. 1	328·032	27·946	269·458	231·338	20·613	118·283	134·643	20·155	301·141	37·896	27·687	148·447
Oct. 1	326·443	27·881	273·045	229·749	20·488	121·447	133·054	20·274	304·275	36·307	27·761	152·028
Nov. 1	324·801	27·810	276·750	228·107	20·361	124·706	131·412	20·399	307·524	34·665	27·834	155·731
Dec. 1	323·213	27·739	280·333	226·519	20·241	127·847	129·824	20·522	310·681	33·077	27·901	159·316
		1934			1939			1944			1949	
Jan. 1	321·570	27·661	284·032	224·876	20·120	131·082	128·182	20·651	313·946	31·435	27·968	163·025
Feb. 1	319·929	27·581	287·728	223·235	20·001	134·303	126·541	20·783	317·241	29·794	28·032	166·737
Mar. 1	318·446	27·507	291·065	221·752	19·896	137·203	125·005	20·908	320·325	28·311	28·086	170·088
Apr. 1	316·805	27·421	294·755	220·111	19·783	140·402	123·364	21·043	323·634	26·670	28·143	173·801
May 1	315·216	27·336	298·323	218·522	19·676	143·487	121·775	21·176	326·849	25·081	28·196	177·397
June 1	313·574	27·244	302·007	216·880	19·569	146·662	120·133	21·315	330·182	23·439	28·247	181·115
July 1	311·986	27·153	305·570	215·292	19·470	149·725	118·545	21·450	333·419	21·851	28·293	184·714
Aug. 1	310·344	27·057	309·246	213·650	19·370	152·877	116·903	21·592	336·775	20·209	28·338	188·433
Sept. 1	308·703	26·957	312·919	212·009	19·274	156·019	115·262	21·734	340·143	18·568	28·378	192·157
Oct. 1	307·114	26·858	316·470	210·420	19·185	159·049	113·673	21·873	343·413	16·979	28·414	195·760
Nov. 1	305·472	26·753	320·136	208·778	19·095	162·179	112·031	22·018	346·803	15·337	28·449	199·486
Dec. 1	303·884	26·649	323·678	207·190	19·015	165·180	110·443	22·158	350·094	13·749	28·479	203·091

TABLE 7.—*Values of I, ν, ξ, ν′, and 2 ν″, corresponding to each half degree of N.*

N	I	ν	ξ	ν′	2 ν″	N	N	I	ν	ξ	ν′	2 ν″	N
°	°	°	°	°	°	°	°	°	°	°	°	°	°
0·0	28·602	0·000	0·000	0·000	0·000	360·0	30·0	28·024	5·478	4·939	3·903	8·249	330·0
0·5	28·602	0·094	0·084	0·067	0·143	359·5	30·5	28·005	5·564	5·017	3·964	8·377	329·5
1·0	28·601	0·188	0·169	0·134	0·285	359·0	31·0	27·985	5·651	5·095	4·025	8·504	329·0
1·5	28·600	0·281	0·253	0·201	0·427	358·5	31·5	27·965	5·736	5·173	4·085	8·631	328·5
2·0	28·599	0·375	0·337	0·268	0·569	358·0	32·0	27·945	5·822	5·251	4·146	8·757	328·0
2·5	28·598	0·468	0·421	0·335	0·711	357·5	32·5	27·925	5·907	5·328	4·206	8·883	327·5
3·0	28·596	0·562	0·506	0·402	0·853	357·0	33·0	27·904	5·992	5·406	4·266	9·008	327·0
3·5	28·594	0·656	0·590	0·469	0·995	356·5	33·5	27·884	6·077	5·482	4·326	9·133	326·5
4·0	28·591	0·749	0·674	0·536	1·137	356·0	34·0	27·862	6·162	5·559	4.386	9·257	326·0
4·5	28·589	0·843	0·758	0·603	1·279	355·5	34.5	27·841	6·246	5·636	4·445	9·381	325·5
5·0	28·585	0·936	0·842	0·670	1·421	355·0	35·0	27·819	6·330	5·712	4·504	9·504	325·0
5·5	28·582	1·030	0·926	0·737	1·563	354·5	35·5	27·797	6·414	5·788	4·563	9·626	324·5
6·0	28·578	1·123	1·010	0·804	1·705	354·0	36·0	27·775	6·497	5·864	4·621	9·748	324·0
6·5	28·574	1·217	1·094	0·871	1·847	353·5	36·5	27·752	6·580	5·939	4·679	9·869	323·5
7·0	28·570	1·310	1·178	0·938	1·989	353·0	37·0	27·729	6·663	6·015	4·737	9·989	323·0
7·5	28·565	1·403	1·262	1·004	2·130	352·5	37·5	27·706	6·745	6·090	4·797	10·109	322·5
8·0	28·560	1·496	1·346	1·070	2·271	352·0	38·0	27·682	6·828	6·164	4·855	10·228	322·0
8·5	28·555	1·590	1·430	1·137	2·413	351·5	38·5	27·658	6·909	6·239	4·912	10·347	321·5
9·0	28·549	1·683	1·514	1·203	2·554	351·0	39·0	27·634	6·991	6·313	4·969	10·465	321·0
9·5	28·543	1·776	1·598	1·270	2·695	350·5	39·5	27·610	7·072	6·387	5·026	10·583	320·5
10·0	28·537	1·869	1·681	1·337	2·836	350·0	40·0	27·585	7·153	6·461	5·083	10·700	320·0
10·5	28·530	1·962	1·765	1·403	2·977	349·5	40·5	27·560	7·234	6·534	5·139	10·816	319·5
11·0	28·523	2·054	1·848	1·469	3·117	349·0	41·0	27·535	7·314	6·608	5·195	10·932	319·0
11·5	28·516	2·147	1·932	1·535	3·257	348·5	41·5	27·510	7·394	6·680	5·251	11·047	318·5
12·0	28·508	2·240	2·015	1·601	3·397	348·0	42·0	27·484	7·473	6·753	5·307	11·161	318·0
12·5	28·500	2·332	2·099	1·667	3·536	347·5	42·5	27·458	7·553	6·825	5·362	11·275	317·5
13·0	28·492	2·424	2·182	1·733	3·676	347·0	43·0	27·432	7·631	6·897	5·416	11·388	317·0
13·5	28·483	2·517	2·265	1·799	3·816	346·5	43·5	27·405	7·710	6·969	5·471	11·500	316·5
14·0	28·475	2·609	2·348	1·864	3·955	346·0	44·0	27·378	7·788	7·040	5·526	11·612	316·0
14·5	28·465	2·701	2·431	1·930	4·094	345·5	44·5	27·351	7·866	7·111	5·580	11·723	315·5
15·0	28·456	2·793	2·514	1·996	4·233	345·0	45·0	27·324	7·943	7·182	5·634	11·833	315·0
15·5	28·446	2·885	2·596	2·061	4·372	344·5	45·5	27·296	8·020	7·253	5·687	11·942	314·5
16·0	28·436	2·977	2·679	2·127	4·510	334·0	46·0	27·268	8·097	7·323	5·740	12·051	314·0
16·5	28·425	3·068	2·762	2·192	4·648	343·5	46·5	27·240	8·173	7·392	5·793	12·159	313·5
17·0	28·414	3·160	2·844	2·257	4·786	343·0	47·0	27·212	8·249	7·462	5·846	12·266	313·0
17·5	28·403	3·251	2·927	2·322	4·923	342·5	47·5	27·183	8·324	7·531	5·898	12·372	312·5
18·0	28·392	3·342	3·009	2·387	5·060	342·0	48·0	27·154	8·399	7·600	5·950	12·477	312·0
18 5	28·380	3·433	3·091	2·452	5·197	341·5	48·5	27·125	8·474	7·668	6·002	12·582	311·5
19·0	28·368	3·524	3·173	2·517	5·334	341·0	49·0	27·095	8·548	7·736	6·053	12·686	311·0
19·5	28·356	3·615	3·255	2·581	5·471	340·5	49·5	27·066	8·622	7·804	6·104	12·789	310·5
20·0	28·343	3·705	3·337	2·646	5·607	340·0	50·0	27·036	8·695	7·871	6·154	12·892	310·0
20·5	28·330	3·796	3·418	2·710	5·743	339·5	50·5	27·006	8·768	7·938	6·205	12·994	309·5
21·0	28·317	3·886	3·500	2·774	5·878	339·0	51·0	26·975	8·841	8·005	6·255	13·095	309·0
21·5	28·303	3·976	3·581	2·838	6·013	338·5	51·5	26·944	8·913	8·071	6·305	13·195	308·5
22·0	28·289	4·066	3·662	2·902	6·148	338·0	52·0	26·913	8·985	8·137	6·354	13·294	308·0
22·5	28·275	4·156	3·743	2·966	6·282	337·5	52·5	26·882	9·056	8·203	6·403	13·392	307·5
23·0	28·260	4·245	3·824	3·030	6·416	337·0	53·0	26·851	9·127	8·268	6·452	13·489	307·0
23·5	28·245	4·335	3·905	3·093	6·550	336·5	53·5	26·819	9·197	8·333	6·500	13·586	306·5
24·0	28·230	4·424	3·985	3·156	6·683	336·0	54·0	26·787	9·267	8·397	6·547	13·682	306·0
24·5	28·215	4·513	4·066	3·219	6·816	335·5	54·5	26·755	9·336	8·461	6·594	13·777	305·5
25·0	28·199	4·602	4·146	3·282	6·948	335·0	55·0	26·723	9·405	8·525	6·641	13·871	305·0
25·5	28·183	4·690	4·226	3·345	7·080	334·5	55·5	26·690	9·474	8·588	6·688	13·964	304·5
26·0	28·166	4·779	4·306	3·408	7·212	334·0	56·0	26·657	9·542	8·651	6·735	14·057	304·0
26·5	28·149	4·867	4·386	3·471	7·343	333·5	56·5	26·624	9·609	8·713	6·781	14·148	303·5
27·0	28·132	4·955	4·466	3·534	7·474	333·0	57·0	26·591	9·676	8·775	6·827	14·238	303·0
27·5	28·115	5·043	4·545	3·596	7·604	332·5	57·5	26·557	9·743	8·836	6·872	14·327	302·5
28·0	28·097	5·130	4·624	3·658	7.734	332·0	58·0	26·523	9·809	8·897	6·917	14·415	302·0
28·5	28·079	5·218	4·703	3·720	7·863	331·5	58·5	26·489	9·874	8·958	6·961	14·502	301·5
29·0	28·061	5·305	4·782	3·781	7·992	331·0	59·0	26·455	9·939	9·018	7·005	14·588	301·0
29·5	28·043	5·391	4·861	3·842	8·121	330·5	59·5	26·421	10·004	9·078	7·048	14·673	300·5
30·0	28·024	5·478	4·939	3·903	8·249	330·0	60·0	26·386	10·068	9·137	7·091	14·757	300·0

See Tables 1 and 5 for explanation of symbols. I is always positive; ν, ξ, ν', and $2\nu''$ are positive when N is between 0° and 180°, and negative when N is between 180° and 360°. N is the longitude of the moon's ascending node.

$u(J_1) = -\nu$; $u(K_1) = -\nu'$; $u(K_2) = -2\nu''$; $u(L_2) = 2\xi - 2\nu - R$; see Table 8 for R; $u(M_1) = \xi - \nu + Q$; see Table 9 for Q; $u(M_2) = 2\xi - 2\nu$; $u(M_3) = 3\xi - 3\nu$; $u(M_4) = 4\xi - 4\nu$; $u(M_6) = 6\xi - 6\nu$; $u(M_8) = 8\xi - 8\nu$; $u(N_2) = 2\xi - 2\nu = u(M_2)$; $u(2N) = 2\xi - 2\nu = u(M_2)$; $u(O_1) = 2\xi - \nu$; $u(OO) = -2\xi - \nu$; $u(P_1) = 0$; $u(Q_1) = 2\xi - \nu = u(O_1)$; $u(R_2) = 0$; $u(S_{1,2,3,4}) = 0$; $u(T_2) = 0$; $u(\lambda_2) = u(\mu_2) = u(\nu_2) = 2\xi - 2\nu = u(M_2)$; $u(MK) = 2\xi - 2\nu - \nu' = u(M_2) + u(K_1)$; $u(2MK) = 4\xi - 4\nu + \nu' = u(M_4) - u(K_1)$; $u(MN) = 4\xi - 4\nu = u(M_4)$; $u(MS) = 2\xi - 2\nu = u(M_2)$; $u(2MS) = 4\xi - 4\nu = u(M_4)$; $u(2SM) = -2\xi + 2\nu = -u(M_2)$; $u(Mf) = -2\xi$; $u(MSf) = -2\xi + 2\nu = -u(M_2)$; $u(Mm) = 0$; $u(Sa) = 0$; $u(Ssa) = 0$.

TABLE 7.—*Values of I, ν, ξ, ν', and 2 ν'', corresponding to each half degree of N*—Continued.

N	I	ν	ξ	ν'	$2\nu''$	N	N	I	ν	ξ	ν'	$2\nu''$	N
°	°	°	°	°	°	°	°	°	°	°	°	°	°
60·0	26·386	10·068	9·137	7·091	14·757	300·0	90·0	23·982	12·751	11·681	8·797	17·783	270·0
60·5	26·351	10·131	9·196	7·134	14·841	299·5	90·5	23·938	12·772	11·704	8·808	17·795	269·5
61·0	26·316	10·194	9·255	7·177	14·924	299·0	91·0	23·894	12·793	11·725	8·819	17·805	269·0
61·5	26·280	10·256	9·313	7·219	15·006	298·5	91·5	23·850	12·814	11·745	8·829	17·814	268·5
62·0	26·245	10·318	9·370	7·261	15·087	298·0	92·0	23·806	12·833	11·765	8·839	17·822	268·0
62·5	26·209	10·379	9·427	7·302	15·167	297·5	92·5	23·761	12·851	11·784	8·848	17·829	267·5
63·0	26·173	10·440	9·484	7·343	15·246	297·0	93·0	23·717	12·869	11·802	8·856	17·834	267·0
63·5	26·137	10·500	9·539	7·383	15·324	296·5	93·5	23·673	12·886	11·819	8·863	17·837	266.5
64·0	26·101	10·560	9·595	7·423	15·401	296·0	94·0	23·628	12·901	11·835	8·870	17·839	266·0
64·5	26·064	10·619	9·650	7·462	15·477	295·5	94·5	23·584	12·916	11·851	8·876	17·840	265·5
65·0	26·027	10·677	9·705	7·501	15·551	295·0	95·0	23·539	12·930	11·866	8·882	17·840	265·0
65·5	25·990	10·735	9·759	7·539	15·624	294·5	95·5	23·495	12·943	11·880	8·887	17·838	264·5
66·0	25·953	10·793	9·812	7·577	15·696	294·0	96·0	23·450	12·955	11·893	8·891	17·835	264·0
66·5	25·916	10·849	9·865	7·614	15·767	293·5	96·5	23·406	12·966	11·905	8·895	17·830	263·5
67·0	25·878	10·906	9·918	7·651	15·837	293·0	97·0	23·361	12·976	11·916	8·898	17·824	263·0
67·5	25·841	10·961	9·970	7·688	15·906	292·5	97·5	23·316	12·985	11·927	8·900	17·816	262·5
68·0	25·803	11·016	10·021	7·724	15·974	292·0	98·0	23·271	12·994	11·936	8·902	17·807	262·0
68·5	25·765	11·070	10·072	7·760	16·042	291·5	98·5	23·227	13·001	11·945	8·903	17·796	261·5
69·0	25·726	11·124	10·123	7·795	16·109	291·0	99·0	23·182	13·007	11·953	8·903	17·784	261·0
69·5	25·688	11·177	10·173	7·830	16·174	290·5	99·5	23·137	13·013	11·960	8·902	17·770	260·5
70·0	25·649	11·230	10·222	7·864	16·238	290·0	100·0	23·092	13·017	11·966	8·901	17·755	260·0
70·5	25·610	11·282	10·271	7·898	16·300	289·5	100·5	23·047	13·021	11·971	8·899	17·739	259·5
71·0	25·571	11·333	10·319	7·932	16·361	289·0	101·0	23·003	13·023	11·975	8·896	17·721	259·0
71·5	25·532	11·383	10·366	7·965	16·421	288·5	101·5	22·958	13·024	11·979	8·892	17·702	258·5
72·0	25·493	11.433	10·414	7·997	16·480	288·0	102·0	22·913	13·025	11·981	8·888	17·681	258·0
72·5	25·453	11·482	10·460	8·029	16·538	287·5	102·5	22·868	13·024	11·983	8·883	17·659	257·5
73·0	25·413	11·531	10·506	8·061	16·594	287·0	103·0	22·823	13·023	11·983	8·878	17·636	257·0
73·5	25·374	11·579	10·551	8·092	16·649	286·5	103·5	22·778	13·020	11·983	8·872	17·611	256·5
74·0	25·334	11·626	10·596	8·122	16·703	286·0	104·0	22·734	13·017	11·982	8·865	17·584	256·0
74·5	25·293	11·673	10·640	8·152	16·756	285·5	104·5	22·689	13·012	11·979	8·858	17·556	255·5
75·0	25·253	11·719	10·684	8·181	16·808	285·0	105·0	22·644	13·006	11·976	8·850	17·526	255·0
75·5	25·213	11·764	10·726	8·209	16·859	284·5	105·5	22·599	13·000	11·972	8·841	17·495	254·5
76·0	25·172	11·809	10·769	8·237	16·909	284·0	106·0	22·554	12·992	11·967	8·831	17·463	254·0
76·5	25·131	11·852	10·811	8·264	16·958	283·5	106·5	22·510	12·983	11·961	8·821	17·430	253·5
77·0	25·090	11·895	10·852	8·291	17·005	283·0	107·0	22·465	12·974	11·954	8·810	17·395	253·0
77·5	25·049	11·938	10·892	8·318	17·051	282·5	107·5	22·420	12·963	11·946	8·799	17·358	252·5
78·0	25·008	11·980	10·932	8·344	17·096	282·0	108·0	22·376	12·951	11·937	8·787	17·320	252·0
78·5	24·966	12·021	10·971	8·370	17·140	281·5	108·5	22·331	12·938	11·927	8·774	17·281	251·5
79·0	24·925	12·061	11·009	8·395	17·183	281·0	109·0	22·287	12·924	11·916	8·760	17·240	251·0
79·5	24·883	12·100	11·047	8·420	17·225	280·5	109·5	22·242	12·909	11·904	8·745	17·197	250·5
80·0	24·841	12·139	11·084	8·444	17·265	280·0	110·0	22·198	12·892	11·891	8·729	17·153	250·0
80·5	24·800	12·177	11·121	8·467	17·303	279·5	110·5	22·153	12·875	11·877	8·713	17·107	249·5
81·0	24·757	12·214	11·157	8·490	17·340	279·0	111·0	22·109	12·857	11·862	8·696	17·060	249·0
81·5	24·715	12·251	11·192	8·512	17·376	278·5	111·5	22·065	12·837	11·846	8·678	17·011	248·5
82·0	24·673	12·287	11·227	8·533	17·410	278·0	112·0	22·021	12·817	11·829	8·659	16·961	248·0
82·5	24·631	12·322	11·261	8·554	17·443	277·5	112·5	21·976	12·795	11·811	8·639	16·910	247·5
83·0	24·588	12·356	11·294	8·574	17·475	277·0	113·0	21·932	12·772	11·792	8·619	16·858	247·0
83·5	24·545	12·389	11·326	8·594	17·505	276·5	113·5	21·888	12·748	11·772	8·599	16·805	246·5
84·0	24·503	12·422	11·358	8·613	17·534	276·0	114·0	21·845	12·723	11·750	8·578	16·750	246·0
84·5	24·460	12·454	11·389	8·631	17·562	275·5	114·5	21·801	12·697	11·728	8·556	16·693	245·5
85·0	24·417	12·485	11·419	8·649	17·589	275·0	115·0	21·757	12·670	11·705	8·533	16·635	245·0
85·5	24·374	12·515	11·449	8·666	17·614	274·5	115·5	21·713	12·642	11·681	8·509	16·576	244·5
86·0	24·331	12·545	11·478	8·683	17·638	274·0	116·0	21·670	12·612	11·655	8·484	16·515	244·0
86·5	24·287	12·573	11·506	8·700	17·661	273·5	116·5	21·627	12·581	11·629	8·458	16·453	243·5
87·0	24·244	12·601	11·533	8·716	17·683	273·0	117·0	21·583	12·550	11·601	8·432	16.389	243·0
87·5	24·200	12·628	11·560	8·731	17·703	272·5	117·5	21·540	12·517	11·572	8·405	16·323	242·5
88·0	24·157	12·654	11·586	8·745	17·722	272·0	118·0	21·497	12·483	11·543	8·378	16·256	242·0
88·5	24·113	12·680	11·611	8·759	17·739	271·5	118·5	21·454	12·447	11·512	8·350	16·188	241·5
89·0	24·070	12·704	11·635	8·772	17·755	271·0	119·0	21·411	12·411	11·480	8·321	16·118	241·0
89·5	24·026	12·728	11·659	8·785	17·770	270·5	119·5	21·368	12·373	11·447	8·291	16·047	240·5
90·0	23·982	12·751	11·681	8·797	17·783	270·0	120·0	21·326	12·335	11·413	8·260	15·975	240·0

TABLE 7.—*Values of I, ν, ξ, ν', and 2ν'', corresponding to each half degree of N*—Continued.

N	I	ν	ξ	ν'	2ν''	N	N	I	ν	ξ	ν'	2ν''	N
°	°	°	°	°	°	°	°	°	°	°	°	°	°
120·0	21·326	12·335	11·413	8·260	15·975	240·0	150·0	19·162	7·854	7·324	5·096	9·392	210·0
120·5	21·283	12·295	11·378	8·229	15·902	239·5	150·5	19·135	7·745	7·223	5·024	9·251	209·5
121·0	21·241	12·254	11·342	8·197	15·827	239·0	151·0	19·108	7·635	7·120	4·951	9·109	209·0
121·5	21·199	12·211	11·304	8·165	15·751	238·5	151·5	19·082	7·523	7·017	4·878	8·966	208·5
122·0	21·157	12·168	11·266	8·132	15·673	238·0	152·0	19·056	7·411	6·913	4·805	8·823	208·0
122·5	21·115	12·123	11·226	8·098	15·594	237·5	152·5	19·030	7·298	6·809	4·730	8·679	207·5
123·0	21·073	12·078	11·186	8·063	15·513	237·0	153·0	19·005	7·184	6·703	4·655	8·534	207·0
123·5	21·032	12·031	11·144	8·028	15·431	236·5	153·5	18·981	7·069	6·596	4·579	8·389	206·5
124·0	20·990	11·983	11·101	7·992	15·347	236·0	154·0	18·956	6·953	6·488	4·502	8·243	206·0
124·5	20·949	11·933	11·057	7·955	15·262	235·5	154·5	18·933	6·836	6·380	4·424	8·096	205·5
125·0	20·908	11·883	11·012	7·917	15·176	235·0	155·0	18·909	6·718	6·270	4·346	7·948	205·0
125·5	20·867	11·831	10·965	7·878	15·089	234·5	155·5	18·886	6·599	6·160	4·268	7·800	204·5
126·0	20·826	11·778	10·918	7·839	15·001	234·0	156·0	18·863	6·480	6·049	4·189	7·651	204·0
126·5	20·786	11·724	10·869	7·799	14·911	233·5	156·5	18·841	6·359	5·937	4·110	7·502	203·5
127·0	20·746	11·669	10·820	7·758	14·820	233·0	157·0	18·819	6·238	5·824	4·030	7·352	203·0
127·5	20·705	11·612	10·769	7·716	14·728	232·5	157·5	18·798	6·116	5·710	3·950	7·201	202·5
128·0	20·666	11·555	10·717	7·674	14·635	232·0	158·0	18·777	5·993	5·596	3·869	7·050	202·0
128·5	20·626	11·496	10·664	7·631	14·540	231·5	158·5	18·756	5·869	5·480	3·787	6·898	201·5
129·0	20·586	11·436	10·610	7·587	14·444	231·0	159·0	18·736	5·744	5·364	3·705	6·745	201·0
129·5	20·547	11·374	10·554	7·542	14·347	230·5	159·5	18·716	5·618	5·247	3·623	6·592	200·5
130·0	20·508	11·312	10·498	7·496	14·248	230·0	160·0	18·697	5·492	5·130	3·541	6·438	200·0
130·5	20·469	11·248	10·440	7·449	14·148	229·5	160·5	18·678	5·365	5·011	3·458	6·284	199·5
131·0	20·430	11·184	10·382	7·401	14·048	229·0	161·0	18·660	5·237	4·892	3·375	6·130	199·0
131·5	20·392	11·118	10·322	7·353	13·946	228·5	161·5	18·642	5·109	4·773	3·291	5·975	198·5
132·0	20·353	11·050	10·261	7·304	13·842	228·0	162·0	18·624	4·980	4·652	3·207	5·819	198·0
132·5	20·315	10·982	10·199	7·255	13·737	227·5	162·5	18·607	4·850	4·531	3·122	5·663	197·5
133·0	20·278	10·912	10·135	7·205	13·631	227·0	163·0	18·591	4·719	4·409	3·037	5·506	197·0
133·5	20·240	10·841	10·071	7·154	13·524	226·5	163·5	18·575	4·588	4·287	2·952	5·349	196·5
134·0	20·203	10·769	10·005	7·102	13·416	226·0	164·0	18·559	4·456	4·164	2·866	5·192	196·0
134·5	20·166	10·696	9·939	7·050	13·306	225·5	164·5	18·544	4·323	4·040	2·780	5·034	195·5
135·0	20·129	10·622	9·871	6·998	13·195	225·0	165·0	18·529	4·190	3·916	2·694	4·875	195·0
135·5	20·092	10·546	9·802	6·945	13·083	224·5	165·5	18·515	4·056	3·791	2·607	4·716	194·5
136·0	20·056	10·469	9·732	6·891	12·970	224·0	166·0	18·501	3·922	3·665	2·520	4·557	194·0
136·5	20·020	10·391	9·660	6·837	12·856	223·5	166·5	18·487	3·787	3·539	2·433	4·397	193·5
137·0	19·984	10·312	9·588	6·782	12·741	223·0	167·0	18·475	3·651	3·413	2·345	4·238	193·0
137·5	19·949	10·232	9·515	6·727	12·624	222·5	167·5	18·462	3·515	3·286	2·257	4·078	192·5
138·0	19·913	10·150	9·440	6·671	12·506	222·0	168·0	18·450	3·379	3·158	2·169	3·918	192·0
138·5	19·878	10·068	9·364	6·614	12·387	221·5	168·5	18·439	3·242	3·030	2·081	3·757	191·5
139·0	19·844	9·984	9·287	6·556	12·268	221·0	169·0	18·428	3·104	2·902	1·992	3·596	191·0
139·5	19·809	9·899	9·209	6·498	12·148	220·5	169·5	18·417	2·966	2·773	1·903	3·435	190·5
140·0	19·775	9·813	9·130	6·439	12·027	220·0	170·0	18·407	2·828	2·644	1·814	3·273	190·0
140·5	19·742	9·725	9·050	6·379	11·904	219·5	170·5	18·398	2·689	2·514	1·725	3·110	189·5
141·0	19·708	9·637	8·969	6·318	11·780	219·0	171·0	18·388	2·550	2·384	1·635	2·948	189·0
141·5	19·675	9·547	8·887	6·256	11·655	218·5	171·5	18·380	2·410	2·254	1·546	2·786	188·5
142·0	19·642	9·457	8·803	6·193	11·529	218·0	172·0	18·372	2·270	2·123	1·456	2·623	188·0
142·5	19·610	9·365	8·719	6·129	11·402	217·5	172·5	18·364	2·130	1·992	1·365	2·460	187·5
143·0	19·577	9·272	8·633	6·064	11·274	217·0	173·0	18·357	1·989	1·860	1·275	2·297	187·0
143·5	19·545	9·177	8·546	5·999	11·145	216·5	173·5	18·350	1·848	1·729	1·185	2·133	186·5
144·0	19·514	9·082	8·458	5·933	11·016	216·0	174·0	18·344	1·707	1·597	1·094	1·970	186·0
144·5	19·483	8·986	8·370	5·866	10·886	215·5	174·5	18·338	1·566	1·464	1·003	1·806	185·5
145·0	19·452	8·888	8·280	5·798	10·755	215·0	175·0	18·333	1·424	1·332	0·912	1·642	185·0
145·5	19·421	8·790	8·189	5·730	10·623	214·5	175·5	18·328	1·282	1·199	0·821	1·478	184·5
146·0	19·391	8·690	8·097	5·661	10·490	214·0	176·0	18·324	1·140	1·067	0·730	1·314	184·0
146·5	19·361	8·589	8·004	5·592	10·356	213·5	176·5	18·320	0·998	0·934	0·639	1·150	183·5
147·0	19·332	8·487	7·910	5·522	10·221	213·0	177·0	18·317	0·856	0·801	0·548	0·986	183·0
147·5	19·302	8·384	7·814	5·452	10·084	212·5	177·5	18·315	0·713	0·667	0·457	0·822	182·5
148·0	19·273	8·280	7·718	5·382	9·947	212·0	178·0	18·312	0·571	0·534	0·366	0·658	182·0
148·5	19·245	8·175	7·621	5·311	9·809	211·5	178·5	18·311	0·428	0·401	0·274	0·493	181·5
149·0	19·217	8·069	7·523	5·240	9·671	211·0	179·0	18·309	0·286	0·267	0·183	0·329	181·0
149·5	19·189	7·962	7·424	5·168	9·532	210·5	179·5	18·309	0·143	0·133	0·091	0·165	180·5
150·0	19·162	7·854	7·324	5·096	9·392	210·0	180·0	18·308	0·000	0·000	0·000	0·000	180·0

TABLE 8.—*Values of R for completing u for* L_2.

P	I = Inclination of moon's orbit.											
	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°
°	°	°	°	°	°	°	°	°	°	°	°	°
0	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
5	1·76	2·00	2·27	2·57	2·90	3·27	3·67	4·14	4·65	5·22	5·88	6·57
10	3·43	3·90	4·42	5·00	5·63	6·32	7·09	7·94	8·89	9·94	11·12	12·43
15	4·94	5·61	6·39	7·15	8·03	8·99	10·04	11·20	12·47	13·86	15·40	17·10
20	6·24	7·06	7·97	8·94	10·00	11·16	12·40	13·76	15·23	16·82	18·56	20·43
25	7·28	8·21	9·22	10·32	11·49	12·76	14·12	15·57	17·14	18·81	20·60	22·50
30	8·02	9·02	10·10	11·26	12·48	13·80	15·19	16·68	18·25	19·90	21·66	23·50
35	8·48	9·51	10·60	11·77	13·00	14·31	15·68	17·13	18·64	20·23	21·89	23·61
40	8·66	9·69	10·75	11·89	13·08	14·34	15·65	17·02	18·44	19·92	21·44	23·02
45	8·56	9·54	10·57	11·64	12·77	13·95	15·17	16·43	17·73	19·08	20·46	21·87
50	8·22	9·13	10·11	11·09	12·12	13·20	14·30	15·44	16·61	17·81	19·03	20·28
55	7·66	8·49	9·36	10·26	11·18	12·14	13·12	14·13	15·16	16·20	17·27	18·34
60	6·91	7·64	8·40	9·19	10·00	10·83	11·68	12·55	13·43	14·32	15·23	16·14
65	6·00	6·62	7·27	7·94	8·62	9·32	10·03	10·75	11·49	12·23	12·98	13·73
70	4·96	5·46	5·99	6·53	7·08	7·64	8·21	8·79	9·38	9·97	10·56	11·16
75	3·80	4·19	4·59	5·00	5·36	5·84	6·26	6·70	7·14	7·58	8·02	8·47
80	2·58	2·84	3·11	3·38	3·66	3·94	4·23	4·52	4·81	5·10	5·40	5·69
85	1·30	1·43	1·57	1·70	1·84	1·98	2·13	2·27	2·42	2·56	2·71	2·86
90	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00	0·00
95	358·24	358·00	357·73	357·43	357·10	356·73	356·33	355·86	355·35	354·78	354·12	353·43
100	356·57	356·10	355·58	355·00	354·37	353·68	352·91	352·06	351·11	350·06	348·88	347·57
105	355·06	354·39	353·61	352·85	351·97	351·01	349·96	348·80	347·53	346·14	344·60	342·90
110	353·76	352·94	352·03	351·06	350·00	348·84	347·60	346·24	344·77	343·18	341·44	339·57
115	352·72	351·79	350·78	349·68	348·51	347·24	345·88	344·43	342·86	341·19	339·40	337·50
120	351·98	350·98	349·90	348·74	347·52	346·20	344·81	343·32	341·75	340·10	338·34	336·50
125	351·52	350·49	349·40	348·23	347·00	345·69	344·32	342·87	341·36	339·77	338·11	336·39
130	351·34	350·31	349·25	348·11	346·92	345·66	344·35	342·98	341·56	340·08	338·56	336·98
135	351·44	350·46	349·43	348·36	347·23	346·05	344·83	343·57	342·27	340·92	339·54	338·13
140	351·78	350·87	349·89	348·91	347·88	346·80	345·70	344·56	343·39	342·19	340·97	339·72
145	352·34	351·51	350·64	349·74	348·82	347·86	346·88	345·87	344·84	343·80	342·73	341·66
150	353·09	352·36	351·60	350·81	350·00	349·17	548·32	347·45	346·57	345·68	344·77	343·86
155	354·00	353·38	352·73	352·06	351·38	350·68	349·97	349·25	348·51	347·77	347·02	346·27
160	355·04	354·54	354·01	353·47	352·92	352·36	351·79	351·21	350·62	350·03	349·44	348·84
165	356·20	355·81	355·41	355·00	354·64	354·16	353·74	353·30	352·86	352·42	351·98	351·53
170	357·42	357·16	356·89	356·62	356·34	356·06	355·77	355·48	355·19	354·90	354·60	354·31
175	358·70	358·57	358·43	358·30	358·16	358·02	357·87	357·73	357·58	357·44	357·29	357·14
180	360·00	360·00	360·00	360·00	360·00	360·00	360·00	360·00	360·00	360·00	360·00	360·00

u for $L_2 = 2(\xi - v) - R$. The values of ξ and v and to be obtained from Table 7; and the above values of R were computed from the equation $\tan R = \dfrac{\sin 2P}{\frac{1}{6}\cot^2 \frac{1}{2} I - \cos 2P}$.

The values of I and P for the first day of every month are given in Table 6.

When P lies between 180° and 360°, subtract 180° from it and enter the table with the remainder.

TABLE 9.—*Values of Q for completing u for* M_1.

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

u for $M_1 = \xi - v + Q$. The values of ξ and v are to be obtained from Table 7; the above values of Q were computed from the equation $\tan Q = \frac{1}{2} \tan P$.

The value of P for the first day of every month is given in Table 6.

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years.*

Component.	1850		1851		1852		1853		1854		1855	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$*	1·1216	0·8916	1·0553	0·9476	0·9935	1·0066	0·9428	1·0607	0·9047	1·1053	0·8788	1·1380
	0·0498	9·9502	0·0234	9·9766	9·9972	0·0028	9·9744	0·0256	9·9565	0·0435	9·9439	0·0561
K_1	1·0840	0·9225	1·0426	0·9591	1·0011	0·9989	0·9647	1·0366	0·9358	1·0686	0·9153	1·0925
	0·0350	9·9650	0·0181	9·9819	0·0005	9·9995	9·9844	0·0156	9·9712	0·0288	9·9616	0·0384
K_2	1·2263	0·8155	1·1276	0·8869	1·0238	0·9767	0·9305	1·0747	0·8559	1·1684	0·8026	1·2459
	0·0886	9·9114	0·0521	9·9479	0·0102	9·9898	9·9687	0·0313	9·9324	0·0676	9·9045	0·0955
L_2	0·8599	1·1629	1·1050	0·9050	1·3801	0·7246	0·9476	1·0553	0·7920	1·2626	1·0594	0·9439
	9·9344	0·0656	0·0434	9·9566	0·1399	9·8601	9·9766	0·0234	9·8987	0·1013	0·0251	9·9749
$[L_2]$*	0·9733	1·0274	0·9830	1·0173	0·9947	1·0053	1·0073	0·9928	1·0192	0·9811	1·0291	0·9717
	9·9882	0·0118	9·9925	0·0075	9·9977	0·0023	0·0032	9·9968	0·0083	9·9917	0·0124	9·9876
M_1	0·9777	1·0228	0·5972	1·6746	0·5066	1·9741	0·6414	1·5591	0·8942	1·1183	0·5378	1·8595
	9·9902	0·0098	9·7761	0·2239	9·7046	0·2954	9·8072	0·1929	9·9514	0·0486	9·7306	0·2694
M_2, M S	0·9733	1·0274	0·9830	1·0173	0·9947	1·0053	1·0073	0·9928	1·0192	0·9811	1·0291	0·9717
	9·9882	0·0118	9·9925	0·0075	9·9977	0·0023	0·0032	9·9968	0·0083	9·9917	0·0124	9·9876
M_3	0·9602	1·0415	0·9746	1·0261	0·9921	1·0080	1·0110	0·9891	1·0289	0·9719	1·0440	0·9579
	9·9824	0·0174	9·9888	0·0112	9·9966	0·0034	0·0047	9·9953	0·0124	9·9876	0·0187	9·9813
M_4, M N	0·9473	1·0557	0·9662	1·0350	0·9895	1·0106	1·0147	0·9856	1·0388	0·9626	1·0590	0·9443
	9·9765	0·0235	9·9851	0·0149	9·9954	0·0046	0·0063	9·9937	0·0165	9·9835	0·0249	9·9751
M_6	0·9220	1·0846	0·9498	1·0529	0·9843	1·0159	1·0221	0·9784	1·0588	0·9445	1·0898	0·9176
	9·9647	0·0353	9·9776	0·0224	9·9931	0·0069	0·0095	9·9905	0·0248	9·9752	0·0374	9·9626
M_8	0·8973	1·1144	0·9336	1·0711	0·9791	1·0213	1·0295	0·9713	1·0791	0·9267	1·1215	0·8917
	9·9530	0·0470	9·9702	0·0298	9·9908	0·0092	0·0126	9·9874	0·0331	9·9669	0·0498	9·9502
N_2, 2 N	0·9733	1·0274	0·9830	1·0173	0·9947	1·0053	1·0073	0·9928	1·0192	0·9811	1·0291	0·9717
	9·9882	0·0118	9·9925	0·0075	9·9977	0·0023	0·0032	9·9968	0·0083	9·9917	0·0124	9·9876
O_1, Q_1	1·1449	0·8735	1·0715	0·9333	1·0023	0·9978	0·9446	1·0587	0·9006	1·1104	0·8700	1·1495
	0·0588	9·9412	0·0300	9·9700	0·0010	9·9990	9·9752	0·0248	9·9545	0·0455	9·9395	0·0605
OO	1·5841	0·6313	1·2732	0·7855	1·0175	0·9829	0·8305	1·2041	0·7031	1·4223	0·6218	1·6084
	0·1998	9·8002	0·1049	9·8951	0·0075	9·9925	9·9194	0·0806	9·8470	0·1530	9·7936	0·2064
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1, 2, 3, 4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ_2, μ_2, ν_2	0·9733	1·0274	0·9830	1·0173	0·9947	1·0053	1·0073	0·9928	1·0192	0·9811	1·0291	0·9717
	9·9882	0·0118	9·9925	0·0075	9·9977	0·0023	0·0032	9·9968	0·0083	9·9917	0·0124	9·9876
M K	1·0550	0·9479	1·0249	0·9757	0·9958	1·0042	0·9717	1·0291	0·9538	1·0484	0·9420	1·0616
	0·0233	9·9767	0·0107	9·9893	9·9982	0·0018	9·9875	0·0125	9·9795	0·0205	9·9740	0·0260
2 M K	1·0268	0·9739	1·0074	0·9926	0·9906	1·0095	0·9788	1·0217	0·9722	1·0286	0·9693	1·0316
	0·0115	9·9885	0·0032	9·9968	9·9959	0·0041	9·9907	0·0093	9·9877	0·0123	9·9865	0·0135
2 M S	0·9473	1·0557	0·9662	1·0350	0·9895	1·0106	1·0147	0·9856	1·0388	0·9626	1·0590	0·9443
	9·9765	0·0235	9·9851	0·0149	9·9954	0·0046	0·0063	9·9937	0·0165	9·9835	0·0249	9·9751
Msf, 2 S M	0·9733	1·0274	0·9830	1·0173	0·9947	1·0053	1·0073	0·9928	1·0192	0·9811	1·0291	0·9717
	9·9882	0·0118	9·9925	0·0075	9·9977	0·0023	0·0032	9·9968	0·0083	9·9917	0·0124	9·9876
Mf	1·3467	0·7426	1·1680	0·8562	1·0098	0·9903	0·8857	1·1290	0·7957	1·2567	0·7355	1·3597
	0·1293	9·8707	0·0674	9·9326	0·0042	9·9958	9·9473	0·0527	9·9008	0·0992	9·8666	0·1334
Mm	0·9138	1·0944	0·9446	1·0587	0·9837	1·0165	1·0278	0·9729	1·0720	0·9328	1·1106	0·9005
	9·9608	0·0392	9·9752	0·0248	9·9929	0·0071	0·0119	9·9881	0·0302	9·9698	0·0455	9·9545
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000

* The unmarked L_2 and M_1 are the compound waves of the British forms, while $[L_2]$ and $[M_1]$ are the larger of their elements or simple components, corresponding to Ferrel's L_2 with the epoch changed by 180°, and to his m_1 or Q'_1, respectively.

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1856		1857		1858		1859		1860		1861	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	0·8636	1·1580	0·8583	1·1651	0·8625	1·1595	0·8764	1·1411	0·9010	1·1098	0·9376	1·0665
	9·9363	0·0637	9·9336	0.0664	9·9357	0·0643	9·9427	0·0573	9·9547	0·0453	9·9720	0·0280
K_1	0·9030	1·1074	0·8987	1·1128	0·9021	1·1085	0·9134	1·0948	0·9330	1·0718	0·9609	1·0407
	9·9557	0·0443	9·9536	0·0464	9·9553	0·0447	9·9607	0·0393	9·9699	0·0301	9·9827	0·0173
K_2	0·7707	1·2976	0·7593	1·3170	0·7683	1·3017	0·7977	1·2537	0·8484	1·1786	0·9207	1·0862
	9·8869	0·1131	9·8804	0·1196	9·8855	0·1145	9·9018	0·0982	9·9286	0·0714	9·9641	0·0359
L_2	2·1324	0·4690	1·0393	0·9622	0·7796	1·2827	0·9992	1·0008	1·7598	0·5683	1·0822	0·9241
	0·3289	9·6711	0·0167	9·9833	9·8919	0·1081	9·9996	0·0004	0·2455	9·7545	0·0343	9·9657
$[L_2]$	1·0357	0·9655	1·0382	0·9632	1·0362	0·9650	1·0301	0·9708	1·0205	0·9799	1·0088	0·9913
	0·0152	9·9848	0·0163	9·9837	0·0155	9·9845	0·0129	9·9871	0·0088	9·9912	0·0038	9·9962
M_1	0·4260	2·3475	0·5343	1·8716	0·8499	1·1766	0·5631	1·7759	0·4490	2·2274	0·5581	1·7919
	9·6294	0·3706	9·7278	0·2722	9·9294	0·0706	9·7506	0·2494	9·6522	0·3478	9·7467	0·2533
M_2, MS	1·0357	0·9655	1·0382	0·9632	1·0362	0·9650	1·0301	0·9708	1·0205	0·9799	1·0088	0·9913
	0·0152	9·9848	0·0163	9·9837	0·0155	9·9845	0·0129	9·9871	0·0088	9·9912	0·0038	9·9962
M_3	1·0540	0·9487	1·0578	0·9453	1·0548	0·9480	1·0454	0·9566	1·0309	0·9700	1·0131	0·9870
	0·0229	9·9771	0·0244	9·9756	0·0232	9·9768	0·0193	9·9807	0·0132	9·9868	0·0057	9·9943
M_4, MN	1·0727	0·9322	1·0779	0·9278	1·0738	0·9313	1·0611	0·9425	1·0415	0·9602	1·0176	0·9827
	0·0305	9·9695	0·0326	9·9674	0·0309	9·9691	0·0257	9·9743	0·0177	9·9823	0·0076	9·9924
M_6	1·1110	0·9001	1·1190	0·8936	1·1127	0·8987	1·0930	0·9149	1·0629	0·9408	1·0265	0·9742
	0·0457	9·9543	0·0488	9·9512	0·0464	9·9536	0·0386	9·9614	0·0265	9·9735	0·0114	9·9886
M_8	1·1507	0·8690	1·1618	0·8608	1·1530	0·8673	1·1258	0·8882	1·0847	0·9219	1·0355	0·9657
	0·0610	9·9390	0·0651	9·9349	0·0618	9·9382	0·0515	9·9485	0·0353	9·9647	0·0152	9·9848
N_2, 2 N	1·0357	0·9655	1·0382	0·9632	1·0362	0·9650	1·0301	0·9708	1·0205	0·9799	1·0088	0·9913
	0·0152	9·9848	0·0163	9·9837	0·0155	9·9845	0·0129	9·9871	0·0088	9·9912	0·0038	9·9962
O_1, Q_1	0·8519	1·1739	0·8455	1·1827	0·8505	1·1758	0·8672	1·1532	0·8962	1·1158	0·9387	1·0654
	9·9304	0·0696	9·9271	0·0729	9·9297	0·0703	9·9381	0·0619	9·9524	0·0476	9·9725	0·0275
OO	0·5763	1·7352	0·5607	1·7834	0·5730	1·7453	0·6145	1·6273	0·6912	1·4467	0·8127	1·2305
	9·7606	0·2394	9·7488	0·2512	9·7581	0·2419	9·7885	0·2115	9·8396	0·1604	9·9099	0·0901
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1,2,3,4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ_2 μ_2 ν_2	1·0357	0·9655	1·0382	0·9632	1·0362	0·9650	1·0301	0·9708	1·0205	0·9799	1·0088	0·9913
	0·0152	9·9848	0·0163	9·9837	0·0155	9·9845	0·0129	9·9871	0·0088	9·9912	0·0038	9·9962
MK	0·9353	1·0692	0·9330	1·0718	0·9348	1·0697	0·9409	1·0628	0·9521	1·0503	0·9693	1·0317
	9·9709	0·0292	9·9699	0·0301	9·9707	0·0293	9·9736	0·0264	9·9787	0·0213	9·9864	0·0136
2 MK	0·9687	1·0323	0·9686	1·0324	0·9687	1·0323	0·9692	1·0318	0·9717	1·0291	0·9778	1·0227
	9·9862	0·0138	9·9862	0·0138	9·9862	0·0138	9·9864	0·0136	9·9875	0·0125	9·9902	0·0098
2 MS	1·0727	0·9322	1·0779	0·9278	1·0738	0·9313	1·0611	0·9425	1·0415	0·9602	1·0176	0·9827
	0·0305	9·9695	0·0326	9·9674	0·0309	9·9691	0·0257	9·9743	0·0177	9·9823	0·0076	9·9924
Msf, 2 SM	1·0357	0·9655	1·0382	0·9632	1·0362	0·9650	1·0301	0·9708	1·0205	0·9799	1·0088	0·9913
	0·0152	9·9848	0·0163	9·9837	0·0155	9·9845	0·0129	9·9871	0·0088	9·9912	0·0038	9·9962
Mf	0·7007	1·4272	0·6886	1·4523	0·6981	1·4325	0·7300	1·3699	0·7871	1·2705	0·8734	1·1449
	9·8455	0·1545	9·8379	0·1621	9·8439	0·1561	9·8633	0·1367	9·8960	0·1040	9·9412	0·0588
Mm	1·1374	0·8792	1·1476	0·8713	1·1395	0·8776	1·1145	0·8973	1·0770	0·9285	1·0331	0·9679
	0·0559	9.9441	0·0598	9·9402	0·0567	9·9433	0·0471	9·9529	0·0322	9·9678	0·0142	9·9858
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1862		1863		1864		1865		1866		1867	
	$\frac{F}{\log F}$	$\frac{f}{\log f}$	$\frac{F}{\log F}$	$\frac{f}{\log f}$	$\frac{F}{\log F}$	$\frac{f}{\log f}$	$\frac{F}{\log F}$	$\frac{f}{\log f}$	$\frac{F}{\log F}$	$\frac{f}{\log f}$	$\frac{F}{\log F}$	$\frac{f}{\log f}$
J_1, $[M_1]$	0·9868 9·9942	1·0134 0·0058	1·0474 0·0201	0·9547 9·9799	1·1139 0·0468	0·8978 9·9532	1·1731 0·0693	0·8524 9·9307	1·2068 0·0816	0·8287 9·9184	1·2013 0·0796	0·8325 9·9204
K_1	0·9964 9·9984	1·0036 0·0016	1·0375 0·0160	0·9638 9·9840	1·0793 0·0331	0·9265 9·9669	1·1140 0·0469	0·8977 9·9531	1·1327 0·0541	0·8828 9·9459	1·1297 0·0530	0·8852 9·9470
K_2	1·0120 0·0052	0·9882 9·9948	1·1150 0·0473	0·8969 9·9527	1·2154 0·0847	0·8228 9·9153	1·2941 0·1120	0·7727 9·8880	1·3344 0·1253	0·7494 9·8747	1·3280 0·1232	0·7530 9·8768
L_2	0·8162 9·9118	1·2252 0·0882	0·8950 9·9518	1·1173 0·0482	1·1564 0·0631	0·8647 9·9369	1·1371 0·0558	0·8794 9·9442	0·9239 9·9656	1·0824 0·0344	0·8405 9·9245	1·1898 0·0755
$[L_2]$	0·9962 9·9984	1·0038 0·0016	0·9843 9·9931	1·0159 0·0069	0·9743 9·9887	1·0264 0·0113	0·9672 9·9855	1·0339 0·0145	0·9638 9·9840	1·0376 0·0160	0·9643 9·9842	1·0370 0·0158
M_1	0·9558 9·9804	1·0462 0·0196	0·7939 9·8998	1·2596 0·1002	0·5952 9·7746	1·6802 0·2254	0·6215 9·7934	1·6091 0·2066	0·8590 9·9340	1·1641 0·0660	1·2312 0·0903	0·8122 9·9097
M_2, MS	0·9962 9·9984	1·0038 0·0016	0·9843 9·9931	1·0159 0·0069	0·9743 9·9887	1·0264 0·0113	0·9672 9·9855	1·0339 0·0145	0·9638 9·9840	1·0376 0·0160	0·9643 9·9842	1·0370 0·0158
M_3	0·9944 9·9975	1·0057 0·0025	0·9766 9·9897	1·0240 0·0103	0·9617 9·9830	1·0398 0·0170	0·9513 9·9783	1·0512 0·0217	0·9462 9·9760	1·0569 0·0240	0·9470 9·9763	1·0560 0·0237
M_4, MN	0·9925 9·9967	1·0076 0·0033	0·9689 9·9863	1·0321 0·0137	0·9492 9·9774	1·0535 0·0226	0·9355 9·9711	1·0689 0·0289	0·9289 9·9680	1·0765 0·0320	0·9300 9·9685	1·0753 0·0315
M_6	0·9887 9·9951	1·0114 0·0049	0·9537 9·9794	1·0486 0·0206	0·9248 9·9661	1·0813 0·0339	0·9049 9·9566	1·1051 0·0434	0·8953 9·9520	1·1169 0·0480	0·8968 9·9527	1·1151 0·0473
M_8	0·9850 9·9934	1·0152 0·0066	0·9387 9·9725	1·0653 0·0275	0·9011 9·9548	1·1098 0·0452	0·8752 9·9421	1·1426 0·0579	0·8629 9·9360	1·1589 0·0640	0·8648 9·9369	1·1563 0·0631
N_2, 2 N	0·9962 9·9984	1·0038 0·0016	0·9843 9·9931	1·0159 0·0069	0·9743 9·9887	1·0264 0·0113	0·9672 9·9855	1·0339 0·0145	0·9638 9·9840	1·0376 0·0160	0·9643 9·9842	1·0370 0·0158
O_1, Q_1	0·9947 9·9977	1·0053 0·0023	1·0627 0·0264	0·9410 9·9736	1·1363 0·0555	0·8800 9·9445	1·2014 0·0797	0·8324 9·9203	1·2382 0·0928	0·8076 9·9072	1·2322 0·0907	0·8116 9·9093
OO	0·9917 9·9964	1·0084 0·0036	1·2389 0·0930	0·8072 9·9070	1·5457 0·1891	0·6470 9·8109	1·8536 0·2680	0·5395 9·7320	2·0436 0·3104	0·4894 9·6896	2·0118 0·3036	0·4971 9·6964
P_1, R_2, T_2	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000
$S_{1, 2, 3, 4}$	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000
λ_2, μ_2, ν_2	0·9962 9·9984	1·0038 0·0016	0·9843 9·9931	1·0159 0·0069	0·9743 9·9887	1·0264 0·0113	0·9672 9·9855	1·0339 0·0145	0·9638 9·9840	1·0376 0·0160	0·9643 9·9842	1·0370 0·0158
MK	0·9927 9·9968	1·0074 0·0032	1·0212 0·0091	0·9792 9·9909	1·0516 0·0218	0·9510 9·9782	1·0775 0·0324	0·9281 9·9676	1·0917 0·0381	0·9160 9·9619	1·0894 0·0372	0·9179 9·9628
2 MK	0·9889 9·9952	1·0112 0·0048	1·0052 0·0022	0·9948 9·9978	1·0245 0·0105	0·9761 9·9895	1·0422 0·0179	0·9595 9·9821	1·0522 0·0221	0·9504 9·9779	1·0506 0·0214	0·9519 9·9786
2 MS	0·9925 9·9967	1·0076 0·0033	0·9689 9·9863	1·0321 0·0137	0·9492 9·9774	1·0535 0·0226	0·9355 9·9711	1·0689 0·0289	0·9289 9·9680	1·0765 0·0320	0·9300 9·9685	1·0753 0·0315
MSf, 2 SM	0·9962 9·9984	1·0038 0·0016	0·9843 9·9931	1·0159 0·0069	0·9743 9·9887	1·0264 0·0113	0·9672 9·9855	1·0339 0·0145	0·9638 9·9840	1·0376 0·0160	0·9643 9·9842	1·0370 0·0158
Mf	0·9932 9·9970	1·0069 0·0030	1·1474 0·0597	0·8715 9·9403	1·3253 0·1223	0·7546 9·8777	1·4923 0·1738	0·6701 9·8262	1·5907 0·2016	0·6287 9·7984	1·5744 0·1971	0·6352 9·8029
Mm	0·9888 9·9951	1·0113 0·0049	0·9489 9·9772	1·0539 0·0228	0·9169 9·9623	1·0906 0·0377	0·8951 9·9519	1·1172 0·0481	0·8848 9·9468	1·1302 0·0532	0·8864 9·9476	1·1281 0·0524
Sa, Ssa	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1868		1869		1870		1871		1872		1873	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	1·1589	0·8629	1·0961	0·9124	1·0303	0·9706	0·9724	1·0284	0·9266	1·0793	0·8933	1·1195
	0·0640	9·9360	0·0398	9·9602	0·0130	9·9870	9·9878	0·0122	9·9669	0·0331	9·9510	0·0490
K_1	1·1059	0·9043	1·0684	0·9360	1·0262	0·9745	0·9862	1·0140	0·9526	1·0498	0·9269	1·0789
	0·0437	9·9563	0·0287	9·9713	0·0112	9·9888	9·9940	0·0060	9·9789	0·0211	9·9670	0·0330
K_2	1·2762	0·7836	1·1898	0·8405	1·0869	0·9201	0·9859	1·0143	0·8992	1·1121	0·8927	1·2010
	0·1059	9·8941	0·0755	9·9245	0·0362	9·9638	9·9938	0·0062	9·9539	0·0461	9·9205	0·0795
L_2	0·9164	1·0912	1·1901	0·8403	1·2073	0·8283	0·8708	1·1484	0·8172	1·2237	1·2260	0·8157
	9·9621	0·0379	0·0756	9·9244	0·0818	9 9182	9·9399	0·0601	9·9123	0·0877	0·0885	9·9115
$[L_2]$	0·9688	1·0322	0·9767	1·0238	0·9874	1·0128	0·9996	1·0004	1·0121	0·9881	1·0234	0·9772
	9·9862	0·0138	9·9898	0·0102	9·9945	0·0055	9·9998	0·0002	0·0052	9·9948	0·0100	9·9900
M_1	0·8409	1·1892	0·5776	1·7313	0·5521	1·8113	0·7693	1·2999	0·8438	1·1851	0·4990	2·0040
	9·9247	0·0753	9·7616	0·2384	9·7420	0·2580	9·8861	0·1139	9·9262	0·0738	9·6981	0·3019
M_2, MS	0·9688	1·0322	0·9767	1·0238	0·9874	1·0128	0·9996	1·0004	1·0121	0·9881	1·0234	0·9772
	9·9862	0·0138	9·9898	0·0102	9·9945	0·0055	9·9998	0·0002	0·0052	9·9948	0·0100	9·9900
M_3	0·9535	1·0487	0·9653	1·0359	0·9811	1·0192	0·9994	1·0006	1·0182	0·9821	1·0352	0·9660
	9·9793	0·0207	9·9847	0·0153	9·9917	0·0083	9·9997	0·0003	0·0078	9·9922	0·0150	9·9850
M_4, MN	0·9386	1·0655	0·9540	1·0482	0·9749	1·0257	0·9992	1·0008	1·0243	0·9763	1·0473	0·9549
	9·9725	0·0275	9·9795	0·0205	9·9890	0·0110	9·9996	0·0004	0·0104	9·9896	0·0201	9·9799
M_6	0·9093	1·0998	0·9318	1·0732	0·9626	1·0389	0·9988	1·0012	1·0366	0·9647	1·0717	0·9331
	9·9587	0·0413	9·9693	0·0307	9·9834	0·0166	9·9995	0·0005	0·0156	9·9844	0·0301	9·9699
M_8	0·8809	1·1352	0·9101	1·0988	0·9504	1·0522	0·9983	1·0017	1·0492	0·9531	1·0968	0·9118
	9·9449	0·0551	9·9591	0·0409	9·9779	0·0221	9·9993	0·0007	0·0208	9·9792	0·0401	9·9599
N_2, 2 N	0·9688	1·0322	0·9767	1·0238	0·9874	1·0128	0·9996	1·0004	1·0121	0·9881	1·0234	0·9772
	9·9862	0·0138	9·9898	0·0102	9·9945	0·0055	9·9998	0·0002	0·0052	9·9948	0·0100	9·9900
O_1, Q_1	1·1858	0·8433	1·1167	0·8955	1·0436	0·9582	0·9784	1·0221	0·9259	1·0800	0·8871	1·1272
	0·0740	9·9260	0·0479	9·9521	0·0185	9·9815	9·9905	0·0095	9·9666	0·0334	9·9480	0·0520
OO	1·7768	0·5628	1·4596	0·6852	1·1658	0·8578	0·9373	1·0669	0·7750	1·2904	0·6667	1·5000
	0·2496	9·7504	0·1642	9·8358	0·0666	9·9334	9·9719	0·0281	9·8893	0·1107	9·8239	0·1761
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0009	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1, 2, 3, 4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ_2, μ_2 ν_2	0·9688	1·0322	0·9767	1·0238	0·9874	1·0128	0·9996	1·0004	1·0121	0·9881	1·0234	0·9772
	9·9862	0·0138	9·9898	0·0102	9·9945	0·0055	9·9998	0·0002	0·0052	9·9948	0·0100	9·9900
MK	1·0714	0.9334	1·0435	0·9583	1·0132	0·9870	0·9858	1·0144	0·9641	1·0373	0·9485	1·0543
	0·0299	9·9701	0·0185	9·9815	0·0057	9·9943	9·9938	0·0062	9·9841	0·0159	9·9770	0·0230
2 MK	1·0379	0·9635	1·0192	0·9811	1·0004	0·9996	0·9854	1·0148	0·9757	1·0249	0·9707	1·0302
	0·0162	9·9838	0·0083	9·9917	0·0002	9·9998	9·9936	0·0064	9·9893	0·0107	9·9871	0·0129
2 MS	0·9386	1·0655	0·9540	1·0482	0·9749	1·0257	0·9992	1·0008	1·0243	0·9763	1·0473	0·9549
	9·9725	0·0275	9·9795	0·0205	9·9890	0·0110	9·9996	0·0004	0·0104	9·9896	0·0201	9·9799
MSf, 2 SM	0·9688	1·0322	0·9767	1·0238	0·9874	1·0128	0·9996	1·0004	1·0121	0·9881	1·0234	0·9772
	9·9862	0·0138	9·9898	0·0102	9·9945	0·0055	9·9998	0·0002	0·0052	9·9948	0·0100	9·9900
Mf	1·4515	0·6889	1·2766	0·7833	1·1030	0·9066	0·9576	1·0443	0·8471	1·1806	0·7690	1·3003
	0·1618	9.8382	0·1061	9·8939	0·0426	9·9574	9·9812	0·0188	9·9279	0·0721	9·8860	0·1140
Mm	0·8999	1·1112	0·9246	1·0816	0·9589	1·0428	1·0004	0·9996	1·0452	0·9568	1·0880	0·9191
	9·9542	0·0458	9·9659	0·0341	9·9818	0·0182	0·0002	9·9998	0·0192	9·9808	0·0366	9·9634
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1874		1875		1876		1877		1878		1879	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	0·8717	1·1472	0·8604	1·1622	0·8588	1·1644	0·8667	1·1538	0·8846	1·1305	0·9137	1·0945
	9·9404	0·0596	9·9347	0·0653	9·9339	0·0661	9·9378	0·0622	9·9468	0·0532	9·9608	0·0392
K_1	0·9096	1·0994	0·9004	1·1106	0·8991	1·1122	0·9056	1·1043	0·9200	1·0869	0·9428	1·0607
	9·9589	0·0411	9·9544	0·0456	9·9538	0·0462	9·9569	0·0431	9·9638	0·0362	9·9744	0·0256
K_2	0·7878	1·2694	0·7638	1·3092	0·7604	1·3151	0·7772	1·2867	0·8148	1·2273	0·8738	1·1444
	9·8964	0·1036	9·8830	0·1170	9·8810	0·1190	9·8905	0·1095	9·9110	0·0890	9·9414	0·0586
L_2	1·8337	0·5453	0·9196	1·0874	0·7874	1·2700	1·1657	0·8578	1·8420	0·5429	0·9649	1·0364
	0·2633	9·7367	9·9636	0·0364	9·8962	0·1038	0·0666	9·9334	0·2653	9·7347	9·9845	0·0155
$[L_2]$	1·0321	0·9689	1·0372	0·9641	1·0380	0·9634	1·0343	0·9668	1·0267	0·9740	1·0162	0·9841
	0·0137	9·9863	0·0159	9·9841	0·0162	9·9838	0·0146	9·9854	0·0115	9·9885	0·0070	9·9930
M_1	0·4374	2·2864	0·6038	1·6562	0·8150	1·2270	0·5005	1·9981	0·4408	2·2688	0·6079	1·6450
	9·6408	0·3592	9·7809	0·2191	9·9111	0·0889	9·6994	0·3006	9·6442	0·3558	9·7838	0·2162
M_2, MS	1·0321	0·9689	1·0372	0·9641	1·0380	0·9634	1·0343	0·9668	1·0267	0·9740	1·0162	0·9841
	0·0137	9·9863	0·0159	9·9841	0·0162	9·9838	0·0146	9·9854	0·0115	9·9885	0·0070	9·9930
M_3	1·0486	0·9537	1·0563	0·9467	1·0575	0·9456	1·0519	0·9506	1·0404	0·9612	1·0244	0·9762
	0·0206	9·9794	0·0238	9·9762	0·0243	9·9757	0·0220	9·9780	0·0172	9·9828	0·0105	9·9895
M_4, MN	1·0653	0·9387	1·0758	0·9296	1·0774	0·9282	1·0698	0·9348	1·0542	0·9486	1·0326	0·9684
	0·0275	9·9725	0·0317	9·9683	0·0324	9·9676	0·0293	9·9707	0·0229	9·9771	0·0139	9·9861
M_6	1·0995	0·9095	1·1158	0·8962	1·1183	0·8943	1·1065	0·9038	1·0824	0·9239	1·0493	0·9530
	0·0412	9·9588	0·0476	9·9524	0·0485	9·9515	0·0440	9·9561	0·0344	9·9656	0·0209	9·9791
M_8	1·1348	0·8812	1·1573	0·8641	1·1607	0·8615	1·1445	0·8738	1·1113	0·8998	1·0663	0·9378
	0·0549	9·9451	0·0634	9·9366	0·0647	9·9353	0·0586	9·9414	0·0458	9·9542	0·0279	9·9721
N_2, 2 N	1·0321	0·9689	1·0372	0·9641	1·0380	0·9634	1·0343	0·9668	1·0267	0·9740	1·0162	0·9841
	0·0137	9·9863	0·0159	9·9841	0·0162	9·9838	0·0146	9·9854	0·0115	9·9885	0·0070	9·9930
O_1, Q_1	0·8615	1·1607	0·8480	1·1792	0·8461	1·1819	0·8556	1·1688	0·8769	1·1404	0·9110	1·0977
	9·9353	0·0647	9·9284	0·0716	9·9274	0·0726	9·9323	0·0677	9·9430	0·0570	9·9595	0·0405
OO	0·6003	1·6658	0·5669	1·7639	0·5622	1·7787	0·5854	1·7082	0·6396	1·5634	0·7322	1·3658
	9·7784	0·2216	9·7535	0·2465	9·7499	0·2501	9·7675	0·2325	9·8059	0·1941	9·8646	0·1354
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1,2,3,4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ_2, μ_2, ν_2	1·0321	0·9689	1·0372	0·9641	1·0380	0·9634	1·0343	0·9668	1·0267	0·9740	1·0162	0·9841
	0·0137	9·9863	0·0159	9·9841	0·0162	9·9838	0·0146	9·9854	0·0115	9·9885	0·0070	9·9930
MK	0·9388	1·0651	0·9339	1·0708	0·9332	1·0716	0·9366	1·0677	0·9446	1·0586	0·9580	1·0438
	9·9726	0·0274	9·9703	0·0297	9·9700	0·0300	9·9716	0·0284	9·9753	0·0248	9·9814	0·0186
2 MK	0·9690	1·0320	0·9686	1·0324	0·9686	1·0324	0·9687	1·0323	0·9699	1·0311	0·9735	1·0272
	9·9863	0·0137	9·9862	0·0138	9·9862	0·0138	9·9862	0·0138	9·9867	0·0133	9·9883	0·0117
2 MS	1·0653	0·9387	1·0758	0·9296	1·0774	0·9282	1·0698	0·9348	1·0542	0·9486	1·0326	0·9684
	0·0275	9·9725	0·0317	9·9683	0·0324	9·9676	0·0293	9·9707	0·0229	9·9771	0·0139	9·9861
MSf, 2 SM	1·0321	0·9689	1·0372	0·9641	1·0380	0·9634	1·0343	0·9668	1·0267	0·9740	1·0162	0·9841
	0·0137	9·9863	0·0159	9·9841	0·0162	9·9838	0·0146	9·9854	0·0115	9·9885	0·0070	9·9930
Mf	0·7192	1·3905	0·6934	1·4422	0·6897	1·4499	0·7077	1·4130	0·7489	1·3352	0·8167	1·2244
	9·8568	0·1432	9·8410	0·1590	9·8387	0·1613	9·8499	0·1501	9·8744	0·1256	9·9121	0·0879
Mm	1·1226	0·8908	1·1435	0·8745	1·1466	0·8721	1·1316	0·8837	1·1012	0·9081	1·0605	0·9430
	0·0502	9·9498	0·0582	9·9418	0·0594	9·9406	0·0537	9·9463	0·0418	9·9582	0·0255	9·9745
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1880		1881		1882		1883		1884		1885	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	0·9551	1·0470	1·0092	0·9909	1·0731	0·9319	1·1386	0·8783	1·1902	0·8402	1·2095	0·8268
	9·9801	0·0199	0·0040	9·9960	0·0306	9·9694	0·0564	9·9436	0·0756	9·9244	0·0826	9·9174
K_1	0·9738	1·0269	1·0119	0·9882	1·0540	0·9488	1·0940	0·9140	1·1236	0·8900	1·1342	0·8817
	9·9884	0·0116	0·0052	9·9948	0·0229	9·9772	0·0390	9·9610	0·0506	9·9494	0·0547	9·9453
K_2	0·9540	1·0483	1·0512	0·9512	1·1553	0·8656	1·2494	0·8004	1·3149	0·7605	1·3376	0·7476
	9·9795	0·0205	0·0217	9·9783	0·0627	9·9373	0·0967	9·9033	0·1189	9·8811	0·1263	9·8737
L_2	0·8024	1·2463	0·9803	1.0201	1·2726	0·7858	1·0594	0·9440	0·8678	1·1523	0·8538	1·1712
	9·9044	0·0956	9·9914	0·0086	0·1047	9·8953	0·0250	9·9750	9·9384	0·0616	9·9314	0.0686
$[L_2]$	1·0039	0·9961	0·9914	1·0086	0·9801	1·0203	0·9712	1·0297	0·9654	1·0358	0·9635	1·0378
	0·0017	9·9983	9·9963	0·0037	9·9913	0·0087	9·9873	0·0127	9·9847	0·0153	9·9839	0·0161
M_1	0·9564	1·0456	0·6543	1·5284	0·5482	1·8242	0·6541	1·5289	1·0314	0·9696	1.1408	0·8766
	9·9807	0.0193	9·8158	0·1842	9·7389	0·2611	9·8156	0·1844	0·0134	9·9866	0·0572	9·9428
M_2, MS	1·0039	0·9961	0·9914	1·0086	0·9801	1·0203	0·9712	1·0297	0·9654	1·0358	0·9635	1·0378
	0·0017	9·9983	9·9963	0·0037	9·9913	0·0087	9·9873	0·0127	9·9847	0·0153	9·9839	0·0161
M_3	1·0059	0·9941	0·9872	1·0130	0·9703	1·0306	0·9571	1·0448	0·9487	1·0541	0·9458	1·0573
	0·0026	9·9974	9·9944	0·0056	9·9869	0·0131	9·9810	0·0190	9·9771	0·0229	9·9758	0·0242
M_4, MN	1·0079	0·9922	0·9830	1·0173	0·9606	1·0410	0·9432	1·0602	0·9321	1·0729	0·9284	1·0771
	0·0034	9·9966	9·9925	0·0075	9·9826	0·0174	9·9746	0·0254	9·9695	0·0305	9·9677	0·0323
M_6	1·0118	0·9883	0·9746	1·0261	0·9415	1·0621	0·9160	1·0917	0·8999	1·1112	0·8946	1·1179
	0·0051	9·9949	9·9888	0·0112	9·9738	0·0262	9·9619	0·0381	9·9542	0·0458	9·9516	0·0484
M_8	1·0158	0·9845	0·9662	1·0350	0·9228	1·0836	0·8896	1·1241	0·8688	1·1510	0·8619	1·1602
	0·0068	9·9932	9·9851	0·0149	9·9651	0·0349	9·9492	0·0508	9·9389	0·0611	9·9355	0·0645
N_2, 2 N	1·0039	0·9961	0·9914	1·0086	0·9801	1·0203	0·9712	1·0297	0·9654	1·0358	0·9635	1·0378
	0·0017	9·9983	9·9963	0·0037	9·9913	0·0087	9·9873	0·0127	9·9847	0·0153	9·9839	0·0161
O_1, Q_1	0·9587	1·0430	1·0199	0·9804	1·0912	0·9164	1·1635	0·8595	1·2201	0·8196	1·2412	0·8057
	9·9817	0·0183	0·0086	9·9914	0·0379	9·9621	0·0658	9·9342	0·0864	9·9136	0·0938	9·9062
OO	0·8744	1·1437	1·0794	0·9264	1·3526	0·7393	1·6700	0·5988	1·9486	0·5132	2·0597	0·4855
	9·9417	0·0583	0·0332	9·9668	0·1312	9·8688	0·2227	9·7773	0·2897	9·7103	0·3138	9·6862
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1, 2, 3, 4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ_2, μ_2, ν_2	1·0039	0·9961	0·9914	1·0086	0·9801	1·0203	0·9712	1·0297	0·9654	1·0358	0·9635	1·0378
	0·0017	9·9983	9·9963	0·0037	9·9913	0·0087	9·9873	0·0127	9·9847	0·0153	9·9839	0·0161
MK	0·9776	1·0229	1·0033	0·9967	1·0331	0·9680	1·0625	0·9412	1·0848	0·9219	1·0929	0·9150
	9·9902	0·0098	0·0014	9·9986	0·0141	9·9859	0·0263	9·9737	0·0353	9·9647	0·0386	9·9614
2 MK	0·9814	1·0189	0·9947	1·0053	1·0125	0·9876	1·0319	0·9691	1·0473	0·9549	1·0530	0·9496
	9·9918	0·0082	9·9977	0·0023	0·0054	9·9946	0·0136	9·9864	0·0201	9·9799	0·0224	9·9776
2 MS	1·0079	0·9922	0·9830	1·0173	0·9606	1·0410	0·9432	1·0602	0·9321	1·0729	0·9284	1·0771
	0·0034	9·9966	9·9925	0·0075	9·9826	0·0174	9·9746	0·0254	9·9695	0·0305	9·9677	0·0323
MSf, 2 SM	1·0039	0·9961	0·9914	1·0086	0·9801	1·0203	0·9712	1·0297	0·9654	1·0358	0·9635	1·0378
	0·0017	9·9983	9·9963	0·0037	9·9913	0·0087	9·9873	0·0127	9·9847	0·0153	9·9839	0·0161
Mf	0·9156	1·0922	1·0493	0·9530	1·2149	0·8231	1·3939	0·7174	1·5419	0·6486	1·5989	0·6255
	9·9617	0·0383	0·0209	9·9791	0·0845	9·9155	0·1442	9·8558	0·1880	9·8120	0·2038	9·7962
Mm	1·0157	0·9845	0·9725	1·0283	0·9354	1·0691	0·9072	1·1023	0·8897	1·1239	0·8840	1·1312
	0·0068	9·9932	9·9879	0·0121	9·9710	0·0290	9·9577	0·0423	9·9493	0·0507	9·9465	0·0535
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1886		1887		1888		1889		1890		1891	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	1·1885	0·8414	1·1360	0·8803	1·0702	0·9344	1·0066	0·9935	0·9531	1·0492	0·9123	1·0962
	0·0750	9·9250	0·0554	9·9446	0·0295	9·9705	0·0028	9·9972	9·9792	0·0208	9·9601	0·0399
K_1	1·1226	0·8908	1·0925	0·9153	1·0522	0·9504	1·0101	0·9900	0·9723	1·0285	0·9417	1·0620
	0·0502	9·9498	0·0384	9·9616	0·0221	9·9779	0·0044	9·9956	9·9878	0·0122	9·9739	0·0261
K_2	1·3129	0·7617	1·2460	0·8026	1·1508	0·8689	1·0467	0·9554	0·9502	1·0524	0·8710	1·1481
	0·1182	9·8818	0·0955	9·9045	0·0610	9·9390	0·0198	9·9802	9·9778	0·0222	9·9400	0·0600
L_2	0·9943	1·0058	1·2143	0·8235	1·0581	0·9451	0·8301	1·2047	0·8671	1·1533	1·4101	0·7092
	9·9975	0·0025	0·0843	9·9157	0·0245	9·9755	9·9191	0·0809	9·9380	0·0620	0·1492	9·8508
$[L_2]$	0·9656	1·0356	0·9715	1·0294	0·9806	1·0198	0·9920	1·0081	1·0045	0·9956	1·0166	0·9836
	9·9848	0·0152	9·9874	0·0126	9·9915	0·0085	9·9965	0·0035	0·0019	9·9981	0·0072	9·9928
M_1	0·7330	1·3643	0·5810	1·7211	0·6278	1·5929	0·9302	1·0750	0·7560	1·3228	0·4783	2·0907
	9·8651	0·1349	9·7642	0·2358	9·7978	0·2022	9·9686	0·0314	9·8785	0·1215	9·6797	0·3203
M_2, MS	0·9656	1·0356	0·9715	1·0294	0·9806	1·0198	0·9920	1·0081	1·0045	0·9956	1·0166	0·9836
	9·9848	0·0152	9·9874	0·0126	9·9915	0·0085	9·9965	0·0035	0·0019	9·9981	0·0072	9·9928
M_3	0·9489	1·0539	0·9575	1·0444	0·9710	1·0299	0·9880	1·0122	1·0067	0·9933	1·0251	0·9755
	9·9772	0·0228	9·9811	0·0189	9·9872	0·0128	9·9948	0·0052	0·0029	9·9971	0·0108	9·9892
M_4, MN	0·9324	1·0725	0·9438	1·0596	0·9615	1·0400	0·9840	1·0162	1·0089	0·9912	1·0336	0·9675
	9·9696	0·0304	9·9749	0·0251	9·9830	0·0170	9·9930	0·0070	0·0039	9·9961	0·0143	9·9857
M_6	0·9003	1·1107	0·9168	1·0907	0·9428	1·0606	0·9761	1·0245	1·0134	0·9868	1·0508	0·9517
	9·9544	0·0456	9·9623	0·0377	9·9744	0·0256	9·9895	0·0105	0·0058	9·9942	0·0215	9·9785
M_8	0·8694	1·1503	0·8907	1·1227	0·9245	1·0816	0·9683	1·0328	1·0179	0·9824	1·0683	0·9361
	9·9392	0·0608	9·9497	0·0503	9·9659	0·0341	9·9860	0·0140	0·0077	9·9923	0·0287	9·9713
N_2, 2 N	0·9656	1·0356	0·9715	1·0294	0·9806	1·0198	0·9920	1·0081	1·0045	0·9956	1·0166	0·9836
	9·9848	0·0152	9·9874	0·0126	9·9915	0·0085	9·9965	0·0035	0·0019	9·9981	0·0072	9·9928
O_1, Q_1	1·2182	0·8209	1·1607	0·8616	1·0880	0·9191	1·0170	0·9833	0·9564	1·0456	0·9093	1·0997
	0·0857	9·9143	0·0647	9·9353	0·0366	9·9634	0·0073	9·9927	9·9806	0·0194	9·9587	0·0413
OO	1·9390	0·5157	1·6568	0·6036	1·3395	0·7465	1·0689	0·9356	0·8671	1·1532	0·7275	1·3746
	0·2876	9·7124	0·2192	9·7808	0·1270	9·8730	0·0289	9·9711	9·9381	0·0619	9·8618	0·1382
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1, 2, 3, 4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ_2, μ_2, ν_2	0·9656	1·0356	0·9715	1·0294	0·9806	1·0198	0·9920	1·0081	1·0045	0·9956	1·0166	0·9836
	9·9848	0·0152	9·9874	0·0126	9·9915	0·0085	9·9965	0·0035	0·0019	9·9981	0·0072	9·9928
MK	1·0840	0·9225	1·0614	0·9422	1·0317	0·9692	1·0020	0·9980	0·9766	1·0239	0·9573	1·0446
	0·0350	9·9650	0·0259	9·9741	0·0136	9·9864	0·0009	9·9991	9·9897	0·0103	9·9811	0·0189
2 MK	1·0467	0·9554	1·0311	0·9698	1·0117	0·9884	0·9940	1·0061	0·9810	1·0194	0·9733	1·0275
	0·0198	9·9802	0·0133	9·9867	0·0050	9·9950	9·9974	0·0026	9·9917	0·0083	9·9882	0·0118
2 MS	0·9324	1·0725	0·9438	1·0596	0·9615	1·0400	0·9840	1·0162	1·0089	0·9912	1·0336	0·9675
	9·9696	0·0304	9·9749	0·0251	9·9830	0·0170	9·9930	0·0070	0·0039	9·9961	0·0143	9·9857
MSf, 2 SM	0·9656	1·0356	0·9715	1·0294	0·9806	1·0198	0·9920	1·0081	1·0045	0·9956	1·0166	0·9836
	9·9848	0·0152	9·9874	0·0126	9·9915	0·0085	9·9965	0·0035	0·0019	9·9981	0·0072	9·9928
Mf	1·5369	0·6506	1·3867	0·7212	1·2072	0·8283	1·0426	0·9591	0·9107	1·0981	0·8133	1·2295
	0·1866	9·8134	0·1420	9·8580	0·0818	9·9182	0·0181	9·9819	9·9594	0·0406	9·9103	0·0897
Mm	0·8903	1·1233	0·9082	1·1011	0·9368	1·0674	0·9744	1·0263	1·0176	0 9827	1·0623	0·9414
	9·9495	0·0505	9·9582	0·0418	9·9717	0·0283	9·9887	0·0113	0·0076	9·9924	0·0262	9·9738
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1892		1893		1894		1895		1896		1897	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	0·8836	1·1317	0·8661	1·1546	0·8587	1·1646	0·8607	1·1619	0·8724	1·1463	0·8945	1·1179
	9·9463	0·0537	9·9376	0·0624	9·9338	0·0662	9·9348	0·0652	9·9407	0·0593	9·9516	0·0484
K_1	0·9192	1·0878	0·9051	1·1049	0·8990	1·1124	0·9006	1·1103	0·9102	1·0987	0·9278	1·0778
	9·9634	0·0366	9·9567	0·0433	9·9538	0·0462	9·9546	0·0454	9·9591	0·0409	9·9675	0·0325
K_2	0·8128	1·2303	0·7760	1·2886	0·7601	1·3156	0·7644	1·3082	0·7892	1·2670	0·8352	1·1974
	9·9100	0·0900	9·8899	0·1101	9·8809	0·1191	9·8833	0·1167	9·8972	0·1028	9·9218	0·0782
L_2	1·4651	0·6826	0·8437	1·1853	0·8202	1·2192	1·4211	0·7037	1·6465	0·6073	0·8766	1·1408
	0·1659	9·8341	9·9262	0·0738	9·9139	0·0861	0·1526	9·8474	0·2166	9·7834	9·9428	0·0572
$[L_2]$	1·0271	0·9736	1·0346	0·9666	1·0380	0·9634	1·0371	0·9643	1·0318	0·9692	1·0229	0·9776
	0·0116	9·9884	0·0148	9·9852	0·0162	9·9838	0·0158	9·9842	0·0136	9·9864	0·0098	9·9902
M_1	0·4633	2·1582	0·6975	1·4337	0·7305	1·3689	0·4596	2·1758	0·4465	2·2398	0·6799	1·4708
	9·6659	0·3341	9·8435	0·1565	9·8636	0·1364	9·6624	0·3376	9·6498	0·3502	9·8324	0·1676
M_2, MS	1·0271	0·9736	1·0346	0·9666	1·0380	0·9634	1·0371	0·9643	1·0318	0·9692	1·0229	0·9776
	0·0116	9·9884	0·0148	9·9852	0·0162	9·9838	0·0158	9·9842	0·0136	9·9864	0·0098	9·9902
M_3	1·0410	0·9607	1·0523	0·9503	1·0576	0·9455	1·0562	0·9468	1·0481	0·9541	1·0346	0·9666
	0·0174	9·9826	0·0221	9·9779	0·0243	9·9757	0·0237	9·9763	0·0204	9·9796	0·0148	9·9852
M_4, MN	1·0550	0·9479	1·0703	0·9343	1·0775	0·9281	1·0755	0·9298	1·0646	0·9393	1·0464	0·9557
	0·0232	9·9768	0·0295	9·9705	0·0324	9·9676	0·0316	9·9684	0·0272	9·9728	0·0197	9·9803
M_6	1·0836	0·9229	1·1073	0·9031	1·1185	0·8941	1·1154	0·8965	1·0985	0·9103	1·0703	0·9343
	0·0349	9·9651	0·0443	9·9557	0·0486	9·9514	0·0474	9·9526	0·0408	9·9592	0·0295	9·9705
M_8	1·1130	0·8985	1·1456	0·8729	1·1610	0·8613	1·1568	0·8645	1·1334	0·8823	1·0949	0·9134
	0·0465	9·9535	0·0590	9·9410	0·0648	9·9352	0·0632	9·9368	0·0544	9·9456	0·0394	9·9606
N_2, 2 N	1·0271	0·9736	1·0346	0·9666	1·0380	0·9634	1·0371	0·9643	1·0318	0·9692	1·0229	0·9776
	0·0116	9·9884	0·0148	9·9852	0·0162	9·9838	0·0158	9·9842	0·0136	9·9864	0·0098	9·9902
O_1, Q_1	0·8758	1·1419	0·8549	1·1697	0·8459	1·1821	0·8484	1·1787	0·8624	1·1596	0·8886	1·1254
	9·9424	0·0576	9·9319	0·0681	9·9273	0·0727	9·9286	0·0714	9·9357	0·0643	9·9487	0·0513
OO	0·6367	1·5707	0·5837	1·7131	0·5618	1·7800	0·5677	1·7614	0·6024	1·6600	0·6706	1·4914
	9·8039	0·1961	9·7662	0·2338	9·7496	0·2504	9·7541	0·2459	9·7799	0·2201	9·8264	0·1736
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1-2-3-4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ_2, μ_2, ν_2	1·0271	0·9736	1·0346	0·9666	1·0380	0·9634	1·0371	0·9643	1·0318	0·9692	1·0229	0·9776
	0·0116	9·9884	0·0148	9·9852	0·0162	9·9838	0·0158	9·9842	0·0136	9·9864	0·0098	9·9902
MK	0·9442	1·0591	0·9364	1·0679	0·9332	1·0716	0·9340	1·0706	0·9391	1·0648	0·9491	1·0536
	9·9750	0·0250	9·9714	0·0286	9·9700	0·0300	9·9704	0·0296	9·9727	0·0273	9·9773	0·0227
2 MK	0·9698	1·0312	0·9687	1·0323	0·9687	1·0324	0·9687	1·0324	0·9690	1·0320	0·9709	1·0300
	9·9867	0·0133	9·9862	0·0138	9·9862	0·0138	9·9862	0·0138	9·9863	0·0137	9·9872	0·0128
2 MS	1·0550	0·9479	1·0703	0·9343	1·0775	0·9281	1·0755	0·9298	1·0646	0·9393	1·0464	0·9557
	0·0232	9·9768	0·0295	9·9705	0·0324	9·9676	0·0316	9·9684	0·0272	9·9728	0·0197	9·9803
MSf, 2 SM	1·0271	0·9736	1·0346	0·9666	1·0380	0·9634	1·0371	0·9643	1·0318	0·9692	1·0229	0·9776
	0·0116	9·9884	0·0148	9·9852	0·0162	9·9838	0·0158	9·9842	0·0136	9·9864	0·0098	9·9902
Mf	0·7467	1·3392	0·7064	1·4156	0·6894	1·4506	0·6940	1·4409	0·7208	1·3874	0·7719	1·2955
	9·8732	0·1268	9·8491	0·1509	9·8385	0·1615	9·8414	0·1586	9·8578	0·1422	9·8876	0·1124
Mm	1·1027	0·9069	1·1326	0·8829	1·1469	0·8719	1·1430	0·8749	1·1214	0·8918	1·0862	0·9206
	0·0424	9·9576	0·0541	9·9459	0·0595	9·9405	0·0580	9·9420	0·0498	9·9502	0·0359	9·9641
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0.0000	0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1898		1899		1900		1901		1902		1903	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	0·9283	1·0773	0·9746	1·0261	1·0329	0·9681	1·0988	0·9101	1·1611	0·8612	1·2022	0·8318
	9·9677	0·0323	9·9888	0·0112	0·0141	9·9859	0·0409	9·9591	0·0649	9·9351	0·0800	9·9200
K_1	0·9538	1·0484	0·9878	1·0124	1·0279	0·9728	1·0701	0·9345	1·1072	0·9032	1·1302	0·8848
	9·9795	0·0205	9·9947	0·0053	0·0120	9·9880	0·0294	9·9706	0·0442	9·9558	0·0532	9·9468
K_2	0·9025	1·1080	0·9899	1·0102	1·0913	0·9164	1·1938	0·8377	1·2790	0·7819	1·3292	0·7524
	9·9555	0·0445	9·9956	0·0044	0·0379	9·9621	0·0769	9·9231	0·1069	9·8931	0·1236	9.8764
L_2	0.8138	1·2288	1·1150	0·8969	1·3279	0·7531	0·9704	1·0305	0·8383	1·1929	0·8951	1·1172
	9·9105	0·0895	0·0473	9·9527	0·1232	9·8768	9·9870	0·0130	9·9234	0·0766	9·9518	0·0482
$[L_2]$	1·0116	0·9886	0·9991	1·0009	0·9869	1·0133	0·9764	1·0242	0·9686	1·0325	0·9642	1·0371
	0·0050	9·9950	9·9996	0·0004	9·9943	0·0057	9·9896	0·0104	9·9861	0·0139	9·9842	0·0158
M_1	0·8576	1.1660	0·5615	1·7809	0·5259	1·9016	0·7149	1·3988	1·1662	0·8575	0·9354	1·0690
	9·9333	0·0667	9·7494	0·2506	9·7209	0·2791	9·8542	0·1458	0·0668	9·9332	9·9710	0·0290
M_2, MS	1·0116	0·9886	0·9991	1·0009	0·9869	1·0133	0·9764	1·0242	0·9686	1·0325	0·9642	1·0371
	0·0050	9·9950	9·9996	0·0004	9·9943	0·0057	9·9896	0·0104	9·9861	0·0139	9·9842	0·0158
M_3	1·0173	0·9829	0·9986	1·0015	0·9804	1·0200	0·9648	1·0365	0·9532	1·0491	0·9468	1·0562
	0·0075	9·9925	9·9994	0·0006	9·9913	0·0086	9·9844	0·0156	9·9792	0·0208	9·9763	0.0237
M_4, MN	1·0232	0·9773	0·9981	1·0019	0·9739	1·0268	0·9533	1·0490	0·9381	1·0660	0·9298	1·0755
	0·0100	9·9900	9·9992	0·0008	9·9885	0·0115	9·9792	0·0208	9·9722	0·0278	9·9684	0·0316
M_6	1·0350	0·9662	0·9972	1·0028	0·9611	1·0404	0·9307	1·0744	0·9086	1·1006	0·8965	1·1154
	0·0149	9·9851	9·9988	0·0012	9·9828	0·0172	9·9688	0·0312	9·9584	0·0416	9·9526	0·0474
M_8	1·0469	0·9552	0·9962	1·0038	0·9485	1·0543	0·9087	1·1004	0·8800	1·1364	0·8645	1·1568
	0·0199	9·9801	9·9984	0·0016	9·9770	0·0230	9·9584	0·0416	9.9445	0·0555	9·9368	0·0632
N_2, 2 N	1·0116	0·9886	0·9991	1·0009	0·9869	1·0133	0·9764	1·0242	0·9686	1·0325	0·9642	1·0371
	0·0050	9·9950	9·9996	0·0004	9·9943	0·0057	9·9896	0·0104	9·9861	0·0139	9·9842	0·0158
O_1, Q_1	0·9279	1·0778	0·9808	1·0195	1·0465	0·9555	1·1197	0·8931	1·1882	0·8416	1·2332	0·8109
	9·9675	0·0325	9·9916	0·0084	0·0198	9·9802	0·0491	9·9509	0·0749	9·9251	0·0910	9·9090
OO	0·7807	1·2809	0·9454	1·0577	1·1769	0·8497	1·4725	0·6791	1·7884	0·5592	2·0172	0·4957
	9·8925	0·1075	9·9756	0·0244	0·0707	9·9293	0·1681	9·8319	0·2525	9·7475	0·3048	9·6952
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1, 2, 3, 4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ_2, μ_2, ν_2	1·0116	0·9886	0·9991	1·0009	0·9869	1·0133	0·9764	1·0242	0·9686	1·0325	0·9642	1·0371
	0·0050	9·9950	9·9996	0·0004	9·9943	0·0057	9·9896	0·0104	9.9861	0·0139	9·9842	0·0158
MK	0·9648	1·0365	0·9868	1·0133	1·0144	0·9858	1·0448	0·9571	1·0723	0·9326	1·0898	0·9176
	9·9844	0·0156	9·9942	0·0058	0·0062	9·9938	0·0190	9·9810	0·0303	9·9697	0·0374	9·9626
2 MK	0·9760	1·0246	0·9859	1·0143	1·0011	0·9989	1·0201	0·9803	1·0386	0·9629	1·0508	0·9516
	9·9894	0·0106	9·9938	0·0062	0·0005	9·9995	0·0086	9·9914	0·0164	9·9836	0·0215	9·9785
2 MS	1·0232	0·9773	0·9981	1·0019	0·9739	1·0268	0·9533	1·0490	0·9381	1·0660	0·9298	1·0755
	0·0100	9·9900	9·9992	0·0008	9·9885	0·0115	9·9792	0·0208	9·9722	0·0278	9·9684	0·0316
MSf, 2 SM	1·0116	0·9886	0·9991	1·0009	0·9869	1·0133	0·9764	1·0242	0·9686	1·0325	0·9642	1·0371
	0·0050	9·9950	9·9996	0·0004	9·9943	0·0057	9·9896	0·0104	9·9861	0·0139	9·9842	0·0158
Mf	0·8511	1·1750	0·9630	1·0384	1·1098	0·9011	1·2840	0·7788	1·4578	0·6860	1·5772	0·6340
	9·9300	0·0700	9·9836	0·0164	0·0452	9·9548	0·1086	9.8914	0·1637	9·8363	0·1979	9·8021
Mm	1·0433	0·9585	0·9986	1·0014	0·9573	1·0446	0·9234	1·0830	0·8991	1·1122	0·8861	1·1285
	0·0184	9·9816	9·9994	0·0006	9·9811	0·0189	9·9654	0·0346	9·9538	0·0462	9·9475	0·0525
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0 0000	0·0000	0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1904		1905		1906		1907		1908		1909	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	1·2061 0·0814	0·8291 9·9186	1·1711 0·0686	0·8539 9·9314	1·1113 0·0458	0·8999 9·9542	1·0449 0·0191	0·9570 9·9809	0·9846 9·9933	1·0156 0·0067	0·9358 9·9712	1·0686 0·0288
K_1	1·1323 0·0540	0·8831 9·9460	1·1128 0·0464	0·8986 9·9536	1·0777 0·0325	0·9279 9·9675	1·0358 0·0153	0·9654 9·9847	0·9949 9·9978	1·0052 0·0023	0·9595 9·9821	1·0422 0·0179
K_2	1·3336 0·1250	0·7499 9·8750	1·2916 0·1111	0·7742 9·8889	1·2117 0·0834	0·8253 9·9166	1·1109 0·0457	0·9002 9·9543	1·0080 0·0035	0·9920 9·9965	0·9172 9·9625	1·0902 0·0375
L_2	1·0807 0·0337	0·9254 9·9663	1·1650 0·0663	0·8584 9·9337	0·9514 9·9783	1·0511 0·0217	0·8192 9·9134	1·2207 0·0866	0·9416 9·9739	1·0620 0·0261	1·5314 0·1851	0·6530 9·8149
$[L_2]$	0·9639 9·9840	1·0375 0·0160	0·9674 9·9856	1·0336 0·0144	0·9746 9·9888	1·0260 0·0112	0·9848 9·9933	1·0155 0·0067	0·9967 9·9986	1·0033 0·0014	1·0093 0·0040	0·9908 9·9960
M_1	0·6636 9·8219	1·5070 0·1781	0·6086 9·7843	1·6432 0·2157	0·7465 9·8730	1·3396 0·1270	1·0574 0·0242	0·9457 9·9758	0·6762 9·8300	1·4789 0·1700	0·4735 9·6753	2·1120 0·3247
M_2, MS	0·9639 9·9840	1·0375 0·0160	0·9674 9·9856	1·0336 0·0144	0·9746 9·9888	1·0260 0·0112	0·9848 9·9933	1·0155 0·0067	0·9967 9·9986	1·0033 0·0014	1·0093 0·0040	0·9908 9·9960
M_3	0·9463 9·9760	1·0567 0·0240	0·9515 9·9784	1·0509 0·0216	0·9623 9·9833	1·0392 0·0167	0·9773 9·9900	1·0233 0·0100	0·9951 9·9979	1·0049 0·0021	1·0140 0·0060	0·9862 9·9940
M_4, MN	0·9291 9·9680	1·0764 0·0320	0·9360 9·9713	1·0684 0·0287	0·9499 9·9777	1·0527 0·0223	0·9698 9·9867	1·0312 0·0133	0·9934 9·9971	1·0066 0·0029	1·0186 0·0080	0·9817 9·9920
M_6	0·8955 9·9521	1·1167 0·0479	0·9055 9·9569	1·1044 0·0431	0·9259 9·9666	1·0801 0·0334	0·9550 9·9800	1·0472 0·0200	0·9902 9·9957	1·0099 0·0043	1·0281 0·0120	0·9727 9·9880
M_8	0·8631 9·9361	1·1586 0·0639	0·8760 9·9425	1·1415 0·0575	0·9024 9·9554	1·1082 0·0446	0·9404 9·9733	1·0634 0·0267	0·9869 9·9943	1·0133 0·0057	1·0376 0·0160	0·9637 9·9840
N_2, 2 N	0·9639 9·9840	1·0375 0·0160	0·9674 9·9856	1·0336 0·0144	0·9746 9·9888	1·0260 0·0112	0·9848 9·9933	1·0155 0·0067	0·9967 9·9986	1·0033 0·0014	1·0093 0·0040	0·9908 9·9960
O_1, Q_1	1·2375 0·0925	0·8081 9·9075	1·1992 0·0789	0·8339 9·9211	1·1335 0·0544	0·8823 9·9456	1·0599 0·0253	0·9435 9·9747	0·9922 9·9966	1·0078 0·0034	0·9366 9·9716	1·0677 0·0284
OO	2·0396 0·3095	0·4903 9·6905	1·8424 0·2654	0·5428 9·7346	1·5329 0·1855	0·6524 9·8145	1·2279 0·0892	0·8144 9·9108	0·9833 9·9927	1·0170 0·0073	0·8066 9·9066	1·2398 0·0934
P_1, R_2, T_2	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000
$S_{1, 2, 3, 4}$	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000
λ_2, μ_2, ν_2	0·9639 9·9840	1·0375 0·0160	0·9674 9·9856	1·0336 0·0144	0·9746 9·9888	1·0260 0·0112	0·9848 9·9933	1·0155 0·0067	0·9967 9·9986	1·0033 0·0014	1·0093 0·0040	0·9908 9·9960
MK	1·0914 0·0380	0·9162 9·9620	1·0766 0·0321	0·9288 9·9679	1·0504 0·0214	0·9520 9·9786	1·0201 0·0086	0·9803 9·9914	0·9916 9·9963	1·0085 0·0037	0·9684 9·9861	1·0326 0·0139
2 MK	1·0520 0·0220	0·9506 9·9780	1·0416 0·0177	0·9601 9·9823	1·0238 0·0102	0·9768 9·9898	1·0045 0·0020	0·9955 9·9980	0·9883 9·9949	1·0118 0·0051	0·9774 9·9901	1·0231 0·0099
2 MS	0·9291 9·9680	1·0764 0·0320	0·9360 9·9713	1·0684 0·0287	0·9499 9·9777	1·0527 0·0223	0·9698 9·9867	1·0312 0·0133	0·9934 9·9971	1·0066 0·0029	1·0186 0·0080	0·9817 9·9920
MSf, 2 SM	0·9639 9·9840	1·0375 0·0160	0·9674 9·9856	1·0336 0·0144	0·9746 9·9888	1·0260 0·0112	0·9848 9·9933	1·0155 0·0067	0·9967 9·9986	1·0033 0·0014	1·0093 0·0040	0·9908 9·9960
Mf	1·5887 0·2010	0·6295 9·7990	1·4864 0·1721	0·6728 9·8279	1·3181 0·1200	0·7586 9·8800	1·1408 0·0572	0·8766 9·9428	0·9878 9·9947	1·0124 0·0053	0·8692 9·9391	1·1506 0·0609
Mm	0·8850 9·9470	1·1299 0·0530	0·8958 9·9522	1·1163 0·0478	0·9180 9.9628	1·0893 0·0372	0·9503 9·9779	1·0523 0·0221	0·9905 9·9958	1·0096 0·0042	1·0350 0·0149	0·9662 9·9851
Sa, Ssa	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1910		1911		1912		1913		1914		1915	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	0·8998 9·9542	1·1113 0·0458	0·8757 9·9423	1·1420 0·0577	0·8621 9·9356	1·1599 0·0644	0·8583 9·9336	1·1650 0·0664	0·8640 9·9365	1·1574 0·0635	0·8796 9·9443	1·1369 0·0557
K_1	0·9320 9·9694	1·0729 0·0306	0·9128 9·9604	1·0955 0·0396	0·9018 9·9551	1·1089 0·0449	0·8987 9·9536	1·1127 0·0464	0·9034 9·9559	1·1070 0·0414	0·9160 9·9619	1·0917 0·0381
K_2	0·8460 9·9274	1·1820 0·0726	0·7962 9·9010	1·2560 0·0990	0·7675 9·8851	1·3030 0·1149	0·7594 9·8805	1·3168 0·1195	0·7715 9·8873	1·2962 0·1127	0·8043 9·9054	1·2433 0·0946
L_2	1·1998 0·0791	0·8335 9·9209	0·8024 9·9044	1·2463 0·0956	0·8811 9·9450	1·1349 0·0550	1·7834 0·2512	0·5607 9·7488	1·3712 0·1371	0·7293 9·8629	0·8193 9·9134	1·2206 0·0866
$[L_2]$	1·0210 0·0090	0·9795 9·9910	1·0304 0·0130	0·9705 9·9870	1·0364 0·0155	0·9649 9·9845	1·0382 0·0163	0·9632 9·9837	1·0355 0·0152	0·9657 9·9848	1·0288 0·0123	0·9720 9·9877
M_1	0·5070 9·7050	1·9723 0·2950	0·8010 9·9036	1·2484 0·0964	0·6424 9·8078	1·5567 0·1922	0·4354 9·6388	2·2969 0·3612	0·4661 9·6685	2·1455 0·3315	0·7636 9·8829	1·3096 0·1171
M_2, MS	1·0210 0·0090	0·9795 9·9910	1·0304 0·0130	0·9705 9·9870	1·0364 0·0155	0·9649 9·9845	1·0382 0·0163	0·9632 9·9837	1·0355 0·0152	0·9657 9·9848	1·0288 0·0123	0·9720 9·9877
M_3	1·0316 0·0135	0·9693 9·9864	1·0459 0·0195	0·9561 9·9805	1·0551 0·0233	0·9477 9·9767	1·0578 0·0244	0·9454 9·9756	1·0538 0·0227	0·9490 9·9773	1·0435 0·0185	0·9583 9·9815
M_4, MN	1·0424 0·0180	0·9594 9·9820	1·0617 0·0260	0·9419 9·9740	1·0741 0·0311	0·9310 9·9689	1·0778 0·0325	0·9278 9·9675	1·0723 0·0303	0·9326 9·9697	1·0584 0·0246	0·9448 9·9754
M_6	1·0642 0·0270	0·9397 9·9730	1·0940 0·0390	0·9141 9·9610	1·1132 0·0466	0·8983 9·9534	1·1189 0·0488	0·8937 9·9512	1·1104 0·0455	0·9006 9·9545	1·0888 0·0370	0·9184 9·9630
M_8	1·0865 0·0360	0·9204 9·9640	1·1272 0·0520	0·8872 9·9480	1·1538 0·0621	0·8667 9·9379	1·1617 0·0651	0·8608 9·9349	1·1498 0·0606	0·8697 9·9394	1·1202 0·0493	0·8927 9·9507
N_2, 2 N	1·0210 0·0090	0·9795 9·9910	1·0304 0·0130	0·9705 9·9870	1·0364 0·0155	0·9649 9·9845	1·0382 0·0163	0·9632 9·9837	1·0355 0·0152	0·9657 9·9848	1·0288 0·0123	0·9720 9·9877
O_1, Q_1	0·8948 9·9517	1·1175 0·0483	0·8663 9·9377	1·1543 0·0623	0·8501 9·9295	1·1763 0·0705	0·8455 9·9271	1·1827 0·0729	0·8524 9·9306	1·1732 0·0694	0·8710 9·9400	1·1482 0·0600
OO	0·6874 9·8372	1·4548 0·1628	0·6124 9·7870	1·6330 0·2130	0·5719 9·7574	1·7484 0·2426	0·5609 9·7488	1·7830 0·2512	0·5775 9·7615	1·7317 0·2385	0·6242 9·7953	1·6020 0·2047
P_1, R_2, T_2	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000
$S_{1,2,3,4}$	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000
λ_2, μ_2, ν_2	1·0210 0·0090	0·9795 9·9910	1·0304 0·0130	0·9705 9·9870	1·0364 0·0155	0·9649 9·9845	1·0382 0·0163	0·9632 9·9837	1·0355 0·0152	0·9657 9·9848	1·0288 0·0123	0·9720 9·9877
MK	0·9516 9·9784	1·0509 0·0216	0·9406 9·9734	1·0632 0·0266	0·9347 9·9706	1·0699 0·0294	0·9330 9·9699	1·0718 0·0301	0·9354 9·9710	1·0690 0·0290	0·9423 9·9742	1·0612 0·0258
2 MK	0·9715 9·9874	1·0293 0·0126	0·9692 9·9864	1·0318 0·0136	0·9687 9·9862	1·0323 0·0138	0·9686 9·9862	1·0324 0·0138	0·9687 9·9862	1·0323 0·0138	0·9695 9·9865	1·0315 0·0135
2 MS	1·0424 0·0180	0·9594 9·9820	1·0617 0·0260	0·9419 9·9740	1·0741 0·0311	0·9310 9·9689	1·0778 0·0325	0·9278 9·9675	1·0723 0·0303	0·9326 9·9697	1·0584 0·0246	0·9448 9·9754
MSf, 2 SM	1·0210 0·0090	0·9795 9·9910	1·0304 0·0130	0·9705 9·9870	1·0364 0·0155	0·9649 9·9845	1·0382 0·0163	0·9632 9·9837	1·0355 0·0152	0·9657 9·9848	1·0288 0·0123	0·9720 9·9877
Mf	0·7843 9·8945	1·2750 0·1055	0·7284 9·8623	1·3730 0·1377	0·6973 9·8434	1·4341 0·1566	0·6886 9·8380	1·4521 0·1620	0·7016 9·8461	1·4254 0·1539	0·7373 9·8677	1·3562 0·1323
Mm	1·0787 0·0329	0·9270 9·9671	1·1157 0·0476	0·8963 9·9524	1·1402 0·0570	0·8770 9·9430	1·1476 0·0598	0·8714 9·9402	1·1366 0·0556	0·8798 9·9444	1·1092 0·0450	0·9015 9·9550
Sa, Ssa	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1916		1917		1918		1819		1920		1921	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	0·9060	1·1038	0·9446	1·0587	0·9958	1·0042	1·0578	0·9453	1·1242	0·8895	1·1806	0·8470
	9·9571	0·0429	9·9752	0·0248	9·9982	0·0018	0·0244	9·9756	0·0508	9·9492	0·0721	9·9279
K_1	0·9368	1·0674	0·9660	1·0352	1·0027	0·9973	1·0443	0·9576	1·0855	0·9212	1·1182	0·8943
	9·9717	0·0283	9·9850	0·0150	0·0012	9·9988	0·0188	9·9812	0·0356	9·9644	0·0485	9·9515
K_2	0·8585	1·1649	0·9340	1·0707	1·0278	0·9729	1·1316	0·8838	1·2299	0·8131	1·3034	0·7672
	9·9337	0·0663	9·9704	0·0296	0·0119	9·9881	0·0537	9·9463	0·0899	9·9101	0·1151	9·8849
L_2	0·8529	1·1725	1·3141	0·7610	1·2821	0·7800	0·8944	1·1181	0·8351	1·1975	0·9669	1·0342
	9·9309	0·0691	0·1186	9·8814	0·1079	9·8921	9·9515	0·0485	9·9218	0·0782	9·9854	0·0146
$[L_2]$	1·0188	0·9816	1·0068	0·9933	0·9942	1·0058	0·9826	1·0177	0·9730	1·0278	0·9664	1·0347
	0·0081	9·9919	0·0029	9·9971	9·9975	0·0025	9·9924	0·0076	9·9881	0·0119	9·9852	0·0148
M_1	0·7294	1·3710	0·5018	1·9929	0·5237	1·9094	0·8047	1·2427	1·1157	0·8963	0·7644	1·3083
	9·8630	0·1370	9·7005	0·2995	9·7191	0·2809	9·9056	0·0944	0·0476	9·9524	9·8833	0·1167
M_2, MS	1·0188	0·9816	1·0068	0·9933	0·9942	1·0058	0·9826	1·0177	0·9730	1·0278	0·9664	1·0347
	0·0081	9·9919	0·0029	9·9971	9·9975	0·0025	9·9924	0·0076	9·9881	0·0119	9·9852	0·0148
M_3	1·0283	0·9725	1·0102	0·9899	0·9914	1·0087	0·9740	1·0267	0·9597	1·0420	0·9501	1·0525
	0·0121	9·9879	0·0044	9·9956	9·9962	0·0038	9·9885	0·0115	9·9822	0·0179	9·9778	0·0222
M_4, MN	1·0379	0·9635	1·0136	0·9866	0·9886	1·0116	0·9654	1·0358	0·9466	1·0564	0·9340	1·0707
	0·0162	9·9838	0·0059	9·9941	9·9950	0·0050	9·9847	0·0153	9·6762	0·0238	9·9703	0·0297
M_6	1·0574	0·9457	1·0205	0·9799	0·9829	1·0174	0·9486	1·0542	0·9210	1·0858	0·9026	1·1079
	0·0242	9·9758	0·0088	9·9912	9·9925	0·0075	9·9771	0·0229	9·9643	0·0357	9·9555	0·0445
M_8	1·0773	0·9283	1·0274	0·9733	0·9772	1·0233	0·9321	1·0729	0·8961	1·1159	0·8723	1·1464
	0·0323	9·9677	0·0118	9·9882	9·9900	0·0100	9·9694	0·0306	9·9524	0·0476	9·9407	0·0593
N_2, 2 N	1·0188	0·9816	1·0068	0·9933	0·9942	1·0058	0·9826	1·0177	0·9730	1·0278	0·9664	1·0347
	1·0081	9·9919	0·0029	9·9971	9·9975	0·0025	9·9924	0·0076	9·9881	0·0119	9·9852	0·0148
O_1, Q_1	0·9020	1·1086	0·9466	1·0564	1·0048	0·9952	1·0743	0·9308	1·1477	0·8713	1·2096	0·8267
	9·9552	0·0448	9·9762	0·0238	0·0021	9·9979	0·0311	9·9689	0·0598	9·9402	0·0826	9·9174
OO	0·7072	1·4141	0·8369	1·1948	1·0263	0·9744	1·2843	0·7787	1·5969	0·6262	1·8950	0·5277
	9·8495	0·1505	9·9227	0·0773	0·0113	9·9887	0·1086	9·8914	0·2033	9·7967	0·2776	9·7224
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1, 2, 3, 4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ_2, μ_2, ν_2	1·0188	0·9816	1·0068	0·9933	0·9942	1·0058	0·9826	1·0177	0·9730	1·0278	0·9664	1·0347
	0·0081	9·9919	0·0029	9·9971	9·9975	0·0025	9·9924	0·0076	9·9881	0·0119	9·9852	0·0148
MK	0·9544	1·0478	0·9726	1·0282	0·9969	1·0031	1·0261	0·9746	1·0562	0·9468	1·0807	0·9253
	9·9797	0·0203	9·9879	0·0121	9·9987	0·0013	0·0112	9·9888	0·0237	9·9763	0·0337	9·9663
2 MK	0·9723	1·0284	0·9792	1·0213	0·9912	1·0089	1·0082	0·9919	1·0276	0·9732	1·0444	0·9575
	9·9878	0·0122	9·9909	0·0091	9·9962	0·0038	0·0035	9·9965	0·0118	9·9882	0·0189	9·9811
2 MS	1·0379	0·9635	1·0136	0·9866	0·9886	1·0116	0·9654	1·0358	0·9466	1·0564	0·9340	1·0707
	0·0162	9·9838	0·0059	9·9941	9·9950	0·0050	9·9847	0·0153	9·9762	0·0238	9·9703	0·0297
MSf, 2 SM	1·0188	0·9816	1·0068	0·9933	0·9942	1·0058	0·9826	1·0177	0·9730	1·0278	0·9664	1·0347
	0·0081	9·9919	0·0029	9·9971	9·9975	0·0025	9·9924	0·0076	9·9881	0·0119	9·9852	0·0148
Mf	0·7987	1·2521	0·8901	1·1235	1·0155	0·9847	1·1746	0·8514	1·3538	0·7387	1·5140	0·6605
	9·9024	0·0976	9·9494	0·0506	0·0067	9·9933	0·0699	9·9301	0·1316	9·8684	0·1801	9·8199
Mm	1·0703	0·9343	1·0260	0·9747	0·9820	1·0183	0·9432	1·0602	0·9127	1·0956	0·8927	1·1202
	0·0295	9·9705	0·0111	9·9889	9·9921	0·0079	9·9746	0·0254	9·9603	0·0397	9·9507	0·0493
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1922		1923		1924		1925		1926		1927	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	1·2087	0·8273	1·1967	0·8357	1·1498	0·8697	1·0854	0·9213	1·0204	0·9800	0·9643	1·0370
	0·0823	9·9177	0·0780	9·9220	0·0606	9·9394	0·0356	9·9644	0·0088	9·9912	9·9842	0·0158
K_1	1·1338	0·8820	1·1272	0·8872	1·1006	0·9086	1·0618	0·9418	1·0195	0·9808	0·9804	1·0200
	0·0545	9·9455	0·0520	9·9480	0·0416	9·9584	0·0260	9·9740	0·0084	9·9916	9·9914	0·0086
K_2	1·3366	0·7482	1·3226	0·7561	1·2644	0·7909	1·1740	0·8518	1·0703	0·9343	0·9710	1·0299
	0·1260	9·8740	0·1214	9·8786	0·1019	9·8981	0·0697	9·9303	0·0295	9·9705	9·9872	0·0128
L_2	1·1489	0·8704	1·0734	0·9316	0·8828	1·1328	0·8340	1·1990	1·0387	0·9627	1·4953	0·6688
	0·0603	9·9397	0·0308	9·9692	9·9459	0·0541	9·9212	0·0788	0·0165	9·9835	0·1747	9·8253
$[L_2]$	0·9636	1·0378	0·9648	1·0365	0·9698	1·0311	0·9783	1·0222	0·9892	1·0109	1·0016	0·9984
	9·9839	0·0161	9·9844	0·0156	9·9867	0·0133	9·9905	0·0095	9·9953	0·0047	0·0007	9·9993
M_1	0·6260	1·5974	0·6653	1·5030	0·9244	1·0818	1·0488	0·9535	0·6177	1·6190	0·4847	2·0630
	9·7966	0·2034	9·8230	0·1770	9·9659	0·0341	0·0207	9·9793	9·7908	0·2092	9·6855	0·3145
M_2, MS	0·9636	1·0378	0·9648	1·0365	0·9698	1·0311	0·9783	1·0222	0·9892	1·0109	1·0016	0·9984
	9·9839	0·0161	9·9844	0·0156	9·9867	0·0133	9·9905	0·0095	9·9953	0·0047	0·0007	9·9993
M_3	0·9459	1·0572	0·9476	1·0553	0·9551	1·0470	0·9676	1·0335	0·9839	1·0164	1·0024	0·9976
	9·9758	0·0242	9·9766	0·0234	9·9800	0·0200	9·9857	0·0143	9·9930	0·0070	0·0010	9·9990
M_4, MN	0·9285	1·0770	0·9308	1·0743	0·9406	1·0632	0·9570	1·0449	0·9786	1·0219	1·0032	0·9968
	9·9678	0·0322	9·9689	0·0311	9·9734	0·0266	9·9809	0·0191	9·9906	0·0094	0·0014	9·9986
M_6	0·8947	1·1176	0·8980	1·1136	0·9122	1·0962	0·9362	1·0681	0·9681	1·0330	1·0048	0·9952
	9·9517	0·0483	9·9533	0·0467	9·9601	0·0399	9·9714	0·0286	9·9859	0·0141	0·0021	9·9979
M_8	0·8622	1·1598	0·8664	1·1542	0·8847	1·1303	0·9159	1·0918	0·9576	1·0442	1·0064	0·9937
	9·9356	0·0644	9·9377	0·0623	9·9468	0·0532	9·9618	0·0382	9·9812	0·0188	0·0028	9·9972
N_2, 2 N	0·9636	1·0378	0·9648	1·0365	0·9698	1·0311	0·9783	1·0222	0·9892	1·0109	1·0016	0·9984
	9·9839	0·0161	9·9844	0·0156	9·9867	0·0133	9·9905	0·0095	9·9953	0·0047	0·0007	9·9993
O_1, Q_1	1·2403	0·8063	1·2272	0·8149	1·1758	0·8504	1·1049	0·9050	1·0325	0·9685	0·9692	1·0318
	0·0935	9·9065	0·0889	9·9111	0·0704	9·9296	0·0433	9·9567	0·0139	9·9861	9·9864	0·0136
OO	2·0547	0·4867	1·9853	0·5037	1·7284	0·5786	1·4095	0·7095	1·1248	0·8891	0·9074	1·1020
	0·3128	9·6872	0·2978	9·7022	0·2376	9·7624	0·1491	9·8509	0·0510	9·9490	9·9578	0·0422
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1, 2, 3, 4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ, μ_2, ν_2	0·9636	1·0378	0·9648	1·0365	0·9698	1·0311	0·9783	1·0222	0·9892	1·0109	1·0016	0·9984
	9·9839	0·0161	9·9844	0·0156	9·9867	0·0133	9·9905	0·0095	9·9953	0·0047	0·0007	9·9993
MK	1·0925	0·9153	1·0875	0·9196	1·0674	0·9368	1·0387	0·9627	1·0086	0·9915	0·9820	1·0184
	0·0384	9·9616	0·0364	9·9636	0·0283	9·9717	0·0165	9·9835	0·0037	9·9963	9·9921	0·0079
2 MK	1·0527	0·9499	1·0492	0·9531	1·0352	0·9660	1·0162	0·9841	0·9977	1·0023	0·9835	1·0168
	0·0223	9·9777	0·0208	9·9792	0·0150	9·9850	0·0070	9·9930	9·9990	0·0010	9·9928	0·0072
2 MS	0·9285	1·0770	0·9308	1·0743	0·9406	1·0632	0·9570	1·0449	0·9786	1·0219	1·0032	0·9968
	9·9678	0·0322	9·9689	0·0311	9·9734	0·0266	9·9809	0·0191	9·9906	0·0094	0·0014	9·9986
MSf, 2 SM	0·9636	1·0378	0·9648	1·0365	0·9698	1·0311	0·9783	1·0222	0·9892	1·0109	1·0016	0·9984
	9·9839	0·0161	9·9844	0·0156	9·9867	0·0133	9·9905	0·0095	9·9953	0·0047	0·0007	9·9993
Mf	1·5964	0·6264	1·5608	0·6407	1·4256	0·7014	1·2480	0·8013	1·0776	0·9280	0·9378	1·0664
	0·2031	9·7969	0·1933	9·8066	0·1540	9·8460	0·0962	9·9038	0·0325	9·9675	9·9721	0·0279
Mm	0·8843	1·1309	0·8878	1·1264	0·9031	1·1073	0·9294	1·0759	0·9651	1·0361	1·0074	0·9926
	9·9466	0·0534	9·9483	0·0517	9·9557	0·0443	9·9682	0·0318	9·9846	0·0154	0·0032	9·9968
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1928		1929		1930		1931		1932		1933	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	0·9204	1·0864	0·8891	1·1247	0·8692	1·1505	0·8595	1·1634	0·8594	1·1636	0·8688	1·1510
	9·9640	0·0360	9·9490	0·0510	9·9391	0·0609	9·9342	0·0658	9·9342	0·0658	9·9389	0·0611
K_1	0·9479	1·0549	0·9236	1·0827	0·9076	1·1018	0·8997	1·1115	0·8996	1·1116	0·9073	1·1022
	9·9768	0·0232	9·9655	0·0345	9·9579	0·0421	9·9541	0.0459	9·9540	0·0460	9·9578	0·0422
K_2	0·8872	1·1271	0·8241	1·2135	0·7826	1·2778	0·7619	1·3125	0·7617	1·3129	0·7818	1·2791
	9·9480	0·0520	9·9160	0·0840	9·8935	0·1065	9·8819	0·1181	9·8818	0·1182	9·8931	0·1069
L_2	1·0256	0·9750	0·7874	1·2700	0·9781	1·0224	2·1230	0·4710	1·1452	0·8732	0·7874	1·2700
	0·0110	9·9890	9·8962	0·1038	9·9904	0·0096	0·3270	9·6730	0·0589	9·9411	9·8962	0·1038
$[L_2]$	1·0140	0·9862	1·0250	0·9756	1·0332	0·9679	1·0376	0·9637	1·0377	0·9637	1·0334	0·9677
	0·0060	9·9940	0·0107	9·9893	0·0142	9·9858	0·0160	9·9840	0·0161	9·9839	0·0142	9·9858
M_1	0·5750	1·7392	0·8787	1·1380	0·7625	1·3115	0·4250	2·3529	0·5020	1·9921	0·8354	1·1970
	9.7597	0·2403	9·9438	0·0562	9·8823	0·1117	9·6284	0·3716	9·7007	0·2993	9·9219	0·0781
M_2, MS	1·0140	0·9862	1·0250	0·9756	1·0332	0·9679	1·0376	0·9637	1·0377	0·9637	1·0334	0·9677
	0·0060	9·9940	0·0107	9·9893	0·0142	9·9858	0·0160	9·9840	0·0161	9·9839	0·0142	9·9858
M_3	1·0210	0·9794	1·0376	0·9637	1·0502	0·9522	1·0570	0·9461	1·0570	0·9460	1·0505	0·9519
	0·0090	9·9910	0·0160	9·9840	0·0213	9·9787	0·0241	9·9759	0·0241	9·9759	0·0214	9·9786
M_4, MN	1·0282	0·9726	1·0506	0·9519	1·0675	0·9368	1·0767	0·9288	1·0768	0·9287	1·0678	0·9365
	0·0121	9·9879	0·0214	9·9786	0·0284	9·9716	0·0321	9·9679	0·0321	9·9679	0·0285	9·9715
M_6	1·0425	0·9592	1·0768	0·9287	1·1029	0·9067	1·1772	0·8951	1·1173	0·8950	1·1034	0·9063
	0·0181	9·9819	0·0321	9·9679	0·0425	9·9575	0·0481	9·9519	0·0482	9·9518	0·0428	9·9572
M_8	1·0571	0·9460	1·1037	0·9061	1·1395	0·8776	1·1592	0·8627	1·1594	0·8625	1·1402	0·8770
	0·0241	9·9759	0·0428	9·9572	0·0567	9·9433	0·0642	9·9358	0·0642	9·9358	0·0570	9·9430
N_2, 2 N	1·0140	0·9862	1·0250	0·9756	1·0332	0·9679	1·0376	0·9637	1·0377	0·9637	1·0334	0·9677
	0·0060	9·9940	0·0107	9·9893	0·0142	9·9858	0·0160	9·9840	0·0161	9·9839	0·0142	9·9858
O_1, Q_1	0·9188	1·0883	0·8822	1·1335	0·8586	1·1647	0·8470	1·1807	0·8468	1·1809	0·8582	1·1653
	9·9632	0·0368	9·9456	0·0544	9·9338	0·0662	9·9279	0·0721	9·9278	0·0722	9·9336	0·0664
OO	0·7545	1·3254	0·6536	1·5300	0·5930	1·6865	0·5643	1·7721	0·5640	1·7732	0·5919	1·6896
	9·8777	0·1223	9·8153	0·1847	9·7730	0·2270	9·7515	0·2485	9·7513	0·2487	9·7722	0·2278
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1, 2, 3, 4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ_2, μ_2, ν_2	1·0140	0·9862	1·0250	0·9756	1·0332	0·9679	1·0376	0·9637	1·0377	0·9637	1·0334	0·9677
	0·0060	9.9940	0·0107	9·9893	0·0142	9·9858	0·0160	9·9840	0·0161	9·9839	0·0142	9·9858
MK	0·9612	1·0404	0·9467	1·0564	0·9377	1·0664	0·9335	1·0712	0·9335	1·0713	0·9376	1·0666
	9·9828	0·0172	9·9762	0·0238	9·9721	0·0279	9·9701	0·0299	9·9701	0·0299	9·9720	0·0280
2 MK	0·9746	1·0260	0·9703	1·0306	0·9689	1·0321	0·9686	1·0324	0·9686	1·0324	0·9689	1·0321
	9·9888	0·0112	9·9869	0·0131	9·9863	0·0137	9·9862	0·0138	9·9862	0·0138	9·9863	0·0137
2 MS	1·0282	0·9726	1·0506	0·9519	1·0675	0·9368	1·0767	0·9288	1·0768	0·9287	1·0678	0·9365
	0·0121	9·9879	0·0214	9·9786	0·0284	9·9716	0·0321	9.9679	0·0321	9·9679	0·0285	9·9715
MSf, 2 SM	1·0140	0·9862	1·0250	0·9756	1·0332	0·9679	1·0376	0·9637	1·0377	0·9637	1·0334	0·9677
	0·0060	9·9940	0·0107	9·9893	0·0142	9·9858	0·0160	9·9840	0·0161	9·9839	0·0142	9.9858
Mf	0·8326	1·2010	0·7594	1·3169	0·7135	1·4015	0·6913	1·4465	0·6911	1·4470	0·7127	1·4032
	9·9204	0·0796	9·8804	0·1196	9·8534	0·1466	9·8397	0·1603	9·8395	0·1605	9·8529	0·1471
Mm	1·0523	0·9503	1·0942	0·9139	1·1270	0·8873	1·1452	0·8732	1·1455	0·8730	1·1277	0·8868
	0·0221	9·9779	0·0391	9·9609	0·0519	9·9481	0·0589	9·9411	0·0590	9·9410	0·0522	9·9478
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1934		1935		1636		1937		1938		1939	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	0·8884	1·1256	0·9194	1·0877	0·9629	1·0385	1·0188	0·9815	1·0837	0·9228	1·1482	0·8710
	9·9486	0·0514	9·9635	0·0365	9·9836	0·0164	0·0081	9·9919	0·0349	9·9651	0·0600	9·9400
K_1	0·9231	1·0834	0·9471	1·0558	0·9794	1·0210	1·0185	0·9819	1·0607	0·9428	1·0997	0·9094
	9·9652	0·0348	9·9764	0·0236	9·9910	0·0090	0·0080	9·9920	0·0256	9·9744	0·0413	9·9587
K_2	0·8227	1·2155	0·8852	1·1297	0·9684	1·0326	1·0677	0·9366	1·1714	0·8537	1·2622	0·7923
	9·9152	0·0848	9·9470	0·0530	9·9861	0·0139	0·0284	9·9716	0·0687	9·9313	0·1011	9·8989
L_2	0·9274	1·0783	1·5720	0·6361	1·1645	0·8588	0·8401	1·1903	0·8602	1·1625	1·0681	0·9363
	9·9673	0·0327	0·1965	9·8035	0·0661	9·9339	9·9243	0·0757	9·9346	0·0654	0·0286	9·9714
$[L_2]$	1·0252	0·9754	1·0143	0·9859	1·0019	0·9981	0·9895	1·0106	0·9785	1·0220	0·9700	1 0309
	0·0108	9·9892	0·0062	9·9938	0·0008	9·9992	9·9954	0·0046	9·9906	0·0094	9·9868	0·0132
M_1	0·6196	1·6139	0·4655	2·1482	0·5407	1·8495	0·9109	1·0978	0·9269	1·0789	0·6518	1·5342
	9·7921	0·2079	9·6679	0·3321	9·7329	0·2671	9·9595	0·0405	9·9670	0·0330	9·8141	0·1859
M_2, MS	1·0252	0·9754	1·0143	0·9859	1·0019	0·9981	0·9895	1·0106	0·9785	1·0220	0·9700	1·0309
	0·0108	9.9892	0·0062	9·9938	0·0008	9·9992	9·9954	0·0046	9·9906	0·0094	9·9868	0·0132
M_3	1·0381	0·9633	1·0216	0·9789	1·0028	0·9972	0·9843	1·0159	0·9680	1·0331	0·9554	1·0467
	0·0162	9·9838	0·0093	9·9907	0·0012	9·9988	9·9931	0·0069	9·9859	0·0141	9·9802	0·0198
M_4, MN	1·0511	0·9514	1·0288	0·9720	1·0038	0·9962	0·9792	1·0213	0·9575	1·0444	0·9409	1·0628
	0·0216	9·9784	0·0123	9·9877	0·0017	9·9983	9·9909	0·0091	9·9811	0·0189	9·9736	0·0264
M_6	1·0776	0·9280	1·0435	0·9583	1·0057	0·9943	0·9689	1·0321	0·9369	1·0673	0·9127	1·0956
	0·0325	9·9675	0·0185	9·9815	0·0025	9·9975	9·9863	0·0137	9·9717	0·0283	9·9603	0·0397
M_8	1·1048	0·9051	1·0585	0·9448	1·0077	0·9924	0·9588	1·0430	0·9168	1·0907	0·8854	1·1295
	0·0433	9·9567	0·0247	9·9753	0·0033	9·9967	9·9817	0·0183	9·9623	0·0377	9·9471	0·0529
N_2, 2 N	1·0252	0·9754	1·0143	0·9859	1·0019	0·9981	0·9895	1·0106	0·9785	1·0220	0·9700	1·0309
	0·0108	9·9892	0·0062	9·9938	0·0008	9·9992	9·9954	0·0046	9·9906	0·0094	9·9868	0·0132
O_1, Q_1	0·8814	1·1345	0·9176	1·0898	0·9676	1·0335	1·0307	0·9702	1·1030	0·9066	1·1740	0·8518
	9·9452	0·0548	9·9627	0·0373	9·9857	0·0143	0·0132	9·9868	0·0426	9·9574	0·0697	9·9303
OO	0·6515	1·5348	0·7510	1·3315	0·9024	1·1081	1·1184	0·8942	1·4014	0·7136	1·7198	0·5814
	9·8139	0·1861	9·8757	0·1243	9·9554	0·0446	0·0486	9·9514	0·1466	9·8534	0·2355	9·7645
P_1, R_2, T_2	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
$S_{1,2,3,4}$	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
λ_2, μ_2, ν_2	1·0252	0·9754	1·0143	0·9859	1·0019	0·9981	0·9895	1·0106	0·9785	1·0220	0·9700	1·0309
	0·0108	9·9892	0·0062	9·9938	0·0008	9·9992	9·9954	0·0046	9·9906	0·0094	9·9868	0·0132
MK	0·9463	1·0567	0·9607	1·0409	0·9813	1·0191	1·0078	0·9922	1·0379	0·9635	1·0667	0·9375
	9·9760	0·0240	9·9826	0·0174	9·9918	0·0082	0·0034	9·9966	0·0162	9·9838	0·0280	9·9720
2 MK	0·9702	1·0307	0·9744	1·0262	0·9832	1·0171	0·9973	1·0027	1·0156	0·9846	1·0347	0·9665
	9·9869	0·0131	9·9888	0·0112	9·9926	0·0074	9·9988	0·0012	0·0067	9·9933	0·0148	9·9852
2 MS	1·0511	0·9514	1·0288	0·9720	1·0038	0·9962	0·9792	1·0213	0·9575	1·0444	0·9409	1·0628
	0·0216	9·9784	0·0123	9·9877	0·0017	9·9983	9·9909	0·0091	9·9811	0·0189	9·9736	0·0264
MSf, 2 SM	1·0252	0·9754	1·0143	0·9859	1·0019	0·9981	0·9895	1·0106	0·9785	1·0220	0·9700	1·0309
	0·0108	9·9892	0·0062	9·9938	0·0008	9·9992	9·9954	0·0046	9·9906	0·0094	9·9868	0·0132
Mf	0·7578	1·3196	0·8302	1·2046	0·9344	1·0702	1·0736	0·9314	1·2433	0·8043	1·4210	0·7038
	9·8796	0·1204	9·9192	0·0808	9·9706	0·0294	0·0309	9·9691	0·0946	9·9054	0·1526	9·8474
Mm	1·0952	0·9131	1·0535	0·9492	1·0086	0·9914	0·9662	1·0350	0·9302	1·0750	0·9037	1·1066
	0·0395	9·9605	0·0226	9·9774	0·0037	9·9963	9·9850	0·0150	9·9686	0·0314	9·9560	0·0440
Sa, Ssa	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1940		1941		1942		1943		1944		1945	
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f
J_1, $[M_1]$	1·1958 0·0776	0·8363 9·9224	1·2089 0·0824	0·8272 9·9176	1·1818 0·0726	0·8462 9·9274	1·1260 0·0515	0·8881 9·9485	1·0597 0·0252	0·9437 9·9748	0·9973 9·9988	1·0028 0·0012
K_1	1·1267 0·0518	0·8876 9·9482	1·1339 0·0546	0·8819 9·9454	1·1189 0·0488	0·8937 9·9512	1·0866 0·0361	0·9203 9·9639	1·0454 0·0193	0·9565 9·9807	1·0037 0·0016	0·9963 9·9984
K_2	1·3216 0·1211	0·7567 9·8789	1·3369 0·1261	0·7480 9·8739	1·3048 0·1156	0·7664 9·8844	1·2323 0·0907	0·8115 9·9093	1·1344 0·0548	0·8815 9·9452	1·0305 0·0130	0·9704 9·9870
L_2	1·1635 0·0658	0·8595 9·9342	0·9794 9·9909	1·0211 0·0091	0·8474 9·9281	1·1801 0.0719	0·8738 9·9414	1·1444 0·0586	1·1415 0·0575	0·8760 9·9425	1·3364 0·1259	0·7483 9·8741
$[L_2]$	0·9649 9·9845	1·0364 0·0155	0·9636 9·9839	1·0378 0·0161	0·9663 9·9851	1·0349 0·0149	0·9727 9·9880	1·0280 0·0120	0·9823 9·9922	1·0181 0·0078	0·9939 9·9974	1·0061 0·0026
M_1	0·6160 9·7896	1·6234 0·2104	0·7616 9·8817	1·3131 0·1183	1·1380 0·0561	0·8787 9·9439	0·9294 9·9682	1·0760 0·0318	0·5834 9·7660	1·7142 0·2340	0·5144 9·7113	1·9442 0·2887
M_2, MS	0·9649 9·9845	1·0364 0·0155	0·9636 9·9839	1·0378 0·0161	0·9663 9·9851	1·0349 0·0149	0·9727 9·9880	1·0280 0·0120	0·9823 9·9922	1·0181 0·0078	0·9939 9·9974	1·0061 0·0026
M_3	0·9477 9·9767	1·0551 0·0233	0·9459 9·9758	1·0572 0·0242	0·9499 9·9777	1·0527 0·0223	0·9593 9·9820	1·0424 0·0180	0·9735 9·9883	1·0272 0·0117	0·9909 9·9960	1·0092 0·0040
M_4, MN	0·9310 9·9689	1·0741 0·0311	0·9285 9·9678	1·0770 0·0322	0·9338 9·9702	1·0709 0·0298	0·9462 9·9760	1·0569 0·0240	0·9649 9·9845	1·0364 0·0155	0·9879 9·9947	1·0122 0·0053
M_6	0·8983 9·9534	1·1132 0·0466	0·8947 9·9517	1·1177 0·0483	0·9023 9·9554	1·1083 0·0446	0·9204 9·9640	1·0865 0·0360	0·9477 9·9767	1·0551 0·0233	0·9819 9·9921	1·0184 0·0079
M_8	0·8667 9·9379	1·1538 0·0621	0·8621 9·9356	1·1600 0·0644	0·8719 9·9405	1·1469 0·0595	0·8953 9·9520	1·1170 0·0480	0·9309 9·9689	1·0742 0·0311	0·9760 9·9894	1·0246 0·0106
N_2, 2 N	0·9649 9·9845	1·0364 0·0155	0·9636 9·9839	1·0378 0·0161	0·9663 9·9851	1·0349 0·0149	0·9727 9·9880	1·0280 0·0120	0·9823 9·9922	1·0181 0·0078	0·9939 9·9974	1·0061 0·0026
O_1, Q_1	1·2262 0·0886	0·8155 9·9114	1·2406 0·0936	0·8061 9·9064	1·2109 0·0831	0·8258 9·9169	1·1497 0·0606	0·8698 9·9394	1·0763 0·0319	0·9291 9·9681	1·0065 0·0028	0·9935 9·9972
OO	1·9802 0·2967	0·5050 9·7033	2·0561 0·3130	0·4864 9·6870	1·9016 0·2791	0·5259 9·7209	1·6059 0·2057	0·6227 9·7943	1·2923 0·1114	0·7738 9·8886	1·0321 0·0137	0·9689 9·9863
P_1, R_2, T_2	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000
$S_{1, 2, 3, 4}$	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000
λ_2, μ_2, ν_2	0·9649 9·9845	1·0364 0·0155	0·9636 9·9839	1·0378 0·0161	0·9663 9·9851	1·0349 0·0149	0·9727 9·9880	1·0280 0·0120	0·9823 9·9922	1·0181 0·0078	0·9939 9·9974	1·0061 0·0026
MK	1·0871 0·0363	0·9199 9·9637	1·0926 0·0385	0·9153 9·9615	1·0812 0·0339	0·9249 9·9661	1·0570 0·0241	0·9461 9·9759	1·0269 0·0115	0·9738 9·9885	0·9976 9·9990	1·0024 0·0010
2 MK	1·0489 0·0207	0·9534 9·9793	1·0528 0·0224	0·9498 9·9776	1·0448 0·0190	0·9571 9·9810	1·0281 0·0120	0·9726 9·9880	1·0087 0·0038	0·9914 9·9962	0·9916 9·9963	1·0085 0·0037
2 MS	0·9310 9·9689	1·0741 0·0311	0·9285 9·9678	1·0770 0·0322	0·9338 9·9702	1·0709 0·0298	0·9462 9·9760	1·0569 0·0240	0·9649 9·9845	1·0364 0·0155	0·9879 9·9947	1·0122 0·0053
MSf, 2 SM	0·9649 9·9845	1·0364 0·0155	0·9636 9·9839	1·0378 0·0161	0·9663 9·9851	1·0349 0·0149	0·9727 9·9880	1·0280 0·0120	0·9823 9·9922	1·0181 0·0078	0·9939 9·9974	1·0061 0·0026
Mf	1·5582 0·1926	0·6417 9·8074	1·5971 0·2033	0·6262 9·7967	1·5174 0·1811	0·6590 9·8189	1·3588 0·1331	0·7360 9·8669	1·1794 0·0717	0·8479 9·9283	1·0192 0·0083	0·9811 9·9917
Mm	0·8380 9·9484	1·1261 0·0516	0·8842 9·9466	1·1310 0·0534	0·8923 9·9505	1·1206 0·0495	0·9120 9·9600	1·0965 0·0400	0·9422 9·9742	1·0613 0·0258	0·9810 9·9916	1·0194 0·0084
Sa, Ssa	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000

TABLE 10.—*Factors F and f for reduction and prediction of tides; computed for the middle of each year, or for July 2, at Greenwich mean noon for common years, and at preceding midnight for leap years*—Continued.

Component.	1946		1947		1948		1949		1950		Mean value of f from the years 1850–1942.
	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	F log F	f log f	
J_1, $[M_1]$	0·9458 9·9758	1·0573 0·0242	0·9069 9·9576	1·1027 0·0424	0·8801 9·9446	1·1362 0·0554	0·8643 9·9367	1·1570 0·0633	0·8584 9·9337	1·1650 0·0663	1·00490
K_1	0·9669 9·9854	1·0342 0·0146	0·9375 9·9720	1·0666 0·0280	0·9164 9·9621	1·0912 0·0379	0·9036 9·9560	1·1067 0·0440	0·8987 9·9536	1·1127 0·0464	1·00609
K_2	0·9363 9·9714	1·0681 0·0286	0·8602 9·9346	1·1624 0·0654	0·8055 9·9061	1·2415 0·0939	0·7721 9·8877	1·2951 0·1123	0·7594 9·8805	1·3168 0·1195	1·02421
L_2	0·9165 9·9621	1·0911 0·0379	0·7970 9·9015	1·2547 0·0985	1·1182 0·0485	0·8943 9·9515	2·0764 0·3173	0·4816 9·6827	0·9888 9·9951	1·0113 0·0049	0·97803
$[L_2]$	1·0065 0·0028	0·9936 9·9972	1·0185 0·0080	0·9819 9·9920	1·0285 0·0122	0·9723 9·9878	1·0354 0·0151	0·9658 9·9849	1·0382 0·0163	0·9632 9·9837	1·00033
M_1	0·6755 9·8296	1·4804 0·1704	0·8786 9·9438	1·1382 0·0562	0·5190 9·7151	1·9269 0·2849	0·4275 9·6310	2·3390 0·3690	0·5572 9·7460	1·7947 0·2540	1·55050
M_2, MS	1·0065 0·0028	0·9936 9·9972	1·0185 0·0080	0·9819 9·9920	1·0285 0·0122	0·9723 9·9878	1·0354 0·0151	0·9658 9·9849	1·0382 0·0163	0·9632 9·9837	1·00033
M_3	1·0096 0·0042	0·9904 9·9958	1·0278 0·0119	0·9729 9·9881	1·0431 0·0183	0·9587 9·9817	1·0535 0·0226	0·9492 9·9774	1·0578 0·0244	0·9454 9·9756	1·00074
M_4, MN	1·0129 0·0056	0·9872 9·9944	1·0373 0·0159	0·9641 9·9841	1·0579 0·0244	0·9453 9·9756	1·0721 0·0302	0·9328 9·9698	1·0778 0·0325	0·9278 9·9675	1·00137
M_6	1·0195 0·0084	0·9809 9·9916	1·0565 0·0238	0·9466 9·9762	1·0881 0·0367	0·9191 9·9633	1·1100 0·0453	0·9009 9·9547	1·1189 0·0488	0·8937 9·9512	1·00307
M_8	1·0260 0·0112	0·9746 9·9888	1·0760 0·0318	0·9294 9·9682	1·1191 0·0489	0·8936 9·9511	1·1493 0·0604	0·8701 9·9396	1·1617 0·0651	0·8608 9·9349	1·00552
N_2, 2 N	1·0065 0·0028	0·9936 9·9972	1·0185 0·0080	0·9819 9·9920	1·0285 0·0122	0·9723 9·9878	1·0354 0·0151	0·9658 9·9849	1·0382 0·0163	0·9632 9·9837	1·00033
O_1, Q_1	0·9480 9·9768	1·0548 0·0232	0·9031 9·9557	1·1073 0·0443	0·8716 9·9403	1·1473 0·0597	0·8527 9·9308	1·1727 0·0692	0·8456 9·9272	1·1826 0·0728	1·00905
OO	0·8411 9·9249	1·1889 0·0751	0·7100 9·8513	1·4084 0·1487	0·6259 9·7965	1·5976 0·2035	0·5784 9·7622	1·7290 0·2378	0·5609 9·7489	1·7828 0·2511	1.10310
P_1, R_2, T_2	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·00000
$S_{1, 2, 3, 4}$	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0060	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·00000
λ_2, μ_2, ν_2	1·0065 0·0028	0·9936 9·9972	1·0185 0·0080	0·9819 9·9920	1·0285 0·0122	0·9723 9·9878	1·0354 0·0151	0·9658 9·9849	1·0382 0·0163	0·9632 9·9837	1·00033
MK	0·9731 9·9882	1·0276 0·0118	0·9548 9·9799	1·0473 0·0201	0·9426 9·9743	1·0609 0·0257	0·9356 9·9711	1·0688 0·0289	0·9330 9·9699	1·0718 0·0301	1·00428
2 MK	0·9794 9·9910	1·0210 0·0090	0·9725 9·9879	1·0283 0·0121	0·9695 9·9865	1·0315 0·0135	0·9687 9·9862	1·0323 0·0138	0·9686 9·9862	1·0324 0·0138	1·00315
2 MS	1·0129 0·0056	0·9872 9·9944	1·0373 0·0159	0·9641 9·9841	1·0579 0·0244	0·9453 9·9756	1·0721 0·0302	0·9328 9·9698	1·0778 0·0325	0·9278 9·9675	1·00137
MSf, 2 SM	1·0065 0·0028	0·9936 9·9972	1·0185 0·0080	0·9819 9·9920	1·0285 0·0122	0·9723 9·9878	1·0354 0·0151	0·9658 9·9849	1·0382 0·0163	0·9632 9·9837	1·00033
Mf	0·8930 9·9508	1·1198 0·0492	0·8008 9·9035	1·2488 0·0965	0·7386 9·8684	1·3539 0·1316	0·7023 9·8465	1·4240 0·1535	0·6887 9·8380	1·4520 0·1620	1·04317
Mm	1·0248 0·0106	0·9758 9·9894	1·0692 0·0290	0·9353 9·9710	1·1083 0·0447	0·9023 9·9553	1·1360 0·0554	0·8802 9·9446	1·1475 0·0598	0·8714 9·9402	0·99992
Sa, Ssa	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·0000 0·0000	1·00000

TABLE 11.—*Values of log R′ for obtaining the factor F of* L_2 *from that of* M_2.

P	I = inclination of moon's orbit.											
	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°
°												
0	0·0778	0·0889	0·1014	0·1154	0·1312	0·1491	0·1696	0·1935	0·2216	0·2555	0·2976	0·3523
5	0·0764	0·0873	0·0994	0·1131	0·1284	0·1459	0·1658	0·1888	0·2158	0·2482	0·2881	0·3393
10	0·0722	0·0824	0·0938	0·1064	0·1206	0·1365	0·1547	0·1754	0·1995	0·2279	0·2622	0·3047
15	0·0656	0·0747	0·0847	0·0959	0·1083	0·1221	0·1377	0·1552	0·1753	0·1984	0·2255	0·2579
20	0·0569	0·0646	0·0731	0·0824	0·0926	0·1040	0·1165	0·1305	0·1462	0·1639	0·1840	0·2072
25	0·0467	0·0528	0·0595	0·0668	0·0748	0·0835	0·0930	0·1035	0·1150	0·1277	0·1418	0·1575
30	0·0354	0·0400	0·0448	0·0501	0·0558	0·0620	0·0687	0·0759	0·0837	0·0922	0·1014	0·1114
35	0·0236	0·0265	0·0296	0·0330	0·0366	0·0404	0·0445	0·0489	0·0536	0·0586	0·0640	0·0697
40	0·0117	0·0130	0·0146	0·0161	0·0178	0·0196	0·0215	0·0235	0·0256	0·0278	0·0301	0·0326
45	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
50	9·9889	9·9877	9·9864	9·9850	9·9836	9·9820	9·9805	9·9788	9·9771	9·9754	9·9736	9·9717
55	9·9787	9·9764	9·9739	9·9714	9·9687	9·9659	9·9631	9·9601	9·9570	9·9539	9·9506	9·9473
60	9·9696	9·9663	9·9628	9·9593	9·9556	9·9518	9·9479	9·9439	9·9398	9·9355	9·9312	9·9267
65	9·9616	9·9575	9·9533	9·9490	9·9445	9·9398	9·9351	9·9302	9·9252	9·9201	9·9149	9·9097
70	9·9549	9·9503	9·9454	9·9404	9·9353	9·9300	9·9246	9·9190	9·9134	9·9077	9·9018	9·8959
75	9·9497	9·9445	9·9392	9·9337	9·9281	9·9223	9·9164	9·9104	9·9043	9·8981	9·8918	9·8854
80	9·9459	9·9404	9·9347	9·9289	9·9229	9·9168	9·9106	9·9042	9·8978	9·8913	9·8846	9·8780
85	9·9436	9·9379	9·9320	9·9260	9·9198	9·9135	9·9071	9·9006	9·8939	9·8872	9·8804	9·8735
90	9·9429	9·9371	9·9312	9·9250	9·9188	9·9124	9·9059	9·8993	9·8926	9·8858	9·8790	9·8720
95	9·9436	9·9379	9·9320	9·9260	9·9198	9·9135	9·9071	9·9006	9·8939	9·8872	9·8804	9·8735
100	9·9459	9·9404	9·9347	9·9289	9·9229	9·9168	9·9106	9·9042	9·8978	9·8913	9·8846	9·8780
105	9·9497	9·9445	9·9392	9·9337	9·9281	9·9223	9·9164	9·9104	9·9043	9·8981	9·8918	9·8854
110	9·9549	9·9503	9·9454	9·9404	9·9353	9·9300	9·9246	9·9190	9·9134	9·9077	9·9018	6·8959
115	9·9616	9·9575	9·9533	9·9490	9·9445	9·9398	9·9351	9·9302	9·9252	9·9201	9·9149	9·9097
120	9·9696	9·9663	9·9628	9·9593	9·9556	9·9518	9·9479	9·9439	9·9398	9·9355	9·9312	9·9267
125	9·9787	9·9764	9·9739	9·9714	9·9687	9·9659	9·9631	9·9601	9·9570	9·9539	9·9506	9·9473
130	9·9889	9·9877	9·9864	9·9850	9·9836	9·9820	9·9805	9·9788	9·9771	9·9754	9·9736	9·9717
135	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
140	0·0117	0·0130	0·0146	0·0161	0·0178	0·0196	0·0215	0·0235	0·0256	0·0278	0·0301	0·0326
145	0·0236	0·0265	0·0296	0·0330	0·0366	0·0404	0·0445	0·0489	0·0536	0·0586	0·0640	0·0697
150	0·0354	0·0400	0·0448	0·0501	0·0558	0·0620	0·0687	0·0759	0·0837	0·0922	0·1014	0·1114
155	0·0467	0·0528	0·0595	0·0668	0·0748	0·0835	0·0930	0·1035	0·1150	0·1277	0·1418	0·1575
160	0·0569	0·0646	0·0731	0·0824	0·0926	0·1040	0·1165	0·1305	0·1462	0·1639	0·1840	0·2072
165	0·0656	0·0747	0·0847	0·0959	0·1083	0·1221	0·1377	0·1552	0·1753	0·1984	0·2255	0·2579
170	0·0722	0·0824	0·0938	0·1064	0·1206	0·1365	0·1547	0·1754	0·1995	0·2279	0·2622	0·3047
175	0·0764	0·0873	0·0994	0·1131	0·1284	0·1459	0·1658	0·1888	0·2158	0·2482	0·2881	0·3393
180	0·0778	0·0889	0·1014	0·1154	0·1312	0·1491	0·1696	0·1935	0·2216	0·2555	0·2976	0·3523

Log $F(L_2) = \log F(M_2) + \log R'$, where $R' = \left(\frac{1}{1 - 12 \tan^2 \frac{1}{2} I \cos 2P}\right)^{\frac{1}{2}}$. The values of I and P for the first day of every month are given in Table 6.

When P lies between 180° and 360° subtract 180° from it, and enter the table with the remainder.

TABLE 12.—*Values of log Q′ for obtaining the factor F of* M_1 *from that of* O_1.

P	Log Q′	P	Log Q′	P	Log Q′	P	Log Q′	P	Log Q′	P	Log Q′
°		°		°		°		°		°	
0	9·6990	60	9·8785	120	9·8785	180	9·6990	240	9·8785	300	9·8785
1	9·6990	61	9·8841	121	9·8729	181	9·6990	241	9·8841	301	9·8729
2	9·6992	62	9·8898	122	9·8673	182	9·6992	242	9·8898	302	9·8673
3	9·6994	63	9·8955	123	9·8618	183	9·6994	243	9·8955	303	9·8618
4	9·6998	64	9·9012	124	9·8563	184	9·6998	244	9·9012	304	9·8563
5	9·7002	65	9·9068	125	9·8509	185	9·7002	245	9·9068	305	9·8509
6	9·7008	66	9·9125	126	9·8456	186	9·7008	246	9·9125	306	9·8456
7	9·7014	67	9·9181	127	9·8403	187	9·7014	247	9·9181	307	9·8403
8	9·7022	68	9·9237	128	9·8351	188	9·7022	248	9·9237	308	9·8351
9	9·7030	69	9·9292	129	9·8300	189	9·7030	249	9·9292	309	9·8300
10	9·7039	70	9·9347	130	9·8249	190	9·7039	250	9·9347	310	9·8249
11	9·7050	71	9·9400	131	9·8200	191	9·7050	251	9·9400	311	9·8200
12	9·7061	72	9·9453	132	9·8151	192	9·7061	252	9·9453	312	9·8151
13	9·7074	73	9·9504	133	9·8103	193	9·7074	253	9·9504	313	9·8103
14	9·7087	74	9·9554	134	9·8056	194	9·7087	254	9·9554	314	9·8056
15	9·7102	75	9·9602	135	9·8010	195	9·7102	255	9·9602	315	9·8010
16	9·7117	76	9·9649	136	9·7965	196	9·7117	256	9·9649	316	9·7965
17	9·7134	77	9·9693	137	9·7921	197	9·7134	257	9·9693	317	9·7921
18	9·7151	78	9·9735	138	6·7878	198	9·7151	258	9·9735	318	9·7878
19	9·7170	79	9·9775	139	9·7836	199	9·7170	259	9·9775	319	9·7836
20	9·7190	80	9·9812	140	9·7795	200	9·7190	260	9·9812	320	9·7795
21	9·7210	81	9·9846	141	9·7755	201	9·7210	261	9·9846	321	9·7755
22	9·7231	82	9·9877	142	9·7716	202	9·7231	262	9·9877	322	9·7716
23	9·7254	83	9·9905	143	9·7678	203	9·7254	263	9·9905	323	9·7678
24	9·7277	84	9·9930	144	9·7641	204	9·7277	264	9·9930	324	9·7641
25	9·7302	85	9·9951	145	9·7605	205	9·7302	265	9·9951	325	9·7605
26	9·7328	86	9·9968	146	9·7570	206	9·7328	266	9·9968	326	9·7570
27	9·7354	87	9·9982	147	9·7536	207	9·7354	267	9·9982	327	9·7536
28	9·7382	88	9·9992	148	9·7503	208	9·7382	268	9·9992	328	9·7503
29	9·7411	89	9·9998	149	9·7471	209	9·7411	269	9·9998	329	9·7471
30	9·7441	90	10·0000	150	9·7441	210	9·7441	270	10.0000	330	9·7441
31	9·7471	91	9·9998	151	9·7411	211	9·7471	271	9·9998	331	9·7411
32	9·7503	92	9·9992	152	9·7382	212	9·7503	272	9·9992	332	9·7382
33	9·7536	93	9·9982	153	9·7354	213	9·7536	273	9·9982	333	9·7354
34	9·7570	94	9·9968	154	9·7328	214	9·7570	274	9·9968	334	9·7328
35	9·7605	95	9·9951	155	9·7302	215	9·7605	275	9·9951	335	9·7302
36	9·7641	96	9·9930	156	9·7277	216	9·7641	276	9·9930	336	9·7277
37	9·7678	97	9·9905	157	9·7254	217	9·7678	277	9·9905	337	9·7254
38	9·7716	98	9·9877	158	9·7231	218	9·7716	278	9·9877	338	9·7231
39	9·7755	99	9·9846	159	9·7210	219	9·7755	279	9·9846	339	9·7210
40	9·7795	100	9·9812	160	9·7190	220	9·7795	280	9·9812	340	9·7190
41	9·7836	101	9·9775	161	9·7170	221	9·7836	281	9·9775	341	9·7170
42	9·7878	102	9·9735	162	9·7151	222	9·7878	282	9·9735	342	9·7151
43	9·7921	103	9·9693	163	9·7134	223	9·7921	283	9·9693	343	9·7134
44	9·7965	104	9·9649	164	9·7117	224	9·7965	284	9·9649	344	9·7117
45	9·8010	105	9·9602	165	9·7102	225	9·8010	285	9·9602	345	9·7102
46	9·8056	106	9·9554	166	9·7087	226	9·8056	286	9·9554	346	9·7087
47	9·8103	107	9·9504	167	9·7074	227	9·8103	287	9·9504	347	9·7074
48	9·8151	108	9·9453	168	9·7061	228	9·8151	288	9·9453	348	9·7061
49	9·8200	109	9·9400	169	9·7050	229	9·8200	289	9·9400	349	9·7050
50	9·8249	110	9·9347	170	9·7039	230	9·8249	290	9·9347	350	9·7039
51	9·8300	111	9·9292	171	9·7030	231	9·8300	291	9·9292	351	9·7030
52	9·8351	112	9·9237	172	9·7022	232	9·8351	292	9·9237	352	9·7022
53	9·8403	113	9·9181	173	9·7014	233	9·8403	293	9·9181	353	9·7014
54	9·8456	114	9·9125	174	9·7008	234	9·8456	294	9·9125	354	9·7008
55	9·8509	115	9·9068	175	9·7002	235	9·8509	295	9·9068	355	9·7002
56	9·8563	116	9·9012	176	9·6998	236	9·8563	296	9·9012	356	9·6998
57	9·8618	117	9·8955	177	9·6994	237	9·8618	297	9·8955	357	9·6994
58	9·8673	118	9·8898	178	9·6992	238	9·8673	298	9·8898	358	9·6992
59	9·8729	119	9·8841	179	9·6990	239	9·8729	299	9·8841	359	9·6990

$\text{Log } F\,(M_1) = \log F\,(O_1) + \log Q'$, where $Q' = \frac{1}{(2{\cdot}5 + 1{\cdot}5 \cos 2P)^{\frac{1}{2}}}$.

The value of P for the first day of every month is given in Table 6.

TABLE 13.—*Factors F and f, corresponding to every tenth of a degree of I, for reduction and prediction of tides.*

I	$F(J_1)$	Diff.	$f(J_1)$	Diff.	I	$F(J_1)$	Diff.	$f(J_1)$	Diff.
°					°				
18·3	1·21005	565	0·82640	389	23·3	0·99297	326	1·00708	332
·4	·20440	558	·83029	387	·4	·98971	323	·01040	330
·5	·19882	552	·83416	385	·5	·98648	319	·01370	330
·6	·19330	546	·83801	385	·6	·98329	317	·01700	328
·7	·18784	539	·84186	384	·7	·98012	313	·02028	327
·8	·18245	533	·84570	383	·8	·97699	310	·02355	326
18·9	·17712	527	·84953	382	23·9	·97389	306	·02681	324
19·0	·17185	520	·85335	381	24·0	·97083	304	·03005	323
·1	·16665	514	·85716	379	·1	·96779	300	·03328	322
·2	·16151	509	·86095	379	·2	·96479	298	·03650	320
·3	·15642	503	·86474	377	·3	·96181	295	·03970	320
·4	·15139	497	·86851	377	·4	·95886	291	·04290	318
19·5	·14642	491	·87228	375	24·5	·95595	288	·04608	316
·6	·14151	486	·87603	375	·6	·95307	286	·04924	316
·7	·13665	480	·87978	373	·7	·95021	283	·05240	314
·8	·13185	475	·88351	372	·8	·94738	280	·05554	313
19·9	·12710	470	·88723	372	24·9	·94458	277	·05867	312
20·0	·12240	464	·89095	370	25·0	·94181	275	·06179	310
·1	·11776	459	·89465	369	·1	·93906	272	·06489	309
·2	·11317	454	·89834	368	·2	·93634	269	·06798	308
·3	·10863	449	·90202	366	·3	·93365	266	·07106	306
·4	·10414	444	·90568	366	·4	·93099	264	·07412	305
20·5	·09970	439	·90934	365	25·5	·92835	261	·07717	304
·6	·09531	435	·91299	363	·6	·92574	258	·08021	303
·7	·09096	429	·91662	362	·7	·92316	256	·08324	301
·8	·08667	425	·92024	362	·8	·92060	254	·08625	300
20·9	·08242	420	·92386	360	25·9	·91806	251	·08925	298
21·0	·07822	416	·92746	359	26·0	·91555	248	·09223	298
·1	·07406	411	·93105	358	·1	·51307	246	·09521	296
·2	·06995	407	·93463	356	·2	·91061	244	·09817	294
·3	·06588	403	·93819	356	·3	·90817	241	·10111	293
·4	·06185	398	·94175	354	·4	·90576	239	·10404	292
21·5	·05787	394	·94529	354	26·5	·90337	236	·10696	291
·6	·05393	389	·94883	352	·6	·90101	234	·10987	289
·7	·05004	386	·95235	351	·7	·89867	232	·11276	288
·8	·04618	381	·95586	350	·8	·89635	230	·11564	286
21·9	·04237	378	·95936	348	26·9	·89405	227	·11850	285
22·0	·03859	373	·96284	348	27·0	·89178	225	·12135	284
·1	·03486	370	·96632	346	·1	·88953	223	·12419	282
·2	·03116	365	·96978	345	·2	·88730	220	·12701	281
·3	·02751	362	·97323	344	·3	·88510	219	·12982	280
·4	·02389	358	·97667	343	·4	·88291	216	·13262	278
22·5	·02031	354	·98010	341	27·5	·88075	214	·13540	277
·6	·01677	351	·98351	341	·6	·87861	213	·13817	275
·7	·01326	347	·98692	339	·7	·87648	210	·14092	274
·8	·00979	343	·99031	338	·8	·87438	208	·14366	273
22·9	·00636	340	·99369	336	27·9	·87230	205	·14639	271
23·0	1·00296	337	0·99705	336	28·0	·87025	204	·14910	270
·1	0·99959	333	1·00041	334	·1	·86821	202	·15180	268
·2	·99626	329	·00375	333	·2	·86619	200	·15448	267
23·3	0·99297	326	1·00708	332	·3	·86419	198	·15715	266
					·4	·86221	196	·15981	264
					·5	·86025	194	·16245	263
					28·6	0·85831		1·16508	

$$F = 1/f = \frac{\sin\omega\cos\omega\,(1 - \frac{3}{2}\sin^2 i)}{\sin I\cos I} = \frac{0{\cdot}72147}{\sin 2I}.$$

$F(J_1) = F$ for lunar K_1.

$f(J_1) = f$ for lunar K_1.

I is given for the first of each month in Table 6.

TABLE 13.—*Factors F and f, corresponding to every tenth of a degree of I, for reduction and prediction of tides*—Continued.

I	$F(K_1)$	Diff.	$f(K_1)$	Diff.	I	$F(K_1)$	Diff.	$f(K_1)$	Diff.
°					°				
18·3	1·13450	308	0·88145	240	23·3	1·00073	228	0·99927	228
·4	·13142	307	·88385	241	·4	0·99845	226	1·00155	228
·5	·12835	305	·88626	240	·5	·99619	224	·00383	227
·6	·12530	303	·88866	240	·6	·99395	223	·00610	226
·7	·12227	301	·89106	239	·7	·99172	222	·00836	226
·8	·11926	299	·89345	240	·8	·98950	221	·01062	225
18·9	·11627	298	·89585	239	23·9	·98729	219	·01287	225
19·0	·11329	296	·89824	240	24·0	·98510	217	·01512	225
·1	·11033	294	·90064	240	·1	·98293	216	·01737	224
·2	·10739	292	·90304	239	·2	·98077	215	·01961	224
·3	·10447	291	·90543	238	·3	·97862	214	·02185	224
·4	·10156	289	·90781	238	·4	·97648	213	·02409	223
19·5	·09867	288	·91019	239	24·5	·97435	210	·02632	222
·6	·09579	286	·91258	239	·6	·97225	209	·02854	222
·7	·09293	284	·91497	238	·7	·97016	208	·03076	221
·8	·09009	282	·91735	239	·8	·96808	207	·03297	221
19·9	·08727	281	·91974	238	24·9	·96601	205	·03518	220
20·0	·08446	280	·92212	239	25·0	·96396	203	·03738	220
·1	·08166	277	·92451	238	·1	·96193	202	·03958	219
·2	·07889	276	·92689	238	·2	·95991	201	·04177	219
·3	·07613	274	·92927	237	·3	·95790	200	·04396	218
·4	·07339	272	·93164	236	·4	·95590	199	·04614	218
20·5	·07067	271	·93400	237	25·5	·95391	197	·04832	217
·6	·06796	269	·93637	237	·6	·95194	195	·05049	216
·7	·06527	268	·93874	237	·7	·94999	194	·05265	216
·8	·06259	267	·94111	236	·8	·94805	193	·05481	215
20·9	·05992	265	·94347	236	25·9	·94612	193	·05696	215
21·0	·05727	263	·94583	236	26·0	·94419	191	·05911	214
·1	·05464	261	·94819	235	·1	·94228	189	·06125	213
·2	·05203	260	·95054	235	·2	·94039	188	·06338	213
·3	·04943	258	·95289	235	·3	·93851	187	·06551	213
·4	·04685	256	·95524	235	·4	·93664	185	·06764	212
21·5	·04429	255	·95759	235	26·5	·93479	184	·06976	211
·6	·04174	254	·95994	234	·6	·93295	183	·07187	211
·7	·03920	252	·96228	234	·7	·93112	182	·07398	210
·8	·03668	251	·96462	234	·8	·92930	181	·07608	209
21·9	·03417	249	·96696	233	26·9	·92749	179	·07817	209
22·0	·03168	247	·96929	233	27·0	·92570	178	·08026	208
·1	·02921	245	·97162	232	·1	·92392	176	·08234	207
·2	·02676	244	·97394	232	·2	·92216	175	·08441	206
·3	·02432	243	·97626	232	·3	·92041	174	·08647	206
·4	·02189	241	·97858	231	·4	·91867	174	·08853	206
22·5	·01948	239	·98089	231	27·5	·91693	172	·09059	205
·6	·01709	238	·98320	231	·6	·91521	170	·09264	204
·7	·01471	237	·98551	230	·7	·91351	170	·09468	204
·8	·01234	236	·98781	230	·8	·91181	168	·09672	203
22·9	·00998	234	·99011	230	27·9	·91013	167	·09875	202
23·0	·00764	232	·99241	229	28·0	·90846	166	·10077	201
·1	·00532	230	·99470	228	·1	·90680	165	·10278	200
·2	·00302	229	·99698	229	·2	·90515	163	·10478	200
23·3	1·00073	228	0·99927	228	·3	·90352	162	·10678	200
					·4	·90190	162	·10878	199
					·5	·90028	160	·11077	198
					28·6	0·89868		1·11275	

$$F = 1/f = \frac{1{\cdot}05628}{(\sin^2 2I + 0{\cdot}66962 \cos \nu \sin 2I + 0{\cdot}11210)^{\frac{1}{2}}}.$$

I is given for the first of each month in Table 6.

TABLE 13.—*Factors F and f, corresponding to every tenth of a degree of I, for reduction and prediction of tides*—Continued.

I	$F(K_2)$	Diff.	$f(K_2)$	Diff.	I	$F(K_2)$	Diff.	$f(K_2)$	Diff.
°					°				
18·3	1·33821	652	0·74732	363	23·3	1·02291	578	0·97760	556
·4	·33169	651	·75095	367	·4	·01713	576	·98316	560
·5	·32518	652	·75462	372	·5	·01137	572	·98876	563
·6	·31866	652	·75834	377	·6	·00565	569	0·99439	566
·7	·31214	652	·76211	381	·7	0·99996	567	1·00005	570
·8	·30562	652	·76592	385	·8	·99429	564	·00575	573
18·9	·29910	653	·76977	388	23·9	·98865	561	·01148	577
19·0	·29257	653	·77365	392	24·0	·98304	558	·01725	580
·1	·28604	653	·77757	397	·1	·97746	554	·02305	583
·2	·27951	653	·78154	401	·2	·97192	551	·02888	587
·3	·27298	653	·78555	405	·3	·96641	548	·03475	590
·4	·26645	652	·78960	409	·4	·96093	545	·04065	594
19·5	·25993	652	·79369	412	24·5	·95548	542	·04659	597
·6	·25341	651	·79781	417	·6	·95006	539	·05256	600
·7	·24690	651	·80198	421	·7	·94467	535	·05856	604
·8	·24039	650	·80619	425	·8	·93932	532	·06460	607
19·9	·23389	649	·81044	429	24·9	·93400	529	·07067	610
20·0	·22740	648	·81473	432	25·0	·92871	526	·07677	613
·1	·22092	647	·81905	436	·1	·92345	523	·08290	616
·2	·21445	646	·82341	440	·2	·91822	520	·08906	620
·3	·20799	645	·82781	445	·3	·91302	516	·09526	623
·4	·20154	644	·83226	449	·4	·90786	513	·10149	626
20·5	·19510	642	·83675	452	25·5	·90273	510	·10775	629
·6	·18868	641	·84127	456	·6	·89763	507	·11404	633
·7	·18227	639	·84583	460	·7	·89256	504	·12037	636
·8	·17588	638	·85043	464	·8	·88752	500	·12673	639
20·9	·16950	637	·85507	468	25·9	·88252	497	·13312	642
21·0	·16313	634	·85975	471	26·0	·87755	494	·13954	645
·1	·15679	632	·86446	475	·1	·87261	491	·14599	648
·2	·15047	630	·86921	479	·2	·86770	488	·15247	651
·3	·14417	629	·87400	483	·3	·86282	484	·15898	654
·4	·13788	627	·87883	487	·4	·85798	481	·16552	658
21·5	·13161	625	·88370	490	26·5	·85317	478	·17210	660
·6	·12536	622	·88860	494	·6	·84839	475	·17870	663
·7	·11914	620	·89354	498	·7	·84364	472	·18533	666
·8	·11294	618	·89852	502	·8	·83892	468	·19199	670
21·9	·10676	616	·90354	506	26·9	·83424	465	·19869	673
22·0	·10060	613	·90860	509	27·0	·82959	462	·20542	075
·1	·09447	610	·91369	513	·1	·82497	459	·21217	678
·2	·08837	608	·91882	516	·2	·82038	456	·21895	681
·3	·08229	606	·92398	520	·3	·81582	453	·22576	684
·4	·07623	604	·92918	524	·4	·81129	450	·23260	688
22·5	·07019	601	·93442	527	27·5	·80679	447	·23948	690
·6	·06418	598	·93969	531	·6	·80232	444	·24638	693
·7	·05820	595	·94500	534	·7	·79788	440	·25331	695
·8	·05225	592	·95034	538	·8	·79348	437	·26026	698
22·9	·04633	590	·95572	542	27·9	·78911	434	·26724	701
23·0	·04043	587	·96114	545	28·0	·78477	431	·27425	704
·1	·03456	584	·96659	549	·1	·78046	428	·28129	707
·2	·02872	581	·97208	552	·2	·77618	425	·28836	710
23·3	1·02291	578	0·97760	556	·3	·77193	422	·29546	713
					·4	·76771	420	·30259	715
					·5	·76351	417	·30974	718
					28·6	0·75934		1·31692	

$$F = 1/f = \frac{0{\cdot}22915}{(\sin^4 I + 0{\cdot}14527 \cos 2\nu \sin^2 I + 0{\cdot}00528)^{\frac{1}{2}}}.$$

I is given for the first of each month in Table 6.

TABLE 13.—*Factors F and f, corresponding to every tenth of a degree of I, for reduction and prediction of tides*—Continued.

I	F for lunar K_2	Diff.	f for lunar K_2	Diff.	I	F for lunar K_2	Diff.	f for lunar K_2	Diff.
°					°				
18·3	1·58749	1661	0·62992	666	23·3	1·00037	805	0·99963	811
·4	·57088	1634	·63658	670	·4	0·99232	796	1·00774	814
·5	·55454	1609	·64328	672	·5	·98436	785	·01588	817
·6	·53845	1583	·65000	676	·6	·97651	775	·02405	820
·7	·52262	1557	·65676	679	·7	·96876	766	·03225	822
·8	·50705	1533	·66355	682	·8	·96110	756	·04047	825
18·9	·49172	1509	·67037	685	23·9	·95354	746	·04872	827
19·0	·47663	1485	·67722	688	24·0	·94608	737	·05699	830
·1	·46178	1462	·68410	691	·1	·93871	728	·06529	833
·2	·44716	1440	·69101	694	·2	·93143	719	·07362	835
·3	·43276	1417	·69795	698	·3	·92424	710	·08197	838
·4	·41859	1395	·70493	700	·4	·91714	701	·09035	840
19·5	·40464	1374	·71193	703	24·5	·91013	693	·09875	843
·6	·39090	1353	·71896	706	·6	·90320	685	·10718	845
·7	·37737	1333	·72602	710	·7	·89635	676	·11563	848
·8	·36404	1313	·73312	712	·8	·88959	668	·12411	851
19·9	·35091	1292	·74024	715	24·9	·88291	660	·13262	853
20·0	·33799	1274	·74739	718	25·0	·87631	652	·14115	855
·1	·32525	1255	·75457	722	·1	·86979	644	·14970	858
·2	·31270	1236	·76179	724	·2	·86335	637	·15828	861
·3	·30034	1218	·76903	727	·3	·85698	629	·16689	863
·4	·28816	1200	·77630	730	·4	·85069	622	·17552	865
20·5	·27616	1183	·78360	733	25·5	·84447	614	·18417	868
·6	·26433	1166	·79093	736	·6	·83833	607	·19285	870
·7	·25267	1149	·79829	739	·7	·83226	600	·20155	873
·8	·24118	1132	·80598	742	·8	·82626	594	·21028	875
20·9	·22986	1116	·81310	745	25·9	·82032	586	·21903	878
21·0	·21870	1100	·82055	747	26·0	·81446	579	·22781	880
·1	·20770	1085	·82802	751	·1	·80867	573	·23661	882
·2	·19685	1070	·83553	753	·2	·80294	567	·24543	884
·3	·18615	1054	·84306	756	·3	·79727	560	·25427	887
·4	·17561	1040	·85062	759	·4	·79167	555	·26314	890
21·5	·16521	1025	·85821	762	26·5	·78614	547	·27204	892
·6	·15496	1012	·86583	765	·6	·78067	541	·28096	894
·7	·14484	997	·87348	768	·7	·77526	535	·28990	896
·8	·13487	984	·88116	770	·8	·76991	529	·29886	899
21·9	·12503	970	·88886	773	26·9	·76462	524	·30785	901
22·0	·11533	957	·89659	776	27·0	·75938	517	·31686	903
·1	·10576	944	·90435	779	·1	·75421	512	·32589	906
·2	·09632	931	·91214	782	·2	·74909	506	·33495	908
·3	·08701	919	·91996	784	·3	·74403	500	·34403	910
·4	·07782	907	·92780	787	·4	·73903	495	·35313	912
22·5	·06875	895	·93567	790	27·5	·73408	490	·36225	915
·6	·05980	883	·94357	793	·6	·72918	484	·37140	916
·7	·05097	871	·95150	795	·7	·72434	479	·38056	919
·8	·04226	860	·95945	798	·8	·71955	474	·38975	921
22·9	·03366	848	·96743	801	27·9	·71481	468	·39896	924
23·0	·02518	838	·97544	804	28·0	·71013	464	·40820	926
·1	·01680	827	·98348	806	·1	·70549	459	·41746	927
·2	·00853	816	·99154	809	·2	·70090	454	·42673	930
23·3	1·00037	805	0·99963	811	·3	·69636	449	·43603	932
					·4	·69187	444	·44535	934
					·5	·68743	440	·45469	937
					28·6	0·68303		1·46406	

$$F = 1/f = \frac{\sin^2\omega\,(1 - \frac{3}{2}\sin^2 i)}{\sin^2 I} = \frac{0{\cdot}15651}{\sin^2 I}.$$

I is given for the first of each month in Table 6.

TABLE 13.—*Factors F and f, corresponding to every tenth of a degree of I, for reduction and prediction of tides*—Continued.

I	$F(M_2)$	Diff.	$f(M_2)$	Diff.	I	$F(M_2)$	Diff.	$f(M_2)$	Diff.
°					°				
18·3	0·96349		1·03789		23·3	0·99486		1·00517	
·4	·96403	54	·03731	58	·4	·99558	72	·00444	73
·5	·96458	55	·03672	59	·5	·99630	72	·00372	72
·6	·96513	55	·03613	59	·6	·99702	72	·00299	73
·7	·96568	55	·03554	59	·7	·99775	73	·00225	74
·8	·96624	56	·03494	60	·8	·99848	73	·00152	73
18·9	·96680	56	·03434	60	23·9	·99922	74	·00078	74
		56		60			74		74
19·0	·96736		·03374		24·0	0·99996		1·00004	
·1	·96793	57	·03313	61	·1	1·00070	74	0·99930	74
·2	·96850	57	·03252	61	·2	·00145	75	·99855	75
·3	·96907	57	·03191	61	·3	·00220	75	·99780	75
·4	·96965	58	·03130	61	·4	·00296	76	·99705	75
		58		62			76		75
19·5	·97023		·03068		24·5	·00372		·99630	
·6	·97081	58	·03006	62	·6	·00448	76	·99554	76
·7	·97140	59	·02944	62	·7	·00525	77	·99478	76
·8	·97199	59	·02881	63	·8	·00602	77	·99402	76
19·9	·97259	60	·02819	62	24·9	·00679	77	·99326	76
		59		63			78		77
20·0	·97318		·02756		25·0	·00757		·99249	
·1	·97378	60	·02692	64	·1	·00835	78	·99172	77
·2	·97439	61	·02629	63	·2	·00914	79	·99095	77
·3	·97500	61	·02565	64	·3	·00992	78	·99017	78
·4	·97561	61	·02500	65	·4	·01072	80	·98940	77
		61		64			80		78
20·5	·97622		·02436		25·5	·01152		·98862	
·6	·97684	62	·02371	65	·6	·01232	80	·98783	79
·7	·97746	62	·02306	65	·7	·01312	80	·98705	78
·8	·97809	63	·02241	65	·8	·01393	81	·98626	79
20·9	·97871	62	·02175	66	25·9	·01474	81	·98547	79
		64		66			82		79
21·0	·97935		·02109		26·0	·01556		·98468	
·1	·97998	63	·02043	66	·1	·01638	82	·98389	79
·2	·98062	64	·01976	67	·2	·01720	82	·98309	80
·3	·98126	64	·01910	66	·3	·01803	83	·98229	80
·4	·98191	65	·01843	67	·4	·01886	83	·98148	81
		65		68			84		80
21·5	·98256		·01775		26·5	·01970		·98068	
·6	·98321	65	·01708	67	·6	·02054	84	·97987	81
·7	·98387	66	·01640	68	·7	·02138	84	·97906	81
·8	·98453	66	·01572	68	·8	·02223	85	·97825	81
21·9	·98519	66	·01503	69	26·9	·02308	85	·97744	81
		67		68			86		82
22·0	·98586		·01435		27·0	·02394		·97662	
·1	·98653	67	·01366	69	·1	·02480	86	·97580	82
·2	·98720	67	·01296	70	·2	·02566	86	·97498	82
·3	·98788	68	·01227	69	·3	·02653	87	·97415	83
·4	·98856	68	·01157	70	·4	·02740	87	·97333	82
		69		70			88		83
22·5	·98925		·01087		27·5	·02828		·97250	
·6	·98994	69	·01017	70	·6	·02916	88	·97167	83
·7	·99063	69	·00946	71	·7	·03005	89	·97083	84
·8	·99132	69	·00875	71	·8	·03093	88	·96999	84
22·9	·99202	70	·00804	71	27·9	·03183	90	·96915	84
		71		71			89		84
23·0	·99273		·00733		28·0	·03272		·96831	
·1	·99343	70	·00661	72	·1	·03363	91	·96747	84
·2	·99414	71	·00589	72	·2	·03453	90	·96662	85
23·3	0·99486	72	1·00517	72	·3	·03544	91	·96577	85
		72		73	·4	·03635	91	·96492	85
					·5	·03727	92	·96407	85
					28·6	1·03819	92	0·96321	86

$$F = 1/f = \frac{\cos^4 \frac{1}{2}\omega \cos^4 \frac{1}{2} i}{\cos^4 \frac{1}{2} I} = \frac{0{\cdot}91538}{\cos^4 \frac{1}{2} I}$$

$$F(M_4) = F(N_2) = F(2\,N) = F(MS) = F(2\,SM) = F(MSf) = F(\lambda_2) = F(\mu_2) = F(\nu_2).$$
$$f(M_4) = f(N_2) = f(2\,N) = f(MS) = f(2\,SM) = f(MSf) = f(\lambda_2) = f(\mu_2) = f(\nu_2).$$

I is given for the first of each month in Table 6.

TABLE 13.—*Factors F and f, corresponding to every tenth of a degree of I, for reduction and prediction of tides*—Continued.

I	$F(O_1)$	Diff.	$f(O_1)$	Diff.	I	$F(O_1)$	Diff.	$f(O_1)$	Diff.
°					°				
18·3	1·24178	617	0·80529	403	23·3	1·00166	368	0·99834	368
·4	·23561	610	·80932	402	·4	0·99798	364	1·00202	368
·5	·22951	603	·81334	400	·5	·99434	362	·00570	367
·6	·22348	596	·81734	400	·6	·99072	358	·00937	366
·7	·21752	590	·82134	400	·7	·98714	354	·01303	365
·8	·21162	583	·82534	399	·8	·98360	352	·01668	365
18·9	·20579	576	·82933	398	23·9	·98008	348	·02033	363
19·0	·20003	570	·83331	398	24·0	·97660	345	·02396	363
·1	·19433	564	·83729	397	·1	·97315	342	·02759	363
·2	·18869	558	·84126	397	·2	·96973	339	·03122	361
·3	·18311	552	·84523	396	·3	·96634	336	·03483	361
·4	·17759	545	·84919	395	·4	·96298	332	·03844	360
19·5	·17214	540	·85314	394	24·5	·95966	330	·04204	359
·6	·16674	533	·85708	394	·6	·95636	327	·04563	358
·7	·16141	528	·86102	394	·7	·95309	323	·04921	358
·8	·15613	523	·86496	392	·8	·94986	321	·05279	357
19·9	·15090	517	·86888	392	24·9	·94665	318	·05636	356
20·0	·14573	511	·87280	392	25·0	·94347	316	·05992	355
·1	·14062	506	·87672	390	·1	·84031	312	·06347	355
·2	·13556	501	·88062	390	·2	·93719	310	·06702	354
·3	·13055	495	·88452	390	·3	·93409	307	·07056	353
·4	·12560	491	·88842	388	·4	·93102	304	·07409	352
20·5	·12069	485	·89230	388	25·5	·92798	301	·07761	351
·6	·11584	480	·89618	388	·6	·92497	299	·08112	351
·7	·11104	475	·90006	387	·7	·92198	296	·08463	349
·8	·10629	471	·90393	386	·8	·91902	294	·08812	349
20·9	·10158	465	·90779	385	25·9	·91608	292	·09161	348
21·0	·09693	461	·91164	385	26·0	·91316	289	·09509	348
·1	·09232	457	·91549	384	·1	·01027	286	·09857	346
·2	·08775	451	·91933	383	·2	·90741	283	·10203	346
·3	·08324	447	·92316	383	·3	·90458	282	·10549	345
·4	·07877	443	·92699	382	·4	·90176	279	·10894	344
21·5	·07434	438	·93081	381	26·5	·89897	276	·11238	343
·6	·06996	434	·93462	380	·6	·89621	274	·11581	343
·7	·06562	430	·93842	380	·7	·89347	272	·11924	342
·8	·06132	425	·94222	379	·8	·89075	270	·12266	340
21·9	·05707	421	·94601	379	26·9	·88805	267	·12606	340
22·0	·05286	417	·94980	377	27·0	·88538	265	·12946	339
·1	·04869	413	·95357	377	·1	·88273	263	·13285	339
·2	·04456	409	·95734	377	·2	·88010	261	·13624	337
·3	·04047	405	·96111	375	·3	·87749	258	·13961	337
·4	·03642	401	·96486	375	·4	·87491	256	·14298	336
22·5	·03241	398	·96861	374	27·5	·87235	254	·14634	335
·6	·02843	393	·97235	374	·6	·86981	253	·14969	334
·7	·02450	390	·97609	372	·7	·86728	250	·15303	333
·8	·02060	386	·97981	372	·8	·86478	248	·15636	332
22·9	·01674	382	·98353	371	27·9	·86230	245	·15968	332
23·0	·01292	379	·98724	371	28·0	·85985	244	·16300	331
·1	·00913	375	·99095	370	·1	·85741	242	·16631	330
·2	·00538	372	·99465	369	·2	·85499	240	·16961	329
23·3	1·00166	368	0·99834	368	·3	·85259	238	·17290	328
					·4	·85021	236	·17618	327
					·5	·84785	234	·17945	326
					28·6	0·84551		1·18271	

$$F = 1/f = \frac{\sin\omega\cos^2\tfrac{1}{2}\omega\cos^4\tfrac{1}{2}i}{\sin I\cos^2\tfrac{1}{2}I} = \frac{0{\cdot}38005}{\sin I\cos^2\tfrac{1}{2}I}$$

$$F(O_1) = F(Q_1) = F(M_1) \div Q'.$$
$$f(O_1) = f(Q_1) = f(M_1) \times Q'.$$

I is given for the first of each month in Table 6.

TABLE 13.—*Factors F and f, corresponding to every tenth of a degree of I, for reduction and prediction of tides*—Continued.

I	F(OO)	Diff.	f(OO)	Diff.	I	F(OO)	Diff.	f(OO)	Diff.
°					°				
18·3	2·06270	3289	0·48482	784	23·3	1·01542	1261	0·98482	1237
·4	2·02981	3218	·49226	793	·4	1·00281	1239	0·99719	1248
·5	1·99763	3149	·50059	802	·5	0·99042	1218	1·00967	1258
·6	·96614	3082	·50861	810	·6	·97824	1198	·02225	1267
·7	·93532	3017	·51671	818	·7	·96626	1178	·03492	1277
·8	·90515	2954	·52489	827	·8	·95448	1159	·04769	1288
18·9	·87561	2892	·53316	835	23·9	·94289	1139	·06057	1297
19·0	·84669	2832	·54151	843	24·0	·93150	1121	·07354	1307
·1	·81837	2774	·54994	852	·1	·92029	1102	·08661	1318
·2	·79063	2717	·55846	861	·2	·90927	1085	·09979	1327
·3	·76346	2662	·56707	869	·3	·89842	1067	·11306	1337
·4	·73684	2607	·57576	877	·4	·88775	1049	·12643	1348
19·5	·71077	2555	·58453	886	24·5	·87726	1033	·13991	1359
·6	·68522	2503	·59339	895	·6	·86693	1016	·15350	1368
·7	·66019	2454	·60234	904	·7	·85677	1000	·16718	1378
·8	·63565	2404	·61138	912	·8	·84677	984	·18096	1389
19·9	·61161	2357	·62050	921	24·9	·83693	969	·19485	1399
20·0	·58804	2310	·62971	929	25·0	·82724	953	·20884	1409
·1	·56494	2265	·63900	939	·1	·81771	939	·22293	1420
·2	·54229	2221	·64839	947	·2	·80832	923	·23713	1430
·3	·52008	2178	·65786	956	·3	·79909	910	·25143	1440
·4	·49830	2135	·66742	965	·4	·78999	895	·26583	1451
20·5	·47695	2095	·67707	974	25·5	·78104	881	·28034	1461
·6	·45600	2055	·68681	983	·6	·77223	868	·29495	1472
·7	·43545	2015	·69664	992	·7	·76355	854	·30967	1482
·8	·41530	1977	·70656	1002	·8	·75501	842	·32449	1493
20·9	·39553	1940	·71658	1010	25·9	·74659	829	·33942	1503
21·0	·37613	1904	·72668	1019	26·0	·73830	816	·35445	1514
·1	·35709	1868	·73687	1028	·1	·73014	804	·36959	1525
·2	·33841	1833	·74715	1038	·2	·72210	791	·38484	1535
·3	·32008	1799	·75753	1047	·3	·71419	780	·40019	1546
·4	·30209	1766	·76800	1056	·4	·70639	768	·41565	1556
21·5	·28443	1734	·77856	1065	26·5	·69871	757	·43121	1567
·6	·26709	1702	·78921	1075	·6	·69114	746	·44688	1578
·7	·25007	1672	·79996	1084	·7	·68368	734	·46266	1589
·8	·23335	1641	·81080	1093	·8	·67634	724	·47855	1600
21·9	·21694	1611	·82173	1103	26·9	·66910	713	·49455	1610
22·0	·20083	1583	·83276	1112	27·0	·66197	703	·51065	1621
·1	·18500	1554	·84388	1122	·1	·65494	693	·52686	1632
·2	·16946	1527	·85510	1131	·2	·64801	682	·54318	1643
·3	·15419	1500	·86641	1141	·3	·64119	673	·55961	1654
·4	·13919	1473	·87782	1150	·4	·63446	663	·57615	1664
22·5	·12446	1448	·88932	1160	27·5	·62783	654	·59279	1676
·6	·10998	1422	·90092	1169	·6	·62129	644	·60955	1686
·7	·09576	1398	·91261	1179	·7	·61485	635	·62641	1698
·8	·08178	1374	·92440	1189	·8	·60850	626	·64339	1708
22·9	·06804	1350	·93629	1199	27·9	·60224	617	66047	1720
23·0	·05454	1326	·94828	1208	28·0	·59607	609	·67767	1730
·1	·04128	1305	·96036	1218	·1	·58998	600	·69497	1742
·2	·02823	1281	·97254	1228	·2	·58398	592	·71239	1753
23·3	1·01542	1261	0·98482	1237	·3	·57806	583	·72992	1764
					·4	·57223	576	·74756	1775
					·5	·56647	567	·76531	1786
					28·6	0·56080		1·78317	

$$F = 1/f = \frac{\sin\omega \sin^2 \tfrac{1}{2}\omega \cos^4 \tfrac{1}{2} i}{\sin I \sin^2 \tfrac{1}{2} I} = \frac{0{\cdot}01638}{\sin I \sin^2 \tfrac{1}{2} I}$$

I is given for the first of each month in Table 6.

TABLE 13.—*Factors F and f, corresponding to every tenth of a degree of I, for reduction and prediction of tides*—Continued.

I	*F*(Mf)	Diff.	*f*(Mf)	Diff.	*I*	*F*(Mf)	Diff.	*f*(Mf)	Diff.
°					°				
18·3	1·60043	1675	0·62486	658	23·3	1·00852	812	0·99156	805
·4	·58368	1648	·63144	663	·4	1·00040	802	0·99961	807
·5	·56720	1622	·63807	668	·5	0·99238	792	1·00768	810
·6	·55098	1596	·64475	671	·6	·98446	782	·01578	813
·7	·53502	1571	·65146	673	·7	·97664	771	·02391	816
·8	·51931	1545	·65819	677	·8	·96893	762	·03207	818
18·9	·50386	1521	·66496	679	23·9	·96131	753	·04025	821
19·0	·48865	1497	·67175	683	24·0	·95378	743	·04846	823
·1	·47368	1474	·67858	685	·1	·94635	734	·05669	826
·2	·45894	1451	·68543	689	·2	·93901	725	·06495	828
·3	·44443	1429	·69232	691	·3	·93176	716	·07323	831
·4	·43014	1407	·69923	695	·4	·92460	707	·08154	834
19·5	·41607	1385	·70618	697	24·5	·91753	698	·08988	836
·6	·40222	1364	·71315	701	·6	·91055	690	·09824	839
·7	·38858	1343	·72016	704	·7	·90365	682	·10663	841
·8	·37515	1324	·72720	707	·8	·89683	673	·11504	843
19·9	·36191	1303	·73427	709	24·9	·89010	666	·12347	846
20·0	·34888	1284	·74136	712	25·0	·88344	657	·13193	849
·1	·33604	1265	·74848	716	·1	·87687	649	·14042	851
·2	·32339	1246	·75564	718	·2	·87038	642	·14893	853
·3	·31093	1228	·76282	721	·3	·86396	634	·15746	856
·4	·29865	1210	·77003	724	·4	·85762	627	·16602	859
20·5	·28655	1193	·77727	728	25·5	·85135	620	·17461	861
·6	·27462	1175	·78455	730	·6	·84515	612	·18322	863
·7	·26287	1158	·79185	733	·7	·83903	605	·19185	865
·8	·25129	1142	·79918	736	·8	·83298	598	·20050	868
20·9	·23987	1125	·80654	738	25·9	·82700	591	·20918	871
21·0	·22862	1109	·81392	742	26·0	·82109	584	·21789	873
·1	·21753	1094	·82134	744	·1	·81525	578	·22662	875
·2	·20659	1078	·82878	747	·2	·80947	570	·23537	877
·3	·19581	1063	·83625	750	3	·80377	565	·24414	880
·4	·18518	1048	·84375	753	·4	·79812	558	·25294	883
21·5	·17470	1034	·85128	756	26 5	·79254	552	·26177	884
·6	·16436	1020	·85884	759	6	·78702	545	·27061	887
·7	·15416	1005	·86643	761	·7	·78157	540	·27984	889
·8	·14411	992	·87404	764	·8	·77617	533	·28837	892
21·9	·13419	978	·88168	767	26·9	·77084	527	·29729	893
22·0	·12441	965	·88935	770	27·0	·76557	522	·30622	896
·1	·11476	952	·89705	773	·1	·76035	516	·31518	899
·2	·10524	939	·90478	775	2	·75519	510	·32417	900
·3	·09585	926	·91253	778	3	·75009	504	·33317	903
·4	·08659	914	·92031	781	·4	·74505	499	·34220	905
22·5	·07745	902	·92812	783	27·5	·74006	494	·35125	907
·6	·06843	890	·93595	786	·6	·73512	488	·36032	909
·7	·05953	878	·94381	789	·7	·73024	483	·36941	912
·8	·05075	867	·95170	792	·8	·72541	478	·37853	914
22·9	·04208	856	·95962	794	27·9	·72063	472	·38767	916
23·0	·03352	844	·96756	797	28·0	·71591	468	·39683	918
·1	·02508	834	·97553	800	·1	·71123	462	·40601	920
·2	·01674	822	·98353	803	·2	·70661	458	·41521	922
23·3	1·00852	812	0·99156	805	·3	·70203	452	·42443	925
					·4	·69751	448	·43368	927
					·5	·69303	443	·44295	928
					28·6	0·68860		1·45223	

$$F = 1/f = \frac{\sin^2 \omega \cos^4 \frac{1}{2} i}{\sin^2 I} = \frac{0{\cdot}15779}{\sin^2 I}.$$

I is given for the first of each month in Table 6.

TABLE 13.—*Factors F and f, corresponding to every tenth of a degree of I, for reduction and prediction of tides*—Continued

I	F (Mm)	Diff.	f (Mm)	Diff.	I	F (Mm)	Diff.	f (Mm)	Diff.
°					°				
18·3	0·88387	163	1·13139	208	23·3	0·98411	246	1.01614	253
·4	·88550	164	·12931	209	·4	·98657	248	·01361	253
·5	·88714	165	·12722	209	·5	·98905	249	·01108	255
·6	·88879	167	·12513	211	·6	·99154	252	·00853	256
·7	·89046	168	·12302	212	·7	·99406	254	·00597	256
·8	·89214	169	·12090	212	·8	·99660	256	·00341	257
18·9	·89383	171	·11878	214	23·9	0·99916	258	1·00084	258
19·0	·89554	172	·11664	214	24·0	1·00174	260	0·99826	259
·1	·89726	174	·11450	216	·1	·00434	263	·99567	259
·2	·89900	175	·11234	216	·2	·00697	265	·99308	260
·3	·90075	177	·11018	218	·3	·00962	267	·99048	262
·4	·90252	178	·10800	218	·4	·01229	269	·98786	262
19·5	·90430	180	·10582	219	24·5	·01498	271	·98524	262
·6	·90610	181	·10363	220	·6	·01769	274	·98262	264
·7	·90791	183	·10143	221	·7	·02043	276	·97998	264
·8	·90974	184	·09922	222	·8	·02319	278	·97734	265
19·9	·91158	185	·09700	223	24·9	·02597	281	·97469	266
20·0	·91343	187	·09477	224	25·0	·02878	283	·97203	267
·1	·91530	189	·09253	225	·1	·03161	285	·96936	267
·2	·91719	191	·09028	226	·2	·03446	288	·96669	268
·3	·91910	192	·08802	226	·3	·03734	290	·96401	269
·4	·92102	193	·08576	228	·4	·04024	293	·96132	270
20·5	·92295	195	·08348	228	25·5	·04317	295	·95862	271
·6	·92490	197	·08120	230	·6	·04612	298	·95591	271
·7	·92687	198	·07890	230	·7	·04910	300	·95320	272
·8	·92885	200	·07660	231	·8	·05210	303	·95048	273
20·9	·93085	201	·07429	232	25 9	·05513	305	·94775	273
21·0	·93286	204	·07197	233	26·0	·05818	308	·94502	275
·1	·93490	205	·06964	234	·1	·06126	311	·94227	275
·2	·93695	206	·06730	235	·2	·06437	313	·93952	275
·3	·93901	209	06495	236	·3	·06750	316	·93677	277
·4	·94110	210	06259	237	·4	·07066	319	·93400	277
21·5	94320	211	·06022	237	26·5	·07385	322	·93123	278
·6	·94531	214	·05785	238	·6	·07707	324	·92845	279
·7	·94745	215	·05547	240	·7	·08031	327	·92566	279
·8	94960	217	·05307	240	·8	·08358	330	·92287	280
21·9	·95177	219	·05067	241	26·9	·08688	333	·92007	281
22·0	·95396	221	·04826	242	27·0	·09021	335	·91726	282
·1	·95617	222	04584	243	·1	·09356	339	·91444	282
·2	·95839	224	·04341	243	·2	·09695	342	·91162	283
·3	96063	227	04098	245	·3	·10037	344	·90879	284
·4	·96290	228	·03853	245	·4	·10381	348	·90595	284
22·5	·96518	230	·03608	246	27·5	·10729	350	·90311	285
·6	·96748	232	·03362	247	·6	·11079	354	·90026	286
·7	·96980	233	·03115	248	·7	·11433	357	·89740	287
8	·97213	236	·02867	249	·8	·11790	360	·89453	287
22·9	·97449	238	·02618	250	27·9	·12150	363	·89166	288
23·0	·97687	239	·02368	250	28·0	·12513	367	·88878	288
·1	·97926	242	·02118	251	·1	·12880	369	·88590	289
·2	·98168	243	·01867	253	·2	·13249	373	·88301	290
23·3	0 98411	246	1·01614	253	·3	·13622	377	·88011	291
					·4	·13999	379	·87720	291
					·5	·14378	383	·87429	292
					28·6	1·14761		0·87137	

$$F = 1/f = \frac{(1 - \frac{3}{2}\sin^2\omega)(1 - \frac{3}{2}\sin^2 i)}{1 - \frac{3}{2}\sin^2 I} = \frac{0{\cdot}75316}{1 - \frac{3}{2}\sin^2 I}.$$

I is given for the first of each month in Table 6.

TABLE 14.—*Factors (F) for reducing* Mn, K_1+O_1, *and* X *to mean values.*

		I, or inclination of orbit to equator.											
		18½°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	28½°
		F (Mn)											
$\frac{K_1+O_1}{M_2}$ =	0·0	0·970	0·972	0·977	0·982	0·988	0·994	1·000	1·006	1·012	1·019	1·026	1·029
	0·2	0·971	0·973	0·978	0·982	0·988	0·994	1·000	1·006	1·012	1·019	1·026	1·029
	0·4	0·972	0·974	0·979	0·983	0·988	0·994	1·000	1·006	1·012	1·018	1.025	1·028
	0·6	0·974	0·976	0·980	0·984	0·989	0·994	1·000	1·006	1·011	1·017	1·023	1·026
	0·8	0·977	0·979	0·982	0·986	0·990	0·995	1·000	1·005	1·010	1·015	1·020	1·022
	1·0	9·980	0·982	0·985	0·989	0·992	0·996	1·000	1·004	1·008	1·013	1·017	1·019
	1·2	0·984	0·985	0·988	0·991	0·994	0·997	1·000	1·003	1·007	1·010	1·014	1·016
	1·4	0·988	0·989	0·991	0·994	0·996	0·998	1·000	1·002	1·005	1·007	1·010	1·012
	1·6	0·994	0.994	0·995	0·997	0·998	0·999	1·000	1·001	1·003	1·004	1·005	1·006
	1·8	1·001	1·000	1·000	1·000	1·000	1·000	1·000	1·000	1·000	1·000	1·000	0·999
	2·0	1·008	1·007	1·006	1·004	1·003	1·001	1·000	0·998	0·997	0·995	0·994	0·993
	2·5	1·025	1·023	1·019	1·014	1·009	1·004	0·999	0·994	0·989	0·984	0·979	0·977
		$F(K_1+O_1)$											
		1·168	1·148	1·109	1·073	1·040	1·010	0·982	0·955	0·931	0·909	0·888	0·878
		F (X)											
X′=	0·1					0·47	0·89	1·16	1·38	1·54	1·68	1·80	1·86
	0·2	0·54	0·61	0·73	0·83	0·91	0·98	1·04	1·09	1·14	1·19	1·23	1·24
	0·3	0·86	0·88	0·91	0·94	0·97	0·99	1·01	1·04	1·05	1·07	1·08	1·09
	0·4	0·96	0·96	0·97′	0·98	0·99	1·00	1·01	1·01	1·02	1·02	1·03	1·03
	0·5	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00

$$F(K_1+O_1)=\frac{2{\cdot}4066}{1{\cdot}4066\,f(K_1)+f(O_1)}. \qquad F(X)=\frac{X}{X'}. \qquad \cos(X\cdot 180°)=F(K_1+O_1)\cos(X'\cdot 180°).$$

This table is based upon Tables 1, 13, 21, and §§ 3, 21, 50.

TABLE 15.—*Acceleration in* HW *and* LW *of a*

[The amplitude of the principal wave is taken as unity.]

HW phase.* / LW phase.*		0° 180	10° 190	20° 200	30° 210	40° 220	50° 230	60° 240	70° 250	80° 260	90° 270
		° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Amplitude of subordinate wave.	0·0	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00
	0·1	0 00	0 54	1 47	2 38	3 25	4 07	4 43	5 12	5 32	5 42
	0·2	0 00	1 40	3 18	4 52	6 22	7 44	8 57	9 59	10 47	11 19
	0·3	0 00	2 18	4 35	6 47	8 55	10 54	12 44	14 20	15 41	16 42
	0·4	0 00	2 51	5 41	8 27	11 08	13 42	16 06	18 18	20 13	21 48
	0·5	0 00	3 20	6 38	9 54	13 05	16 10	19 06	21 52	24 22	26 34
	0·6	0 00	3 45	7 28	11 10	14 48	18 21	21 47	25 04	28 09	30 58
	0·7	0 00	4 07	8 13	12 18	16 19	20 18	24 11	27 57	31 35	35 00
	0·8	0 00	4 27	8 53	13 18	17 41	22 02	26 20	30 33	34 40	38 40
	0·9	0 00	4 44	9 28	14 12	18 54	23 36	28 16	32 53	37 28	41 59
	1·0	0 00	5 00	10 00	15 00	20·00	25 00	30 00	35 00	40 00	45 00
HW phase. LW phase.		360° 180	350° 170	340° 160	330° 150	320° 140	310° 130	300° 120	290° 110	280° 100	270° 90

*i. e. the argument, or phase, of the subordinate component (B) at the time of HW and LW, respectively, of the principal component (A). By § 2

$$\tan \text{acceleration in } \frac{\text{HW}}{\text{LW}} = \frac{a}{b} \frac{\frac{B\,b^2}{A\,a^2} \sin \text{HW phase}}{\pm 1 + \frac{B\,b^2}{A\,a^2} \cos \text{HW phase}}.$$

(When $b = a$, this formula is exact.) If t denote the time after the conspiring of A and B, § 17, then

$$\text{phase} = (b - a)\,t;$$
$$= \frac{b}{a}\, 2\,n\,\pi \text{ for HW},$$
$$= \frac{b}{a}\, \overline{2\,n + 1}\,\pi \text{ for LW},$$

n being an integer denoting the number of high waters of A since the coincidence of the maxima of A and B.

TABLE 16.—*Height of* HW *and* LW *for a*

[The amplitude of the principal wave is taken as unity.]

HW phase. / LW phase.		0° 180	10° 190	20° 200	30° 210	40° 220	50° 230	60° 240	70° 250	80° 260	90° 270
Amplitude of subordinate wave.	0·0	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·1	1·1000	1·0986	1·0945	1·0877	1·0785	1·0670	1·0536	1·0385	1·0221	1·0050
	0·2	1·2000	1·1975	1·1899	1·1775	1·1603	1·1389	1·1135	1·0849	1·0532	1·0198
	0·3	1·3000	1·2965	1·2860	1·2687	1·2448	1·2148	1·1790	1·1381	1·0928	1·0440
	0·4	1·4000	1·3957	1·3827	1·3611	1·3315	1·2939	1·2490	1·1973	1·1397	1·0770
	0·5	1·5000	1·4949	1·4798	1·4546	1·4198	1·3758	1·3228	1·2618	1·1931	1·1180
	0·6	1·6000	1·5943	1·5772	1·5490	1·5097	1·4599	1·4000	1·3306	1·2523	1·1662
	0·7	1·7000	1·6937	1·6749	1·6439	1·6007	1·5459	1·4798	1·4032	1·3165	1·2207
	0·8	1·8000	1·7932	1·7730	1·7395	1·6928	1·6336	1·5620	1·4789	1·3849	1·2806
	0·9	1·9000	1·8928	1·8712	1·8354	1·7858	1.7225	1·6463	1·5575	1·4569	1·3453
	1·0	2·0000	1·9924	1·9696	1·9318	1·8794	1·8126	1·7320	1·6384	1·5320	1·4142
HW phase. LW phase.		360° 180	350° 170	340° 160	330° 150	320° 140	310° 130	300° 120	290° 110	280° 100	270° 90

For high waters use the tabular values as given; but for low waters alter their signs.

wave due to another wave of equal speed.

[The amplitude of the principal wave is taken as unity.]

	HW phase. LW phase.	100° 280	110° 290	120° 300	130° 310	140° 320	150° 330	160° 340	170° 350	180° 360	
		° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	
Amplitude of subordinate wave.	0·0	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	
	0·1	5 43	5 33	5 13	4 41	3 59	3 08	2 10	1 06	0 00	
	0·2	11 32	11 24	10 54	9 58	8 38	6 54	4 49	2 29	0 00	
	0·3	17 19	17 26	17 00	15 54	14 03	11 27	8 08	4 14	0 00	
	0·4	22 57	23 32	23 25	22 25	20 20	17 01	12 22	6 32	0 00	
	0·5	28 20	29 33	30 00	29 27	27 31	23 48	17 53	9 42	0 00	
	0·6	33 25	35 21	36 35	36 48	35 31	31 59	25 12	14 17	0 00	
	0·7	38 07	40 51	43 00	44 16	44 08	41 38	34 59	21 22	0 00	
	0·8	42 27	45 59	49 06	51 36	53 01	52 29	47 49	33 13	0 00	
	0·9	46 25	50 42	54 47	58 34	61 46	63 53	63 23	53 59	0 00	
	1·0	50 00	55 00	60 00	65 00	70 00	75 00	80 00	85 00		
	HW phase. LW phase.	260° 80	250° 70	240° 60	230° 50	220° 40	210° 30	200° 20	190° 10	180° 0	

When the top argument is used the tabular values are positive; when the bottom argument, they are negative.
To express the acceleration in time, divide by a, the speed of the greater component.

To find the acceleration when b is not exactly equal to a, multiply the tabular values by $\frac{b}{a}$.

This acceleration is directly expressed in time by multiplying the tabular values by $\frac{b}{a^2}$.

tide composed of two waves of equal speed.

[The amplitude of the principal wave is taken as unity.]

	HW phase. LW phase.	100° 280	110° 290	120° 300	130° 310	140° 320	150° 330	160° 340	170° 350	180° 360	Mean value.†
Amplitude of subordinate wave.	0·0	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000	1·0000
	0·1	0·9875	0·9703	0·9540	0·9389	0·9256	0·9148	0·9067	0·9017	0·9000	1·0025
	0·2	0·9852	0·9504	0·9166	0·8848	0·8565	0·8329	0·8150	0·8038	0·8000	1·0100
	0·3	0·9929	0·9407	0·8888	0·8392	0·7940	0·7552	0·7253	0·7065	0·7000	1·0226
	0·4	1·0104	0·9415	0·8717	0·8036	0·7397	0·6835	0·6389	0·6100	0·6000	1·0404
	0·5	1·0375	0·9529	0·8660	0·7792	0·6957	0·6197	0·5571	0·5150	0·5000	1·0635
	0·6	1·0731	0·9744	0·8718	0·7672	0·6639	0·5664	0·4820	0·4222	0·4000	1·0922
	0·7	1·1167	1·0055	0·8889	0·7682	0·6462	0·5269	0·4176	0·3336	0·3000	1·1268
	0·8	1·1672	1·0454	0·9165	0·7819	0·6437	0·5044	0·3694	0·2536	0·2000	1·1678
	0·9	1·2237	1·0929	0·9539	0·8081	0·6566	0·5009	0·3443	0·1933	0.1000	1·2160
	1·0	1·2856	1·1472	1·0000	0·8452	0·6840	0·5176	0·3472	0·1744	0·0000	1·2724
	HW phase. LW phase.	260° 80	250° 70	240° 60	230° 50	220° 40	210° 30	200° 20	190° 10	180° 0	

† When b is not exactly to a, mean value $= 1 + (\text{tabular value} - 1)\frac{b^2}{a^2}$.

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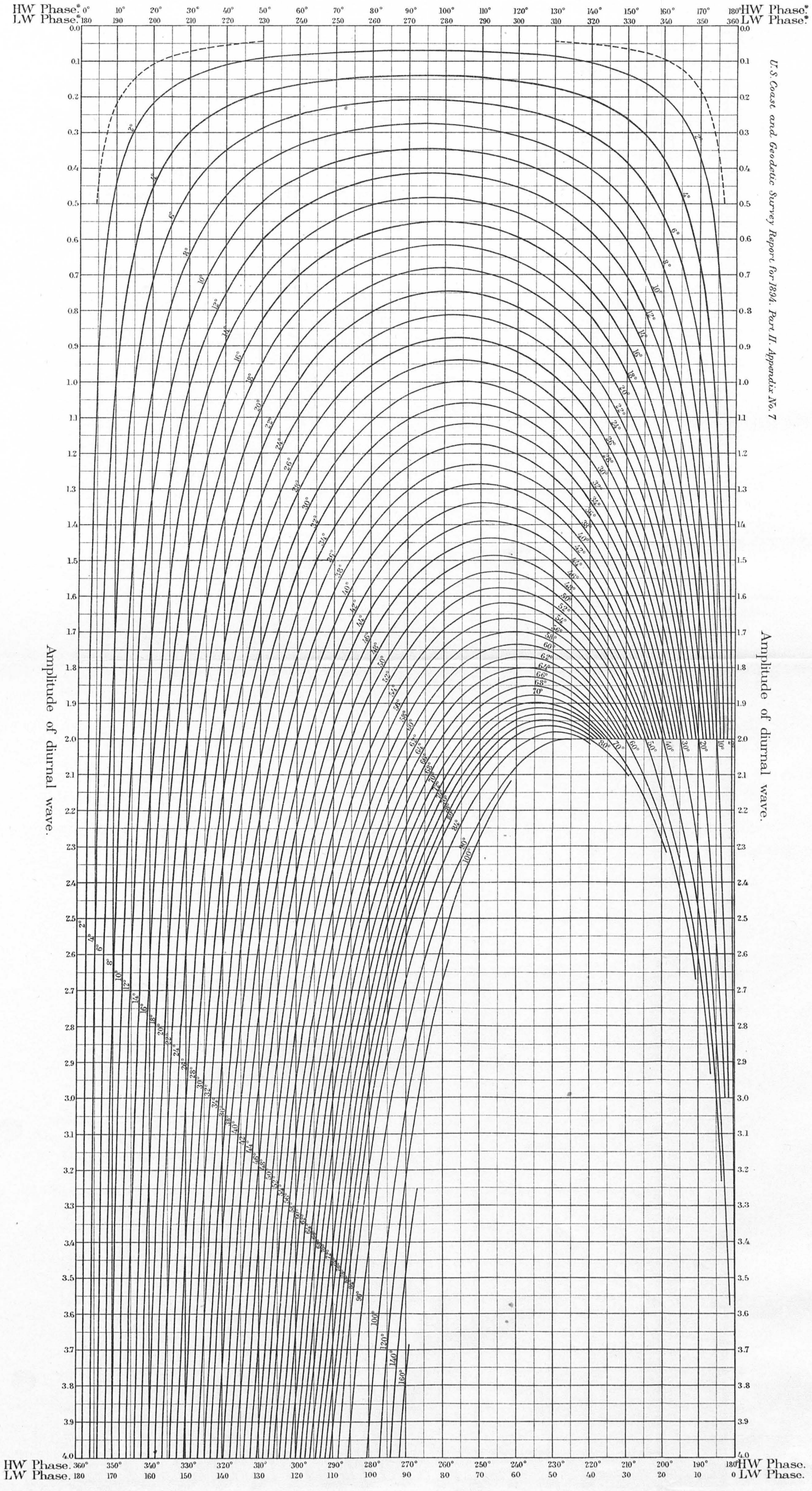
TABLE 17.–ACCELERATION IN HW AND LW OF A SEMIDIURNAL WAVE DUE TO A DIURNAL WAVE.

The amplitude of the semidiurnal wave is taken as unity.



Amplitude of diurnal wave.

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When the top argument is used, the tabular values are positive; when the bottom argument, they are negative.

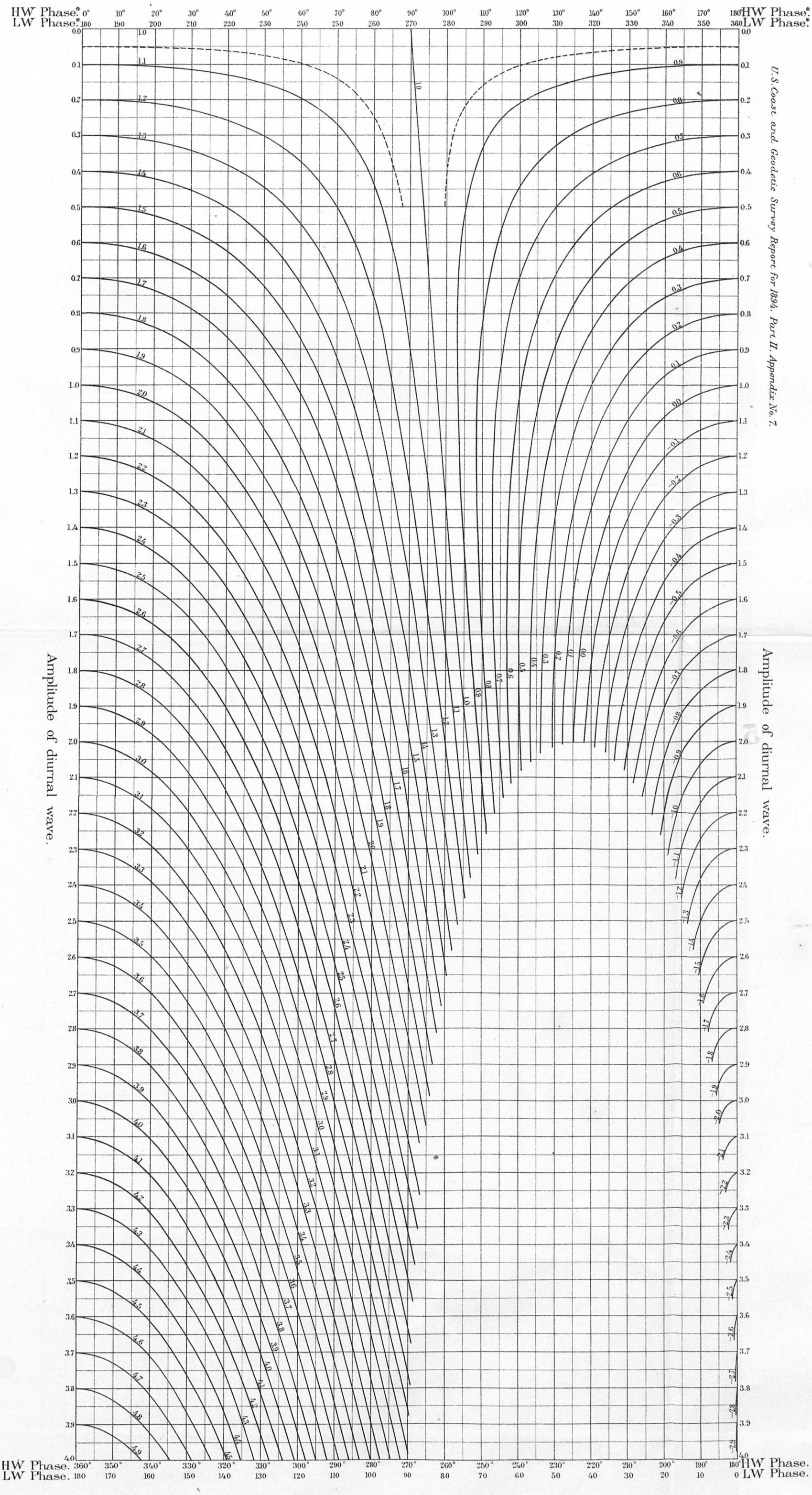
* Note. *i.e., the argument, or phase, of the diurnal wave (B) at the time of HW or LW of the semidiurnal wave (A).*

$$HW\ Phase = n\pi + \tfrac{1}{2}A^\circ - B^\circ \qquad LW\ Phase = n\pi \pm \tfrac{\pi}{2} + \tfrac{1}{2}A^\circ - B^\circ$$

n being an integer. See §§ 5, 20.

TABLE 18.–HEIGHT OF HW AND LW FOR A TIDE COMPOSED OF A DIURNAL AND SEMIDIURNAL WAVE.

The amplitude of the semidiurnal wave is taken as unity.



U. S. Coast and Geodetic Survey Report for 1894. Part II. Appendix No. 7.

Amplitude of diurnal wave.

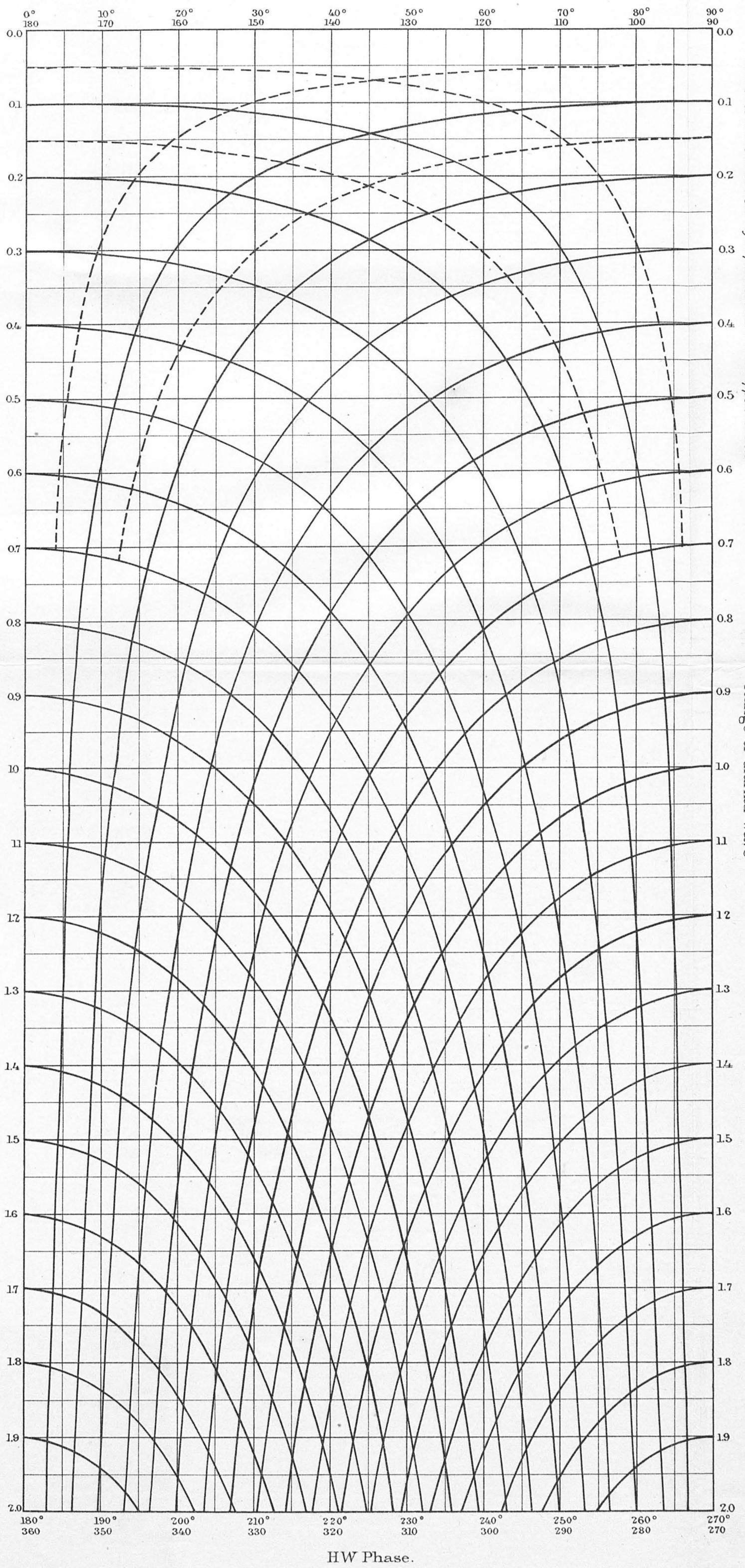
For high waters, use the tabular values as given; but for low waters, alter their signs.

*See footnote, Table 17.

TABLE 19.–HIGH AND LOW WATER INEQUALITIES IN HEIGHT.

The range of the semidiurnal wave is taken as unity.

PLATE III. *No. 6.*



U.S. Coast and Geodetic Survey Report for 1894. Part II. Appendix No. 7.

High water inequality curves terminate in the left margin, low water, in the right.

TABLE 20.—*Great tropic range and its duration.*

[The amplitude of the semidiurnal wave is taken as unity.]

Amplitude of diurnal wave.	Elevation of great tropic HW > depression of great tropic LW.					Depression of gt. tropic LW > elevation of gt. tropic HW.				
HW phase.	0° 180	10° 170	20° 160	30° 150	40° 140	50° 130	60° 120	70° 110	80° 100	90° 90
1·6	3·921 7 50	4·149 7 54	4·326 7 56	4·444 7 57	4·504 7 57	4·504 7 57	4·444 7 57	4·326 7 56	4·149 7 54	3·921 7 50
1·7	4·062 7 57	4·291 7 59	4·487 8 01	4·610 8 02	4·674 8 03	4·674 8 03	4·610 8 02	4·487 8 01	4·291 7 59	4·062 7 57
1·8	4·205 8 03	4·456 8 05	4·649 8 06	4·777 8 07	4·844 8 08	4·844 8 08	4·777 8 07	4·649 8 06	4·456 8 05	4·205 8 03
1·9	4·351 8 10	4·612 8 11	4·813 8 12	4·947 8 12	5·015 8 12	5·015 8 12	4·947 8 12	4·813 8 12	4·612 8 11	4·351 8 10
2·0	4·500 8 17	4·772 8 17	4·978 8 17	5·117 8 17	5·187 8 17	5·187 8 17	5·117 8 17	4·978 8 17	4·772 8 17	4·500 8 17
2·1	4·651 8 24	4·932 8 23	5·144 8 22	5·288 8 21	5·360 8 21	5·360 8 21	5·288 8 21	5·144 8 22	4·932 8 23	4·651 8 24
2·2	4·805 8 31	5·093 8 28	5·311 8 27	5·460 8 26	5·535 8 26	5·535 8 26	5·460 8 26	5·311 8 27	5·093 8 28	4·805 8 31
2·3	4·962 8 38	5·256 8 34	5·487 8 31	5·634 8 31	5·710 8 30	5·710 8 30	5·634 8 31	5·487 8 31	5·256 8 34	4·962 8 38
2·4	5·121 8 45	5·421 8 40	5·652 8 37	5·808 8 35	5·886 8 34	5·886 8 34	5·808 8 35	5·652 8 37	5·421 8 40	5·121 8 45
2·5	5·282 8 53	5·589 8 45	5·824 8 41	5·984 8 39	6·063 8 38	6·063 8 38	5·984 8 39	5·824 8 41	5·589 8 45	5·282 8 53
2·6	5·445 9 01	5·757 8 51	5·997 8 46	6·160 8 44	6·241 8 42	6·241 8 42	6·160 8 44	5·997 8 46	5·757 8 51	5·445 9 01
2·7	5·611 9 08	5·927 8 57	6·170 8 51	6·337 8 48	6·420 8 46	6·420 8 46	6·337 8 48	6·170 8 51	5·927 8 57	5·611 9 08
2·8	5·780 9 17	6·097 9 02	6·345 8 55	6·514 8 52	6·600 8 50	6·600 8 50	6·514 8 52	6·345 8 55	6·097 9 02	5·780 9 17
2·9	5·951 9 25	6·274 9 07	6·522 8 59	6·692 8 55	6·779 8 54	6·779 8 54	6·692 8 55	6·522 8 59	6·274 9 07	5·951 9 25
3·0	6·125 9 34	6·446 9 13	6·700 9 03	6·875 8 59	6·959 8 57	6·959 8 57	6·875 8 59	6·700 9 03	6·446 9 13	6·125 9 34
4·0	8·000 12 25	8·261 10 03	8·517 9 42	8·701 9 32	8·795 9 28	8·795 9 28	8·701 9 32	8·517 9 42	8·261 10 03	8.000 12 25
5·0	10·000 12 25	10·165 10 43	10·399 10 11	10·579 9 58	10·675 9 52	10·675 9 52	10·579 9 58	10·399 10 11	10·165 10 43	10 00 12 25
10·0	20·000 12 25	20·037 11 48	20·146 11 18	20·289 11 01	20·387 10 53	20·387 10 53	20·289 11 01	20·146 11 18	20·037 11 48	20 00 12 25
HW phase.	180° 360	190° 350	200° 340	210° 330	220° 320	230° 310	240° 300	250° 290	260° 280	270° 270

The first value of each pair is the value of the great tropic range; the second, its duration in hours and minutes.
This table assumes that $d_1 = m_1$.
See §§ 25, 37, and 53.

TABLE 21.—*Effects of various tidal components upon the mean semirange of tide.* *

[The amplitude of M_2 is taken as unity.]

Amplitude of subordinate component.	Semidiurnal components.								Amplitude of subordinate component.	Diurnal components.				
	K_2	L_2	N_2	S_2	λ_2	μ_2	ν_2	$\frac{B^2}{4}$		K_1	O_1	P_1	Q_1	$\frac{B^2}{16}$
0·02	·0001	·0001	·0001	·0001	·0001	·0001	·0001	·0001	0·04	·0001	·0001	·0001	·0001	·0001
0·04	·0004	·0004	·0004	·0004	·0004	·0004	·0004	·0004	0·08	·0004	·0004	·0004	·0003	·0004
0·06	·0010	·0009	·0009	·0010	·0009	·0008	·0009	·0009	0·12	·0010	·0008	·0010	·0008	·0009
0·08	·0017	·0017	·0015	·0017	·0017	·0015	·0015	·0016	9·16	·0017	·0015	·0017	·0014	·0016
0·10	·0027	·0026	·0024	·0027	·0026	·0023	·0024	·0025	0·20	·0027	·0023	·0027	·0021	·0025
0·12	·0039	·0037	·0035	·0039				·0036	0·24	·0039	·0033	·0038	·0030	·0036
0·14	·0053	·0051	·0047	·0052				·0049	0·28	·0053	·0045	·0052	·0041	·0049
0·16	·0069		·0061	·0069				·0064	0·32	·0069	·0059	·0068		·0064
0·18	·0087		·0078	·0087				·0081	0·36	·0087	·0075	·0086		·0081
0·20	·0108		·0096	·0107				·0100	0·40	·0108	·0093	·0106		·0100
0·22	·0130		·0116	·0130				·0121	0·44	·0130	·0112	·0127		·0121
0·24	·0155		·0138	·0154				·0144	0·48	·0155	·0133	·0150		·0144
0·26			·0162	·0181				·0169	0·52	·0182	·0156	·0176		·0169
0·28			·0188	·0210				·0196	0·56	·0211	·0181			·0196
0·30			·0216	·0241				·0225	0·60	·0242	·0208			·0225
0·32				·0274				·0256	0·64	·0276	·0237			·0256
0·34				·0310				·0289	0·68	·0311	·0268			·0289
0·36				·0347				·0324	0·72	·0349	·0300			·0324
0·38				·0387				·0361	0·76	·0389	·0334			·0361
0·40				·0428				·0400	0·80	·0431	·0370			·0400
0·42				·0472				·0441	0·84	·0475	·0407			·0441
0·44				·0518				·0484	0·88	·0521	·0447			·0484
0·46				·0567				·0529	0·92	·0570	·0488			·0529
0·48				·0617				·0576	0·96	·0620	·0532			·0576
0·50				·0669				·0625	1·00	·0673	·0577			·0625
									1·04	·0728	·0624			·0676
0·60				·0964				·0900	1·08	·0785	·0673			·0729
0·70				·1312				·1225	1·12	·0845	·0723			·0784
0·80				·1715				·1600	1·16	·0906	·0776			·0841
0·90				·2169				·2025	1·20	·0969	·0831			·0900
1·00				·2678				·2500	1·24	·1035	·0887			·0961
									1·28	·1103	·0945			·1024
									1·32	·1173				·1089
									1·36	·1245				·1156
									1·40	·1320				·1225
									1·44	·1396				·1296
									1·48	·1475				·1369
									1·52	·1555				·1444
									1·56	·1637				·1521
									1·60	·1720				·1600
									1·64	·1805				·1681
									1·68	·1892				·1764

* Tabular value for component $C = \frac{C^2}{4 M_2} \frac{c^2}{m_2^2}$, § 13.

TABLE 22.—*Value of* $\frac{1}{2}$ Mn *when* $M_2 = 1$.

$\frac{K_1+O_1}{M_2}$	S_2/M_2							
	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8
0·0	1·0127	1·0213	1·0357	1·0558	1·0817	1·1134	1·1508	1·1940
0·2	1·0142	1·0228	1·0372	1·0573	1·0832	1·1149	1·1523	1·1955
0·4	1·0185	1·0271	1·0415	1·0616	1·0875	1·1192	1·1566	1·1998
0·6	1·0257	1·0343	1·0487	1·0688	1·0947	1·1264	1·1638	1·2070
0·8	1·0357	1·0443	1·0587	1·0788	1·1047	1·1364	1·1738	1·2170
1·0	1·0486	1·0572	1·0716	1·0917	1·1176	1·1493	1·1867	1·2299
1·2	1·0643	1·0729	1·0873	1·1074	1·1333	1·1650	1·2024	1·2456
1·4	1·0830	1·0916	1·1060	1·1261	1·1520	1·1837	1·2211	1·2643
1·6	1·1045	1·1131	1·1275	1·1476	1·1735	1·2052	1·2426	1·2858
1·8	1·1289	1·1375	1·1519	1·1720	1·1979	1·2296	1·2670	1·3102
2·0	1·1559	1·1645	1·1789	1·1990	1·2249	1·2566	1·2940	1·3372
2·5	1·2360	1·2446	1·2590	1·2791	1·3050	1·3367	1·3741	1·4173

This table, based upon Tables 1 and 21, is computed upon the assumption that the ratios between the diurnal components, the pure lunar semidiurnals, the solar semidiurnals (including luni-solar K_2), are respectively constant for all stations; also that shallow water tides do not occur.

On account of nonpredictable inequalities, the tabular values should be multiplied by about 1·02.

TABLE 23.—*Value of* M_2 *when* $\frac{1}{2}$ Mn = 1.

$\frac{K_1+O_1}{\frac{1}{2}Mn}$	$S_2/\frac{1}{2}Mn$							
	0.1	0·2	0·3	0·4	0·5	0·6	0·7	0·8
0·0	0·9873	0·9785	0·9634	0·9414	0·9116	0·8725	0·8221	0·7574
0·2	0·9858	0·9770	0·9618	0·9396	0·9096	0·8702	0·8194	0·7542
0·4	0·9814	0·9725	0·9572	0·9348	0·9045	0·8648	0·8136	0·7479
0·6	0·9740	0·9650	0·9495	0·9269	0·8963	0·8562	0·8045	0·7382
0·8	0·9635	0·9543	0·9386	0·9157	0·8847	0·8442	0·7919	0·7249
1·0	0·9497	0·9403	0·9243	0·9011	0·8696	0·9286	0·7756	0·7077
1·2	0.9322	0·9225	0·9062	0·8826	0·8506	0·8090	0·7552	0·6863
1·4	0·9106	0·9006	0·8839	0·8598	0·8272	0·7849	0·7302	0·6602
1·6	0·8844	0·8740	0·8568	0·8321	0·7988	0·7557	0·7000	0·6288
1·8	0·8529	0·8421	0·8243	0·7989	0·7648	0·7207	0·6639	0·5913
2·0	0·8151	0·8038	0·7854	0·7592	0·7242	0·6789	0·6208	0·5465
2·5	0·7175	0·7049	0·6848	0·6566	0·6193	0·5710	0·5093	0·4304

This table is Table 22 reverted.

On account of nonpredictable inequalities, the tabular values should be divided by about 1·02.

TABLE 24.—*Variation in lunitidal interval and mean semirange of tide, due to the phase wave composed of* S_2 *and* μ_2

Time.			Increase in lunitidal interval due to S_2.	Increase in mean semirange of tide due to S_2 and μ_2. Length of half group.				
				0 tides.	4 tides.	6 tides.	8 tides.	10 tides.
	d.	*h.*	*m.*					
After spring tides.	0	00	0 S_2/M_2	+0·93 S_2	+0·90 S_2	+0·88 S_2	+0·84 S_2	+0·79 S_2
	0	06	— 9 "	+0·92 "	+0·90 "	+0·87 "	+0·83 "	+0·78 "
	0	12	— 18 "	+0·91 "	+0·89 "	+0·86 "	+0·82 "	+0·77 "
	0	18	— 27 "	+0·89 "	+0·87 "	+0·84 "	+0·81 "	+0·76 "
	1	00	— 35 "	+0·86 "	+0·84 "	+0·81 "	+0·78 "	+0·73 "
	1	06	— 44 "	+0·82 "	+0·80 "	+0·77 "	+0·74 "	+0·69 "
	1	12	— 52 "	+0·78 "	+0·76 "	+0·73 "	+0·70 "	+0·66 "
	1	18	— 61 "	+0·73 "	+0·71 "	+0·69 "	+0·65 "	+0·62 "
	2	00	— 69 "	+0·67 "	+0·65 "	+0·63 "	+0·59 "	+0·56 "
	2	06	— 77 "	+0·60 "	+0·58 "	+0·56 "	+0·53 "	+0·50 "
	2	12	— 84 "	+0·53 "	+0·51 "	+0·50 "	+0·47 "	+0·44 "
	2	18	— 92 "	+0·45 "	+0·44 "	+0·43 "	+0·40 "	+0·37 "
	3	00	— 98 "	+0·36 "	+0·35 "	+0·34 "	+0·32 "	+0·29 "
	3	06	—105 "	+0·27 "	+0·26 "	+0·25 "	+0·23 "	+0·21 "
	3	12	—111 "	+0·18 "	+0·18 "	+0·17 "	+0·15 "	+0·13 "
	3	18	—116 "	+0·07 "	+0·07 "	+0·07 "	+0·05 "	+0·03 "
	4	00	—120 "	—0·03 "	—0·04 "	—0·04 "	—0·06 "	—0·08 "
Before neap tides.	4	00	—108 "	+0·22 "	+0·20 "	+0·19 "	+0·19 "	+0·18 "
	3	18	—113 "	+0·12 "	+0·10 "	+0·09 "	+0·08 "	+0·07 "
	3	12	—118 "	+0·02 "	0·00 "	—0·01 "	—0·02 "	—0·03 "
	3	06	—122 "	—0·09 "	—0·10 "	—0·11 "	—0·12 "	—0·13 "
	3	00	—125 "	—0·20 "	—0·20 "	—0·22 "	—0·23 "	—0·23 "
	2	18	—127 "	—0·31 "	—0·30 "	—0·32 "	—0·32 "	—0·32 "
	2	12	—127 "	—0·42 "	—0·41 "	—0·42 "	—0·42 "	—0·40 "
	2	06	—126 "	—0·53 "	—0·52 "	—0·52 "	—0·51 "	—0·49 "
	2	00	—123 "	—0·64 "	—0·63 "	—0·61 "	—0·60 "	—0·57 "
	1	18	—117 "	—0·74 "	—0·73 "	—0·70 "	—0·68 "	—0·64 "
	1	12	—109 "	—0·84 "	—0·82 "	—0·78 "	—0·76 "	—0·70 "
	1	06	— 99 "	—0·93 "	—0·90 "	—0·86 "	—0·83 "	—0·75 "
	1	00	— 84 "	—1·01 "	—0·98 "	—0·93 "	—0·87 "	—0·80 "
	0	18	— 67 "	—1·08 "	—1·05 "	—0·99 "	—0·93 "	—0·85 "
	0	12	— 47 "	—1·13 "	—1·09 "	—1·03 "	—0·96 "	—0·88 "
	0	06	— 24 "	—1·16 "	—1·11 "	—1·05 "	—0·97 "	—0·89 "
	0	00	0 "	—1·18 "	—1·12 "	—1·06 "	—0·98 "	—0·89 "
After neap tides.	0	00	0 "	—1·18 "	—1·12 "	—1·06 "	—0·98 "	—0·89 "
	0	06	+ 24 "	—1·16 "	—1·11 "	—1·05 "	—0·97 "	—0·89 "
	0	12	+ 47 "	—1·13 "	—1·09 "	—1·03 "	—0·96 "	—0·88 "
	0	18	+ 67 "	—1·08 "	—1·05 "	—0·99 "	—0·93 "	—0·85 "
	1	00	+ 84 "	—1·01 "	—0·98 "	—0·93 "	—0·87 "	—0·80 "
	1	06	+ 99 "	—0·93 "	—0·90 "	—0·86 "	—0·83 "	—0·75 "
	1	12	+109 "	—0·84 "	—0·82 "	—0·78 "	—0·76 "	—0·70 "
	1	18	+117 "	—0·74 "	—0·73 "	—0·70 "	—0·68 "	—0·64 "
	2	00	+123 "	—0·64 "	—0·63 "	—0·61 "	—0·59 "	—0·56 "
	2	06	+126 "	—0·53 "	—0·52 "	—0·52 "	—0·50 "	—0·48 "
	2	12	+127 "	—0·42 "	—0·41 "	—0·42 "	—0·42 "	—0·40 "
	2	18	+127 "	—0·31 "	—0·30 "	—0·32 "	—0·32 "	—0·31 "
	3	00	+125 "	—0·20 "	—0·20 "	—0·21 "	—0·22 "	—0·22 "
	3	06	+122 "	—0·09 "	—0·09 "	—0·11 "	—0·11 "	—0·11 "
	3	12	+118 "	+0·02 "	+0·01 "	+0·01 "	0·00 "	0·00 "
	3	18	+113 "	+0·12 "	+0·11 "	+0·11 "	+0·10 "	+0·10 "
	4	00	+108 "	+0·22 "	+0·21 "	+0·21 "	+0·20 "	+0·19 "
Before spring tides.	4	00	+120 "	—0·03 "	—0·04 "	—0·05 "	—0·06 "	—0·07 "
	3	18	+116 "	+0·07 "	+0·07 "	+0·06 "	+0·04 "	+0·03 "
	3	12	+111 "	+0·18 "	+0·18 "	+0·17 "	+0·15 "	+0·13 "
	3	06	+105 "	+0·27 "	+0·27 "	+0·26 "	+0·24 "	+0·22 "
	3	00	+ 98 "	+0·36 "	+0·36 "	+0·35 "	+0·32 "	+0·30 "
	2	18	+ 92 "	+0·45 "	+0·45 "	+0·43 "	+0·40 "	+0·38 "
	2	12	+ 84 "	+0·53 "	+0·52 "	+0·50 "	+0·47 "	+0·45 "
	2	06	+ 77 "	+0·60 "	+0·58 "	+0·56 "	+0·53 "	+0·50 "
	2	00	+ 69 "	+0·67 "	+0·65 "	+0·63 "	+0·60 "	+0·56 "
	1	18	+ 61 "	+0·73 "	+0·71 "	+0·69 "	+0·66 "	+0·62 "
	1	12	+ 52 "	+0·78 "	+0·76 "	+0·73 "	+0·71 "	+0·66 "
	1	06	+ 44 "	+0·82 "	+0·80 "	+0·77 "	+0·74 "	+0·69 "
	1	00	+ 35 "	+0·86 "	+0·84 "	+0·81 "	+0·78 "	+0·73 "
	0	18	+ 27 "	+0·89 "	+0·87 "	+0·84 "	+0·81 "	+0·76 "
	0	12	+ 18 "	+0·91 "	+0·89 "	+0·86 "	+0·82 "	+0·77 "
	0	06	+ 9 "	+0·92 "	+0·90 "	+0·87 "	+0·83 "	+0·78 "
	0	00	0 "	+0·93 "	+0·90 "	+0·88 "	+0·84 "	+0·79 "

In clearing tides of phase or semimenstrual height inequality, apply the tabulated values as they stand to the low waters, but alter their signs for the high waters.

Spring and neap tides occur $\frac{S_2^\circ - M_2^\circ}{1{\cdot}0159}$ hours after syzygy and quadrature.

This table is based upon Tables 1, 15, 16, and 21.

TABLE 25.—*Variation in mean semirange of tide due to the parallax wave composed of* N_2, L_2, *and* 2N.

Time.		Increase in mean semirange of tide due to N_2, L_2, and 2N. Length of half group.				Time.		Increase in mean semirange of tide due to N_2, L_2, and 2N. Length of half group.			
		0 tides.	4 tides.	8 tides.	12 tides.			0 tides.	4 tides.	8 tides.	12 tides.
	d. *h.*						*d.* *h.*				
After perigean tides.	0 00	+0·94 N_2	+0·93 N_2	+0·90 N_2	+0·85 N_2	After apogean tides.	0 00	−0·77 N_2	−0·77 N_2	−0·76 N_2	−0·73 N_2
	0 06	+0·94 "	+0·93 "	+0·90 "	+0·85 "		0 06	−0·77 "	−0·77 "	−0·76 "	−0·73 "
	0 12	+0·93 "	+0·93 "	+0·89 "	+0·84 "		0 12	−0·77 "	−0·77 "	−0·76 "	−0·73 "
	0 18	+0·92 "	+0·91 "	+0·88 "	+0·83 "		0 18	−0·76 "	−0·76 "	−0·75 "	−0·73 "
	1 00	+0·91 "	+0·91 "	+0·87 "	+0·82 "		1 00	−0·75 "	−0·75 "	−0·74 "	−0·72 "
	1 06	+0·89 "	+0·89 "	+0.85 "	+0·80 "		1 06	−0·75 "	−0·75 "	−0·74 "	−0·72 "
	1 12	+0·87 "	+0·87 "	+0·84 "	+0·79 "		1 12	−0·74 "	−0·74 "	−0·73 "	−0·71 "
	1 18	+0·85 "	+0·85 "	+0·82 "	+0·77 "		1 18	−0·73 "	−0·72 "	−0·72 "	−0·70 "
	2 00	+0·82 "	+0·82 "	+0·80 "	+0·76 "		2 00	−0·71 "	−0·70 "	−0·70 "	−0·67 "
	2 06	+0·79 "	+0·79 "	+0·77 "	+0·73 "		2 06	−0·69 "	−0·69 "	−0·68 "	−0·65 "
	2 12	+0·75 "	+0·75 "	+0·74 "	+0·70 "		2 12	−0·68 "	−0·68 "	−0·65 "	−0·64 "
	2 18	+0·72 "	+0·72 "	+0·72 "	+0·67 "		2 18	−0·66 "	−0·66 "	−0·64 "	−0·63 "
	3 00	+0·68 "	+0·68 "	+0·67 "	+0·64 "		3 00	−0·63 "	−0·63 "	−0·62 "	−0·60 "
	3 06	+0·64 "	+0·64 "	+0·63 "	+0·61 "		3 06	−0·61 "	−0·61 "	−0·60 "	−0·57 "
	3 12	+0·60 "	+0·60 "	+0·59 "	+0·57 "		3 12	−0·58 "	−0·58 "	−0·57 "	−0·54 "
Before midtime tides.	3 12	+0·61 "	+0·61 "	+0·59 "	+0·57 "	Before midtime tides.	3 12	−0·60 "	−0·60 "	−0·58 "	−0·56 "
	3 06	+0.57 "	+0·57 "	+0·55 "	+0·53 "		3 06	−0·57 "	−0·57 "	−0·55 "	−0·53 "
	3 00	+0·52 "	+0·51 "	+0·50 "	+0·49 "		3 00	−0·55 "	−0·54 "	−0·52 "	−0·50 "
	2 18	+0·48 "	+0·47 "	+0·45 "	+0·45 "		2 18	−0·51 "	−0·51 "	−0·50 "	−0·46 "
	2 12	+0·43 "	+0·43 "	+0·40 "	+0·40 "		2 12	−0·47 "	−0·47 "	−0·46 "	−0·43 "
	2 06	+0·38 "	+0·38 "	+0·36 "	+0·36 "		2 06	−0·45 "	−0·45 "	−0·44 "	−0·41 "
	2 00	+0·33 "	+0·33 "	+0·31 "	+0·31 "		2 00	−0·41 "	−0·41 "	−0·40 "	−0·37 "
	1 18	+0·28 "	+0·28 "	+0·27 "	+0·28 "		1 18	−0·37 "	−0·37 "	−0·35 "	−0·32 "
	1 12	+0·23 "	+0·23 "	+0·23 "	+0·24 "		1 12	−0·33 "	−0·33 "	−0·32 "	−0·29 "
	1 06	+0·18 "	+0·18 "	+0·19 "	+0·20 "		1 06	−0·29 "	−0·29 "	−0·27 "	−0·24 "
	1 00	+0·12 "	+0·12 "	+0·13 "	+0·14 "		1 00	−0·26 "	−0·26 "	−0·24 "	−0·21 "
	0 18	+0·08 "	+0·08 "	+0·09 "	+0·10 "		0 18	−0·21 "	−0·21 "	−0·19 "	−0·16 "
	0 12	+0·02 "	+0·02 "	+0·04 "	+0·04 "		0 12	−0·17 "	−0·17 "	−0·15 "	−0·13 "
	0 06	−0·02 "	−0·02 "	0·00 "	+0·01 "		0 06	−0·12 "	−0·12 "	−0·10 "	−0·09 "
	0 00	−0·07 "	−0·07 "	−0·06 "	−0·04 "		0 00	−0·07 "	−0·07 "	−0·06 "	−0·04 "
After midtime tides.	0 00	−0·07 "	−0·07 "	−0·06 "	−0·04 "	After midtime tides.	0 00	−0·07 "	−0·07 "	−0·06 "	−0·04 "
	0 06	−0·12 "	−0·12 "	−0·10 "	−0·09 "		0 06	−0·02 "	−0·02 "	0·00 "	+0·01 "
	0 12	−0·17 "	−0·17 "	−0·15 "	−0·13 "		0 12	+0·02 "	+0·02 "	+0·04 "	+0·04 "
	0 18	−0·21 "	−0·21 "	−0·19 "	−0·16 "		0 18	+0·08 "	+0·08 "	+0·09 "	+0·10 "
	1 00	−0·26 "	−0·26 "	−0·24 "	−0·21 "		1 00	+0·12 "	+0·12 "	+0·13 "	+0·14 "
	1 06	−0·29 "	−0·29 "	−0·27 "	−0·24 "		1 06	+0·18 "	+0·18 "	+0·19 "	+0·20 "
	1 12	−0·33 "	−0·33 "	−0·32 "	−0·29 "		1 12	+0·23 "	+0·23 "	+0·23 "	+0·24 "
	1 18	−0·37 "	−0·37 "	−0·35 "	−0·32 "		1 18	+0·28 "	+0·28 "	+0·27 "	+0·28 "
	2 00	−0·41 "	−0·41 "	−0·40 "	−0·37 "		2 00	+0·33 "	+0·33 "	+0·31 "	+0·31 "
	2 06	−0·45 "	−0·45 "	−0·44 "	−0·41 "		2 06	+0·38 "	+0·38 "	+0·36 "	+0·36 "
	2 12	−0.47 "	−0·47 "	−0·46 "	−0·43 "		2 12	+0·43 "	+0·43 "	+0·40 "	+0·40 "
	2 18	−0·51 "	−0·51 "	−0·50 "	−0·46 "		2 18	+0·48 "	+0·47 "	+0·45 "	+0·45 "
	3 00	−0·55 "	−0·54 "	−0·52 "	−0·50 "		3 00	+0·52 "	+0·51 "	+0·50 "	+0·49 "
	3 06	−0·57 "	−0·57 "	−0·55 "	−0·53 "		3 06	+0·57 "	+0·57 "	+0·55 "	+0·53 "
	3 12	−0·60 "	−0·60 "	−0·58 "	−0·56 "		3 12	+0·61 "	+0·61 "	+0·59 "	+0·57 "
Before apogean tides.	3 12	−0·58 "	−0·58 "	−0·57 "	−0·54 "	Before perigean tides.	3 12	+0·60 "	+0·60 "	+0·59 "	+0·57 "
	3 06	−0·61 "	−0·61 "	−0·60 "	−0·57 "		3 06	+0·64 "	+0·64 "	+0·63 "	+0·61 "
	3 00	−0·63 "	−0·63 "	−0·62 "	−0·60 "		3 00	+0·68 "	+0·68 "	+0·67 "	+0·64 "
	2 18	−0·66 "	−0·66 "	−0·64 "	−0·63 "		2 18	+0·72 "	+0·72 "	+0·72 "	+0·67 "
	2 12	−0·68 "	−0·68 "	−0·65 "	−0·64 "		2 12	+0·75 "	+0·75 "	+0·74 "	+0·70 "
	2 06	−0·69 "	−0·69 "	−0·67 "	−0·65 "		2 06	+0·79 "	+0·79 "	+0·77 "	+0·73 "
	2 00	−0·71 "	−0·70 "	−0·68 "	−0·67 "		2 00	+0·82 "	+0·82 "	+0·80 "	+0·76 "
	1 18	−0·73 "	−0·72 "	−0·72 "	−0·70 "		1 18	+0·85 "	+0·85 "	+0·82 "	+0·77 "
	1 12	−0·74 "	−0·74 "	−0·73 "	−0·71 "		1 12	+0·87 "	+0·87 "	+0·84 "	+0·79 "
	1 06	−0·75 "	−0·75 "	−0·74 "	−0·72 "		1 06	+0·89 "	+0·89 "	+0·85 "	+0·80 "
	1 00	−0·75 "	−0·75 "	−0·74 "	−0·72 "		1 00	+0·91 "	+0·91 "	+0·87 "	+0·82 "
	0 18	−0·76 "	−0·76 "	−0·75 "	−0·73 "		0 18	+0·92 "	+0·91 "	+0·88 "	+0·83 "
	0 12	−0·77 "	−0·77 "	−0·76 "	−0·73 "		0 12	+0·93 "	+0·93 "	+0·89 "	+0·84 "
	0 06	−0·77 "	−0·77 "	−0·76 "	−0·73 "		0 06	+0·94 "	+0·93 "	+0·90 "	+0·85 "
	0 00	−0·77 "	−0·77 "	−0·76 "	−0·73 "		0 00	+0·94 "	+0·93 "	+0·90 "	+0·85 "

In clearing tides of this inequality, apply the tabular values as they stand to the low waters, but alter their signs for the high waters.

Perigean tides, apogean tides, etc., occur $\frac{M_2^\circ - N_2^\circ}{0{\cdot}5444}$ hours after perigee, apogee, etc.

This table is based upon Tables 1, 16, and 21.

TABLE 26.—*Effect of* Q_1 *upon the amplitude of* O_1.

Time.		Resultant amp. O_1 and Q_1. $O_1 = 1$.	Time.		Resultant amp. O_1 and Q_1. $O_1 = 1$.
	d.			*d.*	
After perigee.	0	1·19	After apogee.	0	0·81
	1	1·19		1	0·81
	2	1·18		2	0·83
	3	1·16		3	0·86
Before midtime.	3	1·13	Before midtime.	3	0·89
	2	1·10		2	0·93
	1	1·06		1	0·98
	0	1·02		0	0·02
After midtime.	0	1·02	After midtime.	0	1·02
	1	0·98		1	1·06
	2	0·93		2	1·10
	3	0·89		3	1·13
Before apogee.	3	0·86	Before perigee.	3	1·16
	2	0·83		2	1·18
	1	0·81		1	1·19
	0	0·81		0	1·19

This table is based upon Tables 1 and 16.

TABLE 27.—*Perturbations in* K_1 *due to* O_1.

Time.			Increase in K_1 tidal interval due to O_1.	Increase in semi-range of K_1 tide due to O_1.	Time.			Increase in K_1 tidal interval due to O_1.	Increase in semi-range of K_1 tide due to O_1.
	d.	*h.*	*h.* *m.*			*d.*	*h.*	*h.* *m.*	
After maximum declinational tides.	0	00	+0 00 O_1/K_1	+1·00 O_1	After minimum declinational tides.	0	00	0 00 O_1/K_1	−1·00 O_1
	0	06	+0 14 "	+0·99 "		0	06	−1 14 "	−0·97 "
	0	12	+0 28 "	+0·98 "		0	12	−2 16 "	−0·91 "
	0	18	+0 43 "	+0·96 "		0	18	−3 03 "	−0·83 "
	1	00	+0 57 "	+0·94 "		1	00	−3 27 "	−0·73 "
	1	06	+1 11 "	+0·90 "		1	06	−3 44 "	−0·63 "
	1	12	+1 25 "	+0·86 "		1	12	−3 53 "	−0·51 "
	1	18	+1 39 "	+0·81 "		1	18	−3 54 "	−0·40 "
	2	00	+1 53 "	+0·75 "		2	00	−3 52 "	−0·28 "
	2	06	+2 06 "	+0·69 "		2	06	−3 48 "	−0·17 "
	2	12	+2 19 "	+0·62 "		2	12	−3 40 "	−0·06 "
	2	18	+2 32 "	+0·55 "		2	18	−3 32 "	+0·05 "
	3	00	+2 45 "	+0·46 "		3	00	−3 23 "	+0·15 "
	3	06	+2 57 "	+0·37 "		3	06	−3 12 "	+0·25 "
	3	12	+3 09 "	+0·28 "		3	12	−3 01 "	+0·35 "
Before minimum declinational tides.	3	12	+3 01 "	+0·35 "	Before maximum declinational tides.	3	12	−3 09 "	+0·28 "
	3	06	+3 12 "	+0·25 "		3	06	−2 57 "	+0·37 "
	3	00	+3 23 "	+0·15 "		3	00	−2 45 "	+0·46 "
	2	18	+3 32 "	+0·05 "		2	18	−2 32 "	+0·55 "
	2	12	+3 40 "	−0·06 "		2	12	−2 19 "	+0·62 "
	2	06	+3 48 "	−0·17 "		2	06	−2 06 "	+0·69 "
	2	00	+3 52 "	−0·28 "		2	00	−1 53 "	+0·75 "
	1	18	+3 54 "	−0·40 "		1	18	−1 39 "	+0·81 "
	1	12	+3 53 "	−0·51 "		1	12	−1 25 "	+0·86 "
	1	06	+3 44 "	−0·63 "		1	06	−1 11 "	+0·90 "
	1	00	+3 27 "	−0·73 "		1	00	−0 57 "	+0·94 "
	0	18	+3 03 "	−0·83 "		0	18	−0 43 "	+0·96 "
	0	12	+2 16 "	−0·91 "		0	12	−0 28 "	+0·98 "
	0	06	+1 14 "	−0·97 "		0	06	−0 14 "	+0·99 "
	0	00	+0 00 "	−1·00 "		0	00	−0 00 "	+1·00 "

Maximum and minimum declinational tides occur $\frac{K_1^\circ - O_1^\circ}{1{\cdot}0980}$ hours after extreme and zero declination, provided K_1° is decreased by the acceleration in K_1 due to P_1, Table 31. See § 67.

This table is based upon Tables 1, 15, and 16.

TABLE 28.—*The speed which corresponds to a period of given length.*

Length of half period.			Speed.		Time equal to one degree.
			Per hour.	Per minute.	
h.	*m.*	*m.*	°	°	*m.*
10	00	600	18·000	0·3000	3·333
	10	610	17·705	0·2951	3·389
	20	620	17·419	0·2903	3·445
	30	630	17·143	0·2857	3·500
	40	640	16·875	0·2813	3·556
	50	650	16·615	0·2769	3·611
11	00	660	16·364	0·2727	3·667
	10	670	16·119	0·2687	3·722
	20	680	15·882	0·2647	3·778
	30	690	15·652	0·2609	3·833
	40	700	15·429	0·2571	3·889
	50	710	15·211	0·2535	3·945
12	00	720	15·000	0·2500	4·000
	10	730	14·795	0·2466	4·055
	20	740	14·595	5·2433	4·111
	30	750	14·400	0·2400	4·167
	40	760	14·211	0·2369	4·222
	50	770	14·026	0·2338	4·278
13	00	780	13·846	0·2308	4·333
	10	790	13·671	0·2279	4·389
	20	800	13·500	0·2250	4·444
	30	810	13·333	0·2222	4·500
	40	820	13·171	0·2195	4·555
	50	830	13·012	0·2169	4·611
14	00	840	12·857	0·2143	4·667

TABLE 29.—*The sun's mean longitude at Greenwich mean noon.*

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

This table assumes that the value for January 1 is 280·6.

TABLE 30.—*Approximate equation of time at Greenwich mean noon.*

[To change apparent to mean time.]

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.
	m.	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*
1	+ 3·8	+13·8	+12·5	+3·9	−3·0	−2·4	+3·5	+6·1	0·0	−10·3	−16·3	−10·8
2	+ 4·2	+13·9	+12·3	+3·6	−3·1	−2·3	+3·7	+6·0	− 0·4	−10·6	−16·3	−10·5
3	+ 4·7	+14·0	+12·1	+3·3	−3·2	−2·1	+3·9	+6·0	− 0·7	−10·9	−16·3	−10·0
4	+ 5·2	+14·1	+11·9	+3·0	−3·3	−2·0	+4·1	+5·9	− 1·1	−11·2	−16·3	− 9·7
5	+ 5·6	+14·2	+11·7	+2·8	−3·4	−1·8	+4·3	+5·8	− 1·3	−11·5	−16·3	− 9·3
6	+ 6·1	+14·3	+11·4	+2·5	−3·5	−1·6	+4·5	+5·7	− 1·7	−11·8	−16·3	− 8·8
7	+ 6·5	+14·3	+11·2	+2·2	−3·6	−1·4	+4·6	+5·6	− 2·0	−12·1	−16·2	− 8·4
8	+ 6·9	+14·4	+11·0	+1·9	−3·7	−1·3	+4·8	+5·5	− 2·4	−12·4	−16·2	− 8·0
9	+ 7·3	+14·4	+10·7	+1·6	−3·7	−1·0	+4·9	+5·3	− 2·7	−12·7	−16·0	− 7·5
10	+ 7·7	+14·4	+10·4	+1·3	−3·8	−0·9	+5·0	+5·2	− 3·1	−12·9	−16·0	− 7·1
11	+ 8·1	+14·4	+10·2	+1·0	−3·8	−0·7	+5·2	+5·1	− 3·4	−13·2	−15·9	− 6·6
12	+ 8·5	+14·4	+ 9·9	+0·8	−3·8	−0·5	+5·3	+4·9	− 3·7	−13·5	−15·7	− 6·1
13	+ 8·9	+14·4	+ 9·6	+0·5	−3·9	−0·3	+5·5	+4·7	− 4·1	−13·7	−15·6	− 5·7
14	+ 9·3	+14·4	+ 9·3	+0·3	−3·9	−0·1	+5·6	+4·5	− 4·4	−13·9	−15·3	− 5·2
15	+ 9·6	+14·3	+ 9·1	+0·1	−3·9	+0·2	+5·7	+4·3	− 4·8	−14·1	−15·3	− 4·7
16	+10·0	+14·3	+ 8·7	−0·2	−3·9	+0·4	+5·8	+4·1	− 5·2	−14·4	−15·1	− 4·2
17	+10·3	+14·2	+ 8·5	−0·5	−3·8	+0·6	+5·9	+3·9	− 5·5	−14·6	−14·9	− 3·7
18	+10·6	+14·1	+ 8·2	−0·7	−3·8	+0·8	+6·0	+3·7	− 5·9	−14·8	−14·7	− 3·2
19	+10·9	+14·0	+ 7·9	−0·9	−3·8	+1·0	+6·1	+3·5	− 6·2	−14·9	−14·5	− 2·7
20	+11·2	+13·9	+ 7·6	−1·1	−3·7	+1·2	+6·1	+3·3	− 6·6	−15·1	−14·3	− 2·2
21	+11·5	+13·8	+ 7·3	−1·3	−3·6	+1·5	+6·2	+3·0	− 6·9	−15·3	−14·0	− 1·7
22	+11·8	+13·7	+ 7·0	−1·5	−3·6	+1·7	+6·2	+2·8	− 7·3	−15·4	−13·7	− 1·2
23	+12·1	+13·5	+ 6·7	−1·7	−3·5	+1·9	+6·2	+2·5	− 7·6	−15·6	−13·5	− 0·7
24	+12·3	+13·4	+ 6·4	−1·9	−3·4	+2·1	+6·3	+2·3	− 8·0	−15·7	−13·2	− 0·2
25	+12·5	+13·2	+ 6·0	−2·1	−3·3	+2·3	+6·3	+2·0	− 8·3	−15·8	−12·9	+ 0·3
26	+12·8	+13·0	+ 5·8	−2·3	−3·2	+2·5	+6·3	+1·7	− 8·6	−15·9	−12·6	+ 0·7
27	+13·0	+12·9	+ 5·5	−2·4	−3·1	+2·7	+6·3	+1·4	− 9·0	−16·0	−12·2	+ 1·2
28	+13·2	+12·7	+ 5·2	−2·6	−3·0	+3·0	+6·3	+1·2	− 9·3	−16·1	−11·9	+ 1·7
29	+13·3	+12·5	+ 4·9	−2·7	−2·9	+3·2	+6·3	+0·9	− 9·6	−16·2	−11·6	+ 2·2
30	+13·5		+ 4·6	−2·9	−2·7	+3·4	+6·2	+0·6	−10·0	−16·2	−11·2	+ 2·7
31	+13·7		+ 4·3		−2·6		+6·2	+0·3		−16·3		+ 3·2

$\frac{\text{Sun's mean longitude}}{15}$ = right ascension of mean sun = sidereal time of mean noon.

Sun's right ascension = right ascension of mean sun + equation of time.

TABLE 31.—*Perturbations in* K_1, S_2, *due to the components* P_1, K_2, *and* T_2.

Date. Greenwich mean noon.	Acceleration				Resultant amplitude.			
	In K_1 due to P_1.	In S_2 due to K_2.	In S_2 due to solar K_2.	In S_2 due to T_2.	K_1 and P_1 $K_1=1$.*	S_2 and K_2 $S_2=1$.	S_2 and solar K_2 $S_2=1$.	S_2 and T_2 $S_2=1$.
	°	°	°	c				
Jan. 1	— 5·2	— 7·6	—2·4	+0 1	1·314	·76	0·92	1·06
11	— 9·9	—12·5	—3·9	—0·5	1·267	·82	0·94	1·06
21	—13·8	—15·2	—4·8	—1·0	1·197	·90	0·96	1·06
31	—17·0	—15·6	—4·9	—1·5	1·105	·99	0·99	1·05
Feb. 10	—18·8	—14·1	—4·5	—1·9	0·993	1·08	1·02	1·05
20	—18·7	—11·6	—3·7	—2·3	0·885	1·16	1·05	1·04
Mar. 2	—15·8	— 8·2	—2·6	—2·7	0·782	1·22	1·07	1·03
12	— 9·4	— 4·4	—1·4	—3·0	0·706	1·25	1·08	1·02
22	— 0·5	— 0·3	—0·1	—3·2	0·676	1·27	1·09	1·01
Apr. 1	+ 8·5	+ 3·9	+1·2	—3·4	0·701	1·26	1·08	1·00
11	+15·4	+ 7·8	+2·5	—3·4	0·772	1·23	1·07	0·99
21	+18·6	+11·2	+3·6	—3·3	0·873	1·16	1·04	0·98
May 1	+18·9	+14·0	+4·4	—3·1	0·985	1·09	1·02	0·97
11	+17·3	+15·4	+4·9	—2·9	1·092	1·00	0·99	0·96
21	+14·2	+15·4	+4·9	—2·5	1·188	·91	0·96	0·96
31	+10·2	+13·0	+4·1	—2·0	1·261	·82	0·94	0·95
June 10	+ 5·7	+ 8·2	+2·6	—1·4	1·309	·76	0·92	0·95
20	+ 0·9	+ 1·3	+0·4	—0·8	1·329	·73	0·91	0·94
30	— 4·0	— 5·6	—1·8	—0·3	1·321	·74	0·92	0·94
July 10	— 8·7	—11·5	—3·7	+0·4	1·282	·80	0·93	0·94
20	—12·8	—14·6	—4·6	+1·0	1·217	·88	0·95	0·94
30	—16·3	—15·6	—5·0	+1·6	1·131	·97	0·98	0·95
Aug. 9	—18·6	—14·6	—4·7	+2·1	1·028	1·06	1·01	0·95
19	—19·1	—12·3	—3·9	+2·6	0·913	1·14	1·04	0·96
29	—17·0	— 9·2	—2·9	+2·9	0·807	1·21	1·06	0·97
Sept. 8	—11·7	— 5·5	—1·8	+3·2	0·721	1·25	1·08	0·98
18	— 3·1	— 1·3	—0·4	+3·3	0·677	1·27	1·08	0·99
28	+ 6·4	+ 2·8	+0·9	+3·4	0·687	1·26	1·08	1·00
Oct. 8	+14·0	+ 6·8	+2·2	+3·3	0·748	1·23	1·08	1·01
18	+18·2	+10·4	+3·3	+3·2	0·844	1·18	1·06	1·02
28	+19·2	+13·3	+4·2	+3·0	0·956	1·11	1·03	1·03
Nov. 7	+18·0	+15·2	+4·8	+2·7	1·065	1·03	1·00	1·03
17	+15·1	+15·4	+4·9	+2·3	1·165	·93	0·97	1·04
27	+11·3	+13·7	+4·4	+1·9	1·244	·84	0·95	1·05
Dec. 7	+ 7·0	+ 9·7	+3·1	+1·4	1·299	·78	0·93	1·05
17	+ 2·2	+ 3·3	+1·0	+0·7	1·327	·73	0·92	1·05
27	— 2·7	— 4·0	—1·2	+0·3	1·325	·74	0·92	1·06
Jan. 6	— 7·4	— 9·9	—3·3	—0·2	1·295	·79	0·92	1·06
Modification of tabular value for long. of moon's node.	Tabular value × $F(K_1)$.	Tabular value × $f(K_2)$.	Tabular value.	Tabular value.	(Tab. — 1) × $F(K_1)$ + 1 = c_1 or c_{11}.	(Tab. — 1) × $f(K_2)$ + 1.	Tabular value.	Tabular value.

* i. e. K_1' or the K_1 for the given year.

For the acceleration in S_2 due to lunar K_2, use the tabular value multiplied by $[f(K_2) - 0{\cdot}317]$.

This table is based upon Tables 1, 15, 16, and 29.

TABLE 32.—*Factor F_1 for clearing D_1 of the effects of the longitude of the moon's node and of P_1.*

Date.		*I*, or inclination of orbit to equator.											
		18½°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	28½°
Jan.	1	0·963	0·949	0·923	0·898	0·874	0·853	0·833	0·814	0·796	0·779	0·764	0·757
	11	0·988	0·974	0·946	0·919	0·895	0·872	0·851	0·831	0·813	0·795	0·779	0·772
	21	1·030	1·014	0·983	0·955	0·929	0·905	0·882	0·861	0·841	0·822	0·805	0·797
	30	1·091	1·073	1·038	1·008	0·978	0·951	0·926	0·903	0·881	0·861	0·842	0·833
Feb.	10	1·172	1·151	1·112	1·077	1·043	1·012	0·984	0·958	0·933	0·911	0·889	0·879
	20	1·270	1·245	1·200	1·158	1·119	1·084	1·052	1·022	0·994	0·968	0·945	0·933
Mar.	2	1·373	1·345	1·293	1·245	1·200	1·159	1·122	1·088	1·057	1·028	1·001	0·989
	12	1·463	1·431	1·371	1·317	1·268	1·223	1·182	1·144	1·109	1·077	1·047	1·034
	22	1·499	1·466	1·404	1·347	1·296	1·248	1·205	1·166	1·130	1·097	1·067	1·052
Apr.	1	1·468	1·436	1·376	1·321	1·272	1·226	1·185	1·147	1·112	1·080	1·050	1·037
	11	1·384	1·356	1·302	1·253	1·208	1·167	1·130	1·095	1·063	1·034	1·007	0·994
	21	1·280	1·256	1·209	1·167	1·128	1·093	1·059	1·029	1·000	0·974	0·951	0·939
May	1	1·181	1·161	1·121	1·084	1·051	1·020	0·991	0·964	0·940	0·916	0·895	0·885
	11	1·100	1·082	1·048	1·015	0·986	0·959	0·933	0·909	0·887	0·866	0·848	0·839
	21	1·036	1·019	0·989	0·961	0·934	0·910	0·886	0·865	0·845	0·826	0·809	0·801
	31	0·991	0·977	0·949	0·922	0·898	0·875	0·854	0·833	0·815	0·798	0·782	0·774
June	10	0·965	0·951	0·925	0·900	0·876	0·854	0·834	0·815	0·797	0·780	0·765	0·758
	20	0·954	0·941	0·915	0·890	0·867	0·846	0·826	0·808	0·790	0·773	0·758	0·751
	30	0·958	0·944	0·918	0·893	0·871	0·849	0·829	0·810	0·793	0·776	0·761	0·754
July	10	0·980	0·965	0·938	0·912	0·888	0·866	0·845	0·825	0·807	0·790	0·774	0·767
	20	1·017	1·002	0·972	0·945	0·920	0·895	0·873	0·852	0·833	0·815	0·798	0·790
	30	1·072	1·055	1·022	0·992	0·964	0·937	0·913	0·890	0·869	0·850	0·832	0·823
Aug.	9	1·146	1·127	1·090	1·055	1·024	0·994	0·966	0·941	0·917	0·895	0·875	0·866
	19	1·243	1·219	1·176	1·135	1·099	1·065	1·033	1·005	0·977	0·953	0·930	0·919
	29	1·346	1·319	1·268	1·222	1·179	1·140	1·104	1·071	1·040	1·013	0·987	0·974
Sept.	8	1·443	1·412	1·354	1·301	1·253	1·209	1·169	1·132	1·098	1·066	1·038	1·024
	18	1·499	1·465	1·403	1·346	1·295	1·248	1·205	1·166	1·130	1·097	1·066	1·052
	28	1·487	1·454	1·392	1·336	1·286	1·240	1·197	1·159	1·123	1·091	1·060	1·046
Oct.	8	1·412	1·382	1·326	1·275	1·229	1·187	1·148	1·112	1·079	1·050	1·021	1·008
	18	1·309	1·283	1·235	1·191	1·150	1·113	1·079	1·047	1·018	0·991	0·967	0·955
	28	1·205	1·184	1·142	1·105	1·070	1·037	1·008	0·980	0·954	0·931	0·909	0·898
Nov.	7	1·119	1·100	1·065	1·031	1·001	0·973	0·946	0·922	0·899	0·878	0·858	0·849
	17	1·050	1·033	1·002	0·973	0·946	0·920	0·896	0·874	0·855	0·836	0·818	0·809
	27	1·001	0·986	0·957	0·930	0·906	0·883	0·861	0·841	0·822	0·804	0·788	0·780
Dec.	7	0·970	0·956	0·929	0·904	0·880	0·858	0·838	0·818	0·801	0·784	0·768	0·761
	17	0·955	0·941	0·915	0·891	0·868	0·846	0·826	0·808	0·790	0·774	0·759	0·752
	27	0·956	0·942	0·916	0·892	0·869	0·847	0·827	0·809	0·791	0·775	0·760	0·752
Jan.	6	0·976	0·962	0·934	0·908	0·884	0·862	0·842	0·822	0·804	0·787	0·772	0·764

$$F_1 = \frac{2{\cdot}4066}{c_{11}\ 1{\cdot}4066 f(K_1) + f(O_1)}. \quad F_1 \times \text{observed } D_1 = K_1 + O_1. \quad 1{\cdot}02\ F_1 \times \text{observed } D_1 = D_1.$$

This table is based on Tables 13 and 31.

TABLE 33.—*Factor F_2 for clearing S_2 of K_2 and T_2.*

Date.	*I*, or inclination of orbit to equator.											
	18½°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°	28½°
Jan. 1	1·14	1·15	1·16	1·18	1·19	1·20	1·22	1·24	1·27	1·30	1·33	1·34
11	1·08	1·09	1·10	1·10	1·11	1·12	1·14	1·15	1·17	1·19	1·21	1·22
21	1·02	1·02	1·02	1·03	1·03	1·04	1·04	1·05	1·06	1·06	1·07	1·08
31	·96	·96	·96	·96	·96	·96	·96	·96	·96	·96	·96	·96
Feb. 10	·90	·90	·90	·89	·89	·89	·88	·88	·88	·87	·87	·86
20	·86	·86	·85	·85	·84	·84	·83	·83	·82	·81	·81	·80
Mar. 2	·83	·83	·83	·82	·82	·81	·80	·79	·78	·77	·76	·76
12	·83	·82	·82	·81	·80	·79	·78	·77	·76	·75	·74	·74
22	·83	·82	·81	·80	·79	·79	·78	·77	·76	·75	·74	·73
Apr. 1	·83	·83	·83	·82	·81	·80	·79	·78	·77	·76	·75	·75
11	·86	·86	·85	·84	·83	·82	·82	·81	·80	·79	·78	·78
21	·91	·91	·90	·89	·89	·88	·88	·87	·86	·85	·85	·84
May 1	·96	·96	·96	·95	·95	·95	·94	·94	·93	·93	·92	·92
11	1·04	1·04	1·04	1·04	1·04	1·04	1·04	1·04	1·04	1·04	1·04	1·04
21	1·12	1·12	1·13	1·13	1·14	1·14	1·15	1·16	1·16	1·17	1·18	1·19
31	1·23	1·24	1·25	1·26	1·27	1·28	1·30	1·32	1·34	1·37	1·39	1·40
June 10	1·30	1·31	1·33	1·35	1·37	1·39	1·41	1·44	1·47	1·51	1·55	1·57
20	1·35	1·37	1·39	1·41	1·44	1·47	1·50	1·54	1·58	1·63	1·68	1·70
30	1·34	1·35	1·37	1·39	1·42	1·45	1·48	1·51	1·55	1·59	1·64	1·67
July 10	1·26	1·27	1·28	1·30	1·32	1·34	1·36	1·38	1·41	1·43	1·46	1·47
20	1·17	1·18	1·19	1·19	1·20	1·22	1·23	1·24	1·25	1·26	1·27	1·28
30	1·07	1·07	1·08	1·08	1·08	1·09	1·09	1·09	1·09	1·10	1·10	1·10
Aug. 9	1·00	1·00	1·00	1·00	1·00	·99	·99	·99	·98	·98	·97	·97
19	·94	·93	·93	·93	·92	·92	·91	·90	·89	·88	·88	·87
29	·88	·88	·88	·87	·86	·85	·84	·83	·83	·82	·81	·80
Sept. 8	·85	·85	·84	·84	·83	·82	·81	·80	·79	·78	·77	·76
18	·84	·83	·83	·82	·81	·80	·79	·78	·77	·76	·75	·75
28	·83	·83	·83	·82	·81	·80	·79	·78	·77	·76	·75	·74
Oct. 8	·85	·84	·83	·83	·82	·81	·80	·79	·78	·77	·77	·76
18	·86	·86	·86	·85	·85	·84	·83	·82	·81	·80	·79	·79
28	·90	·89	·89	·89	·88	·88	·88	·87	·86	·86	·85	·85
Nov. 7	·95	·95	·95	·95	·95	·94	·94	·94	·94	·94	·93	·93
17	1·01	1·01	1·02	1·02	1·02	1·03	1·03	1·04	1·04	1·05	1·05	1·06
27	1·07	1·08	1·09	1·09	1·10	1·11	1·12	1·14	1·15	1·16	1·18	1·19
Dec. 7	1·13	1·14	1·15	1·16	1·18	1·19	1·21	1·23	1·25	1·28	1·31	1·32
17	1·16	1·18	1·19	1·21	1·23	1·25	1·27	1·30	1·33	1·36	1·39	1·41
27	1·16	1·17	1·18	1·19	1·21	1·23	1·25	1·28	1·31	1·34	1·37	1·39
Jan. 6	1·11	1·11	1·12	1·14	1·15	1·16	1·18	1·20	1 22	1·24	1·27	1·28

This table is based upon Tables 13 and 31.

TABLE 34.—*Effect of ν_2 upon the amplitude of N_2.*

Apparent time of moon's upper or lower transit. ☽ in perigee or apogee.	Resultant amplitude N_2 and ν_2. $N_2=1$.	Apparent time of moon's upper or lower transit. ☽ in perigee or apogee.	Resultant amplitude N_2 and ν_2. $N_2=1$.
h. *h.* *m.*		*h.* *h.* *m.*	
0, 12 00	1·19	6, 18 00	0·81
20	1·19	20	0·81
40	1·18	40	0·82
1, 13 00	1·17	7, 19 00	0·84
20	1·16	20	0·86
40	1·14	40	0·89
2, 14 00	1·11	8, 20 00	0·92
20	1·08	20	0·95
40	1·05	40	0·99
3, 15 00	1·02	9, 21 00	1·02
20	0·99	20	1·05
40	0·95	40	1·08
4, 16 00	0·92	10, 22 00	1·11
20	0·89	20	1·14
40	0·86	40	1·16
5, 17 00	0·84	11, 23 00	1·17
20	0·82	20	1·18
40	0·81	40	1·19

This table is based upon Tables 1 and 16.

TABLE 35.—*Group factors.*

For phase reduction.

Number of tides before springs or neaps.	Number of tides after springs or neaps.						
	0	2	4	6	8	10	12
$S_2/M_2 = 0.2$							
0	1.00	1.01	1.03	1.07	1.13	1.22	1.34
2	1.01	1.01	1.02	1.06	1.11	1.18	1.29
4	1.03	1.02	1.03	1.05	1.10	1.16	1.25
6	1.07	1.06	1.05	1.07	1.11	1.16	1.24
8	1.13	1.11	1.10	1.11	1.13	1.18	1.25
10	1.22	1.18	1.16	1.16	1.18	1.22	1.28
12	1.34	1.29	1.25	1.24	1.25	1.28	1.34
$S_2/M_2 = 0.3$							
0	1.00	1.01	1.03	1.07	1.14	1.23	1.35
2	1.01	1.01	1.03	1.06	1.11	1.19	1.30
4	1.03	1.03	1.03	1.06	1.10	1.17	1.26
6	1.07	1.06	1.06	1.08	1.11	1.17	1.25
8	1.14	1.11	1.10	1.11	1.14	1.19	1.26
10	1.23	1.19	1.17	1.17	1.19	1.23	1.29
12	1.35	1.30	1.26	1.25	1.26	1.29	1.35
$S_2/M_2 = 0.4$							
0	1.00	1.01	1.03	1.08	1.14	1.24	1.37
2	1.01	1.01	1.03	1.06	1.12	1.20	1.31
4	1.03	1.03	1.03	1.06	1.11	1.18	1.27
6	1.08	1.06	1.06	1.08	1.12	1.17	1.26
8	1.14	1.12	1.11	1.12	1.15	1.19	1.27
10	1.24	1.20	1.18	1.17	1.19	1.24	1.30
12	1.37	1.31	1.27	1.26	1.27	1.30	1.37
$S_2/M_2 = 0.5$							
0	1.00	1.01	1.04	1.09	1.16	1.25	1.39
2	1.01	1.01	1.03	1.07	1.13	1.21	1.33
4	1.04	1.03	1.04	1.07	1.12	1.19	1.29
6	1.09	1.07	1.07	1.09	1.13	1.19	1.27
8	1.16	1.13	1.12	1.13	1.16	1.21	1.29
10	1.25	1.21	1.19	1.19	1.21	1.25	1.32
12	1.39	1.33	1.29	1.27	1.29	1.32	1.39

For parallax reduction.

Number of tides before or after greatest and least parallax effects.	Factor.
0	1.00
4	1.01
6	1.02
8	1.04
10	1.06

For declinational reduction.

Number of tides before or after moon's extreme declination.	Factor (for diurnal wave).
0	1.000
2	1.005
4	1.012
6	1.024
8	1.040

This table is based upon Tables 1 and 16.

APPENDIX No. 8—1894.

NOTES ON SOME INSTRUMENTS RECENTLY MADE IN THE INSTRUMENT DIVISION OF THE COAST AND GEODETIC SURVEY OFFICE.

PREPARED BY

EDWIN SMITH,

Assistant, United States Coast and Geodetic Survey and Chief of the Instrument Division.

Submitted for publication December 18, 1894.

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The instrument shop is a repair and experimental shop, and the construction of new instruments is incidental to this work, being mostly confined to such instruments as may be required for experiment or may be suggested by the experience of the field parties, the construction of which involves a considerable amount of experimental work and personal supervision. Such instruments are often evolutions and their construction would not be undertaken by private or commercial shops except at a much greater cost to the Survey.

In order to secure the best results, the Superintendent, in October, 1890, appointed an advisory board on instruments and their construction, consisting of the following officers: Assistants C. A. Schott, R. S. Woodward, O. H. Tittmann, Andrew Braid, Edwin Smith, E. D. Preston, and the chief instrument maker, Mr. E. G. Fischer. The Chief of the Instrument Division acted as chairman. Since that date all important matters referring to instruments have been considered by this board, and as regards new instruments its aim has been to make them as perfect as possible, taking advantage of the experience of all surveys in this as well as foreign countries.

The Survey is fortunate in having a well-equipped shop and several excellent instrument makers. To the chief instrument maker especial credit is due for excellent designs and many valuable mechanical suggestions.

The instruments briefly described in this paper are some that have been constructed since 1890. Descriptions of others will be found in other reports, the pendulums in report of 1891, the Holton base apparatus in report of 1892, etc.

TWO 30·5^{cm} (12-INCH) POSITION THEODOLITES, NOS. 145 AND 146, MADE IN THE INSTRUMENT DIVISION OF THE COAST AND GEODETIC SURVEY OFFICE, 1890-1893. SEE PLATE I.

These numbers (145 and 146) belonged to two theodolites that had been in the possession of the Survey for several years, but had not proved satisfactory. An attempt was made to remodel them. As the work progressed various difficulties were encountered, and the result was the construction of two instruments entirely new except the circles. The two old circles had been cast from different patterns, and when they had been turned off, regraduated, and mounted upon the instruments, it was discovered that the circle of No. 146 was weak and had sprung when taken off the chuck. It was quite as perfect as many now in use and the defect was not thought to be

serious—in fact, would not have been noticed but for the unusually high power of the micrometer microscopes. Before the instrument was sent to the field a new circle similar to the one on No. 145 was made for it. The two instruments are now as nearly alike as it is practicable to make them. The following description will apply to both:

The base is of cast iron, into the socket of which is fitted another cast-iron socket, to which is rigidly attached the brass circle and into which is fitted the center which carries the alidade. Under the circle is a device for firmly clamping this socket to the base in any position of the circle. The center is 22·2^{cm} (8 inches) long, its two bearing surfaces being cones of different angles. It is made of the best quality of tool steel, and the cones are made glass hard. No pains were spared in the construction of these centers and sockets, and it is believed they are the most perfect ever made for theodolites, and are probably the first theodolite centers with glass-hard bearing surfaces.

In the alidade the cover of the circle, the supports for the micrometer microscopes, the wye supports, axis, and setting circle of telescope are made of aluminum. The bearing surfaces of the wyes are of brass, and the pivots of telescope axis are of bell metal. The draw tube of telescope, micrometer microscopes, clamps, and other small parts are of brass.

The use of aluminum in the construction of these instruments was not with the special purpose of reducing the total weight of the instrument, but to reduce the weight supported upon the centers. The cast-iron bases of these instruments, in proportion to the whole mass of the instruments, are much heavier than is usual in other theodolites of the same size. These heavy bases and long centers give great stability to the instruments. The weight of the whole alidade is 7·5 kilogrammes (17 pounds), whereas in other instruments of the same size that have been used in the Survey the weight of similar parts is 18 kilogrammes (40 pounds). The centers of the old instruments are of various forms, and the friction is so great that it has to be relieved by some device at lower end of centers. No such device is necessary with the new instruments. The total weight of one of the new instruments is 18·5 kilogrammes (41 pounds).

The telescope objective was made by J. Brashear, and is 6·1^{cm} (2.4 inches) aperture, and 73·7^{cm} (29 inches) focus. The telescope has an ocular micrometer, with three Ramsden eyepieces, giving powers of 30, 45, and 60. Several levels, all made by A. Pesseler, of Germany, are attached to the alidade for convenience. The stride level has divisions of 2^{mm}, with arc value of 4″.

The graduation of the circle is on coin silver and is 30·5^{cm} (12 inches) in diameter. It is divided to 5′ and reads to seconds by three equidistant micrometer microscopes. Each degree of the graduation is numbered. The degrees and nearest 5′ are read by a low-power index microscope 50° to the right of micrometer microscope A. Attached to the cover of the circle is a small camel's-hair brush which sweeps over the graduation.

The circles were graduated on the United States Coast and Geodetic Survey engine. This graduating engine was originally made by Troughton & Simms, of London, and bears the date of 1841. In the hands of the Survey it has received various improvements, the chief of which are a new tracing apparatus and new support for the same. The engine is driven by a small turbine wheel upon which a constant water pressure is maintained. To graduate a circle to 5′ takes about 3^{h} 35^{m}. The graduations are made at a temperature of 36°·66 C. (98° F.), that temperature being most easily maintained at any season of the year and least affected by the occasional presence of the operator. For the last nine years this engine has been manipulated exclusively by the present chief instrument maker of the Survey and in his hands has produced some very fine graduations, as the results with the two new theodolites, Nos. 145 and 146, show.

In April and May of 1893 a critical examination of these theodolites was made by Assistant R. S. Woodward under instruction from the Superintendent of the Survey. He has submitted only a preliminary report, from which the following is taken:

"This examination has special reference to the perfection of the horizontal circles of the instruments, and was conducted in accordance with the following plan submitted to you in my letter of March 31, 1893. It is here restated as there given, in order that the lines along which the inquiry proceeded may be clearly apparent.

"(1) In order to determine the value of a space on the horizontal circle, which space may be used as a standard space, it will be essential to compare such space with a large number of other spaces situated at equidistant intervals about the circle. The average value of this large number

of spaces may be assumed to be the nominal value, whence the standard space will become known, and it may then be used for determining error of runs of micrometers. This process will also give the errors of all spaces observed, and thus afford a good general test of the equality of the spaces.

"(2) We may then pass to an examination of the inequality of the arcs covered by the distance between consecutive microscopes. By observing these inequalities for a large number of arcs symmetrically disposed about the entire circle the harmonic series expressing the divergence for any arc may be computed. A comparison of the computed and observed values of such divergencies will reveal any considerable accidental errors.

"(3) By far the most important class of errors affecting circles of precision are the periodic errors not eliminated in the sum (or mean) of the equidistant microscope readings. These errors affect measured angles, while the periodic errors mentioned under (2) above do not. To determine the harmonic expression for this more important class of errors the best method appears to be to observe as carefully as practicable a series of angles which will produce the maximum effect, respectively, from the several terms of the series. Such measures will enable us to compute the amplitudes and the phase angles of the several harmonic terms, and thus give a formula for the correction to any measured angle, whatever its size and whatever the part of the circle on which it may be observed.

"Before giving an abstract of the results of the examination it appears proper to make some statements with reference to the general features of these instruments and the degree of mechanical perfection shown by them. Having examined a number of similar instruments made by Troughton & Simms, the Repsolds, Pistor & Martins, and Fauth & Co., it has been easy to judge of the relative merits of the new theodolites.

"With respect to design and perfection of mechanical construction, these new theodolites must, I think, take rank with the highest of their class. In equality of spacing of consecutive graduation lines and in the uniformity of width and aspect of these lines the circles of the instruments appear to be superior to all circles I have examined under an equal magnifying power.

"With respect to their capacity for measuring horizontal angles, repeated trials show that they are at least equal to the best instruments made elsewhere. It appears, in fact, that, so far as purely instrumental and observational errors are concerned, a mean measured angle from four equidistant positions of the circle of either instrument will have a precision equal to the requirements of the highest order of primary triangulation.

"Concerning the lightness of the instruments, which is a novel feature, it appears to me quite satisfactory. Without assistance an observer can take one of them from its case and place it on a pier or stand with perfect safety; and this is often a matter of economy and great convenience. On the other hand, the small mass of the instruments may not be satisfactory to some observers. After using heavier instruments of the same class (like those made by Troughton & Simms, for example) one's first impression is that the new theodolites are lacking in rigidity. This is most noticeable in the micrometer arms, which are quite sensitive to lateral stress. It does not appear, however, that this lack of rigidity can be sensibly detrimental, especially with observers who understand their work. If any disadvantage result therefrom, it is, in my opinion, more than offset by the advantage coming from the lightness.

"There is one noticeable defect of theodolite No. 146. It lies in departures of the graduated surface of its circle from a conical surface. These departures, though small, are large enough to require different focal adjustments of the particular microscope used on different parts of the circle in order to secure satisfactory freedom from parallax. Nevertheless, when the microscopes are adjusted for the average distance of the circle from them, the effect of parallax does not appear to be sensible in measured angles. The defect manifests itself then only by indistinct vision on some parts of the circle.

"With respect to the clamp and tangent for the alidade and the movement of the latter about its axis, the performance of the instrument is very satisfactory. The great length of the alidade axis undoubtedly gives precision and stability to the motion of the microscopes. The projection of the socket of this axis below the plane of the foot screws would be counted an objection by some, but if a real objection it appears to be of little weight.

"*Spacing of consecutive graduation marks.*—In accordance with section (1) of the plan outlined above, a large number of spaces were measured by means of the micrometers on each circle. The results have been computed for theodolite No. 145 only; and it may be doubted whether those for No. 146 are properly trustworthy, since they involve errors due to parallax which may equal or even surpass those of spacing. The observations on the spacing of No. 145 were made by Assistant Sinclair. Each space of a group of equidistant spaces on the circle was measured with the micrometer four times independently; and at intervals during the measures of these spaces several similar determinations were made of the assumed standard space. This latter is the space 50°05′ to 50°10′. The data thus obtained give the latter space in terms of the average value of all the spaces of the group. Four such groups of measures were made. The results are given in the tables below. The position of any space is defined by the index reading of microscope A, with which the measures were made. In all cases the space referred to is that between the 5′ and 10′ marks, these being chosen because they are of the same length and thus present the same aspect to the observer.

Results of measures of 5′ spaces on theodolite No. 145, C. H. Sinclair, observer, April 5, 1893.

Index reading.	Observed value of space *O*.	Sums by quadrants.	*C* − *O*.	Measures of space.
°				
0	5 rev. + 1·08 div.		+0·30 div.	50° 05′ to 50° 10′.
10	0·92		+0·46	
20	0·78		+0·60	5 rev. + 1·08 div.
30	1·10		+0·28	0·88
40	1·28		+0·10	1·28
50	1·20		+0·18	1·30
60	1·32		+0·08	0·98
70	1·50		−0·12	1·50
80	1·00	+ 10·18 div.	+0·38	1·08
90	1·25		+0·13	
100	1·42		−0·04	Mean + 1·16
110	1·40		−0·02	
120	1·20		+0·18	
130	1·50		−0·12	
140	1·02		+0·36	
150	1·65		−0·27	It appears from these observations that the space 50° 5′ to 50° 10′ is short by 0·″22. That is, this space = 299·″78.
160	1·18		+0·20	
170	1·28	+ 11·90	+0·10	
180	1·38		0·00	
190	1·48		−0·10	
200	1·80		−0·42	
210	1·38		0·00	
220	1·42		−0·04	
230	1·68		−0·30	
240	1·15		+0·23	
250	1·25		+0·13	
260	1·58	+ 13·12	−0·20	
270	1·45		−0·07	
280	1·25		+0·13	
290	1·75		−0·37	
300	1·78		−0·40	
310	1·72		−0·34	
320	1·58		−0·20	
330	1·58		−0·20	
340	1·78		−0·40	
350	1·52	+ 14·41	−0·14	
	Mean + 1·378 = C			

Results of measures of 5′ spaces on theodolite No. 145, C. H. Sinclair, observer, April 5, 1893—Continued.

APRIL 6, 1893.

Index reading.	Observed space O.	Sum for semicircle.	C − O.	Space 50° 05′ to 50° 10′.
°				
0	5 rev. + 1·08 div.		+0·18	5 rev. + 1·08 div.
20	1·10		+ ·16	0·88
40	1·20		+ ·06	1·08
60	1·00		+ ·26	1·08
80	1·02		+ ·24	
100	1·42		− ·16	Mean 1·03
120	1·30		− ·04	
140	1·02		+ ·24	
160	1·88	+11·02	− ·62	Space 50° 05′ to 50° 10′ is short by 0″·23.
180	1·20		+ ·06	
200	1·22		+ ·04	
220	1·22		+ ·04	
240	1·20		+ ·06	
260	1·60		− ·34	
280	1·38		− ·12	
300	1·28		− ·02	
320	1·38		− ·12	
340	1·22	+11·70	+ ·04	
	Mean 1·262 = C			

APRIL 8, 1893.

10	5 rev. + 0·35		−0·03	5 rev. − 1·08 div.
30	0·52		+ ·40	0·72
50	1·28		− ·36	1·18
70	1·22		− ·30	
90	0·72		+ ·20	Mean 0·99
110	0·40		+ ·52	
130	1·08		− ·16	
150	0·65		+ ·27	Space 50° 05′ to 50° 10′ is too long by 0″·07.
170	0·55	+7·37	+ ·37	
190	1·02		− ·10	
210	0·95		− ·03	
230	1·25		− ·33	
250	1·02		− ·10	
270	1·18		− ·26	
290	0·75		+ ·17	
310	1·00		− ·08	
330	1·18		− ·26	
350	0·78	+9·13	+ ·14	
	Mean = 0·917 = C			

Results of measures of 5′ spaces on theodolite No. 145, C. H. Sinclair, observer, April 5, 1893—Continued.

JUNE 8, 1893.

Index reading.	Observed space *O*.	Sum by quadrants.	*C* − *O*.	Space 50° 05′ to 50° 10′.
°				
5	5 rev. + 1·40 div.		−0·30 div.	5 rev. + 1·02 div.
15	0·78		+ ·32	0·95
25	0·88		+ ·22	0·85
35	1·02		+ ·08	0·75
45	1·05		+ ·05	1·15
55	1·30		− ·20	
65	0·78		+ ·32	Mean 0·944
75	0·92		+ ·18	
85	0·90	+ 9·03	+ ·20	
95	1·38		− ·28	Space 50° 05′ to 50° 10′ is short by 0″·15.
105	1·32		− ·22	
115	1·08		+ ·02	
125	0·90		+ ·20	
135	1·25		− ·15	
145	1·22		− ·12	
155	0·80		+ ·30	
165	0·90		+ ·20	
175	0·80	+ 9·65	+ ·30	
185	1·32		− ·22	
195	1·25		− ·15	
205	0·98		+ ·12	
215	1·10		·00	
225	1·18		− ·08	
235	0·78		+ ·32	
245	1·08		+ ·02	
255	0·82		+ ·28	
265	0·98	+ 9·49	+ ·12	
275	1·20		− ·10	
285	1·32		− ·22	
295	1·18		− ·08	
305	0·92		+ ·18	
315	1·20		− ·10	
325	1·32		− ·22	
335	1·22		− ·12	
345	1·50		− ·40	
355	1·42	+11·28	− ·32	
	Mean = 1·096 = C			

"Collecting the results for the value of the space 50° 05′ to 50° 10′ and giving them weights proportional to the number of spaces in the groups, we have

		Rev.	Div.	
1893, April	5, space	= 5	−0·22, weight	2
	6,	= 5	− ·23,	1
	7,	= 5	+ ·07,	1
	8,	= 5	− ·15,	2
Weighted mean		= 5	−0·15 ± 0·04	

"Similarly, taking averages of the residuals (*C* − *O*), or the space errors, and weighting the values proportionally to the numbers of residuals in the groups, we get

		Div.	
1893, April	5, average (C − O)	− 0·21, weight	2
	6,	− ·16	1
	7,	− ·23	1
	8,	− ·19	2
Weighted average		− 0·20	

"Thus it appears that the average error of spacing of the spaces examined is 0·20 div., or but 0·15 microns. This indicates a degree of precision in spacing of a very high order. In this respect the graduation must be regarded as practically perfect.

"Attention may be called to the progressive increase in the sums of the measured spaces when taken by quadrants or by semicircles. This is quite large in the case of the observations of April 5, but the subsequent observations are less consistent on this point.

"*Inequality of arcs comprised between consecutive microscopes.*—Several series of measures of the distance between a pair of microscopes were made on the equidistant arcs with each instrument. The following results will suffice to show what is developed by this test. Suppose A and B denote the readings of the microscopes having the same designation on any part of the circle; the difference, $(B-A)$ will involve the excess of the distance between these microscopes over the nominal distance, or 120°. Call this excess a. Then if $(B-A)$ be observed on a large number of arcs at equal intervals about the circle, it may be shown that a is the mean of the differences $(B-A)$ so observed. The table gives the values of $(B-A)-a$ for intervals of 10° for each instrument.

Observed inequalities in values of intervals $(B-A)-a$.

Position of Mic. A.	$(B-A)-a$ for No. 145.	$(B-A)-a$ for No. 146.	Position of Mic. A.	$(B-A)-a$ for No. 145.	$(B-A)-a$ for No. 146.
°	″	″	°	″	″
0	−3·8	+0·9	180	+0·4	−6·6
10	−2·9	+3·1	190	−1·3	−1·6
20	−0·6	+5·4	200	−1·3	−2·6
30	+1·3	−0·2	210	−0·3	−2·3
40	+0·9	+2·9	220	−0·7	−1·9
50	+2·4	+2·3	230	−6·9	+1·1
60	+3·8	+1·9	240	−1·5	+5·1
70	+6·2	+0·2	250	−5·3	+4·9
80	+6·2	−0·8	260	−2·9	+1·6
90	+5·9	−4·3	270	−3·3	+4·8
100	+4·5	−4·3	280	−4·1	+1·1
110	+7·5	−5·7	290	−5·5	+6·3
120	+6·5	−4·7	300	−4·6	+4·7
130	+8·7	−6·6	310	−6·1	+2·1
140	+5·1	−6·0	320	−6·5	+1·7
150	+2·1	−2·2	330	−6·4	+5·0
160	+4·1	−2·5	340	−4·7	+3.9
170	+3·5	−7·2	350	+0·3	+0·9

"These inequalities show a range of about 15″. They are fairly regular, however, and will undoubtedly be very closely represented by two or three harmonic terms when these are computed.

"The incautious reader should be warned against the common error of supposing that such inequalities are necessarily due to eccentricity of the alidade with respect to the circle. One can only say that these inequalities are the resultant of all sources of error, including eccentricity, which manifest themselves in the difference of a pair of microscope readings. In general the components of this resultant are numerous, but not separately determinable. Moreover, these inequalities are relatively unimportant. So far as they are purely periodic they shed no light on that class which affects the sum or mean of the microscope readings, which is the only really important class of errors with which we have to deal. It should not be inferred, therefore, that the circles of these theodolites are defective. The common notion that such inequalities constitute defects is not founded on adequate knowledge.

"*Results for measured angles.*—In order to test the instruments in the actual work of measuring angles, a temporary observatory was set up on Meridian Hill, where a clear view of a good share of the horizon could be had. A heavy stone pier was set firmly in the ground, and on this was placed a capstone fitted to receive the theodolites. The capstone was cemented to the pier and the footplates to the capstone with Portland cement. Thus arranged the foundation for the instruments was very rigid. About the pier was built a platform, on which an ordinary station tent was placed to protect the instrument from wind and the ordinary rays of the sun.

"The following tabular statement gives the results obtained. A result for an angle is here taken to be the mean of two measures made, the one by turning the alidade in the direction of the graduation, and the other by turning in the opposite direction immediately afterward. This is done to eliminate twist of the instrument and its support. Some observations made with No. 146 showed a twist of 0″.3 due to turning the alidade through 360°.

"The magnifying power used in the telescope was about 60 diameters (the measured value for No. 146 was 57.6).

"Direct observations with No. 146 showed a probable error of a single pointing to be $\pm 0''.25$. This is the resultant of the error of fixing the telescope on the object and the error in the mean of the three microscope readings. If we suppose the first of these errors and that of a single microscope reading to be equal, their common value must be $\pm 0''.22$ in order to produce the resultant just given.

"The objects observed were from 2 to 3 miles distant.

"The results are arranged in groups of four each with reference to the positions of the circle, these being such as to give the best elimination of the circle errors in the mean of the four values of a group. The accordance of these means for the different groups is the point to which attention should be directed. The individual results of any group may, and should, in general, differ from one another; but if the graduation of the circle is good, the group means should show small ranges.

Results for angles measured with theodolite No. 146.

Position of Mic. A, B, or C.	Value for angle.	Position of Mic. A, B, or C.	Value for angle.
°	° ′ ″	°	° ′ ″
257	25 30 14·50	61	150 03 53·95
287	9·50	91	51·85
317	11·45	121	55·30
347	13·15	151	52·55
	Mean 12·25		Mean 53·41
		76	
272	11·50	106	150 03 52·25
302	14·00	136	53·95
332	9·20	166	55·15
2	13·85		54·20
	Mean 12·14		Mean 53·89
		48	
264·5	13·30	78	25 30 14·40
294·5	10·35	108	10·15
324·5	10·95	138	13·75
354·5	12·05		10·85
	Mean 11·66		Mean 12·29
		63	
279·5	8·80	93	15·75
309·5	14·80	123	9·85
339·5	12·75	153	12·05
9·5	13·50		12·40
	Mean 12·46		Mean 12·51
		264	
312	164 11 4·45	294	150 03 53·20
342	6·45	324	55·45
12	6·75	354	51·75
42	5·50		55·75
	Mean 5·79		Mean 54·04
		272	
327	4·20	302	55·00
357	7·45	332	57·05
27	2·15	2	52·65
57	5·15		53·00
	Mean 4·74		Mean 54·42
		257	
333	184 54 59·50	287	53·15
3	58·10	317	55·35
33	58·85	347	51·25
63	62·50		54·45
	Mean 59·74	279	Mean 53·55
		309	
348	61·45	339	150 03 55·05
18	60·50	9	55·85
48	58·10		53·80
78	61·30		52·55
	Mean 60·34		Mean 54·31

"Considering the above group means as so many measures of the several angles to which they refer, respectively, it appears that the probable error of one such mean, or the probable error of the mean angle from four positions of the circle, is ±0″·28. This error is the resultant of all sources of error which affect such measures, namely, periodic and accidental errors of graduation, errors of observation, errors due to unsteadiness of the atmosphere (which was not exceptionally favorable during the period covered by the observations), etc. It is evident, therefore, that the periodic and accidental errors not eliminated in the mean result from four positions of the circle are very small.

"The range amongst the individual measures of a group rises at most to 6″, and since the angles measured were selected with a view to developing this range, it is probable that this represents the maximum range, due to periodic errors, which one may expect to find in angles measured with these instruments.

"The results of this test are, then, very favorable to the instruments and show that they are fully equal in their capacity to the best instruments hitherto made."

After the new circle was made for No. 146 there was no time for a critical examination of it before it was sent to the field. A partial examination made in the Instrument Division brought out the same characteristics as were found by Assistant Woodward for No. 145. The two instruments were sent to the field in the summer of the present year (1894). No. 145 was used at station Bison by Assistant F. W. Perkins and No. 146 at Mount Elbert by Assistant P. A. Welker. These stations are in the main transcontinental triangulation in the Rocky Mountains. Mount Bison is 3,749 metres (12,300 feet) and Mount Elbert is 4,389 metres (14,400 feet) above sea level. The following results are from the field records:

Station: Bison, 1894. Observer: F. W. Perkins. Instrument, U. S. C. & G. S. theodolite No. 145.

Group.	Position.	Index.	Mark o	Pikes Peak 1	Ouray 2	Elbert 3	Divide 4
			0° 00′	8° 05′	84° 58′	130° 53′	331° 53′
		°	*d.*	*d.*	*d.*	*d.*	*d.*
1	I	0	0·00	6·90	57·80	7·12	8·88
	II	15		7·27	59·52	5·97	11·25
	III	30		9·56	59·43	8·85	10·62
	IV	45		6·73	56·70	5·59	8·27
Mean of group *g* 1				7·61	58·36	6·88	9·76
		° ′					
2	V	7 30	0·00	8·13	59·23	7·66	12·03
	VI	22 30		8·17	59·46	7·63	11·39
	VII	37 30		7·67	56·85	6·79	8·48
	VIII	52 30		7·03	57·30	6·65	9·07
Mean of group *g* 2				7·75	58·21	7·18	10·24
		° ′					
3	IX	3 45	0·00	7·61	58·59	7·08	11·10
	X	18 45		8·43	60·19	7·21	11·28
	XI	33 45		8·81	58·21	8·04	9·82
	XII	48 45		7·29	58·33	6·46	9·56
Mean of group *g* 3				8·03	58·83	7·20	10·44
		° ′					
4	XIII	11 15	0·00	7·74	59·85	6·51	10·52
	XIV	26 15		9·08	59·88	9·05	11·24
	XV	41 15		7·18	57·53	6·81	9·78
	XVI	56 15		7·88	57·66	6·69	9·94
Mean of group *g* 4				7·97	58·73	7·26	10·37
Mean of groups *g m*				7·84	58·53	7·13	10·20
g m — *g* 1				+ ·23	+ ·17	+ ·25	+ ·44
g m — *g* 2				+ ·09	+ ·32	— ·05	— ·04
g m — *g* 3				— ·19	— ·30	— ·07	— ·24
g m — *g* 4				— ·13	— ·20	— ·13	— ·17
M. E. of 1 group				± ·19	± ·30	± ·17	± ·31
P. E. of 1 group				± ·13	± ·20	± ·12	± ·21
P. E. of mean of all				± ·07	± ·10	± ·06	± ·11

These results are not corrected for run of micrometer or station adjustment. Average value of 1 div. of micrometer is 0″·9976.

Each result of the above table is the mean of at least two series. A complete series comprises pointings as follows:

Telescope direct	0, 1, 2, 3, 4	------	4, 3, 2, 1, 0
Telescope reversed	0, 1, 2, 3, 4	------	4, 3, 2, 1, 0

This method of observing was adopted in order to detect any flexure or disturbance of the instrument in turning the alidade from left to right and back from right to left. The detailed results do not show either flexure or disturbance of instrument. The individual results in the table depend upon at least eight pointings on each signal, and the angle between each signal and the mark is measured by six symmetrical arcs on the circle. The resulting mean of each group of four positions depends upon at least thirty-two pointings on each signal, and the angle between each signal and the mark is measured by twenty-four symmetrical arcs on the circle. The final means depend upon at least one hundred and twenty-eight pointings on each signal, and the angles are measured by ninety-six symmetrical arcs on the circle. The probable error of an angle from the mark from the mean of a group of four positions is $\pm$ 0″·16 and from the mean of the four groups of four positions is $\pm$ 0″·08. The greatest deviation of any individual result in the table from the mean of the sixteen positions is 1″·93 in Position IV, angle 4.

At this station the signals were distant as follows: Pikes Peak, 59 kilometres (36·6 miles); Ouray, 110·5 kilometres (68·4 miles); Elbert, 83 kilometres (51·6 miles), and Divide, 87 kilometres (54·1 miles). These signals were heliotropes. The distance and description of mark is not given, but was probably a painted board about 3 kilometres, or 2 miles, distant.

This practical field test of these instruments is highly satisfactory and shows that with them a very much smaller number of positions and pointings will meet the requirements of the highest class of primary triangulation.

The results at Mount Elbert with No. 146 are not given, but are reported to be satisfactory. Before the observations were finished theodolite No. 146 was twice struck by lightning. The objective of the telescope was seriously injured and the pivots of telescope, bearings of wyes and leveling screws burned. The instrument seems to have sustained no other injury. It was repaired as well as possible in the field and the observations completed. It has since been through the instrument shop of the office, a new objective was furnished, and the whole instrument put in good order again.

A 20·3^{cm} (8-INCH) POSITION THEODOLITE REMODELED IN THE INSTRUMENT DIVISION OF THE UNITED STATES COAST AND GEODETIC SURVEY OFFICE, 1894. SEE PLATE II.

The remodeling of this theodolite was so thorough that it is practically a new instrument. The following are the changes made:

New double cone center of hardened steel and cast-iron socket.

New micrometer screws and eyepieces to the micrometer microscopes.

Circle regraduated and every degree numbered.

Circle firmly attached to center and device added for shifting position of circle and center.

Cover to circle added.

New eyepieces to telescope.

General repairs.

The center is 14·7^{cm} (5·8 inches) long and projects above the circle. It is clamped to the base in any position of the circle by means of the wheel nut shown in the illustration. The socket carries the alidade. The only aluminum used in this instrument is the cover to the circle.

The diameter of the graduation is 20·3^{cm} (8 inches). It is divided to 10′ and read to 2″ by two micrometer microscopes. The heads of the micrometers are divided into 60 parts and numbered as follows: 0, 10, 20, 0, 10, 20. One revolution of the screw is 2′, and one division of the head is 2″. In the micrometer, in place of the usual rack, is a glass scale, 10 parts of which correspond to a space of 10′ on the circle and to 5 revolutions of the micrometer screw. The micrometer slide carries double wires. The micrometer reads 0 when the right-hand wire of double wires is on middle line of glass scale and the head of screw is at 0. Degrees and minutes are read directly in the microscope. The readings of the micrometer heads should be recorded as divisions. The

sum of the readings of the two micrometer heads will give the mean reading of the two microscopes in seconds. The telescope objective has a clear aperture of 4·45^{cm} (1·75 inches) and a focal length of 40·64^{cm} (16 inches). Three Ramsden eyepieces give powers of 16, 24, and 32.

The levels are by Pessler, of Germany. The stride level has divisions of 2^{mm}, with arc value of about 4″·6. Three more such instruments are now being remodeled in the Instrument Division.

ALT-AZIMUTH AND MAGNETOMETERS NOS. 17, 18, 19, AND 20, MADE IN THE INSTRUMENT DIVISION OF THE UNITED STATES COAST AND GEODETIC SURVEY OFFICE, 1892-93. SEE PLATE III.

In their general form these instruments are similar to those that have been in use in the Survey for some years, an illustration of which will be found in United States Coast and Geodetic Survey Report for 1881, Appendix No. 8, plate 36. This form of magnetometer is now so well known that a detailed description is here unnecessary. The new instruments are a little larger than the old ones and are improvements upon them in details of design and especially in stability and perfection of workmanship.

The new collimating magnets are octagonal in form. The stirrups in which the magnets are suspended are very light and made to support the magnets on two of their plane surfaces. The magnets can be suspended in the stirrups with scales accurately vertical, either erect or inverted at once, and the inertia ring can be accurately balanced upon the magnet with equal facility. With the old cylindrical magnets these operations were difficult and very trying to the patience of the observer. By means of a small rod attached to the stirrup the point at which the suspension fiber is fastened is raised a considerable distance above the center of the magnet. The effect of dip in different localities to displace the magnet from its horizontal position is thus overcome and the sliding ring used in the old instruments is unnecessary in these new ones. The oscillating mass is always the same and consequently its moment of inertia also. Another new feature is the black velvet screen connecting the telescope with the suspension box. This does away with the glass window usually placed in the suspension box between the telescope objective and the objective of the magnet. It also cuts off all stray light between the telescope and the magnet and renders the illumination of the magnet scale a matter of great ease.

PLANE TABLE ALIDADE NO. 85, MADE IN THE INSTRUMENT DIVISION OF THE UNITED STATES COAST AND GEODETIC SURVEY OFFICE, 1893. SEE PLATE IV.

The general form of this instrument is similar to that illustrated in Appendix No. 13, Report for 1880. In the new instrument the workmanship is of the finest class, and every detail has received close attention. The following are the principal improvements:

(1) The rule is made of aluminum bronze, a heavy metal, and the standard and telescope are made as far as practicable of aluminum, a light metal. This balances the instrument very nicely and gives it stability. The older instruments are made of brass and are top-heavy.

(2) Openings are made in the ruler giving a fiducial edge directly under the line of collimation of telescope for use in large scale work.

(3) The arc for measuring small vertical angles is placed so that it can be read by slightly moving the head after pointing the telescope. In the older instruments it was necessary to turn the alidade at right angles or walk about the table. There are two arcs that are interchangeable, one with a range of $\pm 15°$ for ordinary work, and one with a range of $\pm 30°$ for mountain work.

(4) An ocular micrometer is provided for use in mountain work.

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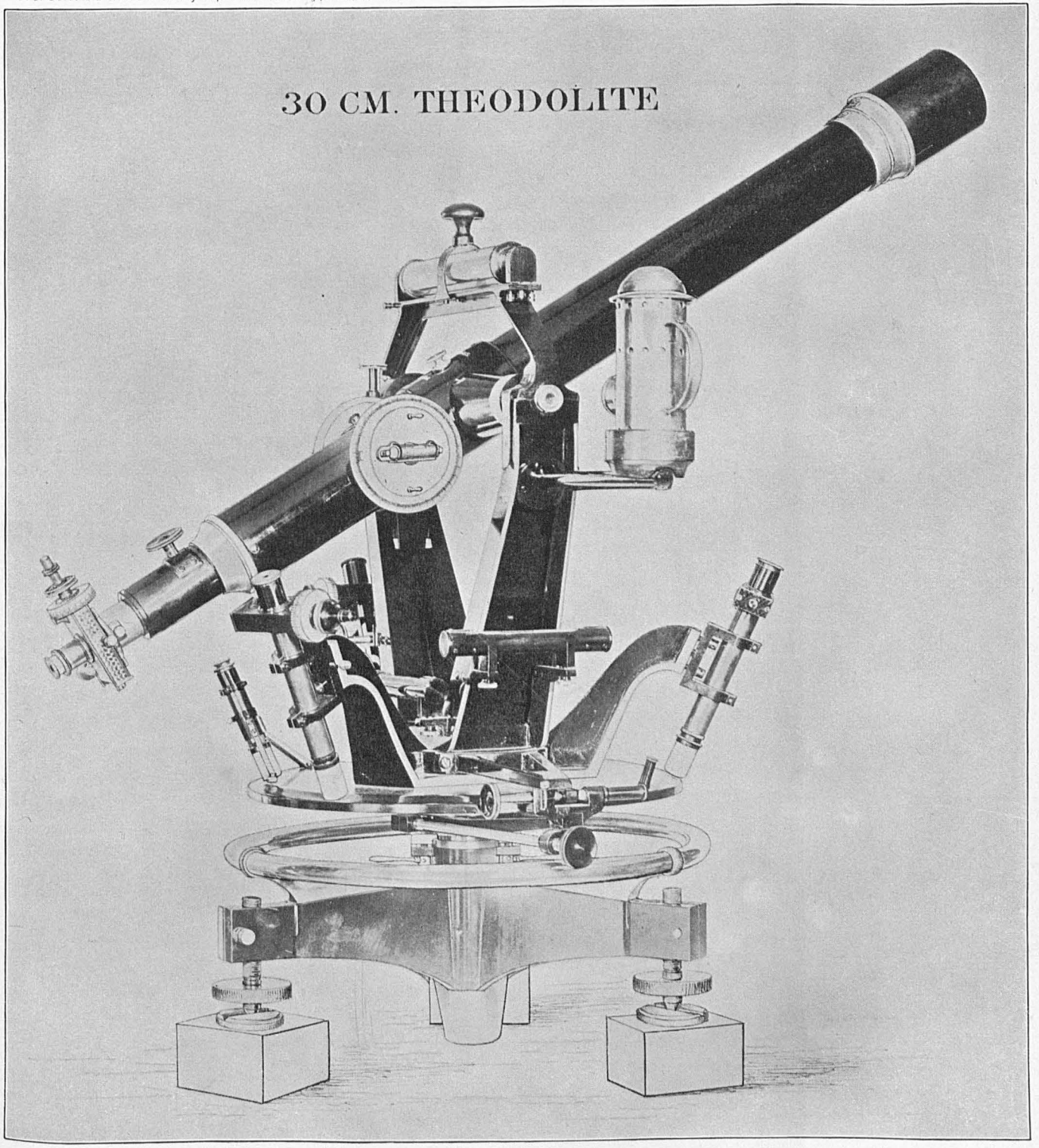
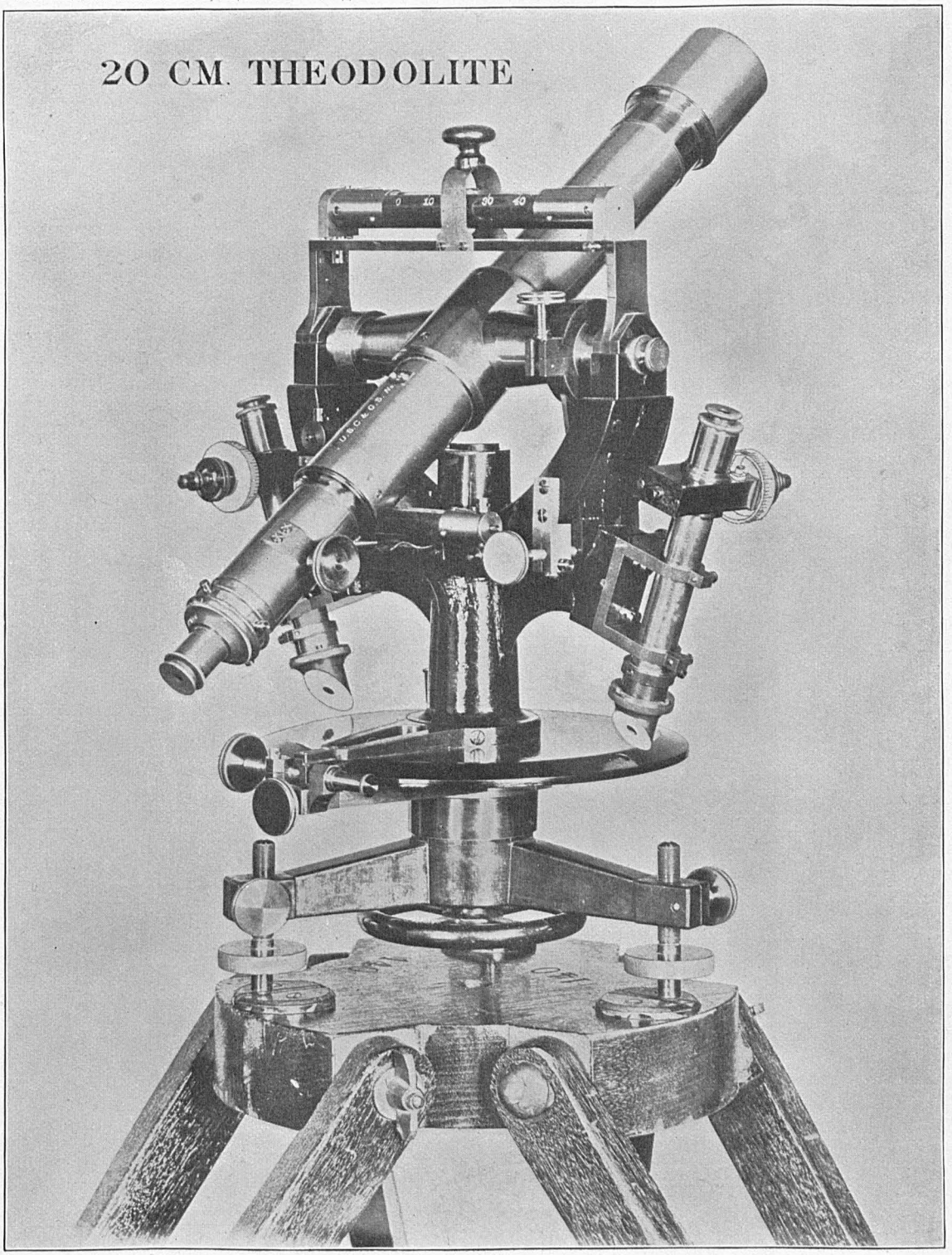
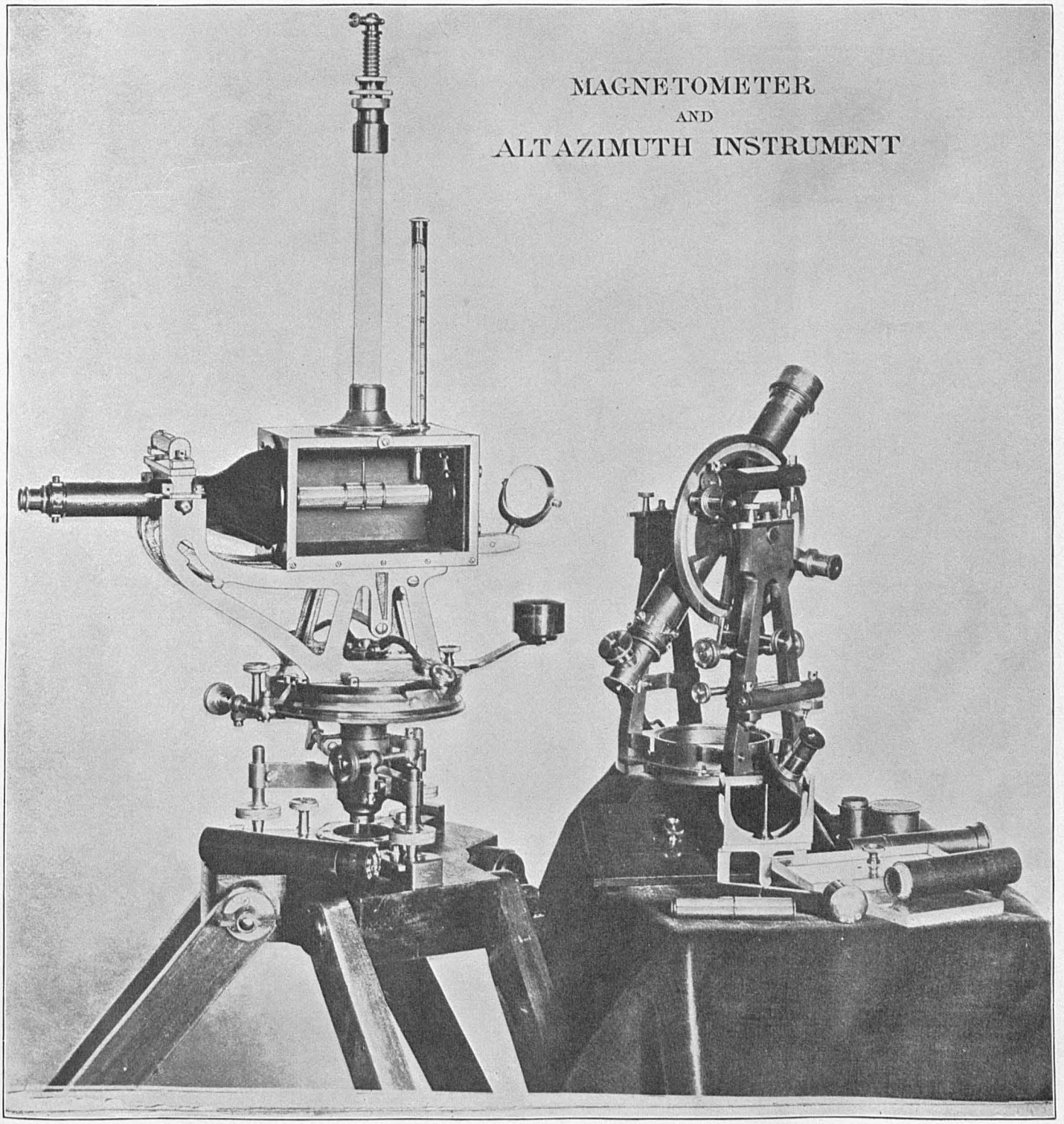
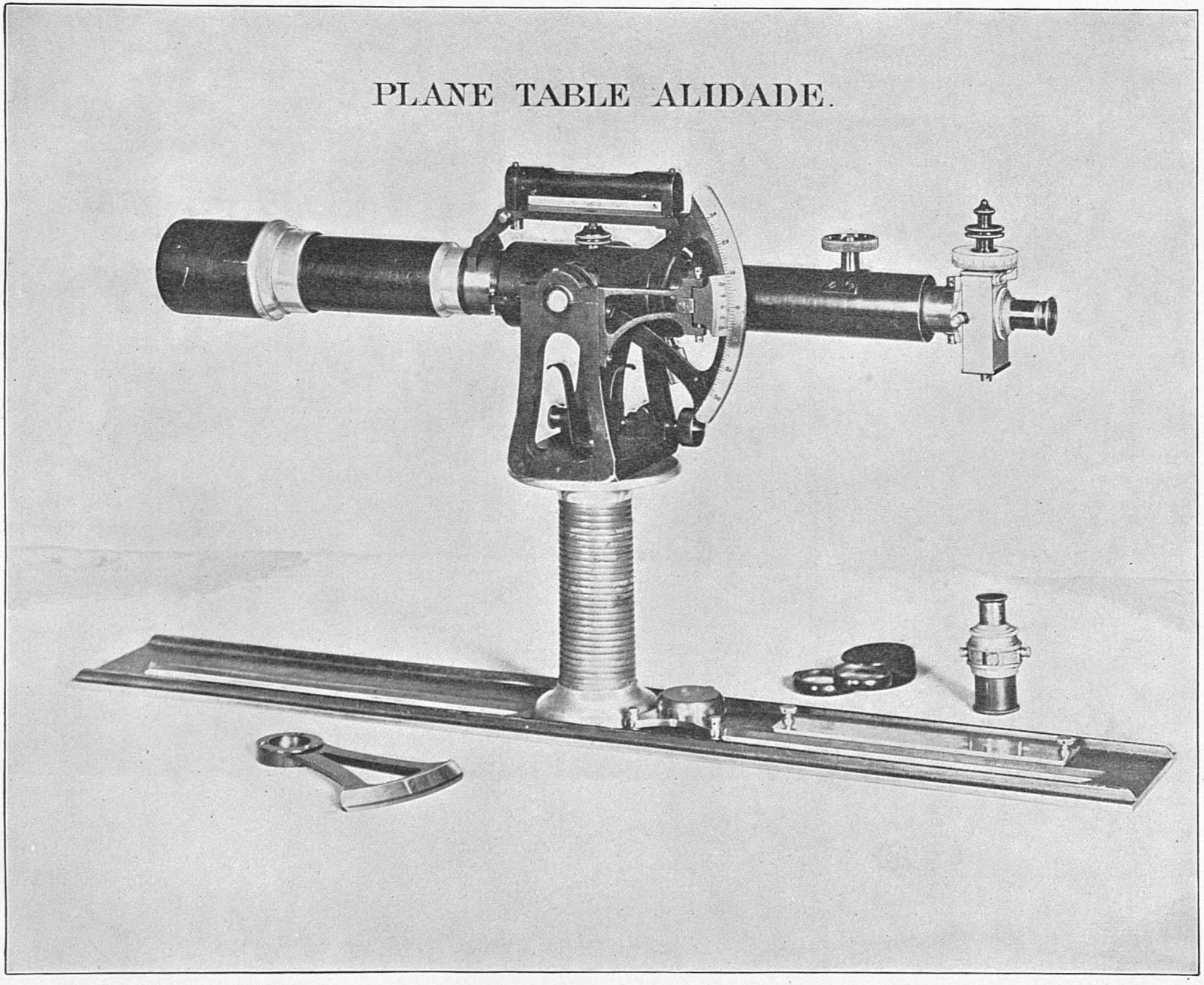
30 CM. THEODOLITE




20 CM. THEODOLITE


MAGNETOMETER
AND
ALTAZIMUTH INSTRUMENT

PLANE TABLE ALIDADE.



APPENDIX No. 9—1894.

FORMULÆ AND TABLES FOR THE COMPUTATION OF GEODETIC POSITIONS.

[Fourth Edition.]

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APPENDIX No. 9—1894.

FORMULÆ AND TABLES FOR THE COMPUTATION OF GEODETIC POSITIONS.

[Fourth edition.]

The first edition of these formulæ and tables was published as Appendix No. 36, Coast Survey Report for 1860, under the title "Formulæ, tables, and example for the geodetic computation of latitudes, longitudes, and azimuths of trigonometrical points, as used in the United States Coast Survey." The tables were first computed by Assistant Th. W. Werner in 1847, and were used in manuscript form up to 1860, and at later dates they were extended in range of latitude in order to satisfy further demands of the Survey. They are based upon the formulæ for the computation of geodetic positions as developed by Puissant, and their derivation will be found in Volume I, Chapter XV, of his Treatise on Geodesy.* These formulæ were adapted in 1846 to the use of the Coast Survey by Assistant J. E. Hilgard (Superintendent during 1881–85), who added an intermediate term to the expression for difference of latitude to render it more accurate, and provided for the table of factors to facilitate the computation of geodetic positions. The spheroid of reference upon the surface of which the triangulations of the Survey were supposed to be developed was that derived by Bessel and published in the Astronomische Nachrichten, No. 438 (December, 1841). The second edition of the tables is contained in Coast Survey Report for 1875, Appendix No. 19. The derivation of the formulæ is there given and the tables are extended from latitude 50° to latitude 65°; it contains, besides, two auxiliary tables to facilitate computations when changing the reference spheroid from that of Bessel to that of Clarke (1866). However, it was not till February 4, 1880, that Superintendent Patterson ordered the substitution of the latter spheroid for the Besselian, which latter had been in use on the Survey since the year 1844.† This change necessitated the issue of the third edition in Coast and Geodetic Survey Report for 1884, Appendix No. 7. The text was reprinted and the table given in connection with the computation of the spherical excess appeared extended in latitude.

The present edition differs from the preceding one by the introduction of a change in the notation of the formulæ, substituting for the older form one in better accord with modern custom, and, further, by an extension of the tables so as to take in the highest latitude of United States territory, besides 5° added to the former southernmost limit.

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*Traité de Géodésie, etc., par L. Puissant, Troisième édition. Tomes I et II, Paris, 1842.

† As is shown by tables of factors (for latitudes 30° to 45°), different from those now in use, but dependent on the (metric) dimensions of Bessel's spheroid, computed in 1843–44 by Assistant C. O. Boutelle; before this date and about the period 1838-40 a spheroid having a depression of $\frac{1}{302}$ appears to have been employed. The matter is now of little interest, since all computations of positions have long since been repeated.

The linear dimensions of Bessel's spheroid were originally expressed in toises. Their metric equivalents as generally adopted are given below. The dimensions of Clarke's spheroid (of 1866) are stated by him in feet, toises, and metres. (See Appendix to Comparisons of the Standards of Length, etc., by Capt. A. R. Clarke, under the direction of Col. Sir H. James, etc., London, 1866, page 287.) The dimensions in metres are:

	According to Bessel (1841).	According to Clarke (1866).
Equatorial semi-axis $= a$	6 377 397·2	6 378 206·4
Polar semi-axis $= b$	6 356 079·0	6 356 583·8
$b/a =$	$\frac{298{\cdot}15}{299{\cdot}15}$	$\frac{293{\cdot}98}{294{\cdot}98}$

Strictly speaking, the latter dimensions, to be expressed, as they must be, in terms of the prototype metre, should be slightly changed, for the reason that Clarke's results depend primarily on the yard and the relation of the yard and metre as found by him, 1 yard = 0·914 391 80^m (or 1 foot = 0·304 797 27^m),* should now be changed to conform to the more correct relation,† viz: 1 foot = 0·304 800 61^m, or 1 metre = 3·280 833 3 feet; the difference, however, is unimportant, since either spheroid might have been adopted, and it would be inexpedient to recompute the tables of factors.

Among later determinations of spheroids representing the earth's figure, and apart from several published by Colonel Clarke, we may mention two of very different derivation, viz: Prof. W. Harkness, U. S. N., in his "The Solar Parallax and its Related Constants, Washington, D. C., 1891," reached the following result, viz: Equatorial semidiameter, 6 377 972 ± 125 metres; polar semidiameter, 6 356 727 ± 99 metres, and $\frac{a-b}{a} = \frac{1}{300{\cdot}2 \pm 3{\cdot}0}$; F. Tisserand, in his "Traité de Méchanique Céleste, Tome II, Paris, 1891," states that the *aplatissement* (flattening) could not be greater than $\frac{1}{297{\cdot}3}$ provided the earth's density increases continuously from surface to center and the shape of the surface is due to original fluidity. A new value for this representative figure of the geoid, more reliable than any yet deduced, may be expected to result from the labors of the International Geodetic Association for the measurement of arcs, particularly since arcs of the parallel can no longer be regarded as so far inferior in value to arcs of the meridian as to exclude them from combination with the latter, both however being seriously influenced by local deflections of the vertical. Arc measures in a country, if of sufficient extent, may be utilized for deducing or choosing a special spheroid adapted to its surface, as was, for instance, the case with the Clarke spheroid, which is supposed to conform better to the compact area of the United States than the one previously in use.

In what follows, the derivation of the formulæ and the arrangement for the computation of geodetic positions, as given by Assistant J. E. Hilgard, have been reproduced from the preceding edition, after changing the notation as mentioned above.

C. A. SCHOTT, *Assistant.*

DECEMBER, 1894.

* This is equivalent to 1 metre = 39·370 432 inches, whereas the value adopted (November, 1891) by the United States Office of Standard Weights and Measures is 1 metre = 39·3700 inches, which agrees with the legal value adopted in the United States.

† See Appendix No. 16, Coast and Geodetic Survey Report for 1890, "On the relation of the yard to the metre," by O. H. Tittmann, Assistant.

FORMULÆ AND FACTORS FOR THE COMPUTATION OF GEODETIC LATITUDES, LONGITUDES, AND AZIMUTHS.

When the geographical coordinates of latitude and longitude of a point on the earth's surface and the distance and azimuth to another point are known, the problem of computing the latitude and longitude of the second point and the reverse azimuth may be treated in two different ways.

We may either solve the spheroidal triangle formed by the two points and the pole, as a whole, arriving at trigonometrical functions of the required co-latitude, azimuth, and difference of longitude, or we may develop expressions for the differences of the required and the given quantities.

The former or direct method has the inconvenience of requiring the use of ten places of decimals in the computation, in order to give the positions with a degree of exactness corresponding to that of the known distance between the two points, while the second leads to very convenient expressions, on account of the smallness of the differential arcs in ordinary triangulation.

When, however, the arc between the two points reaches several degrees in length, the direct method must be resorted to. This solution has been very completely and elegantly effected by Bessel, and is given in Astronomische Nachrichten, No. 86, 1826.

Adopting the second method, we follow in the main Puissant (Traité de Géodésie)* in the development of the difference of latitude of two points on the spheroid in terms of the distance, azimuth, and latitude of the given point. It will be desirable first to recall the expressions of several lines of an ellipse in terms involving the latitude φ which is the angle the normal to any point on the ellipse makes with the major axis.

Designating the major or equatorial semi-axis by a and the minor or polar semi-axis by b then the ellipticity ε or the ratio of their difference to the former is

$$\varepsilon = \frac{a-b}{a}$$

The eccentricity e is expressed by

$$e^2 = \frac{a^2-b^2}{a^2}$$

and shown in fig. 1 by cf, the distance from the center to the focus.

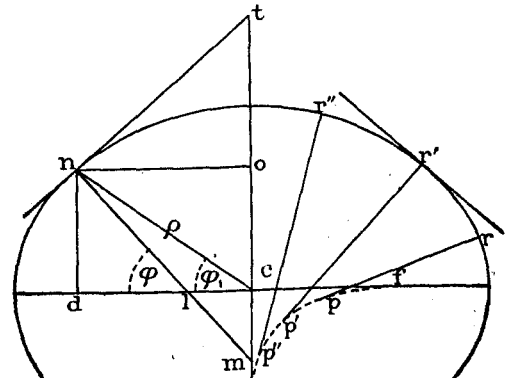

Fig. 1.

The normal nl terminating at the major axis equals

$$\frac{a(1-e^2)}{(1-e^2\sin^2\varphi)^{\frac{1}{2}}}$$

* Traité de Géodésie, par L. Puissant, troisième edition, Tome I, Chapter XV, page 347 and fol., Paris, 1842.

The normal nm produced to the minor axis is

$$N=\frac{a}{(1-e^2\sin^2\varphi)^{\frac{1}{2}}}$$

The abscissa cd or no equals $N\cos\varphi$. This is the radius of a parallel on the spheroid.

The tangent nt ending at the minor axis equals $N\cot\varphi$.

The ordinate nd equals

$$\frac{a(1-e^2)\sin\varphi}{(1-e^2\sin^2\varphi)^{\frac{1}{2}}}$$

The reduced latitude being ψ, we have

$$\tan\psi=\frac{b}{a}\tan\varphi$$

The radius vector $\rho=a(1-e^2\sin^2\psi)^{\frac{1}{2}}$,

The radius of curvature $rp, r'p', r''p''$ . . . at any point of the ellipse r, r', r'' . . . is

$$R=\frac{a(1-e^2)}{(1-e^2\sin^2\varphi)}$$

The terminal points f, p, p', p'', q form an evolute; at the equator where $\sin\varphi=0$, $R=\frac{b^2}{a}$ and the center of curvature is in the focus; at the pole, where $\sin\varphi=1$, $R=\frac{a^2}{b}$

The radius of curvature R and the normal N are principal quantities used in geodesy. It will be observed that radii of curvature for different latitudes do not intersect unless produced, and that when they lie in different meridional planes on the spheroid they will not intersect at all.

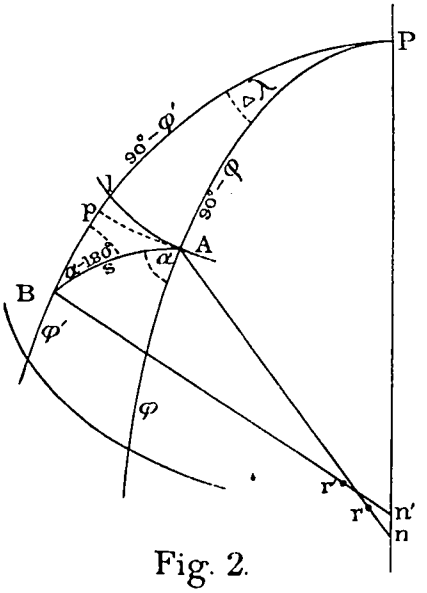

Fig. 2.

A and B in fig. 2 are two points on a spheroid of revolution, having the latitudes φ, φ', and joined by the geodetic line $AB=s$, making the angles with the meridian $PAB=180°-\alpha$, and $PBA=\alpha'-180°$. The azimuths α, α' are reckoned from south around by west in consequence of the latitudes being reckoned, by settled custom, from the equator toward the poles, otherwise the meridional coordinate of a point would be more properly measured from the pole and the azimuth of a line reckoned from the north. The angle APB between the two meridional planes passing through A and B is the difference of their longitudes λ, λ', which being reckoned positive to the westward we have $\lambda'-\lambda=\Delta\lambda$. Furthermore, An, Bn', Ar, Br' indicate the normals N, N', and the radii of curvature in the meridian R, R', at the points A and B.

This being premised and the latitude φ of the point A being given, as well as the length s of the geodetic line AB and its azimuth α, we propose to find the latitude φ' of the point B, the angle

$\Delta\lambda$, and the reverse azimuth α', by solving the geodetic triangle ABP. Writing γ, γ', for the co-latitudes, ξ for $180 - \alpha$, and σ for the arc AB referred to radius = 1, we have in a spherical triangle for γ' the following equation:

$$\cos \gamma' = \cos \gamma \cos \sigma + \sin \gamma \sin \sigma \cos \xi$$

Observing now that σ is always a small arc, rarely exceeding 1°, and generally less than 30′, we can develop the increment of γ with reference to that of σ in a rapidly converging series, and will have, by Taylor's theorem,

$$\gamma' = \gamma + \frac{d\gamma}{d\sigma}\sigma + \tfrac{1}{2}\frac{d^2\gamma}{d\sigma^2}\sigma^2 + \tfrac{1}{6}\frac{d^3\gamma}{d\sigma^3}\sigma^3 + \quad . \quad . \quad . \qquad (a)$$

In order to determine the differential coefficients, we consider a differential spherical triangle having the sides γ, $d\sigma$, and $\gamma + d\gamma$, in which

$$\cos (\gamma + d\gamma) = \cos \gamma \cos d\sigma + \sin \gamma \sin d\sigma \cos \xi,$$

and developing, as usual, by the differential calculus, we find

$$\frac{d\gamma}{d\sigma} = -\cos \xi, \quad \frac{d^2\gamma}{d\sigma^2} = \sin^2 \xi \cot \gamma, \quad \frac{d^3\gamma}{d\sigma^3} = \sin^2 \xi \cos \xi (1 + 3 \cot^2 \gamma)$$

Introducing these values in (a) we obtain

$$\gamma' - \gamma = -\sigma \cos \xi + \tfrac{1}{2}\sigma^2 \sin^2 \xi \cot \gamma + \tfrac{1}{6}\sigma^3 \sin^2 \xi \cos \xi (1 + 3 \cot^2 \gamma) + \quad . \quad . \quad . \quad . \quad .$$

and substituting φ, φ' and α in this expression, we have for the difference of latitude

$$\varphi - \varphi' = \sigma \cos \alpha + \tfrac{1}{2}\sigma^2 \sin^2 \alpha \tan \varphi - \tfrac{1}{6}\sigma^3 \sin^2 \alpha \cos \alpha (1 + 3 \tan^2 \varphi) + \quad . \quad . \quad . \quad . \quad . \qquad (b)$$

It will be readily seen that the first term expresses the distance on the meridian PB from B to p, the foot of the perpendicular from A; the second term, the distance, very nearly, from p to the parallel passing through A; while the third term is a further approximation, and so on.

Referring now our case to an imaginary sphere of radius equal to N, with its center at the point where the normal An intersects the polar diameter of the spheroid, we have

$$\sigma = \frac{s}{N}$$

substituting which, we get

$$\varphi - \varphi' = \frac{s \cos \alpha}{N} + \tfrac{1}{2}\frac{s^2 \sin^2 \alpha \tan \varphi}{N^2} - \tfrac{1}{6}\frac{s^3 \sin^2 \alpha \cos \alpha}{N^3}(1 + 3 \tan^2 \varphi) + \quad . \quad . \quad . \qquad (c)$$

This difference of latitude is, however, referred to a sphere whose radius is N and requires still to be transformed by referring it to one whose radius is R_m, the radius of curvature in the meridian for the middle latitude. Since we do not at first know the middle latitude, it is more convenient to refer to the radius of curvature R of the starting point, the latitude of which is known, and then find the small correction due to the ratio of R to R_m.

Multiplying then equation (c) by $\frac{N}{R}$ and dividing, moreover, by arc 1″, in order to express $\varphi - \varphi'$ in seconds of arc, we get

$$-\delta\varphi = \frac{s}{R \operatorname{arc} 1''} \cos \alpha + \tfrac{1}{2}\frac{s^2}{R N \operatorname{arc} 1''} \sin^2 \alpha \tan \varphi - \tfrac{1}{6}\frac{s^3}{R N^2 \operatorname{arc} 1''} \sin^2 \alpha \cos \alpha (1 + 3 \tan^2 \varphi) + \quad . \quad . \qquad (d)$$

The computation of this series is facilitated by tables giving the logarithms of the following factors to the argument of φ, viz:

$$B = \frac{1}{R \operatorname{arc} 1''} \qquad C = \frac{\tan \varphi}{2 R N \operatorname{arc} 1''}$$

Moreover, substituting in the third term the value of the first term, designated by h, we can write it

$$\tfrac{1}{6} h \cdot \frac{s^2 \sin^2 \alpha}{N^2}(1 + 3 \tan^2 \varphi)$$

and tabulate another factor

$$E=\frac{1+3\tan^2\varphi}{6N^2},$$

when our formula for computation becomes

$$-\delta\varphi=s\cos\alpha\,.\,B+s^2\sin^2\alpha\,.\,C-h\,.\,s^2\sin^2\alpha\,.\,E+\quad .\quad .\quad . \qquad (e)$$

In order, finally, to obtained the true $\Delta\varphi$ referred to R_m we must increase $\delta\varphi$ by $\frac{R-R_m}{R_m}\delta\varphi$

Now

$$R-R_m=a(1-e^2)\left(\frac{1}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}}-\frac{1}{(1-e^2\sin^2\varphi_m)^{\frac{3}{2}}}\right)$$
$$=a(1-e^2)\,\frac{\frac{3}{2}e^2(\sin^2\varphi-\sin^2\varphi_m)}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}(1-e^2\sin^2\varphi_m)^{\frac{3}{2}}}$$

by developing and neglecting terms involving higher powers of e^2; but

$$\sin^2\varphi-\sin^2\varphi_m=\sin(\varphi-\varphi_m)\sin(\varphi+\varphi_m)=\delta\varphi\sin 1''\sin\varphi\cos\varphi$$

very nearly, because $\frac{1}{2}\sin 2\varphi=\sin\varphi\cos\varphi$; hence we write

$$\frac{R-R_m}{R^m}=\frac{a(1-e^2)\frac{3}{2}e^2\,\delta\varphi\sin 1''\sin\varphi\cos\varphi}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}(1-e^2\sin^2\varphi_m)^{\frac{3}{2}}}\times\frac{(1-e^2\sin^2\varphi_m)^{\frac{3}{2}}}{a(1-e^2)}=\frac{\frac{3}{2}e^2\,\delta\varphi\sin 1''\sin\varphi\cos\varphi}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}}$$

nearly, but making

$$D=\frac{\frac{3}{2}e^2\sin\varphi\cos\varphi\,\mathrm{arc}\,1''}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}}$$

we get for the desired corrective term*

$$\frac{R-R_m}{R_m}\delta\varphi=(\delta\varphi)^2\,D$$

and we finally have for the true difference of latitude

$$-\Delta\varphi=s\cos\alpha\,.\,B+s^2\sin^2\alpha\,.\,C+(\delta\varphi)^2.\,D-h.\,s^2\sin^2\alpha\,.\,E \qquad (1)$$

which formula, although of a somewhat complicated derivation, is very simple and convenient in practical computation with the aid of the tabulated log. factors B, C, D, E. The term† $(\delta\varphi)^2\,D$ is here interposed between the second and third terms of the series proper, because the latter is frequently not required, being insensible when the distance s is less than about 10 statute miles or log s, in metres, less than 4·23 . The term $(\delta\varphi)^2\,D$ should be used whenever log h exceeds 2·31, and h^2 may be substituted for $(\delta\varphi)^2$ in all cases where log s does not exceed 4·93 .

The term depending on the fourth differential coefficient, neglected in equation (a) never exceeds 0″·002 for $\sigma=1^\circ$ or $s=109$ kilometres, and may therefore be safely neglected in practice.‡

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* In his "The Theory and Practice of Surveying" Prof. J. B. Johnson develops this corrective term in a direct manner as contrasted with the approximate and laborious method given in the text, and points out that the $\frac{3}{2}$-power in the denominator of D should be replaced by unity. This has been done in the appended tables; although the defect is not more than 0·001 of the value of this term, which is itself very small.—C. A. S.

† This term was devised by the writer of this article in 1846, while arranging the formulæ for use in the Coast Survey and putting them into the form above given, in which they have been employed ever since.—J. E. H.

‡ This additional term has, however, been lately developed by Mr. M. H. Doolittle, of the Computing Division, who finds that it can be given as a function of the factors A, C, and E of the tables, thus requiring no special tabulation. It is as follows:

The additional term of Taylor's theorem

$$\frac{1}{24}\frac{d^4\gamma}{d\sigma^4}\sigma^4=-\frac{1}{24}\sigma^4\sin^2\xi\cot\gamma\left[(1-3\cos^2\xi)(1+3\cot^2\gamma)-6\cos^2\xi\operatorname{cosec}^2\gamma\right]$$

Substituting $90^\circ-\varphi$ for γ, $180^\circ-\alpha$ for ξ, $\frac{s}{N}$ for σ, and multiplying by $\frac{N}{R\,\mathrm{arc}\,1''}$ in the same manner as for the other terms

$$\frac{1}{24}\frac{d^4\gamma}{d\sigma^4}\sigma^4=-\frac{1}{24}\frac{s^4}{RN^3\,\mathrm{arc}\,1''}\sin^2\alpha\tan\varphi(1+3\tan^2\varphi)$$
$$+\frac{1}{8}\frac{s^4}{RN^3\,\mathrm{arc}\,1''}\sin^2\alpha\cos^2\alpha\tan\varphi(1+3\tan^2\varphi)$$
$$+\frac{1}{4}\frac{s^4}{RN^3\,\mathrm{arc}\,1''}\sin^2\alpha\cos^2\alpha\tan\varphi\sec^2\varphi$$

For secondary triangulation and when the sides do not exceed about 12 statute miles, or say 20 kilometres, the formula (1) may be advantageously reduced to the following:

$$-\Delta\varphi = s\cos\alpha\,.\,B + s^2\sin^2\alpha\,.\,C + h^2\,.\,D \qquad (2)$$

In order next to deduce the angle APB (fig. 2) between the meridional planes passing through A and B and intersecting in the polar axis, or the difference $\Delta\lambda$ of the longitudes λ and λ' of the points A and B, counted from east to west, we avail ourselves of the latitude φ' of B, which has become known by the previous calculation, and have simply, using the same notation as before,

$$\sin\gamma' : \sin\xi = \sin\sigma : \sin\Delta\lambda$$

Referring σ to a sphere the radius of which is the normal $Bn' = N'$, we have $\sigma = \frac{s}{N'}$ and assuming for the present the small arcs σ and $\Delta\lambda$ proportional to their sines, we obtain

$$\Delta\lambda = \frac{s\sin\alpha}{N'\cos\varphi'\,\mathrm{arc}\,1''} \quad . \quad . \quad . \qquad (3)$$

dividing by arc $1''$ in order to obtain $\Delta\lambda$ expressed in seconds of arc. The table gives the logarithm of the factor $A = \frac{1}{N\,\mathrm{arc}\,1''}$, which must be taken out for φ'. We have

$$\Delta\lambda = \frac{s\sin\alpha}{\cos\varphi'}A$$

In order to correct for the assumption that the small arcs s and $\Delta\lambda$ are proportional to their sines we use a table giving the differences of the logarithms of the arcs and sines. This table is given before the tabulation of the factors A to F. In using it take out the differences for the arguments log. s and log. $\Delta\lambda$ the first with a negative, the second with a positive sign, and add their algebraic sum to log. $\Delta\lambda$.

We obtain finally the reverse azimuth α' by considering that in the spherical triangle APB (fig. 2) we have the following relation

$$\cot\tfrac{1}{2}(\xi+\xi') = \tan\tfrac{1}{2}(\Delta\lambda)\frac{\cos\frac{1}{2}(\gamma'+\gamma)}{\cos\frac{1}{2}(\gamma'-\gamma)} = \tan\tfrac{1}{2}(\Delta\lambda)\frac{\sin\frac{1}{2}(\varphi'+\varphi)}{\cos\frac{1}{2}(\varphi'-\varphi)}$$

but $\xi = 180^\circ - \alpha$, therefore

$$\cot\tfrac{1}{2}(180^\circ - \alpha + \xi') = -\tan\tfrac{1}{2}(\xi' - \alpha)$$

and

$$-\tan\tfrac{1}{2}(\Delta\alpha) = \tan\tfrac{1}{2}(\Delta\lambda)\frac{\sin\frac{1}{2}(\varphi'+\varphi)}{\cos\frac{1}{2}(\varphi'-\varphi)}$$

Assuming the tangents of $\frac{1}{2}\Delta\alpha$ and $\frac{1}{2}\Delta\lambda$ proportional to their arcs, and writing $\varphi_m = \frac{1}{2}(\varphi+\varphi')$ for the middle latitude, we have

$$-\Delta\alpha = \Delta\lambda\frac{\sin\varphi_m}{\cos\frac{1}{2}(\Delta\varphi)} \quad \text{and} \quad \alpha' = \alpha + 180^\circ + \Delta\alpha$$

Denoting the second term $s^2\sin^2\alpha\,C$ in formula (6) by C_1

$$C_1\,E = \frac{s^2\sin^2\alpha\tan\varphi\,(1+3\tan^2\varphi)}{12\,RN^3\,\mathrm{arc}\,1''}$$

$$A^2\,C_1 = \frac{s^2\sin^2\alpha\tan\varphi}{2\,RN^3\,\mathrm{arc}^3\,1''}$$

and we finally obtain

$$-\Delta\varphi = s\cos\alpha\,B + s^2\sin^2\alpha\,C + (\delta\varphi)^2\,D - h\,.\,s^2\sin^2\alpha\,E$$
$$-\frac{1}{2}s^2\,C_1\,E + \frac{3}{2}s^2\cos^2\alpha\,C_1\,E + \frac{1}{2}s^2\cos^2\alpha\sec^2\varphi\,.\,A^2\,C_1\,\mathrm{arc}^2\,1''$$

In the line from Ibepah to Ogden, in Utah, 230 kilometres long, the additional term amounted to $0''{\cdot}038$. In Puissant's time no such long lines had to be provided for as have since been observed in triangulations; e. g., in California, Nevada, Utah, and Colorado, where several sides reach to nearly 2° in length, or slightly surpass this limit, with a maximum sight of $2\frac{3}{4}^\circ$. The formulæ applicable for the computation of the largest triangles that it is possible to measure, given in Clarke's Geodesy (Oxford, 1880) and in Appendix No. 9, Coast and Geodetic Survey Report for 1885, pages 462–464, and employed in the British Ordnance Survey, also in the extension of La Caille's arc in South Africa, may be employed for a check computation, but they demand the use of not less than 9-place logarithms.

For distances greater than any that can be directly observed, see development of formulæ in series by Dr. F. R. Helmert, "Theorieen der Höheren Geodäsie, Leipzig, 1880," Vol. I, pages 296–298. It includes terms of the fifth order.

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When the difference of longitude is very large it becomes necessary to correct for the error in the assumption that $\tan \frac{1}{2}(\Delta\alpha) : \tan \frac{1}{2}(\Delta\lambda) = \Delta\alpha : \Delta\lambda$. By an obvious transformation we find the correction to be $\frac{1}{12}(\Delta\lambda)^3 \sin \varphi_m \cos^2 \varphi_m \sin^2 1''$, for which we write $(\Delta\lambda)^3 F$ where log. F is to be taken from the table (see last column of table of factors). This term is only $0''{\cdot}01$ when log. $\Delta\lambda = 3{\cdot}36$ and need never to be used for secondary triangulation. A convenient table for finding the reciprocal of $\cos \frac{1}{2}(\Delta\varphi)$ is appended.

The following examples will illustrate the use of the formulæ and tables:

The formulæ for the computation of the geodetic differences in latitude $\Delta\varphi$, in longitude $\Delta\lambda$, and in azimuth $\Delta\alpha$ are as follows:

$$\begin{cases} -\Delta\varphi = s \cos\alpha \,.\, B + s^2 \sin^2\alpha \,.\, C + (\delta\varphi)^2 D - h \,.\, s^2 \sin^2\alpha \,.\, E \\ \Delta\lambda = s \sin\alpha \sec\varphi' \,.\, A \\ -\Delta\alpha = \Delta\lambda \sin \frac{1}{2}(\varphi + \varphi') \sec \frac{1}{2}(\Delta\varphi) + (\Delta\lambda)^3 F \end{cases}$$

where

$$\begin{cases} \varphi' = \varphi + \Delta\varphi \\ \lambda' = \lambda + \Delta\lambda \\ \alpha' = \alpha + \Delta\alpha + 180 \end{cases} \qquad \text{and} \begin{cases} -\delta\varphi = s \cos\alpha \,.\, B + s^2 \sin^2\alpha \,.\, C - h \,.\, s^2 \sin^2\alpha \,.\, E \\ \text{also } h = s \cos\alpha \,.\, B \end{cases}$$

For subordinate triangulation when the sides do not exceed say 25 kilometres, or about 15 statute miles, the term involving E in $\Delta\varphi$ and the factor $\sec \frac{1}{2}(\Delta\varphi)$, as well as the term involving F in $\Delta\alpha$, may be omitted.

Our formulæ can also be used for the solution of the inverse problem, viz, given the positions of two points on the spheroid, to find their distance and mutual azimuths, i. e., given φ, λ, φ', λ' (or φ, φ', $\Delta\lambda$), to find s, α, and α'. For its direct solution put

$$\begin{cases} s \cos\alpha = x = -\frac{1}{B}\left[\Delta\varphi + C \,.\, y^2 + D\,(\Delta\varphi)^2 + E\,(\Delta\varphi)\, y^2 + E \,.\, C \,.\, y^4\right] \\ s \sin\alpha = y = \frac{\Delta\lambda \cos\varphi'}{A} \end{cases}$$

whence

$$\tan\alpha = y/x \quad \text{and} \quad s = x \sec\alpha = y \operatorname{cosec}\alpha$$

Position computation: Given, φ, λ, s, and α; required, φ', λ', α'.

FORM FOR PRIMARY TRIANGULATION.

		°	′	″
α	Mount Blue to Mount Pleasant	26	19	28·69
$\angle$	Ragged Mountain and Mount Pleasant	− 85	35	25·78
α	Mount Blue to Ragged Mountain	300	44	02·91
$\Delta\alpha$		+	50	03·88
		180		
α'	Ragged Mountain to Mount Blue	121	34	06·79

	°	′	″			°	′	″
φ	44	43	41·437	Mount Blue	λ	70	20	33·157
$\Delta\varphi$	—	30	56·052	s = 110 743·7 metres*	$\Delta\lambda$	− 1	11	27·830
φ'	44	12	45·385	Ragged Mountain	λ'	69	09	05·327

Form for primary triangulation.—Continued.

s	5·044 3191	s^2	10·08864			h	3·2633
cos α	9·708 4678	$\sin^2\alpha$	9·86854	$(\delta\varphi)^2$	6·5372	$s^2\sin^2\alpha$	9·9572
B	8·510 4887	C	1·39991	D	2·3926	E	6·2069
h	3·263 2756		1·35709		8·9298		9·4274
	//		//				
1st term	+1833·478	3d term	+ 0·0851			$\Delta\lambda^3$	10·897n
2d term	+ 22·756	4th term	− 0·2675			F	7·844
	+1856·234						8·741n
3d and 4th terms	− 0·182						
$-\Delta\varphi$	+1856·052	s	5·044 3191			$\Delta\lambda$	3·632 237n
	° ′ ″	$\sin\alpha$	9·934 2701n	Arg.		$\sin\frac{1}{2}(\varphi+\varphi')$	9·845 433
$\frac{1}{2}(\varphi+\varphi')$	44 28 13·4	A	8·509 0107	s	− 218	sec. $\frac{1}{2}(\Delta\varphi)$	0·000 004
$\frac{1}{2}\Delta\varphi$	0 15 28·0	sec φ'	0·144 6280	$\Delta\lambda_u$	+ 314		
			3·632 2375n	Corr.	+ 96		3·477 674n
		$\Delta\lambda$	// −4287·830			1st term	− 3003·82
						2d term	− 0·06
						$-\Delta a$	− 3003·88

* 68·8 statute miles, nearly.

N. B.—Take out A from table for φ'.

FORM FOR SUBORDINATE TRIANGULATION.

		°	′	″
α	Tomales Bay to Sonoma Mountain	244	08	30·9
$\angle$	Bodega and Sonoma Mountain	− 83	14	34·7
α	Tomales Bay to Bodega	160	53	56·2
$\Delta\alpha$		—	2	01·9
		180		
α'	Bodega to Tomales Bay	340	51	54·3

	°	′	″				°	′	″
φ	38	10	47·982	Tomales Bay.		λ	122	56	47·301
$\Delta\varphi$	+	7	28·222	s = 14 626·8 metres.		$\Delta\lambda$	+	3	16·993
φ'	38	18	16·204	Bodega.		λ'	123	00	04·294

	° ′ ″	s	4·165 1480	s^2	8·3303		
$\frac{1}{2}(\varphi+\varphi')$	38 14 32	cos α	9·975 4055n	$\sin^2\alpha$	9·0297	h^2	5·303
	//	B	8·510 9892	C	1·3003	D	2·380
1st term	−448·273	h	2·651 5427n		8·6603		7·683
2d and 3d terms	+ 0·051				0·046		0·005
$-\Delta\varphi$	−448·222						

s	4·165 1480		
sin α	9·514 8602		
A	8·509 1611	$\Delta\lambda$	2·29445
sec φ'	0·105 2810	$\sin\frac{1}{2}(\varphi+\varphi')$	9·79168
	2·294 4503		2·08613
	//		//
$\Delta\lambda$	+196·993	$-\Delta\alpha$	+121·9

N. B.—Take out A from table for φ'.

The inverse problem.—Cases frequently occur where the distance and mutual azimuths are demanded of two points whose latitudes and longitudes only are known. It has not been found necessary to prepare special formulæ and blank forms for this computation, as it can readily be made with the help of the preceding forms. It is done by dividing $\Delta\lambda = s \sin \alpha \,.\, A \,.\, \sec \varphi'$ by the first term for $\Delta\varphi$, $h = s \cos \alpha \,.\, B$, whence we get

$$\tan \alpha = \frac{\Delta\lambda \,.\, B}{A \sec \varphi' h}$$

This would give the azimuth at once, provided we knew h, since $\Delta\lambda$ is given. We therefore compute the smaller terms for the difference of latitude in order to obtain h by subtracting them from the known value of $\Delta\varphi$. The only addition to the usual form is the term log. tan α = log (s sin α) − log (s cos α). The value of s will best be taken from the term h when sin α exceeds cos α, and from the term $\Delta\lambda$ when the reverse is the case. When the distance s is large, as in primary triangulation, it will be necessary to introduce the correction for $\Delta\lambda$ due to difference of ratio between sine and arc, using the form for primary work, inversely, as indicated above.

Distance and azimuth computation: Given, φ, φ', λ, λ'; required, s, α, α'.

		°	′	″
α	Tomales Bay to Bodega	160	53	56·2
$\Delta\alpha$		—	2	01·9
		180		
α'	Bodega to Tomales Bay	340	51	54·3

		°	′	″			°	′	″
φ		38	10	47·982		λ	122	56	47·301
$\Delta\varphi$	Tomales Bay. s = 14 626·8 metres.	+	7	28·222		$\Delta\lambda$	+	3	16·993
φ'	Bodega.	38	18	16·204		λ'	123	00	04·294

$\frac{1}{2}(\varphi+\varphi')$ = 38° 14′ 32″		s / cos α }	4·140 5535n	s^2 / sin² α }	7·3600	h^2	5·303
		B	8·510 9892	C	1·3003	D	2·380
	″						
1st term	−448·273	h	2·651 5427n		8·6603		7·683
2d and 3d terms	+ 0·051				0·046		0·005
$-\Delta\varphi$	−448·222	s / sin α }	3·680 0082			s sin α	3·680 0082
						s cos α	4·140 5535n
		A	8·509 1611	$\Delta\lambda$	2·29445	tan α	9·539 4547n
		sec φ'	0·105 2810	sin ½(φ+φ')	9·79168		
						α	160° 53′ 56″·2
			2·294 4503		2·08613		
			″		″	sin α	9·514 8602
		$\Delta\lambda$	+196·993	$-\Delta\alpha$	+121·9	s	4·165 1480

*Table of corrections to longitude for difference in arc and sine.**

log s (−)	log difference.	log $\Delta\lambda$ (+)	log s (−)	log difference.	log $\Delta\lambda$ (+)	log s (−)	log difference.	log $\Delta\lambda$ (+)
3·876	0·000 0001	2·385	4·871	0·000 0098	3·380	5·172	0·000 0392	3·681
4·026	02	2·535	4·882	103	3·391	5·178	402	3·687
4·114	03	2·623	4·892	108	3·401	5·183	412	3·692
4·177	04	2·686	4·903	114	3·412	5·188	422	3·697
4·225	05	2·734	4·913	119	3·422	5·193	433	3·702
4·265	06	2·774	4·922	124	3·431	5·199	443	3·708
4·298	07	2·807	4·932	130	3·441	5·204	453	3·713
4·327	08	2·836	4·941	136	3·450	5·209	464	3·718
4·353	09	2·862	4·950	142	3·459	5·214	474	3·723
4·376	10	2·885	4·959	147	3·468	5·219	486	3·728
4·396	11	2·905	4·968	153	3·477	5·223	497	3·732
4·415	12	2·924	4·976	160	3·485	5·228	508	3·737
4·433	13	2·942	4·985	166	3·494	5·233	519	3·742
4·449	14	2·958	4·993	172	3·502	5·238	530	3·747
4·464	15	2·973	5·002	179	3·511	5·242	541	3·751
4·478	16	2·987	5·010	186	3·519	5·247	553	3·756
4·491	17	3·000	5·017	192	3·526	5·251	565	3·760
4·503	18	3·012	5·025	199	3·534	5·256	577	3·765
4·526	20	3·035	5·033	206	3·542	5·260	588	3·769
4·548	23	3·057	5·040	213	3·549	5·265	600	3·774
4·570	25	3·079	5·047	221	3·556	5·269	613	3·778
4·591	27	3·100	5·054	228	3·563	5·273	625	3·782
4·612	30	3·121	5·062	236	3·571	5·278	637	3·787
4·631	33	3·140	5·068	243	3·577	5·282	650	3·791
4·649	36	3·158	5·075	251	3·584	5·286	663	3·795
4·667	39	3·176	5·082	259	3·591	5·290	674	3·799
4·684	42	3·193	5·088	267	3·597	5·294	687	3·803
4·701	45	3·210	5·095	275	3·604	5·299	702	3·808
4·716	48	3·225	5·102	284	3·611	5·303	716	3·812
4·732	52	3·241	5·108	292	3·617	5·307	729	3·816
4·746	56	3·255	5·114	300	3·623	5·311	743	3·820
4·761	59	3·270	5·120	309	3·629	5·315	757	3·824
4·774	63	3·283	5·126	318	3·635	5·319	771	3·828
4·788	67	3·297	5·132	327	3·641	5·323	785	3·832
4·801	71	3·310	5·138	336	3·647	5·327	800	5·836
4·813	75	3·322	5·144	345	3·653	5·331	814	3·840
4·825	80	3·334	5·150	354	3·659	5·335	829	3·844
4·834	84	3·343	5·156	364	3·665	5·339	845	3·848
4·849	89	3·358	5·161	373	3·670	5·343	861	3·852
4·860	94	3·369	5·167	383	3·676	5·347	877	3·856

* From $\sin x = x - \frac{x^3}{6} + \frac{x^5}{120} - \ldots$ we have with sufficient accuracy for our purpose $\log \sin x = \log x - M\frac{x^2}{6}$, and $\log (\log x - \log \sin x) = \log \left(M\frac{x^2}{6}\right)$.

Substituting the value of M or modulus of common log's, and putting $x \sin 1''$ for x, when expressed in seconds, we get $\log \left(M\frac{x^2}{6}\right) = 2 \log x + [8{\cdot}23078]$; hence the expression log (log diff.) $= [8{\cdot}2308] + 2 \log \Delta\lambda$. By taking an average value for log A, say [8·5090], we get by means of log $\Delta\lambda$ = log A + log s, the corresponding expression log (log diff.) = 2 log s + 2 log A + [8·5090], and the numerical difference of the corresponding tabular values of log s and log $\Delta\lambda$ equals 1·4910.

Table of values of log sec ½ (Δφ).

Δφ	log sec ½ (Δφ)	Δφ	log sec ½ (Δφ)	Δφ	log sec ½ (Δφ)	Δφ	log sec ½ (Δφ)	Δφ	log sec ½ (Δφ)
′		′		′		′		′	
10	0·000 000	28	0·000 004	46	0·000 010	64	0·000 019	82	0·000 031
11	1	29	4	47	10	65	19	83	32
12	1	30	4	48	11	66	20	84	32
13	1	31	4	49	11	67	21	85	33
14	1	32	5	50	11	68	21	86	34
15	1	33	5	51	12	69	22	87	35
16	1	34	5	52	12	70	22	88	36
17	1	35	6	53	13	71	23	89	36
18	1	36	6	54	13	72	24	90	37
19	2	37	6	55	14	73	24	91	38
20	2	38	7	56	14	74	25	92	39
21	2	39	7	57	15	75	26	93	40
22	2	40	7	58	15	76	26	94	41
23	2	41	8	59	16	77	27	95	41
24	3	42	8	60	16	78	28	96	42
25	3	43	8	61	17	79	29	97	43
26	3	44	9	62	18	80	29	98	44
27	3	45	9	63	18	81	30	99	45

To convert: Metres to feet.		To convert: Feet to metres.		To convert: Kilometres to statute miles.		To convert: Statute miles to kilometres.	
1 =	3·280 833	1 =	0·304 8006	1 =	0·621 3699	1 =	1·609 347
2	6·561 667	2	0·609 6012	2	1·242 7399	2	3·218 694
3	9·842 500	3	0·914 4018	3	1·864 1098	3	4·828 042
4	13·123 333	4	1·219 2024	4	2·485 4798	4	6·437 389
5	16·404 166	5	1·524 0030	5	3·106 8497	5	8·046 736
6	19·685 000	6	1·828 8037	6	3·728 2196	6	9·656 083
7	22·965 833	7	2·133 6043	7	4·349 5896	7	11·265 430
8	26·246 666	8	2·438 4049	8	4·970 9595	8	12·874 778
9	29·527 500	9	2·743 2055	9	5·592 3295	9	14·484 125

FORMULA AND TABLE FOR COMPUTING THE SPHERICAL EXCESS OF TRIANGLES.

In every spherical triangle the excess of the sum of the three angles over 180° bears the same ratio to eight right angles as the area of the triangle bears to that of the whole sphere. Putting r for radius, ε for the excess, we have $\frac{\varepsilon}{4\pi} = \frac{area}{4r^2\pi}$, hence $\varepsilon = \frac{area}{r^2}$. In order to express ε in seconds of arc, we must divide the expression by sin 1″. The area of the triangle, when it is small in relation to the whole sphere, as is the case in all geodetic triangles, may be expressed with sufficient accuracy for this purpose by $\frac{1}{2}\, a_1\, b_1 \sin C_1$ where a_1 and b_1 are two sides and C_1 the included angle. We then have

$$\varepsilon = \frac{a_1\, b_1 \sin C_1}{2\, r^2 \sin 1''}$$

In determining ε in a triangle on the terrestrial spheroid, we can refer it to an osculating sphere, the radius of which is taken as $\sqrt{R\,N}$, where R equals radius of curvature in the meridian and N equals radius of curvature in the prime vertical at the center of the triangle. These are respectively

$$R = \frac{a\,(1-e^2)}{(1-e^2\sin^2\varphi)^{\frac{3}{2}}} \qquad N = \frac{a}{(1-e^2\sin^2\varphi)^{\frac{1}{2}}}$$

using the notation of the preceding formulæ for position computation.

We have, therefore, for the spherical triangle,

$$\varepsilon = \frac{a_1\, b_1 \sin C_1}{2\, R\, N \sin 1''} = \frac{a_1\, b_1 \sin C_1}{2\, a^2\,(1-e^2)\sin 1''}\,[1 - e^2\sin^2\varphi]^2$$

for which we write $\varepsilon = a_1\, b_1 \sin C_1 \times m$, and tabulate the logarithms of $m = \frac{[1-e^2\sin^2\varphi]^2}{2\, a^2\,(1-e^2)\sin 1''}$ for different latitudes.

Table of log m.

Latitude.	Log *m*.	Latitude.	Log *m*.	Latitude.	Log *m*.	Latitude.	Log *m*.
° ′		° ′		° ′		° ′	
18 00	1·40639	33 00	1·40520	48 00	1·40369	63 00	1·40227
18 30	636	33 30	516	48 30	364	63 30	223
19 00	632	34 00	511	49 00	359	64 00	219
19 30	629	34 30	506	49 30	354	64 30	215
20 00	626	35 00	501	50 00	349	65 00	210
20 30	623	35 30	496	50 30	344	65 30	207
21 00	619	36 00	491	51 00	339	66 00	203
21 30	616	36 30	486	51 30	334	66 30	199
22 00	612	37 00	482	52 00	329	67 00	195
22 30	608	37 30	477	52 30	324	67 30	192
23 00	605	38 00	472	53 00	319	68 00	188
23 30	601	38 30	467	53 30	314	68 30	185
24 00	597	39 00	462	54 00	309	69 00	181
24 30	594	39 30	457	54 30	304	69 30	178
25 00	590	40 00	452	55 00	299	70 00	174
25 30	586	40 30	446	55 30	295	70 30	171
26 00	582	41 00	441	56 00	290	71 00	168
26 30	578	41 30	436	56 30	285	71 30	164
27 00	573	42 00	431	57 00	280	72 00	1·40161
27 30	569	42 30	426	57 30	276		
28 00	565	43 00	421	58 00	271		
28 30	560	43 30	416	58 30	266		
29 00	556	44 00	411	59 00	262		
29 30	552	44 30	406	59 30	257		
30 00	548	45 00	400	60 00	253		
30 30	544	45 30	395	60 30	249		
31 00	539	46 00	390	61 00	244		
31 30	534	46 30	385	61 30	240		
32 00	530	47 00	380	62 00	235		
32 30	1·40525	47 30	1·40375	62 30	1·40231		

[The above table is computed for the Clarke spheroid of 1866.]

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TABLE OF LOGARITHMS OF FACTORS A, B, C, D, E, F,

BASED UPON THE CLARKE SPHEROID OF 1866 AND THE METRIC SYSTEM, BETWEEN LATITUDES 18° AND 72°.

CONSTANTS.

$$A = \frac{(1 - e^2 \sin^2 \varphi)^{\frac{1}{2}}}{a \text{ arc } 1''}$$

$$B = \frac{(1 - e^2 \sin^2 \varphi)^{\frac{3}{2}}}{a (1 - e^2) \text{ arc } 1''}$$

$$C = \frac{(1 - e^2 \sin^2 \varphi)^2 \tan \varphi}{2a^2 (1 - e^2) \text{ arc } 1''}$$

$$D = \frac{\frac{3}{2} e^2 \sin \varphi \cos \varphi \text{ arc } 1''}{1 - e^2 \sin^2 \varphi}$$

$$E = \frac{(1 + 3 \tan^2 \varphi)(1 - e^2 \sin^2 \varphi)}{6a^2}$$

$$F = \tfrac{1}{2} \sin \varphi \cos^2 \varphi \text{ arc}^2 1''$$

$$\log a = 6{\cdot}804\ 698\ 57$$
$$\log b = 6{\cdot}803\ 223\ 78$$
$$\log e^2 = \bar{7}{\cdot}830\ 502\ 57$$
$$\log \frac{1}{a \text{ arc } 1''} = \bar{8}{\cdot}509\ 726\ 56$$
$$\log \frac{1}{a (1 - e^2) \text{ arc } 1''} = \bar{8}{\cdot}512\ 676\ 15$$
$$\log \frac{1}{2a^2 (1 - e^2) \text{ arc } 1''} = \bar{1}{\cdot}406\ 947\ 6$$
$$\log (\tfrac{3}{2} e^2 \text{ arc } 1'') = \bar{\bar{2}}{\cdot}692\ 168\ 7$$
$$\log \frac{1}{6a^2} = \bar{\bar{5}}{\cdot}612\ 45$$
$$\log (\tfrac{1}{2} \text{ arc}^2 1'') = \bar{8}{\cdot}291\ 96$$

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LATITUDE 18°

Lat.	log A diff. 1″ = − 0·04	log B diff. 1″ = − 0·13	log C diff. 1″ = + 0·70	log D diff. 1″ = + 0·06	log E diff. 1″ = + 0·03	log F diff. 10′ = + 3·0
° ′						
18 00	8·509 5862	8·512 2550	0·91816	2·1606	5·7317	7·738
1	59	42	859	10	19	
2	57	35	902	13	21	
3	54	27	945	17	23	
4	52	19	0·91987	20	25	
05	49	12	0·92030	24	27	
6	46	8·512 2504	073	27	29	
7	44	8·512 2497	115	31	31	
8	41	89	158	34	33	
9	39	81	201	38	35	
10	8·509 5836	8·512 2474	0·92243	2·1641	5·7337	
11	34	66	286	44	39	
12	31	59	328	48	41	
13	29	51	371	51	44	
14	26	43	413	55	46	
15	24	36	456	58	48	
16	21	28	498	62	50	
17	19	20	540	65	52	
18	16	13	582	68	54	
19	13	8·512 2405	625	72	56	
20	8·509 5811	8·512 2397	0·92667	2·1675	5·7358	7·744
21	08	90	709	79	60	
22	06	82	751	82	62	
23	03	74	793	85	64	
24	8·509 5801	67	836	89	67	
25	8·509 5798	59	878	92	69	
26	96	51	920	95	71	
27	93	44	0·92962	2·1699	73	
28	90	36	0·93004	2·1702	75	
29	88	28	046	06	77	
30	8·509 5785	8·512 2320	0·93088	2·1709	5·7379	
31	83	13	129	12	81	
32	80	8·512 2305	171	16	83	
33	78	8·512 2297	213	19	85	
34	75	90	255	22	88	
35	72	82	296	26	90	
36	70	74	338	29	92	
37	67	66	380	32	94	
38	65	58	421	36	96	
39	62	51	463	39	5·7398	
40	8·509 5759	8·512 2243	0·93505	2·1742	5·7400	7·750
41	57	35	546	46	02	
42	54	27	588	49	05	
43	52	19	629	52	07	
44	49	12	671	56	09	
45	46	8·512 2204	712	59	11	
46	44	8·512 2196	753	62	13	
47	41	88	795	65	15	
48	39	80	836	69	17	
49	36	72	877	72	19	
50	8·509 5733	8·512 2165	0·93919	2·1775	5·7422	
51	31	57	0·93960	79	24	
52	28	49	0·94001	82	26	
53	25	41	042	85	28	
54	23	33	083	88	30	
55	20	25	125	92	32	
56	18	17	166	95	34	
57	15	10	207	2·1798	37	
58	12	8·512 2102	248	2·1801	39	
59	10	8·512 2094	289	05	41	
60	8·509 5707	8·512 2086	0·94330	2·1808	5·7443	7·756

LATITUDE 19°

Lat.	log A diff. 1″ = −0·04	log B diff. 1″ = −0·13	log C diff. 1″ = +0·67	log D diff 1″ = +0·05	log E diff. 1″ = +0·04	log F diff. 10′ = +2·7
° ′						
19 00	8·509 5707	8·512 2086	0·94330	2·1808	5·7443	7·756
1	04	78	370	11	45	
2	8·509 5702	70	411	14	47	
3	8·509 5699	62	452	18	49	
4	96	54	493	21	52	
05	94	46	534	24	54	
6	91	38	575	27	56	
7	89	30	615	30	58	
8	86	22	656	34	60	
9	83	14	697	37	62	
10	8·509 5681	8·512 2006	0·94737	2·1840	5·7464	
11	78	8·512 1999	778	43	67	
12	75	91	819	46	69	
13	73	83	859	50	71	
14	70	75	900	53	73	
15	67	67	940	56	75	
16	65	59	0·94981	59	78	
17	62	51	0·95021	62	80	
18	59	43	061	66	82	
19	57	35	102	69	84	
20	8·509 5654	8·512 1927	0·95142	2·1872	5·7486	7·761
21	52	19	182	75	88	
22	49	11	223	78	91	
23	46	8·512 1903	263	81	93	
24	43	8·512 1895	303	84	95	
25	41	87	344	88	97	
26	38	79	384	91	5·7499	
27	35	71	424	94	5·7501	
28	33	63	464	2·1897	04	
29	30	55	504	2·1900	06	
30	8·509 5627	8·512 1847	0·95544	2·1903	5·7508	
31	25	38	584	07	10	
32	22	30	624	10	12	
33	19	22	664	13	15	
34	16	14	704	16	17	
35	14	8·512 1806	744	19	19	
36	11	8·512 1798	784	22	21	
37	08	90	824	25	23	
38	06	82	863	28	26	
39	03	74	903	31	28	
40	8·509 5600	8·512 1766	0·95943	2·1934	5·7530	7·767
41	8·509 5598	57	0·95983	38	32	
42	95	49	0·96022	41	34	
43	92	41	062	44	37	
44	89	33	102	47	39	
45	87	25	142	50	41	
46	84	17	181	53	43	
47	81	08	221	56	46	
48	78	8·512 1700	260	59	48	
49	76	8·512 1692	300	62	50	
50	8·509 5573	8·512 1684	0·96339	2·1965	5·7552	
51	70	75	379	68	54	
52	68	67	418	71	57	
53	65	59	457	74	59	
54	62	51	497	77	61	
55	59	43	536	80	63	
56	57	34	575	83	65	
57	54	26	615	86	68	
58	51	18	654	89	70	
59	48	10	693	92	72	
60	8·509 5546	8·512 1602	0·96733	2·1996	5·7574	7·772

LATITUDE 20°

Lat.	log A diff. 1″ = − 0·05	log B diff. 1″ = − 0·14	log C diff. 1″ = + 0·64	log D diff. 1″ = + 0·05	log E diff. 1″ = + 0·04	log F diff. 10′ = + 2·5
° ′						
20 00	8·509 5546	8·512 1602	0·96733	2·1996	5·7574	7·772
1	43	8·512 1593	772	2·1999	77	
2	40	85	811	2·2002	79	
3	37	77	850	05	81	
4	35	68	889	08	83	
05	32	60	928	11	86	
6	29	52	0·96967	14	88	
7	26	44	0·97006	17	90	
8	24	35	045	20	92	
9	21	27	084	23	94	
10	8·509 5518	8·512 1519	0·97123	2·2026	5·7597	
11	15	10	162	28	5·7599	
12	12	8·512 1502	201	31	5·7601	
13	10	8·512 1494	240	34	03	
14	07	85	279	37	06	
15	04	77	318	40	08	
16	8·509 5501	69	356	43	10	
17	8·509 5499	60	395	46	12	
18	96	52	434	49	15	
19	93	44	472	52	17	
20	8·509 5490	8·512 1435	0·97511	2·2055	5·7619	7·777
21	87	27	550	58	21	
22	85	18	588	61	24	
23	82	10	627	64	26	
24	79	8·512 1402	666	67	28	
25	76	8·512 1393	704	70	30	
26	73	85	743	73	33	
27	71	76	781	76	35	
28	68	68	819	79	37	
29	65	60	858	81	40	
30	8·509 5462	8·512 1351	0·97896	2·2084	5·7642	
31	59	43	935	87	44	
32	57	34	0·97973	90	46	
33	54	26	0·98011	93	49	
34	51	17	050	96	51	
35	48	09	088	2·2099	53	
36	45	8·512 1301	126	2·2102	55	
37	42	8·512 1292	164	05	58	
38	40	84	203	08	60	
39	37	75	241	10	62	
40	8·509 5434	8·512 1267	0·98279	2·2113	5·7664	7·782
41	31	58	317	16	67	
42	28	50	355	19	69	
43	25	41	393	22	71	
44	23	33	431	25	74	
45	20	24	469	28	76	
46	17	16	507	31	78	
47	14	8·512 1207	545	33	81	
48	11	8·512 1199	583	36	83	
49	08	90	621	39	85	
50	8·509 5406	8·512 1182	0·98659	2·2142	5·7688	
51	03	73	697	45	90	
52	8·509 5400	64	735	48	92	
53	8·509 5397	56	773	50	94	
54	94	47	811	53	97	
55	91	39	848	56	5·7699	
56	88	30	886	59	5·7701	
57	86	21	924	62	04	
58	83	13	962	65	06	
59	80	8·512 1104	0·98999	67	08	
60	8·509 5377	8·512 1096	0·99037	2·2170	5·7711	7·787

LATITUDE 21°

Lat.	log A diff. 1″ = −0·05	log B diff. 1″ = −0·15	log C diff. 1″ = +0·62	log D diff. 1″ = +0·04	log E diff. 1″ = +0·04	log F diff. 10′ = +2·2
° ′						
21 00	8·509 5377	8·512 1096	0·99037	2·2170	5·7711	7·787
1	74	87	075	73	13	
2	71	79	112	76	15	
3	68	70	150	79	18	
4	66	62	187	81	20	
05	63	53	225	84	22	
6	60	45	262	87	24	
7	57	36	300	90	27	
8	54	27	337	93	29	
9	51	19	375	95	31	
10	8·509 5348	8·512 1010	0·99412	2·2198	5·7734	
11	46	8·512 1002	450	2·2201	36	
12	43	8·512 0993	487	04	38	
13	40	84	524	07	41	
14	37	76	562	09	43	
15	34	67	599	12	45	
16	31	58	636	15	48	
17	28	50	673	18	50	
18	25	41	711	20	52	
19	22	32	748	23	55	
20	8·509 5320	8·512 0924	0·99785	2·2226	5·7757	7·791
21	17	15	822	29	59	
22	14	8·512 0906	859	31	62	
23	11	8·512 0897	896	34	64	
24	08	89	933	37	66	
25	05	80	0·99971	40	69	
26	8·509 5302	71	1·00008	42	71	
27	8·509 5299	62	045	45	73	
28	96	54	082	48	76	
29	93	45	119	50	78	
30	8·509 5290	8·512 0836	1·00156	2·2253	5·7780	
31	88	27	192	56	83	
32	85	19	229	59	85	
33	82	10	266	61	87	
34	79	8·512 0801	303	64	90	
35	76	8·512 0792	340	67	92	
36	73	84	377	69	94	
37	70	75	413	72	97	
38	67	66	450	75	5·7799	
39	64	57	487	78	5·7802	
40	8·509 5261	8·512 0748	1·00524	2·2280	5·7804	7·796
41	58	39	560	83	06	
42	55	31	597	86	09	
43	52	22	634	88	11	
44	49	13	670	91	13	
45	46	8·512 0704	707	94	16	
46	44	8·512 0695	743	96	18	
47	41	86	780	2·2299	20	
48	38	78	816	2·2301	23	
49	35	69	853	04	25	
50	8·509 5232	8·512 0660	1·00890	2·2307	5·7828	
51	29	51	926	09	30	
52	26	42	962	12	32	
53	23	33	1·00999	15	35	
54	20	24	1·01035	17	37	
55	17	15	072	20	40	
56	14	8·512 0606	108	23	42	
57	11	8·512 0598	144	25	44	
58	08	89	181	28	47	
59	05	80	217	31	49	
60	8·509 5202	8·512 0571	1·01253	2·2333	5·7851	7·800

LATITUDE 22°

Lat.	log A diff. 1″ = −0·05	log B diff. 1″ = −0·15	log C diff. 1″ = +0·59	log D diff. 1″ = +0·04	log E diff. 1″ = +0·04	log F diff. 10′ = +2·0
° ′						
22 00	8·509 5202	8·512 0571	1·01253	2·2333	5·7851	7·800
1	8·509 5199	62	289	36	54	
2	96	53	326	38	56	
3	93	44	362	41	59	
4	90	35	398	44	61	
05	87	26	434	46	63	
6	84	17	470	49	66	
7	81	8·512 0508	506	51	68	
8	78	8·512 0499	542	54	71	
9	75	90	578	57	73	
10	8·509 5172	8·512 0481	1·01615	2·2359	5·7875	
11	69	72	651	62	78	
12	66	63	687	64	80	
13	63	54	723	67	83	
14	60	45	759	70	85	
15	57	36	794	72	87	
16	54	27	830	75	90	
17	51	18	866	77	92	
18	48	09	902	80	95	
19	45	8·512 0400	938	83	97	
20	8·509 5142	8·512 0391	1·01974	2·2385	5·7899	7·804
21	39	82	1·02010	88	5·7902	
22	36	73	045	90	04	
23	33	64	081	93	07	
24	30	55	117	95	09	
25	27	46	153	2·2398	11	
26	24	37	188	2·2400	14	
27	21	28	224	03	16	
28	18	19	260	06	19	
29	15	10	295	08	21	
30	8·509 5112	8·512 0301	1·02331	2·2411	5·7924	
31	09	8·512 0292	367	13	26	
32	06	83	402	16	28	
33	03	73	438	18	31	
34	8·509 5100	64	473	21	33	
35	8·509 5097	55	509	23	36	
36	94	46	544	26	38	
37	91	37	580	28	41	
38	88	28	615	31	43	
39	85	19	651	33	45	
40	8·509 5082	8·512 0210	1·02686	2·2436	5·7948	7·808
41	79	8·512 0200	721	38	50	
42	76	8·512 0191	757	41	53	
43	72	82	792	43	55	
44	69	73	828	46	58	
45	66	64	863	48	60	
46	63	55	898	51	62	
47	60	46	933	53	65	
48	57	36	1·02969	56	67	
49	54	27	1·03004	58	70	
50	8·509 5051	8·512 0118	1·03039	2·2461	5·7972	
51	48	09	074	63	75	
52	45	8·512 0100	109	68	77	
53	42	8·512 0090	145	68	80	
54	39	81	180	70	82	
55	36	72	215	73	84	
56	33	63	250	75	87	
57	30	54	285	78	89	
58	27	44	320	80	92	
59	23	35	355	83	94	
60	8·509 5020	8·512 0026	1·03390	2·2485	5·7997	7·812

LATITUDE 23°

Lat.	log A diff. 1″ = −0·05	log B diff. 1″ = −0·16	log C diff. 1″ = +0·57	log D diff. 1″ = +0·04	log E diff. 1″ = +0·04	log F diff. 10′ = +1·8
° ′						
23 00	8·509 5020	8·512 0026	1·03390	2·2485	5·7997	7·812
1	17	17	425	88	5·7999	
2	14	8·512 0008	460	90	5·8002	
3	11	8·511 9998	495	93	04	
4	08	89	530	95	07	
05	05	80	565	2·2497	09	
6	8·509 5002	71	600	2·2500	12	
7	8·509 4999	61	634	02	14	
8	96	52	669	05	16	
9	93	43	704	07	19	
10	8·509 4990	8·511 9934	1·03739	2·2510	5·8021	
11	87	24	774	12	24	
12	83	15	809	14	26	
13	80	8·511 9906	843	17	29	
14	77	8·511 9896	878	19	31	
15	74	87	913	22	34	
16	71	78	947	24	36	
17	68	68	1·03982	26	39	
18	65	59	1·04017	29	41	
19	62	50	052	31	44	
20	8·509 4959	8·511 9840	1·04086	2·2534	5·8046	7·816
21	55	31	121	36	49	
22	52	22	155	38	51	
23	49	12	190	41	54	
24	46	8·511 9803	224	43	56	
25	43	8·511 9794	259	45	59	
26	40	84	293	48	61	
27	37	75	328	50	64	
28	34	66	362	53	66	
29	31	56	397	55	69	
30	8·509 4927	8·511 9747	1·04431	2·2557	5·8071	
31	24	37	466	60	74	
32	21	28	500	62	76	
33	18	19	534	64	79	
34	15	09	569	67	81	
35	12	8·511 9700	603	69	84	
36	09	8·511 9690	637	71	86	
37	05	81	672	74	89	
38	8·509 4902	71	706	76	91	
39	8·509 4899	62	740	78	93	
40	8·509 4896	8·511 9653	1·04775	2·2581	5·8096	7·819
41	93	43	809	83	5·8099	
42	90	34	843	85	5·8101	
43	87	24	877	88	04	
44	83	15	911	90	06	
45	80	8·511 9605	945	92	09	
46	77	8·511 9596	1·04980	95	11	
47	74	86	1·05014	97	14	
48	71	77	048	2·2599	16	
49	68	67	082	2·2601	19	
50	8·509 4865	8·511 9558	1·05116	2·2604	5·8121	
51	61	48	150	06	24	
52	58	39	184	09	26	
53	55	29	218	11	29	
54	52	20	252	13	31	
55	49	10	286	16	34	
56	45	8·511 9501	320	18	36	
57	42	8·511 9491	354	20	39	
58	39	82	388	23	41	
59	36	72	422	25	44	
60	8·509 4833	8·511 9463	1·05456	2·2627	5·8146	7·823

LATITUDE 24°

Lat.	log A diff. 1″ = −0·05	log B diff. 1″ = −0·16	log C diff. 1″ = +0·56	log D diff. 1″ = +0·04	log E diff. 1″ = +0·04	log F diff. 10′ = +1·6
° ′						
24 00	8·509 4833	8·511 9463	1·05456	2·2627	5·8146	7·823
1	30	53	490	29	49	
2	26	44	523	31	51	
3	23	34	557	34	54	
4	20	24	591	36	57	
05	17	15	625	38	59	
6	14	8·511 9405	658	41	62	
7	10	8·511 9396	692	43	64	
8	07	86	726	45	67	
9	04	77	760	47	69	
10	8·509 4801	8·511 9367	1·05794	2·2650	5·8172	
11	8·509 4798	58	827	52	74	
12	94	48	861	54	77	
13	91	38	894	56	79	
14	88	29	928	59	82	
15	85	19	962	61	85	
16	82	09	1·05995	63	87	
17	78	8·511 9300	1·06029	65	90	
18	75	8·511 9290	062	68	92	
19	72	81	096	70	95	
20	8·509 4769	8·511 9271	1·06130	2·2672	5·8197	7·826
21	66	61	163	74	5·8200	
22	62	52	197	77	02	
23	59	42	230	79	05	
24	56	32	263	81	07	
25	53	23	297	83	10	
26	50	13	330	85	13	
27	46	8·511 9203	364	88	15	
28	43	8·511 9194	397	90	18	
29	40	84	431	92	20	
30	8·509 4737	8·511 9174	1·06464	2·2694	5·8223	
31	33	65	497	96	25	
32	30	55	530	2·2699	28	
33	27	45	564	2·2701	31	
34	24	35	597	03	33	
35	20	26	630	05	36	
36	17	16	664	07	38	
37	14	8·511 9106	697	10	41	
38	11	8·511 9096	730	12	43	
39	07	87	763	14	46	
40	8·509 4704	8·511 9077	1·06797	2·2716	5·8249	7·829
41	8·509 4701	67	830	18	51	
42	8·509 4698	58	863	20	54	
43	94	48	896	23	56	
44	91	38	929	25	59	
45	88	28	962	27	61	
46	85	18	1·06995	29	64	
47	81	8·511 9009	1·07028	31	67	
48	78	8·511 8999	061	33	69	
49	75	89	095	36	72	
50	8·509 4672	8·511 8979	1·07128	2·2738	5·8274	
51	68	70	161	40	77	
52	65	60	194	42	80	
53	62	50	226	44	82	
54	59	40	259	46	85	
55	55	30	292	49	87	
56	52	21	325	51	90	
57	49	11	358	53	92	
58	45	8·511 8901	391	55	95	
59	42	8·511 8891	424	57	5·8298	
60	8·509 4639	8·511 8881	1·07457	2·2759	5·8300	7·832

LATITUDE 25°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·16	log C diff. 1″ = +0·54	log D diff. 1″ = +0·03	log E diff. 1″ = +0·04	log F diff. 10′ = +1·5
° ′						
25 00	8·509 4639	8·511 8881	1·07457	2·2759	5·8300	7·832
1	36	71	490	61	03	
2	32	62	523	63	05	
3	29	52	555	66	08	
4	26	42	588	68	11	
05	23	32	621	70	13	
6	19	22	654	72	16	
7	16	12	687	74	18	
8	13	8·511 8802	719	76	21	
9	09	8·511 8793	752	78	24	
10	8·509 4606	8·511 8783	1·07785	2·2780	5·8326	
11	03	73	817	82	29	
12	8·509 4600	63	850	85	32	
13	8·509 4596	53	883	87	34	
14	93	43	915	89	37	
15	90	33	948	91	39	
16	86	23	1·07981	93	42	
17	83	13	1·08013	95	45	
18	80	8·511 8704	046	97	47	
19	76	8·511 8694	078	2·2799	50	
20	8·509 4573	8·511 8684	1·08111	2·2801	5·8352	7·835
21	70	74	143	03	55	
22	66	64	176	05	59	
23	63	54	208	07	60	
24	60	44	241	10	63	
25	56	34	273	12	66	
26	53	24	306	14	68	
27	50	14	338	16	71	
28	46	8·511 8604	370	18	73	
29	43	8·511 8594	403	20	76	
30	8·509 4540	8·511 8584	1·08435	2·2822	5·8379	
31	37	74	468	24	81	
32	33	64	500	26	84	
33	30	54	532	28	87	
34	26	44	565	30	89	
35	23	34	597	32	92	
36	20	24	629	34	94	
37	17	14	662	36	5·8397	
38	13	8·511 8504	694	38	5·8400	
39	10	8·511 8494	726	40	02	
40	8·509 4507	8·511 8484	1·08758	2·2842	5·8405	7·838
41	03	74	791	44	08	
42	8·509 4500	64	823	46	10	
43	8·509 4496	54	855	48	13	
44	93	44	887	50	16	
45	90	34	919	52	18	
46	86	24	951	54	21	
47	83	14	1·08984	56	24	
48	80	8·511 8404	1·09016	58	26	
49	76	8·511 8393	048	60	29	
50	8·509 4473	8·511 8383	1·09080	2·2862	5·8431	
51	70	73	112	64	34	
52	66	63	144	66	37	
53	63	53	176	68	39	
54	60	43	208	70	42	
55	56	33	240	72	45	
56	53	23	272	74	47	
57	50	13	304	76	50	
58	46	8·511 8303	336	78	53	
59	43	8·511 8293	368	80	55	
60	8·509 4439	8·511 8283	1·09400	2·2882	5·8458	7·841

LATITUDE 26°

Lat.	log A diff. 1″ = − 0·06	log B diff. 1″ = − 0·17	log C diff. 1″ = + 0·52	log D diff. 1″ = + 0·03	log E diff. 1″ = + 0·04	log F diff. 10′ = + 1·3
° ′						
26 00	8·509 4439	8·511 8283	1·09400	2·2882	5·8458	7·841
1	36	72	432	84	61	
2	33	62	464	86	63	
3	29	52	496	88	66	
4	26	42	527	90	69	
05	22	32	559	92	71	
6	19	22	591	94	74	
7	16	12	623	96	77	
8	12	8·511 8201	655	2·2898	79	
9	09	8·511 8191	687	2·2900	82	
10	8·509 4406	8·511 8181	1·09718	2·2902	5·8485	
11	8·509 4402	71	750	04	88	
12	8·509 4399	61	782	06	90	
13	95	51	814	08	93	
14	92	40	845	10	96	
15	88	30	877	12	5·8498	
16	85	20	909	14	5·8501	
17	82	10	940	16	04	
18	78	8·511 8100	1·09972	18	06	
19	75	8·511 8089	1·10004	20	09	
20	8·509 4372	8·511 8079	1·10036	2·2922	5·8512	7·844
21	68	69	067	23	14	
22	65	59	099	25	17	
23	61	48	130	27	20	
24	58	38	162	29	22	
25	54	28	194	31	25	
26	51	18	225	33	28	
27	48	8·511 8008	257	35	30	
28	44	8·511 7997	288	37	33	
29	41	87	320	39	36	
30	8·509 4337	8·511 7977	1·10351	2·2941	5·8539	
31	34	67	383	43	41	
32	31	56	414	45	44	
33	27	46	446	47	47	
34	24	36	477	48	49	
35	20	25	509	50	52	
36	17	15	540	52	55	
37	13	9·511 7905	571	54	57	
38	10	8·511 7895	603	56	60	
39	07	84	634	58	63	
40	8·509 4303	8·511 7874	1·10666	2·2960	5·8566	7·846
41	8·509 4300	64	697	62	68	
42	8·509 4296	53	728	63	71	
43	93	43	760	65	74	
44	89	33	791	67	76	
45	86	22	822	69	79	
46	83	12	854	71	82	
47	79	8·511 7802	885	73	85	
48	76	8·511 7791	916	75	87	
49	72	81	947	77	90	
50	8·509 4269	8·511 7771	1·10979	2·2978	5·8593	
51	65	60	1·11010	80	95	
52	62	50	041	82	5·8598	
53	58	40	072	84	5·8601	
54	55	29	103	86	04	
55	52	19	134	88	06	
56	48	8·511 7709	166	89	09	
57	45	8·511 7698	197	91	12	
58	41	88	228	93	14	
59	38	77	259	95	17	
60	8·509 4234	8·511 7667	1·11290	2·2997	5·8620	7·849

LATITUDE 27°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·18	log C diff. 1″ = +0·51	log D diff. 1″ = +0·03	log E diff. 1″ = +0·05	log F diff. 10′ = +1·1
° ′						
27 00	8·509 4234	8·511 7667	1·11290	2·2997	5·8620	7·849
1	31	57	321	2·2999	23	
2	27	46	352	2·3001	25	
3	24	36	383	03	28	
4	20	25	414	04	31	
05	17	15	445	06	34	
6	13	8·511 7605	476	08	36	
7	10	8·511 7594	507	10	39	
8	06	84	538	12	42	
9	03	73	569	14	44	
10	8·509 4200	8·511 7563	1·11600	2·3015	5·8647	
11	8·509 4196	53	631	17	50	
12	93	42	662	19	53	
13	89	32	693	21	55	
14	86	21	724	23	58	
15	82	11	755	24	61	
16	79	8·511 7500	786	26	64	
17	75	8·511 7490	817	28	66	
18	72	79	848	30	69	
19	68	69	878	32	72	
20	8·509 4165	8·511 7458	1·11909	2·3033	5·8675	7·851
21	61	48	940	35	77	
22	58	37	1·11971	37	80	
23	54	27	1·12002	39	83	
24	51	16	032	41	86	
25	47	8·511 7406	063	42	88	
26	44	8·511 7395	094	44	91	
27	40	85	125	46	94	
28	37	74	156	48	97	
29	33	64	186	50	5·8699	
30	8·509 4130	8·511 7353	1·12217	2·3051	5·8702	
31	26	43	248	53	05	
32	23	32	278	55	08	
33	19	22	309	57	10	
34	16	11	340	58	13	
35	12	8·511 7301	370	60	16	
36	08	8·511 7290	401	62	19	
37	05	80	432	64	22	
38	8·509 4101	69	462	65	24	
39	8·509 4098	58	493	67	27	
40	8·509 4094	8·511 7248	1·12523	2·3069	5·8730	7·853
41	91	37	554	70	33	
42	87	27	584	72	35	
43	84	16	615	74	38	
44	80	8·511 7206	646	76	41	
45	77	8·511 7195	676	78	44	
46	73	84	707	79	46	
47	70	74	737	81	49	
48	66	63	768	83	52	
49	63	53	798	85	55	
50	8·509 4059	8·511 7142	1·12829	2·3086	5·8757	
51	56	31	859	88	60	
52	52	21	889	90	63	
53	49	10	920	91	66	
54	45	8·511 7100	950	93	69	
55	41	8·511 7089	1·12981	95	72	
56	38	78	1·13011	97	74	
57	34	68	041	2·3099	77	
58	31	57	072	2·3100	80	
59	27	46	102	02	83	
60	8·509 4024	8·511 7036	1·13132	2·3104	5·8785	7·855

LATITUDE 28°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·18	log C diff. 1″ = +0·50	log D diff. 1″ = +0·03	log E diff. 1″ = +0·05	log F diff. 10′ = +1·0
° ′						
28 00	8·509 4024	8·511 7036	1·13132	2·3104	5·8785	7·855
1	20	25	163	05	88	
2	17	14	193	07	91	
3	13	8·511 7004	223	09	94	
4	10	8·511 6993	254	10	97	
05	06	82	284	12	5·8799	
6	8·509 4002	72	314	14	5·8802	
7	8·509 3999	61	345	16	05	
8	95	50	375	17	08	
9	92	40	405	19	11	
10	8·509 3988	8·511 6929	1·13435	2.3121	5·8813	
11	85	18	465	22	16	
12	81	8·511 6908	496	24	19	
13	78	8·511 6897	526	26	22	
14	74	86	556	27	25	
15	70	75	586	29	27	
16	67	65	616	31	30	
17	63	54	646	32	33	
18	60	43	677	34	36	
19	56	33	707	36	39	
20	8·509 3952	8·511 6822	1·13737	2·3137	5·8841	7·857
21	49	11	767	39	44	
22	45	8·511 6800	797	41	47	
23	42	8·511 6790	827	42	50	
24	38	79	857	44	53	
25	35	68	887	46	55	
26	31	57	917	47	58	
27	27	47	947	49	61	
28	24	36	1·13977	51	64	
29	20	25	1·14007	52	67	
30	8·509 3917	8·511 6714	1·14037	2·3154	5·8870	
31	13	8·511 6704	067	56	72	
32	09	8·511 6693	097	57	75	
33	06	82	127	59	78	
34	8·509 3902	71	157	61	81	
35	8·509 3899	61	187	62	84	
36	95	50	217	64	87	
37	92	39	247	65	89	
38	88	28	277	67	92	
39	84	17	307	69	95	
40	8·509 3881	8·511 6607	1·14337	2·3170	5·8898	7·859
41	77	8·511 6596	366	72	5·8901	
42	73	85	396	74	04	
43	70	74	426	75	06	
44	66	63	456	77	09	
45	63	52	486	78	12	
46	59	42	516	80	15	
47	55	31	545	82	18	
48	52	20	575	83	21	
49	48	8·511 6509	605	85	23	
50	8·509 3845	8·511 6498	1·14635	2·3187	5·8926	
51	41	87	664	88	29	
52	37	76	694	90	32	
53	34	66	724	91	35	
54	30	55	754	93	38	
55	26	44	783	95	40	
56	23	33	813	96	43	
57	19	22	843	98	46	
58	16	11	872	2·3199	49	
59	12	8·511 6400	902	2·3201	52	
60	8·509 3808	8·511 6389	1·14932	2·3203	5·8955	7·861

LATITUDE 29°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·18	log C diff. 1″ = +0·49	log D diff. 1″ = +0·03	log E diff. 1″ = +0·05	log F diff. 10′ = +0·8
° ′						
29 00	8·509 3808	8·511 6389	1·14932	2·3203	5·8955	7·861
1	05	78	961	04	58	
2	8·509 3801	68	1·14991	06	60	
3	8·509 3797	57	1·15021	07	63	
4	94	46	050	09	66	
05	90	35	080	10	69	
6	86	24	109	12	72	
7	83	13	139	14	75	
8	79	8·511 6302	168	15	78	
9	76	8·511 6291	198	17	80	
10	8·509 3772	8·511 6280	1·15228	2·3218	5·8983	
11	68	69	257	20	86	
12	65	58	287	21	89	
13	61	47	316	23	92	
14	57	36	346	25	95	
15	54	26	375	26	5·8998	
16	50	15	405	28	5·9000	
17	46	8·511 6204	434	29	03	
18	43	8·511 6193	464	31	06	
19	39	82	493	32	09	
20	8·509 3735	8·511 6171	1·15522	2·3234	5·9012	7·863
21	32	60	552	35	15	
22	28	49	581	37	18	
23	24	38	611	38	21	
24	21	27	640	40	23	
25	17	16	670	42	26	
26	13	8·511 6105	699	43	29	
27	10	8·511 6094	728	45	32	
28	06	83	758	46	35	
29	8·509 3702	72	787	48	38	
30	8·509 3699	8·511 6061	1·15816	2·3249	5·9041	
31	95	50	846	51	43	
32	91	39	875	52	46	
33	88	28	904	54	49	
34	84	17	934	55	52	
35	80	8·511 6006	963	57	55	
36	77	8·511 5995	1·15992	58	58	
37	73	84	1·16021	60	61	
38	69	73	051	61	64	
39	66	61	080	63	67	
40	8·509 3662	8·511 5950	1·16109	2·3264	5·9069	7·864
41	58	39	138	66	72	
42	55	28	167	67	75	
43	51	17	197	69	78	
44	47	8·511 5906	226	70	81	
45	44	8·511 5895	255	72	84	
46	40	84	284	73	87	
47	36	73	313	75	90	
48	33	62	343	76	93	
49	29	51	372	78	96	
50	8·509 3625	8·511 5840	1·16401	2·3279	5·9098	
51	21	29	430	81	5·9101	
52	18	18	459	82	04	
53	14	8·511 5806	488	84	07	
54	10	8·511 5795	517	85	10	
55	07	84	546	87	13	
56	8·509 3603	73	575	88	16	
57	8·509 3599	62	604	90	19	
58	96	51	633	91	22	
59	92	40	663	93	25	
60	8·509 3588	8·511 5729	1·16692	2·3294	5·9127	7·866

LATITUDE 30°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·19	log C diff. 1″ = +0·48	log D diff. 1″ = +0·02	log E diff. 1″ = +0·05	log F diff. 10′ = +0·7
° ′						
30 00	8·509 3588	8·511 5729	1·16692	2·3294	5·9127	7·866
1	84	18	721	96	30	
2	81	8·511 5706	750	97	33	
3	77	8·511 5695	778	2·3298	36	
4	73	84	807	2·3300	39	
05	69	73	836	01	42	
6	66	62	865	03	45	
7	62	51	894	04	48	
8	58	40	923	06	51	
9	55	28	952	07	54	
10	8·509 3551	8·511 5617	1·16981	2·3309	5·9157	
11	47	8·511 5606	1·17010	10	59	
12	43	8·511 5595	039	12	62	
13	40	84	068	13	65	
14	36	73	097	14	68	
15	32	61	126	16	71	
16	29	50	155	17	74	
17	25	39	184	18	77	
18	21	28	212	20	80	
19	17	17	241	22	83	
20	8·509 3514	8·511 5505	1·17270	2·3323	5·9186	7·867
21	10	8·511 5494	299	24	89	
22	06	83	328	26	92	
23	8·509 3502	72	357	27	95	
24	8·509 3499	61	385	29	5·9198	
25	95	49	414	30	5·9200	
26	91	38	443	32	03	
27	88	27	472	33	06	
28	84	16	500	34	09	
29	80	8·511 5404	529	36	12	
30	8·509 3476	8·511 5393	1·17558	2·3337	5·9215	
31	72	82	587	39	18	
32	69	71	615	40	21	
33	65	59	644	41	24	
34	61	48	673	43	27	
35	57	37	701	44	30	
36	54	26	730	46	33	
37	50	14	759	47	36	
38	46	8·511 5303	788	48	39	
39	42	8·511 5292	816	50	42	
40	8·509 3439	8·511 5281	1·17845	2·3351	5·9245	7·869
41	35	69	874	53	48	
42	31	58	902	54	51	
43	27	47	931	55	53	
44	24	35	959	57	56	
45	20	24	1·17988	58	59	
46	16	13	1·18017	59	62	
47	12	8·511 5202	045	61	65	
48	09	8·511 5190	074	62	68	
49	05	79	102	64	71	
50	8·509 3401	8·511 5168	1·18131	2·3365	5·9274	
51	8·509 3397	56	160	66	77	
52	94	45	188	68	80	
53	90	34	217	69	83	
54	86	22	245	70	86	
55	82	11	274	72	89	
56	78	8·511 5100	302	73	92	
57	75	8·511 5088	331	74	95	
58	71	77	359	76	5·9298	
59	67	66	388	77	5·9301	
60	8·509 3363	8·511 5054	1·18416	2·3379	5·9304	7·870

LATITUDE 31°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·19	log C diff. 1″ = +0·47	log D diff. 1″ = +0·02	log E diff. 1″ = +0·05	log F diff. 10′ = +0·5
° ′						
31 00	8·509 3363	8·511 5054	1·18416	2·3379	5·9304	7·870
·1	60	43	445	80	07	
2	56	32	473	81	10	
3	52	20	501	83	13	
4	48	8·511 5009	530	84	16	
05	44	8·511 4998	558	85	19	
6	41	86	587	87	22	
7	37	75	615	88	25	
8	33	64	643	89	28	
9	29	52	672	91	31	
10	8·509 3325	8·511 4941	1·18700	2·3392	5·9334	
11	22	29	729	93	37	
12	18	18	757	95	39	
13	14	8·511 4907	785	96	42	
14	10	8·511 4895	813	97	45	
15	06	84	842	2·3399	48	
16	8·509 3303	72	870	2·3400	51	
17	8·509 3299	61	898	01	54	
18	95	50	927	03	57	
19	91	38	955	04	60	
20	8·509 3287	8·511 4827	1·18983	2·3405	5·9363	7·871
21	84	15	1·19012	06	66	
22	80	8·511 4804	040	08	69	
23	76	8·511 4793	068	09	72	
24	72	81	096	10	75	
25	68	70	125	12	78	
26	65	58	153	13	81	
27	61	47	181	14	84	
28	57	35	209	16	87	
29	53	24	238	17	90	
30	8·509 3249	8·511 4713	1·19266	2·3418	5·9393	
31	46	8·511 4701	294	20	96	
32	42	8·511 4690	322	21	5·9399	
33	38	78	351	22	5·9402	
34	34	67	379	23	05	
35	30	55	407	25	08	
36	26	44	435	26	11	
37	23	32	463	27	14	
38	19	21	491	29	17	
39	15	8·511 4609	520	30	20	
40	8·509 3211	8·511 4598	1·19548	2·3431	5·9423	7·872
41	07	86	576	32	26	
42	03	75	604	34	29	
43	8·509 3200	63	632	35	32	
44	8·509 3196	52	660	36	35	
45	92	40	688	37	38	
46	88	29	716	39	41	
47	84	17	744	40	44	
48	81	8·511 4506	772	41	47	
49	77	8·511 4494	800	43	50	
50	8·509 3173	8·511 4483	1·19828	2·3444	5·9453	
51	69	71	856	45	56	
52	65	60	884	46	59	
53	61	48	912	48	62	
54	57	37	940	49	65	
55	54	25	968	50	68	
56	50	14	1·19996	51	72	
57	46	8·511 4402	1·20024	53	75	
58	42	8·511 4391	052	54	78	
59	38	79	080	55	81	
60	8·509 3134	8·511 4368	1·20108	2·3456	5·9484	7·873

LATITUDE 32°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·19	log C diff. 1″ = +0·46	log D diff. 1″ = +0·02	log E diff. 1″ = +0·05	log F diff. 10′ = +0·3
° ′						
32 00	8·509 3134	8·511 4368	1·20108	2·3456	5·9484	7·873
1	31	56	136	57	87	
2	27	44	164	59	90	
3	23	33	192	60	93	
4	19	21	220	61	96	
05	15	8·511 4310	248	62	5·9499	
6	11	8·511 4298	276	64	5·9502	
7	07	87	304	65	05	
8	04	75	332	66	08	
9	8·509 3100	63	360	67	11	
10	8·509 3096	8·511 4252	1·20387	2·3469	5·9514	
11	92	40	415	70	17	
12	88	29	443	71	20	
13	84	17	471	72	23	
14	80	8·511 4205	499	73	26	
15	76	8·511 4194	527	75	29	
16	73	82	555	76	32	
17	69	71	582	77	35	
18	65	59	610	78	38	
19	61	47	638	79	41	
20	8·509 3057	8·511 4136	1·20666	2·3481	5·9544	7·874
21	53	24	694	82	47	
22	49	13	722	83	50	
23	46	8·511 4101	749	84	53	
24	42	8·511 4089	777	85	56	
25	38	78	805	87	60	
26	34	66	833	88	63	
27	30	54	860	89	66	
28	26	43	888	90	69	
29	22	31	916	91	72	
30	8·509 3018	8·511 4020	1·20944	2·3493	5·9575	
31	15	8·511 4008	971	94	78	
32	11	8·511 3996	1·20999	95	81	
33	07	85	1·21027	96	84	
34	8·509 3003	73	054	97	87	
35	8·509 2999	61	082	2·3499	90	
36	95	50	110	2·3500	93	
37	91	38	137	01	96	
38	87	26	165	02	5·9599	
39	83	15	193	03	5·9602	
40	8·509 2980	8·511 3903	1·21220	2·3504	5·9605	7·875
41	76	8·511 3891	248	06	08	
42	72	79	276	07	11	
43	68	68	303	08	15	
44	64	56	331	09	18	
45	60	44	358	10	21	
46	56	33	386	11	24	
47	52	21	414	13	27	
48	48	8·511 3809	441	14	30	
49	44	8·511 3798	469	15	33	
50	8·509 2940	8·511 3786	1·21496	2·3516	5·9636	
51	37	74	524	17	39	
52	33	63	551	18	42	
53	29	51	579	19	45	
54	25	39	607	21	48	
55	21	27	634	22	51	
56	17	16	662	23	54	
57	13	8·511 3704	689	24	58	
58	09	8·511 3692	717	25	61	
59	05	80	744	26	64	
60	8·509 2901	8·511 3669	1·21772	2·3527	5·9667	7·875

LATITUDE 33°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·20	log C diff. 1″ = +0·45	log D diff. 1″ = +0·02	log E diff. 1″ = +0·05	log F diff. 10′ = +0·2
° ′						
33 00	8·509 2901	8·511 3669	1·21772	2·3527	5·9667	7·875
1	8·509 2897	57	799	29	70	
2	94	45	827	30	73	
3	90	33	854	31	76	
4	86	22	882	32	79	
05	82	8·511 3610	909	33	82	
6	78	8·511 3598	937	34	85	
7	74	86	964	35	88	
8	70	75	1·21992	36	92	
9	66	63	1·22019	38	95	
10	8·509 2862	8·511 3551	1·22047	2·3539	5·9698	
11	58	39	074	40	5·9701	
12	54	28	101	41	04	
13	51	16	129	42	07	
14	47	8·511 3504	156	43	10	
15	43	8·511 3492	184	44	13	
16	39	80	211	45	16	
17	35	69	238	46	19	
18	31	57	266	48	22	
19	27	45	293	49	26	
20	8·509 2823	8·511 3433	1·22321	2·3550	5·9729	7·876
21	19	21	348	51	32	
22	15	8·511 3410	375	52	35	
23	11	8·511 3398	403	53	38	
24	07	86	430	54	41	
25	8·509 2803	74	457	55	44	
26	8·509 2799	62	485	56	47	
27	95	51	512	57	50	
28	91	39	539	58	53	
29	88	27	567	60	57	
30	8·509 2784	8·511 3315	1·22594	2·3561	5·9760	
31	80	8·511 3303	621	62	63	
32	76	8·511 3291	648	63	66	
33	72	80	676	64	69	
34	68	68	703	65	72	
35	64	56	730	66	75	
36	60	44	757	67	78	
37	56	32	785	68	81	
38	52	20	812	69	85	
39	48	8·511 3209	839	70	88	
40	8·509 2744	8·511 3197	1·22866	2·3571	5·9791	7·876
41	40	85	893	72	94	
42	36	73	921	73	5·9797	
43	32	61	948	75	5·9800	
44	28	49	1·22975	76	03	
45	24	37	1·23002	77	06	
46	20	25	029	78	10	
47	16	13	057	79	13	
48	12	8·511 3102	084	80	16	
49	08	8·511 3090	111	81	19	
50	8·509 2704	8·511 3078	1·23138	2·3582	5·9822	
51	8·509 2701	66	165	83	25	
52	8·509 2697	54	192	84	28	
53	93	42	220	85	31	
54	89	30	247	86	35	
55	85	18	274	87	38	
56	81	8·511 3006	301	88	41	
57	77	8·511 2995	328	89	44	
58	73	83	355	90	47	
59	69	71	382	91	50	
60	8·509 2665	8·511 2959	1·23409	2·3592	5·9853	7·877

LATITUDE 34°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·20	log C diff. 1″ = +0·45	log D diff. 1″ = +0·02	log E diff. 1″ = +0·05	log F diff. 10′ = +0·0
° ′						
34 00	8·509 2665	8·511 2959	1·23409	2·3592	5·9853	7·877
1	61	47	437	93	57	
2	57	35	464	94	60	
3	53	23	491	95	63	
4	49	8·511 2911	518	96	66	
05	45	8·511 2899	545	97	69	
6	41	87	572	98	72	
7	37	75	599	2·3599	75	
8	33	63	626	2·3600	79	
9	29	51	653	01	82	
10	8·509 2625	8·511 2840	1·23680	2·3602	5·9885	
11	21	28	707	03	88	
12	17	16	734	04	91	
13	13	8·511 2804	761	05	94	
14	09	8·511 2792	788	06	5·9897	
15	05	80	815	07	5·9901	
16	8·509 2601	68	842	08	04	
17	8·509 2597	56	869	09	07	
18	93	44	896	10	10	
19	89	32	923	11	13	
20	8·505 2585	8·511 2720	1·23950	2·3612	5·9916	7·877
21	81	8·511 2708	1·23977	13	19	
22	77	8·511 2696	1·24004	14	23	
23	73	84	031	15	26	
24	69	72	058	16	29	
25	65	60	085	17	32	
26	61	48	112	18	35	
27	57	36	139	19	38	
28	53	24	165	20	42	
29	49	12	192	21	45	
30	8·509 2545	8·511 2600	1·24219	2·3622	5·9948	
31	41	8·511 2588	246	23	51	
32	37	76	273	24	54	
33	33	64	300	25	57	
34	29	52	327	26	61	
35	25	40	354	27	64	
36	21	28	381	28	67	
37	17	16	408	29	70	
38	13	8·511 2504	434	30	73	
39	09	8·511 2492	461	31	76	
40	8·509 2505	8·511 2480	1·24488	2·3632	5·9980	7·877
41	8·509 2501	68	515	33	83	
42	8·509 2497	56	542	34	86	
43	93	44	569	35	89	
44	89	32	595	36	92	
45	85	20	622	37	96	
46	81	8·511 2408	649	38	5·9999	
47	77	8·511 2396	676	39	6·0002	
48	73	84	703	40	05	
49	69	72	729	41	08	
50	8·509 2465	8·511 2360	1·24756	2·3642	6·0011	
51	61	48	783	43	15	
52	57	35	810	43	18	
53	53	23	837	44	21	
54	49	8·511 2311	863	45	24	
55	45	8·511 2299	890	46	27	
56	41	87	917	47	31	
57	37	75	944	48	34	
58	33	63	970	49	37	
59	29	51	1·24997	50	40	
60	8·509 2425	8·511 2239	1·25024	2·3651	6·0043	7·877

LATITUDE 35°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·20	log C diff. 1″ = +0·44	log D diff. 1″ = +0·01	log E diff. 1″ = +0·05	log F diff. 10′ = +0·0
° ′						
35 00	8·509 2425	8·511 2239	1·25024	2·3651	6·0043	7·877
1	21	27	050	52	47	
2	17	15	077	53	50	
3	13	8·511 2203	104	54	53	
4	09	8·511 2191	131	55	56	
05	05	78	157	56	59	
6	8·509 2401	66	184	56	63	
7	8·509 2396	54	211	57	66	
8	92	42	237	58	69	
9	88	30	264	59	72	
10	8·509 2384	8·511 2118	1·25291	2·3660	6·0075	
11	80	8·511 2106	317	61	79	
12	76	8·511 2094	344	62	82	
13	72	82	371	63	85	
14	68	70	397	64	88	
15	64	57	424	65	91	
16	60	45	451	66	95	
17	56	33	477	66	6·0098	
18	52	21	504	67	6·0101	
19	48	8·511 2009	531	68	04	
20	8·509 2344	8·511 1997	1·25557	2·3669	6·0107	7·877
21	40	85	584	70	11	
22	36	72	610	71	14	
23	32	60	637	72	17	
24	28	48	664	73	20	
25	24	36	690	74	23	
26	20	24	717	75	27	
27	16	12	743	75	30	
28	12	8·511 1900	770	76	33	
29	08	8·511 1887	796	77	36	
30	8·509 2304	8·511 1875	1·25823	2·3678	6·0140	
31	8·509 2300	63	850	79	43	
32	8·509 2296	51	876	80	46	
33	92	39	903	81	49	
34	87	27	929	82	52	
35	83	15	956	82	56	
36	79	8·511 1802	1·25982	83	59	
37	75	8·511 1790	1·26009	84	62	
38	71	78	035	85	65	
39	67	66	062	86	69	
40	8·509 2263	8·511 1754	1·26088	2·3687	6·0172	7·877
41	59	41	115	88	75	
42	55	29	141	88	78	
43	51	17	168	89	81	
44	47	8·511 1705	194	90	85	
45	43	8·511 1693	221	91	88	
46	39	80	247	92	91	
47	35	68	274	93	94	
48	31	56	300	94	6·0198	
49	27	44	327	94	6·0201	
50	8·509 2222	8·511 1632	1·26353	2·3695	6·0204	
51	18	20	380	96	07	
52	14	8·511 1607	406	97	11	
53	10	8·511 1595	432	98	14	
54	06	83	459	99	17	
55	8·509 2202	71	485	2·3699	20	
56	8·509 2198	58	512	2·3700	24	
57	94	46	538	01	27	
58	90	34	565	02	30	
59	86	22	591	03	33	
60	8·509 2182	8·511 1510	1·26617	2·3704	6·0237	7·877

LATITUDE 36°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·20	log C diff. 1″ = +0·44	log D diff. 1″ = +0·01	log E diff. 1″ = +0·05	log F diff. 10′ = −0·2
° ′						
36 00	8·509 2182	8·511 1510	1·26617	2·3704	6·0237	7·877
1	78	8·511 1497	644	04	40	
2	74	85	670	05	43	
3	70	73	697	06	46	
4	65	61	723	07	50	
05	61	48	749	08	53	
6	57	36	776	09	56	
7	53	24	802	09	59	
8	49	8·511 1412	828	10	63	
9	45	8·511 1399	855	11	66	
10	8·509 2141	8·511 1387	1·26881	2·3712	6·0269	
11	37	75	908	13	72	
12	33	63	934	13	76	
13	29	50	960	14	79	
14	25	38	1·26987	15	82	
15	21	26	1·27013	16	85	
16	16	14	039	17	89	
17	12	8·511 1301	066	17	92	
18	08	8·511 1289	092	18	95	
19	04	77	118	19	6·0299	
20	8·509 2100	8·511 1265	1·27145	2·3720	6·0302	7·877
21	8·509 2096	52	171	21	05	
22	92	40	197	21	08	
23	88	28	223	22	12	
24	84	15	250	23	15	
25	80	8·511 1203	276	24	18	
26	75	8·511 1191	302	25	21	
27	71	79	329	25	25	
28	67	66	355	26	28	
29	63	54	381	27	31	
30	8·509 2059	8·511 1142	1·27407	2·3728	6·0334	
31	55	29	434	29	38	
32	51	17	460	29	41	
33	47	8·511 1105	486	30	44	
34	43	8·511 1092	512	31	48	
35	39	80	539	32	51	
36	35	68	565	32	54	
37	30	56	591	33	57	
38	26	43	617	34	61	
39	22	31	644	35	64	
40	8·509 2018	8·511 1019	1·27670	2·3735	6·0367	7·877
41	14	8·511 1006	696	36	71	
42	10	8·511 0994	722	37	74	
43	06	82	748	38	77	
44	8·509 2002	69	775	39	80	
45	8·509 1998	57	801	39	84	
46	93	45	827	40	87	
47	89	32	853	41	90	
48	85	20	879	42	94	
49	81	8·511 0908	905	42	6·0397	
50	8·509 1977	8·511 0895	1·27932	2·3743	6·0400	
51	73	83	958	44	03	
52	69	71	1·27984	45	07	
53	65	58	1·28010	45	10	
54	61	46	036	46	13	
55	56	34	062	47	17	
56	52	21	088	48	20	
57	48	8·511 0809	114	48	23	
58	44	8·511 0797	141	49	27	
59	40	84	167	50	30	
′′	8·509 1936	8·511 0772	1·28193	2·3750	6·0433	7·876

LATITUDE 37°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·43	log D diff. 1″ = +0·01	log E diff. 1″ = +0·06	log F diff. 10′ = −0·3
° ′						
37 00	8·509 1936	8·511 0772	1·28193	2·3750	6·0433	7·876
1	32	60	219	51	37	
2	28	47	245	52	40	
3	23	35	271	53	43	
4	19	22	297	53	46	
05	15	8·511 0710	324	54	50	
6	11	8·511 0698	350	55	53	
7	07	85	376	56	56	
8	8·509 1903	73	402	56	60	
9	8·509 1899	61	428	57	63	
10	8·509 1895	8·511 0648	1·28454	2·3758	6·0466	
11	90	36	480	59	70	
12	86	23	506	59	73	
13	82	8·511 0611	532	60	76	
14	78	8·511 0599	558	61	80	
15	74	86	584	61	83	
16	70	74	610	62	86	
17	66	61	636	63	89	
18	62	49	662	63	93	
19	57	37	688	64	96	
20	8·509 1853	8·511 0524	1·28715	2·3765	6·0499	7·876
21	49	12	741	66	6·0503	
22	45	8·511 0500	767	66	06	
23	41	8·511 0487	793	67	09	
24	37	75	819	68	13	
25	33	62	845	68	16	
26	28	50	871	69	19	
27	24	37	897	70	23	
28	20	25	923	70	26	
29	16	13	949	71	29	
30	8·509 1812	8·511 0400	1·28975	2·3772	6·0533	
31	08	8·511 0388	1·29001	72	36	
32	04	75	027	73	39	
33	8·509 1800	63	053	74	43	
34	8·509 1795	51	079	74	46	
35	91	38	104	75	49	
36	87	26	130	76	53	
37	83	13	156	76	56	
38	79	8·511 0301	182	77	59	
39	75	8·511 0288	208	78	63	
40	8·509 1771	8·511 0276	1·29234	2·3779	6·0566	7·875
41	66	64	260	79	69	
42	62	51	286	80	73	
43	58	39	312	81	76	
44	54	26	338	81	79	
45	50	14	364	82	83	
46	46	8·511 0201	390	82	86	
47	41	8·511 0189	416	83	89	
48	37	76	442	84	93	
49	33	64	468	84	6·0596	
50	8·509 1729	8·511 0151	1·29494	2·3785	6·0600	
51	25	39	520	86	03	
52	21	26	546	86	06	
53	16	14	571	87	10	
54	12	8·511 0102	597	88	13	
55	08	8·511 0089	623	88	16	
56	04	77	649	89	20	
57	8·509 1700	64	675	90	23	
58	8·509 1696	52	701	90	26	
59	92	39	727	91	30	
60	8·509 1687	8·511 0027	1·29753	2·3792	6·0633	7·874

LATITUDE 38°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·43	log D diff. 1″ = +0·01	log E diff. 1″ = +0·06	log F diff. 10′ = −0·4
° ′						
38 00	8·509 1687	8·511 0027	1·29753	2·3792	6·0633	7·874
1	83	14	778	92	36	
2	79	8·511 0002	804	93	40	
3	75	8·510 9989	830	93	43	
4	71	77	856	94	47	
05	67	64	882	95	50	
6	62	52	908	95	53	
7	58	39	934	96	57	
8	54	27	959	97	60	
9	50	14	1·29985	97	63	
10	8·509 1646	8·510 9902	1·30011	2·3798	6·0667	
11	42	8·510 9889	037	2·3799	70	
12	37	77	063	2·3800	73	
13	33	64	089	00	77	
14	29	52	114	01	80	
15	25	39	140	01	84	
16	21	27	166	02	87	
17	17	14	192	02	90	
18	12	8·510 9802	218	03	94	
19	08	8·510 9789	243	03	6·0697	
20	8·509 1604	8·510 9777	1·30269	2·3804	6·0701	7·874
21	8·509 1600	64	295	05	04	
22	8·509 1596	52	321	05	07	
23	92	39	347	06	11	
24	87	27	372	06	14	
25	83	14	398	07	17	
26	79	8·510 9701	424	08	21	
27	75	8·510 9689	450	08	24	
28	71	77	476	09	28	
29	66	64	501	09	31	
30	8·509 1562	8·510 9652	1·30527	2·3810	6·0734	
31	58	39	553	11	38	
32	54	27	579	11	41	
33	50	14	604	12	44	
34	46	8·510 9601	630	12	48	
35	41	8·510 9589	656	13	51	
36	37	76	682	14	55	
37	33	64	707	14	58	
38	29	51	733	15	61	
39	25	39	759	15	65	
40	8·509 1521	8·510 9526	1·30785	2·3816	6·0768	7·873
41	16	14	810	16	72	
42	12	8·510 9501	836	17	75	
43	08	8·510 9488	862	18	78	
44	04	76	887	18	82	
45	8·509 1500	63	913	19	85	
46	8·509 1495	51	939	19	89	
47	91	38	965	20	92	
48	87	26	1·30990	20	95	
49	83	13	1·31016	21	6·0799	
50	8·509 1479	8·510 9401	1·31042	2·3822	6·0802	
51	75	8·510 9388	067	22	06	
52	70	76	093	23	09	
53	66	63	119	23	13	
54	62	50	144	24	16	
55	58	38	170	24	19	
56	53	25	196	25	23	
57	49	13	221	25	26	
58	45	8·510 9300	247	26	30	
59	41	8·510 9287	273	27	33	
60	8·509 1437	8·510 9275	1·31299	2·3827	6·0836	7·872

LATITUDE 39°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·43	log D diff. 1″ = +0·01	log E diff. 1″ = +0·06	log F diff. 10′ = −0·5
° ′						
39 00	8·509 1437	8·510 9275	1·31299	2·3827	6·0836	7·872
1	33	62	324	28	40	
2	28	50	350	28	43	
3	24	37	375	29	47	
4	20	25	401	29	50	
05	16	8·510 9212	427	30	53	
6	12	8·510 9199	452	30	57	
7	07	87	478	31	60	
8	8·509 1403	74	504	31	64	
9	8·509 1399	62	529	32	67	
10	8·509 1395	8·510 9149	1·31555	2·3832	6·0871	
11	91	36	581	33	74	
12	86	24	606	33	77	
13	82	8·510 9111	632	34	81	
14	78	8·510 9098	658	35	84	
15	74	86	683	35	88	
16	70	73	709	36	91	
17	65	61	734	36	95	
18	61	48	760	37	6·0898	
19	57	36	786	37	6·0902	
20	8·509 1353	8·510 9023	1·31811	2·3838	6·0905	7·871
21	49	8·510 9010	837	38	08	
22	44	8·510 8998	862	39	12	
23	40	85	888	39	15	
24	36	73	913	40	19	
25	32	60	939	40	22	
26	28	47	965	41	26	
27	23	35	1·31990	41	29	
28	19	22	1·32016	42	32	
29	15	8·510 8909	041	42	36	
30	8·509 1311	8·510 8897	1·32067	2·3843	6·0939	
31	07	84	092	43	43	
32	8·509 1302	72	118	44	46	
33	8·509 1298	59	144	44	50	
34	94	46	169	45	53	
35	90	34	195	45	57	
36	86	21	220	46	60	
37	81	8·510 8808	246	46	63	
38	77	8·510 8796	271	47	67	
39	73	83	297	47	70	
40	8·509 1269	8·510 8771	1·32323	2·3848	6·0974	7·870
41	64	58	348	48	77	
42	60	45	374	49	81	
43	56	33	399	49	84	
44	52	20	425	50	88	
45	48	8·510 8707	450	50	91	
46	43	8·510 8695	476	51	95	
47	39	82	501	51	6·0998	
48	35	69	527	52	6·1002	
49	31	57	552	52	05	
50	8·509 1227	8·510 8644	1·32578	2·3852	6·1008	
51	22	31	603	53	12	
52	18	19	629	53	15	
53	14	8·510 8606	654	54	19	
54	10	8·510 8593	680	54	22	
55	06	81	705	55	26	
56	8·509 1201	68	731	55	29	
57	8·509 1197	55	756	56	33	
58	93	43	782	56	36	
59	89	30	807	57	40	
60	8·509 1184	8·510 8517	1·32833	2·3857	6·1043	7·869

LATITUDE 40°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·42	log D diff. 1″ = +0·01	log E diff. 1″ = +0·06	log F diff. 10′ = −0·7
° ′						
40 00	8·509 1184	8·510 8517	1·32833	2·3857	6·1043	7·869
1	80	8·510 8505	858	58	47	
2	76	8·510 8492	884	58	50	
3	72	79	909	58	54	
4	67	67	935	59	57	
05	63	54	960	59	61	
6	59	41	1·32986	60	64	
7	55	29	1·33011	60	67	
8	50	16	037	60	71	
9	46	8·510 8403	062	61	74	
10	8·509 1142	8·510 8391	1·33088	2·3861	6·1078	
11	38	78	113	62	81	
12	34	65	139	62	85	
13	29	53	164	63	88	
14	25	40	189	63	92	
15	21	27	215	64	95	
16	17	15	240	64	6·1099	
17	12	8·510 8302	266	65	6·1102	
18	08	8·510 8289	291	65	06	
19	04	77	317	65	09	
20	8·509 1100	8·510 8264	1·33342	2·3866	6·1113	7·867
21	8·509 1096	51	368	66	16	
22	91	38	393	67	20	
23	87	26	418	67	23	
24	83	13	414	68	27	
25	79	8·510 8200	469	68	30	
26	74	8·510 8188	495	68	34	
27	70	75	520	69	37	
28	66	62	546	69	41	
29	62	50	571	70	44	
30	8·509 1057	8·510 8137	1·33596	2·3870	6·1148	
31	53	24	622	70	51	
32	49	8·510 8111	647	71	55	
33	45	8·510 8099	673	71	58	
34	41	86	698	72	62	
35	36	73	723	72	65	
36	32	61	749	72	69	
37	28	48	774	73	72	
38	24	35	800	73	76	
39	19	23	825	74	79	
40	8·509 1015	8·510 8010	1·33850	2·3874	6·1183	7·866
41	11	8·510 7997	876	74	86	
42	07	84	901	75	90	
43	8·509 1002	72	926	75	93	
44	8·509 0998	59	952	76	6·1197	
45	94	46	1·33977	76	6·1200	
46	90	33	1·34003	76	04	
47	85	21	028	77	07	
48	81	8·510 7908	053	77	11	
49	77	8·510 7895	079	77	15	
50	8·509 0973	8·510 7883	1·34104	2·3878	6·1218	
51	68	70	129	78	22	
52	64	57	155	79	25	
53	60	44	180	79	29	
54	56	32	206	79	32	
55	52	19	231	80	36	
56	47	8·510 7806	256	80	39	
57	43	8·510 7793	282	80	43	
58	39	81	307	81	46	
59	34	68	332	81	50	
60	8·509 0930	8·510 7755	1·34358	2·3882	6·1253	7·864

LATITUDE 41°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·42	log D diff. 1″ = +0·01	log E diff. 1″ = +0·06	log F diff. 10′ = −0 8
° ′						
41 00	8·509 0930	8·510 7755	1·34358	2·3882	6·1253	7·864
1	26	42	383	82	57	
2	22	30	408	82	60	
3	18	17	434	83	64	
4	13	8·510 7704	459	83	67	
05	09	8·510 7691	484	83	71	
6	05	79	510	84	75	
7	8·509 0900	66	535	84	78	
8	8·509 0896	53	560	84	82	
9	92	40	586	85	85	
10	8·509 0888	8·510 7628	1·34611	2·3885	6·1289	
11	83	15	636	85	92	
12	79	8·510 7602	662	86	96	
13	75	8·510 7590	687	86	6·1299	
14	71	77	712	87	6·1303	
15	67	64	738	87	06	
16	62	51	763	87	10	
17	58	39	788	88	14	
18	54	26	814	88	17	
19	49	13	839	88	21	
20	8·509 0845	8·510 7500	1·34864	2·3889	6·1324	7·863
21	41	8·510 7488	890	89	28	
22	37	75	915	89	31	
23	32	62	940	90	35	
24	28	49	965	90	38	
25	24	36	1·34991	90	42	
26	20	24	1·35016	91	46	
27	15	8·510 7411	041	91	49	
28	11	8·510 7398	066	91	53	
29	07	85	092	91	56	
30	8·509 0803	8·510 7373	1·35117	2·3892	6·1360	
31	8·509 0798	60	142	92	63	
32	94	47	168	92	67	
33	90	34	193	93	70	
34	86	22	218	93	74	
35	81	8·510 7309	243	93	78	
36	77	8·510 7296	269	94	81	
37	73	83	294	94	85	
38	69	70	319	94	88	
39	64	58	345	95	92	
40	8·509 0760	8·510 7245	1·35370	2·3895	6·1395	7·861
41	56	32	395	95	6·1399	
42	52	19	420	96	6·1403	
43	47	8·510 7207	446	96	06	
44	43	8·510 7194	471	96	10	
45	39	81	496	97	13	
46	35	68	522	97	17	
47	30	55	547	97	20	
48	26	43	572	97	24	
49	22	30	597	98	28	
50	8·509 0718	8·510 7117	1·35623	2·3898	6·1431	
51	13	8·510 7104	648	98	35	
52	09	8·510 7091	673	98	38	
53	05	79	698	99	42	
54	8·509 0700	66	723	99	46	
55	8·509 0696	53	749	2·3899	49	
56	92	40	774	2·3900	53	
57	88	27	799	00	56	
58	83	15	824	00	60	
59	79	8·510 7002	850	00	63	
60	8·509 0675	8·510 6989	1·35875	2·3901	6·1467	7·860

LATITUDE 42°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·42	log D diff. 1″ = +0·00	log E diff. 1″ = +0·06	log F diff. 10′ = −0·9
° ′						
42 00	8·509 0675	8·510 6989	1·35875	2·3901	6·1467	7·860
1	71	76	900	01	71	
2	66	64	925	01	74	
3	62	51	951	01	78	
4	58	38	1·35976	02	81	
05	54	25	1·36001	02	85	
6	49	12	026	02	89	
7	45	8·510 6900	052	03	92	
8	41	8·510 6887	077	03	96	
9	36	74	102	03	6·1499	
10	8·509 0632	8·510 6861	1·36127	2·3903	6·1503	
11	28	48	152	04	07	
12	24	36	178	04	10	
13	19	23	203	04	14	
14	15	8·510 6810	228	04	17	
15	11	8·510 6797	253	05	21	
16	07	84	278	05	25	
17	8·509 0602	72	304	05	28	
18	8·509 0598	59	329	05	32	
19	94	46	354	06	35	
20	8·509 0590	8·510 6733	1·36379	2·3906	6·1539	7·858
21	85	20	404	06	43	
22	81	8·510 6707	430	06	46	
23	77	8·510 6695	455	07	50	
24	72	82	480	07	54	
25	68	69	505	07	57	
26	64	56	530	07	61	
27	60	43	556	08	64	
28	55	31	581	08	68	
29	51	18	606	08	72	
30	8·509 0547	8·510 6605	1·36631	2·3908	6·1575	
31	43	8.510 6592	656	08	79	
32	38	79	682	09	83	
33	34	66	707	09	86	
34	30	54	732	09	90	
35	25	41	757	09	93	
36	21	28	782	10	6·1597	
37	17	15	808	10	6·1601	
38	13	8·510 6502	833	10	04	
39	08	8·510 6490	858	10	08	
40	8·509 0504	8·510 6477	1·36883	2·3910	6·1612	7·856
41	8·509 0500	64	908	11	15	
42	8·509 0496	51	934	11	19	
43	91	38	959	11	22	
44	87	25	1·36984	11	26	
45	83	13	1·37009	12	30	
46	78	8·510 6400	034	12	33	
47	74	8·510 6387	059	12	37	
48	70	74	085	12	41	
49	66	61	110	12	44	
50	8·509 0461	8·510 6348	1·37135	2·3913	6·1648	
51	57	36	160	13	52	
52	53	23	185	13	55	
53	48	8·510 6310	210	13	59	
54	44	8·510 6297	235	13	63	
55	40	84	261	14	66	
56	36	71	286	14	70	
57	31	59	311	14	73	
58	27	46	336	14	77	
59	23	33	361	14	81	
60	8·509 0419	8·510 6220	1·37386	2·3914	6·1684	7·854

LATITUDE 43°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·42	log D diff. 1″ = +0·00	log E diff. 1″ = +0·06	log F diff. 10′ = −1·0
° ′						
43 00	8·509 0419	8·510 6220	1·37386	2·3914	6·1684	7·854
1	14	8·510 6207	412	15	88	
2	10	8·510 6195	437	15	92	
3	06	82	462	15	95	
4	8·509 0401	69	487	15	6·1699	
05	8·509 0397	56	512	15	6·1703	
6	93	43	537	16	06	
7	89	30	563	16	10	
8	84	17	588	16	14	
9	80	8·510 6105	613	16	17	
10	8·509 0376	8·510 6092	1·37638	2·3916	6·1721	
11	71	79	663	16	25	
12	67	66	688	17	28	
13	63	53	713	17	32	
14	59	40	739	17	36	
15	54	28	764	17	39	
16	50	15	789	17	43	
17	46	8·510 6002	814	17	47	
18	41	8·510 5989	839	18	50	
19	37	76	864	18	54	
20	8·509 0333	8·510 5963	1·37889	2·3918	6·1758	7·852
21	29	50	915	18	61	
22	24	38	940	18	65	
23	20	25	965	18	69	
24	16	8·510 5912	1·37990	18	72	
25	12	8·510 5899	1·38015	19	76	
26	07	86	040	19	80	
27	8·509 0303	73	065	19	83	
28	8·509 0299	60	091	19	87	
29	94	48	116	19	91	
30	8·509 0290	8·510 5835	1·38141	2·3919	6·1795	
31	86	22	166	20	6·1798	
32	82	8·510 5809	191	20	6·1802	
33	77	8·510 5796	216	20	06	
34	73	83	241	20	09	
35	69	71	266	20	13	
36	64	58	292	20	17	
37	60	45	317	20	20	
38	56	32	342	20	24	
39	52	19	367	21	28	
40	8·509 0247	8·510 5706	1·38392	2·3921	6·1831	7·850
41	43	8·510 5693	417	21	35	
42	39	81	442	21	39	
43	34	68	467	21	42	
44	30	55	492	21	46	
45	26	42	518	21	50	
46	22	29	543	21	53	
47	17	16	568	22	57	
48	13	8·510 5603	593	22	61	
49	09	8·510 5591	618	22	65	
50	8·509 0204	8·510 5578	1·38643	2·3922	6·1868	
51	8·509 0200	65	668	22	72	
52	8·509 0196	52	693	22	76	
53	92	39	719	22	79	
54	87	26	744	22	83	
55	83	13	769	22	87	
56	79	8·510 5501	794	23	91	
57	74	8·510 5488	819	23	94	
58	70	75	844	23	6·1898	
59	66	62	869	23	6·1902	
60	8·509 0162	8·510 5449	1·38894	2·3923	6·1905	7·848

LATITUDE 44°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·42	log D diff. 1″ = +0·00	log E diff. 1″ = +0·06	log F diff. 10′ = 1·2
° ′						
44 00	8·509 0162	8·510 5449	1·38894	2·3923	6·1905	7·848
1	57	36	919	23	09	
2	53	23	945	23	13	
3	49	8·510 5411	970	23	17	
4	44	8·510 5398	1·38995	23	20	
05	40	85	1·39020	23	24	
6	36	72	045	24	28	
7	31	59	070	24	31	
8	27	46	095	24	35	
9	23	33	120	24	39	
10	8·509 0119	8·510 5320	1·39145	2·3924	6·1943	
11	14	8·510 5307	171	24	46	
12	10	8·510 5295	196	24	50	
13	06	82	221	24	54	
14	8·509 0102	69	246	24	58	
15	8·509 0097	56	271	24	61	
16	93	43	296	24	65	
17	89	30	321	24	69	
18	84	18	346	24	72	
19	80	8·510 5205	371	25	76	
20	8·509 0076	8·510 5192	1·39396	2·3925	6·1980	7·845
21	72	79	422	25	84	
22	67	66	447	25	87	
23	63	53	472	25	91	
24	59	40	497	25	95	
25	54	28	522	25	6·1999	
26	50	15	547	25	6·2002	
27	46	8·510 5102	572	25	06	
28	42	8·510 5089	597	25	10	
29	37	76	623	25	14	
30	8·509 0033	8·510 5063	1·39648	2·3925	6·2017	
31	29	50	673	25	21	
32	24	37	698	25	25	
33	20	25	723	25	29	
34	16	8·510 5012	748	25	32	
35	11	8·510 4999	773	25	36	
36	07	86	798	26	40	
37	8·509 0003	73	823	26	44	
38	8·508 9999	60	848	26	47	
39	94	47	873	26	51	
40	8·508 9990	8·510 4935	1·39898	2·3926	6·2055	7·843
41	86	22	924	26	59	
42	81	8·510 4909	949	26	62	
43	77	8·510 4896	974	26	66	
44	73	83	1·39999	26	70	
45	69	70	1·40024	26	74	
46	64	57	049	26	77	
47	60	44	074	26	81	
48	56	32	099	26	85	
49	51	19	124	26	89	
50	8·508 9947	8·510 4806	1·40149	2·3926	6·2092	
51	43	8·510 4793	174	26	6·2096	
52	39	80	200	26	6·2100	
53	34	67	225	26	04	
54	30	54	250	26	08	
55	26	41	275	26	11	
56	21	29	300	26	15	
57	17	16	325	26	19	
58	13	8·510 4703	350	26	23	
59	09	8·510 4690	375	26	27	
60	8·508 9904	8·510 4677	1·40400	2·3926	6·2130	7·840

LATITUDE 45°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·42	log D diff. 1″ = ±0·00	log E diff. 1″ = +0·06	log F diff. 10′ = −1·3
° ′						
45 00	8·508 9904	8·510 4677	1·40400	2·3926	6·2130	7·840
1	8·508 9900	64	425	26	34	
2	8·508 9896	51	450	26	38	
3	91	39	475	26	42	
4	87	26	501	26	46	
05	83	13	526	26	49	
6	78	8·510 4600	551	26	53	
7	74	8·510 4587	576	26	57	
8	70	74	601	26	61	
9	66	61	626	26	64	
10	8·508 9861	8·510 4548	1·40651	2·3926	6·2168	
11	57	36	676	26	72	
12	53	23	701	26	76	
13	48	8·510 4510	727	26	80	
14	44	8·510 4497	752	26	83	
15	40	84	777	26	87	
16	36	71	802	26	91	
17	31	59	827	26	95	
18	27	46	852	26	6·2199	
19	23	33	877	26	6·2202	
20	8·508 9818	8·510 4420	1·40902	2·3926	6·2206	7·838
21	14	8·510 4407	927	26	10	
22	10	8·510 4394	952	26	14	
23	06	81	1·40978	26	18	
24	8·508 9801	68	1·41003	26	21	
25	8·508 9797	56	028	26	25	
26	93	43	053	26	29	
27	88	30	078	26	33	
28	84	17	103	26	37	
29	80	8·510 4304	128	26	40	
30	8·508 9776	8·510 4291	1·41153	2·3926	6·2244	
31	71	78	178	26	48	
32	67	65	203	26	52	
33	63	52	229	26	56	
34	58	40	254	26	60	
35	54	27	279	26	63	
36	50	14	304	25	67	
37	46	8·510 4201	329	25	71	
38	41	8·510 4188	354	25	75	
39	37	75	379	25	79	
40	8·508 9733	8·510 4162	1·41404	2·3925	6·2283	7·835
41	28	49	429	25	86	
42	24	37	454	25	90	
43	20	24	479	25	94	
44	16	8·510 4111	505	25	6·2298	
45	11	8·510 4098	530	25	6·2302	
46	07	85	555	25	06	
47	8·508 9703	72	580	25	09	
48	8·508 9698	60	605	25	13	
49	94	47	630	25	17	
50	8·508 9689	8·510 4034	1·41655	2·3925	6·2321	
51	85	21	680	25	25	
52	81	8·510 4008	705	25	29	
53	77	8·510 3995	731	25	32	
54	72	82	756	24	36	
55	68	69	781	24	40	
56	64	57	806	24	44	
57	60	44	831	24	48	
58	55	31	856	24	52	
59	51	18	881	24	55	
60	8·508 9647	8·510 3905	1·41906	2·3924	6·2359	7·832

LATITUDE 46°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·42	log D diff. 1″ = −0·00	log E diff. 1″ = +0·06	log F diff. 10′ = −1·4
° ′						
46 00	8·508 9647	8·510 3905	1·41906	2·3924	6·2359	7·832
1	43	8·510 3892	931	24	63	
2	38	79	957	24	67	
3	34	67	1·41982	24	71	
4	30	54	1·42007	24	75	
05	25	41	032	24	79	
6	21	28	057	23	82	
7	17	15	082	23	86	
8	13	8·510 3802	107	23	90	
9	08	8·510 3789	132	23	94	
10	8·508 9604	8·510 3776	1·42157	2·3923	6·2398	
11	8·508 9600	64	183	23	6·2402	
12	8·508 9595	51	208	23	06	
13	91	38	233	23	09	
14	87	25	258	23	13	
15	83	8·510 3712	283	23	17	
16	78	8·510 3699	308	23	21	
17	74	86	333	22	25	
18	70	74	358	22	29	
19	65	61	384	22	33	
20	8·508 9561	8·510 3648	1·42409	2·3922	6·2436	7·830
21	57	35	434	22	40	
22	53	22	459	22	44	
23	48	8·510 3609	484	22	48	
24	44	8·510 3596	509	22	52	
25	40	84	534	22	56	
26	35	71	559	21	60	
27	31	58	584	21	64	
28	27	45	610	21	67	
29	23	32	635	21	71	
30	8·508 9518	8·510 3519	1·42660	2·3921	6·2475	
31	14	8·510 3506	685	21	79	
32	10	8·510 3494	710	21	83	
33	05	81	735	21	87	
34	8·508 9501	68	760	20	91	
35	8·508 9497	55	786	20	95	
36	93	42	811	20	6·2499	
37	88	29	836	20	6·2502	
38	84	17	861	20	06	
39	80	8·510 3404	886	20	10	
40	8·508 9475	8·510 3391	1·42911	2·3920	6·2514	7·827
41	71	78	936	19	18	
42	67	65	961	19	22	
43	63	52	1·42987	19	26	
44	58	39	1·43012	19	30	
45	54	27	037	19	34	
46	50	14	062	19	38	
47	45	8·510 3301	087	19	41	
48	41	8·510 3288	112	18	45	
49	37	75	137	18	49	
50	8·508 9433	8·510 3262	1·43163	2·3918	6·2553	
51	28	49	188	18	57	
52	24	37	213	18	61	
53	20	24	238	18	65	
54	16	8·510 3211	263	18	69	
55	11	8·510 3198	288	17	73	
56	07	85	314	17	77	
57	8·508 9403	72	339	17	81	
58	8·508 9398	60	364	17	84	
59	94	47	389	17	88	
60	8·508 9390	8·510 3134	1·43414	2·3917	6·2592	7·824

LATITUDE 47°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·42	log D diff. 1″ = −0·00	log E diff. 1″ = +0·07	log F diff. 10′ = −1·6
° ′						
47 00	8·508 9390	8·510 3134	1·43414	2·3917	6·2592	7·824
1	86	21	439	16	6·2596	
2	81	8·510 3108	465	16	6·2600	
3	77	8·510 3095	490	16	04	
4	73	82	515	16	08	
05	68	70	540	16	12	
6	64	57	565	16	16	
7	60	44	590	15	20	
8	56	31	615	15	24	
9	51	18	641	15	28	
10	8·508 9347	8·510 3005	1·43666	2·3915	6·2632	
11	43	8·510 2993	691	15	35	
12	38	80	716	14	39	
13	34	67	741	14	43	
14	30	54	766	14	47	
15	26	41	792	14	51	
16	21	28	817	14	55	
17	17	16	842	13	59	
18	13	8·510 2903	867	13	63	
19	09	8·510 2890	892	13	67	
20	8·508 9304	8·510 2877	1·43917	2·3913	6·2671	7·821
21	8·508 9300	64	943	13	75	
22	8·508 9296	51	968	12	79	
23	91	39	1·43993	12	83	
24	87	26	1·44018	12	87	
25	83	13	043	12	91	
26	79	8·510 2800	069	12	95	
27	74	8·510 2787	094	11	6·2699	
28	70	74	119	11	6·2702	
29	66	62	144	11	06	
30	8·508 9261	8·510 2749	1·44169	2·3911	6·2710	
31	57	36	195	11	14	
32	53	23	220	10	18	
33	49	8·510 2710	245	10	22	
34	44	8·510 2698	270	10	26	
35	40	85	295	10	30	
36	36	72	321	10	34	
37	32	59	346	09	38	
38	27	46	371	09	42	
39	23	33	396	09	46	
40	8·508 9219	8·510 2621	1·44421	2·3909	6·2750	7·817
41	14	8·510 2608	447	08	54	
42	10	8·510 2595	472	08	58	
43	06	82	497	08	62	
44	8·508 9202	69	522	08	66	
45	8·508 9197	57	547	07	70	
46	93	44	573	07	74	
47	89	31	598	07	78	
48	84	18	623	07	82	
49	80	8·510 2505	648	07	86	
50	8·508 9176	8·510 2493	1·44673	2·3906	6·2790	
51	72	80	699	06	94	
52	67	67	724	06	6·2798	
53	63	54	749	06	6·2802	
54	59	41	774	05	06	
55	55	28	800	05	10	
56	50	16	825	05	14	
57	46	8·510 2403	850	05	18	
58	42	8·510 2390	875	04	22	
59	38	77	900	04	26	
60	8·508 9133	8·510 2364	1·44926	2·3904	6·2830	7·814

LATITUDE 48°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·42	log D diff. 1″ = −0·00	log E diff. 1″ = +0·07	log F diff. 10′ = −1·7
° ′						
48 00	8·508 9133	8·510 2364	1·44926	2·3904	6·2830	7·814
1	29	52	951	04	34	
2	25	39	1·44976	03	38	
3	20	26	1·45001	03	42	
4	16	13	027	03	46	
05	12	8·510 2300	052	02	50	
6	08	8·510 2288	077	02	54	
7	8·508 9103	75	102	02	58	
8	8·508 9099	62	128	02	62	
9	95	49	153	01	66	
10	8·508 9091	8·510 2236	1·45178	2·3901	6·2870	
11	86	24	203	01	74	
12	82	8·510 2211	229	01	78	
13	78	8·510 2198	254	00	82	
14	74	85	279	00	86	
15	69	72	304	2·3900	90	
16	65	60	330	2·3899	94	
17	61	47	355	99	6·2898	
18	57	34	380	99	6·2902	
19	52	21	406	99	06	
20	8·508 9048	8·510 2108	1·45431	2·3898	6·2910	7·811
21	44	8·510 2096	456	98	14	
22	39	83	481	98	18	
23	35	70	507	97	22	
24	31	57	532	97	26	
25	27	45	557	97	30	
26	22	32	582	97	34	
27	18	19	608	96	38	
28	14	8·510 2006	633	96	42	
29	10	8·510 1993	658	96	46	
30	8·508 9005	8·510 1981	1·45683	2·3895	6·2950	
31	8·508 9001	68	709	95	54	
32	8·508 8997	55	734	95	58	
33	93	42	759	95	62	
34	88	30	785	94	66	
35	84	17	810	94	70	
36	80	8·510 1904	835	94	74	
37	76	8·510 1891	861	93	78	
38	71	78	886	93	82	
39	67	66	911	93	86	
40	8·508 8963	8·510 1853	1·45937	2·3892	6·2990	7·807
41	59	40	962	92	94	
42	54	27	1·45987	92	6·2998	
43	50	15	1·46012	91	6·3002	
44	46	8·510 1802	038	91	06	
45	41	8·510 1789	063	91	10	
46	37	76	088	90	15	
47	33	64	114	90	19	
48	29	51	139	90	23	
49	24	38	164	89	27	
50	8·508 8920	8·510 1725	1·46190	2·3889	6·3031	
51	16	13	215	89	35	
52	12	8·510 1700	240	88	39	
53	08	8·510 1687	266	88	43	
54	8·508 8903	74	291	88	47	
55	8·508 8899	62	316	87	51	
56	95	49	342	87	55	
57	90	36	367	87	59	
58	86	23	392	86	63	
59	82	8·510 1610	418	86	67	
60	8·508 8878	8·510 1598	1·46443	2·3886	6·3071	7·804

LATITUDE 49°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·42	log D diff. 1″ = −0·01	log E diff. 1″ = +0·07	log F diff. 10′ = −1·9
° ′						
49 00	8·508 8878	8·510 1598	1·46443	2·3886	6·3071	7·804
1	73	85	468	85	75	
2	69	72	494	85	79	
3	65	59	519	85	84	
4	61	47	544	84	88	
05	57	34	570	84	92	
6	52	21	595	84	6·3096	
7	48	8·510 1508	621	83	6·3100	
8	44	8·510 1496	646	83	04	
9	39	83	671	83	08	
10	8·508 8835	8·510 1470	1·46696	2·3882	6·3112	
11	31	58	722	82	16	
12	27	45	747	81	20	
13	23	32	773	81	24	
14	18	19	798	81	28	
15	14	8·510 1407	824	80	32	
16	10	8·510 1394	849	80	37	
17	06	81	874	80	41	
18	8·508 8801	68	899	79	45	
19	8·508 8797	56	925	79	49	
20	8·508 8793	8·510 1343	1·46950	2·3878	6·3153	7·800
21	89	30	1·46976	78	57	
22	84	17	1·47001	78	61	
23	80	8·510 1305	026	77	65	
24	76	8·510 1292	052	77	69	
25	72	79	077	77	73	
26	67	67	103	76	78	
27	63	54	128	76	82	
28	59	41	153	75	86	
29	55	28	179	75	90	
30	8·508 8750	8·510 1216	1·47204	2·3875	6·3194	
31	46	8·510 1203	230	74	6·3198	
32	42	8·510 1190	255	74	6·3202	
33	38	78	281	73	06	
34	33	65	306	73	10	
35	29	52	331	73	15	
36	25	39	357	72	19	
37	21	27	382	72	23	
38	16	14	408	71	27	
39	12	8·510 1101	433	71	31	
40	8·508 8708	8·510 1088	1·47459	2·3871	6·3235	7·796
41	04	76	484	70	39	
42	8·508 8700	63	509	70	43	
43	8·508 8695	50	535	69	47	
44	91	38	560	69	52	
45	87	25	586	69	56	
46	83	12	611	68	60	
47	78	8·510 1000	637	68	64	
48	74	8·510 0987	662	67	68	
49	70	74	688	67	72	
50	8·508 8666	8·510 0962	1·47713	2·3866	6·3276	
51	61	49	738	66	81	
52	57	36	764	66	85	
53	53	23	789	65	89	
54	49	8·510 0911	815	65	93	
55	45	8·510 0898	840	64	6·3297	
56	40	85	866	64	6·3301	
57	36	73	891	63	05	
58	32	60	917	63	09	
59	28	48	942	63	14	
60	8·508 8623	8·510 0835	1·47968	2·3862	6·3318	7·792

LATITUDE 50°

Lat.	log A diff. 1″ = − 0·07	log B diff. 1″ = − 0·21	log C diff. 1″ = + 0·43	log D diff. 1″ = − 0·01	log E diff. 1″ = + 0·07	log F diff. 10′ = − 2·0
° ′						
50 00	8·508 8623	8·510 0835	1·47968	2·3862	6·3318	7·792
1	19	22	1·47993	62	22	
2	15	8·510 0809	1·48019	61	26	
3	11	8·510 0797	044	61	30	
4	06	84	070	60	34	
05	8·508 8602	71	095	60	39	
6	8·508 8598	59	121	60	43	
7	94	46	146	59	47	
8	90	33	172	59	51	
9	85	21	197	58	55	
10	8·508 8581	8·510 0708	1·48223	2·3858	6·3359	
11	77	8·510 0695	248	57	63	
12	73	83	274	57	68	
13	68	70	299	56	72	
14	64	57	325	56	76	
15	60	45	350	55	80	
16	56	32	376	55	84	
17	52	19	401	55	88	
18	47	8·510 0607	427	54	93	
19	43	8·510 0594	452	54	6·3397	
20	8·508 8539	8·510 0581	1·48478	2·3853	6·3401	7·788
21	35	69	504	53	05	
22	30	56	529	52	09	
23	26	43	555	52	14	
24	22	31	580	51	18	
25	18	18	606	51	22	
26	14	8·510 0505	631	50	26	
27	09	8·510 0493	657	50	30	
28	05	80	682	49	34	
29	8·508 8501	67	708	49	39	
30	8·508 8497	8·510 0455	1·48734	2·3848	6·3443	
31	93	42	759	48	47	
32	88	29	785	47	51	
33	84	17	810	47	55	
34	80	8·510 0404	836	46	60	
35	76	8·510 0392	861	46	64	
36	71	79	887	45	68	
37	67	66	913	45	72	
38	63	54	938	44	76	
39	59	41	964	44	81	
40	8·508 8455	8·510 0328	1·48989	2·3843	6·3485	7·784
41	50	16	1·49015	43	89	
42	46	8·510 0303	041	42	93	
43	42	8·510 0291	066	42	6·3497	
44	38	78	092	41	6·3502	
45	34	65	117	41	06	
46	29	53	143	40	10	
47	25	40	169	40	14	
48	21	27	194	39	18	
49	17	15	220	39	23	
50	8·508 8413	8·510 0202	1·49246	2·3838	6·3527	
51	08	8·510 0190	271	38	31	
52	04	77	297	37	35	
53	8·508 8400	64	322	37	40	
54	8·508 8396	52	348	36	44	
55	92	39	374	36	48	
56	87	27	399	35	52	
57	83	14	425	35	56	
58	79	8·510 0101	451	34	61	
59	75	8·510 0089	476	34	65	
60	8·508 8371	8·510 0076	1·49502	2·3833	6·3569	7·780

LATITUDE 51°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·43	log D diff. 1″ = −0·01	log E diff. 1″ = +0·07	log F diff. 10′ = −2·2
° ′						
51 00	8·508 8371	8·510 0076	1·49502	2·3833	6·3569	7·780
1	66	64	528	33	73	
2	62	51	553	32	78	
3	58	38	579	32	82	
4	54	26	605	31	86	
05	50	13	630	31	90	
6	45	8·510 0001	656	30	95	
7	41	8·509 9988	682	29	6·3599	
8	37	75	707	29	6·3603	
9	33	63	733	28	07	
10	8·508 8329	8·509 9950	1·49759	2·3828	6·3612	
11	24	38	785	27	16	
12	20	25	810	27	20	
13	16	13	836	26	24	
14	12	8·509 9900	862	26	28	
15	08	8·509 9887	887	25	33	
16	8·508 8303	75	913	25	37	
17	8·508 8299	62	939	24	41	
18	95	50	965	23	45	
19	91	37	1·49990	23	50	
20	8·508 8287	8·509 9825	1·50016	2·3822	6·3654	7·776
21	82	8·509 9812	042	22	58	
22	78	8·509 9799	067	21	63	
23	74	87	093	21	67	
24	70	74	119	20	71	
25	66	62	145	20	75	
26	62	49	170	19	80	
27	57	37	196	18	84	
28	53	24	222	18	88	
29	49	8·509 9711	248	17	92	
30	8·508 8245	8·509 9699	1·50273	2·3817	6·3697	
31	41	86	299	16	6·3701	
32	36	74	325	16	05	
33	32	61	351	15	10	
34	28	49	376	14	14	
35	24	36	402	14	18	
36	20	24	428	13	22	
37	16	8·509 9611	454	13	27	
38	11	8·509 9599	480	12	31	
39	07	86	505	11	35	
40	8·508 8203	8·509 9574	1·50531	2·3811	6·3740	7·772
41	8·508 8199	61	557	10	44	
42	95	48	583	10	48	
43	90	36	609	09	52	
44	86	23	634	08	57	
45	82	8·509 9511	660	08	61	
46	78	8·509 9498	686	07	65	
47	74	86	712	07	70	
48	70	73	738	06	74	
49	65	61	764	05	78	
50	8·508 8161	8·509 9448	1·50789	2·3805	6·3782	
51	57	36	815	04	87	
52	53	23	841	04	91	
53	49	8·509 9411	867	03	6·3795	
54	45	8·509 9398	893	02	6·3800	
55	40	86	919	02	04	
56	36	73	944	01	08	
57	32	61	970	01	13	
58	28	48	1·50996	2·3800	17	
59	24	36	1·51022	2·3799	21	
60	8·508 8120	8·509 9323	1·51048	2·3799	6·3826	7·767

LATITUDE 52°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·43	log D diff. 1″ = −0·01	log E diff. 1″ = +0·07	log F diff. 10′ = −2·3
° ′						
52 00	8·508 8120	8·509 9323	1·51048	2·3799	6·3826	7·767
1	15	8·509 9311	074	98	30	
2	11	8·509 9298	100	97	34	
3	07	86	126	97	39	
4	8·508 8103	73	151	96	43	
05	8·508 8099	61	177	96	47	
6	95	48	203	95	52	
7	90	36	229	94	56	
8	86	23	255	94	60	
9	82	8·509 9211	281	93	65	
10	8·508 8078	8·509 9198	1·51307	2·3792	6·3869	
11	74	86	333	92	73	
12	70	73	359	91	78	
13	65	61	385	91	82	
14	61	48	411	90	86	
15	57	36	436	89	91	
16	53	23	462	88	95	
17	49	8·509 9111	488	88	6·3899	
18	45	8·509 9099	514	87	6·3904	
19	41	86	540	87	08	
20	8·508 8036	8·509 9074	1·51566	2·3786	6·3912	7·763
21	32	61	592	85	17	
22	28	49	618	85	21	
23	24	36	644	84	25	
24	20	24	670	83	30	
25	16	8·509 9011	696	83	34	
26	11	8·509 8999	722	82	38	
27	07	86	748	81	43	
28	8·508 8003	74	774	81	47	
29	8·508 7999	62	800	80	51	
30	8·508 7995	8·509 8949	1·51826	2·3779	6·3956	
31	91	37	852	79	60	
32	87	24	878	78	65	
33	82	8·509 8912	904	78	69	
34	78	8·509 8899	930	77	73	
35	74	87	956	76	78	
36	70	74	1·51982	75	82	
37	66	62	1·52008	75	86	
38	62	50	034	74	91	
39	58	37	060	73	6·3995	
40	8·508 7953	8·509 8825	1·52086	2·3773	6·4000	7·758
41	49	12	112	72	04	
42	45	8·509 8800	138	71	08	
43	41	8·509 8788	164	71	13	
44	37	75	190	70	17	
45	33	63	216	69	21	
46	29	50	242	68	26	
47	24	38	268	68	30	
48	20	25	294	67	35	
49	16	13	320	66	39	
50	8·508 7912	8·509 8701	1·52347	2·3766	6·4043	
51	08	8·509 8688	373	65	48	
52	04	76	399	64	52	
53	8·508 7900	63	425	64	57	
54	8·508 7895	51	451	63	61	
55	91	39	477	62	65	
56	87	26	503	61	70	
57	83	14	529	61	74	
58	79	8·509 8602	555	60	79	
59	75	8·509 8589	581	59	83	
60	8·508 7871	8·509 8577	1·52608	2·3759	6·4088	7·753

LATITUDE 53°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·21	log C diff. 1″ = +0·44	log D diff. 1″ = −0·01	log E diff. 1″ = +0·07	log F diff. 10′ = −2·5
° ′						
53 00	8·508 7871	8·509 8577	1·52608	2·3759	6·4088	7·753
1	67	64	634	58	92	
2	62	52	660	57	6·4096	
3	58	40	686	56	6·4101	
4	54	27	712	56	05	
05	50	15	738	55	10	
6	46	8·509 8502	764	54	14	
7	42	8·509 8490	790	53	18	
8	38	78	817	53	23	
9	34	65	843	52	27	
10	8·508 7829	8·509 8453	1·52869	2·3751	6·4132	
11	25	41	895	51	36	
12	21	28	921	50	41	
13	17	16	947	49	45	
14	13	8·509 8404	1·52974	48	49	
15	09	8·509 8391	1·53000	48	54	
16	05	79	026	47	58	
17	8·508 7801	67	052	46	63	
18	8·508 7797	54	078	45	67	
19	92	42	105	45	72	
20	8·508 7788	8·509 8329	1·53131	2·3744	6·4176	7·748
21	84	17	157	43	80	
22	80	8·509 8305	183	42	85	
23	76	8·509 8292	209	42	89	
24	72	80	236	41	94	
25	68	68	262	40	6·4198	
26	64	55	288	39	6·4203	
27	60	43	314	39	07	
28	55	31	341	38	12	
29	51	18	367	37	16	
30	8·508 7747	8·509 8206	1·53393	·3736	6·4221	
31	43	8·509 8194	419	36	25	
32	39	82	446	35	29	
33	35	69	472	34	34	
34	31	57	498	33	38	
35	27	45	524	33	43	
36	23	32	551	32	47	
37	18	20	577	31	52	
38	14	8·509 8108	603	30	56	
39	10	8·509 8095	630	29	61	
40	8·508 7706	8·509 8083	1·53656	2·3729	6·4265	7·743
41	8·508 7702	71	682	28	70	
42	8·508 7698	58	709	27	74	
43	94	46	735	26	79	
44	90	34	761	26	83	
45	86	22	788	25	88	
46	82	8·509 8009	814	24	92	
47	77	8·509 7997	840	23	6·4297	
48	73	85	867	22	6·4301	
49	69	72	893	22	06	
50	8·508 7665	8·509 7960	1·53919	2·3721	6·4310	
51	61	48	946	20	15	
52	57	36	972	19	19	
53	53	23	1·53998	18	24	
54	49	8·509 7911	1·54025	18	28	
55	45	8·509 7899	051	17	33	
56	41	87	077	16	37	
57	37	74	104	15	42	
58	32	62	130	14	46	
59	28	50	157	14	51	
60	8·508 7624	8·509 7838	1·54183	2·3713	6·4355	7·738

LATITUDE 54°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·20	log C diff. 1″ = +0·44	log D diff. 1″ = −0·01	log E diff. 1″ = +0·08	log F diff. 10′ = 2·6
° ′						
54 00	8·508 7624	8·509 7838	1·54183	2·3713	6·4355	7·738
1	20	25	209	12	60	
2	16	13	236	11	64	
3	12	8·509 7801	262	10	69	
4	08	8·509 7789	288	09	73	
05	04	76	315	09	78	
6	8·508 7600	64	341	08	82	
7	8·508 7596	52	368	07	87	
8	92	40	394	06	91	
9	88	27	421	05	6·4396	
10	8·508 7584	8·509 7715	1·54447	2·3705	6·4400	
11	79	8·509 7703	474	04	05	
12	75	8·509 7691	500	03	09	
13	71	78	527	02	14	
14	67	66	553	01	18	
15	63	54	580	00	23	
16	59	42	606	2·3700	28	
17	55	30	633	2·3699	32	
18	51	17	659	98	37	
19	47	8·509 7605	686	97	41	
20	8·508 7543	8·509 7593	1·54712	2·3696	6·4446	7·733
21	39	81	739	95	50	
22	35	69	765	94	55	
23	31	56	792	94	59	
24	27	44	818	93	64	
25	22	32	845	92	68	
26	18	20	871	91	73	
27	14	8·509 7508	898	90	78	
28	10	8·509 7495	924	89	82	
29	06	83	951	88	87	
30	8·508 7502	8·509 7471	1·54977	2·3688	6·4491	
31	8·508 7498	59	1·55004	87	6·4496	
32	94	47	031	86	6·4500	
33	90	34	057	85	05	
34	86	22	084	84	09	
35	82	8·509 7410	110	83	14	
36	78	8·509 7398	137	82	19	
37	74	86	163	82	23	
38	70	74	190	81	28	
39	66	61	217	80	32	
40	8·508 7462	8·509 7349	1·55243	2·3679	6·4537	7·728
41	58	37	270	78	41	
42	53	25	297	77	46	
43	49	13	323	76	51	
44	45	8·509 7301	350	75	55	
45	41	8·509 7289	376	74	60	
46	37	76	403	74	64	
47	33	64	430	73	69	
48	29	52	456	72	74	
49	25	40	483	71	78	
50	8·508 7421	8·509 7228	1·55510	2·3670	6·4583	
51	17	16	536	69	87	
52	13	8·509 7204	563	68	92	
53	09	8·509 7191	590	67	6·4597	
54	05	79	616	66	6·4601	
55	8·508 7401	67	643	66	06	
56	8·508 7397	55	670	65	10	
57	93	43	696	64	15	
58	89	31	723	63	20	
59	85	19	750	62	24	
60	8·508 7381	8·509 7107	1·55777	2·3661	6·4629	7·723

LATITUDE 55°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·20	log C diff. 1″ = +0·45	log D diff. 1″ = −0·02	log E diff. 1″ = +0·08	log F diff. 10′ = −2·8
° ′						
55 00	8·508 7381	8·509 7107	1·55777	2·3661	6·4629	7·723
1	77	8·509 7095	803	60	33	
2	73	82	830	59	38	
3	69	70	857	58	43	
4	65	58	884	57	47	
05	61	46	910	56	52	
6	56	34	937	56	57	
7	52	22	964	55	61	
8	48	8·509 7010	1·55991	54	66	
9	44	8·509 6998	1·56017	53	70	
10	8·508 7340	8·509 6986	1·56044	2·3652	6·4675	
11	36	74	071	51	80	
12	32	62	098	50	84	
13	28	49	125	49	89	
14	24	37	151	48	94	
15	20	25	178	47	6·4698	
16	16	13	205	46	6·4703	
17	12	8·509 6901	232	45	08	
18	08	8·509 6889	259	44	12	
19	04	77	286	43	17	
20	8·508 7300	8·509 6865	1·56312	2·3642	6·4721	7·717
21	8·508 7296	53	339	42	26	
22	92	41	366	41	31	
23	88	29	393	40	35	
24	84	17	420	39	40	
25	80	8·509 6805	447	38	45	
26	76	8·509 6793	474	37	49	
27	72	81	500	36	54	
28	68	69	527	35	59	
29	64	57	554	34	63	
30	8·508 7260	8·509 6745	1·56581	2·3633	6·4768	
31	56	33	608	32	73	
32	52	21	635	31	77	
33	48	8·509 6709	662	30	82	
34	44	8·509 6696	689	29	87	
35	40	84	716	28	91	
36	36	72	743	27	6·4796	
37	32	60	770	26	6·4801	
38	28	48	797	25	05	
39	24	36	823	24	10	
40	8·508 7220	8·509 6624	1·56850	2·3623	6·4815	7·711
41	16	12	877	22	20	
42	12	8·509 6600	904	21	24	
43	08	8·509 6588	931	20	29	
44	04	76	958	19	34	
45	8·508 7200	64	1·56985	18	38	
46	8·508 7196	52	1·57012	17	43	
47	92	40	039	16	48	
48	88	28	066	15	52	
49	84	16	093	14	57	
50	8·508 7180	8·509 6505	1·57120	2·3613	6·4862	
51	76	8·509 6493	147	12	66	
52	72	81	174	11	71	
53	68	69	201	10	76	
54	64	57	229	09	81	
55	60	45	256	08	85	
56	56	33	283	07	90	
57	52	21	310	06	6·4895	
58	48	8·509 6409	337	05	6·4900	
59	44	8·509 6397	364	04	04	
60	8·508 7140	8·509 6385	1·57391	2·3603	6·4909	7·706

LATITUDE 56°

Lat.	log A diff. 1″ = −0·07	log B diff. 1″ = −0·20	log C diff. 1″ = +0·45	log D diff. 1″ = −0·02	log E diff. 1″ = +0·08	log F diff. 10′ = −3·0
° ′						
56 00	8·508 7140	8·509 6385	1·57391	2·3613	6·4909	7·706
1	36	73	418	02	14	
2	32	61	445	01	18	
3	28	49	472	2·3600	23	
4	24	37	499	2·3599	28	
05	20	25	526	98	33	
6	16	13	554	97	37	
7	12	8·509 6301	581	96	42	
8	08	8·509 6289	608	95	47	
9	04	77	635	94	52	
10	8·508 7100	8·509 6266	1·57662	2·3593	6·4956	
11	8·508 7096	54	689	92	61	
12	92	42	717	91	66	
13	88	30	744	90	71	
14	84	18	771	89	75	
15	80	8·509 6206	798	88	80	
16	76	8·509 6194	825	87	85	
17	72	82	852	86	90	
18	69	70	880	85	94	
19	65	58	907	84	6·4999	
20	8·508 7061	8·509 6147	1·57934	2·3583	6·5004	7·700
21	57	35	961	82	09	
22	53	23	1·57989	81	13	
23	49	8·509 6111	1·58016	80	18	
24	45	8·509 6099	043	78	23	
25	41	87	070	77	28	
26	37	75	098	76	32	
27	33	63	125	75	37	
28	29	51	152	74	42	
29	25	40	179	73	47	
30	8·508 7021	8·509 6028	1·58207	2·3572	6·5052	
31	17	16	234	71	56	
32	13	8·509 6004	261	70	61	
33	09	8·509 5992	289	69	66	
34	05	80	316	68	71	
35	8·508 7001	68	343	67	75	
36	8·508 6997	57	371	66	80	
37	93	45	398	65	85	
38	89	33	425	64	90	
39	86	21	453	62	95	
40	8·508 6982	8·509 5909	1·58480	2·3561	6·5099	7·694
41	78	8·509 5897	507	60	6·5104	
42	74	86	535	59	09	
43	70	74	562	58	14	
44	66	62	589	57	19	
45	62	50	617	56	24	
46	58	38	644	55	28	
47	54	27	672	54	33	
48	50	15	699	53	38	
49	46	8·509 5803	726	52	43	
50	8·508 6942	8·509 5791	1·58754	2·3550	6·5148	
51	38	79	781	49	52	
52	34	67	809	48	57	
53	30	56	836	47	62	
54	26	44	864	46	67	
55	23	32	891	45	72	
56	19	20	919	44	77	
57	15	8·509 5709	946	43	81	
58	11	8·509 5697	1·58974	42	86	
59	07	85	1·59001	41	91	
60	8·508 6903	8·509 5673	1·59028	2·3539	6·5196	7·688

LATITUDE 57°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·19	log C diff. 1″ = +0·46	log D diff. 1″ = −0·02	log E diff. 1″ = +0·08	log F diff. 10′ = −3·2
° ′						
57 00	8·508 6903	8·509 5673	1·59028	2·3539	6·5196	7·688
1	8·508 6899	61	056	38	6·5201	
2	95	50	083	37	06	
3	91	38	111	36	10	
4	87	26	139	35	15	
05	83	14	166	34	20	
6	79	8·509 5603	194	33	25	
7	75	8·509 5591	221	32	30	
8	72	79	249	30	35	
9	68	67	276	29	40	
10	8·508 6864	8·509 5556	1·59304	2·3528	6·5244	
11	60	44	331	27	49	
12	56	32	359	26	54	
13	52	20	387	25	59	
14	48	8·509 5509	414	24	64	
15	44	8·509 5497	442	22	69	
16	40	85	469	21	74	
17	36	73	497	20	79	
18	32	62	525	19	83	
19	28	50	552	18	88	
20	8·508 6825	8·509 5438	1·59580	2·3517	6·5293	7·682
21	21	27	608	16	6·5298	
22	17	15	635	14	6·5303	
23	13	8·509 5403	663	13	08	
24	09	8·509 5392	691	12	13	
25	05	80	718	11	18	
26	8·508 6801	68	746	10	22	
27	8·508 6797	56	774	09	27	
28	93	45	801	07	32	
29	90	33	829	06	37	
30	8·508 6786	8·509 5321	1·59857	2·3505	6·5342	
31	82	8·509 5310	885	04	47	
32	78	8·509 5298	912	03	52	
33	74	86	940	02	57	
34	70	75	968	2·3500	62	
35	66	63	1·59996	2·3499	67	
36	62	51	1·60023	98	72	
37	58	40	051	97	76	
38	54	28	079	96	81	
39	51	16	107	95	86	
40	8·508 6747	8·509 5205	1·60134	2·3493	6·5391	7·675
41	43	8·509 5193	162	92	6·5396	
42	39	81	190	91	6·5401	
43	35	70	218	90	06	
44	31	58	246	89	11	
45	27	46	274	87	16	
46	23	35	301	86	21	
47	20	23	329	85	26	
48	16	12	357	84	31	
49	12	8·509 5100	385	83	36	
50	8·508 6708	8·509 5088	1·60413	2·3481	6·5441	
51	04	77	441	80	46	
52	8·508 6700	65	469	79	50	
53	8·508 6696	54	496	78	55	
54	92	42	524	76	60	
55	89	30	552	75	65	
56	85	19	580	74	70	
57	81	8·509 5007	608	73	75	
58	77	8·509 4996	636	72	80	
59	73	84	664	70	85	
60	8·508 6669	8·509 4972	1·60692	2·3469	6·5490	7·669

LATITUDE 58°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·19	log C diff. 1″ = +0·47	log D diff. 1″ = −0·02	log E diff. 1″ = +0·08	log F diff. 10′ = −3·3
° ′						
58 00	8·508 6669	8·509 4972	1·60692	2·3469	6·5490	7·669
1	65	61	720	68	6·5495	
2	62	49	748	67	6·5500	
3	58	38	776	66	05	
4	54	26	804	64	10	
05	50	14	832	63	15	
6	46	8·509 4903	860	62	20	
7	42	8·509 4891	888	61	25	
8	38	80	916	59	30	
9	35	68	944	58	35	
10	8·508 6631	8·509 4857	1·60972	2·3457	6·5540	
11	27	45	1·61000	56	45	
12	23	33	028	54	50	
13	19	22	056	53	55	
14	15	8·509 4810	084	52	60	
15	11	8·509 4799	112	51	65	
16	08	87	140	49	70	
17	04	76	168	48	75	
18	8·508 6600	64	197	47	80	
19	8·508 6596	53	225	46	85	
20	8·508 6592	8·509 4741	1·61253	2·3444	6·5590	7·662
21	88	30	281	43	6·5595	
22	85	18	309	42	6·5600	
23	81	8·509 4707	337	41	05	
24	77	8·509 4695	365	39	10	
25	73	84	393	38	15	
26	69	72	422	37	20	
27	65	61	450	35	25	
28	62	49	478	34	30	
29	58	38	506	33	35	
30	8·508 6554	8·509 4626	1·61534	2·3432	6·5640	
31	50	15	563	30	45	
32	46	8·509 4603	591	29	50	
33	42	8·509 4592	619	28	55	
34	39	80	647	26	60	
35	35	69	675	25	65	
36	31	57	704	24	70	
37	27	46	732	23	75	
38	23	35	760	21	80	
39	20	23	789	20	86	
40	8·508 6516	8·509 4512	1·61817	2·3419	6·5691	7·656
41	12	8·509 4500	845	17	6·5696	
42	08	8·509 4489	873	16	6·5701	
43	04	77	902	15	06	
44	8·508 6500	66	930	14	11	
45	8·508 6497	54	958	12	16	
46	93	43	1·61987	11	21	
47	89	32	1·62015	10	26	
48	85	20	043	08	31	
49	81	8·509 4409	072	07	36	
50	8·508 6478	8·509 4397	1·62100	2·3406	6·5741	
51	74	86	129	04	46	
52	70	74	157	03	51	
53	66	63	185	02	56	
54	62	52	214	2·3400	62	
55	59	40	242	2·3399	67	
56	55	29	271	98	72	
57	51	17	299	96	77	
58	47	8·509 4306	327	95	82	
59	43	8·509 4295	356	94	87	
60	8·508 6440	8·509 4283	1·62384	2·3392	6·5792	7·649

LATITUDE 59°

Lat.	log A diff. 1″=−0·06	log B diff. 1″=−0·19	log C diff. 1″=+0·48	log D diff. 1″=−0·02	log E diff. 1″=+0·09	log F diff. 10′=−3·5
° ′						
59 00	8·508 6440	8·509 4283	1·62384	2·3392	6·5792	7·649
1	36	72	413	91	6·5797	
2	32	61	441	90	6·5802	
3	28	49	470	88	07	
4	24	38	498	87	13	
05	21	26	527	86	18	
6	17	15	555	84	23	
7	13	8·509 4204	584	83	28	
8	09	8·509 4192	612	82	33	
9	05	81	641	80	38	
10	8·508 6402	8·509 4170	1·62669	2·3379	6·5843	
11	8·508 6398	58	698	78	48	
12	94	47	727	76	54	
13	90	36	755	75	59	
14	87	24	784	74	64	
15	83	13	812	72	69	
16	79	8·509 4102	841	71	74	
17	75	8·509 4090	870	69	79	
18	71	79	898	68	84	
19	68	68	927	67	89	
20	8·508 6364	8·509 4056	1·62955	2·3365	6·5895	7·642
21	60	45	1·62984	64	6·5900	
22	56	34	1·63013	63	05	
23	53	22	041	61	10	
24	49	11	070	60	15	
25	45	8·509 4000	099	58	20	
26	41	8·509 3989	127	57	26	
27	38	77	156	56	31	
28	34	66	185	54	36	
29	30	55	214	53	41	
30	8·508 6326	8·509 3943	1·63242	2·3351	6·5946	
31	23	32	271	50	51	
32	19	21	300	49	57	
33	15	8·509 3910	329	47	62	
34	11	8·509 3898	357	46	67	
35	08	87	386	44	72	
36	04	76	415	43	77	
37	8·508 6300	65	444	42	82	
38	8·508 6296	53	473	40	88	
39	93	42	501	39	93	
40	8·508 6289	8·509 3831	1·63530	2·3337	6·5998	7·635
41	85	20	559	36	6·6003	
42	81	8·509 3808	588	35	08	
43	78	8·509 3797	617	33	14	
44	74	86	646	32	19	
45	70	75	674	30	24	
46	66	63	703	29	29	
47	63	52	732	28	34	
48	59	41	761	26	40	
49	55	30	790	25	45	
50	8·508 6251	8·509 3719	1·63819	2·3323	6·6050	
51	48	8·509 3708	848	22	55	
52	44	8·509 3696	877	20	61	
53	40	85	906	19	66	
54	36	74	935	17	71	
55	33	63	964	16	76	
56	29	52	1·63993	15	81	
57	25	40	1·64022	13	87	
58	22	29	051	12	92	
59	18	18	080	10	6·6097	
60	8·508 6214	8·509 3607	1·64109	2·3309	6·6102	7·627

LATITUDE 60°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·18	log C diff. 1″ = +0·49	log D diff. 1″ = −0·03	log E diff. 1″ = +0·09	log F diff. 10′ = −3·7
° ′						
60 00	8·508 6214	8·509 3607	1·64109	2·3309	6·6102	7·627
1	10	8·509 3596	138	07	08	
2	07	85	167	06	13	
3	8·508 6203	73	196	04	18	
4	8·508 6199	62	225	03	23	
05	96	51	254	02	29	
6	92	40	283	2·3300	34	
7	88	29	312	2·3299	39	
8	84	18	341	97	44	
9	81	8·509 3507	370	96	50	
10	8·508 6177	8·509 3495	1·64400	2·3294	6·6155	
11	73	84	429	93	60	
12	70	73	458	91	66	
13	66	62	487	90	71	
14	62	51	516	88	76	
15	58	40	545	87	81	
16	55	29	574	85	87	
17	51	18	604	84	92	
18	47	8·509 3407	633	82	6·6197	
19	44	8·509 3395	662	81	6·6203	
20	8·508 6140	8·509 3384	1·64691	2·3279	6·6208	7·620
21	36	73	720	78	13	
22	33	62	750	76	18	
23	29	51	779	75	24	
24	25	40	808	73	29	
25	21	29	838	72	34	
26	18	18	867	70	40	
27	14	8·509 3307	896	69	45	
28	10	8·509 3296	925	67	50	
29	07	85	955	66	56	
30	8·508 6103	8·509 3274	1·64984	2·3264	6·6261	
31	8·508 6099	63	1·65013	63	66	
32	96	52	043	61	72	
33	92	40	072	60	77	
34	88	29	101	58	82	
35	85	18	131	57	87	
36	81	8·509 3207	160	55	93	
37	77	8·509 3196	190	54	6·6298	
38	74	85	219	52	6·6304	
39	70	74	248	51	09	
40	8·508 6066	8·509 3163	1·65278	2·3249	6·6314	7·613
41	63	52	307	48	20	
42	59	41	337	46	25	
43	55	30	366	45	30	
44	52	19	396	43	36	
45	48	8·509 3108	425	41	41	
46	44	8·509 3097	455	40	46	
47	41	86	484	38	52	
48	37	75	514	37	57	
49	33	64	543	35	62	
50	8·508 6030	8·509 3053	1·65573	2·3234	6·6368	
51	26	42	602	32	73	
52	22	31	632	31	79	
53	19	20	661	29	84	
54	15	8·509 3010	691	28	89	
55	11	8·509 2999	721	26	6·6395	
56	08	88	750	24	6·6400	
57	04	77	780	23	05	
58	8·508 6000	66	809	21	11	
59	8·508 5997	55	839	20	16	
60	8·508 5993	8·509 2944	1·65869	2·3218	6·6422	7·605

LATITUDE 61°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·18	log C diff. 1″ = +0·50	log D diff. 1″ = −0·03	log E diff. 1″ = +0·09	log F diff. 10′ = −4·0
° ′						
61 00	8·508 5993	8·509 2944	1·65869	2·3218	6·6422	7·605
1	89	33	898	17	27	
2	86	22	928	15	32	
3	82	11	958	13	38	
4	79	8·509 2900	1·65987	12	43	
05	75	8·509 2889	1·66017	10	48	
6	71	78	047	09	54	
7	68	67	076	07	59	
8	64	56	106	06	65	
9	60	46	136	04	70	
10	8·508 5957	8·509 2835	1·66166	2·3202	6·6476	
11	53	24	195	2·3201	81	
12	49	13	225	2·3199	87	
13	46	8·509 2802	255	98	92	
14	42	8·509 2791	285	96	6·6497	
15	39	80	315	94	6·6503	
16	35	69	344	93	08	
17	31	58	374	91	14	
18	28	48	404	90	19	
19	24	37	434	88	25	
20	8·508 5920	8·509 2726	1·66464	2·3186	6·6530	7·597
21	17	15	494	85	36	
22	13	8·509 2704	524	83	41	
23	10	8·509 2693	553	81	46	
24	06	83	583	80	52	
25	8·508 5902	72	613	78	57	
26	8·508 5899	61	643	77	63	
27	95	50	673	75	68	
28	92	39	703	73	74	
29	88	28	733	72	79	
30	8·508 5884	8·509 2618	1·66763	2·3170	6·6585	
31	81	8·509 2607	793	68	90	
32	77	8·509 2596	823	67	6·6596	
33	74	85	853	65	6·6601	
34	70	74	883	64	07	
35	66	64	913	62	12	
36	63	53	943	60	18	
37	59	42	1·66973	58	23	
38	56	31	1·67003	57	29	
39	52	20	033	55	34	
40	8·508 5848	8·509 2510	1·67063	2·3154	6·6640	7·589
41	45	8·509 2499	094	52	45	
42	41	88	124	50	51	
43	38	77	154	49	56	
44	34	67	184	47	62	
45	30	56	214	45	67	
46	27	45	244	44	73	
47	23	34	274	42	78	
48	20	24	305	40	84	
49	16	13	335	39	89	
50	8·508 5813	8·509 2402	1·67365	2·3137	6·6695	
51	09	8·509 2391	395	35	6·6700	
52	05	81	425	34	06	
53	8·508 5802	70	456	32	12	
54	8·508 5798	59	486	30	17	
55	95	49	516	29	23	
56	91	38	547	27	28	
57	88	27	577	25	34	
58	84	16	607	23	39	
59	80	8·509 2306	637	22	45	
60	8·508 5777	8·509 2295	1·67668	2·3120	6·6750	7·581

LATITUDE 62°

Lat.	log A diff. 1′ = −0·06	log B diff. 1″ = −0·18	log C diff. 1″ = +0·51	log D diff. 1″ = −0·03	log E diff. 1″ = +0·09	log F diff. 10′ = −4·2
° ′						
62 00	8·508 5777	8·509 2295	1·67668	2·3120	6·6750	7·581
1	73	84	698	18	56	
2	70	74	728	17	61	
3	66	63	759	15	67	
4	63	52	789	13	73	
05	59	42	820	12	78	
6	55	31	850	10	84	
7	52	20	880	08	89	
8	48	8·509 2210	911	06	6·6795	
9	45	8·509 2199	941	05	6·6801	
10	8·508 5741	8·509 2188	1·67972	2·3103	6·6806	
11	38	78	1·68002	01	12	
12	34	67	033	2·3100	17	
13	30	56	063	2·3098	23	
14	27	46	094	96	29	
15	24	35	124	94	34	
16	20	25	155	93	40	
17	16	14	185	91	45	
18	13	8·509 2103	216	89	51	
19	09	8·509 2093	246	87	57	
20	8·508 5706	8·509 2082	1·68277	2·3086	6·6862	7·573
21	8·508 5702	71	307	84	68	
22	8·508 5699	61	338	82	73	
23	95	50	369	80	79	
24	92	40	399	79	85	
25	88	29	430	77	90	
26	85	19	461	75	6·6896	
27	81	8·509 2008	491	74	6·6902	
28	78	8·509 1997	522	72	07	
29	74	87	553	70	13	
30	8·508 5671	8·509 1976	1·68583	2·3068	6·6919	
31	67	66	614	66	24	
32	64	55	645	65	30	
33	60	45	675	63	36	
34	56	34	706	61	41	
35	53	23	737	59	47	
36	49	13	768	58	53	
37	46	8·509 1902	799	56	58	
38	42	8·509 1892	829	54	64	
39	39	81	860	52	70	
40	8·508 5635	8·509 1871	1·68891	2·3050	6·6975	7·564
41	32	60	922	49	81	
42	28	50	953	47	87	
43	25	39	1·68984	45	92	
44	21	29	1·69014	43	6·6998	
45	18	18	045	42	6·7004	
46	14	8·509 1808	076	40	09	
47	11	8·509 1797	107	38	15	
48	07	87	138	36	21	
49	04	76	169	34	26	
50	8·508 5600	8·509 1766	1·69200	2·3033	6·7032	
51	8·508 5597	55	231	31	38	
52	93	45	262	29	44	
53	90	34	293	27	49	
54	86	24	324	25	55	
55	83	14	355	23	61	
56	80	8·509 1703	386	22	67	
57	76	8·509 1693	417	20	72	
58	73	82	448	18	78	
59	69	72	479	16	84	
60	8·508 5566	8·509 1661	1·69510	2·3014	6·7089	7·556

LATITUDE 63°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·17	log C diff. 1″ = +0·52	log D diff. 1″ = −0·03	log E diff. 1″ = +0·10	log F diff. 10′ = −4·5
° ′						
63 00	8·508 5566	8·509 1661	1·69510	2·3014	6·7089	7·556
1	62	51	541	13	6·7095	
2	59	40	572	11	6·7101	
3	55	30	603	09	07	
4	52	20	635	07	12	
05	48	8·509 1609	666	05	18	
6	45	8·509 1599	697	03	24	
7	41	88	728	02	30	
8	38	78	759	2·3000	35	
9	34	68	791	2·2998	41	
10	8·508 5531	8·509 1557	1·69822	2·2996	6·7147	
11	27	47	853	94	53	
12	24	36	884	92	59	
13	20	26	915	90	64	
14	17	16	947	89	70	
15	14	8·509 1505	1·69978	87	76	
16	10	8·509 1495	1·70009	85	82	
17	07	85	041	83	88	
18	03	74	072	81	93	
19	8·508 5500	64	103	79	6·7199	
20	8·508 5496	8·509 1454	1·70135	2·2977	6·7205	7·547
21	93	43	166	75	11	
22	89	33	197	74	17	
23	86	23	229	72	22	
24	83	[illegible]	260	70	28	
25	79	8·509 14[illegible]	292	68	34	
26	76	8·509 13[illegible]	323	66	40	
27	72	[illegible]	355	64	46	
28	69	[illegible]	386	62	51	
29	65	[illegible]	417	60	57	
30	8·508 5462	8·509 1350	1·70449	2·2958	6·7263	
31	58	40	480	57	69	
32	55	30	512	55	75	
33	52	19	544	53	81	
34	48	8·509 1309	575	51	86	
35	45	8·509 1299	607	49	92	
36	41	89	638	47	6·7298	
37	38	78	670	45	6·7304	
38	34	68	701	43	10	
39	31	58	733	41	16	
40	8·508 5428	8·509 1248	1·70765	2·2939	6·7322	7·538
41	24	37	796	37	28	
42	21	27	828	36	33	
43	17	17	860	34	39	
44	14	8·509 1207	891	32	45	
45	11	8·509 1196	923	30	51	
46	07	86	955	28	57	
47	04	76	1·70986	26	63	
48	8·508 5400	66	1·71018	24	69	
49	8·508 5397	55	050	22	75	
50	8·508 5394	8·509 1145	1·71082	2·2920	6·7381	
51	90	35	114	18	86	
52	87	25	145	16	92	
53	83	15	177	14	6·7398	
54	80	8·509 1104	209	12	6·7404	
55	77	8·509 1094	241	10	10	
56	73	84	273	08	16	
57	70	74	305	06	22	
58	66	64	337	04	28	
59	63	54	368	02	34	
60	8·508 5360	8·509 1043	1·71400	2·2901	6·7440	7·529

LATITUDE 64°

Lat.	log A diff. 1″ = −0·06	log B diff. 1″ = −0·17	log C diff. 1″ = +0·54	log D diff. 1″ = −0·03	log E diff. 1″ = +0·10	log F diff. 10′ = −4·7
° ′						
64 00	8·508 5360	8·509 1043	1·71400	2·2901	6·7440	7·529
1	56	33	432	2·2899	46	
2	53	23	464	97	52	
3	49	13	496	95	58	
4	46	8·509 1003	528	93	63	
05	43	8·509 0993	560	91	69	
6	39	82	592	89	75	
7	36	72	624	87	81	
8	33	62	656	85	87	
9	29	52	688	83	93	
10	8·508 5326	8·509 0942	1·71720	2·2881	6·7499	
11	22	32	752	79	6·7505	
12	19	22	785	77	11	
13	16	12	817	75	17	
14	12	8·509 0902	849	73	23	
15	·09	8·509 0891	881	71	29	
16	06	81	913	69	35	
17	8·508 5302	71	945	67	41	
18	8·508 5299	61	1·71977	65	47	
19	96	51	1·72010	63	53	
20	8·508 5292	8·509 0841	1·72042	2·2861	6·7559	7·520
21	89	31	074	59	65	
22	85	21	106	57	71	
23	82	11	139	55	77	
24	79	8·509 0801	171	53	83	
25	75	8·509 0791	203	51	89	
26	72	81	235	49	6·7595	
27	69	71	268	47	6·7601	
28	65	61	300	45	07	
29	62	51	332	42	13	
30	8·508 5259	8·509 0741	1·72365	2·2840	6·7619	
31	55	31	397	38	25	
32	52	21	430	36	31	
33	49	11	462	34	37	
34	45	8·509 0701	495	32	43	
35	42	8·509 0691	527	30	49	
36	39	81	559	28	56	
37	35	71	592	26	62	
38	32	61	624	24	68	
39	29	51	657	22	74	
40	8·508 5225	8·509 0641	1·72689	2·2820	6·7680	7·511
41	22	31	722	18	86	
42	19	21	755	16	92	
43	15	11	787	14	6·7698	
44	12	8·509 0601	820	12	6·7704	
45	09	8·509 0591	852	10	10	
46	05	81	885	07	16	
47	8·508 5202	71	918	05	22	
48	8·508 5199	61	950	03	28	
49	95	51	1·72983	2·2801	35	
50	8·508 5192	8·509 0541	1·73016	2·2799	6·7741	
51	89	31	048	97	47	
52	86	21	081	95	53	
53	82	11	114	93	59	
54	79	8·509 0501	146	91	65	
55	76	8·509 0491	179	89	71	
56	72	82	212	87	77	
57	69	72	245	84	84	
58	66	62	278	82	90	
59	62	52	310	80	6·7796	
60	8·508 5159	8·509 0442	1·73343	2·2778	6·7802	7·501

LATITUDE 65°

Lat.	log A diff. 1″ = − 0·05	log B diff. 1″ = − 0·16	log C diff. 1″ = + 0·56	log D diff. 1″ = − 0·04	log E diff. 1″ = + 0·10	log F diff. 10′ = − 5·0
° ′						
65 00	8·508 5159	8·509 0442	1·73343	2·2778	6·7802	7·501
1	56	32	376	76	08	
2	52	22	409	74	14	
3	49	12	442	72	20	
4	46	8·509 0402	475	70	27	
05	43	8·509 0393	508	68	33	
6	39	83	541	65	39	
7	36	73	574	63	45	
8	33	63	607	61	51	
9	30	53	640	59	57	
10	8·508 5126	8·509 0344	1·73673	2·2757	6·7864	
11	23	34	706	55	70	
12	20	24	739	53	76	
13	17	14	772	50	82	
14	13	8·509 0304	805	48	88	
15	10	8·509 0295	838	46	6·7895	
16	07	85	871	44	6·7901	
17	03	75	904	42	07	
18	8·508 5100	65	937	40	13	
19	8·508 5097	55	1·73970	38	19	
20	8·508 5094	8·509 0245	1·74004	2·2735	6·7926	7·491
21	90	36	037	33	32	
22	87	26	070	31	38	
23	84	16	103	29	44	
24	81	8·509 0206	136	27	51	
25	77	8·509 0197	170	24	57	
26	74	87	203	22	63	
27	71	77	236	20	69	
28	68	67	270	18	76	
29	64	57	303	16	82	
30	8·508 5061	8·509 0148	1·74336	2·2714	6·7988	
31	58	38	370	11	6·7994	
32	54	28	403	09	6·8001	
33	51	18	436	07	07	
34	48	8·509 0109	470	05	13	
35	45	8·509 0099	503	03	19	
36	41	89	537	2·2700	26	
37	38	80	570	2·2698	32	
38	35	70	604	96	38	
39	32	60	637	94	44	
40	8·508 5029	8·509 0051	1·74670	2·2692	6·8051	7·481
41	25	41	704	89	57	
42	22	31	738	87	63	
43	19	22	771	85	70	
44	16	12	805	83	76	
45	13	8·509 0002	838	80	82	
46	09	8·508 9993	872	78	89	
47	06	83	906	76	6·8095	
48	03	73	939	74	6·8101	
49	8·508 5000	64	1·74973	72	07	
50	8·508 4996	8·508 9954	1·75007	2·2669	6·8114	
51	93	44	040	67	20	
52	90	35	074	65	27	
53	87	25	108	63	33	
54	84	15	142	60	39	
55	80	8·508 9906	175	58	46	
56	77	8·508 9896	209	56	52	
57	74	87	243	53	58	
58	71	77	277	51	65	
59	68	67	311	49	71	
60	8·508 4964	8·508 9858	1·75344	2·2647	6·8177	7·471

LATITUDE 66°

Lat.	log A diff. 1″ = −0·05	log B diff. 1″ = −0·16	log C diff. 1″ = +0·57	log D diff. 1″ = −0·04	log E diff. 1″ = +0·11	log F diff. 10′ = −5·3
° ′						
66 00	8·508 4964	8·508 9858	1·75344	2·2647	6·8177	7·471
1	61	48	378	44	84	
2	58	39	412	42	90	
3	55	29	446	40	6·8196	
4	52	20	480	38	6·8203	
05	48	10	514	35	09	
6	45	8·508 9801	548	33	16	
7	42	8·508 9791	582	31	22	
8	39	82	616	28	28	
9	36	72	650	26	35	
10	8·508 4933	8·508 9762	1·75684	2·2624	6·8241	
11	29	53	718	22	48	
12	26	43	752	19	54	
13	23	34	786	17	61	
14	20	24	820	15	67	
15	17	14	854	12	73	
16	13	8·508 9705	889	10	80	
17	10	8·508 9696	923	08	86	
18	07	86	957	05	93	
19	04	77	1·75991	03	6·8299	
20	8·508 4901	8·508 9667	1·76025	2·2601	6·8306	7·461
21	8·508 4898	58	060	2·2598	12	
22	95	48	094	96	19	
23	91	39	128	94	25	
24	88	29	163	91	31	
25	85	20	197	89	38	
26	82	11	231	87	44	
27	79	8·508 9601	266	84	51	
28	76	8·508 9592	300	82	57	
29	73	82	334	80	64	
30	8·508 4869	8·508 9573	1·76369	2·2578	6·8370	
31	66	63	403	75	77	
32	63	54	438	73	83	
33	60	44	472	70	90	
34	57	35	507	68	6·8396	
35	54	25	541	66	6·8403	
36	50	16	576	63	09	
37	47	8·508 9507	610	61	16	
38	44	8·508 9497	645	59	22	
39	41	88	679	56	29	
40	8·508 4838	8·508 9478	1·76714	2·2554	6·8436	7·450
41	35	69	749	51	42	
42	32	60	783	49	49	
43	29	51	818	47	55	
44	26	41	853	44	62	
45	22	32	887	42	68	
46	19	23	922	39	75	
47	16	13	957	37	81	
48	13	8·508 9404	1·76991	35	88	
49	10	8·508 9395	1·77026	32	6·8495	
50	8·508 4807	8·508 9385	1·77061	2·2530	6·8501	
51	04	76	096	27	08	
52	8·508 4801	66	131	25	14	
53	8·508 4797	57	166	23	21	
54	94	48	200	20	27	
55	91	38	235	18	34	
56	88	29	270	15	41	
57	85	20	305	13	47	
58	82	10	340	11	54	
59	79	8·508 9301	375	08	60	
60	8 508 4776	8·508 9292	1·77410	2·2506	6·8567	7·440

LATITUDE 67°

Lat.	log A diff. 1″ = −0·05	log B diff. 1″ = −0·15	log C diff. 1″ = +0·59	log D diff. 1″ = −0·04	log E diff. 1″ = +0·11	log F diff. 10′ = −5·6
° ′						
67 00	8·508 4776	8·508 9292	1·77410	2·2506	6·8567	7·440
1	73	83	445	03	74	
2	70	73	480	2·2501	80	
3	66	64	515	2·2498	87	
4	63	55	550	96	6·8594	
05	60	46	585	93	6·8600	
6	57	36	620	91	07	
7	54	27	656	89	14	
8	51	18	691	86	20	
9	48	8·508 9208	726	84	27	
10	8·508 4745	8·508 9199	1·77761	2·2481	6·8634	
11	42	90	796	79	40	
12	39	81	831	76	47	
13	36	72	867	74	54	
14	33	62	902	71	60	
15	30	53	937	69	67	
16	26	44	1·77973	66	74	
17	23	35	1·78008	64	80	
18	20	26	043	61	87	
19	17	16	079	59	6·8694	
20	8·508 4714	8·508 9107	1·78114	2·2456	6·8700	7·429
21	11	8·508 9098	149	54	07	
22	08	89	185	51	14	
23	05	80	220	49	20	
24	8·508 4702	71	256	46	27	
25	8·508 4699	62	291	44	34	
26	96	52	327	41	41	
27	93	43	362	39	47	
28	90	34	398	36	54	
29	87	25	433	34	61	
30	8·508 4684	8·508 9016	1·78469	2·2431	6·8768	
31	81	8·508 9007	505	29	74	
32	78	8·508 8998	540	26	81	
33	75	88	576	24	88	
34	72	79	612	21	6·8795	
35	68	70	647	19	6·8802	
36	65	61	683	16	08	
37	62	52	719	14	15	
38	59	43	755	11	22	
39	56	34	790	09	29	
40	8·508 4653	8·508 8925	1·78826	2·2406	6·8835	7·418
41	50	16	862	03	42	
42	47	8·508 8907	898	2·2401	49	
43	44	8·508 8898	934	2·2398	56	
44	41	89	1·78970	96	63	
45	38	80	1·79006	93	70	
46	35	71	042	91	76	
47	32	62	078	88	83	
48	29	53	114	86	90	
49	26	44	150	83	6·8897	
50	8·508 4623	8·508 8834	1·79186	2·2380	6·8904	
51	20	25	222	78	10	
52	17	16	258	75	17	
53	14	8·508 8807	294	73	24	
54	11	8·508 8798	330	70	31	
55	08	89	366	67	38	
56	05	80	402	65	45	
57	8·508 4602	71	438	62	52	
58	8·508 4599	62	474	60	59	
59	96	54	511	57	65	
60	8·508 4593	8·508 8745	1·79547	2·2354	6·8972	7·406

LATITUDE 68°

Lat.	log A diff. 1″ = − 0·05	log B diff. 1″ = − 0·15	log C diff. 1″ = + 0·62	log D diff. 1″ = − 0·4	log E diff. 1″ = + 0·12	log F diff. 10′ = − 5·9
° ′						
68 00	8·508 4593	8·508 8745	1·79547	2·2354	6·8972	7·406
1	90	36	583	52	79	
2	87	27	620	49	86	
3	84	18	656	47	6·8993	
4	81	09	692	44	6·9000	
05	78	8·508 8700	728	41	07	
6	76	8·508 8691	765	39	14	
7	73	82	801	36	21	
8	70	73	838	33	28	
9	67	64	874	31	35	
10	8·508 4564	8·508 8656	1·79911	2·2328	6·9042	
11	61	47	947	26	48	
12	58	38	1·79984	23	55	
13	55	29	1·80020	20	62	
14	52	20	057	18	69	
15	49	11	093	15	76	
16	46	8·508 8602	130	12	83	
17	43	8·508 8593	166	10	90	
18	40	84	203	07	6·9097	
19	37	75	240	04	6·9104	
20	8·508 4534	8·508 8566	1·80276	2·2302	6·9111	7·395
21	31	58	313	2·2299	18	
22	28	49	350	96	25	
23	25	40	387	94	32	
24	22	31	423	91	39	
25	19	22	460	88	46	
26	16	13	497	85	53	
27	13	8·508 8505	534	83	60	
28	10	8·508 8496	571	80	67	
29	07	87	608	77	74	
30	8·508 4504	8·508 8478	1·80645	2·2275	6·9181	
31	8·508 4501	69	682	72	88	
32	8·508 4499	60	719	69	6·9195	
33	96	52	756	67	6·9203	
34	93	43	793	64	10	
35	90	34	830	61	17	
36	87	25	867	58	24	
37	84	17	904	56	31	
38	81	8·508 8408	941	53	38	
39	78	8·508 8399	1·80978	50	45	
40	8·508 4475	8·508 8390	1·81015	2·2248	6·9252	7·383
41	72	82	052	45	59	
42	70	73	089	42	66	
43	67	64	127	39	73	
44	64	56	164	36	80	
45	61	47	201	34	88	
46	58	38	239	31	6·9295	
47	55	30	276	28	6·9302	
48	52	21	313	26	09	
49	49	12	350	23	16	
50	8·508 4446	8·508 8303	1·81388	2·2220	6·9323	
51	43	8·508 8295	425	17	30	
52	40	86	463	14	37	
53	38	77	500	12	45	
54	35	68	538	09	52	
55	32	60	575	06	59	
56	29	51	613	03	66	
57	26	43	650	2·2201	73	
58	23	34	688	2·2198	80	
59	20	25	726	95	88	
60	8·508 4417	8·508 8217	1·81763	2·2192	6·9395	7·371

LATITUDE 69°

Lat.	log A diff. 1″ = −0·05	log B diff. 1″ = −0·14	log C diff. 1″ = +0·64	log D diff. 1″ = −0·05	log E diff. 1″ = +0·12	log F diff. 10′ = −6·2
° ′						
69 00	8·508 4417	8·508 8217	1·81763	2·2192	6·9395	7·371
1	14	08	801	89	6·9402	
2	12	8·508 8200	838	87	09	
3	09	8·508 8191	876	84	16	
4	06	82	914	81	24	
5	03	74	952	78	31	
6	8·508 4400	65	1·81989	75	38	
7	8·508 4397	57	1·82027	72	45	
8	94	48	065	70	52	
9	92	39	103	67	60	
10	8·508 4389	8·508 8131	1·82141	2·2164	6·9467	
11	86	22	179	61	74	
12	83	14	217	58	82	
13	80	8·508 8105	255	55	89	
14	77	8·508 8096	293	53	6·9496	
15	74	88	330	50	6·9503	
16	71	79	369	47	11	
17	69	71	407	44	18	
18	66	62	445	41	25	
19	63	54	483	38	32	
20	8·508 4360	8·508 8045	1·82521	2·2136	6·9540	7·358
21	57	37	559	33	47	
22	55	28	597	30	54	
23	52	20	636	27	62	
24	49	11	674	24	69	
25	46	8·508 8003	712	21	76	
26	43	8·508 7994	750	18	84	
27	40	86	789	15	91	
28	37	77	827	12	6·9598	
29	35	69	865	10	6·9606	
30	8·508 4332	8·508 7960	1·82904	2·2107	6·9613	
31	29	52	942	04	20	
32	26	43	1·82981	2·2101	28	
33	23	35	1·83019	2·2098	35	
34	21	26	058	95	42	
35	18	18	096	92	50	
36	15	09	135	89	57	
37	12	8·508 7901	173	86	65	
38	09	8·508 7893	212	83	72	
39	06	84	250	80	79	
40	8·508 4304	8·508 7876	1·83289	2·2078	6·9687	7·346
41	8·508 4301	67	328	75	6·9694	
42	8·508 4298	59	366	72	6·9702	
43	95	51	405	69	09	
44	93	42	444	66	16	
45	90	34	483	63	24	
46	87	26	521	60	31	
47	84	17	560	57	39	
48	81	09	599	54	46	
49	79	8·508 7801	638	51	54	
50	8·508 4276	8·508 7792	1·83677	2·2048	6·9761	
51	73	84	716	45	69	
52	70	75	755	42	76	
53	67	67	794	39	84	
54	65	59	833	36	91	
55	62	50	872	33	6·9799	
56	59	42	911	30	6·9806	
57	56	34	950	27	14	
58	54	25	1·83989	24	21	
59	51	17	1·84028	21	29	
60	8·508 4248	8·508 7709	1·84068	2·2018	6·9836	7·333

LATITUDE 70°

Lat.	log A diff. 1″ = −0·04	log B diff. 1″ = −0·14	log C diff. 1″ = +0·67	log D diff. 1″ = −0·05	log E diff. 1″ = +0·13	log F diff. 10′ = −6·7
° ′						
70 00	8·508 4248	8·508 7709	1·84068	2·2018	6·9836	7·333
1	45	8·508 7701	107	15	44	
2	43	8·508 7692	146	12	51	
3	40	84	185	09	59	
4	37	76	225	06	66	
05	34	68	264	03	74	
6	32	59	303	2·2000	81	
7	29	51	343	2·1997	89	
8	26	43	382	94	6·9896	
9	23	35	421	91	6·9904	
10	8·508 4221	8·508 7626	1·84461	2·1988	6·9912	
11	18	18	500	85	19	
12	15	10	540	82	27	
13	12	8·508 7602	579	79	34	
14	10	8·508 7594	619	76	42	
15	07	86	658	73	50	
16	04	78	698	70	57	
17	8·508 4201	69	738	66	65	
18	8·508 4199	61	778	63	73	
19	96	52	817	60	80	
20	8·508 4193	8·508 7544	1·84857	2·1957	6·9988	7·320
21	90	36	897	54	6·9995	
22	88	28	937	51	7·0003	
23	85	20	1·84976	48	11	
24	82	12	1·85016	45	18	
25	80	8·508 7504	056	42	26	
26	77	8·508 7495	096	39	34	
27	74	87	136	36	41	
28	71	79	176	33	49	
29	69	71	216	29	57	
30	8·508 4166	8·508 7462	1·85256	2·1926	7·0064	
31	63	54	296	23	72	
32	60	46	336	20	80	
33	58	38	376	17	88	
34	55	30	416	14	7·0095	
35	52	22	456	11	7·0103	
36	50	14	497	08	11	
37	47	8·508 7406	537	04	19	
38	44	8·508 7398	577	2·1901	26	
39	42	90	618	2·1898	34	
40	8·508 4139	8·508 7382	1·85658	2·1895	7·0142	7·307
41	36	74	698	92	50	
42	34	66	739	89	57	
43	31	58	779	85	65	
44	28	50	819	82	73	
45	26	42	860	79	81	
46	23	34	900	76	88	
47	20	26	941	73	7·0196	
48	18	18	1·85981	70	7·0204	
49	15	10	1·86022	66	12	
50	8·508 4112	8·508 7302	1·86063	2·1863	7·0220	
51	10	8·508 7294	103	60	27	
52	07	86	144	57	35	
53	04	77	185	54	43	
54	8·508 4101	69	225	50	51	
55	8·508 4099	61	266	47	59	
56	96	53	307	44	67	
57	93	45	348	41	75	
58	91	38	389	38	82	
59	88	30	430	34	90	
60	8·508 4086	8·508 7222	1·86470	2·1831	7·0298	7·293

LATITUDE 71°

Lat.	log A diff. 1″ = −0·04	log B diff. 1″ = −0·13	log C diff. 1″ = +0·70	log D diff. 1″ = −0·05	log E diff. 1″ = +0·13	log F diff. 10′ = −7·2
° ′						
71 00	8·508 4086	8·508 7222	1·86470	2·1831	7·0298	7·293
1	83	14	511	28	7·0306	
2	80	8·508 7206	552	25	14	
3	78	8·508 7198	593	21	22	
4	75	90	634	18	30	
05	72	82	675	15	38	
6	70	74	717	12	46	
7	67	66	758	08	54	
8	64	58	799	05	62	
9	62	50	840	2·1802	70	
10	8·508 4059	8·508 7142	1·86881	2·1799	7·0378	
11	57	34	923	95	85	
12	54	27	1·86964	92	7·0393	
13	51	19	1·87005	89	7·0401	
14	49	11	046	86	09	
15	46	8·508 7103	088	82	17	
16	43	8·508 7095	129	79	25	
17	41	87	171	76	33	
18	38	79	212	72	41	
19	36	72	254	69	49	
20	8·508 4033	8·508 7064	1·87295	2·1766	7·0457	7·279
21	30	56	337	62	65	
22	28	48	378	59	73	
23	25	40	420	56	82	
24	23	33	462	52	90	
25	20	25	503	49	7·0498	
26	17	17	545	46	7·0506	
27	15	09	587	42	14	
28	12	8·508 7002	629	39	22	
29	10	8·508 6994	671	36	30	
30	8·508 4007	8·508 6986	1·87712	2·1732	7·0538	
31	05	78	754	29	46	
32	8·508 4002	71	796	26	54	
33	8·508 3999	63	838	22	62	
34	97	55	880	19	70	
35	94	47	922	16	79	
36	92	40	1·87964	12	87	
37	89	32	1·88006	09	7·0595	
38	86	24	049	06	7·0603	
39	84	16	091	2·1702	11	
40	8·508 3981	8·508 6908	1·88133	2·1699	7·0619	7·265
41	79	8·508 6901	175	95	27	
42	76	8·508 6893	217	92	36	
43	74	85	260	89	44	
44	71	78	302	85	52	
45	68	70	344	82	60	
46	66	62	387	78	68	
47	63	55	429	75	77	
48	61	47	472	72	85	
49	58	40	514	68	7·0693	
50	8·508 3956	8·508 6832	1·88557	2·1665	7·0701	
51	53	24	599	61	09	
52	51	17	642	58	18	
53	48	09	685	54	26	
54	46	8·508 6802	727	51	34	
55	43	8·508 6794	770	48	42	
56	41	86	813	44	51	
57	38	79	855	41	59	
58	36	71	898	37	67	
59	33	64	941	34	75	
60	8·508 3930	8·508 6756	1·88984	2·1630	7·0784	7·250

APPENDIX No. 10—1894.

GEOGRAPHIC POSITIONS OF TRIGONOMETRIC POINTS IN THE STATE OF MASSACHUSETTS, DETERMINED BY THE UNITED STATES COAST AND GEODETIC SURVEY BETWEEN THE YEARS 1843 AND 1894, AND INCLUDING THOSE DETERMINED BY THE SURVEY MADE BY BORDEN IN THE YEARS 1832 TO 1838.

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APPENDIX No. 10—REPORT FOR 1894.

GEOGRAPHIC POSITIONS OF TRIGONOMETRIC POINTS IN THE STATE OF MASSACHUSETTS, DETERMINED BY THE UNITED STATES COAST AND GEODETIC SURVEY BETWEEN THE YEARS 1843 AND 1894, AND INCLUDING THOSE DETERMINED BY THE SURVEY MADE BY BORDEN IN THE YEARS 1832 TO 1838.

Second enlarged and revised edition, with three plates. Submitted for publication February 3, 1893.

INTRODUCTION, AND EXPLANATION OF THE TABLE OF POSITIONS.

The geographic positions in the State of Massachusetts herewith presented were determined by the United States Coast and Geodetic Survey between the years 1843 and 1894, and include the work of the Borden Survey of the years 1832 to 1838. A first edition was published by the Survey as Appendix No. 8, Report for 1885, which contained the results reached to the end of that year.* In the present second edition, enlarged and revised, the latest observations made since 1885 and in connection with the Massachusetts State survey, are incorporated. Prior to, during, and after 1890 the State of Massachusetts was engaged upon a trigonometric survey of its township boundaries which is based on the standard data of the Coast and Geodetic Survey. The Borden, the Coast and Geodetic, and the Massachusetts State surveys, being based on the same standard geodetic data, form a systematic whole. After 1890 the cooperation of the Coast and Geodetic Survey with the Massachusetts State survey ceased. This addition to the field-work necessitated in many cases a readjustment or an additional adjustment of part of the secondary and tertiary triangulations, due to remeasures of old angles or measures of new ones, in order to complete former weak figures. In most cases the reaction on the results of positions already published was small, and within the limits of accuracy assigned to them in the preface to the first edition.

All results depend on the standard geodetic data of the Survey, and in particular on the data adopted for the Atlantic Coast; they are given below.

Unit of length.—The unit of length now adopted on the Survey is the international metre,† or, in this country, since January 2, 1890, its representative, the national prototype metre No. 27; fortunately, the length of the committee metre, standarded in France in 1799 and brought to the United States in 1805 by the first Superintendent of the Survey, and used here up to the time of the adoption of the national prototype metre, was found to be so nearly equal to the length of the latter‡ that none but the most refined results of the Survey would need a small correction. The change produces no sensible effect upon the results here presented.

* Excepting a piece of triangulation of 1885, received too late for publication.

† Bulletin No. 26. Fundamental standards of length and mass (April 5, 1893).

‡ The difference is probably less than a micron, i. e., less than one-millionth part of the length. See Bulletin No. 17, October, 1889.

Geodetic surface of reference.—The geometric surface or spheroid of rotation most nearly conforming to the earth's surface as a whole, and upon which the triangulations of the Survey have been developed since February, 1880, for the purpose of computing the latitudes and longitudes of the points of triangulation, is that deduced in 1866 by Capt. A. R. Clarke, R. E., and from which the later result given in his "Geodesy" (1880) differs but slightly. The Besselian spheroid which had been used for some time on the Survey prior to 1880 was found to be too small for our middle latitudes. The dimensions of the Clarke spheroid of 1866 are as follows:

a = Equatorial semidiameter,*	6 378 206·4 metres	$\log a = 6{\cdot}804\ 698\ 57$
b = Polar semi-axis,	6 356 583·8 metres	$\log b = 6{\cdot}803\ 223\ 78$
$a : b = 294{\cdot}98 : 293{\cdot}98$		

The standard latitude is that of the primary triangulation along the Atlantic Coast, viz: Principio station, $\varphi_0 = 39° 35' 36{\cdot}''692$ (see Appendix No. 8, Report for 1879).

The standard longitude is that resulting from the adjusted telegraphic longitude system which connects directly with Greenwich as the initial or zero meridian. We have for Principio station $\lambda_0 = 76° 00' 16{\cdot}''407$ west of Greenwich (see Appendix No. 11, Report for 1884).

The standard azimuth is that of the primary triangulation, viz: Principio to Turkey station $\alpha_0 = 1° 34' 36{\cdot}''413$ (see Appendix No. 8, Report for 1879).

The older publications by this Office of geographic positions in Appendix No. 12, Report for 1851, Appendix No. 15, Report for 1864, and Appendix No. 13, Report for 1868, are therefore superseded as based upon a different spheroid as well as upon different standard data from those now in use. Nor had the old results been subjected to thorough adjustment. All of the results published in the report of 1885 are reproduced here, improved or corrected when necessary, and to those 1 564 new positions are added.†

Respecting elevations of stations above the half tide or average sea level, the Survey is not at present in a condition to furnish them accurately. Copies of descriptions of stations, how marked on the surface and below ground, can generally be given on application to the Survey Office.

The additional work of triangulation done in and since the year 1885 was for the most part confined to the eastern section of the State, but owing to its minuteness demanded a larger scale projection to clearly distinguish it than was required for the preceding edition. Two of the accompanying triangulation sketches‡ are on the scale of 1:150 000. The first contains the region about Cape Cod, the second that of Cape Ann, while the third sketch, on a scale of 1:300 000, is a copy from the former publication, and comprises the middle and western part of the State. The positions and connecting lines of all adjusted stations are shown on these maps. All less important points, or in regions where much crowded, are simply shown by dots.

The results of the computation of the primary triangulation are contained in Appendix No. 21, Report for 1865, from which article the *lengths* of the triangle sides upon which the survey in Massachusetts depends have been taken.

In a general way and sufficient for illustration we may explain the process of computing and of producing systematic results as follows: The position of that particular trigonometrical station which is connected *most strongly* with the main triangulation is first fixed by adjustment, taking into consideration the lines directed to it from primary stations as well as lines diverging from it and intersecting the latter. Should there be more than one such point, say two or more, having equal strength of connection, they may be treated together in one least-square adjustment. In this manner point after point or a series of such is adjusted in position, so that the sum of the squares of the corrections to the observed horizontal directions shall be a minimum; the geometrical relations of the *preceding* points being always considered as fixed with respect to the variable elements of the new point or points next under treatment. The principal secondary stations having thus become known in position, the tertiary positions are determined in the same systematic, though somewhat less elaborate, manner as that followed for the secondaries, and generally without least square adjustment.

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* We suppose here the metres to be prototype metres.

† Eleven positions determined in 1894 were added while this report passed through the press.

‡ The positions were plotted and connecting lines run in by Mr. J. B. Boutelle.

The final result of this systematic treatment may be summarized by stating that no discrepancy remains in the results themselves, and that the length and direction of any side of a triangle may be computed from any starting side, and through any series of connecting triangles, and yet the same results will be reached.

The latitudes and longitudes of the trigonometric points were computed by the usual formulæ, aided by the tables ordinarily employed in the Survey, for which see Appendix No. 7, Report for 1884, but preferably the preceding Appendix No. 9 of this report. For primary sides, not exceeding in length (s) 100 or 150 kilometres (about 62 or 93 statute miles), the formulæ for difference of latitude ($\Delta\varphi$), difference of longitude ($\Delta\lambda$), and difference of azimuth ($\Delta\alpha$), are very accurate or sufficiently perfect for the purpose; these are:*

$$-\Delta\varphi = s\cos\alpha\,.\,\mathrm{B} + s^2\sin^2\alpha\,.\,\mathrm{C} + (\delta\varphi)^2\,\mathrm{D} - h\,s^2\sin^2\alpha\,.\,\mathrm{E}$$
$$\Delta\lambda = s\sin\alpha\sec\varphi'\,.\,\mathrm{A}$$
$$-\Delta\alpha = \Delta\lambda\sin\tfrac{1}{2}(\varphi+\varphi')\sec\tfrac{1}{2}(\Delta\varphi) + (\Delta\lambda)^3.\mathrm{F}$$

where $-\delta\varphi = s\cos\alpha\,\mathrm{B} + s^2\sin^2\alpha\,\mathrm{C}$ nearly and $h = s\cos\alpha\,\mathrm{B}$

hence the results for the new position

$$\varphi' = \varphi + \Delta\varphi$$
$$\lambda' = \lambda + \Delta\lambda$$
$$\alpha' = \alpha + \Delta\alpha + 180^\circ$$

For sides not exceeding 25 or 30 kilometres (about 15 or 19 statute miles) the fourth term in the expression for $\Delta\varphi$ may be omitted, also the factor sec $\frac{1}{2}(\Delta\varphi)$, as well as the second term in the expression for $\Delta\alpha$. For full explanation, forms, examples, and auxiliary tables the reader may consult the latest appendix cited above.

There also is shown the inverse problem, viz, given φ and λ and φ' and λ' (or φ, φ', and $\Delta\lambda$) to find s and α and α'. This process may be used in cases where the required distance and azimuths are not directly contained in the table of results.

For the direct solution put:

$$\begin{cases} s\cos\alpha = x = -\dfrac{1}{\mathrm{B}}(\Delta\varphi + \mathrm{C}\,.\,y^2 + \mathrm{D}\,(\Delta\varphi)^2 + \mathrm{E}\,(\Delta\varphi)y^2 + \mathrm{E\ C}\ y^4) \\ s\sin\alpha = y = \dfrac{\Delta\lambda\cos\varphi'}{\mathrm{A}} \end{cases}$$

whence

$$\tan\alpha = \frac{y}{x} \quad \text{and} \quad s = x\sec\alpha = y\,\mathrm{cosec}\,\alpha$$

In secondary and tertiary work the terms in E may be omitted.

For convenience of computing secondary and tertiary positions, the logarithms of factors A, B, C, D, E are here reproduced for the limiting latitudes 40° 55′ to 42° 55′ so as to cover the parallels of Connecticut, Rhode Island, and Massachusetts, and two applications are added, one to exemplify the direct, the other the inverse, process. In the first case we start from a known point (φ λ) and determine the position (φ' λ') of a second point, the distance (s) and direction (α) of which from the given point are known from triangulation; in the second case we have given the positions of two points (φ λ and φ' λ') and require the distance (s) between them and their directions (α α'). For further explanation Appendix No. 9, Report for 1894, should be consulted.

* With slightly changed notation conformably to more modern practice, as given in Appendix No. 9.

Table of log factors for the computation of geodetic positions, between latitudes 40° 55′ and 42° 55′.

φ		log A diff. for 1″, −0·07	log B diff. for 1″, −0·21	log C diff. for 1″, +0·42	log D	log E
°	′					
40	55	8·509 0952	8·510 7819	1·34231	2·3880	6·1236
	56	947	806	256		
	57	943	793	282		
	58	939	781	307		
	59	934	768	332		
41	00	8·509 0930	8·510 7755	1·34358	2·3882	6·1253
	01	926	742	383		
	02	922	730	408		
	03	918	717	434		
	04	913	704	459		
41	05	8·509 0909	8·510 7691	1·34484	2·3883	6·1271
	06	905	679	510		
	07	900	666	535		
	08	896	653	560		
	09	892	640	586		
41	10	8·509 0888	8·510 7628	1·34611	2·3885	6·1289
	11	883	615	636		
	12	879	602	662		
	13	875	590	687		
	14	871	577	712		
41	15	8·509 0867	8·510 7564	1·34738	2·3887	6·1306
	16	862	551	763		
	17	858	539	788		
	18	854	526	814		
	19	849	513	839		
41	20	8·509 0845	8·510 7500	1·34864	2·3889	6·1324
	21	841	488	890		
	22	837	475	915		
	23	832	462	940		
	24	828	449	965		
41	25	8·509 0824	8·510 7436	1·34991	2·3890	6·1342
	26	820	424	1·35016		
	27	815	411	041		
	28	811	398	066		
	29	807	385	092		
41	30	8·509 0803	8·510 7373	1·35117	2·3892	6·1360
	31	798	360	142		
	32	794	347	168		
	33	790	334	193		
	34	786	322	218		
41	35	8·509 0781	8·510 7309	1·35243	2·3893	6·1378
	36	777	296	269		
	37	773	283	294		
	38	769	270	319		
	39	764	258	345		

Table of log factors for the computation of geodetic positions, etc.—Continued.

φ		log A diff. for 1″, −0·07	log B diff. for 1″, −0·21	log C diff. for 1″, +0·42	log D	log E
°	′					
41	40	8·509 0760	8·510 7245	1·35370	2·3895	6·1395
	41	756	232	395		
	42	752	219	420		
	43	747	207	446		
	44	743	194	471		
41	45	8·509 0739	8·510 7181	1·35496	2·3897	6·1413
	46	735	168	522		
	47	730	155	547		
	48	726	143	572		
	49	722	130	597		
41	50	8·509 0718	8·510 7117	1·35623	2·3898	6·1431
	51	713	104	648		
	52	709	091	673		
	53	705	079	698		
	54	700	066	723		
41	55	8·509 0696	8·510 7053	1·35749	2·3900	6·1449
	56	692	040	774		
	57	688	027	799		
	58	683	015	824		
	59	679	8·510 7002	850		
42	00	8·509 0675	8·510 6989	1·35875	2·3901	6·1467
	01	671	976	900		
	02	666	964	925		
	03	662	951	951		
	04	658	938	1·35976		
42	05	8·509 0654	8·510 6925	1·36001	2·3902	6·1485
	06	649	912	026		
	07	645	900	052		
	08	641	887	077		
	09	636	874	102		
42	10	8·509 0632	8·510 6861	1·36127	2·3903	6·1503
	11	628	848	152		
	12	624	836	178		
	13	619	823	203		
	14	615	810	228		
42	15	8·509 0611	8·510 6797	1·36253	2·3905	6·1521
	16	607	784	278		
	17	602	772	304		
	18	598	759	329		
	19	594	746	354		
42	20	8·509 0590	8·510 6733	1·36379	2·3906	6·1539
	21	585	720	404		
	22	581	707	430		
	23	577	695	455		
	24	572	682	480		

Table of log factors for the computation of geodetic positions, etc.—Continued.

φ	log A diff. for 1″, −0·07	log B diff. for 1″, −0·21	log C diff. for 1″, +0·42	log D	log E
° ′					
42 25	8·509 0568	8·510 6669	1·36505	2·3907	6·1557
26	564	656	530		
27	560	643	556		
28	555	631	581		
29	551	618	606		
42 30	8·509 0547	8·510 6605	1·36631	2·3908	6·1575
31	543	592	656		
32	538	579	682		
33	534	566	707		
34	530	554	732		
42 35	8·509 0525	8·510 6541	1·36757	2·3909	6·1593
36	521	528	782		
37	517	515	808		
38	513	502	833		
39	508	490	858		
42 40	8·509 0504	8·510 6477	1·36883	2·3910	6·1612
41	500	464	908		
42	496	451	934		
43	491	438	959		
44	487	425	1·36984		
42 45	8·509 0483	8·510 6413	1·37009	2·3912	6·1630
46	478	400	034		
47	474	387	059		
48	470	374	085		
49	466	361	110		
42 50	8·509 0461	8·510 6348	1·37135	2·3913	6·1648
51	457	336	160		
52	453	323	185		
53	448	310	210		
54	444	297	235		
42 55	8·509 0440	8·510 6284	1·37261	2·3914	6·1666

Log F = 7·86 within the limits of the table.

Specimen of position computation for secondary and tertiary triangulation.* Form for direct computation.

		°	′	″
α	School-house Hill to Box Hill.	230	00	56·6
$\angle$	Talcott and Box Hill.	— 79	58	58·4
α	School-house Hill to Talcott.	150	01	58·2
$\triangle\alpha$		—	4	42·4
		180		
α'	Talcott to School-house Hill.	329	57	15·8

	°	′	″			°	′	″
φ	41	39	31·321	School-house Hill.	λ	72	40	52·913
$\triangle\varphi$	+	9	10·316	*Metres.*	$\triangle\lambda$	+	7	04·273
				19 606·04				
φ'	41	48	41·637	Talcott.	λ'	72	47	57·186

	°	′	″						
				s	4·292 389 8	s^2	8·5848		
$\frac{1}{2}(\varphi+\varphi') =$	41	44	06	Cos α	$_n$9·937 674 2	Sin^2 α	9·3971	$(\delta\varphi)^2$	5·48
				B	8·510 725 1	C	1·3536	D	2·39
			″		$_n$2·740 789 1		9·3355		7·87
1st term.			−550·540				+0·217		+0·007
2d & 3d terms.			+ 0·224						
$-\triangle\varphi$			−550·316						

s	4·292 389 8		
Sin α	9·698 538 7		
A	8·509 072 3	$\triangle\lambda$	2·627 65
Sec φ'	0·127 644 7	Sin $\frac{1}{2}(\varphi+\varphi')$	9·823 27
	2·627 645 5		2·450 92
	″		″
$\triangle\lambda$	+424·273	$-\triangle\alpha$	+282·4

N. B.—A is to be taken out for φ'.

* For primary triangulation forms see preceding Appendix No. 9, Report for 1894.

Position computation. Form for inverse solution.

		°	′	″
α	Stamford Harbor L. H. to Round Hill 2.	132	15	36·2
$\triangle\alpha$		—	5	09·7
		180		
′	Round Hill 2 to Stamford Harbor L. H.	312	10	26·5

	°	′	″			°	′	″
φ	41	00	49·212	Stamford Har. L. H.	λ	73	32	34·740
$\triangle\varphi$	+	5	23·810	*Metres.*	$\triangle\lambda$	+	7	51·490
				14 865·77				
φ'	41	06	13·022	Round Hill 2.	λ'	73	40	26·230

$\frac{1}{2}(\varphi+\varphi') = 41\ 03\ 31$		$\left.\begin{matrix}s\\ \text{Cos}\ \alpha\end{matrix}\right\}$	$_n3{\cdot}999\ 877\ 8$	$\left.\begin{matrix}s^2\\ \text{Sin}^2\ \alpha\end{matrix}\right\}$	8·0830	$(\delta\varphi)^2$	5·02
		B	8·510 774 4	C	1·3438	D	2·39
			$_n2{\cdot}510\ 652\ 2$		9·4268		7·41
1st term.	″ — 324·080						
2d & 3d terms.	+ 0·270				+ 0·267		+ 0·003
$-\triangle\varphi$	— 323·810						

$\left.\begin{matrix}s\\ \text{Sin}\ \alpha\end{matrix}\right\}$	4·041 478 0			$s.\ \sin\alpha$	4·041 478 0
				$s.\ \cos\alpha$	$_n3{\cdot}999\ 877\ 8$
A′	8·509 090 4	$\triangle\lambda$	2·673 47	$\tan\alpha$	$_n0{\cdot}041\ 600\ 2$
Sec φ'	0·122 904 1	Sin $\frac{1}{2}(\varphi+\varphi')$	9·817 45	α	132° 15′ 36″·2
	2·673 472 5		2·490 92	Sin α	9·869 290 5
	″		″	s	4·172 187 5
$\triangle\lambda$	+ 471·490	$-\triangle\alpha$	+ 309·7		

N. B.—A is to be taken out for φ'.

We have also the length of the angular measures of one minute in the meridian and in the parallel φ, given by the formulæ

$$1' \text{ of the meridian} = 1852^{m}\cdot2015 - 9^{m}\cdot4342 \cos 2\varphi + 0^{m}\cdot020 \cos 4\varphi - \ldots$$

$$1' \text{ of the parallel} = 1856^{m}\cdot9183 \cos \varphi - 1^{m}\cdot5757 \cos 3\varphi + 0^{m}\cdot002 \cos 5\varphi - \ldots$$

whence the following tabular values expressed in metres:

Latitude.	Arc of 1′	
	In meridian.	In parallel.
° ′	*m*	*m*
40 00	1850·54	1423·27
20	0·65	16·33
40	0·76	09·34
41 00	0·87	1402·29
20	0·98	1395·20
40	1·09	88·07
42 00	1·19	80·89
20	1·30	73·66
40	1·41	66·38
43 00	1851·52	1359·05

The effect of the earth's curvature may be estimated from the fact that the area of a triangle in latitude 40° having one second (1″) of spherical excess, is 76·060 square statute miles; in latitude 41°, 76·078 square statute miles, and in latitude 42°, 76·096 square statute miles. The shape of the triangle is of no consequence. To convert square statute miles into square kilometres we have the relations, 1 sq. st. mile = 2·589 998 sq. km., and 1 sq. km. = 0·386 101 sq. st. miles.

The spherical excess ε of a triangle whose sides are A and B and included angle c is given by the formula

$$\varepsilon = \frac{A\ B \sin c}{2a^2 (1 - \frac{1}{2}e^2 \cos 2\varphi)^2 \operatorname{arc} 1''}, \text{ expressed in seconds.}$$

$$\text{Putting } m = \frac{1}{2a^2 (1 - \frac{1}{2}e^2 \cos 2\varphi)^2 \operatorname{arc} 1''} \quad \text{we have} \quad \varepsilon = m\ A\ B \sin c$$

φ		log m.
°	′	
40	0	1·40452
40	30	446
41	0	441
41	30	436
42	0	431
42	30	426
43	0	421

To facilitate reference to the table an alphabetical index to stations is supplied and these have been subdivided geographically as follows:

	No. of Stations.		No. of Stations.
1. Primaries	13	12. Cape Ann and vicinity	41
2. Subordinate primaries and secondaries	20	13. Coast north of Cape Ann	169
3. Nantucket and vicinity	56	14. Massachusetts and New Hampshire boundary	114
4. Marthas Vineyard and Vineyard Sound	108	15. Worcester and Middlesex counties	10
5. Buzzards Bay	203	16. Connecticut River Valley	166
6. Massachusetts and Rhode Island boundary	92	17. Massachusetts, New York, and Connecticut boundary	15
7. Taunton River	211	Connections with surrounding States	65
8. Cape Cod Bay and Peninsula	376		2726
9. Cape Cod Bay to Boston Bay	549		
10. Boston Bay	469		
11. Salem and vicinity	49		

Observers and years of observation.

Observer.	Year.	Observer.	Year.
A. D. Bache	1844-45-46-47, 1862.	B. A. Gould	1864-65.
F. Blake, jr.	1877-78.	I. W. Gregorie	1850.
E. Blunt	1843, 1845, 1861-62-63.	A. M. Harrison	1876.
C. P. Bolles	1848-49.	C. Hosmer	1860.
S. Borden	1832-33-34-35-36-37-38.	W. E. McClintock	1887-88.
C. O. Boutelle	1845-46-47-48-49-50-51, 1860-61, 1867.	S. C. McCorkle	1870, 1878.
C. H. Boyd	1861, 1868.	H. L. Marindin	1880.
G. Bradford	1884, 1886-87.	R. A. Marr	1887.
E. L. Brown	1889.	F. J. Norris	1894.
C. L. Carpenter	1886.	E. E. Peirce	1888-89-90.
T. J. Cram	1847-48-49.	F. W. Perkins	1885.
R. D. Cutts	1874, 1876-77.	S. Petersen	1887.
G. Davidson	1846-47.	E. T. Quimby	1886.
F. J. Davis	1886.	J. B. Rogers	1886.
G. W. Dean	1848.	C. H. Sinclair	1876.
C. M. Eakin	1844-45-46.	W. H. Stearns	1874.
G. A. Fairfield	1849-50, 1877.	J. A. Sullivan	1875.
G. W. Fernald	1886.	O. H. Tittmann	1894.
H. E. Gage	1886.	J. B. Tolley	1885, 1888-89-90.
H. R. Garland	1887.	C. H. Van Orden	1885, 1887-88-89-90-91.
E. Goodfellow	1870.	J. B. Weir	1886.

Number of stations occupied	1 467
Number of triangles formed	7 231

of which 447 belong to the Borden survey. Of the occupied stations 103 are Borden stations, and 43 are common to both surveys. A number of computers was engaged upon this work, but the principal share of the work fell to Mr. E. H. Courtenay of the Computing Division, to whose zeal, industry, and scrupulous care much of the accuracy of the results is due. The results now communicated were deduced in 1884, 1885, 1886, 1889, 1890, 1891, 1892, and 1894.

Respecting the accuracy of a triangulation the mean error m of an adjusted or resulting angle has been advantageously employed as a quantity of comparison for different triangulations by which to judge of their relative value (see, e. g., Coast and Geodetic Survey Report for 1884, p. 389). The value m may be deduced in various more or less accurate ways, according to circumstances; in adjusted triangulations it may be readily deduced from

$$m = 1{\cdot}25\sqrt{\frac{2}{n.\ s}}\cdot\Sigma[c$$

where $\Sigma[c$ is the sum of corrections, *irrespective of signs*, to observed *directions*, n the number of conditional equations involved, and s the number of directions in the adjusted figure. In unadjusted work, it may be found from

$$m = \sqrt{\frac{\Sigma e^2}{3\ t}}$$

or, without squaring, from

$$m = 1{\cdot}25\ \frac{[e}{t\sqrt{3}}$$

where e = triangle closing error (or difference from $\pi + \varepsilon$), to be taken with *positive* sign in last formula, and t = number of triangles. We thus find for the adjusted triangulation of the Coast and Geodetic Survey, but *exclusive* of the primary triangulation, for Massachusetts, the value of $m = \pm\ 3''{\cdot}7$, and for its unadjusted work $m = \pm\ 3''{\cdot}9$; similarly for the Borden survey we find the average values $m = \pm\ 6''{\cdot}0$ and $m = \pm\ 6''{\cdot}4$ for adjusted and unadjusted work, respectively.

The accuracy of the triangulation may otherwise be roughly expressed in terms of the distance, and thus estimated the average error of secondary work may range between $\frac{1}{40\,000}$ and $\frac{1}{20\,000}$ of the length, while that of tertiary work may be estimated as low as $\frac{1}{10\,000}$ or less near its inferior limit.

There remain but a few words to be added explanatory of the table of results. Column 1 contains the names of the stations, column 2 the latitude, column 4 the longitude, columns 3 and 5 contain the equivalents in metres of the seconds (in arc) of latitude and longitude respectively, solely for the use of the draftsman in projections; column 6 gives the azimuth of the first to the second named station, counted from south round by west from 0° to 360°; it is followed by the reverse azimuth in the next column. The distances are all referred to the surface of the spheroid at the average sea level. Those who may prefer the English foot as the unit of length can readily make the conversion from one unit into the other by means of the following tables:

1 m. =	3·280 83 ft.	1 ft. =	0·304 801 m.
2	6·561 67	2	0·609 601
3	9·842 50	3	0·914 402
4	13·123 33	4	1·219 202
5	16·404 17	5	1·524 003
6	19·685 00	6	1·828 804
7	22·965 83	7	2·133 604
8	26·246 67	8	2·438 405
9	29·527 50	9	2·743 205
10	32·808 33	10	3·048 006

and for the conversion of kilometres into statute miles, and *vice versa:*

1 km.	= 0·621 370 st. m.	1 st. m.	= 1·609 347 km.
2	1·242 740	2	3·218 694
3	1·864 110	3	4·828 042
4	2·485 480	4	6·437 388
5	3·106 850	5	8·046 736
6	3·728 219	6	9·656 083
7	4·349 589	7	11·265 430
8	4·970 959	8	12·874 778
9	5·592 329	9	14·484 125
10	6·213 699	10	16·093 472

C. A. SCHOTT, *Assistant.*

COMPUTING DIVISION, COAST AND GEODETIC SURVEY OFFICE, *February 3, 1895.*

N. B.—The following errata refer to Appendix No. 8, Report for 1885, containing the geodetic positions in Massachusetts and Rhode Island:

p. 288, line 17, for 125 read 1·25.
p. 294, line 13, for 370 read 372.
p. 308, line 8 from bottom, for 57·08 read 57·111, for 1761·3 read 1762·4, for 18·76 read 18·756, and for 425·9 read 425·8.
p. 310, line 4, for 231·8 read 27·7.
p. 325, line 21, for 192° read 292°.
p. 327, line 23 from bottom, for 281° read 285°.
p. 329, line 17, for 7706·5 read 7724·3.
p. 337, line 8 from bottom, for 173° read 175°.
p. 340, line 10, for 20° read 70°.
p. 340, line 15, for 21° read 71°.
p. 341, line 8, for 307° read 207°.
p. 341, line 8 from bottom, for 132° read 134°.
p. 343, line 13, for 235° read 325°.
p. 344, line 11, for 71° 07′ read 71° 02′.
p. 344, bottom line, for 26″·68 read 28″·68.
p. 345, line 6 from bottom, for 314° read 313°.
p. 358, line 8 from bottom, for 833·0 read 883·0.
p. 359, line 16 from bottom, for 109° read 105°.
p. 362, line 8 from bottom, for 48·13 read 58·13.
p. 366, line 3 from bottom, for 1243·2 read 1551·7.
p. 377, line 5, for 13911·3 read 13011·2.
p. 381, line 5, for 104° read 101°.
p. 381, line 8 from bottom, for 351·5 read 531·6.
p. 413, line 12, for 127° read 126°.
p. 424, line 4, for 414″·328 read 41″·328.
p. 424, line 5 wrong; for correct position see bottom of p. 430.
p. 424, line 13, for 1709·5 read 1609·5.
p. 425, line 18, for 3404·1 read 3104·1.
p. 425, line 21, for 45′ 30″ read 4° 45′ 30″.
p. 430, bottom line, for 1861 read 1861–69.

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TABLE OF GEOGRAPHIC POSITIONS

DETERMINED IN THE

STATE OF MASSACHUSETTS

AND

CONNECTIONS WITH STATIONS IN SURROUNDING STATES.

TRIANGULATIONS OF 1832–1890

AND OF 1894.

PRIMARY STATIONS.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Agamenticus, Me., astronomic azimuth and latitude station of 1847 (1847–'85).	43 13 24·630	760·1	70 41 32·907	742·6
Thompson, astronomic azimuth and latitude station of 1846. (1846–'50.)	42 36 41·924	1293·6	70 43 49·164	1120·6
Unkonoonuc, N. H., astronomic azimuth and latitude station of 1848 (1848–'86).	42 58 59·864	1847·4	71 35 19·380	439·0
Blue Hill, astronomic azimuth station of 1845. 1845–'85.	42 12 43·941	1355·7	71 06 52·638	1207·3
Wachusett, astronomic azimuth station of 1860 (C. & G. S. & Bdn.), 1833–'60.	42 29 20·784	641·4	71 53 13·984	319·4
Wachusett, astronomic latitude station of 1860.	42 29 19·836	612·1	71 53 12·232	279·3
Monadnock, N. H. 1860–'85.	42 51 41·174	1270·6	72 06 30·776	698·6
Mount Tom, astronomic azimuth station of 1862. 1860–'85.	42 14 30·798	950·2	72 38 55·056	1262·3
Mount Tom, astronomic latitude station of 1862.	42 14 29·892	922·3	72 38 55·614	1275·1
Bald Hill (Tolland County), Conn. 1860–'64.	41 58 25·890	798·9	72 11 55·027	1266·9
Box Hill, Conn. 1861–'75.	41 47 59·794	1844·9	72 27 21·404	494·1
Sandford, Conn., astronomic azimuth station of 1862 (1861–'65).	41 27 42·801	1320·4	72 56 59·304	1376·3
Ivy, Conn. 1861–'65.	41 52 18·500	570·7	73 13 27·926	644·0
Beaconpole, R. I., astronomic azimuth station of 1844 (1844–'89).	41 59 42·468	1310·2	71 27 01·257	28·9
Great Meadow. (C. & G. S. & Bdn.), 1836–'90.	41 52 45·138	1392·7	71 13 02·292	52·9
Copecut, astronomic azimuth station of 1844. (C. & G. S. & Bdn.), 1837–'90.	41 43 17·245	532·1	71 03 36·644	847·1
Massachusetts North Base. 1844 (1844–'89).	42 03 06·592	203·4	71 12 24·871	572·0
Massachusetts South Base. 1844 (1844–'45).	41 54 49·921	1540·3	71 18 16·114	371·3
Manomet, astronomic latitude station of 1867. (C. & G. S. & Bdn.), 1835–'90.	41 55 38·699	1194·0	70 35 28·128	648·1
Greylock or Saddle Mountain. 1874–'82.	42 38 14·088	434·6	73 09 59·130	1347·2
Mount Equinox, Vt.. 1874–'83.	43 09 57·980	1789·2	73 07 02·708	61·2
Mount Rafinesque, N. Y. 1874–'82.	42 47 21·155	652·9	73 36 58·818	1336·8
Perry Peak. (C. & G. S. & Bdn.), 1837–'74.	42 25 15·648	482·8	73 22 48·781	1115·3
Yellow Pine, N. Y. 1862–'76.	42 29 28·727	886·4	73 40 27·902	637·3
Helderberg, N. Y. 1875–'82.	42 37 39·072	1205·7	74 00 38·487	877·0
Prospect, N. Y. 1875–'82.	43 25 17·949	554·0	73 46 04·570	102·8

PRIMARY STATIONS.

Azimuth.	Back azimuth	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
182 35 25·476	2 36 58·261	Agamenticus	68 041·91	4·832 776 5
249 36 12·618	70 12 57·351	Agamenticus	77 686·65	4·890 346 4
300 09 32·872	120 44 32·424	Thompson.	81 461·91	4·910 954 6
155 43 45·770	335 24 30·537	Unkonoonuc	94 078·56	4·973 490 7
215 21 29·380	35 37 02·480	Thompson.	54 491·94	4·736 332 3
203 54 04·099	24 06 13·358	Unkonoonuc	60 093·82	4·778 829 8
295 31 38·891	116 02 52·610	Blue Hill.	70 700·04	4·849 419 7
336 14 24·474	156 23 24·577	Wachusett	45 164·53	4·654 797 5
252 07 57·590	72 29 12·028	Unkonoonuc.	44 548·68	4·648 834 8
246 05 57·988	66 36 45·098	Wachusett	68 470·37	4·835 502 7
212 37 17·232	32 59 12·085	Monadnock.	81 877·61	4·913 165 2
128 48 17·330	308 30 11·049	Mount Tom	47 662·88	4·678 180 3
204 05 01·004	24 17 34·496	Wachusett.	62 740·03	4·797 544 7
162 03 16·319	341 55 31·984	Mount Tom	51 616·87	4·712 791 7
227 47 14·069	47 57 32·578	Bald Hill.	28 797·56	4·459 355 7
227 27 39·231	47 47 20·351	Box Hill	55 707·02	4·745 909 9
196 00 11·934	16 12 15·370	Mount Tom.	90 171·62	4·955 069 9
333 14 07·820	153 25 05·059	Sandford	50 949·29	4·707 138 2
276 52 14·769	97 23 00·053	Box Hill.	64 330·97	4·808 420 1
146 50 05·792	326 32 28·490	Wachusett	65 656·70	4·817 279 0
228 55 19·774	49 08 50·124	Blue Hill.	36 777·41	4·565 581 1
123 44 56·597	303 35 35·905	Beaconpole	23 223·72	4·365 931 8
192 54 36·214	12 58 43·781	Blue Hill.	37 951·70	4·579 231 2
133 18 14·851	313 02 37·562	Beaconpole	44 425·23	4·647 629 7
175 17 06·299	355 14 55·237	Blue Hill.	54 694·51	4·737 943 7
2 34 36·135	182 34 11·112	Great Meadow	19 193·11	4·283 145 4
72 44 05·443	252 34 18·759	Beaconpole.	21 123·09	4·324 757 5
207 47 11·966	27 51 06·916	Massachusetts North Base	17 326·376	4·238 707 7
126 46 54·940	306 41 03·861	Beaconpole.	15 091·32	4·178 727 3
59 44 30·308	239 25 44·316	Copecut	45 185·59	4·655 000 0
126 18 34·859	305 57 32·162	Blue Hill.	53 642·95	4·729 512 7
253 35 57·679	74 19 02·804	Monadnock	90 121·17	4·954 826 8
315 41 37·385	136 02 35·298	Mount Tom.	61 186·51	4·786 655 7
292 01 23·100	112 42 40·752	Monadnock	88 939·22	4·949 093 3
3 54 40·434	183 52 50·335	Greylock.	58 886·79	4·770 017 9
224 01 02·231	44 21 26·671	Mount Equinox	58 390·01	4·766 338 6
294 27 18·781	114 45 37·465	Greylock.	40 539·34	4·607 876 6
154 43 48·875	334 34 13·448	Mount Rafinesque	45 258·32	4·655 698 5
216 06 22·198	36 15 02·456	Greylock.	29 757·38	4·473 594 6
188 10 18·052	8 12 39·685	Mount Rafinesque	33 432·70	4·524 171 4
287 47 03·641	107 58 58·575	Perry Peak.	25 429·20	4·405 332 7
240 47 42·718	61 03 45·635	Mount Rafinesque	36 965·44	4·567 795 9
268 49 12·873	89 23 31·424	Greylock.	69 261·34	4·840 490 9
298 02 50·279	118 29 36·200	Mount Equinox	59 941·35	4·777 726 5
349 59 10·459	170 05 23·401	Mount Rafinesque.	71 335·75	4·853 307 3

SUBORDINATE PRIMARIES AND SECONDARIES.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Indian, astronomical azimuth station of 1845. (C. & G. S. & Bdn.), 1835–'87.	41 25 46·744	1442·0	70 40 40·699	945·0
Shootflying, astronomical azimuth station of 1845. 1845–'87.	41 41 07·334	226·2	70 20 49·738	1150·3
Nantucket Cliff. 1845–'75.	41 17 35·813	1104·8	70 06 53·793	1251·6
Holt. (C. &. G. S. & Bdn.), 1833–'90.	42 38 28·026	864·8	71 06 24·872	566·7
Nantasket. 1846–'77.	42 18 15·690	484·1	70 54 20·203	462·8
Prospect Waltham. (C. & G. S. & Bdn.), 1833–'90.	42 23 18·831	581·0	71 15 15·333	350·7
Orne. 1848–'77.	42 30 10·264	316·7	70 57 54·451	1243·1
Powderhorn. 1846–'61.	42 24 04·683	144·5	71 01 52·006	1189·3
Corey. 1847–'61.	42 20 33·376	1029·9	71 08 02·199	50·3
Cambridge Observatory, center of dome. Telegraphic longitude station, 1851–'72.	42 22 53·490	1650·6	71 07 43·885	1003·9
Sampson. 1845–'75.	41 22 41·830	1290·4	70 29 02·471	57·4
Hyannis. (C. & G. S. & Bdn.), 1835–'87.	41 37 53·339	1645·5	70 18 26·666	617·3
Nantucket (Great Point) light-house. (C. & G. S. & Bdn.), 1835–'87.	41 23 24·345	751·1	70 02 46·056	1070·0
Spencer, R. I., astronomical azimuth station of 1844.	41 40 43·256	1334·4	71 29 40·685	941·0
Quaker, R. I. (C. & G. S. & Bdn.), 1836–'74.	41 34 57·376	1770·1	71 15 18·337	424·7
McSparran, R. I. 1839–'44.	41 29 46·953	1448·5	71 27 24·737	573·7
Pocasset, R. I. (C. & G. S. & Bdn.), 1837–'87.	41 39 09·420	290·6	71 11 32·364	748·9
Cuttyhunk. (C. & G. S. & Bdn.), 1835–'87.	41 25 14·887	459·3	70 56 02·646	61·4
East Rock, R. I. 1843–'70.	41 27 04·650	143·4	71 11 38·340	889·9
Nootas. 1843–'44.	41 32 13·020	401·6	71 07 25·832	598·8
Mount Hope, R. I. 1843–'61.	41 40 26·130	806·1	71 14 26·209	606·2
Bald Peak or Mount Washington or Mount Everett or Taughannuc Mount or Dome Peak (C. & G. S. & Bdn.), 1837–'74.	42 06 07·301	225·3	73 25 59·109	1358·2
French Hill. (C. & G. S. & Bdn.), 1836-'74.	42 25 38·470	1187·0	73 02 16·447	375·9
Isles of Shoals, Me., astronomical latitude station of 1847. 1846–'50.	42 59 14·862	458·6	70 36 50·285	1139·2

SUBORDINATE PRIMARIES AND SECONDARIES.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
187 25 18·24	7 28 46·08	Manomet	55 755·26	4·746 285 8
135 36 04·33	315 20 51·24	Copecut.	45 458·21	4·657 612 3
44 17 20·61	224 04 10·56	Indian	39 601·75	4·597 714 4
143 03 20·31	322 53 34·76	Manomet.	33 673·18	4·527 284 1
156 04 20·29	335 55 06·49	Shootflying	47 668·76	4·678 233 8
108 00 24·87	287 38 05·47	Indian.	49 486·52	4·694 486 9
0 45 57·22	180 45 38·49	Blue Hill	47 647·90	4·678 043 8
275 55 18·82	96 10 36·93	Thompson.	31 066·38	4·492 290 6
59 22 52·32	239 14 26·33	Blue Hill	20 055·70	4·302 237 8
156 11 49·30	336 03 39·97	Holt.	40 906·81	4·611 795 6
329 30 20·54	149 35 58·86	Blue Hill	22 723·08	4·356 467 3
20 24 11·44	200 16 17·33	Beaconpole.	46 606·15	4·668 443 2
142 53 16·06	322 47 30·75	Holt	19 272·40	4·284 935 7
237 50 41·09	58 00 12·78	Thompson.	22 757·45	4·357 123 5
85 40 19·75	265 31 18·12	Prospect Waltham	18 427·94	4·265 476 7
18 10 41·64	198 07 19·29	Blue Hill.	22 104·06	4·344 472 1
232 22 39·62	52 26 49·11	Powderhorn	10 688·86	4·028 931 2
117 17 35·42	297 12 43·55	Prospect Waltham.	11 148·73	4·047 225 5
94 22 19·77	274 17 15·44	Prospect Waltham	10 356·65	4·015 219 1
356 25 24·69	176 25 59·18	Blue Hill.	18 844·17	4·275 177 0
286 52 09·96	107 06 47·50	Nantucket Cliff	32 305·24	4·509 273 0
109 26 33·38	289 18 51·59	Indian.	17 192·59	4·235 341 4
151 03 58·99	331 02 23·89	Shootflying	6 839·50	3·835 024 7
27 43 48·12	207 36 46·78	Sampson.	31 752·19	4·501 773 7
28 12 03·52	208 09 19·88	Nantucket Cliff	12 197·72	4·086 278 8
142 38 50·92	322 26 52·32	Shootflying.	41 309·46	4·616 049 5
185 57 36·34	5 59 22·68	Beaconpole	35 339·35	4·548 258 6
262 22 17·91	82 39 38·36	Copecut.	36 475·19	4·561 997 6
226 24 37·79	46 32 24·14	Copecut	22 393·41	4·350 120 2
118 12 27·73	298 02 54·85	Spencer.	22 634·29	4·354 766 8
171 10 21·59	351 08 51·35	Spencer	20 491·06	4·311 564 4
240 18 12·34	60 26 14·04	Quaker.	19 370·85	4·287 148 7
150 41 04·12	330 30 44·69	Beaconpole	43 666·53	4·640 148 7
235 09 32·46	55 14 48·84	Copecut.	13 397·89	4·127 036 5
123 56 41·52	303 43 55·71	Quaker	32 270·72	4·508 808 6
162 33 26·03	342 28 24·78	Copecut.	35 000·26	4·544 182 9
160 44 27·59	340 42 01·77	Quaker	15 450·37	4·188 938 8
278 46 25·33	98 56 44·56	Cuttyhunk.	21 986·15	4·342 149 1
309 04 33·44	129 12 05·94	Cuttyhunk	20 436·54	4·310 407 3
156 03 33·63	336 00 49·97	Pocasset.	14 058·13	4·147 927 5
6 47 22·05	186 46 47·42	Quaker	10 213·98	4·009 195 0
300 27 25·96	120 29 21·52	Pocasset.	4 666·63	3·669 003 3
155 21 59·47	335 12 14·80	Yellow Pine	47 600·92	4·677 615 4
187 00 04·08	7 02 12·09	Perry Peak.	35 699·39	4·552 660 8
155 40 41·39	335 35 28·62	Greylock	25 595·11	4·408 156 9
88 41 00·95	268 27 09·60	Perry Peak.	28 181·49	4·449 963 9
12 53 01·04	192 48 16·44	Thompson	42 819·83	4·631 645 0
166 19 50·29	346 16 37·16	Agamenticus.	26 990·73	4·431 214 6

SUBORDIDATE PRIMARIES AND SECONDARIES—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Powow. 1849–'50.	42 51 57·006	1758·9	70 56 18·812	427·0
Prospect Rowley. (C. & G. S. & Bdn.), 1834–'50.	42 42 19·154	591·0	70 53 33·128	754·0
Cape Poge light-house. 1845–'75.	41 25 16·028	494·5	70 27 05·704	132·4
Patuccawa, N. H. 1849–'86.	43 07 13·689	422·5	71 11 51·318	1160·1
Hampton Falls, N. H. 1850–'51.	42 54 44·372	1369·2	70 53 51·877	1176·7
College Hill, R. I. (C. & G. S. & Bdn.), 1835–'45.	41 50 18·850	581·6	71 24 00·627	14·5

NANTUCKET AND VICINITY.

Tuckanuck Telegraph. 1845.	41 18 14·507	447·5	70 15 08·473	197·1
Clark Cove.	41 15 20·474	631·7	70 10 43·165	1004·9
Windmill Range. 1845.	41 16 40·219	1240·8	70 06 49·575	1153·7
Weeweeder Pond. 1845.	41 14 35·284	1088·4	70 05 37·923	883·1
Gibbs Pond. 1845–1887.	41 16 53·650	1655·1	70 01 31·457	732·0
Squam Head. 1845.	41 19 33·485	1032·9	69 59 56·052	1303·5
Nantucket south-towered Unitarian church. (C. & G. S. & Bdn.) 1835–1887.	41 16 56·717	1749·7	70 05 58·086	1351·5
Shawaukemo. 1875–1887.	41 17 01·808	55·8	70 03 04·813	112·0
Sankaty Head light-house. 1867–1887.	41 17 01·217	37·5	69 57 56·535	1315·7
Water tank.	41 17 19·186	591·9	70 07 59·438	1383·1
Surfside Hotel.	41 14 39·573	1220·8	70 04 58·170	1354·5
Hummock.	41 15 10·761	332·0	70 10 01·207	28·1
Tuckanuck. 1887.	41 18 15·481	477·6	70 15 08·234	191·6
North Pond.	41 17 38·41	1184·9	70 10 32·15	748·1
Sankaty Head. 1845.	41 16 59·91	1848·1	69 57 53·41	1242·9
Forked Pond.	41 14 15·94	491·7	70 01 03·65	85·0

SUBORDIDATE PRIMARIES AND SECONDARIES—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
328 48 07·28	148 56 36·04	Thompson	32 986·27	4·518 333 2
28 57 40·16	208 50 48·74	Holt.	28 515·06	4·445 074 3
307 59 01·76	128 05 37·47	Thompson	16 887·32	4·227 560 7
14 51 34·25	194 48 37·35	Orne.	23 266·58	4·366 732 6
92 56 29·40	272 47 30·16	Indian	18 948·38	4·277 572 1
207 12 12·72	27 17 56·82	Hyannis.	26 280·49	4·419 633 5
254 15 15·37	74 35 59·52	Agamenticus	42 638·85	4·629 805 5
64 34 34·63	244 18 33·40	Unkonoonuc.	35 323·24	4·548 060 5
205 44 26·82	25 52 51·44	Agamenticus	38 401·12	4·584 343 9
133 30 41·93	313 18 25·53	Patuccawa.	33 647·75	4·526 956 0
253 23 08·32	73 30 27·63	Great Meadow	15 841·36	4·199 792 6
7 06 04·06	187 03 48·37	McSparran.	38 298·07	4·583 176 9

NANTUCKET AND VICINITY.

275 52 33·5	95 58 00·0	Nantucket Cliff	11 570·8	4·063 364
172 48 38·0	352 46 26·8	Hyannis.	36 657·0	4·564 157
231 57 02·5	51 59 33·8	Nantucket Cliff	6 777·2	3·831 053
131 01 56·7	310 59 01·6	Tuckanuck Telegraph.	8 182·1	3·912 864
65 40 37·8	245 38 03·7	Clark Cove	5 967·9	3·775 823
176 43 31·0	356 43 28·2	Nantucket Cliff.	1 717·8	3·234 985
156 36 16·3	336 35 29·1	Windmill Range	4 199·6	3·623 209
101 07 33·2	281 04 12·0	Clark Cove.	7 242·4	3·859 885
171 49 01·3	351 48 12·0	Nantucket (Great Point) light-house	12 177·0	4·085 540
86 49 33·5	266 46 03·6	Windmill Range.	7 415·0	3·870 110
69 33 15·4	249 28 39·7	Nantucket Cliff	10 373·3	4·015 918
24 14 32·5	204 13 29·5	Gibbs Pond.	5 407·3	3·732 982
132 56 28·1	312 55 51·3	Nantucket Cliff	1 770·6	3·248 117
200 27 28·0	20 29 34·8	Nantucket (Great Point) light-house.	12 764·6	4·106 008
101 09 32·6	281 07 01·5	Nantucket Cliff	5 430·5	3·734 837
182 06 53·2	2 07 05·6	Nantucket (Great Point) light-house.	11 809·2	4·072 219
150 21 43·0	330 18 31·8	Nantucket (Great Point) light-house	13 602·1	4·133 605
94 55 43·4	274 49 48·9	Nantucket Cliff.	12 547·1	4·098 542
212 52 00·9	32 55 27·9	Nantucket (Great Point) light-house	13 416·2	4·127 629
274 57 03·7	95 01 19·7	Gibbs Pond.	9 062·8	3·957 263
139 25 22·2	319 23 22·6	Water tank	6 484·5	3·811 874
229 18 00·3	49 20 16·6	Gibbs Pond.	6 345·3	3·802 452
215 34 06·4	35 35 26·7	Water tank	4 871·2	3·687 637
277 44 14·4	97 47 34·2	Surfside Hotel.	7 121·0	3·852 542
279 50 07·6	99 54 50·6	Water tank	10 126·6	4·005 464
308 32 39·3	128 36 01·9	Hummock.	9 139·4	3·960 919
270 53 05	90 55 29	Nantucket Cliff	5 081·4	3·705 98
3 26 50	183 26 43	Clark Cove.	4 263·0	3·629 72
148 57 26	328 56 05	Squam Head	5 530·2	3·742 74
95 04 58	274 59 02	Nantucket Cliff.	12 622·9	4·101 16
118 57 34	298 53 46	Windmill Range	9 201·1	3·963 84
95 21 42	275 18 41	Weeweeder Pond.	6 414·6	3·807 17

NANTUCKET AND VICINITY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Further Creek.	41 16 39·72	1225·2	70 14 06·85	159·4
Muskeget Island. 1845.	41 20 14·14	436·2	70 17 58·58	1362·1
Mitchell's house, astronomical station. 1845–1849.	41 16 59·45	1833·9	70 06 00·50	11·6
Bluff.	41 17 31·40	968·7	70 06 26·77	622·9
Coatue Point 2. 1875.	41 18 05·40	166·6	70 04 39·86	927·4
Coatue Point. 1845.	41 19 06·62	204·3	70 02 57·07	1327·3
Folger.	41 17 17·01	524·7	70 06 16·56	385·3
Folger, astronomical latitude station of 1866.	41 17 16·94	522·6	70 06 16·56	385·3
Nantucket High School, cupola.	41 17 05·98	184·4	70 06 12·76	296·9
Nantucket Baptist church. 1867.	41 16 52·66	1624·4	70 06 07·00	162·9
Nantucket north-towered church. 1867.	41 17 09·94	306·6	70 06 08·22	191·2
Brant Point light-house. 1867–1875.	41 17 23·20	715·7	70 05 34·60	805·1
Nantucket Range Beacon (discontinued Aug. 1, 1880). 1875.	41 16 23·92	737·9	70 04 42·85	997·3
Nantucket Cliff Range Beacon (front). 1875.	41 17 37·97	1171·3	70 06 24·12	561·2
Nantucket Cliff Range Beacon (rear). 1875.	41 17 35·56	1097·0	70 06 25·09	583·8
Nantucket (Borden).	41 17 39·86	1229·6	70 06 39·85	927·2
Tuckanuck Island, north house (Borden). 1835.	41 18 38·81	1197·2	70 15 55·41	1288·9
Brant Point light-house (Borden). 1835.	41 17 24·48	755·1	70 05 35·81	833·3
Windmill. 1887.	41 16 39·48	1218·0	70 06 05·91	137·5
Weeweeder. 1887.	41 14 37·28	1150·0	70 05 54·09	1259·5
Meridian south stone.	41 14 57·16	1763·3	70 05 06·38	148·5
North.	41 17 02·47	76·2	70 09 02·64	61·4
Squam Head 2. 1887.	41 19 33·39	1030·1	69 59 56·10	1304·7
Sankaty Head 2. 1887.	41 16 57·23	1765·5	69 57 52·45	1220·6

NANTUCKET AND VICINITY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
297 15 37	117 17 51	Clark Cove	5 334·4	3·727 09
250 03 39	70 06 01	North Pond.	5 314·0	3·725 42
287 28 11	107 35 30	Nantucket Cliff	16 216·2	4·209 95
294 47 16	114 52 11	North Pond.	11 441·4	4·058 48
132 08 17	312 07 42	Nantucket Cliff	1 671·9	3·223 22
62 32 40	242 32 08	Windmill Range.	1 286·9	3·109 53
205 12 51	25 15 17	Nantucket (Great Point) light-house	12 037·0	4·080 52
280 58 31	101 00 44	Shawaukemo.	4 787·2	3·680 08
311 33 43	131 34 46	Shawaukemo	2 956·3	3·470 75
67 09 05	247 07 54	Bluff.	2 699·3	3·431 25
298 55 46	118 59 07	Sankaty Head	8 073·6	3·907 07
334 05 39	154 06 36	Gibbs Pond.	4 560·2	3·658 98
123 48 13	303 47 48	Nantucket Cliff	1 042·4	3·018 02
325 31 22	145 31 34	Nantucket south-towered Unitarian church.	759·7	2·880 62
180 00	0 00	Folger	2·234	0·349 11
165 24 52	345 24 49	Folger	351·6	2·546 02
309 56 45	129 56 55	Nantucket south-towered Unitarian church.	445·4	2·648 77
140 43 44	320 43 12	Nantucket Cliff	1 719·8	3·235 48
238 54 03	58 54 09	Nantucket south-towered Unitarian church.	242·4	2·384 60
329 59 12	149 59 19	Nantucket south-towered Unitarian church	470·9	2·672 92
138 20 34	318 20 29	Folger.	291·8	2·465 04
101 46 36	281 46 02	Bluff	1 240·0	3·093 43
224 22 16	44 22 52	Coatue Point 2.	1 821·0	3·260 30
130 43 49	310 42 40	Bluff	3 190·8	3·503 90
242 52 05	62 53 10	Shawaukemo.	2 563·6	3·408 84
250 45 17	70 46 26	Coatue Point 2	2 568·9	3·409 74
283 30 13	103 32 25	Shawaukemo.	4 769·9	3·678 51
249 23 01	69 24 10	Coatue Point 2	2 615·6	3·417 57
16 59 57	196 59 56	Bluff.	133·9	2·126 73
207 04 02	27 06 37	Nantucket (Great Point) light-house	11 936·3	4·076 87
323 51 45	143 52 13	Nantucket south-towered Unitarian church.	1 647·9	3·216 93
277 57 27	98 03 34	Nantucket (Borden)	13 051·8	4·115 67
282 42 48	102 49 22	Nantucket south-towered Unitarian church.	14 249·8	4·153 81
107 40 01	287 39 19	Nantucket (Borden)	1 563·8	3·194 17
31 11 25	211 11 10	Nantucket south-towered Unitarian church.	1 001·2	3·000 51
336 54 20	156 55 05	Surfside Hotel	4 021·0	3·604 33
114 53 01	294 51 46	Water tank.	2 912·1	3·464 20
266 53 39	86 54 16	Surfside Hotel	1 304·0	3·115 27
175 49 38	355 49 30	Windmill.	3 779·6	3·577 45
137 25 24	317 23 30	Water tank	5 951·7	3·774 64
156 18 24	336 17 45	Windmill.	3 447·6	3·537 52
250 39 59	70 40 41	Water tank	1 558·4	3·192 68
21 35 27	201 34 48	Hummock.	3 706·0	3·568 90
24 14 36	204 13 33	Gibbs Pond	5 404·1	3·732 72
43 12 35	223 10 30	Shawaukemo.	6 414·0	3·807 13
88 46 47	268 44 23	Gibbs Pond	5 097·8	3·707 38
91 08 33	271 05 07	Shawaukemo.	7 270·4	3·861 56

NANTUCKET AND VICINITY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Siasconset, Atlantic Hotel flagstaff. 1887.	41 15 44·42	1370·3	69 58 04·18	97·3
Tom Nevers Head.	41 15 07·28	224·6	69 59 51·57	1200·7
Gibbs' (Mrs. Richard) house, square cupola.	41 15 35·46	1093·9	70 03 15·16	352·9
Weeweeder Life-Saving Station.	41 14 39·08	1205·6	70 05 55·39	1289·8
Starbuck's (Alfred) house, east chimney.	41 15 28·79	888·1	70 07 35·08	816·7
Coleman's house.	41 16 04·37	134·8	70 08 58·60	1364·0
Roadside.	41 17 05·58	172·1	70 08 24·91	579·6
Fisher flagstaff. 1887.	41 17 01·64	50·6	70 10 39·60	921·5
Perry's house, chimney.	41 16 19·46	600·3	70 12 08·19	190·6
Smith Point.	41 16 55·01	1697·0	70 14 15·44	359·3
Muskeget Life-Saving Station.	41 20 20·41	629·6	70 18 49·22	1144·4
Muskeget Island 2. 1887.	41 20 14·58	449·8	70 17 58·88	1369·1
Meridian middle stone.	41 14 59·32	1830·0	70 05 06·36	148·1
Meridian north stone.	41 15 01·46	45·0	70 05 06·33	147·4
Gardner's (Francis) house, chimney.	41 16 37·64	1161·1	70 06 01·65	38·4
Tuckanuck Island, north house. 1887.	41 18 38·94	1201·3	70 15 56·32	1310·1

MARTHAS VINEYARD AND VINEYARD SOUND.

Prospect Chilmark. (C. & G. S. & Bdn.) 1835–1887.	41 21 56·838	1753·5	70 44 51·049	1186·3
Davis Hill. 1875–1887.	41 31 24·305	749·9	70 39 39·245	910·0
Desert Hill. 1875–1887.	41 29 28·731	886·4	70 44 21·354	495·3
East Chop 2. 1875.	41 28 04·635	143·0	70 33 50·903	1181·2
Cape Poge.	41 25 11·499	354·8	70 27 03·747	87·0
Gay Head 2. 1887.	41 20 50·381	1554·3	70 50 14·026	326·1

NANTUCKET AND VICINITY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
78 18 43	258 14 10	Surfside Hotel	9 844·0	3·993 17
108 51 59	288 48 41	Shawaukemo.	7 393·0	3·868 82
128 10 04	308 07 57	Shawaukemo	5 719·8	3·757 38
144 41 30	324 40 24	Gibbs Pond.	4 021·7	3·604 41
185 09 44	5 09 51	Shawaukemo	2 674·7	3·427 28
225 00 24	45 01 32	Gibbs Pond.	3 412·5	3·533 07
176 13 47	356 13 40	Windmill	3 722·2	3·570 80
269 20 44	89 21 22	Surfside Hotel.	1 332·4	3·124 64
223 34 42	43 35 39	Windmill	3 010·6	3·478 66
292 33 16	112 34 59	Surfside Hotel.	3 956·1	3·597 27
41 23 58	221 23 17	Hummock	2 204·3	3·343 28
176 59 56	356 59 53	North.	1 794·9	3·254 04
313 05 15	133 07 31	Surfside Hotel	6 591·4	3·818 98
32 20 07	212 19 03	Hummock.	4 191·8	3·622 40
269 20 10	89 21 14	North	2 256·6	3·353 45
345 21 16	165 21 41	Hummock.	3 535·1	3·548 40
252 54 13	72 56 15	North	4 517·5	3·654 90
305 37 41	125 39 05	Hummock.	3 637·1	3·560 75
153 40 40	333 40 05	Tuckanuck	2 769·6	3·442 42
268 09 41	88 13 07	North.	7 283·0	3·862 31
290 14 22	110 21 31	Water tank	16 115·4	4·207 24
306 50 35	126 53 01	Tuckanuck.	6 423·6	3·807 78
291 09 17	111 15 53	Water tank	14 956·8	4·174 84
312 46 34	132 48 27	Tuckanuck.	5 408·3	3·733 06
342 37 13	162 37 18	Surfside Hotel	638·0	2·804 84
0 27 58	180 27 58	Meridian south stone.	66·8	1·824 75
344 16 20	164 16 25	Surfside Hotel	701·1	2·845 78
0 27 58	180 27 58	Meridian south stone.	132·7	2·123 03
119 48 00	299 47 57	Windmill	114·3	2·058 05
259 42 47	79 44 44	Shawaukemo.	4 182·4	3·621 43
287 08 42	107 13 15	North	10 074·2	4·003 21
302 54 28	122 55 00	Tuckanuck.	1 332·3	3·124 60

MARTHAS VINEYARD AND VINEYARD SOUND.

219 19 40·2	39 22 25·8	Indian	9 172·2	3·962 471
266 18 36·5	86 29 03·5	Sampson.	22 088·2	4·344 161
302 56 44·7	123 05 03·7	Cape Poge light-house	20 852·1	4·319 151
7 48 07·7	187 47 27·0	Indian.	10 511·0	4·021 646
2 50 03·3	182 49 43·7	Prospect Chilmark	13 958·0	4·144 824
323 11 30·1	143 13 56·2	Indian.	8 551·3	3·932 032
127 21 09·5	307 17 18·7	Davis Hill	10 160·2	4·006 904
65 56 35·1	245 52 03·8	Indian.	10 420·2	4·017 875
119 30 31·7	299 26 02·2	East Chop 2	10 856·5	4·035 691
93 21 19·8	273 12 19·3	Indian.	19 001·4	4·278 786
163 11 26·0	343 10 11·5	Nashawena	9 042·5	3·956 289
254 41 46·1	74 45 19·5	Prospect Chilmark.	7 782·5	3·891 120

MARTHAS VINEYARD AND VINEYARD SOUND—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Forbes.	41 29 32·700	1008·8	70 42 41·065	952·7
West Chop 3. 1887.	41 28 53·968	1664·9	70 36 18·208	422·4
Waquoit Congregational church. 1888.	41 35 07·176	221·4	70 31 29·067	673·3
West Chop 2. 1875.	41 28 52·61	1622·9	70 35 58·26	1351·6
Watcha Pond.	41 20 52·19	1609·9	70 36 38·35	891·5
Nashaquitsa Cliff.	41 20 00·34	10·5	70 44 27·30	634·7
Herring Pond.	41 20 47·35	1460·6	70 31 34·16	794·1
Edgartown.	41 23 51·77	1596·9	70 32 55·96	1299·9
Edgartown church spire. 1844–45.	41 23 18·64	575·1	70 30 55·88	1298·2
Edgartown light-house. 1875.	41 23 27·29	841·9	70 30 12·76	296·4
Molasha Hill. 1844–45.	41 20 29·02	895·2	70 48 38·48	894·7
Gay Head. 1844–45.	41 20 50·30	1551·7	70 50 13·96	324·5
Gay Head light-house. (Borden) 1835–36.	41 20 54·54	1682·4	70 50 09·36	217·6
Gay Head light-house. 1843–1845.	41 20 54·10	1668·9	70 50 08·54	198·6
Gay Head light-house. 1875–1887.	41 20 54·57	1683·5	70 50 07·59	176·4
East Chop. 1844–45.	41 28 04·80	148·1	70 33 50·91	1181·3
East Chop Telegraph.	41 28 04·72	145·6	70 33 49·00	1137·0
East Chop light-house. 1875.	41 28 13·43	414·3	70 34 04·94	114·6
Tarpaulin Cove light-house. (C. & G. S. & Bdn.) 1835–1887.	41 28 07·90	243·7	70 45 28·74	666·8
Katama House, north tower.	41 21 30·10	928·5	70 30 19·67	457·2
Observatory with red roof, flagstaff.	41 26 12·76	393·6	70 36 18·67	433·5
Prospect House, cupola, flagstaff.	41 26 41·34	1275·2	70 34 45·39	1053·6
Union chapel.	41 27 16·82	518·9	70 33 31·05	720·6
Highland House, north tower.	41 27 50·26	1550·4	70 33 36·17	839·4

MARTHAS VINEYARD AND VINEYARD SOUND—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
338 09 03·8	158 10 23·5	Indian	7 509·7	3·875 620
12 07 28·2	192 06 02·2	Prospect Chilmark.	14 383·6	4·157 869
46 33 06·0	226 30 12·2	Indian	8 395·1	3·924 026
97 41 50·6	277 37 37·0	Forbes.	8 961·8	3·952 394
100 20 24·3	280 16 41·0	Falmouth	7 919·5	3·898 699
165 50 02·6	345 48 23·2	Pine Hill.	14 126·9	4·150 046
132 25 13	312 22 47	Davis Hill	6 940·6	3·841 40
296 35 19	116 36 43	East Chop 2.	3 304·9	3·519 16
99 55 21	279 49 55	Prospect Chilmark	11 624·9	4·065 39
148 14 21	328 11 41	Indian.	10 690·1	4·028 98
171 16 11	351 15 55	Prospect Chilmark	3 635·8	3·560 60
256 52 02	77 02 13	Sampson.	22 067·3	4·343 75
96 40 26	276 31 39	Prospect Chilmark	18 646·6	4·270 60
126 04 56	305 58 55	Indian.	15 701·8	4·195 95
78 01 14	257 53 21	Prospect Chilmark	16 989·9	4·230 19
108 14 05	288 08 58	Indian.	11 361·4	4·055 43
82 40 02	262 30 50	Prospect Chilmark	19 570·4	4·291 60
108 38 42	288 32 15	Indian.	14 331·1	4·156 28
149 23 47	329 21 22	East Chop 2	9 942·8	3·997 51
310 38 40	130 39 26	Sampson.	2 152·9	3·333 03
242 50 44	62 53 14	Prospect Chilmark	5 940·7	3·773 84
130 33 20	310 28 26	Cuttyhunk.	13 575·9	4·132 77
135 14 46	315 10 56	Cuttyhunk	11 500·6	4·060 72
235 28 19	55 34 38	Indian.	16 156·6	4·208 35
134 24 32	314 20 38	Cuttyhunk	11 484·4	4·060 11
235 38 30	55 44 46	Indian.	15 994·5	4·203 97
134 23 19	314 19 25	Cuttyhunk	11 507·5	4·060 98
235 33 50	55 40 05	Indian.	15 986·0	4·203 74
216 50 46	36 57 42	Davis Hill	24 295·2	4·385 52
255 20 33	75 24 02	Prospect Chilmark.	7 604·3	3·881 06
326 03 48	146 06 59	Sampson	12 005·8	4·079 39
65 54 57	245 50 26	Indian.	10 422·0	4·017 95
99 28 08	279 21 01	Naushon	15 154·1	4·180 53
128 57 22	308 53 28	Woods Hole.	10 511·6	4·021 67
127 14 39	307 10 58	Davis Hill	9 736·4	3·988 40
114 41 44	294 40 29	West Chop 2.	2 893·5	3·461 43
303 03 01	123 06 12	Indian	7 979·4	3·901 97
355 37 26	175 37 51	Prospect Chilmark.	11 480·7	4·059 97
118 48 51	298 42 00	Indian	16 457·4	4·216 36
219 01 41	39 02 32	Sampson.	2 848·4	3·454 60
82 30 29	262 27 36	Indian	6 136·3	3·787 91
278 17 44	98 23 51	Cape Poge.	13 022·7	4·114 70
206 11 43	26 12 19	East Chop 2	2 864·2	3·457 00
284 27 19	104 32 24	Cape Poge.	11 070·8	4·044 18
162 39 15	342 39 02	East Chop 2	1 545·3	3·189 01
323 39 05	143 42 04	Sampson.	10 529·6	4·022 41
326 13 56	146 16 57	Sampson	11 442·7	4·058 53
68 53 54	248 49 13	Indian.	10 565·7	4·023 90

MARTHAS VINEYARD AND VINEYARD SOUND—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Seaview House, north tower.	41 27 28·54	880·4	70 33 23·06	535·2
No Man's Land. (C. & G. S. & Bdn.) 1835–1845.	41 15 11·70	360·9	70 48 49·20	1145·4
Bowman Point.	41 32 36·46	1124·8	70 36 05·84	135·4
Falmouth Heights (formerly Bowman Hill) observatory. 1875–1888.	41 32 38·10	1175·4	70 36 04·31	99·9
Nobska Point light-house. (C. & G. S. & Bdn.) 1835–1875.	41 30 57·24	1765·9	70 39 20·20	468·4
White house, south gable.	41 32 46·42	1432·1	70 35 43·10	998·9
White house, chimney.	41 32 09·08	280·1	70 39 10·00	231·8
Menauhant Hotel, west chimney.	41 33 01·00	30·8	70 33 09·76	226·2
Menauhant Landing, flagstaff. 1875–1888.	41 32 59·68	1841·2	70 33 08·92	206·7
Woods Hole, Episcopal church spire. 1875.	41 31 19·86	612·7	70 39 48·10	1115·3
Davis Neck.	41 32 54·42	1678·9	70 33 48·63	1127·1
Monaunt Hill.	41 33 05·51	169·9	70 32 32·48	752·7
Sampson. (Borden) 1835.	41 22 41·51	1280·5	70 29 02·66	61·8
Succonnesset. 1845.	41 33 31·43	969·6	70 28 36·29	840·9
Succonnesset. (Borden) 1835.	41 33 34·76	1072·4	70 28 31·66	733·6
West Chop. 1844–45.	41 28 54·29	1674·8	70 36 18·04	418·6
Cape Poge light-house. (Borden) 1835.	41 25 18·54	571·9	70 27 03·40	79·0
Holmes Hole, church spire. 1844–45.	41 27 15·15	467·3	70 36 20·18	468·4
Holmes Hole, windmill. (Borden.)	41 27 14·81	456·8	70 36 20·71	480·7
West Chop light-house. (C. & G. S. & Bdn.) 1835–1845.	41 28 57·66	1778·7	70 36 10·78	250·1
West Chop light-house. 1875–1888.	41 28 51·06	1575·2	70 36 00·98	22·7
Cotuit Neck.	41 35 31·16	961·3	70 26 44·25	1024·9
Tarpaulin Cove.	41 27 41·24	1272·3	70 45 43·96	1020·2
Whiting.	41 24 18·30	564·6	70 42 08·68	201·6

MARTHAS VINEYARD AND VINEYARD SOUND—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
295 36 42	115 40 53	Cape Poge	9 768·3	3·989 82
72 51 45	252 46 55	Indian.	10 633·6	4·026 68
151 35 57	331 31 11	Cuttyhunk	21 162·2	4·325 56
203 52 57	23 55 34	Prospect Chilmark.	13 671·3	4·135 81
331 47 15	151 51 55	Sampson	20 810·4	4·318 28
26 47 39	206 44 37	Indian.	14 157·3	4·150 98
358 50 36	178 50 40	West Chop 2	6 957·9	3·842 48
65 27 52	245 25 30	Davis Hill.	5 477·7	3·738 60
11 02 33	191 01 40	Indian	9 759·3	3·989 42
68 40 29	248 37 09	Desert Hill.	7 499·3	3·875 02
343 19 41	163 20 55	East Chop 2	9 074·0	3·957 80
28 05 44	208 02 27	Indian.	14 672·7	4·166 51
315 30 25	135 33 56	East Chop 2	10 566·0	4·023 91
10 07 22	190 06 22	Indian.	11 981·5	4·078 51
329 35 08	149 39 11	Cape Poge	16 790·0	4·225 05
38 01 31	217 56 32	Indian.	16 997·3	4·230 38
329 34 24	149 38 26	Cape Poge	16 745·2	4·223 89
38 09 42	218 04 43	Indian.	16 977·4	4·229 87
305 58 51	126 02 48	East Chop 2	10 243·1	4·010 43
6 46 37	186 46 02	Indian.	10 348·8	4·014 89
340 36 44	160 39 53	Sampson	20 031·3	4·301 71
35 57 42	215 53 09	Indian.	16 292·6	4·211 99
345 46 00	165 48 19	Sampson	19 848·1	4·297 72
39 57 48	219 52 25	Indian.	17 649·4	4·246 73
86 30 32	266 20 05	Prospect Chilmark	22 082·6	4·344 05
109 28 44	289 21 03	Indian.	17 191·4	4·235 31
1 44 18	181 44 01	Sampson	20 049·3	4·302 10
49 35 50	229 27 50	Indian.	22 088·2	4·344 16
240 17 24	60 24 06	Hyannis	16 123·2	4·207 45
109 46 24	289 40 43	Falmouth.	12 645·3	4·101 93
46 31 14	226 28 20	Indian	8 404·8	3·924 53
94 45 47	274 40 19	Naushon.	11 530·5	4·061 85
29 46 21	209 45 02	Sampson (Borden)	5 580·3	3·746 66
92 42 02	272 33 01	Indian.	18 997·7	4·278 70
309 38 06	129 42 56	Sampson	13 207·2	4·120 81
65 44 56	245 42 04	Indian.	6 634·4	3·821 80
222 49 07	42 54 18	Succonnesset (Borden)	15 991·6	4·203 89
231 32 49	51 44 41	Hyannis.	31 745·9	4·501 69
46 47 36	226 44 37	Indian	8 598·4	3·934 42
94 11 22	274 05 48	Naushon.	11 690·4	4·067 83
95 45 47	275 40 16	Desert Hill	11 665·9	4·066 92
133 03 48	313 01 24	Davis Hill.	6 926·9	3·840 54
249 06 38	69 12 08	Hyannis	12 327·9	4·090 89
7 42 26	187 40 54	Sampson.	23 949·7	4·379 30
296 37 08	116 40 29	Indian	7 876·1	3·896 31
353 23 57	173 24 32	Prospect Chilmark.	10 695·5	4·029 20
60 25 03	240 19 42	Gay Head 2	12 974·8	4·113 10
99 13 25	279 06 50	Nashawena.	14 067·0	4·148 20

MARTHAS VINEYARD AND VINEYARD SOUND—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Cedar Tree Neck.	41 26 01·32	40·7	70 42 03·97	92·2
Molasha Hill 2. 1887.	41 20 34·33	1059·1	70 48 02·13	49·5
Squibnocket.	41 18 29·80	919·3	70 46 28·16	655·1
Tilton.	41 21 53·47	1649·5	70 42 23·10	536·9
Glidden's water tower, flagstaff.	41 31 10·22	315·3	70 39 40·54	940·0
Nobska Point light-house. 1887.	41 30 57·02	1759·1	70 39 20·16	467·5
Fish Commission building, red tower.	41 31 31·01	956·7	70 40 27·37	634·6
Nonamesset, hydrographic.	41 30 44·46	1371·6	70 40 36·10	837·1
Glidden's guano works, tall chimney.	41 31 43·58	1344·5	70 40 50·71	1175·7
Forbes's house, cupola, tall chimney on west end.	41 30 24·39	752·4	70 42 38·10	883·6
West Chop, hydrographic.	41 28 57·39	1770·5	70 36 13·04	302·5
Chappaquansett.	41 28 07·68	236·9	70 37 51·99	1206·5
Water tank (Vineyard Haven).	41 27 12·30	379·5	70 36 38·54	894·5
Tashmoo.	41 27 11·76	362·8	70 38 18·90	438·7
Alfred.	41 27 15·38	474·5	70 38 54·10	1255·7
Norton Point.	41 27 13·88	428·2	70 39 53·59	1243·8
Norton Point, hydrographic.	41 27 24·83	766·0	70 39 52·11	1209·5
North Shore church, square spire. 1887.	41 26 17·44	538·0	70 40 02·92	67·8
Indian Hill, boulder.	41 25 21·76	671·3	70 41 16·37	380·1
Cedar Tree Neck, Signal-Service flagstaff. 1887.	41 26 02·92	90·1	70 41 51·92	1205·5
Middletown, church spire. 1887.	41 24 17·20	530·6	70 40 32·96	765·6
West Tisbury, church spire. 1887.	41 22 52·68	1625·2	70 40 31·46	731·0
Hancock.	41 20 56·59	1745·8	70 39 35·10	816·0
Clay Pits.	41 23 10·34	319·0	70 41 38·20	887·6

MARTHAS VINEYARD AND VINEYARD SOUND—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
27 14 48	207 12 57	Prospect Chilmark	8 482·2	3·928 51
86 13 30	266 06 51	Nashawena.	14 024·9	4·146 90
99 11 08	279 09 41	Gay Head 2	3 106·4	3·492 26
148 11 16	328 08 34	Nashawena.	10 771·3	4·032 27
129 33 58	309 31 29	Gay Head 2	6 811·8	3·833 26
199 27 36	19 28 40	Prospect Chilmark.	6 774·5	3·830 88
42 13 45	222 11 03	Squibnocket	8 482·0	3·928 50
91 45 04	271 43 26	Prospect Chilmark.	3 440·3	3·536 60
7 58 10	187 57 30	Indian	10 076·5	4·003 31
311 50 04	131 52 18	West Chop 3.	6 300·1	3·799 35
11 03 15	191 02 22	Indian	9 752·8	3·989 13
311 57 22	131 59 23	West Chop 3.	5 676·6	3·754 09
1 40 10	181 40 01	Indian	10 625·8	4·026 36
12 26 09	192 25 05	Cedar Tree Neck.	10 415·7	4·017 69
299 39 01	119 41 52	West Chop 3	6 884·6	3·837 88
0 40 03	180 40 00	Indian.	9 185·4	3·963 10
358 47 25	178 47 32	Indian	11 011·3	4·041 84
9 09 05	189 08 16	Cedar Tree Neck.	10 695·2	4·029 19
342 20 42	162 22 00	Indian	8 989·2	3·953 72
356 32 21	176 32 40	Whiting.	11 314·4	4·053 63
46 35 24	226 32 27	Indian	8 554·6	3·932 20
96 56 10	276 51 53	Forbes.	9 066·9	3·957 46
111 23 14	291 20 03	Forbes	7 201·5	3·857 42
236 42 51	56 43 53	West Chop 3.	2 602·8	3·415 44
39 09 52	219 06 04	Tilton	12 680·6	4·103 14
64 52 33	244 49 53	Indian.	6 210·4	3·793 12
51 28 07	231 26 33	Indian	4 209·0	3·624 18
125 34 46	305 31 52	Forbes.	7 477·2	3·873 74
42 09 13	222 08 03	Indian	3 688·1	3·566 80
128 50 00	308 47 30	Forbes.	6 758·5	3·829 85
22 08 26	202 07 55	Indian	2 902·2	3·462 72
137 47 46	317 45 55	Forbes.	5 782·8	3·762 14
135 11 39	315 09 47	Forbes	5 561·1	3·745 16
20 26 51	200 26 19	Indian.	3 229·3	3·509 11
97 43 59	277 39 10	Naushon, southwest 2	10 238·8	4·010 25
148 39 50	328 38 05	Forbes.	7 053·7	3·848 42
110 07 29	290 03 28	Naushon, southwest 2	8 989·6	3·953 74
165 45 43	345 44 47	Forbes.	7 987·1	3·902 39
103 27 26	283 23 49	Naushon, southwest 2	7 830·5	3·893 79
170 00 40	350 00 08	Forbes.	6 571·4	3·817 66
90 52 16	270 51 13	Whiting	2 224·0	3·347 13
176 16 35	356 16 30	Indian.	2 768·2	3·442 20
139 28 30	319 27 26	Whiting	3 475·6	3·541 03
177 42 49	357 42 43	Indian.	5 374·5	3·730 34
114 12 05	294 10 14	Tilton	4 281·0	3·631 55
170 20 30	350 19 47	Indian.	9 080·7	3·958 12
23 45 00	203 44 30	Tilton	2 591·2	3·413 50
63 10 49	243 08 41	Prospect Chilmark.	5 022·5	3·700 92

MARTHAS VINEYARD AND VINEYARD SOUND—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Cape Higgon.	41 23 53·62	1654·2	70 43 51·63	1199·4
Brickyard, chimney.	41 22 36·96	1140·2	70 44 41·12	955·5
Peaked Hill.	41 21 19·42	599·1	70 44 07·55	175·5
Prospect Cliff, hydrographic.	41 22 12·88	397·3	70 45 18·84	437·8
Stewart's house, south chimney.	41 21 35·52	1095·8	70 45 10·21	237·3
Lookout, flagstaff. 1887.	41 21 18·25	563·0	70 46 01·38	32·1
Weequobska.	41 20 02·22	68·5	70 44 29·65	689·5
Mayhew's (B.), east chimney.	41 19 28·92	892·2	70 46 24·10	560·5
Lobsterville, flagstaff. 1887.	41 21 03·16	97·5	70 47 43·86	1019·6
Gay Head Baptist church, square tower. 1887.	41 20 28·17	869·0	70 48 50·12	1165·3
Gay Head Hotel, flagstaff. 1887.	41 20 50·34	1553·0	70 50 14·19	329·9
Barker's (G. H.) house, main chimney.	41 20 43·00	1326·5	70 49 16·21	376·9
Wash, hydrographic.	41 21 14·17	437·1	70 50 02·80	65·1
No Man's Land 2. 1887.	41 15 11·72	361·5	70 48 49·28	1147·3
No Man's Land, east.	41 15 20·80	641·7	70 48 20·56	478·7
No Man's Land, flagstaff. 1887.	41 14 58·98	1819·5	70 48 29·72	692·0
No Man's Land, house chimney.	41 15 00·26	8·0	70 48 32·38	753·9
No Man's Land, west.	41 15 25·20	777·4	70 49 53·78	1252·0
Waquoit, flag in tree.	41 33 59·54	1836·8	70 30 47·47	1099·9
Meadow.	41 34 06·57	202·7	70 30 55·29	1281·0
Mashpee, corner 1.	41 34 08·07	249·0	70 30 56·73	1314·4
Mashpee, corner 2.	41 34 07·07	218·1	70 30 53·57	1241·2
Hamblin.	41 35 56·85	1753·9	70 31 20·84	482·7
Hamblin, peg.	41 35 59·60	1838·7	70 31 33·52	776·2

MARTHAS VINEYARD AND VINEYARD SOUND—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
140 12 56	320 10 38	Naushon, southwest 2	7 559·1	3·878 47
188 53 35	8 54 22	Forbes.	10 588·4	4·024 83
117 27 17	297 22 22	Nashawena	11 658·2	4·066 63
155 42 42	335 40 57	Naushon, southwest 2.	8 966·9	3·952 64
246 35 54	66 37 03	Tilton	2 645·2	3·422 46
138 47 24	318 46 55	Prospect Chilmark.	1 534·8	3·186 04
122 51 40	302 47 10	Nashawena	11 273·3	4·052 05
162 29 21	342 28 01	Naushon, southwest 2.	9 349·1	3·970 77
163 20 19	343 18 53	Naushon, southwest 2	10 509·5	4·021 58
176 01 44	356 01 22	Tarpaulin Cove.	11 309·9	4·053 46
81 41 46	261 38 59	Gay Head 2	5 935·9	3·773 49
132 36 22	312 32 21	Nashawena.	11 523·6	4·061 59
101 21 27	281 19 07	Molasha Hill 2	5 038·6	3·702 31
171 59 20	351 59 06	Prospect Chilmark.	3 571·0	3·552 79
174 41 35	354 40 58	Naushon, southwest 2	14 033·3	4·147 16
205 21 24	25 22 25	Prospect Chilmark.	5 049·9	3·703 28
143 33 31	323 30 38	Nashawena	10 273·1	4·011 70
247 34 25	67 36 19	Prospect Chilmark.	4 344·9	3·637 98
189 46 13	9 47 13	Naushon, southwest 2	12 324·5	4·090 77
243 46 22	63 49 00	Prospect Chilmark.	6 193·8	3·791 96
163 13 03	343 11 49	Nashawena	9 042·7	3·956 30
254 41 30	74 45 04	Prospect Chilmark.	7 786·5	3·891 34
155 59 24	335 57 31	Nashawena	9 725·9	3·987 93
192 59 34	13 00 51	Naushon, southwest 2.	11 995·5	4·079 02
160 03 07	340 01 45	Nashawena	8 428·3	3·925 74
259 40 33	79 43 59	Prospect Chilmark.	7 365·1	3·867 18
169 19 12	349 18 16	Gay Head 2	10 631·9	4·026 61
203 53 26	23 56 03	Prospect Chilmark.	13 670·7	4·135 79
165 27 19	345 26 04	Gay Head 2	10 504·6	4·021 38
204 09 05	24 10 19	Squibnocket.	6 390·4	3·805 53
167 23 24	347 22 15	Gay Head 2	11 108·9	4·045 67
201 30 54	21 33 18	Prospect Chilmark.	13 857·7	4·141 69
167 39 30	347 38 23	Gay Head 2	11 056·3	4·043 61
204 04 53	24 06 15	Squibnocket.	7 081·4	3·850 12
177 18 51	357 18 38	Gay Head 2	10 042·5	4·001 84
210 12 34	30 15 54	Prospect Chilmark.	13 984·0	4·145 63
111 50 40	291 46 29	Falmouth	9 431·5	3·974 58
155 12 46	335 12 18	Waquoit Congregational church.	2 298·6	3·361 46
320 06 47	140 06 52	Waquoit, flag in tree	282·6	2·451 20
320 50 06	140 50 12	Waquoit, flag in tree	339·6	2·530 94
324 24 45	144 24 46	Meadow.	57·1	1·756 64
328 38 32	148 38 36	Waquoit, flag in tree	271·9	2·434 40
68 55 17	248 55 16	Meadow.	42·6	1·629 41
7 05 42	187 05 37	Waquoit Congregational church	1 544·1	3·188 67
100 56 21	280 54 30	East end meetinghouse.	3 932·4	3·594 66
286 08 57	106 09 05	Hamblin	305·8	2·485 42
356 21 13	176 21 16	Waquoit Congregational church.	1 620·6	3·209 67

MARTHAS VINEYARD AND VINEYARD SOUND—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Mashpee, corner 4.	41 35 59·82	1845·5	70 31 33·21	769·0
East Falmouth, church spire. 1888.	41 34 41·65	1284·9	70 33 26·59	616·0
Lightning rod.	41 35 18·04	556·6	70 31 05·31	123·0
Cupola.	41 35 15·04	464·0	70 30 52·11	1207·0
Mashpee, corner 3.	41 35 38·26	1180·4	70 29 53·88	1247·9
Cotuit Port, church spire. 1887.	41 36 54·73	1688·5	70 26 11·24	260·2

BUZZARDS BAY.

Falmouth. (C. & G. S. & Bdn.) 1835–1888.	41 35 53·114	1638·6	70 37 05·477	126·9
Naushon. 1844–45.	41 29 25·030	772·2	70 44 33·380	774·4
Mishaum Point.	41 30 56·112	1731·1	70 57 16·438	381·1
Swift Hill.	41 34 02·457	75·7	70 38 30·704	711·3
West Island. 1844.	41 34 56·619	1746·6	70 49 29·791	481·5
Angelica Point.	41 38 28·974	894·0	70 45 55·351	1280·9
Pine Hill. (C. & G. S. & Bdn.) 1835–1890.	41 42 31·126	960·2	70 33 58·608	1354·9
Woods Hole.	41 31 38·796	1196·9	70 39 41·578	964·0
Great Hill. (C. & G. S. & Bdn.) 1835–1887.	41 42 33·278	1026·6	70 43 20·441	472·8
Mendal. (C. & G. S. & Bdn.) 1835–1887.	41 42 03·029	93·4	70 53 00·021	0·5
New Bedford court-house. (C. & G. S. & Bdn.) 1835–1887.	41 38 03·723	114·9	70 55 52·961	1225·9
Dartmouth. (C. & G. S. & Bdn.) 1835–1844.	41 34 11·594	357·7	71 01 47·538	1101·4
Eldridge.	41 31 46·109	1422·4	71 05 08·269	191·7
Gooseberry Neck.	41 29 20·083	619·6	71 02 19·612	455·0
Almy.	41 30 42·286	1304·5	71 01 49·855	1156·0
Deer Horn.	41 39 37·355	1152·4	70 35 22·052	510·2
East end meeting-house. 1888.	41 36 20·997	647·8	70 34 07·570	175·3

MARTHAS VINEYARD AND VINEYARD SOUND—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
287 46 28	107 46 36	Hamblin	300·8	2·478 29
47 00 58	227 00 58	Hamblin, peg.	9·937	0·997 26
162 47 56	342 47 29	East end meetinghouse	3 208·8	3·506 34
253 51 02	73 52 20	Waquoit Congregational church.	2 834·1	3·452 41
58 39 46	238 39 30	Waquoit Congregational church	644·4	2·809 15
223 38 28	43 42 01	Shootflying	10 774·3	4·032 39
260 24 53	80 30 01	Hyannis	10 905·4	4·037 64

BUZZARDS BAY.

183 30 32·8	3 31 37·5	Manomet	36 646·7	4·564 035
246 40 36·4	66 51 24·7	Shootflying.	24 574·7	4·390 489
64 18 42·8	244 11 06·5	Cuttyhunk	17 761·7	4·249 485
220 53 15·1	40 58 12·1	Falmouth.	15 846·9	4·199 944
278 57 06·3	99 05 31·9	Naushon	17 919·2	4·253 320
350 45 14·3	170 46 03·2	Cuttyhunk.	10 665·3	4·027 971
77 40 44·5	257 28 17·9	Mishaum Point	26 719·4	4·426 827
44 31 29·2	224 27 28·7	Naushon.	11 997·9	4·079 106
276 16 15·3	96 23 26·7	Swift Hill	15 153·1	4·180 503
264 05 20·4	84 13 28·5	Falmouth.	17 120·1	4·233 507
308 34 05·4	128 39 00·6	Swift Hill	13 176·7	4·119 807
291 21 18·3	111 27 10·2	Falmouth	13 176·0	4·119 784
277 59 36·0	98 08 20·8	Shootflying	18 423·8	4·265 378
175 08 52·8	355 07 53·1	Manomet.	24 386·1	4·387 143
87 00 55·3	266 49 16·1	Mishaum Point	24 493·7	4·389 055
114 30 11·1	294 23 47·0	West Island.	14 745·2	4·168 651
28 56 16·9	208 47 51·3	Cuttyhunk	36 580·9	4·563 254
324 51 59·0	144 56 08·2	Falmouth.	15 089·5	4·178 675
7 45 54·3	187 43 53·1	Cuttyhunk	31 388·6	4·496 772
297 14 08·2	117 24 42·6	Falmouth.	24 862·7	4·395 548
0 32 35·8	180 32 29·4	Cuttyhunk	23 720·2	4·375 118
278 40 15·8	98 52 44·6	Falmouth.	26 413·3	4·421 821
334 10 48·7	154 14 37·2	Cuttyhunk	18 389·0	4·264 559
264 39 02·7	84 55 26·4	Falmouth.	34 473·0	4·537 479
104 36 20·2	284 34 49·0	Nootas	32 95·3	3·517 897
46 13 00·8	226 08 42·4	East Rock.	12 540·9	4·098 329
247 07 31·1	67 10 52·0	Mishaum Point	7 630·2	3·882 535
310 48 37·4	130 52 47·0	Cuttyhunk.	11 566·0	4·063 182
63 52 05·2	243 45 35·4	East Rock	15 214·7	4·182 265
321 23 15·1	141 27 05·0	Cuttyhunk.	12 920·4	4·111 276
199 47 25·2	19 48 20·7	Pine Hill	5 697·9	3·755 714
19 05 53·3	199 04 44·6	Falmouth.	7 320·6	3·864 548
78 13 22·5	258 11 24·4	Falmouth	4 208·7	3·624 152
181 02 22·3	1 02 28·3	Pine Hill.	11 420·9	4·057 699

BUZZARDS BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Pasque.	41 26 57·833	1784·2	70 50 04·431	102·9
Sconticut Neck. 1844–1887.	41 35 02·650	81·8	70 51 20·401	472·6
Wenaumet Neck.	41 40 58·142	1793·7	70 39 41·002	948·3
Tempes Knob.	41 42 58·451	1803·3	70 39 48·835	1128·9
Indian Neck.	41 43 33·278	1026·7	70 41 27·038	624·9
Cromeset Neck. 1844–1887.	41 43 41·757	1288·3	70 43 20·565	475·3
Nashawena. 1844–1887.	41 25 30·956	955·0	70 52 06·641	154·2
North Pocasset, church spire. 1844–1887.	41 41 41·479	1279·7	70 36 18·101	418·6
Marion (formerly Sippican) Congregational church spire. 1844–1887.	41 42 09·924	306·2	70 45 47·914	1107·9
Bird Island light-house. (C. & G. S. & Bdn.) 1835–1888.	41 40 09·661	298·0	70 43 04·146	95·9
West Falmouth, observatory. 1888.	41 35 56·659	1748·0	70 37 47·597	1102·2
New Bedford High School, rod of vane. 1887.	41 38 17·357	535·5	70 55 58·643	1357·3
Rogers School, north cupola. 1887.	41 38 10·107	311·8	70 53 58·186	1346·7
Guano, iron chimney on north end of southern building of Clark Cove Guano Company.	41 35 45·161	1393·2	70 55 46·001	1065·4
Wareham Congregational church, rod of vane. 1887.	41 45 57·339	1769·0	70 43 36·136	834·7
Rochester Congregational church, steeple. 1887.	41 43 54·003	1666·0	70 49 22·195	512·9
Naushon, southwest 2. 1887.	41 27 01·863	57·5	70 47 20·020	464·7
Faunce.	41 40 31·354	967·3	70 59 18·605	430·4
Perry Hill Christian Baptist church, cupola. 1887.	41 42 32·751	1010·4	70 53 05·347	123·6
Braley's (T. E.) barn, cupola flagstaff. 1887.	41 45 21·415	660·7	70 54 14·768	341·2
Hubbard's (W. L.) barn, ridgepole. 1887.	41 44 53·149	1639·7	70 51 05·797	133·9
O'Shaughnessy's (J. F.) house, turret. 1887.	41 43 16·164	498·7	70 40 06·295	145·5
Swift's (R.) barn.	41 43 55·767	1720·5	70 45 06·338	146·5
Rocky Woods.	41 46 52·747	1627·3	70 57 37·180	858·6

BUZZARDS BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
69 07 57·6	249 04 00·5	Cuttyhunk	8 902·5	3·949 510
126 17 51·0	306 13 04·8	Mishaum Point.	12 429·5	4·094 452
317 47 28·4	137 51 58·3	Naushon	14 053·8	4·147 795
19 52 34·1	199 49 27·1	Cuttyhunk.	19 278·2	4·285 067
352 45 41·9	172 46 28·6	Swift Hill	12 927·2	4·111 505
62 03 02·3	241 58 53·5	Angelica Point.	9 807·7	3·991 568
357 12 20·8	177 12 26·0	Wenaumet Neck	3 716·1	3·570 093
80 59 55·1	260 57 34·3	Great Hill.	4 953·2	3·694 883
295 19 17·3	115 20 22·7	Tempes Knob	2 511·4	3·399 919
54 46 58·4	234 45 42·9	Great Hill.	3 209·1	3·506 390
275 40 57·3	95 42 12·9	Indian Neck	2 636·9	3·421 097
359 55 20·6	179 55 20·7	Great Hill.	2 112·7	3·324 839
192 24 53·5	12 26 43·4	West Island	17 869·9	4·252 122
235 29 26·2	55 34 26·3	Naushon.	12 759·8	4·105 843
110 50 34·3	290 45 53·2	Cromeset Neck	10 447·9	4·019 027
115 48 20·2	295 44 54·6	Indian Neck.	7 931·5	3·899 356
284 35 38·9	104 39 42·9	Wenaumet Neck	8 769·1	3·942 956
326 01 24·4	146 06 14·9	Swift Hill.	18 126·7	4·258 318
330 46 39·2	150 49 40·8	Swift Hill	12 977·5	4·113 192
42 06 37·3	222 02 27·1	West Island.	13 011·2	4·114 318
203 30 23·8	23 32 56·0	Pine Hill	13 273·3	4·122 978
276 23 38·4	96 24 06·4	Falmouth.	981·6	2·991 920
131 10 31·3	311 05 26·7	Copecut	14 064·9	4·148 136
210 49 22·3	30 42 21·1	Mendal.	8 096·2	3·908 281
190 36 01·6	10 36 40·3	Mendal	7 310·9	3·863 970
327 42 12·7	147 43 57·5	Sconticut Neck.	6 840·6	3·835 094
176 26 03·6	356 25 55·2	New Bedford High School	4 704·5	3·672 518
282 00 36·6	102 03 32·9	Sconticut Neck.	6 290·1	3·798 655
61 02 03·8	240 55 48·4	Mendal	14 902·4	4·173 256
356 42 04·6	176 42 15·0	Great Hill.	6 306·1	3·799 762
55 48 26·4	235 46 01·5	Mendal	6 089·1	3·784 554
286 33 07·2	106 37 07·9	Great Hill.	8 725·0	3·940 767
283 59 53·9	104 04 18·2	Indian	9 555·7	3·980 261
339 47 51·9	159 49 30·4	Prospect Chilmark.	10 026·1	4·001 130
252 03 45·5	72 07 57·3	Mendal	9 200·9	3·963 831
311 45 45·1	131 47 58·0	New Bedford High School.	6 204·5	3·792 708
352 21 05·4	172 21 08·9	Mendal	925·2	2·966 233
66 34 42·6	246 30 34·3	Faunce.	9 409·2	3·973 554
344 13 51·5	164 14 41·2	Mendal	6 359·7	3·803 438
38 09 19·9	218 05 57·7	Faunce.	11 376·1	4·055 994
26 42 51·2	206 41 35·2	Mendal	5 875·1	3·769 018
101 18 47·3	281 16 41·5	Braley's barn cupola.	4 452·2	3·648 576
73 35 31·5	253 33 22·3	Great Hill	4 679·1	3·670 158
135 44 29·2	315 42 09·5	Wareham Congregational church.	6 945·3	3·841 690
89 29 46·6	269 26 56·3	Rochester Congregational church	5 913·4	3·771 834
209 03 02·6	29 04 02·7	Wareham Congregational church.	4 290·9	3·632 544
321 54 44·4	141 57 45·4	Perry Hill Christian Baptist church cupola	10 188·0	4·008 087
351 50 15·4	171 51 21·0	New Bedford High School.	16 063·0	4·205 826

BUZZARDS BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Borden.	41 45 49·331	1521·9	70 54 31·792	734·4
Round Hill.	41 32 24·78	764·5	70 55 50·62	1173·4
Clark Point.	41 35 34·16	1053·9	70 54 03·71	85·9
New Bedford Fort.	41 37 27·07	835·1	70 54 10·40	240·8
Wild Harbor.	41 38 22·19	684·6	70 39 09·04	209·2
Sippican Neck.	41 40 35·93	1108·5	70 42 58·06	1343·9
Long Neck.	41 44 20·22	623·8	70 38 45·42	1049·6
Back River Harbor.	41 43 18·58	573·2	70 36 50·49	1167·0
Hog Island Harbor.	41 36 15·83	488·4	70 38 57·00	1319·9
Naushon, southwest. 1844.	41 27 01·82	56·1	70 47 19·98	463·7
Naushon, northeast.	41 30 35·72	1101·7	70 42 48·91	1134·2
Penikese. 1844.	41 26 58·16	1794·3	70 55 26·90	624·4
Penikese. (Borden) 1835.	41 26 58·19	1795·3	70 55 27·10	629·1
Padanaram.	41 35 39·28	1211·8	70 56 35·76	828·2
Padanaram, gray church spire. 1844.	41 35 20·13	621·0	70 56 28·10	650·9
New Bedford Baptist church spire. 1844–1887.	41 38 12·36	381·3	70 55 37·00	856·4
New Bedford Beacon. 1844.	41 36 33·62	1037·2	70 53 28·75	665·7
Fairhaven, black church spire. 1844.	41 38 09·82	303·9	70 54 18·87	436·7
Pamanset River.	41 31 41·30	1274·1	70 59 31·01	718·9
Monument church spire. 1844.	41 44 32·45	1001·1	70 35 49·73	1149·1
South Pocasset church spire. 1844.	41 40 36·26	1118·7	70 36 22·84	528·3
Scraggy Neck.	41 39 59·28	1828·9	70 39 15·57	360·2
North Falmouth Congregational church spire. 1844–1888.	41 38 33·31	1027·6	70 37 07·29	168·7
Falmouth church spire. 1844.	41 33 14·95	461·2	70 37 12·52	290·1

BUZZARDS BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
341 45 37·9	161 46 35·5	Perry Hill Christian Baptist church cupola	6 385·4	3·805 189
114 34 27·5	294 32 24·0	Rocky Woods.	4 707·6	3·672 804
289 23 14	109 30 43	Naushon	16 654·4	4·221 53
232 05 51	52 08 50	Sconticut Neck.	7 932·5	3·899 41
284 23 38	104 25 27	Sconticut Neck	3 905·5	3·591 68
22 59 07	202 57 56	Round Hill.	6 345·6	3·802 47
318 31 17	138 33 10	Sconticut Neck	5 945·2	3·774 17
357 27 20	177 27 24	Clark Point.	3 486·8	3·542 43
65 56 08	245 49 22	West Island	15 519·6	4·190 88
353 40 19	173 40 44	Swift Hill.	8 061·9	3·906 44
46 20 26	226 18 28	Angelica Point	5 671·8	3·753 72
171 51 55	351 51 40	Great Hill.	3 657·1	3·563 14
296 53 16	116 56 27	Pine Hill	7 434·8	3·871 27
62 35 50	242 32 47	Great Hill.	7 162·3	3·855 05
290 12 39	110 14 33	Pine Hill	4 234·9	3·626 84
81 13 19	261 09 00	Great Hill.	9 122·4	3·960 11
351 34 38	171 34 55	Swift Hill	4 159·5	3·619 04
80 27 24	260 20 30	West Island.	14 652·4	4·165 91
117 38 04	297 31 29	Mishaum Point	15 612·1	4·193 46
169 11 03	349 09 43	West Island.	14 913·2	4·173 57
131 34 55	311 30 35	West Island	12 135·8	4·084 07
223 09 26	43 12 18	Swift Hill.	8 746·4	3·941 83
270 03 00	90 06 33	Pasque	7 485·1	3·874 20
14 35 59	194 35 35	Cuttyhunk.	3 292·5	3·517 53
276 01 56	96 11 43	Indian	20 695·7	4·315 88
14 31 36	194 31 12	Cuttyhunk.	3 292·2	3·517 48
272 33 16	92 34 57	Clark Point	3 525·0	3·547 16
350 06 23	170 06 53	Round Hill.	6 090·6	3·784 66
262 36 45	82 38 21	Clark Point	3 372·2	3·527 91
350 52 25	170 52 50	Round Hill.	5 478·7	3·738 68
316 33 11	136 40 31	Naushon	22 385·2	4·349 96
9 43 18	189 42 12	Mishaum Point.	13 654·6	4·135 28
313 20 37	133 22 02	Sconticut Neck	4 088·1	3·611 52
23 48 56	203 48 33	Clark Point.	2 005·4	3·302 20
324 23 38	144 25 37	Sconticut Neck	7 100·5	3·851 29
355 49 04	175 49 14	Clark Point.	4 815·4	3·682 63
255 15 58	75 18 24	Round Hill	5 282·4	3·722 83
294 03 38	114 05 07	Mishaum Point.	3 417·4	3·533 69
31 38 53	211 38 13	Back River Harbor	2 676·8	3·427 61
84 42 15	264 40 18	Long Neck.	4 077·4	3·610 38
89 58 18	269 53 55	Sippican Neck	9 142·0	3·961 04
132 39 34	312 37 17	Tempes Knob.	6 475·9	3·811 30
357 07 04	177 07 08	Wild Harbor	2 999·2	3·477 00
102 24 47	282 22 19	Sippican Neck.	5 269·3	3·721 75
115 01 26	294 57 33	Sippican Neck	8 953·6	3·952 00
89 25 16	269 19 25	Angelica Point.	12 221·9	4·087 14
49 21 48	229 20 09	Woods Hole	4 552·6	3·658 26
55 16 57	235 12 05	Naushon.	12 442·6	4·094 91

BUZZARDS BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Mattapoisett Neck.	41 37 46·57	1436·7	70 48 11·30	261·6
Mattapoisett gray church spire. 1844.	41 39 43·93	1355·2	70 49 12·28	284·1
Wareham Catholic (formerly Baptist) church spire. 1844–1887.	41 45 27·20	839·2	70 43 03·62	83·6
Charles Neck.	41 40 21·60	666·4	70 44 45·04	1041·9
West Island 2. 1844.	41 35 25·09	774·1	70 49 04·85	112·3
New Falmouth.	41 33 42·42	1308·7	70 37 52·42	1214·6
Ned Point light-house. 1844.	41 39 03·34	103·0	70 47 46·11	1067·0
Dumpling Rock light-house. (C. & G. S. & Bdn.), 1835–1844.	41 32 17·88	551·6	70 55 19·08	442·3
Clark Point light-house. (C. & G. S. & Bdn.), 1835–1844.	41 35 34·27	1057·3	70 54 03·92	90·8
Cuttyhunk light-house. (C. &. G. S. & Bdn.), 1835–1844.	41 24 52·35	1615·0	70 57 00·18	4·2
Naushon. (Borden) 1836.	41 29 24·97	770·4	70 44 33·34	773·4
Wings Neck light-house. 1875 (changed after August 1, 1889).	41 40 49·38	1523·4	70 39 41·75	965·6
Palmer Island light-house. 1875.	41 37 37·27	1149·7	70 54 34·72	803·7
Clark Point light-house. 1887.	41 35 35·62	1098·9	70 54 06·60	152·9
Lane.	41 36 43·43	1339·8	70 55 00·14	3·2
Studley.	41 37 14·39	443·9	70 51 51·00	1180·7
Boundary stone, New Bedford 1.	41 36 47·62	1469·1	70 55 52·21	1208·8
Boundary stone, Mattapoisett 1.	41 37 42·76	1319·2	70 50 37·20	861·1
Flag in oak tree near boundary stone, Mattapoisett 2.	41 38 40·99	1264·6	70 50 44·32	1025·7
Boundary stone, Mattapoisett 2.	41 38 40·98	1264·3	70 50 44·64	1033·1
Flag in tree near boundary stone, Mattapoisett 2½.	41 40 21·76	671·3	70 51 20·68	478·4
Boundary stone, Mattapoisett 2½.	41 40 21·38	659·6	70 51 20·62	477·0
Flag in pine tree near boundary stone, Mattapoisett 3.	41 42 00·87	26·8	70 51 56·52	1306·9
Boundary stone, Mattapoisett 3.	41 42 00·77	23·8	70 51 55·77	1289·5
Flag in maple tree near boundary stone, Mattapoisett 4.	41 42 06·20	191·3	70 50 37·21	860·4

BUZZARDS BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
297 09 34	117 15 59	Swift Hill	15 119·6	4·179 54
341 54 18	161 56 43	Naushon.	16 276·1	4·211 55
305 17 09	125 24 15	Swift Hill	18 210·8	4·260 33
1 16 23	181 16 17	West Island.	8 866·3	3·947 74
294 40 32	114 44 40	Back River Harbor	9 492·1	3·977 36
330 32 54	150 35 09	Wenaumet Neck.	9 531·0	3·979 14
295 19 33	115 23 16	Wild Harbor	8 603·2	3·934 66
25 05 27	205 04 40	Angelica Point.	3 836·7	3·583 96
217 42 03	37 44 09	Angelica Point	7 171·5	3·855 61
298 05 11	118 11 25	Woods Hole.	14 802·3	4·170 33
33 34 24	213 33 12	Woods Hole	4 576·6	3·660 54
49 32 05	229 27 39	Naushon.	12 225·6	4·087 27
305 46 10	125 52 19	Swift Hill	15 860·2	4·200 31
345 55 50	165 57 58	Naushon.	18 391·6	4·264 62
4 26 01	184 25 32	Cuttyhunk	13 088·5	4·116 89
47 10 41	227 09 23	Mishaum Point.	3 710·3	3·569 41
280 01 00	100 04 08	West Island	6 660·2	3·823 49
27 29 14	207 27 06	Mishaum Point.	9 672·1	3·985 52
133 10 46	313 03 52	Nootas	19 888·9	4·298 61
178 04 34	358 04 23	Mishaum Point.	11 228·5	4·050 32
135 31 30	315 23 59	New Bedford court-house	22 452·8	4·351 27
110 20 25	290 08 59	Dartmouth.	25 555·2	4·407 48
2 48 50	182 48 11	Indian	27 881·8	4·445 32
17 10 04	197 06 58	Desert Hill.	21 973·5	4·341 90
334 55 53	155 02 20	Prospect Chilmark	32 016·2	4·505 37
316 37 24	136 44 11	Desert Hill.	20 716·7	4·316 32
97 18 09	277 17 03	Guano	2 320·9	3·365 66
182 20 25	2 20 31	Rogers School.	4 770·2	3·678 54
30 34 26	210 33 56	Guano	2 087·9	3·319 72
154 57 25	334 56 46	New Bedford high school.	3 198·5	3·504 95
77 42 57	257 40 51	Lane	4 482·3	3·651 50
120 17 24	300 16 00	Rogers School.	3 409·3	3·532 66
355 43 59	175 44 03	Guano	1 932·3	3·286 08
276 06 45	96 07 20	Lane.	1 212·4	3·083 65
62 53 01	242 52 12	Studley	1 919·2	3·283 13
100 17 58	280 15 44	Rogers School.	4 728·1	3·674 69
30 00 52	210 00 08	Studley	3 085·2	3·489 28
84 18 21	264 14 52	New Bedford high school.	7 311·1	3·863 98
91 34 35	271 29 17	Faunce	11 059·6	4·043 74
59 11 57	239 08 52	New Bedford high school.	7 488·9	3·874 42
92 36 35	272 35 53	Mendal	1 469·7	3·167 24
192 25 57	12 26 31	Hubbard's barn.	5 443·0	3·735 84
88 19 00	268 17 25	Mendal	3 303·6	3·518 99
172 41 30	352 41 11	Hubbard's barn.	5 193·0	3·715 42

BUZZARDS BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Boundary stone, Mattapoisett 4.	41 42 06·03	186·0	70 50 36·98	855·1
Flag in pine tree near boundary stone, Mattapoisett 5.	41 42 19·45	600·1	70 50 35·20	813·8
Boundary stone, Mattapoisett 5.	41 42 19·46	600·4	70 50 37·66	870·7
Boundary stone, Mattapoisett 6.	41 42 36·58	1128·5	70 47 58·44	1351·1
Grove, flag in tree.	41 40 47·15	1454·6	70 49 50·12	1159·3
Russell.	41 39 19·22	593·0	70 57 49·68	1149·5
Wilbur.	41 41 51·16	1578·4	70 58 57·82	1337·0
Acushnet Congregational church, southeastern pinnacle of square steeple, 1887.	41 40 58·61	1808·2	70 55 23·07	533·6
Acushnet Methodist church spire. 1887.	41 40 58·23	1796·5	70 54 53·42	1235·5
Boundary stone, Fairhaven 1.	41 39 51·72	1595·6	70 54 55·14	1275·7
Flag in pine tree near boundary stone, Fairhaven 2.	41 40 06·77	208·9	70 53 23·70	548·3
Boundary stone, Fairhaven 2.	41 40 06·79	209·5	70 53 24·48	566·3
Boundary stone, Acushnet 4.	41 41 09·08	280·1	70 55 23·04	532·9
Boundary stone, Acushnet 5.	41 41 08·87	273·6	70 55 26·60	615·2
Boundary stone, New Bedford 2.	41 38 55·22	1703·6	70 58 12·52	289·7
Flag in apple tree near boundary stone, Acushnet 6.	41 42 11·63	358·8	70 55 47·58	1100·1
Boundary stone, Acushnet 6.	41 42 12·03	371·1	70 55 47·31	1093·9
Flag in pine tree near boundary stone, Acushnet 7.	41 44 41·16	1269·9	70 56 36·30	838·8
Boundary stone, Acushnet 7.	41 44 40·97	1264·0	70 56 36·50	843·4
Chase's (C. E.) barn.	41 45 52·54	1620·9	70 58 02·55	58·9
Flag in pine tree near boundary stone, Acushnet 8.	41 45 17·18	530·0	70 55 22·24	513·8
Boundary stone, Acushnet 8.	41 45 17·61	543·3	70 55 21·76	502·7
Flag in pine tree near boundary stone, Acushnet 9.	41 45 32·29	996·2	70 55 35·73	825·4
Boundary stone, Acushnet 9.	41 45 32·21	993·7	70 55 35·85	828·2
Boundary stone, New Bedford 3.	41 40 43·40	1338·9	70 58 40·79	943·5
Boundary stone, New Bedford 4.	41 44 02·47	76·2	70 57 54·12	1250·7
Boundary stone, Acushnet 2.	41 40 55·19	1702·7	70 55 10·76	248·9
Boundary stone, Acushnet 3.	41 40 54·92	1694·4	70 55 12·22	282·6
Boundary stone, Acushnet 3¼.	41 41 00·16	4·9	70 55 12·85	297·2
Boundary stone, Acushnet 3½.	41 41 01·36	42·0	70 55 13·24	306·2

BUZZARDS BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
81 24 29	261 22 53	Mendal	3 386·5	3·529 75
171 31 18	351 30 58	Hubbard's barn.	4 794·2	3·680 72
140 58 54	320 57 58	Rochester Congregational church	3 074·6	3·487 79
238 25 44	58 27 39	Swift's barn.	4 668·3	3·669 16
118 04 45	298 02 39	Mendal	4 976·7	3·696 94
61 34 40	241 30 35	New Bedford high school.	9 698·4	3·986 70
306 35 25	126 36 39	New Bedford high school	3 201·1	3·505 30
232 56 53	53 00 06	Mendal.	8 392·5	3·923 89
327 50 14	147 52 13	New Bedford high school	7 790·4	3·891 56
267 25 59	87 29 57	Mendal.	8 281·3	3·918 10
9 23 46	189 23 22	New Bedford high school	5 042·7	3·702 66
238 59 14	59 00 49	Mendal.	3 859·2	3·586 50
16 54 59	196 54 16	New Bedford high school	5 187·5	3·714 96
53 11 01	233 09 04	Russell.	5 094·5	3·707 10
26 47 08	206 46 26	New Bedford high school	3 261·0	3·513 35
162 37 23	342 37 04	Acushnet Congregational church, square steeple.	2 162·4	3·334 94
95 18 39	275 14 43	Faunce	8 244·4	3·916 16
188 40 39	8 40 55	Mendal.	3 628·3	3·559 70
00 08 19	180 08 19	Acushnet Congregational church, square steeple	322·9	2·509 11
296 02 20	116 02 40	Acushnet Methodist church spire.	762·4	2·882 18
345 31 45	165 31 47	Acushnet Congregational church, square steeple	326·9	2·514 46
293 09 35	113 09 57	Acushnet Methodist church spire.	834·8	2·921 56
215 30 03	35 30 18	Russell	909·6	2·958 84
169 04 45	349 04 15	Wilbur.	5 528·2	3·742 58
345 51 54	165 52 10	Acushnet Congregational church, square steeple	2 322·7	3·366 00
260 08 09	80 09 57	Perry Hill Christian Baptist church.	3 807·1	3·580 59
25 58 15	205 56 27	Faunce	8 571·8	3·933 07
309 04 23	129 06 43	Perry Hill Christian Baptist church.	6 282·9	3·798 16
271 08 34	91 10 54	Borden	4 869·5	3·687 48
197 30 20	17 30 37	Rocky Woods.	1 948·0	3·289 58
328 02 20	148 03 51	Perry Hill Christian Baptist church	5 978·7	3·776 61
265 12 09	85 12 54	Braley's barn cupola.	1 564·1	3·194 26
327 52 50	147 54 30	Perry Hill Christian Baptist church	6 539·1	3·815 52
280 09 40	100 10 34	Braley's barn cupola.	1 900·2	3·278 80
66 59 00	246 58 35	Faunce	950·3	2·977 86
176 43 02	356 42 56	Chase's (C. E) barn	3 401·5	3·531 67
146 27 25	326 27 17	Boundary stone, Acushnet 4	514·1	2·711 07
150 12 35	330 12 38	Boundary stone, Acushnet 4	503·5	2·702 00
139 25 35	319 25 28	Boundary stone, Acushnet 4	362·4	2·559 13
136 25 25	316 25 18	Boundary stone, Acushnet 4	328·9	2·517 06

BUZZARDS BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Boundary stone, Acushnet 3⅞.	41 41 05·31	163·8	70 55 15·98	369·6
Boundary stone, Acushnet 9⅛.	41 45 48·33	1491·1	70 54 30·24	698·6
Boundary stone, Acushnet 9⅜.	41 45 48·30	1490·1	70 54 30·24	698·6
Boundary stone, Acushnet 10.	41 45 48·93	1509·6	70 54 27·62	638·0
Boundary stone, Rochester 3.	41 45 28·98	894·1	70 54 17·74	409·8
Boundary stone, Rochester 3⅛.	41 45 35·53	1096·2	70 54 20·52	474·0
Boundary stone, Rochester 3⅜.	41 45 39·18	1208·8	70 54 22·53	520·5
Peak Rock.	41 45 44·88	1384·6	70 54 25·49	588·8
Flag in pine tree near boundary stone, Rochester 2.	41 45 37·00	1141·5	70 53 12·91	298·2
Boundary stone, Rochester 2.	41 45 37·02	1142·1	70 53 12·95	299·1
Flag in pine tree near bounda y stone, Rochester 4.	41 47 28·89	891·3	70 55 20·39	470·8
Boundary stone, Rochester 4.	41 47 28·66	884·2	70 55 20·18	466·0
Reynolds.	41 43 36·96	1140·3	70 58 54·42	1257·8
Hillside.	41 43 29·21	901·2	71 00 46·84	1082·6
Boundary stone, Fairhaven 3.	41 40 52·31	1613·8	70 51 31·31	724·2
Flag in pine tree near boundary stone, Fairhaven 3.	41 40 52·46	1618·5	70 51 32·48	751·2
Flag in oak tree near boundary stone, Freetown 2.	41 44 46·28	1427·8	71 00 35·84	828·1
Boundary stone, Freetown 2.	41 44 46·49	1434·3	71 00 36·10	834·1
Flag in pine tree near boundary stone, Freetown 1.	41 42 42·58	1313·7	71 00 44·59	1030·9
Boundary stone, Freetown 1.	41 42 42·58	1313·7	71 00 44·55	1030·0
Ashley's (E. R.) barn cupola.	41 44 17·04	525·7	70 53 42·27	976·8
Flag in pine tree near boundary stone, Marion 2.	41 40 28·14	868·2	70 47 11·29	261·1
Boundary stone, Marion 2.	41 40 28·15	868·5	70 47 11·64	269·3
Flag in pine tree near boundary stone, Marion 3.	41 41 13·64	420·8	70 48 11·87	274·5
Boundary stone, Marion 3.	41 41 13·69	422·4	70 48 12·35	285·6
Flag in pine tree near boundary stone, Marion 4.	41 43 42·34	1306·3	70 47 47·69	1102·2
Boundary stone, Marion 4.	41 43 42·28	1304·4	70 47 48·06	1110·8
Flag in pine tree near boundary stone, Marion 5.	41 44 35·60	1098·3	70 47 37·11	857·5
Boundary stone, Marion 5.	41 44 35·64	1099·5	70 47 37·34	862·8
Flag in pine tree near boundary stone, Marion 6.	41 44 50·87	1569·4	70 47 11·52	266·2
Boundary stone, Marion 6.	41 44 50·82	1567·9	70 47 10·54	243·5
Flag in pine tree near boundary stone, Marion 7.	41 44 59·42	1833·2	70 47 16·74	386·8
Boundary stone, Marion 7.	41 44 59·51	1836·0	70 47 16·77	387·5
Flag in pine tree near boundary stone, Marion 8.	41 45 25·02	771·9	70 47 13·46	310·9

BUZZARDS BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
129 33 53	309 33 48	Boundary stone, Acushnet 4	211·7	2·325 66
130 50 22	310 50 21	Borden	47·178	1·673 74
131 35 56	311 35 55	Borden	48·0	1·681 22
97 17 53	277 17 50	Borden	97·038	1·986 94
152 39 38	332 39 29	Borden	706·7	2·849 21
148 33 59	328 33 52	Borden	499·1	2·698 15
145 39 41	325 39 35	Borden	379·3	2·579 02
133 19 52	313 19 48	Borden	199·9	2·300 84
300 46 45	120 49 19	Rochester Congregational church	6 206·1	3·792 82
358 14 22	178 14 27	Perry Hill Christian Baptist church.	5 686·7	3·754 86
70 34 10	250 32 39	Rocky Woods	3 349·8	3·525 02
221 45 08	41 46 36	Pasture.	4 575·7	3·660 46
84 42 00	264 38 52	Copecut	6 551·5	3·816 34
337 34 34	157 36 31	New Bedford high school.	10 665·2	4·027 97
320 11 13	140 12 25	Wilbur	3 936·9	3·595 16
264 43 51	84 45 06	Reynolds.	2 609·3	3·416 53
136 46 26	316 45 27	Mendal	2 994·83	3·476 37
56 41 44	236 39 44	Copecut	5 000·6	3·699 02
312 22 26	132 23 34	Reynolds.	3 173·3	3·501 51
177 55 59	357 55 57	Hillside	1 439·7	3·158 26
236 36 41	56 37 54	Reynolds.	3 049·7	3·484 26
346 42 14	166 42 42	Mendal	4 248·1	3·628 19
15 52 42	195 51 11	New Bedford high school.	11 536·1	4·062 06
242 09 02	62 13 45	O'Shaughnessy's house	11 109·9	4·045 71
204 16 05	24 17 28	Swift's barn.	7 027·8	3·846 82
102 54 14	282 51 03	Mendal	6 835·3	3·834 76
161 48 38	341 47 51	Rochester Congregational church.	5 208·1	3·716 68
99 21 36	279 20 33	Rochester Congregational church	2 213·8	3·345 14
234 21 07	54 23 54	Wareham Congregational church.	7 150·4	3·854 33
289 24 57	109 26 37	Swift's barn	3 694·4	3·567 54
62 09 15	242 08 05	Rochester Congregational church.	2 746·8	3·438 82
300 25 48	120 27 11	Swift's barn	3 355·2	3·525 72
247 34 52	67 37 15	Wareham Congregational church.	5 381·8	3·730 93
303 04 52	123 06 19	Swift's barn	3 596·7	3·555 91
250 39 32	70 41 59	Wareham Congregational church.	5 400·6	3·732 44
313 08 14	133 09 39	Swift's barn	4 026·2	3·604 90
258 44 32	78 46 57	Wareham Congregational church.	5 118·2	3·709 12

BUZZARDS BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Boundary stone, Marion 8.	41 45 24·89	767·9	70 47 13·64	315·1
Flag in pine tree near boundary stone, Marion 9.	41 45 45·84	1414·2	70 46 49·16	1135·6
Boundary stone, Marion 9.	41 45 46·24	1426·6	70 46 49·96	1154·1
Brandy Hill.	41 45 18·71	577·2	70 41 20·30	469·0
Hovey.	41 40 20·35	627·8	70 44 44·48	1028·9
Hiller.	41 40 08·10	249·9	70 45 34·14	789·8
Cove.	41 39 27·84	858·9	70 45 29·69	687·0
Boundary stone, Marion 1.	41 40 38·58	1190·2	70 45 48·62	1124·6
Academy.	41 42 09·20	283·8	70 46 02·95	68·2
Hill Pine.	41 46 15·18	468·3	70 44 24·47	565·2
Knoll.	41 47 38·70	1194·0	70 43 28·86	666·3
Low.	41 47 55·56	1714·1	70 43 06·02	139·0
Pond.	41 48 03·07	94·7	70 43 33·81	780·6
Bank.	41 48 12·84	396·1	70 43 08·74	201·8
Scrub.	41 48 03·24	100·0	70 43 09·01	208·0
Boundary stone, Wareham 6.	41 48 05·67	174·9	70 43 04·04	93·3
Boundary stone, Wareham 5½.	41 48 04·26	131·4	70 43 31·66	730·9
Road.	41 48 27·30	842·2	70 43 32·64	753·4
Stump.	41 48 24·17	745·7	70 43 54·12	1249·3
Small.	41 48 09·18	283·2	70 44 27·16	627·0
Rock.	41 48 22·72	701·0	70 44 39·62	914·6
Leaf.	41 48 13·47	415·6	70 44 44·88	1036·1
Boundary stone, Wareham 4½.	41 48 21·23	655·6	70 44 51·72	1193·9
Boundary stone, Wareham 5.	41 48 01·35	41·7	70 44 28·92	667·6
Flag in pine tree near boundary stone, Wareham 2.	41 48 32·32	997·1	70 46 20·17	465·6

BUZZARDS BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
325 00 50	145 01 58	Swift's barn	4 144·6	3·617 48
265 26 04	85 28 13	Wareham Congregational church.	4 473·0	3·650 60
110 48 40	290 47 10	Wareham Congregational church	3 356·8	3·525 93
63 55 18	243 52 48	Swift's barn.	5 816·3	3·764 65
278 04 20	98 05 27	Bird Island light-house	2 344·5	3·370 05
205 21 00	25 21 56	Great Hill.	4 538·5	3·656 91
251 46 55	71 47 28	Hovey	1 209·5	3·082 59
269 11 12	89 12 52	Bird Island light-house.	3 470·5	3·540 39
175 15 59	355 15 56	Hiller	1 246·4	3·095 64
212 50 48	32 51 18	Hovey.	1 928·5	3·285 21
340 23 58	160 24 08	Hiller	998·2	2·999 22
290 45 10	110 45 53	Hovey.	1 586·6	3·200 47
201 42 06	21 42 44	Swift's barn	3 538·4	3·548 81
311 42 43	131 44 42	Bird Island light-house.	5 541·0	3·743 59
292 14 49	112 16 52	Brandy Hill	4 597·3	3·662 50
342 40 02	162 40 45	Cromeset Neck.	4 958·0	3·695 31
3 04 39	183 04 34	Wareham Congregational church	3 131·7	3·495 78
325 28 50	145 30 16	Brandy Hill.	5 241·3	3·719 44
10 47 54	190 47 34	Wareham Congregational church	3 712·9	3·569 71
45 23 50	225 23 35	Knoll.	740·5	2·869 55
289 51 57	109 52 16	Low	682·1	2·833 85
351 21 20	171 21 23	Knoll.	760·5	2·881 08
353 17 36	173 17 38	Low	537·2	2·730 12
62 29 07	242 28 50	Pond.	652·6	2·814 64
181 12 10	1 12 10	Bank	296·3	2·471 79
89 28 44	269 28 27	Pond.	572·6	2·757 84
56 49 48	236 49 45	Scrub	137·0	2·136 74
153 53 23	333 53 20	Bank.	246·5	2·391 75
294 24 23	114 24 40	Low	650·0	2·812 92
53 25 55	233 25 54	Pond.	61·7	1·790 62
327 53 10	147 53 28	Low	1 156·2	3·063 04
2 03 31	182 03 30	Pond.	748·0	2·873 90
258 59 04	78 59 18	Road	505·1	2·703 34
324 14 04	144 14 18	Pond.	802·3	2·904 35
278 40 42	98 41 18	Pond	1 245·8	3·095 46
238 44 07	58 44 29	Stump.	892·1	2·950 41
325 25 51	145 25 59	Small	507·4	2·705 35
267 32 09	87 32 39	Stump.	1 051·4	3·021 77
203 03 21	23 03 25	Rock	310·2	2·491 59
287 55 27	107 55 39	Small.	430·3	2·633 73
260 40 20	80 40 28	Rock	283·0	2·451 82
326 37 11	146 37 16	Leaf.	286·8	2·457 64
135 25 00	315 24 49	Leaf	525·1	2·720 22
189 35 13	9 35 14	Small.	245·0	2·389 14
321 36 01	141 37 50	Wareham Congregational church	6 099·9	3·785 32
26 06 21	206 04 20	Rochester Congregational church.	9 560·7	3·980 49

BUZZARDS BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Boundary stone, Wareham 2.	41 48 32·29	996·2	70 46 20·24	467·2
Flag in pine tree near boundary stone, Wareham 1.	41 45 40·96	1263·7	70 46 45·58	1052·9
Boundary stone, Wareham 1.	41 45 40·70	1255·7	70 46 44·90	1037·2
Boundary stone, Wareham 3.	41 48 35·44	1093·4	70 45 49·22	1136·1
Boundary stone, Wareham 4.	41 49 32·99	1017·8	70 46 14·72	339·7
Boundary stone, Carver 3.	41 49 45·29	1397·3	70 46 18·43	425·3
South Pasque.	41 26 37·55	1158·4	70 48 39·58	918·8
Cupola.	41 25 16·72	515·8	70 55 48·50	1126·2
South Cuttyhunk.	41 24 35·46	1093·9	70 56 57·62	1338·3
South Naushon.	41 26 48·60	1499·3	70 47 59·80	1388·1
Hope Spring.	41 39 15·47	477·3	70 37 08·98	207·8
Beaumont water tank.	41 39 57·20	1764·7	70 37 31·36	725·5
Bourne, corner 4.	41 39 27·16	837·9	70 37 15·38	355·9
Hope Spring, peg.	41 39 30·80	950·2	70 36 49·92	1155·0
Bourne, corner 3.	41 39 30·54	942·2	70 36 49·47	1144·6
Cataumet, peg.	41 39 32·12	991·0	70 36 43·85	1014·6
Bourne, corner 2.	41 39 28·68	884·8	70 36 40·79	943·8
Falmouth Congregational church spire. 1888.	41 33 15·86	489·3	70 37 10·64	246·6
Ashunet.	41 38 17·12	528·2	70 32 26·40	611·0
Hatch.	41 37 20·56	634·3	70 32 36·08	835·3
Mashpee, corner 5.	41 38 14·40	444·3	70 32 24·65	570·5
Turpentine.	41 38 40·32	1243·9	70 33 53·20	1231·2
Bourne, corner 1.	41 38 44·17	1362·7	70 34 06·24	144·4
Hilman's barn cupola. 1887–88.	41 40 26·04	803·4	70 31 38·60	892·8

BUZZARDS BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
279 29 38	99 30 37	Boundary stone, Wareham 4½	2 070·84	3·316 15
324 44 55	144 46 01	Swift's barn	3 973·7	3·599 20
263 23 33	83 25 39	Wareham Congregational church.	4 404·9	3·643 94
288 15 55	108 16 33	Boundary stone, Wareham 4½	1 398·03	3·145 52
3 53 23	183 53 19	Boundary stone, Wareham 2	1 877·28	3·273 53
1 03 55	181 03 54	Boundary stone, Wareham 2	2 252·34	3·352 63
66 52 39	246 50 22	Nashawena	5 227·7	3·718 51
328 28 15	148 30 46	Prospect Chilmark.	10 156·9	4·006 76
265 06 29	85 08 56	Nashawena	5 170·7	3·713 55
308 45 12	128 50 20	Molasha Hill 2.	13 903·4	4·143 12
255 45 17	75 48 30	Nashawena	6 971·4	3·843 32
306 28 42	126 33 09	Gay Head 2.	11 668·6	4·067 02
67 20 13	247 17 30	Nashawena	6 211·4	3·793 19
246 06 19	66 06 45	Naushon southwest 2.	1 009·8	3·004 23
216 05 20	36 07 27	Pine Hill	7 471·7	3·873 42
254 43 16	74 44 27	Deer Horn.	2 564·3	3·408 97
281 33 04	101 34 30	Deer Horn	3 053·7	3·484 82
2 53 57	182 53 46	West Falmouth Observatory.	7 430·4	3·871 01
158 15 48	338 15 37	Beaumont water tank	997·8	2·999 06
263 08 41	83 09 56	Deer Horn.	2 641·1	3·421 78
42 58 46	222 58 33	Hope Spring	646·6	2·810 62
79 11 28	259 11 11	Bourne, corner 4.	599·9	2·778 10
127 44 46	307 44 46	Hope Spring peg	13·163	1·119 35
48 33 04	228 32 47	Hope Spring	775·6	2·889 61
78 10 12	258 09 51	Bourne, corner 4.	745·7	2·872 54
146 18 51	326 18 49	Cataumet peg	127·522	2·105 59
170 12 48	350 12 23	West Falmouth Observatory	5 034·4	3·701 95
246 30 31	66 34 18	Waquoit Congregational church.	8 627·0	3·935 86
121 21 38	301 19 41	Deer Horn	4 759·3	3·677 54
164 46 58	344 45 57	Pine Hill.	8 121·8	3·909 65
137 42 40	317 40 50	Deer Horn	5 706·8	3·756 39
168 44 18	348 43 23	Pine Hill.	9 770·3	3·989 91
130 33 57	310 32 58	Deer Horn	2 706·3	3·432 37
178 59 36	358 59 32	Pine Hill.	7 122·0	3·852 60
291 29 18	111 29 27	Turpentine	324·44	2·511 14
140 00 51	319 59 18	Pine Hill	5 037·8	3·702 24
207 08 23	27 10 01	Bourne Hill.	7 446·5	3·871 95

MASSACHUSETTS AND RHODE ISLAND BOUNDARY.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Beaconpole, R. I. (Borden) 1834.	42 00 03·257	100·5	71 26 43·159	993·2
Red Brush. (C. & G. S. & Bdn.) 1834–1889.	42 01 49·546	1528·7	71 22 23·459	539·6
Oak Hill. 1884–1890.	41 54 51·238	1580·8	71 16 43·230	996·3
Mansfield Unitarian church spire. 1884.	42 01 23·432	722·9	71 13 04·034	92·8
North Attleboro waterworks. 1884–1889.	41 59 46·529	1435·6	71 19 21·668	498·7
Hoppin Hill. 1884–1889.	41 57 52·698	1625·9	71 20 52·274	1203·7
Foxboro Congregational church spire. 1884–1889.	42 03 54·643	1686·0	71 15 08·334	191·6
Norton Congregational church spire. 1884–1889.	41 58 10·491	323·7	71 10 55·376	1275·0
Wing, R. I.	41 35 23·225	716·7	71 11 10·352	239·8
Paradise Rock, R. I.	41 30 05·511	169·9	71 15 45·504	1055·3
Simmons 2, R. I. 1870.	41 29 32·078	989·7	71 09 34·665	804·1
Little Compton 2, R. I. 1870.	41 31 12·440	383·7	71 11 01·694	39·3
Quicksand 2. 1870–1891.	41 29 56·406	1740·2	71 07 09·162	212·5
Massachusetts South Base reference mark. 1844–1889.	41 54 50·116	1546·2	71 18 16·464	379·4
Quicksand. 1843.	41 30 01·683	51·9	71 07 12·194	282·8
Nootas. (Borden) 1836.	41 32 13·094	404·0	71 07 25·874	599·8
Attleboro grammar school cupola.	41 56 46·158	1424·1	71 17 08·951	206·2
Mansfield Congregational church spire. 1889.	42 01 28·858	890·4	71 13 04·848	111·5
Bear Hill, R. I.	41 56 45·078	1390·8	71 23 23·185	534·1
Pawtucket waterworks, pole on gate-house, R. I	41 53 11·098	342·4	71 25 22·327	514·7
Joes Rock. (Borden.)	42 01 52·99	1634·9	71 24 17·24	396·6
Great Rock. (C. & G. S. & Bdn.) 1834–1844.	41 51 32·36	998·4	71 17 15·47	356·8
King Rock. (Borden.)	41 45 22·82	704·0	71 16 17·27	399·0

MASSACHUSETTS AND RHODE ISLAND BOUNDARY.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
229 16 01·8	49 29 20·0	Blue Hill (Borden)	36 036·0	4·556 737
131 55 21·2	311 37 08·9	Hasnebumskit.	50 107·9	4·699 906
322 22 16·3	142 28 31·5	Great Meadow	21 193·4	4·326 202
58 30 07·5	238 27 01·6	Beaconpole.	7 498·8	3·874 993
148 46 29·5	328 42 41·9	Red Brush	15 097·5	4·178 904
307 21 19·9	127 23 47·4	Great Meadow.	6 409·0	3·806 791
359 51 21·8	179 51 23·0	Great Meadow	15 991·0	4·203 876
22 39 42·8	202 37 16·2	Oak Hill.	13 110·8	4·117 630
326 03 16·7	146 07 30·3	Great Meadow	15 665·7	4·194 949
89 21 50·4	269 16 42·9	Beaconpole.	10 578·8	4·024 436
238 51 17·8	58 56 31·1	Mansfield Unitarian church spire	12 586·8	4·099 915
311 10 53·6	131 16 07·6	Great Meadow.	14 398·8	4·158 327
7 25 55·0	187 24 51·5	Oak Hill	16 907·5	4·228 079
68 56 54·9	248 52 03·5	Red Brush.	10 725·3	4·030 411
16 15 14·9	196 13 50·1	Great Meadow	10 455·4	4·019 340
52 32 14·2	232 28 21·7	Oak Hill.	10 099·5	4·004 302
154 08 19·3	334 06 09·2	Mount Hope	10 386·6	4·016 473
82 07 08·5	262 04 23·9	Quaker.	5 799·2	3·763 371
213 01 28·1	33 04 30·6	Wing	11 693·8	4·067 957
314 11 29·3	134 14 12·9	East Rock.	8 001·3	3·903 161
96 52 18·7	276 48 13·0	Paradise Rock	8 663·3	3·937 683
32 15 42·2	212 14 20·3	East Rock.	5 377·9	3·730 613
72 36 29·8	252 33 21·7	Paradise Rock	6 897·9	3·838 715
326 53 33·1	146 54 30·8	Simmons 2.	3 696·0	3·567 735
113 31 47·7	293 29 13·6	Little Compton 2	5 880·7	3·769 427
77 28 34·3	257 26 57·9	Simmons 2.	3 457·5	3·538 759
207 49 10·0	27 53 05·2	Massachusetts North Base	17 324·8	4·238 668
306 46 54·7	126 46 54·9	Massachusetts South Base.	10·06	1·002 530
221 43 16·3	41 44 38·4	Eldridge	4 317·0	3·635 184
175 32 19·6	355 32 10·6	Nootas.	4 064·2	3·608 975
244 58 18·0	65 02 02·4	Dartmouth	8 651·3	3·937 081
309 04 44·8	129 12 17·3	Cuttyhunk.	20 438·7	4·310 454
322 34 51·2	142 37 36·0	Great Meadow	9 360·0	3·971 277
111 48 01·1	291 41 25·0	Beaconpole.	14 682·9	4·166 811
359 47 27·5	179 47 29·2	Great Meadow	16 158·5	4·208 400
32 48 51·0	212 46 07·7	Attleboro grammar school.	10 375·6	4·016 013
188 19 15·5	8 19 55·5	Red Brush	9 493·8	3·977 442
290 49 38·5	110 54 05·8	Oak Hill.	9 861·6	3·993 948
194 25 28·9	14 27 28·5	Red Brush	16 517·6	4·217 946
255 28 26·1	75 34 12·8	Oak Hill.	12 357·9	4·091 946
317 20 11	137 27 42	Great Meadow	22 963·8	4·361 04
229 58 58	50 10 40	Blue Hill (Borden).	31 285·6	4·495 34
19 20 33	199 13 48	McSparran	42 668·3	4·630 10
354 56 55	174 58 13	Quaker.	30 816·3	4·488 78
130 32 00	310 26 51	College Hill	14 066·5	4·148 19
198 13 55	18 16 05	Great Meadow.	14 369·1	4·157 43

MASSACHUSETTS AND RHODE ISLAND BOUNDARY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Burnt Swamp. (Borden.)	42 01 08·36	257·9	71 22 54·53	1254·6
Bald Hill. (Borden.)	42 02 44·22	1364·3	71 42 35·59	818·4
Alumpond. (Borden.)	42 01 14·51	447·7	71 45 45·24	1040·8
Mount Daniel. (Borden.)	42 01 41·54	1281·6	71 48 10·30	236·9
Northwest corner of Rhode Island. (Borden.)	42 00 29·15	899·4	71 47 58·92	1355·8
Northeast corner of Connecticut. (Borden.)	42 01 24·82	765·8	71 48 04·20	96·6
Foxboro Baptist church spire. 1884.	42 03 51·18	1579·1	71 15 05·06	116·3
Lone fir tree.	41 54 57·45	1772·5	71 13 43·32	998·3
Attleboro Catholic church spire. 1884–1889.	41 56 54·14	1670·4	71 17 22·58	520·1
Verification south base, R. I. (Borden) 1836.	41 50 13·04	402·3	71 21 28·68	661·8
Verification north base. (Borden) 1836.	41 54 25·94	800·3	71 21 20·68	476·6
Blackbeard. 1843–1861.	41 40 28·88	891·0	71 10 58·83	1360·8
Joe Sanford. (Borden.)	41 35 37·56	1158·7	71 07 55·53	1286·1
Quicksand. (Borden) 1836.	41 30 01·73	53·4	71 07 12·18	282·5
Newcomb.	42 00 11·54	356·0	71 09 12·30	283·1
Tune.	42 00 53·63	1654·7	71 09 28·61	658·3
Cutting Plain.	42 00 53·41	1647·9	71 17 26·75	615·5
Smith. 1889–90.	41 54 56·76	1751·2	71 13 42·71	984·2
Woodward.	41 55 58·07	1791·6	71 09 46·70	1075·9
Rhodes.	41 56 36·67	1131·4	71 19 53·18	1225·0
Cumberland, R. I.	41 55 40·01	1234·4	71 23 35·50	818·0
Mowry.	41 54 56·23	1734·8	71 22 48·55	1118·8
Attleboro Methodist church spire. 1889.	41 56 43·93	1355·4	71 17 08·97	206·6

MASSACHUSETTS AND RHODE ISLAND BOUNDARY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
125 54 18	305 53 23	Joes Rock	2 348·4	3·370 77
209 20 39	29 21 00	Red Brush.	1 458·0	3·163 75
151 27 14	331 19 40	Hasnebumskit	32 365·1	4·510 08
249 12 18	69 36 15	Blue Hill (Borden).	52 578·1	4·720 80
160 22 24	340 16 58	Hasnebumskit	33 114·0	4·520 01
274 40 34	94 53 18	Beaconpole (Borden).	26 372·0	4·421 14
284 01 11	104 02 48	Alumpond.	3 438·3	3·536 35
89 56 35	269 45 28	Hatchet.	22 921·2	4·360 24
95 26 56	275 15 41	Hatchet	23 288·5	4·367 14
173 17 09	353 17 01	Mount Daniel.	2 248·8	3·351 96
164 50 30	344 50 26	Mount Daniel	534·4	2·727 86
275 40 05	95 41 38	Alumpond.	3 211·9	3·506 76
7 44 06	187 43 00	Oak Hill	16 811·3	4·225 60
69 37 28	249 32 34	Red Brush.	10 757·7	4·031 72
346 57 11	166 57 38	Great Meadow	4 190·3	3·622 24
87 22 16	267 20 16	Oak Hill.	4 150·5	3·618 10
215 35 33	35 38 26	Mansfield Unitarian church spire	10 220·4	4·009 47
321 59 33	142 02 27	Great Meadow.	9 747·2	3·988 88
169 49 19	349 47 26	Joes Rock	21 942·1	4·341 28
247 14 49	67 17 38	Great Rock.	6 333·1	3·801 61
313 25 31	133 28 14	Great Rock	7 787·7	3·891 41
1 21 22	181 21 17	Verification south base.	7 804·4	3·892 34
17 33 47	197 33 25	Pocasset	2 571·2	3·410 14
89 00 23	268 58 05	Mount Hope.	4 797·7	3·681 03
353 46 48	173 47 08	Nootas (Borden)	6 345·6	3·802 47
83 08 51	263 03 57	Quaker.	10 331·1	4·014 15
175 31 13	355 31 04	Nootas (Borden)	4 065·1	3·609 07
299 36 00	119 43 23	Cuttyhunk.	17 881·7	4·252 41
86 54 26	266 47 38	North Attleboro waterworks	14 045·9	4·147 55
32 26 28	212 25 19	Norton Congregational church spire.	4 424·8	3·645 89
21 39 08	201 38 10	Norton Congregational church spire	5 414·9	3·733 59
81 25 41	261 19 04	North Attleboro waterworks.	13 804·2	4·140 01
209 38 34	29 40 07	Foxboro Congregational church spire	6 434·2	3·808 49
356 55 17	176 55 29	Attleboro grammar school.	7 639·2	3·883 05
347 04 29	167 04 56	Great Meadow	4 166·4	3·619 76
87 40 21	267 38 20	Oak Hill.	4 163·6	3·619 47
37 09 24	217 07 14	Great Meadow	7 466·9	3·873 14
158 50 27	338 49 41	Norton Congregational church spire.	4 381·1	3·641 58
265 33 29	85 35 19	Attleboro grammar school	3 794·2	3·579 12
306 36 12	126 38 19	Oak Hill.	5 453·2	3·736 65
278 57 40	99 02 16	Oak Hill	9 618·3	3·983 10
28 12 01	208 10 50	Pawtucket waterworks, gate house.	5 214·4	3·717 04
47 33 16	227 31 33	Pawtucket waterworks, gate house	4 804·7	3·681 67
141 18 36	321 18 05	Cumberland.	1 730·4	3·238 15
212 34 00	32 36 43	Mansfield Congregational church spire	10 433·2	4·018 43
322 19 16	142 22 00	Great Meadow.	9 305·7	3·968 75

MASSACHUSETTS AND RHODE ISLAND BOUNDARY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Central Falls high school cupola, R. I.	41 53 14·52	448·0	71 23 16·67	384·4
Central Falls Baptist church spire, R. I. 1889.	41 53 09·62	296·8	71 23 14·62	337·1
Pleasant View.	41 53 43·78	1350·7	71 22 39·10	901·4
North Attleboro, corner 3.	41 59 07·23	223·1	71 21 53·37	1228·6
Norton, corner 2.	41 58 27·32	842·9	71 15 35·24	811·4
North Attleboro, corner 5.	41 59 14·48	446·8	71 16 09·22	212·2
Attleboro, corner 1.	41 53 36·95	1139·9	71 22 54·98	1267·4
Switch.	41 54 40·21	1240·6	71 18 22·77	524·8
Switch, middle base.	41 54 50·13	1546·6	71 18 15·58	359·1
Switch, base 1.	41 54 15·31	472·4	71 18 15·69	361·6
Switch, base 2.	41 54 16·70	515·2	71 18 22·08	508·9
Switch, base 3.	41 54 16·41	506·3	71 18 15·62	360·0
Barn cupola.	41 54 10·78	332·6	71 18 28·05	646·5
North Attleboro, corner 6, base.	41 56 22·65	698·8	71 20 05·42	124·9
North Attleboro, corner 6.	41 56 27·01	833·3	71 20 11·16	257·1
Richards, R. I.	41 59 09·09	280·4	71 22 57·39	1321·1
North Attleboro, corner 2.	41 59 06·47	199·6	71 22 54·99	1265·8
North Attleboro, corner 4.	42 00 52·21	1610·9	71 17 19·56	450·1
Easton, corner 3.	42 03 40·38	1245·9	71 10 09·02	207·4
Norton, corner 4.	42 00 03·95	121·9	71 09 24·98	574·9
Norton, corner 3.	42 00 45·61	1407·2	71 09 33·07	760·9
Attleboro, corner 6 (7?). 1889.	41 54 44·26	1365·5	71 13 22·71	523·4
Norton, corner 7.	41 56 16·98	523·9	71 09 22·16	510·5
North Attleboro, corner 1.	41 54 53·51	1650·9	71 22 55·15	1270·9
Seekonk and Rehoboth corner and Attleboro line stone.	41 54 13·36	412·2	71 18 04·31	99·4
Norton, corner 6.	41 56 09·07	279·8	71 09 33·44	770·4
Pleasant View, base 1.	41 53 39·09	1206·0	71 22 45·66	1052·6
Pleasant View, base 2.	41 53 40·83	1259·7	71 22 47·48	1094·5
Strawberry.	41 52 57·55	1775·6	71 12 03·19	73·6
Orange.	41 52 45·12	1392·1	71 11 11·70	269·8

MASSACHUSETTS AND RHODE ISLAND BOUNDARY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
178 40 33	358 40 29	Bear Hill	6 498·3	3·812 80
251 44 54	71 49 17	Oak Hill.	9 547·5	3·979 89
156 43 03	336 40 31	Beaconpole	13 196·8	4·120 47
250 47 57	70 52 18	Oak Hill.	9 551·0	3·980 05
43 49 22	223 48 57	Central Falls high school	1 251·2	3·097 31
75 00 57	254 59 08	Pawtucket waterworks, gate house.	3 895·8	3·590 60
250 50 16	70 51 57	North Attleboro waterworks	3 696·4	3·567 78
328 32 16	148 32 57	Hoppin Hill.	2 695·8	3·430 69
13 13 31	193 12 46	Oak Hill	6 848·4	3·835 59
115 08 26	295 05 55	North Attleboro waterworks.	5 757·0	3·760 20
5 30 46	185 30 23	Oak Hill	8 159·2	3·911 65
102 36 21	282 34 12	North Attleboro waterworks.	4 538·8	3·656 94
205 26 44	25 26 48	Massachusetts South Base reference mark	338·4	2·529 49
261 33 16	81 34 23	Oak Hill.	2 319·2	3·365 34
269 04 05	89 05 07	Oak Hill	2 128·5	3·328 08
28 27 28	208 27 23	Switch.	348·0	2·541 57
168 00 09	348 00 04	Switch	785·3	2·895 06
178 44 04	358 44 04	Switch	725·6	2·860 72
286 11 01	106 11 05	Switch, base 1.	153·3	2·185 58
2 55 32	182 55 32	Switch, base 1	33·864	1·529 74
93 25 28	273 25 24	Switch, base 2.	149·2	2·173 87
187 37 34	7 37 38	Switch	916·0	2·961 89
217 01 50	37 01 54	Switch, base 2.	228·5	2·358 98
213 05 50	33 05 58	Rhodes	516·2	2·712 82
234 15 41	54 15 53	Rhodes	510·3	2·707 79
315 27 08	135 27 12	North Attleboro, corner 6, base.	188·604	2·275 55
7 37 02	187 36 45	Bear Hill	4 482·6	3·651 53
100 25 11	280 22 28	Beaconpole.	5 707·2	3·756 42
145 36 19	325 36 17	Richards	97·784	1·990 27
102 34 09	282 34 04	Cutting Plain	169·462	2·229 07
44 55 07	224 53 09	Mansfield Congregational church spire	5 728·9	3·758 07
93 41 14	273 37 54	Foxboro Congregational church spire.	6 895·9	3·838 59
231 14 52	51 15 00	Newcomb	374·30	2·573 22
202 33 06	22 33 09	Tune	267·85	2·427 89
129 54 39	309 54 26	Smith	600·93	2·778 82
44 05 58	224 05 42	Woodward	812·33	2·909 73
241 06 14	61 06 18	Mowry	173·70	2·239 79
102 54 02	282 53 54	Switch, base 1	269·12	2·429 95
41 59 52	221 59 43	Woodward	456·64	2·659 57
226 17 11	46 17 15	Pleasant View	209·4	2·320 94
244 47 53	64 47 59	Pleasant View	213·6	2·329 66
322 01 03	142 01 04	Pleasant View, base 1.	68·17	1·833 59
118 32 41	298 29 34	Oak Hill	7 346·8	3·866 10
148 03 22	328 02 16	Smith.	4 334·8	3·636 97
228 22 28	48 26 06	Prospect Taunton	10 044·3	4·001 92
328 50 03	148 52 22	Richmond Hill.	9 294·8	3·968 24

MASSACHUSETTS AND RHODE ISLAND BOUNDARY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Pickle.	41 52 53·96	1664·8	71 11 10·30	237·5
Dighton, corner 4.	41 52 54·82	1691·3	71 12 14·20	327·4
Taunton, corner 7.	41 52 45·82	1413·7	71 11 14·17	326·8
Norton, corner 8.	41 54 38·94	1201·4	71 11 39·78	916·8
Attleboro, corner 6. 1890.	41 54 32·05	988·8	71 12 31·12	717·2
Canadian Catholic church spire. 1890–91.	41 40 31·30	965·7	71 10 56·28	1301·8
Mount Hope Bay, west boundary (R. I.). (Toweset Neck, Borden) 1836–1890.	41 42 45·03	1389·2	71 13 36·28	838·7
Mount Hope Bay, east boundary. 1890.	41 40 29·63	914·1	71 11 40·68	941·0
Warren Methodist church spire (R. I.). 1863–1890.	41 43 48·78	1504·9	71 17 02·73	63·1
Cherry (R. I.).	41 46 28·10	866·9	71 19 03·27	75·5
Cherry, west base (R. I.).	41 46 31·62	975·5	71 19 03·85	88·9
Cherry, east base (R. I.).	41 46 32·17	992·5	71 19 00·73	16·9
Cherry, north peg (R. I.).	41 46 33·89	1045·6	71 19 04·54	104·8
Rehoboth, corner 2.	41 46 29·75	917·8	71 17 34·55	798·0
Marsh.	41 46 29·32	904·6	71 17 02·66	61·4
Rehoboth, corner 1.	41 46 29·47	909·2	71 17 02·63	60·8
Swansea, corner 3.	41 46 32·17	992·5	71 19 00·70	16·2
Rhode Island corner (R. I.)	41 46 34·31	1058·5	71 19 05·56	128·4
Line stone.	41 42 45·25	1396·0	71 13 36·58	845·7
Fall River, corner 4.	41 40 16·17	498·9	71 10 34·68	802·2
Globe Village.	41 40 23·03	710·5	71 11 02·42	56·0
Chimney.	41 40 13·72	423·3	71 10 40·96	947·5
Cupola.	41 40 15·47	477·3	71 10 42·48	982·7
X 1.	41 40 11·76	362·8	71 10 34·62	800·8
X 2.	41 40 08·69	268·1	71 10 34·80	805·0
Fall River, corner 3.	41 40 05·86	180·8	71 10 35·74	826·8
Fall River, corner 2.	41 39 37·52	1157·5	71 07 58·94	1363·7

MASSACHUSETTS AND RHODE ISLAND BOUNDARY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
229 26 13	49 29 50	Prospect Taunton	9 840·6	3·993 02
329 51 02	149 53 20	Richmond Hill.	9 513·1	3·978 32
251 36 46	71 36 53	Strawberry	267·41	2·427 18
290 44 41	110 44 43	Orange	60·906	1·784 66
28 27 15	208 26 20	Great Meadow	3 993·0	3·601 30
93 08 06	273 04 43	Oak Hill.	7 003·6	3·845 32
12 17 39	192 17 18	Great Meadow	3 375·7	3·528 37
95 50 36	275 47 48	Oak Hill.	5 840·4	3·766 44
88 16 42	268 14 22	Mount Hope 2	4 855·6	3·686 24
151 33 22	331 32 23	Gardner Neck.	4 296·7	3·633 13
271 29 33	91 32 46	Fall River	6 723·7	3·827 61
15 13 08	195 12 35	Mount Hope (Borden).	4 395·2	3·642 98
88 34 23	268 32 33	Mount Hope 2	3 827·5	3·582 91
165 04 55	345 04 26	Gardner Neck.	3 963·0	3·598 02
329 51 33	149 53 17	Mount Hope 2	7 214·7	3·858 22
244 50 06	64 52 27	Swansea belfry.	5 405·8	3·732 86
288 48 12	108 51 53	Swansea belfry	8 111·3	3·909 09
330 26 58	150 28 18	Warren Methodist church spire.	5 650·0	3·752 05
352 59 33	172 59 33	Cherry	109·4	2·038 90
25 04 35	205 04 33	Cherry	138·7	2·142 12
76 40 23	256 40 21	Cherry, west base.	74·1	1·869 99
301 01 48	121 01 51	Cherry, east base	102·8	2·011 80
350 41 50	170 41 51	Cherry.	181·0	2·257 65
295 21 14	115 23 56	Swansea belfry	6 228·7	3·794 40
351 34 03	171 34 24	Warren Methodist church spire.	5 020·7	3·700 76
0 00 52	180 00 52	Warren Methodist church spire	4 953·2	3·694 89
91 01 55	271 01 34	Rehoboth, corner 2.	737·1	2·867 53
7 41 55	187 41 55	Marsh	4·670	0·669 32
83 04 51	263 04 51	Cherry, east base	0·770	9·886 49
296 49 40	116 49 41	Cherry, north peg	28·423	1·453 67
314 05 24	134 05 24	Mount Hope Bay, west boundary	9·600	0·982 27
133 02 28	313 02 14	Canadian Catholic church	683·8	2·834 94
207 41 38	27 42 35	Fall River high school.	4 297·2	3·633 19
209 06 15	29 06 19	Canadian Catholic church	291·8	2·465 09
288 15 30	108 15 48	Fall River, corner 4.	675·6	2·829 70
146 50 06	326 49 56	Canadian Catholic church	647·7	2·811 39
242 34 13	62 34 17	Fall River, corner 4.	163·9	2·214 51
146 48 39	326 48 30	Canadian Catholic church	583·4	2·765 93
263 12 54	83 12 59	Fall River, corner 4.	181·7	2·259 45
112 22 10	292 22 06	Chimney	158·7	2·200 54
179 27 14	359 27 14	Fall River, corner 4.	135·9	2·133 27
137 24 17	317 24 13	Chimney	210·8	2·323 78
182 28 39	2 28 39	X 1.	94·9	1·977 06
153 31 22	333 31 19	Chimney	270·9	2·432 78
194 03 48	14 03 49	X 2.	90·0	1·954 28
187 00 11	7 00 25	Fall River water tower	4 033·9	3·605 73
232 45 35	52 46 31	Highway.	2 426·8	3·385 03

MASSACHUSETTS AND RHODE ISLAND BOUNDARY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	econds in metres.
	° ′ ″		° ′ ″	
Quicksand 2, base 1.	41 29 56·07	1729·8	71 07 10·46	242·6
Rooster.	41 29 58·26	1797·4	71 07 11·46	265·8
Quicksand 2, base 2.	41 29 56·65	1747·7	71 07 13·28	308·0
Quicksand 2, base 3.	41 29 58·65	1809·4	71 07 16·28	377·6
Peaked Rock.	41 29 58·55	1806·3	71 07 16·25	376·9
Monument.	41 29 58·60	1807·8	71 07 16·26	377·1
Tree base.	41 40 22·81	703·7	71 11 05·04	116·6
Fall River, corner 5.	41 40 23·15	714·2	71 11 05·17	119·6

TAUNTON RIVER.

Mount Hope 2 (R. I.). 1874–1890.	41 40 26·515	818·0	71 14 26·094	603·6
Mound (R. I.).	41 38 14·042	433·2	71 13 11·906	275·4
Chase (R. I.).	41 40 23·917	737·9	71 11 16·462	380·9
Gardner Neck. 1874–1890.	41 42 33·742	1040·9	71 12 24·807	573·5
City.	41 41 43·770	1350·3	71 10 19·091	441·4
Somerset 2. 1874.	41 43 44·048	1358·9	71 10 08·164	188·7
Calvary.	41 43 40·822	1259·4	71 08 05·039	116·4
Steep Brook.	41 44 56·973	1757·7	71 07 23·161	535·1
Wood.	41 45 03·100	95·6	71 08 27·345	631·8
Bluff. 1874–1887.	41 45 54·520	1682·0	71 07 49·699	1148·0
Burns. 1874–1887.	41 44 26·705	823·9	71 08 52·720	1218·2
Ridge. 1874–1887.	41 45 33·468	1032·5	71 07 10·979	253·6
Depot.	41 46 31·093	959·3	71 07 15·062	347·9
Terry. 1874–1887.	41 46 31·456	970·5	71 06 43·067	994·6
Fall River water tower. 1887–1891.	41 41 47·292	1459·0	71 07 37·667	871·0
Richmond Hill. 1874–1890.	41 48 27·288	841·9	71 07 43·331	1000·2

MASSACHUSETTS AND RHODE ISLAND BOUNDARY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
250 48 40	70 48 41	Quicksand 2	31·873	1·503 42
317 00 39	137 00 41	Quicksand 2	78·1	1·892 83
341 05 10	161 05 11	Quicksand 2, base 1.	71·5	1·854 23
220 26 29	40 26 30	Rooster	65·3	1·815 13
274 26 22	94 26 25	Quicksand 2.	95·9	1·982 02
276 10 39	96 10 42	Rooster	112·4	2·050 72
311 42 37	131 42 39	Quicksand 2, base 2.	92·9	1·968 05
168 34 10	348 34 10	Quicksand 2, base 3	3·055	0·485 01
162 54 15	342 54 15	Quicksand 2, base 3	1·721	0·235 78
263 40 13	83 40 15	Globe Village	61·1	1·785 97
273 14 31	93 14 33	Globe Village	63·8	1·804 90
343 51 42	163 51 42	Tree base.	10·768	1·032 14

TAUNTON RIVER.

6 47 47·5	186 47 12·8	Quaker	10 226·1	4·009 711
157 13 25·6	337 12 36·3	Mount Hope 2	4 432·8	3·646 681
25 46 07·3	205 44 43·3	Quaker.	6 736·7	3·828 449
33 42 01·7	213 40 45·0	Mound	4 815·6	3·682 651
91 03 50·6	271 01 44·5	Mount Hope 2.	4 387·3	3·642 195
7 44 52·7	187 44 21·4	Mound	8 085·9	3·907 728
338 27 33·1	158 28 18·6	Chase.	4 305·9	3·634 061
117 57 10·9	297 55 47·3	Gardner Neck	3 290·3	3·517 239
67 22 33·6	247 19 49·3	Mount Hope 2.	6 189·9	3·791 687
44 24 16·2	224 21 24·6	Mount Hope 2	8 526·8	3·930 787
3 53 43·5	183 53 36·2	City.	3 719·3	3·570 467
92 00 50·6	271 59 28·7	Somerset 2	2 847·4	3·454 456
71 00 27·8	250 57 34·9	Gardner Neck.	6 351·4	3·802 868
22 23 29·3	202 23 01·4	Calvary	2 540·9	3·404 984
59 28 20·6	239 26 30·8	Somerset 2.	4 427·3	3·646 136
277 15 28·5	97 16 11·2	Steep Brook	1 494·9	3·174 625
348 31 09·4	168 31 24·2	Calvary.	2 590·2	3·413 333
28 44 07·1	208 43 42·0	Wood	1 809·2	3·257 475
340 56 48·1	160 57 05·8	Steep Brook.	1 878·3	3·273 766
245 42 14·4	65 43 14·0	Steep Brook	2 270·3	3·356 092
208 14 55·0	28 15 37·0	Bluff.	3 075·7	3·487 947
125 59 19·4	305 58 53·6	Bluff	1 105·4	3·043 515
48 47 00·1	228 45 52·3	Burns.	3 125·4	3·494 911
356 57 46·9	176 57 49·6	Ridge	1 780·3	3·250 505
30 27 34·8	210 26 29·8	Burns.	4 451·6	3·648 520
53 29 19·2	233 28 34·8	Bluff	1 915·0	3·282 164
89 08 04·9	269 07 43·6	Depot.	739·0	2·868 657
159 45 33·3	339 41 57·0	Great Meadow	21 636·0	4·335 176
243 30 10·0	63 32 50·4	Copecut.	6 225·1	3·794 147
329 11 39·2	149 14 23·5	Copecut	11 134·1	4·046 655
359 23 31·0	179 23 34·8	Fall River water tower.	12 341·3	4·091 362

TAUNTON RIVER—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Fall River high school, tower. 1887–1890.	41 42 19·485	601·1	71 09 08·300	191·9
Mack.	41 47 30·970	955·5	71 07 02·316	53·5
Marsh.	41 47 38·168	1177·5	71 07 33·787	780·1
Nichols.	41 48 25·961	800·9	71 06 59·333	1369·6
New.	41 49 33·058	1019·9	71 06 58·379	1347·2
Bare Top.	41 48 52·832	1629·9	71 06 00·411	9·5
Assonet. 1874–1887.	41 47 25·334	781·6	71 05 56·873	1313·2
Graveyard.	41 49 34·478	1063·7	71 07 28·905	667·1
Schoolhouse Hill.	41 50 01·405	43·3	71 06 17·508	403·9
Beveled Barn, ball on cupola.	41 50 12·733	392·8	71 07 09·093	209·8
Telegraph.	41 50 59·360	1831·4	71 06 50·266	1159·6
Florence.	41 50 45·035	1389·4	71 06 57·977	1337·5
High.	41 50 57·519	1774·6	71 06 29·829	688·2
Brown Hill. 1874-1887.	41 47 25·276	779·8	71 06 27·654	638·5
Highway. 1887–1891.	41 40 25·109	774·6	71 06 35·416	819·2
North Dighton.	41 51 14·524	448·1	71 06 39·325	907·0
Meadow.	41 51 11·216	346·0	71 06 11·892	274·3
River.	41 51 36·079	1113·1	71 06 16·949	390·9
Burt.	41 51 28·716	885·9	71 05 49·541	1142·7
Herbert.	41 51 45·403	1400·8	71 05 46·910	1081·9
Carpenter's (J.) barn, cupola.	41 51 36·073	1112·9	71 05 33·562	774·1
Clark's (C. E.) barn, cupola.	41 51 52·684	1625·4	71 05 13·056	301·1
Whitmore.	41 52 12·500	385·7	71 05 31·814	733·7

TAUNTON RIVER—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
189 48 23·4	9 49 20·0	Richmond Hill	11 516·0	4·061 300
256 53 06·1	76 56 46·8	Copecut.	7 871·5	3·896 056
151 24 54·1	331 24 26·8	Richmond Hill	1 978·8	3·296 405
346 23 22·9	166 23 35·7	Terry.	1 889·2	3·276 273
286 59 30·1	106 59 51·1	Mack	759·8	2·880 717
171 43 44·1	351 43, 37·7	Richmond Hill.	1 531·4	3·185 088
92 18 45·4	272 18 16·1	Richmond Hill	1 016·5	3·007 093
28 20 51·5	208 20 28·5	Marsh.	1 675·4	3·224 114
27 05 06·3	207 04 36·3	Richmond Hill	2 279·0	3·357 749
0 36 35·2	180 36 34·6	Nichols.	2 070·2	3·316 016
132 51 20·7	312 50 42·0	New	1 824·9	3·261 234
71 39 25·9	251 38 17·3	Richmond Hill.	2 503·0	3·398 458
127 52 55·7	307 51 44·7	Richmond Hill	3 113·6	3·493 260
178 16 03·0	358 16 00·6	Bare Top.	2 700·8	3·431 486
9 07 35·8	189 07 26·2	Richmond Hill	2 099·5	3·322 119
302 09 56·2	122 10 55·2	Bare Top.	2 412·9	3·382 543
63 14 50·9	243 14 03·3	Graveyard	1 845·1	3·266 030
34 18 26·7	214 17 29·5	Richmond Hill.	3 514·9	3·545 918
21 10 33·6	201 10 20·4	Graveyard	1 265·7	3·102 328
286 21 30·2	106 22 04·6	Schoolhouse Hill.	1 240·5	3·093 599
16 48 08·2	196 47 55·6	Beveled Barn	1 502·7	3·176 874
337 05 01·6	157 05 23·4	Schoolhouse Hill.	1 941·2	3·288 074
14 25 52·6	194 25 45·2	Beveled Barn	1 029·1	3·012 439
201 55 27·4	21 55 32·5	Telegraph.	476·4	2·678 005
96 52 21·2	276 52 07·6	Telegraph	474·9	2·676 557
59 19 40·1	239 19 21·3	Florence.	755·0	2·877 944
34 05 38·4	214 04 43·7	Bluff	3 380·9	3·529 030
137 36 17·5	317 35 27·1	Richmond Hill.	2 590·9	3·413 454
217 52 50·4	37 54 49·3	Copecut	6 729·9	3·828 008
134 57 27·8	314 55 46·1	Fall River high school, tower.	4 995·2	3·698 555
28 20 54·0	208 20 46·7	Telegraph	531·6	2·725 561
337 20 21·7	157 20 28·0	High.	568·5	2·754 744
99 09 48·9	279 09 30·6	North Dighton	641·0	2·806 839
67 33 09·8	247 32 44·2	Telegraph.	957·8	2·981 280
37 48 59·1	217 48 44·2	North Dighton	841·8	2·925 223
351 21 14·5	171 21 17·9	Meadow.	775·9	2·889 812
43 40 50·2	223 40 35·3	Meadow	746·6	2·873 063
109 46 03·6	289 45 45·3	River.	671·8	2·827 213
6 43 18·9	186 43 17·1	Burt	518·4	2·714 664
67 27 15·2	247 26 55·2	River.	750·2	2·875 168
58 22 24·3	238 22 13·6	Burt	432·8	2·636 324
133 04 40·9	313 04 32·0	Herbert.	421·5	2·624 767
42 42 22·1	222 42 08·4	Carpenter's barn	697·4	2·843 466
73 57 13·6	253 56 51·0	Herbert.	812·5	2·909 810
324 42 57·0	144 43 09·5	Clark's barn	749·0	2·874 464
22 36 38·2	202 36 28·1	Herbert.	905·6	2·956 943

TAUNTON RIVER—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Birch.	41 52 08·499	262·2	71 05 04·569	105·4
Hunt's (J.) house, roof.	41 52 38·977	1202·5	71 05 30·130	694·8
Williams.	41 52 43·051	1328·2	71 05 52·594	1212·7
Schoolhouse, eastern angle of roof.	41 53 14·109	435·3	71 05 38·715	892·6
Hatch's (E. house, ridge of roof.	41 53 01·421	43·8	71 05 13·866	319·7
Johnson.	41 53 20·790	641·4	71 04 43·396	1000·5
French's (Capt. A.) house, cupola.	41 53 35·588	1098·0	71 05 34·546	796·4
Taunton Unitarian church, spire. 1876.	41 54 04·556	140·6	71 05 19·786	456·1
Frederick, (C. F. Johnson's barn, cupola.)	41 53 41·330	1275·1	71 04 26·991	622·2
Mason.	41 54 29·208	901·1	71 04 10·992	253·3
Wilbur's (E.) house, roof.	41 54 40·283	1242·8	71 05 11·527	265·6
Bradford (N. B. Dean's house, roof).	41 54 17·294	533·6	71 04 37·907	873·7
Briggs' (W. S.) house, roof.	41 54 56·168	1732·9	71 03 49·319	1136·6
Dean.	41 54 37·291	1150·5	71 04 15·212	350·6
Hall's (R.) house, roof.	41 54 22·342	689·3	71 04 16·162	372·5
King.	41 54 22·631	698·2	71 03 49·358	1137·6
Taunton waterworks, tall chimney, lightning rod.	41 54 11·169	344·6	71 03 50·492	1163·8
Alex.	41 54 07·042	217·3	71 03 34·846	803·2
Martin's (M. G.) barn, ridge of roof.	41 54 23·391	721·7	71 03 28·356	653·5
Prospect Taunton. 1889–90.	41 56 21·239	655·3	71 05 45·780	1054·6
Taunton Insane Asylum. 1889–90.	41 54 52·460	1618·5	71 06 02·200	50·7
Fall River. (C. & G. S. & Bdn.) 1834–1843.	41 42 39·25	1210·9	71 08 45·54	1052·8
Fall River 2. 1861.	41 42 39·74	1226·0	71 08 45·38	1049·1

TAUNTON RIVER—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
101 07 06·1	281 06 47·9	Whitmore	640·3	2·806 407
21 51 31·2	201 51 25·5	Clark's barn.	525·7	2·720 768
2 43 22·7	182 43 21·6	Whitmore	817·8	2·912 641
327 54 58·0	147 55 15·1	Birch.	1 109·8	3·045 240
333 03 01·7	153 03 15·6	Whitmore	1 057·4	3·024 232
283 38 19·7	103 38 34·7	Hunt's house.	533·0	2·726 754
349 38 58·5	169 39 04·2	Hunt's house	1 101·8	3·042 119
18 28 08·2	198 27 58·9	Williams.	1 010·2	3·004 420
124 20 44·7	304 20 28·1	Schoolhouse	693·9	2·841 278
57 36 02·6	237 35 36·7	Williams.	1 057·6	3·024 337
80 49 28·5	260 48 51·6	Schoolhouse	1 291·9	3·111 234
49 37 02·4	229 36 42·1	Hatch's house.	922·3	2·964 861
8 15 11·4	188 15 08·6	Schoolhouse	669·6	2·825 833
291 09 40·5	111 10 14·6	Johnson.	1 264·5	3·101 917
20 50 33·6	200 50 23·7	French's house	956·3	2·980 598
328 08 46·8	148 09 11·1	Johnson.	1 589·7	3·201 306
120 29 42·6	300 29 07·3	Taunton Unitarian church spire	1 412·3	3·149 924
30 49 46·4	210 49 35·4	Johnson.	738·0	2·868 055
14 01 09·9	194 00 59·2	Frederick	1 522·5	3·182 553
64 22 52·6	244 22 06·7	Taunton Unitarian church spire.	1 758·6	3·245 168
330 33 22·5	150 33 52·2	Frederick	2 088·5	3·319 844
9 47 55·1	189 47 49·6	Taunton Unitarian church spire.	1 118·6	3·048 672
132 28 19·6	312 27 57·1	Wilbur's house	1 050·5	3·021 384
67 51 02·8	247 50 34·8	Taunton Unitarian church spire.	1 042·2	3·017 965
75 30 14·9	255 29 20·0	Wilbur's house	1 956·9	3·291 573
43 02 24·0	223 01 51·6	Bradford.	1 640·9	3·215 072
324 44 21·9	144 44 38·4	Taunton waterworks	987·0	2·994 313
40 17 38·9	220 17 23·7	Bradford.	808·8	2·907 863
182 42 55·5	2 42 56·1	Dean	461·7	2·664 376
72 44 21·4	252 44 06·9	Bradford.	524·8	2·720 033
89 10 33·7	269 10 15·8	Hall's house	617·9	2·790 886
127 12 04·0	307 11 46·7	Dean.	748·1	2·873 960
84 20 50·1	264 19 50·5	Taunton Unitarian church spire	2 068·3	3·315 613
115 41 32·5	295 40 38·4	Wilbur's house.	2 072·5	3·316 490
109 26 50·1	289 26 39·7	Taunton waterworks	382·5	2·582 586
145 11 09·7	325 11 00·0	King.	585·8	2·767 781
87 13 39·6	267 13 25·6	King	484·6	2·685 406
16 31 09·1	196 31 04·8	Alex.	526·1	2·721 107
56 30 26·6	236 25 35·0	Great Meadow	12 069·3	4·081 681
79 40 26·1	259 33 06·8	Oak Hill.	15 400·8	4·187 544
89 54 47·8	269 47 39·6	Oak Hill	14 772·9	4·169 466
132 09 44·9	312 06 29·0	Norton Congregational church spire.	9 107·1	3·959 381
62 29 50	242 26 03	Mount Hope	8 884·4	3·948 63
30 48 42	210 46 51	Pocasset.	7 536·0	3·877 14
37 24 38	217 23 09	Blackbeard	5 081·7	3·706 01
62 25 28	242 21 41	Mount Hope.	8 894·5	3·949 12

TAUNTON RIVER—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Mattapoisett. 1843–1861.	41 42 40·47	1248·6	71 12 51·76	1196·6
Globe Village chimney. 1861.	41 41 17·27	532·8	71 10 23·84	551·3
Slade.	41 43 41·20	1271·1	71 10 09·12	210·8
Somerset. 1861.	41 44 07·60	234·5	71 10 06·49	150·0
Fall River church spire. 1861.	41 42 06·87	211·9	71 09 15·00	346·8
Fall River tower. 1861.	41 42 00·87	26·7	71 09 25·42	587·7
Fall River derrick. 1861.	41 42 19·32	596·0	71 09 56·72	1311·4
Dodge's stable, turret.	41 40 56·33	1737·9	71 10 40·24	930·7
Durfee's cupola.	41 42 36·36	1121·8	71 09 04·82	111·4
Swansea Christian church, belfry. 1843–1890.	41 45 03·21	99·0	71 13 30·90	713·9
Somerset meetinghouse spire. 1843.	41 44 11·54	356·0	71 10 06·89	159·2
Somerset Methodist Episcopal church spire. 1861–1887.	41 44 11·64	359·1	71 10 06·86	158·5
Somerset, church spire. 1874–1887.	41 46 17·88	551·7	71 07 38·87	897·8
Beacon. 1874.	41 42 16·82	518·9	71 10 29·71	686·9
Large chimney with rail on top.	41 42 13·60	419·5	71 09 52·38	1211·0
White barn with square window, cupola.	41 43 28·38	875·6	71 09 43·70	1010·0
Ferry wharf, chimney.	41 42 34·30	1058·2	71 10 46·90	1084·2
Mill with conical cupola, chimney.	41 43 06·66	205·5	71 09 22·27	514·8
White church spire. 1874.	41 45 08·93	275·5	71 08 32·06	740·7
Steep Brook, brown church spire. 1874–1887.	41 44 30·40	937·9	71 07 46·13	1065·9
Assonet, flat topped church, west gable, chimney. 1874.	41 47 30·22	932·3	71 04 15·22	351·4
Farm house, white chimney.	41 48 30·38	937·3	71 04 53·02	1223·9
Assonet Academy spire.	41 47 45·92	1416·7	71 04 07·98	184·2

TAUNTON RIVER—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
327 14 22	147 15 37	Blackbeard	4 827·4	3·683 71
27 47 47	207 46 44	Mount Hope.	4 685·0	3·670 71
74 18 11	254 15 30	Mount Hope	5 823·7	3·765 20
126 53 58	306 52 20	Mattapoisett.	4 276·5	3·631 09
12 56 22	192 55 27	Pocasset	8 603·2	3·934 66
44 40 17	224 37 26	Mount Hope.	8 459·0	3·927 32
325 19 15	145 20 09	Fall River 2	3 295·8	3·517 96
41 20 10	221 17 17	Mount Hope.	9 096·2	3·958 86
66 40 21	246 36 54	Mount Hope	7 840·1	3·894 32
101 42 21	281 39 57	Mattapoisett.	5 117·4	3·709 05
67 14 17	247 10 57	Mount Hope	7 545·7	3·877 70
104 23 01	284 20 44	Mattapoisett.	4 925·0	3·692 41
60 45 46	240 42 47	Mount Hope	7 143·6	3·853 92
176 07 59	356 07 53	Somerset.	3 348·0	3·524 79
79 54 51	259 52 21	Mount Hope	5 309·1	3·725.02
188 03 03	8 03 24	Slade.	5 137·1	3·710 72
61 38 06	241 34 32	Mount Hope	8 448·5	3·926 78
143 23 46	323 23 03	Slade.	2 492·1	3·396 57
337 25 52	157 27 33	Blackbeard	9 165·2	3·962 14
8 30 40	188 30 03	Mount Hope.	8 643·1	3·936 67
326 32 10	146 33 04	Fall River	3 412·1	3·533 02
40 47 20	220 44 27	Mount Hope.	9 183·1	3·962 99
288 38 56	108 40 17	Calvary	2 971·6	3·472 99
40 49 04	220 46 12	Mount Hope 2.	9 173·8	3·962 55
19 08 16	199 08 09	Bluff	763·0	2·882 52
334 49 04	154 49 23	Ridge.	1 514·3	3·180 20
190 29 02	10 29 16	Somerset 2	2 736·6	3·437 22
346 27 34	166 27 41	City.	1 048·9	3·020 74
33 52 04	213 51 46	City	1 108·1	3·044 60
222 40 14	42 41 25	Calvary.	3 660·5	3·563 55
14 13 39	194 13 15	City	3 329·4	3·522 36
260 26 02	80 27 08	Calvary.	2 312·6	3·364 10
337 35 05	157 35 24	City	1 686·2	3·226 90
241 14 14	61 16 02	Calvary.	4 267·4	3·630 17
239 26 12	59 27 03	Calvary	2 073·1	3·316 63
27 11 38	207 11 00	City.	2 874·9	3·458 63
347 03 35	167 03 53	Calvary	2 789·1	3·445 46
214 49 40	34 50 08	Bluff.	1 713·5	3·233 88
15 56 32	195 56 19	Calvary	1 590·8	3·201 62
136 39 18	316 38 51	Wood.	1 387·2	3·142 14
136 23 36	316 22 26	Bare Top	3 520·4	3·546 59
110 08 36	290 06 17	Richmond Hill.	5 117·1	3·709 02
114 00 53	294 00 08	Bare Top	1 702·8	3·231 17
88 37 45	268 35 51	Richmond Hill.	3 932·4	3·594 66
75 50 10	255 48 57	Assonet	2 593·2	3·413 84
104 25 10	284 22 46	Richmond Hill.	5 132·9	3·710 36

TAUNTON RIVER—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Thrasher.	41 52 22·45	692·6	71 05 16·63	383·5
Williams's (J. R.) house, cupola.	41 52 31·54	973·1	71 05 47·94	1105·5
Taunton Iron Works, southeast corner of chimney.	41 52 54·10	1669·1	71 05 38·44	886·3
Brickyard.	41 54 33·06	1020·0	71 04 44·87	1034·1
Eddy's (L.) barn, roof.	41 54 24·80	765·1	71 03 58·05	1337·9
Padelford.	41 54 07·98	246·2	71 03 12·15	280·0
Henry.	41 54 23·08	712·1	71 03 12·70	292·7
Pine.	41 54 12·51	386·0	71 02 58·08	1338·7
Walker.	41 54 23·18	715·2	71 02 57·73	1330·6
Woods.	41 54 19·04	587·4	71 02 44·82	1033·0
Edward.	41 54 10·59	326·7	71 02 46·41	1069·7
Roach.	41 54 08·40	259·2	71 02 27·88	642·6
Grave.	41 54 04·67	144·1	71 02 38·54	888·3
Elisha.	41 53 58·54	1806·1	71 02 23·14	533·4
Cord.	41 53 56·09	1730·5	71 02 36·52	841·8
Kimball.	41 53 48·35	1491·7	71 02 27·04	623·3
Elm.	41 53 51·68	1594·3	71 02 17·43	401·8
Sycamore.	41 53 37·87	1168·4	71 02 20·84	480·4
Rockheap.	41 53 44·12	1361·2	71 02 12·63	291·1
Maplewood.	41 53 27·70	854·6	71 02 12·85	296·2
Stonewall.	41 53 34·04	1050·2	71 02 04·13	95·2
Washburn.	41 53 25·37	782·7	71 01 56·44	1301·1
Squawbetty.	41 53 20·23	624·1	71 02 05·64	130·0

TAUNTON RIVER—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
327 07 57	147 08 05	Birch	512·5	2·709 70
48 45 31	228 45 21	Whitmore.	465·7	2·668 13
240 48 41	60 48 53	Hunt's house	470·6	2·672 68
163 13 09	343 13 06	Williams.	371·0	2·569 39
43 45 09	223 45 00	Williams	471·7	2·673 64
337 38 44	157 38 50	Hunt's house.	504·3	2·702 71
109 56 15	289 55 57	Wilbur's house	653·6	2·815 28
341 44 40	161 44 45	Bradford.	512·2	2·709 46
79 42 39	259 42 27	Hall's house	424·3	2·627 70
134 15 09	314 14 58	Dean.	552·3	2·742 18
141 50 10	321 49 59	Martin's barn	604·6	2·781 50
86 49 30	266 49 15	Alex.	524·1	2·719 38
91 29 26	271 29 16	Martin's barn	361·3	2·557 86
358 28 13	178 28 13	Padelford.	466·2	2·668 54
134 05 22	314 05 12	Henry	469·0	2·671 21
66 42 47	246 42 38	Padelford.	353·2	2·548 07
89 29 36	269 29 26	Henry	345·0	2·537 76
1 23 54	181 23 54	Pine.	329·5	2·517 85
113 15 09	293 15 00	Walker	323·8	2·510 28
56 35 19	236 35 10	Pine.	366·0	2·563 54
146 06 26	326 06 18	Walker	467·9	2·670 19
187 59 04	7 59 05	Woods.	263·1	2·420 20
98 59 56	278 59 44	Edward	432·3	2·635 75
130 03 18	310 03 07	Woods.	510·0	2·707 58
135 10 26	315 10 21	Edward	257·4	2·410 61
244 54 21	64 54 28	Roach.	271·1	2·433 09
118 03 12	298 03 02	Grave	402·3	2·604 53
160 11 46	340 11 43	Roach.	323·3	2·509 55
256 13 02	76 13 11	Elisha	317·8	2·502 12
207 39 45	27 39 51	Roach.	428·9	2·632 33
137 31 09	317 31 03	Cord	323·7	2·510 10
195 58 51	15 58 54	Elisha.	327·0	2·514 60
65 07 16	245 07 10	Kimball	244·3	2·387 88
148 08 03	328 07 59	Elisha.	249·2	2·396 53
190 27 49	10 27 51	Elm	433·3	2·636 74
156 09 00	336 08 56	Kimball.	353·5	2·548 34
111 26 18	291 26 08	Kimball	356·9	2·552 60
44 28 34	224 28 29	Sycamore.	270·2	2·431 74
180 33 58	0 33 58	Rockheap	506·7	2·704 73
149 34 22	329 34 17	Sycamore.	363·9	2·561 04
107 03 46	287 03 35	Sycamore	403·0	2·605 32
45 46 33	225 46 27	Maplewood.	280·4	2·447 80
100 45 47	280 45 36	Maplewood	385·1	2·585 62
146 26 50	326 26 45	Stonewall.	321·0	2·506 48
233 14 31	53 14 37	Washburn	264·9	2·423 08
144 12 35	324 12 30	Maplewood.	284·1	2·453 45

TAUNTON RIVER—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Jesse.	41 53 11·95	368·7	71 02 19·15	441·5
Hampden.	41 53 20·11	620·4	71 02 23·80	548·7
Weetamoe.	41 53 08·91	274·9	71 02 30·12	694·4
Sassacus.	41 53 19·84	612·1	71 02 35·80	825·3
Canonicus.	41 53 10·23	315·6	71 02 47·23	1088·9
George.	41 53 17·54	541·1	71 02 48·04	1107·5
Squawbetty nail factory chimney.	41 53 12·12	373·9	71 01 53·98	1244·5
Squawbetty, white church spire. 1876.	41 52 57·34	1769·1	71 01 39·92	920·5
Bryant Hill.	41 49 39·80	1227·9	71 04 43·72	1008·9
White house, chimney, on west shore.	41 47 08·38	258·5	71 07 28·63	661·2
Davis' (R.) barn, vane of cupola.	41 40 40·79	1258·4	71 05 24·45	565·6
Bare Field.	41 41 39·75	1226·3	71 05 30·50	705·3
Freelove.	41 41 21·97	677·8	71 06 24·88	575·4
Wall.	41 41 35·16	1084·7	71 06 19·52	451·4
Boundary stone, Fall River 1.	41 41 34·28	1057·6	71 06 22·24	514·3
Niagara fire-engine house, smaller of two turrets. 1887–1890.	41 41 20·62	636·2	71 09 35·86	829·3
Flag in maple tree near boundary stone, Dartmouth 1.	41 41 15·20	468·9	71 04 37·46	866·3
Boundary stone, Dartmouth 1.	41 41 15·07	464·9	71 04 37·78	873·7
Flag in pine tree near boundary stone, Dartmouth 2.	41 41 08·42	259·8	71 04 01·76	40·7
Boundary stone, Dartmouth 2.	41 41 08·41	259·5	71 04 01·62	37·5
Juniper.	41 44 41·76	1288·4	71 11 23·06	532·8
Long Rock.	41 44 23·30	718·8	71 08 53·99	1247·6
Boundary stone, Somerset 1.	41 44 42·08	1298·2	71 11 27·14	627·1
Boundary stone, Somerset 2.	41 44 22·28	687·4	71 09 24·44	564·8

TAUNTON RIVER—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
230 38 20	50 38 29	Squawbetty	402·8	2·605 13
196 38 55	16 38 59	Maplewood.	507·2	2·705 16
227 07 58	47 08 05	Maplewood	344·4	2·537 01
336 56 54	156 56 57	Jesse.	273·5	2·436 94
202 53 09	22 53 13	Hampden	375·2	2·574 26
249 36 59	69 37 06	Jesse.	269·9	2·431 21
268 15 53	88 16 01	Hampden	276·8	2·442 23
338 48 08	158 48 12	Weetamoe.	361·8	2·558 42
275 52 48	95 52 59	Weetamoe	396·5	2·598 26
221 37 26	41 37 34	Sassacus.	396·9	2·598 63
255 54 12	75 54 20	Sassacus	291·1	2·464 04
355 15 39	175 15 40	Canonicus.	226·5	2·355 14
172 06 24	352 06 22	Washburn	412·6	2·615 55
132 56 10	312 56 02	Squawbetty.	367·3	2·565 05
156 15 01	336 14 50	Washburn	944·9	2·975 38
139 59 46	319 59 29	Squawbetty.	922·4	2·964 90
61 39 33	241 37 33	Richmond Hill	4 710·7	3·673 09
116 28 54	296 23 21	Great Meadow.	12 844·0	4·108 70
317 15 50	137 16 20	Terry	1 550·7	3·190 52
221 04 29	41 04 47	Mack.	924·8	2·966 03
123 40 15	303 38 46	Fall River water tower	3 701·6	3·568 39
73 34 56	253 34 09	Highway.	1 711·4	3·233 35
103 41 53	283 39 28	Fall River high school	5 183·2	3·714 60
221 10 47	41 12 03	Copecut.	3 996·8	3·601 71
7 54 29	187 54 22	Highway	1 771·0	3·248 23
114 54 22	294 53 34	Fall River water tower.	1 855·7	3·268 51
16 57 41	196 57 37	Freelove	425·4	2·628 81
101 42 41	281 41 49	Fall River water tower.	1 845·7	3·266 15
246 38 27	66 38 29	Wall	68·6	1·836 37
9 08 37	189 08 35	Freelove.	384·6	2·585 00
292 17 43	112 19 43	Highway	4 511·3	3·654 30
199 20 00	19 20 18	Fall River high school.	1 924·5	3·284 32
45 40 35	225 40 04	Davis' barn	1 519·2	3·181 62
103 22 43	283 20 43	Fall River water tower.	4 283·5	3·631 80
103 31 35	283 29 11	Fall River water tower	5 135·1	3·710 55
69 24 41	249 22 59	Highway.	3 796·8	3·579 42
1 12 02	181 11 56	Pocasset	10 255·1	4·010 94
102 38 26	282 37 01	Swansea Christian church belfry.	3 027·3	3·481 06
4 57 03	184 56 53	Fall River high school	3 834·1	3·583 66
77 56 52	257 56 03	Somerset Methodist Episcopal church.	1 721·9	3·236 01
276 02 22	96 02 25	Juniper	94·8	1·976 71
0 40 21	180 40 18	Pocasset.	10 263·6	4·011 30
354 22 21	174 22 32	Fall River high school	3 806·5	3·580 53
267 25 37	87 25 57	Long Rock.	704·5	2·847 89

TAUNTON RIVER—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Boundary stone, Somerset 4.	41 47 24·89	767·9	71 07 53·74	1240·8
Boundary stone, Freetown 3.	41 45 55·49	1712·0	71 06 57·92	1337·9
Flag in oak tree near boundary stone, Somerset 3.	41 47 22·69	700·0	71 09 12·52	289·1
Boundary stone, Somerset 3.	41 47 22·59	696·9	71 09 13·12	303·0
Skunk Hill.	41 50 19·32	596·1	71 02 44·82	1034·0
Fair Ground pole.	41 53 55·52	1712·9	71 07 04·46	102·8
Sears' barn, cupola.	41 49 41·62	1284·1	71 09 41·48	957·2
Raynham Center church spire. 1890.	41 55 21·76	671·4	71 03 07·93	182·7
Taunton Baptist church spire. 1890.	41 54 01·47	45·4	71 05 44·55	1026·9
Meadow Dam.	41 52 24·49	755·6	71 04 35·45	817·5
Hathaway.	41 52 20·18	622·6	71 05 41·52	957·5
Stork.	41 52 13·01	401·4	71 04 24·89	574·0
Kings Knoll.	41 54 19·31	595·8	71 03 43·48	1002·1
Berkley white church spire. 1890.	41 50 32·02	987·9	71 05 01·68	38·8
O'Brien.	41 52 13·62	420·2	71 08 05·23	120·6
Dighton Unitarian church spire. 1890.	41 49 01·74	53·7	71 07 48·12	1110·6
Quequechan engine house.	41 42 33·76	1041·6	71 08 56·06	1296·0
Little Rock.	41 48 55·23	1704·0	71 11 22·40	517·0
Chase's barn cupo	41 47 36·26	1118·7	71 10 24·51	565·9
Hog Back.	41 47 47·44	1463·6	71 11 06·14	141·8
Dillon.	41 46 59·21	1826·7	71 11 14·52	335·3
Chase's barn cupola, peg.	41 47 24·34	750·9	71 10 18·90	436·5
Dighton, corner 2.	41 48 57·45	1772·5	71 10 36·15	834·3
Taunton, corner 2.	41 51 00·34	10·5	71 02 01·84	42·4

TAUNTON RIVER—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
187 06 55	7 07 02	Richmond Hill	1 940·3	3·287 86
269 38 34	89 39 31	Brown Hill.	1 987·8	3·298 37
88 34 25	268 33 50	Bluff	1 196·4	3·077 88
197 10 27	17 10 37	Terry.	1 161·5	3·065 01
225 55 39	45 56 38	Richmond Hill	2 865·8	3·457 24
268 47 07	88 48 57	Brown Hill.	3 807·6	3·580 65
107 35 18	287 28 26	Great Meadow	14 935·9	4·174 23
159 31 48	339 29 47	Prospect Taunton.	11 920·1	4·076 28
201 57 12	21 58 05	Prospect Taunton	4 847·6	3·685 53
318 03 49	138 06 42	Skunk Hill.	8 963·8	3·952 49
203 45 56	23 48 33	Prospect Taunton	13 474·1	4·129 50
260 12 18	80 18 56	Pigeon Hill.	13 973·7	4·145 31
64 00 10	243 57 32	Fair Ground pole	6 066·2	3·782 92
116 47 24	296 45 39	Prospect Taunton.	4 073·6	3·609 98
304 13 15	124 17 15	Pigeon Hill	10 042·7	4·001 85
14 53 41	194 52 22	Richmond Hill.	10 667·9	4·028 08
129 16 49	309 15 09	Fair Ground pole	4 437·3	3·647 12
167 29 32	347 28 45	Prospect Taunton.	7 482·4	3·874 04
48 33 19	228 30 39	Sears' barn, cupola	7 387·4	3·868 49
179 14 38	359 14 35	Prospect Taunton.	7 438·1	3·871 46
57 25 53	237 22 22	Sears' barn, cupola	8 669·4	3·937 99
166 19 31	346 18 37	Prospect Taunton.	7 882·2	3·896 65
107 45 17	287 43 44	Taunton Insane Asylum	3 356·8	3·525 92
143 10 31	323 09 09	Prospect Taunton.	4 700·3	3·672 13
76 29 00	256 25 53	Sears' barn cupola	6 640·8	3·822 22
174 36 50	354 36 21	Prospect Taunton.	10 822·3	4·034 32
202 48 13	22 49 46	Prospect Taunton	8 288·6	3·918 48
295 28 31	115 32 05	Skunk Hill.	8 189·2	3·913 24
354 03 52	174 03 55	Richmond Hill	1 068·7	3·028 87
115 11 43	295 10 27	Sears' barn cupola.	2 891·2	3·461 08
62 48 42	242 45 02	Mount Hope 2	8 582·4	3·933 61
188 45 02	8 45 50	Richmond Hill.	11 036·0	4·042 81
162 00 45	341 59 38	Great Meadow	7 458·1	3·872 63
279 39 11	99 41 37	Richmond Hill.	5 129·7	3·710 09
151 15 59	331 15 20	Little Rock	2 778·7	3·443 84
194 23 49	14 24 18	Sears' barn cupola.	3 993·1	3·601 31
169 49 59	349 49 48	Little Rock	2 124·8	3·327 32
209 00 44	29 01 41	Sears' barn cupola.	4 028·3	3·605 12
187 24 12	7 24 18	Hog Back	1 500·9	3·176 35
225 17 12	45 17 45	Chase's barn cupola.	1 624·7	3·210 76
123 10 36	303 10 05	Hog Back	1 303·2	3·115 01
160 34 02	340 33 58	Chase's barn cupola.	389·8	2·590 83
222 46 48	42 47 24	Sears' barn cupola	1 857·0	3·268 82
283 06 49	103 08 44	Richmond Hill.	4 096·4	3·612 40
271 09 10	91 10 42	Pigeon Hill	3 167·2	3·500 68
38 04 54	218 04 25	Skunk Hill.	1 607·4	3·206 12

TAUNTON RIVER—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Whip-poor-will Mountain.	41 47 58·18	1795·0	71 02 08·23	190·0
Rocky Mountain.	41 47 44·37	1368·9	71 03 14·68	339·0
Ridge Hill.	41 49 07·27	224·3	71 02 20·63	476·1
Peirce.	41 49 31·30	965·7	71 00 46·62	1075·9
Assonet Baptist church spire. 1890.	41 47 29·98	924·9	71 04 14·58	336·6
Dillingham.	41 49 03·98	122·8	71 05 39·69	916·0
Dillingham, peg 1.	41 48 46·54	1435·9	71 05 36·79	849·2
Dillingham, peg 3.	41 48 59·13	1824·3	71 05 17·45	402·7
Dillingham, peg 2.	41 48 49·08	1514·2	71 05 28·83	665·4
Dillingham, peg 4.	41 49 04·02	124·0	71 05 08·31	191·8
Misery.	41 46 42·22	1302·6	71 01 14·86	343·2
Ridge Hill, peg 1.	41 49 02·65	81·8	71 02 15·79	364·4
Ridge Hill, peg 3.	41 48 59·43	1833·6	71 02 14·32	330·5
Berkley–Freetown roadstone.	41 48 59·70	1841·9	71 02 14·13	326·1
Ridge Hill, peg 2.	41 49 01·09	33·6	71 02 14·20	327·7
Freetown, corner 4.	41 48 46·45	1433·1	71 05 37·03	854·7
Freetown, corner 5.	41 49 04·22	130·2	71 05 20·21	466·4
Freetown, corner 6.	41 49 04·06	125·3	71 05 03·96	91·5
Lakeville, corner 3.	41 48 59·69	1841·6	71 02 13·41	309·5
Lakeville, corner 4.	41 50 18·76	578·8	71 00 28·56	659·0
Lakeville, corner 2.	41 47 58·64	1809·2	71 00 54·29	1253·4
Lakeville, corner 1.	41 46 44·19	1363·3	71 01 36·39	840·4
High peg.	41 56 19·45	600·1	71 05 40·23	926·8
Low peg.	41 56 22·48	693·6	71 05 40·87	941·5
North base.	41 56 22·36	689·9	71 05 37·45	862·8
South base.	41 56 20·92	645·4	71 05 38·08	877·3

TAUNTON RIVER—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
96 39 15	276 35 32	Richmond Hill	7 787·9	3·891 42
162 06 27	342 04 02	Prospect Taunton.	16 311·4	4·212 49
167 41 20	347 39 39	Prospect Taunton	16 323·4	4·212 81
219 00 41	39 03 01	Pigeon Hill.	7 700·0	3·886 49
226 25 42	46 27 26	Pigeon Hill	4 968·8	3·696.25
352 20 40	172 20 48	Whip-poor-will Mountain.	2 150·8	3·332 60
33 15 22	213 14 28	Whip-poor-will Mountain	3 435·3	3·535 97
71 08 42	251 07 39	Ridge Hill.	2 292·8	3·360 36
110 09 57	290 07 38	Richmond Hill	5 133·2	3·710 39
224 05 49	44 08 49	Pigeon Hill.	8 951·0	3·951 87
325 52 37	145 53 34	Assonet Baptist church	3 503·0	3·544 44
68 22 16	248 20 54	Richmond Hill.	3 070·0	3·487 14
172 54 55	352 54 53	Dillingham	542·1	2·734 07
106 16 04	286 15 49	Dillingham	534·6	2·728 04
66 56 18	246 56 13	Dillingham, peg 1	199·63	2·300 22
151 24 50	331 24 43	Dillingham.	523·6	2·718 98
54 24 41	234 24 35	Dillingham, peg 3	259·44	2·414 04
89 54 15	269 53 54	Dillingham.	724·2	2·859 85
124 44 02	304 42 42	Rocky Mountain	3 366·6	3·527 19
152 15 44	332 15 08	Whip-poor-will Mountain.	2 647·6	3·422 85
141 55 02	321 54 59	Ridge Hill	181·28	2·258 34
246 44 42	66 45 41	Peirce.	2 239·7	3·350 19
161 08 44	341 08 43	Ridge Hill, peg 1	105·0	2·021 03
27 27 02	207 27 02	Ridge Hill, peg 3	9·35	0·970 73
3 00 59	183 00 59	Ridge Hill, peg 3	51·29	1·710 02
142 43 29	322 43 28	Ridge Hill, peg 1.	60·5	1·781 48
243 51 15	63 51 15	Dillingham, peg 1	6·20	0·792 58
271 15 22	91 15 30	Dillingham, peg 4	274·7	2·438 86
337 55 52	157 55 54	Dillingham, peg 3.	169·4	2·228 99
63 58 44	243 58 35	Dillingham, peg 3	346·4	2·539 62
89 50 50	269 50 26	Dillingham.	824·5	2·916 20
69 01 47	249 01 46	Ridge Hill, peg 3	22·6	1·353 50
148 55 29	328 55 27	Ridge Hill, peg 1.	106·5	2·027 52
27 56 51	207 55 45	Whip-poor-will Mountain	4 909·3	3·691 02
38 50 55	218 49 04	Rocky Mountain.	6 114·6	3·786 37
89 31 27	269 30 38	Whip-poor-will Mountain	1 707·0	3·232 23
136 44 13	316 43 15	Ridge Hill.	2 907·8	3·463 57
129 17 38	309 16 33	Rocky Mountain	2 932·5	3.467 24
276 58 25	96 58 39	Misery.	501·0	2·699 87
10 40 58	190 40 43	Taunton Insane Asylum	2 731·4	3·436 39
113 24 51	293 24 47	Prospect Taunton.	139·2	2·143 57
351 05 30	171 05 30	High peg	94·5	1·975 55
71 22 46	251 22 43	Prospect Taunton.	119·3	2·076 72
35 36 45	215 36 43	High peg	110·3	2·042 56
79 50 53	259 50 47	Prospect Taunton.	195·0	2·290 04
47 34 07	227 34 06	High peg	67·2	1·827 30
93 13 05	273 13 00	Prospect Taunton.	177·6	2·249 43

TAUNTON RIVER—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Burnt stump.	41 56 30·90	953·3	71 05 54·60	1257·7
Road peg.	41 56 25·77	795·1	71 05 32·25	742·9
Oak Brush.	41 56 29·10	897·8	71 05 31·60	728·0
Connect.	41 56 21·23	655·0	71 05 58·94	1357·8
Storm peg.	41 56 36·36	1121·8	71 05 21·93	505·2
Hawk.	41 56 43·91	1354·7	71 05 12·50	287·9
Leon.	41 57 24·36	751·6	71 05 06·98	160·8
Taunton, corner 18.	41 57 16·79	518·0	71 05 02·48	57·1
Taunton, corner 17.	41 57 34·49	1064·1	71 04 51·70	1190·6
Taunton, corner 3.	41 52 12·17	375·5	71 04 23·69	546·4
Taunton, corner 4.	41 52 22·88	705·9	71 04 36·98	852·8
Taunton, corner 5.	41 52 21·44	661·5	71 05 37·08	855·1
Taunton, corner 6.	41 52 13·59	419·3	71 07 54·82	1264·2
Taunton, corner 19.	41 56 59·57	1837·9	71 05 10·27	236·5
Taunton, corner 20.	41 56 51·11	1576·9	71 05 11·45	263·7
Taunton, corner 21.	41 56 46·68	1440·2	71 05 12·34	284·2
Taunton, corner 22.	41 56 36·69	1132·0	71 05 21·58	497·1
Taunton, corner 23.	41 56 31·40	968·8	71 05 24·91	573·8
Taunton, corner 24.	41 56 29·74	917·6	71 05 26·49	610·2
Taunton, corner 25.	41 56 28·48	878·7	71 05 28·35	653·0
Taunton, corner 26.	41 56 27·92	861·4	71 05 30·35	699·1
Taunton, corner 27.	41 56 25·80	796·0	71 05 32·50	748·7
Taunton, corner 28.	41 56 23·79	734·0	71 05 32·74	754·2
Taunton, corner 29.	41 56 20·55	634·0	71 05 35·47	817·1
Taunton, corner 30.	41 54 12·70	391·8	71 03 50·47	1163·3
Dighton, corner 1.	41 47 21·94	676·9	71 10 17·51	404·3
Little Rock, south base.	41 48 55·28	1705·5	71 11 37·65	869·0
Little Rock, north base.	41 48 59·85	1846·5	71 11 38·58	890·4
Dighton, corner 3.	41 48 59·70	1841·9	71 11 38·28	883·5
Rehoboth, corner 10.	41 46 59·56	1837·6	71 11 17·71	409·0
Barn clock.	41 44 11·47	353·9	71 10 06·65	153·7
Niagara engine house. 1890.	41 41 20·17	622·3	71 09 35·59	823·0

TAUNTON RIVER—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
303 43 22	123 43 33	North base	475·0	2·676 69
325 43 44	145 43 50	Prospect Taunton.	360·7	2·557 16
43 19 26	223 19 21	High peg	268·0	2·428 19
65 51 15	245 51 06	Prospect Taunton.	341·5	2·533 42
53 23 52	233 23 43	Prospect Taunton	406·9	2·609 44
95 59 00	275 58 45	Burnt stump.	532·6	2·726 40
248 55 07	68 55 25	Oak Brush	675·0	2·829 30
269 58 05	89 58 14	Prospect Taunton.	303·2	2·481 66
49 39 55	229 39 39	Prospect Taunton	720·7	2·857 78
77 23 01	257 22 39	Burnt stump.	771·2	2·887 15
47 37 45	227 37 23	Prospect Taunton	1 037·7	3·016 09
67 31 21	247 30 53	Burnt stump.	1 049·4	3·020 94
276 13 08	96 13 43	North Raynham church	1 207·0	3·081 71
24 39 00	204 38 34	Prospect Taunton.	2 142·8	3·330 98
156 03 33	336 03 30	Leon	255·64	2·407 63
48 24 03	228 23 53	Leon	470·54	2·672 60
133 05 14	313 05 13	Stork	37·84	1·577 96
215 25 12	35 25 13	Meadow Dam	60·79	1·783 84
69 11 35	249 11 32	Hathaway	109·62	2·039 88
90 13 18	270 13 11	O'Brien	240·12	2·380 42
6 04 00	186 03 59	Hawk	486·00	2·686 64
6 11 45	186 11 44	Hawk	223·51	2·349 30
2 24 36	182 24 36	Hawk	85·39	1·931 40
38 16 34	218 16 34	Storm peg	12·89	1·110 25
44 12 10	224 12 05	Road peg	242·35	2·384 45
47 16 55	227 16 51	Road peg	180·51	2·256 49
47 03 20	227 03 17	Road peg	122·79	2·089 16
33 18 25	213 18 24	Road peg	79·54	1·900 60
280 08 15	100 08 15	Road peg	5·75	0·759 67
190 35 03	10 35 03	Road peg	62·03	1·792 60
100 38 35	280 38 33	South base	61·21	1·786 82
218 18 10	38 18 15	Kings Knoll	259·981	2·414 94
156 36 32	336 36 31	Chase's barn cupola, peg	80·62	1·906 46
270 14 58	90 15 08	Little Rock	351·9	2·546 47
290 53 57	110 54 08	Little Rock	399·8	2·601 79
351 19 41	171 19 42	Little Rock, south base.	142·702	2·154 43
123 22 32	303 22 32	Little Rock, north base	8·240	0·915 93
278 16 40	98 16 42	Dillon	74·49	1·872 12
331 34 15	151 35 02	Quequechan engine house	3 428·0	3·535 04
46 39 38	226 38 06	Gardner Neck.	4 392·1	3·642 67
34 41 43	214 41 04	Fall River, corner 4	2 401·4	3·380 46
51 04 24	231 03 30	Canadian Catholic church.	2 399·3	3·380 09

CAPE COD BAY AND PENINSULA.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Provincetown.	42 03 08·452	260·7	70 11 20·533	472·2
Scargo. 1846–1877.	41 44 22·481	693·6	70 10 49·824	1151·3
Chatham. (C. & G. S. & Bdn.), 1835–1887.	41 41 50·705	1564·3	69 58 48·380	1118·7
Mill Hill. (C. & G. S. & Bdn.), 1835–1887.	41 46 34·142	1053·4	70 00 06·967	160·7
Bourne Hill. (C. & G. S. & Bdn.), 1835–1888.	41 44 00·818	25·2	70 29 11·627	268·7
Smalls Hill. (Borden.)	42 00 35·256	1087·8	70 02 10·298	237·0
Griffin Island.	41 56 14·374	443·4	70 04 06·046	139·3
German Hill. 1846.	41 41 27·962	862·7	70 12 35·978	832·0
Point Gammon. 1846.	41 37 04·965	153·2	70 15 39·322	910·3
Monomoy.	41 35 37·602	1160·0	69 59 03·358	77·8
Hamblin Hill.	41 41 49·931	1540·4	70 24 13·644	315·5
Peaked Cliff.	41 48 31·383	968·1	70 32 25·060	578·5
Holmes. 1848.	41 55 26·564	819·5	70 32 39·017	899·0
Scorton Neck.	41 44 19·130	590·1	70 24 41·190	951·8
Mount Schaum.	41 45 25·096	774·2	70 30 49·984	1154·7
Scorton Hill.	41 43 17·257	532·4	70 23 41·434	957·7
Rock Point.	41 46 12·951	399·5	70 04 46·025	1063·1
Race Point light-house. 1877.	42 03 44·564	1374·9	70 14 36·989	850·4
Orleans 2. 1868–1887.	41 47 32·585	1005·4	70 00 51·627	1191·9
Atwood.	41 45 11·393	351·6	70 04 24·315	561·7
Billingsgate light-house. 1868–1887.	41 52 18·221	562·1	70 04 09·871	227·6
Cape Cod light-house. 1877–1887.	42 02 23·165	714·7	70 03 39·833	916·1
Long Point light-house. 1877–1887.	42 01 59·467	1834·8	70 10 09·008	207·2

CAPE COD BAY AND PENINSULA.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
67 31 32·8	247 15 24·4	Manomet	36 095·1	4·557 448
17 54 15·3	197 47 55·4	Shootflying.	42 821·5	4·631 662
178 50 07·6	358 49 47·1	Provincetown	34 746·5	4·540 911
66 35 20·7	246 28 41·5	Shootflying.	15 119·3	4·179 530
105 45 02·0	285 37 01·9	Scargo	17 321·8	4·238 592
75 04 18·8	254 51 15·5	Hyannis.	28 226·4	4·450 655
74 45 44·4	254 38 36·3	Scargo	15 396·6	4·187 426
153 13 22·7	333 05 52·7	Provincetown.	34 380·9	4·536 317
158 03 37·6	337 59 26·5	Manomet	23 218·0	4·365 825
263 08 42·4	83 28 04·2	Mill Hill.	40 583·2	4·608 346
78 56 11·1	258 33 55·2	Manomet	46 903·2	4·671 202
353 44 10·1	173 45 32·5	Mill Hill.	26 105·9	4·416 739
141 59 15·2	321 54 24·5	Provincetown	16 224·2	4·210 163
342 51 22·2	162 54 01·7	Mill Hill.	18 731·8	4·272 579
50 48 53·8	230 45 00·7	Hyannis	10 472·5	4·020 052
267 49 25·5	87 58 36·0	Chatham.	19 150·7	4·282 185
207 35 10·2	27 37 12·1	German Hill	9 156·0	3·961 704
249 15 22·7	69 26 34·7	Chatham.	24 996·8	4·397 885
96 45 26·8	276 34 25·5	Point Gammon	23 219·7	4·365 856
181 43 24·1	1 43 34·1	Chatham.	11 515·9	4·061 299
312 14 51·6	132 18 42·3	Hyannis	10 849·8	4·035 423
255 42 43·2	75 51 38·1	Scargo.	19 167·8	4·282 573
162 15 35·5	342 13 33·3	Manomet	13 843·3	4·141 240
310 23 26·8	130 31 09·8	Shootflying.	21 113·8	4·324 567
95 30 15·8	275 28 22·8	Manomet	3 914·5	3·592 678
358 33 33·1	178 33 42·4	Peaked Cliff.	12 813·4	4·107 665
144 36 32·7	324 29 21·2	Manomet	25 737·7	4·410 570
126 02 17·2	305 57 08·2	Peaked Cliff.	13 241·9	4·121 950
283 23 55·2	103 28 00·8	Scorton Neck	8 760·8	3·942 544
159 06 04·8	339 05 01·4	Peaked Cliff.	6 152·4	3·789 046
111 45 18·9	291 40 33·6	Mount Schaum	10 659·6	4·027 742
128 45 07·0	308 39 18·2	Peaked Cliff.	15 499·0	4·190 304
67 57 38·2	247 53 35·9	Scargo	9 069·5	3·957 585
264 10 55·2	84 14 01·1	Mill Hill.	6 478·3	3·811 459
62 37 00·1	242 23 03·0	Manomet	32 465·0	4·511 415
11 38 05·1	191 33 56·3	Shootflying.	42 747·2	4·630 907
65 36 34·1	245 33 57·9	Rock Point	5 944·5	3·774 116
330 13 40·1	150 14 09·9	Mill Hill.	2 077·2	3·317 471
246 44 03·6	66 46 55·0	Mill Hill	6 469·6	3·810 878
80 25 13·7	260 20 57·0	Scargo.	9 034·4	3·955 902
32 12 30·4	212 08 03·8	Scargo	17 340·0	4·239 050
332 08 25·9	152 11 07·9	Mill Hill.	12 004·8	4·079 357
74 19 09·7	253 57 53·2	Manomet	45 668·2	4·659 614
31 12 18·1	211 00 50·8	Shootflying.	45 974·5	4·662 517
71 34 23·9	251 17 27·8	Manomet	36 893·3	4·566 947
20 59 38·6	200 52 31·0	Shootflying.	41 361·8	4·616 599

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Wood End light-house. 1877–1887.	42 01 16·608	512·4	70 11 38·491	885·7
Scargo Observatory flagstaff. 1887.	41 44 22·400	691·1	70 10 49·789	1150·5
Chatham, corner 8.	41 43 21·106	651·2	69 55 42·607	984·9
South Orleans Progressive Lyceum Association Hall, chimney.	41 44 34·255	1056·8	69 59 46·635	1077·6
Strong. 1868–1887.	41 43 12·480	385·0	69 57 29·616	684·6
Refuge.	41 42 29·782	918·8	69 55 54·041	1249·4
Chatham Congregational church spire. 1868–1887.	41 40 58·540	1806·0	69 57 41·721	964·9
Chatham, north light-house. 1880–1886.	41 40 18·280	564·0	69 57 01·272	29·4
Pine. 1868–1886.	41 40 08·555	263·9	69 59 35·482	820·8
Yarmouth Congregational church spire. 1887.	41 42 22·440	692·3	70 14 21·711	501·9
Sandy Neck light-house. 1887.	41 43 21·750	671·0	70 16 53·128	1228·0
Harwich Exchange, center ball of cupola.	41 41 11·586	357·4	70 04 34·453	796·8
Brewster Station. 1887.	41 45 12·536	386·8	70 04 24·850	574·1
West Brewster.	41 44 32·013	987·6	70 07 05·833	134·8
Wash. 1886–87.	41 43 54·542	1682·7	69 55 41·774	965·4
South Point.	41 40 46·138	1423·4	69 56 25·124	581·1
Sand Peak.	41 52 04·330	133·6	70 00 18·402	424·4
Wyer.	41 52 49·989	1542·2	69 57 28·671	661·0
North Wellfleet Congregational church spire. 1887.	41 56 20·465	631·4	70 01 43·715	1007·1
South Truro Methodist church spire. 1887.	41 58 41·914	1293·2	70 04 04·919	113·2
Holbrook.	41 56 34·468	1063·4	70 03 55·912	1287·9
Mount Ararat.	42 03 58·644	1809·4	70 09 06·112	140·5
High Pole Hill, flagstaff. 1887.	42 03 08·805	271·7	70 11 19·766	454·7

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
72 33 29·5	252 17 33·4	Manomet	34 527·5	4·538 165
18 52 17·5	198 46 09·7	Shootflying.	39 416·5	4·595 678
285 36 35·4	105 44 35·5	Chatham	17 320·2	4·238 554
66 35 56·8	246 29 17·6	Shootflying.	15 119·0	4·179 522
57 01 04·7	236 59 01·1	Chatham	5 121·0	3·709 354
134 18 02·4	314 15 06·4	Mill Hill.	8 530·9	3·930 995
345 03 08·2	165 03 47·0	Chatham	5 222·4	3·717 871
291 47 13·0	111 49 55·4	Chatham, corner 8.	6 074·5	3·783 507
35 49 40·5	215 48 48·1	Chatham	3 111·4	3·492 962
128 33 25·4	308 31 54·2	South Orleans P. L. A. Hall chimney.	4 048·8	3·607 327
73 21 54·2	253 19 58·2	Chatham	4 207·4	3·624 013
120 48 48·6	300 47 45·0	Strong.	2 572·3	3·410 330
221 29 07·1	41 30 18·7	Refuge	3 758·2	3·574 981
136 14 20·8	316 13 36·5	Chatham.	2 228·6	3·348 023
200 57 43·2	20 58 27·9	Refuge	4 344·8	3·637 966
139 01 38·5	319 00 27·3	Chatham.	3 777·2	3·577 171
199 03·53·4	19 04 24·7	Chatham	3 334·5	3·523 028
265 10 41·0	85 12 23·5	Chatham north light-house.	3 580·0	3·553 879
272 30 41·0	92 41 01·9	Chatham	21 602·5	4·334 504
232 54 28·0	52 56 49·0	Scargo Observatory.	6 139·4	3·788 124
257 24 16·4	77 28 18·3	Scargo Observatory	8 603·2	3·934 661
297 35 04·1	117 36 44·9	Yarmouth Congregational church.	3 949·8	3·596 575
261 23 32·4	81 27 22·6	Chatham	8 093·5	3·908 138
124 11 23·2	304 07 13·4	Scargo Observatory.	10 485·5	4·020 588
308 39 08·2	128 42 52·1	Chatham	9 962·7	3·998 375
1 42 39·9	181 42 33·5	Harwich Exchange.	7 437·0	3·871 399
86 44 26·6	266 41 57·5	Scargo Observatory	5 183·6	3·714 635
330 28 43·1	150 30 23·8	Harwich Exchange.	7 105·1	3·851 570
128 48 45·7	308 45 49·1	Mill Hill	7 860·2	3·895 436
48 29 13·7	228 27 09·5	Chatham.	5 762·5	3·760 610
121 01 47·8	301 00 12·5	Chatham	3 865·8	3·587 236
192 39 57·1	12 40 17·8	Refuge.	3 277·4	3·515 526
358 30 53·5	178 31 01·1	Mill Hill	10 190·5	4·008 196
94 36 42·4	274 34 07·9	Billingsgate light-house, 1868–1887.	5 355·2	3·728 775
17 30 00·7	197 28 15·1	Mill Hill	12 157·5	4·084 846
83 59 22·4	263 54 54·6	Billingsgate light-house, 1868–1887.	9 303·2	3·968 631
352 57 30·0	172 58 34·6	Mill Hill	18 226·7	4·260 707
24 16 34·0	204 14 56·4	Billingsgate light-house, 1868–1887.	8 198·0	3·913 708
184 49 52·8	4 50 09·6	Cape Cod light-house, 1877–1887	6 850·7	3·835 734
323 17 44·7	143 19 19·1	North Wellfleet Congregational church, 1887.	5 442·4	3·735 794
176 58 52·9	356 58 46·9	South Truro Methodist church	3 937·6	3·595 229
278 03 43·0	98 05 11·4	North Wellfleet Congregational church, 1887.	3 075·8	3·487 956
291 24 20·7	111 27 59·2	Cape Cod light-house, 1877–1887	8 060·6	3·906 366
21 28 43·8	201 28 01·7	Long Point light-house, 1877–1887.	3 951·3	3·596 737
277 32 24·8	97 37 32·8	Cape Cod light-house, 1877–1887	10 670·9	4·028 202
322 43 59·2	142 44 46·6	Long Point light-house, 1877–1887.	2 688·0	3·429 424

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Ames.	41 39 49·282	1520·4	70 27 56·350	1303·7
Crocker.	41 38 41·174	1270·2	70 27 09·870	228·4
Indian Brook.	41 51 30·36	936·7	70 00 23·41	539·9
Blackfish Creek.	41 54 28·86	890·4	70 01 04·80	110·6
Hamblin Mound.	41 56 14·18	437·5	70 02 47·46	1093·2
Cambria.	41 59 14·88	459·1	70 00 45·13	1038·8
Highland.	42 01 41·33	1275·2	70 02 47·49	1092·4
Pamet.	42 00 14·91	460·0	70 04 52·68	1212·3
Stout.	42 04 09·52	293·8	70 07 32·83	754·7
Lombard Head.	41 55 51·66	1593·9	69 58 51·02	1175·4
Race.	42 04 50·41	1555·3	70 12 26·65	612·5
Truro Congregational church spire. 1847.	41 59 54·06	1667·9	70 03 18·44	424·4
Long Point schoolhouse.	42 01 21·71	669·8	70 10 55·15	1268·8
Long Point light-house. 1847.	42 01 59·12	1824·1	70 10 08·87	204·0
Race Point light-house. (C. & G. S. & Bdn.), 1835–1847.	42 03 44·34	1368·1	70 14 36·98	850·2
Provincetown old Universalist church belfry. (C. & G. S. & Bdn.), 1835–1847.	42 02 51·02	1574·2	70 11 26·99	620·7
Provincetown Baptist church belfry. 1847.	42 03 27·45	847·0	70 10 39·74	913·7
Provincetown Methodist church belfry. 1847.	42 03 06·52	201·2	70 11 17·82	409·8
Provincetown new Universalist church spire. 1847.	42 03 02·08	64·2	70 11 19·94	458·5
Provincetown Orthodox church spire. 1847.	42 03 04·03	124·3	70 11 17·61	405·0
Provincetown schoolhouse.	42 02 41·17	1270·2	70 11 36·90	848·6
Provincetown Academy.	42 03 09·78	301·8	70 11 14·50	333·4
Provincetown Methodist center church. 1877.	42 03 12·55	387·2	70 11 05·52	126·9

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
120 49 38·4	300 45 37·5	Pine Hill	9 753·2	3·989 145
167 21 53·1	347 21 03·0	Bourne Hill.	7 953·1	3·900 538
164 04 31·4	344 03 10·4	Bourne Hill	10 255·7	4·010 965
242 49 08·2	62 53 20·9	Shootflying.	9 883·0	3·994 889
47 40 05	227 33 07	Scargo	19 580·6	4·291 826
149 39 44	329 37 15	Griffin Island.	10 154·8	4·006 671
35 52 16	215 45 46	Scargo	23 071·2	4·363 070
127 56 42	307 54 41	Griffin Island.	5 295·2	3·723 886
26 55 23	206 50 01	Scargo	24 616·6	4·391 228
137 18 43	317 13 00	Provincetown.	17 401·7	4·240 591
357 50 55	177 51 20	Mill Hill	23 487·6	4·370 839
116 17 58	296 10 53	Provincetown.	16 299·1	4·212 164
102 52 48	282 47 05	Provincetown	12 101·9	4·082 854
10 10 23	190 09 31	Griffin Island.	10 248·5	4·010 659
121 00 07	300 55 47	Provincetown	10 405·1	4·017 248
227 11 31	47 12 55	Highland.	3 925·1	3·593 847
304 50 27	124 53 38	Highland	7 997·8	3·902 968
341 59 52	162 02 10	Griffin Island.	15 412·7	4·187 879
50 21 46	230 20 17	Blackfish Creek	4 003·6	3·602 45
95 32 23	275 28 53	Griffin Island.	7 291·6	3·862 82
334 12 03	154 12 47	Provincetown	3 493·9	3·543 31
280 33 11	100 36 28	Stout.	6 871·0	3·837 02
106 31 31	286 30 28	Pamet	2 261·8	3·354 46
192 08 24	12 08 45	Highland.	3 385·7	3·529 65
221 55 45	41 58 01	Stout	6 961·3	3·842 69
315 09 21	135 13 54	Griffin Island.	13 364·8	4·125 96
221 42 59	41 44 43	Stout	5 390·7	3·731 64
142 23 51	322 23 03	Provincetown.	2 700·2	3·431 40
283 45 20	103 47 32	Provincetown	4 651·2	3·667 56
235 45 30	55 46 57	Race.	3 623·8	3·559 17
245 45 57	65 48 34	Stout	5 904·0	3·771 14
320 17 18	140 22 13	Griffin Island.	15 899·5	4·201 38
253 10 38	73 12 43	Stout	4 489·3	3·652 17
325 49 18	145 53 41	Griffin Island.	16 144·3	4·208 02
249 23 08	69 25 39	Stout	5 526·3	3·742 44
321 57 04	142 01 53	Griffin Island.	16 138·6	4·207 87
248 15 14	68 17 46	Stout	5 621·7	3·749 87
321 30 48	141 35 38	Griffin Island.	16 061·2	4·205 78
248 37 37	68 40 08	Stout	5 549·1	3·744 22
321 47 43	141 52 32	Griffin Island.	16 075·4	4·206 16
244 04 18	64 07 01	Stout	6 239·0	3·795 12
318 56 58	139 02 00	Griffin Island.	15 814·8	4·199 06
250 05 53	70 08 21	Stout	5 420·1	3·734 00
322 23 05	142 27 52	Griffin Island.	16 171·3	4·208 74
67 33 07	247 16 49	Manomet	36 462·5	4·561 85
18 17 33	198 11 03	Shootflying.	43 049·2	4·633 96

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Provincetown Methodist Centenary church. 1877.	42 02 52·44	1617·9	70 11 26·78	615·9
Provincetown town hall.	42 03 04·81	148·4	70 11 17·35	399·0
Mayo Beach light-house. 1877.	41 55 49·82	1537·2	70 02 05·66	130·4
Cape Cod light-house. (C. & G. S. & Bdn.) 1835–1847.	42 02 23·19	715·5	70 03 39·85	916·5
North Wellfleet Methodist church belfry. 1847–1887.	41 56 19·65	606·2	70 01 48·96	1127·9
North Wellfleet Congregational church belfry. 1847.	41 56 09·64	297·4	70 01 16·48	379·7
South Wellfleet Congregational church belfry. 1847.	41 54 32·07	989·5	69 59 07·10	163·6
South Wellfleet Methodist meetinghouse. 1847.	41 54 24·54	757·1	69 59 07·72	177·9
Billingsgate light-house. (C. & G. S. & Bdn.) 1835–1847	41 51 38·77	1196·1	70 04 16·72	384·8
Nauset Beach, center beacon. 1846–1887.	41 51 38·62	1191·5	69 57 05·42	125·0
Eastham Congregational church spire. 1847.	41 50 28·28	872·5	69 58 54·33	1253·5
Eastham Methodist church spire. 1887.	41 50 35·55	1096·8	69 59 01·11	25·6
Nauset Harbor.	41 47 22·72	701·0	69 56 46·80	1080·6
Station south of Nauset lights.	41 51 10·90	336·3	69 57 00·54	12·5
Eastham.	41 49 26·09	804·9	70 00 14·92	344·3
Orleans. 1847.	41 47 32·47	1002·2	70 00 51·46	1188·2
Brewster. 1847.	41 46 12·76	393·7	70 04 46·46	1073·1
Pleasant Bay.	41 44 34·89	1076·4	69 58 39·64	916·0
Nauset Beach.	41 44 05·66	174·6	69 55 34·32	793·1
Brewster Unitarian church spire. 1846–1887.	41 45 43·24	1334·0	70 04 57·32	1324·1
Brewster Baptist church spire. 1887.	41 45 33·81	1043·1	70 05 07·55	174·4
Orleans Orthodox church spire. 1847–1887.	41 47 04·86	149·9	69 58 30·20	697·4
North Dennis. 1846.	41 44 42·24	1303·2	70 12 29·82	689·0

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
68 10 02	247 53 58	Manomet	35 775·7	4·553 59
17 55 23	197 49 07	Shootflying.	42 307·4	4·626 42
276 55 02	97 00 08	Cape Cod light-house, 1877–1887	10 599·9	4·025 30
313 19 34	133 25 57	North Wellfleet Congregational church, 1887.	18 165·2	4·259 24
350 54 53	170 56 12	Mill Hill	17 361·1	4·239 58
29 44 47	209 38 57	Scargo.	24 412·4	4·387 61
97 33 06	277 27 57	Provincetown	10 687·1	4·028 86
3 02 01	183 01 43	Griffin Island.	11 395·2	4·056 72
343 25 10	163 25 39	Blackfish Creek	3 566·5	3·552 24
87 03 21	267 01 49	Griffin Island.	3 162·8	3·500 07
355 03 18	175 03 26	Blackfish Creek	3 120·7	3·494 25
92 09 08	272 07 15	Griffin Island.	3 909·0	3·592 07
87 55 18	267 53 59	Blackfish Creek	2 714·2	3·433 63
114 38 28	294 35 08	Griffin Island.	7 577·3	3·879 51
92 50 20	272 49 02	Blackfish Creek	2 701·5	3·431 61
116 15 52	296 12 33	Griffin Island.	7 664·0	3·884 46
328 27 18	148 30 05	Mill Hill	11 024·9	4·042 37
34 01 25	213 57 03	Scargo.	16 233·9	4·210 42
24 03 22	204 01 21	Mill Hill	10 285·9	4·012 24
54 48 58	234 39 48	Scargo.	23 309·3	4·367 53
55 43 46	235 35 49	Scargo	20 007·6	4·301 19
146 05 15	326 01 47	Griffin Island.	12 870·9	4·109 61
11 32 31	191 31 47	Mill Hill	7 601·5	3·880 90
146 56 55	326 56 03	Sand Peak.	3 268·3	3·514 32
146 49 16	326 46 52	Indian Brook	9 130·2	3·960 48
72 03 28	252 01 15	Mill Hill.	4 858·7	3·686 52
357 25 22	177 25 31	Nauset Harbor	7 047·4	3·848 03
26 45 49	206 43 45	Mill Hill.	9 561·2	3·980 51
358 00 57	178 01 02	Mill Hill	5 308·0	3·724 93
57 29 10	237 22 07	Scargo.	17 399·0	4·240 52
67 04 26	246 57 47	Scargo	15 012·7	4·176 46
178 37 43	358 37 34	Blackfish Creek.	12 850·3	4·108 91
226 24 12	46 27 13	Eastham	8 653·6	3·937 19
264 08 22	84 11 28	Mill Hill.	6 488·7	3·812 16
151 16 22	331 15 24	Mill Hill	4 195·9	3·622 82
206 42 18	26 43 33	Nauset Harbor.	5 796·6	3·763 17
101 54 35	281 52 32	Pleasant Bay	4 376·6	3·641 14
126 03 10	306 00 08	Mill Hill.	7 788·6	3·891 46
223 27 28	43 30 36	Eastham	9 475·9	3·976 62
256 47 43	76 50 56	Mill Hill.	6 887·6	3·838 07
303 37 48	123 38 16	Brewster Station	1 184·6	3·073 58
74 27 49	254 24 01	Scargo Observatory.	8 208·4	3·914 26
150 59 18	330 58 08	Eastham	4 983·0	3·697 49
67 01 51	247 00 47	Mill Hill.	2 427·3	3·385 13
1 21 45	181 21 41	German Hill	5 995·4	3·777 82
284 46 13	104 47 20	Scargo.	2 389·5	3·378 31

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
North Dennis, white church spire. 1846–1868.	41 44 13·77	424·8	70 11 35·41	818·3
North Dennis, gray church spire. 1846–1887.	41 44 14·85	458·2	70 11 32·54	752·0
North Dennis 2. 1868.	41 43 29·20	900·9	70 12 04·70	108·6
Bass Hole.	41 42 49·98	1542·0	70 14 15·54	358·4
Monomoy light-house. (C. & G. S. & Bdn.) 1835–1846.	41 33 35·02	1080·4	69 59 40·76	944·5
Monomoy light-house. 1867–1887.	41 33 33·78	1042·1	69 59 39·02	904·2
Point Gammon light-house. (C. & G. S. & Bdn.) 1835–1847.	41 36 35·00	1079·8	70 16 00·19	4·4
Barnstable.	41 41 48·82	1506·2	70 18 25·58	591·5
Barnstable Unitarian church spire. 1846.	41 42 02·46	75·9	70 17 57·67	1333·4
Barnstable light-house. 1846.	41 43 21·16	652·8	70 16 53·34	1232·9
Barnstable, west church spire. 1848.	41 41 54·89	1693·4	70 23 03·28	75·8
Barn cupola.	41 42 15·22	469·6	70 19 03·24	74·9
Yarmouth Port church spire. 1846.	41 42 24·82	765·7	70 14 37·13	858·4
Sursuit Creek.	41 45 32·41	999·7	70 08 37·40	864·0
Morris Island. 1846.	41 39 29·48	909·5	69 57 34·14	789·9
Harwich Port.	41 39 51·30	1582·6	70 04 06·57	152·0
West Chatham.	41 40 09·42	290·6	70 01 42·19	976·0
South Dennis.	41 39 06·59	203·3	70 08 12·40	286·9
South Dennis Congregational church spire. 1846–1887.	41 40 34·25	1056·6	70 09 24·50	566·7
South Dennis, south church spire. 1846.	41 40 21·64	667·6	70 09 23·64	546·8
West Harwich Baptist church spire. 1846–1887.	41 40 13·01	401·4	70 07 02·60	60·1
Bass River.	41 38 38·44	1185·9	70 12 12·13	280·7
West Yarmouth church spire. 1846.	41 38 59·08	1822·7	70 13 46·73	1081·3

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
124 56 48	304 56 12	North Dennis	1 533·5	3·185 69
255 41 00	75 41 30	Scargo.	1 087·2	3·036 31
122 33 44	302 33 06	North Dennis	1 570·1	3·195 94
256 34 52	76 35 20	Scargo.	1 014·8	3·006 36
206 11 59	26 12 19	North Dennis, white church spire	1·532·4	3·185 36
226 27 41	46 28 31	Scargo.	2 387·0	3·377 86
317 41 47	137 42 53	German Hill	3 421·0	3·534 15
239 00 37	59 02 54	Scargo.	5 545·5	3·743 94
129 11 02	309 02 28	German Hill	23 128·5	4·364 15
184 31 43	4 32 18	Chatham.	15 340·9	4·185 85
115 33 16	295 19 12	Shootflying	32 576·2	4·512 90
184 22 10	4 22 44	Chatham.	15 375·9	4·186 84
207 35 10	27 37 26	German Hill	10 198·8	4·008 55
141 27 13	321 24 01	Shootflying.	10 746·7	4·031 28
0 11 54	180 11 53	Hyannis	7 264·8	3·861 23
274 31 03	94 34 56	German Hill.	8 109·9	3·909 02
278 06 44	98 10 18	German Hill	7 514·7	3·875 91
236 55 34	56 59 12	North Dennis.	9 040·3	3·956 18
300 23 10	120 26 01	German Hill	6 899·2	3·838 80
257 16 32	77 20 34	Scargo.	8 611·7	3·935 09
84 37 59	264 37 12	Hamblin Hill	1 634·2	3·213 31
160 51 43	340 51 18	Scorton Hill.	2 689·9	3·429 74
83 49 25	263 45 58	Hamblin Hill	7 219·9	3·858 53
49 37 32	229 36 21	Shootflying.	3 232·7	3·509 57
302 02 40	122 04 01	German Hill	3 305·2	3·519 19
235 20 18	55 22 49	Scargo.	6 386·0	3·805 23
73 56 30	253 53 55	North Dennis	5 588·8	3·747 32
54 49 36	234 48 08	Scargo.	3 744·2	3·573 36
16 06 39	196 05 40	Monomoy	7 446·3	3·871 94
158 29 38	338 28 49	Chatham.	4 683·6	3·670 58
318 05 16	138 08 37	Monomoy	10 512·6	4·021 71
72 18 56	252 11 16	Point Gammon.	16 833·7	4·226 18
232 07 35	52 09 31	Chatham	5 091·7	3·706 86
336 18 53	156 20 39	Monomoy.	9 156·7	3·961 74
296 50 45	116 56 50	Monomoy	14 251·9	4·153 87
70 06 06	250 01 10	Point Gammon.	11 003·9	4·041 55
53 22 16	233 18 07	Point Gammon	10 813·3	4·033 96
93 44 52	273 37 16	Shootflying.	15 882·2	4·200 91
55 07 21	235 03 11	Point Gammon	10 602·1	4·025 39
95 08 22	275 00 46	Shootflying.	15 932·0	4·202 27
145 41 55	325 39 24	Scargo Observatory	9 316·0	3·969 23
242 10 45	62 12 24	Harwich Exchange.	3 874·0	3·588 16
173 58 38	353 58 22	German Hill	5 259·1	3·720 91
59 00 07	238 57 50	Point Gammon.	5 595·9	3·747 88
112 03 12	291 58 31	Shootflying	10 555·6	4·023 48
72 38 29	252 35 23	Hyannis.	6 788·8	3·831 79

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Fish-house, north gable.	41 38 19·40	598·5	70 10 38·15	883·0
Point Gammon 2. 1875.	41 37 04·96	153·0	70 15 39·32	910·3
Mannersen.	41 41 31·14	960·7	70 12 16·86	389·9
Bass River light-house. 1875.	41 39 06·44	198·7	70 10 10·84	250·8
Harwich church belfry. (C. & G. S. & Bdn.) 1835–1846.	41 41 12·39	382·3	70 04 35·97	831·8
Harwich Congregational church spire. 1887.	41 41 12·28	378·9	70 04 35·88	829·8
Marsh.	41 43 51·92	1601·8	69 55 39·96	923·5
Eldridge.	41 44 34·87	1075·8	69 58 39·69	917·1
Pochet.	41 46 39·97	1233·1	69 56 26·10	602·8
Sampson.	41 45 21·74	670·7	69 57 00·44	10·2
Old Harbor.	41 42 19·93	614·9	69 56 01·12	25·9
Camp.	41 43 59·58	1838·1	69 59 33·25	768·4
Basin.	41 39 48·49	1496·0	69 56 41·66	963·8
Shells.	41 37 52·79	1628·6	69 57 41·45	959·5
Mosquito. 1868–1886.	41 39 26·91	830·1	69 57 32·60	754·3
Cove.	41 36 56·18	1733·1	69 58 35·16	814·1
Crow Lookout.	41 43 06·96	214·7	69 58 25·47	588·8
Sipson Island.	41 44 09·28	286·3	69 57 52·04	1202·6
Namequoit.	41 45 26·54	818·8	69 57 42·48	981·3
Mayo.	41 46 00·16	4·9	69 57 10·44	241·2
Cumming's (D.) flagstaff. 1868.	41 47 12·16	375·2	69 57 04·37	100·9
Mayo's house, south chimney.	41 47 20·68	638·0	69 56 45·81	1057·8
Hopkins.	41 46 02·05	63·2	70 02 51·54	1190·5

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
105 06 46	285 05 44	Bass River	2 253·2	3·352 80
246 38 09	66 39 46	South Dennis.	3 674·1	3·565 15
111 05 16	291 03 25	Hyannis	4 151·6	3·618 21
136 10 50	316 07 23	Shootflying.	10 368·8	4·015 73
29 43 22	209 41 07	Point Gammon 2	9 454·6	3·975 64
51 53 24	231 49 18	Hyannis.	10 879·4	4·036 60
63 47 16	243 43 38	Point Gammon 2	8 476·6	3·928 22
146 51 58	326 50 34	Mannersen.	5 331·5	3·726 85
63 37 12	243 29 50	Point Gammon	17 143·5	4·234 10
72 21 27	252 12 15	Hyannis.	20 176·7	4·304 85
181 58 17	1 58 24	Brewster Station	7 416·7	3·870 21
261 34 43	81 38 34	Chatham.	8 123·3	3·909 73
49 22 12	229 20 07	Chatham	5 740·9	3·758 98
129 04 40	309 01 42	Mill Hill.	7 943·6	3·900 02
287 40 45	107 42 45	Marsh	4 359·7	3·639 46
2 16 19	182 16 13	Chatham.	5 068·9	3·704 91
348 22 42	168 23 13	Marsh	5 293·1	3·723 71
38 39 35	218 38 06	Eldridge.	4 941·6	3·693 87
326 07 39	146 08 33	Marsh	3 337·2	3·523 38
57 46 42	237 45 36	Eldridge.	2 710·9	3·433 12
76 53 23	256 51 32	Chatham	3 971·2	3·598 92
138 39 12	318 37 26	Eldridge.	5 546·5	3·744 02
272 29 20	92 31 55	Marsh	5 396·7	3·732 13
345 22 31	165 23 01	Chatham.	4 108·8	3·613 72
142 09 07	322 07 43	Chatham	4 775·5	3·679 02
191 20 41	11 21 08	Old Harbor.	4 765·3	3·678 09
168 05 38	348 04 54	Chatham	7 501·4	3·875 14
195 43 10	15 44 17	Old Harbor.	8 562·3	3·932 59
114 19 53	294 18 31	Pine	3 119·8	3·494 12
158 26 53	338 26 03	Chatham.	4 770·0	3·678 52
166 46 16	346 45 36	Pine	6 097·3	3·785 14
197 17 27	17 18 09	Mosquito.	4 870·6	3·687 58
250 03 14	70 05 04	Marsh	4 069·2	3·609 51
293 28 57	113 30 33	Old Harbor.	3 638·6	3·560 94
208 04 00	28 04 34	Sampson	2 533·5	3·403 72
279 56 24	99 57 52	Marsh.	3 099·0	3·491 22
217 54 09	37 55 00	Pochet	2 871·5	3·458 11
315 52 00	135 53 22	Marsh.	4 066·4	3·609 21
38 05 30	218 04 31	Eldridge	3 343·0	3·524 13
104 26 04	284 24 06	Mill Hill.	4 209·8	3·624 26
318 19 53	138 20 19	Pochet	1 329·4	3·123 66
358 28 31	178 28 34	Sampson.	3 407·9	3·532 49
340 04 16	160 04 29	Pochet	1 335·8	3·125 73
5 15 46	185 15 36	Sampson.	3 684·9	3·566 43
224 44 29	44 45 49	Orleans 2	3 933·3	3·594 76
255 23 01	75 24 51	Mill Hill.	3 928·0	3·594 17

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Sears.	41 44 38·30	1181·6	70 07 57·09	1319·1
Morris Island 2. 1880.	41 39 29·24	902·1	69 57 34·16	790·4
Chatham church spire. 1846.	41 41 02·79	86·1	69 57 39·96	924·2
Chatham Congregational church belfry. 1846.	41 41 15·97	492·7	69 58 18·40	425·5
Chatham flagstaff. 1868.	41 40 43·77	1350·3	69 57 23·51	543·8
Chatham, south light-house. 1846.	41 40 17·00	524·5	69 56 58·48	1352·8
Chatham, south light-house. 1880.	41 40 17·30	533·8	69 57 01·50	34·7
Stage Harbor light-house 1880.	41 39 31·54	973·0	69 59 03·16	73·1
Hyannis Baptist church spire. 1846–1887.	41 39 05·77	178·0	70 17 15·23	352·4
Hyannis Universalist church spire. 1875–1887.	41 39 14·37	443·3	70 16 56·08	1297·7
Hyannis light-house. 1875.	41 38 10·79	332·9	70 17 20·20	467·5
Bishop and Clerks.	41 34 27·44	846·5	70 15 01·96	45·4
Bishop and Clerks light-house. 1875–1887.	41 34 27·52	849·0	70 15 02·03	47·0
Breakwater, east end spindle. 1875.	41 37 27·31	842·5	70 17 34·06	788·5
Great Rock spindle. 1875.	41 37 03·52	108·6	70 17 10·38	240·3
Marvin's cottage cupola.	41 38 04·00	123·4	70 18 12·06	279·1
Marston mill.	41 38 49·68	1532·7	70 24 56·98	1318·6
Osterville.	41 37 52·16	1609·2	70 22 57·14	1322·6
Osterville church spire. 1846–1887.	41 37 42·08	1298·2	70 23 09·29	215·1
Osterville Point.	41 37 02·13	65·7	70 22 10·70	247·7
Collier Ledge.	41 35 48·36	1492·0	70 21 06·69	154·9
Centerville church spire. 1846–1887.	41 38 44·94	1386·4	70 20 49·27	1140·2
Indian Hill.	41 52 58·13	1793·4	70 32 01·75	40·4

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
236 29 35	56 31 42	Rock Point	5 292·0	3·723 62
251 44 27	71 49 40	Mill Hill.	11 434·1	4·058 20
113 22 50	293 21 29	Pine	3 057·5	3·485 37
158 32 11	338 31 22	Chatham.	4 689·8	3·671 15
133 04 16	313 03 30	Chatham	2 165·1	3·335 49
73 38 48	253 36 07	West Chatham.	5 840·2	3·766 43
147 06 53	327 06 33	Chatham	1 276·1	3·105 89
66 28 52	246 26 36	West Chatham.	5 141·8	3·711 11
136 27 49	316 26 53	Chatham	2 848·9	3·454 68
212 42 03	32 42 58	Old Harbor.	3 526·1	3·547 29
29 22 06	209 21 42	Morris Island	1 682·2	3·225 88
138 41 16	318 40 03	Chatham.	3 849·1	3·585 36
85 40 52	265 39 09	Pine	3 572·2	3·552 94
139 23 13	319 22 02	Chatham.	3 796·6	3·579 39
184 33 07	4 33 17	Chatham	4 306·9	3·634 16
271 57 59	91 58 58	Morris Island 2.	2 060·3	3·313 92
36 30 27	216 29 39	Hyannis	2 779·8	3·444 01
127 05 58	307 03 35	Shootflying.	6 220·3	3·793 81
39 59 36	219 58 36	Hyannis	3 262·7	3·513 58
336 00 25	156 01 16	Point Gammon 2.	4 370·0	3·640 48
311 00 21	131 01 28	Point Gammon 2	3 094·9	3·490 64
70 43 07	250 42 23	Hyannis.	1 629·9	3·212 16
146 54 23	326 50 32	Shootflying	14 731·2	4·168 24
194 35 06	14 36 43	German Hill.	13 406·6	4·127 32
143 17 05	323 14 49	Hyannis	7 923·6	3·898 92
196 17 28	16 19 18	Mannersen.	13 617·0	4·134 08
123 24 36	303 24 01	Hyannis	1 458·8	3·164 01
284 32 29	104 33 45	Point Gammon 2.	2 744·2	3·438 42
146 00 32	325 58 06	Shootflying	9 074·4	3·957 82
268 47 12	88 48 12	Point Gammon 2.	2 108·8	3·324 03
232 05 49	52 09 45	Mannersen	10 410·6	4·017 48
297 14 29	117 16 10	Point Gammon 2.	3 977·4	3·599 60
190 12 51	10 13 20	Hamblin Hill	5 650·6	3·752 09
233 23 02	53 25 46	Shootflying.	7 124·1	3·852 73
278 08 03	98 12 53	Point Gammon	10 239·3	4·010 27
166 26 30	346 25 39	Hamblin Hill.	7 546·2	3·877 73
266 56 07	86 59 15	Hyannis	6 551·0	3·816 31
207 00 15	27 01 48	Shootflying.	7 108·2	3·851 76
253 02 21	73 04 50	Hyannis	5 421·5	3·734 12
193 54 09	13 55 03	Shootflying.	7 793·3	3·891 72
182 16 53	2 17 04	Shootflying	9 848·5	3·993 37
252 39 14	72 42 51	Point Gammon.	7 940·2	3·899 83
295 44 23	115 45 58	Hyannis	3 664·3	3·563 99
179 51 28	359 51 28	Shootflying.	4 392·9	3·642 75
3 44 24	183 44 08	Peaked Cliff	8 247·3	3·916 31
136 11 00	316 08 42	Manomet.	6 867·9	3·836 83

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
East Plymouth.	41 52 58·09	1792·2	70 32 01·74	40·1
Plymouth Cliff.	41 49 40·62	1253·2	70 32 37·24	859·4
Sandwich Congregational church spire. 1848–1887.	41 45 28·35	874·6	70 30 00·44	10·2
Spring Hill Academy.	41 44 58·86	1815·9	70 27 36·58	845·2
East Scargo. (Borden.)	41 44 00·87	26·8	70 10 16·39	378·8
German Hill. (Borden) 1835.	41 41 27·90	860·7	70 12 36·07	834·1
Barnstable court-house. (Borden) 1835.	41 42 06·02	185·7	70 18 17·64	407·8
Beach.	41 39 41·35	1275·7	69 56 52·14	1206·3
Cut.	41 38 04·12	127·1	69 57 42·42	981·9
Point.	41 36 28·57	881·4	69 59 20·10	465·4
Wreck.	41 36 23·01	709·9	69 58 23·99	555·5
Monomoy Life-Saving Station, northeast chimney.	41 35 27·52	849·0	69 59 12·34	285·8
Loveland's flagstaff. 1886.	41 41 34·54	1065·6	69 57 16·71	386·4
Orleans Life-Saving Station, northeast chimney.	41 45 36·99	1141·2	69 55 52·94	1222·9
Bay peg.	41 43 44·69	1378·7	69 59 32·70	755·8
Bound Brook Island.	41 57 18·88	582·5	70 04 37·02	852·6
Rich.	41 57 25·82	796·6	70 04 25·88	596·0
Truro, corner 1.	41 57 28·89	891·3	70 04 37·03	852·8
Gull Pond.	41 57 24·52	756·5	70 00 00·68	15·7
Humane Society.	41 57 53·26	1643·2	70 00 07·62	175·5
Truro, corner 8, base 1.	41 58 01·43	44·1	69 59 58·88	1355·8
Truro, corner 8, base 2.	41 57 57·87	1785·4	70 00 00·17	3·9
Truro, corner 8.	41 58 00·00	00·0	69 59 56·69	1305·3
Mount Gilboa.	42 03 54·26	1674·1	70 09 30·81	708·3

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
298 19 57	118 34 05	Scargo	33 391·9	4·523 64
324 39 06	144 46 34	Shootflying.	26 864·0	4·429 17
287 53 18	108 07 49	Scargo	31 746·8	4·501 70
314 01 42	134 09 33	Shootflying.	22 758·0	4·357 14
149 24 56	329 23 20	Peaked Cliff	6 560·2	3·816 92
286 07 01	106 10 34	Scorton Neck.	7 678·6	3·885 28
100 17 06	280 14 57	Mount Schaum	4 540·9	3·657 14
134 34 11	314 30 59	Peaked Cliff.	9 347·6	3·970 70
90 06 05	269 53 29	Bourne Hill	26 235·9	4·418 90
121 49 17	301 32 29	Manomet.	40 993·4	4·612 71
101 40 35	281 29 34	Bourne Hill	23 494·7	4·370 97
129 46 43	309 31 28	Manomet.	41 134·9	4·614 21
278 26 16	98 30 03	German Hill (Borden)	7 985·4	3·902 29
136 36 20	316 24 53	Manomet.	34 559·6	4·538 57
64 32 56	244 32 29	Mosquito	1 036·6	3·015 63
169 29 56	349 29 50	Chatham, north light-house.	1 158·7	3·063 96
145 44 12	325 42 57	Pine	4 645·6	3·667 04
192 57 12	12 57 39	Chatham, north light-house.	4 247·1	3·628 09
176 59 58	356 59 48	Pine	6 796·1	3·832 26
217 28 49	37 29 54	Cut.	3 715·6	3·570 03
97 31 30	277 30 53	Point	1 310·5	3·117 43
197 08 30	17 08 58	Cut.	3 264·8	3·513 86
174 33 02	354 32 57	Point	1 892·2	3·276 96
213 10 44	33 11 16	Wreck.	2 045·7	3·310 84
103 14 58	283 13 57	Chatham	2 177·7	3·338 00
228 16 11	48 17 06	Refuge.	2 560·9	3·408 40
0 15 00	180 14 59	Refuge	5 775·8	3·761 61
30 09 46	210 07 49	Chatham.	8 073·4	3·907 06
266 43 11	86 45 45	Wash	5 345·6	3·728 00
343 45 11	163 45 40	Chatham.	3 662·9	3·563 83
196 05 40	16 06 01	South Truro Methodist church	2 666·5	3·425 94
325 20 55	145 21 22	Holbrook.	1 665·4	3·221 53
336 27 18	156 27 38	Holbrook	1 728·2	3·237 60
50 08 46	230 08 39	Bound Brook Island.	334·2	2·524 02
290 13 28	110 13 35	Rich	273·6	2·437 15
359 57 53	179 57 53	Bound Brook Island	308·8	2·489 64
50 13 11	230 12 02	North Wellfleet Congregational church, 1887	3 088·6	3·489 76
113 01 38	292 58 55	South Truro Methodist church.	6 109·8	3·786 03
349 47 30	169 47 35	Gull Pond	900·8	2·954 62
37 42 59	217 41 55	North Wellfleet Congregational church, 1887.	3 618·9	3·558 58
38 36 55	218 36 49	Humane Society	322·4	2·508 41
50 17 31	230 17 26	Humane Society	222·9	2·348 03
195 11 55	15 11 56	Truro corner 8, base 1.	113·5	2·055 02
50 34 53	230 34 51	Truro corner 8, base 2	103·6	2·015 40
131 01 21	311 01 20	Truro corner 8, base 1.	66·6	1·823 79
256 35 48	76 36 05	Mount Ararat	583·8	2·766 28
31 07 55	211 06 29	Wood End light-house.	5 681·7	3·754 48

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Truro, corner 7.	42 04 33·36	1029·3	70 09 14·49	333·1
Dyke.	42 03 49·71	1533·7	70 08 52·20	1200·1
Truro, corner 2.	42 03 49·17	1517·1	70 08 52·39	1204·5
Truro, corner 3.	42 03 50·17	1547·9	70 08 52·36	1203·8
Truro, corner 4.	42 03 52·67	1625·1	70 08 50·86	1169·4
Truro, corner 5.	42 03 52·91	1632·5	70 08 50·74	1166·6
Truro, corner 6.	42 04 01·57	48·4	70 08 53·67	1233·9
Truro town hall.	41 59 54·24	1673·4	70 03 24·53	564·6
Rink chimney.	41 51 53·78	1659·2	69 59 01·62	37·4
Lincoln.	41 52 48·04	1482·2	69 59 34·05	785·1
Commons.	41 52 48·46	1495·1	69 58 51·48	1187·0
Eastham, corner 4.	41 52 52·05	1605·9	70 00 15·99	368·7
Eastham, corner 5, base 1.	41 52 43·04	1327·9	69 58 48·92	1128·0
Eastham, corner 5, base 2.	41 52 44·38	1369·2	69 58 43·33	999·1
Eastham, corner 5.	41 52 38·36	1183·5	69 58 48·58	1120·2
Eastham, corner 6.	41 52 47·74	1472·9	69 57 29·80	687·1
Freeman.	41 48 22·11	682·1	69 57 35·70	824·1
Hopkins' flagstaff. 1887.	41 47 24·16	745·4	69 56 35·44	818·3
Penniman's flagstaff. 1887.	41 49 07·24	223·4	69 57 58·80	1357·1
Neck.	41 47 38·34	1182·8	70 00 04·50	103·9
Snow's Block flagstaff. 1887.	41 47 18·56	572·6	69 59 36·04	832·2
Young.	41 47 29·36	905·8	69 59 21·70	501·1
Boat Meadow.	41 48 09·17	282·9	69 59 13·96	322·3
Rock Harbor.	41 47 58·24	1796·8	69 59 39·57	913·6
Town Cove.	41 47 44·27	1365·8	69 58 57·19	1320·4

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
349 48 12	169 48 18	Mount Ararat	1 088·3	3·036 75
17 16 44	197 16 33	Mount Gilboa.	1 263·4	3·101 55
130 45 48	310 45 39	Mount Ararat	422·0	2·625 36
39 00 34	218 58 43	Wood End light-house.	6 077·9	3·783 75
194 47 24	14 47 24	Dyke	17·35	1·239 30
345 02 09	165 02 09	Dyke	14·64	1·165 54
18 35 35	198 35 34	Dyke	96·5	1·984 34
117 43 21	297 43 11	Mount Ararat.	395·9	2·597 54
18 45 43	198 45 42	Dyke	104·4	2·018 67
116 34 43	296 34 33	Mount Ararat.	395·0	2·596 57
354 44 28	174 44 29	Dyke	367·5	2·565 25
72 27 41	252 27 33	Mount Ararat.	299·9	2·477 01
6 41 18	186 40 57	Holbrook	6 205·8	3·792 80
22 37 08	202 36 41	South Truro Methodist church.	2 417·4	3·383 35
100 25 28	280 24 37	Sand Peak	1 800·7	3·255 43
155 35 31	335 33 43	North Wellfleet Congregational church, 1887.	9 036·5	3·956 00
268 47 46	88 49 09	Wyer	2 891·6	3·461 14
37 10 52	217 10 22	Sand Peak.	1 692·6	3·228 55
55 49 17	235 48 19	Sand Peak	2 423·0	3·384 35
89 14 56	269 14 28	Lincoln.	981·7	2·991 96
277 17 24	97 17 52	Lincoln	974·9	2·988 97
2 09 54	182 09 52	Sand Peak.	1 473·4	3·168 33
160 34 15	340 34 13	Commons	177·2	2·248 46
123 46 40	303 46 35	Commons	226·1	2·354 38
72 13 10	252 13 06	Eastham, corner 5, base 1.	135·50	2·131 94
176 54 58	356 54 58	Eastham, corner 5, base 1	144·7	2·160 43
213 07 05	33 07 09	Eastham, corner 5, base 2.	221·9	2·346 17
200 30 12	20 30 13	Wyer	74·12	1·869 94
71 00 31	250 58 39	Sand Peak.	4 112·3	3·614 09
46 22 17	226 20 36	Mill Hill	4 826·6	3·683 64
7 55 26	187 54 38	Chatham.	12 191·9	4·086 07
72 29 11	252 26 50	Mill Hill	5 122·7	3·709 50
142 06 58	322 06 18	Freeman.	2 265·3	3·355 13
339 03 01	159 03 16	Freeman	1 490·9	3·173 45
32 04 46	212 03 21	Mill Hill.	5 573·9	3·746 16
1 38 50	181 38 48	Mill Hill	1 981·4	3·296 97
80 43 25	260 42 54	Orleans 2.	1 102·5	3·042 39
27 31 40	207 31 19	Mill Hill	1 545·4	3·189 04
132 53 19	312 53 00	Neck.	896·8	2·952 67
302 26 31	122 27 05	Orleans Orthodox church	1 409·0	3·148 90
31 32 32	211 32 02	Mill Hill.	1 998·7	3·300 75
333 00 25	153 00 54	Orleans Orthodox church	2 226·5	3·347 63
8 16 13	188 16 08	Young.	1 241·0	3·093 76
13 42 30	193 42 12	Mill Hill	2 670·6	3·426 61
43 09 31	223 09 14	Neck.	841·6	2·925 13
332 51 22	152 51 40	Orleans Orthodox church	1 366·2	3·135 33
50 53 35	230 53 19	Young.	729·0	2·862 75

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Eastham, corner 1.	41 47 44·26	1365·5	69 58 57·12	1318·8
Eastham, corner 2.	41 48 09·01	278·0	69 59 16·56	382·3
Eastham, corner 3.	41 47 55·29	1705·8	69 59 37·37	862·8
Eastham, corner 7.	41 48 37·24	1148·9	69 56 17·45	402·8
Eastham, corner 8.	41 48 46·36	1430·3	69 57 13·64	314·8
Lone pole.	41 46 52·13	1608·3	70 01 59·30	1369·4
Edwards.	41 46 22·39	690·8	70 00 32·31	746·3
Baker Pond.	41 45 59·15	1824·9	70 00 37·03	855·4
Scrub.	41 45 51·60	1591·9	70 00 03·16	73·0
Brewster, corner 3.	41 46 37·84	1167·4	70 00 35·18	812·5
Brewster, corner 4.	41 46 07·96	245·6	70 00 21·20	489·7
Brewster, corner 5.	41 45 52·88	1631·4	70 00 21·24	490·6
Brewster, corner 7.	41 44 36·53	1127·0	69 59 48·29	1115·9
Brewster, corner 8.	41 44 36·45	1124·5	69 59 47·38	1094·8
Brewster, corner 10.	41 43 44·41	1370·1	69 59 31·63	731·0
Chatham, corner 7.	41 43 29·13	898·7	69 57 04·23	97·8
Black.	41 43 43·75	1349·8	70 02 36·30	839·0
Black, base 1.	41 43 26·10	805·2	70 02 28·94	668·9
Black, base 2.	41 43 24·98	770·5	70 02 30·99	716·3
King Hill.	41 43 35·30	1089·1	70 01 49·56	1145·5
South Harwich, flagstaff. 1887.	41 40 42·89	1323·2	70 02 24·46	565·8
Harwich Port Congregational church spire. 1887.	41 40 03·43	105·8	70 04 36·57	846·0
Chatham, corner 4.	41 41 59·60	1838·8	70 01 40·12	927·7
Crowell Hill.	41 42 03·46	106·7	70 00 48·76	1127·4
Crowell Hill base.	41 42 00·43	13·3	70 00 46·89	1084·2

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
99 59 35	279 59 35	Town Cove	1·65	0·217 48
50 59 27	230 59 11	Young.	730·1	2·863 40
265 22 02	85 22 04	Boat Meadow	60·13	1·779 09
21 41 30	201 40 57	Mill Hill.	3 149·8	3·498 28
50 08 43	230 08 25	Neck	816·1	2·911 74
150 49 36	330 49 35	Rock Harbor.	104·2	2·017 77
10 26 27	190 26 15	Hopkins' flagstaff	2 292·7	3·360 34
75 30 51	255 29 59	Freeman.	1 865·7	3·270 85
340 49 11	160 49 36	Hopkins' flagstaff	2 684·9	3·428 93
34 14 15	214 14 00	Freeman.	905·0	2·956 63
241 43 06	61 44 22	Neck	3 010·0	3·478 57
282 03 44	102 04 59	Mill Hill.	2 653·1	3·423 76
168 21 40	348 21 27	Orleans 2	2 211·1	3·344 60
238 13 12	58 13 29	Mill Hill.	688·4	2·837 86
173 19 42	353 19 32	Orleans 2	2 902·4	3·462 75
212 44 19	32 44 39	Mill Hill.	1 283·5	3·108 41
106 34 47	286 34 24	Baker Pond	816·1	2·911 73
176 10 09	356 10 06	Mill Hill.	1 315·4	3·119 05
279 55 29	99 55 48	Mill Hill	661·5	2·820 51
352 04 29	172 04 31	Edwards.	481·2	2·682 31
320 28 34	140 28 46	Scrub	654·3	2·815 80
53 22 17	233 22 06	Baker Pond.	455·7	2·658 71
194 30 38	14 30 48	Mill Hill	1 315·0	3·118 91
275 23 53	95 24 05	Scrub.	419·3	2·622 51
331 29 37	151 29 38	South Orleans P. L. A. hall, chimney	79·8	1·901 86
345 48 58	165 48 58	South Orleans P. L. A. hall, chimney	69·6	1·842 52
109 14 42	289 14 41	Bay peg	26·2	1·418 30
344 05 18	164 05 47	Chatham.	3 647·8	3·562 03
277 28 07	97 29 01	Chatham, corner 8	1 902·8	3·279 39
48 48 08	228 47 51	Strong.	779·9	2·892 02
303 28 44	123 31 16	Chatham	6 318·9	3·800 64
30 12 06	210 10 47	Harwich Exchange.	5 431·4	3·734 91
162 38 49	342 38 44	Black	570·6	2·756 32
168 01 25	348 01 21	Black	591·9	2·772 22
234 02 44	54 02 45	Black, base 1.	58·52	1·767 30
307 35 43	127 37 43	Chatham	5 287·4	3·723 24
40 42 17	220 40 27	Harwich Exchange.	5 847·5	3·766 97
177 11 26	357 11 18	Black	5 586·5	3·747 14
247 15 44	67 18 08	Chatham.	5 417·8	3·733 82
181 20 10	1 20 11	Harwich Exchange	2 103·4	3·322 92
247 37 35	67 41 27	Chatham.	8 707·0	3·939 87
23 25 55	203 25 25	South Harwich, flagstaff	2 579·2	3·411 49
273 56 09	93 58 03	Chatham.	3 980·7	3·599 96
278 02 04	98 03 24	Chatham	2 811·5	3·448 94
72 58 26	252 55 56	Harwich Exchange.	5 459·1	3·737 12
155 07 51	335 07 50	Crowell Hill	103·05	2·013 05

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Chatham, corner 5.	41 42 00·20	6·2	70 00 49·58	1146·4
Chatham, corner 6.	41 42 04·89	150·9	70 00 41·82	967·0
Nickerson.	41 40 29·93	923·4	70 02 13·72	317·4
Clearing.	41 40 15·55	479·7	70 02 08·56	198·0
Fish house flagstaff. 1887.	41 39 57·38	1770·3	70 02 44·64	1032·7
Chatham, corner 2.	41 40 06·32	195·0	70 02 17·14	396·5
Long Pond.	41 43 31·03	957·3	70 04 27·67	639·6
Chatham, corner 3, peg.	41 40 40·65	1254·1	70 02 02·38	55·0
Chatham, corner 3.	41 40 44·58	1375·3	70 01 56·41	1304·8
Chatham, corner 1.	41 40 01·99	61·4	70 02 16·34	378·0
Hinckley.	41 43 00·95	29·3	70 05 45·50	1051·8
Seymour.	41 43 31·26	964·4	70 05 59·48	1374·8
Pleasant Lake.	41 42 52·21	1610·8	70 05 14·91	344·7
Atkins, peg.	41 42 57·53	1774·9	70 05 48·36	1118·0
Railroad, peg.	41 43 29·98	924·9	70 05 09·62	222·4
Cahoon.	41 43 09·73	300·2	70 05 29·93	691·8
Bassett's chimney.	41 43 45·05	1389·9	70 05 39·08	903·2
Brewster, corner 15.	41 43 11·15	344·0	70 05 44·90	1037·9
Brewster, corner 14.	41 43 33·92	1046·5	70 05 07·74	178·9
Brewster, corner 16.	41 42 57·83	1784·1	70 05 48·76	1127·2
Brewster, corner 1.	41 42 22·39	690·8	70 08 03·68	85·1
Dennis Port school, globe on belfry.	41 39 57·80	1783·2	70 07 37·75	873·3
West Dennis Methodist church spire. 1887.	41 39 52·46	1618·5	70 10 16·09	372·2
South Yarmouth Methodist church spire. 1887.	41 39 59·05	1821·8	70 11 10·55	244·0
Kelly.	41 39 30·59	943·7	70 07 04·40	101·8

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
190 39 26	10 39 27	Crowell Hill	102·5	2·010 74
263 22 09	83 22 10	Crowell Hill base.	62·7	1·797 37
40 23 09	220 23 06	Crowell Hill base	180·8	2·257 28
74 35 18	254 35 13	Crowell Hill.	166·5	2·221 39
111 33 32	291 31 58	Harwich Exchange	3 499·7	3·544 03
148 08 37	328 08 30	South Harwich, flagstaff.	470·8	2·672 81
117 08 30	297 06 53	Harwich Exchange	3 791·8	3·578 84
156 26 46	336 26 35	South Harwich, flagstaff.	920·3	2·963 91
215 27 51	35 28 12	Nickerson	1 233·0	3·090 96
236 06 10	56 06 34	Clearing.	1 005·3	3·002 29
66 34 54	246 34 36	Fish house flagstaff	693·3	2·840 95
186 12 24	6 12 26	Nickerson.	732·8	2·865 00
2 05 17	182 05 12	Harwich Exchange	4 305·0	3·633 97
100 12 31	280 08 17	Scargo Observatory.	8 972·2	3·952 90
38 24 18	218 24 10	Nickerson	422·2	2·625 50
97 41 48	277 41 33	South Harwich, flagstaff.	515·4	2·712 12
48 45 26	228 45 22	Chatham, corner 3, peg	183·795	2·264 33
172 05 40	352 05 39	Chatham, corner 2	134·95	2·130 17
242 42 42	62 43 34	Long Pond	2 024·3	3·306 28
334 01 57	154 02 44	Harwich Exchange.	3 752·6	3·574 34
270 11 09	90 12 10	Long Pond	2 122·1	3·326 77
340 56 15	160 56 24	Hinckley.	989·3	2·995 33
343 13 38	163 14 05	Harwich Exchange	3 242·3	3·510 85
110 52 21	290 52 01	Hinckley.	756·9	2·879 01
212 04 53	32 04 55	Hinckley	124·5	2·095 09
281 58 53	101 59 15	Pleasant Lake.	790·6	2·897 93
42 48 32	222 48 08	Hinckley	1 220·6	3·086 56
91 58 21	271 57 48	Seymour.	1 153·1	3·061 86
134 12 13	314 11 53	Seymour	952·7	2·978 97
216 55 23	36 55 36	Railroad, peg.	781·4	2·892 86
304 19 28	124 19 48	Railroad, peg	824·5	2·916 20
349 00 44	169 00 50	Cahoon.	1 109·9	3·045 30
187 20 01	7 20 05	Bassett's chimney	1 054·6	3·023 09
234 31 55	54 32 18	Railroad, peg.	1 001·4	3·000 60
19 39 12	199 39 11	Railroad, peg	128·96	2·110 46
315 15 01	135 15 01	Atkins, peg	13·05	1·115 61
198 29 08	18 29 46	West Brewster	4 216·8	3·624 98
294 16 41	114 19 00	Harwich Exchange.	5 308·6	3·724 98
151 28 34	331 26 26	Scargo Observatory	9 293·1	3·968 16
241 44 58	61 47 00	Harwich Exchange.	4 812·6	3·682 38
207 00 32	27 02 38	West Brewster	9 682·1	3·985 97
257 01 18	77 08 55	Chatham.	16 318·9	4·212 69
213 52 35	33 55 18	West Brewster	10 146·1	4·006 30
258 35 06	78 43 20	Chatham.	17 507·7	4·243 23
137 25 05	317 24 43	Dennis Port school	1 140·1	3·056 96
228 03 09	48 04 49	Harwich Exchange.	4 662·8	3·668 65

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Brewster, corner 12, peg.	41 43 35·26	1087·8	70 02 19·16	442·9
Brewster, corner 12.	41 43 36·45	1124·5	70 02 20·21	467·1
Brewster, corner 13, peg.	41 43 30·87	952·4	70 02 34·26	791·9
Brewster, corner 13.	41 43 30·34	936·0	70 02 34·50	797·4
Dennis, corner 1, base 1.	41 39 36·01	1111·0	70 07 01·71	39·6
Dennis, corner 1, base 2.	41 39 36·89	1138·1	70 07 04·25	98·3
Dennis, corner 1.	41 39 38·20	1178·5	70 07 11·16	258·2
East Dennis Methodist church spire. 1887.	41 44 53·68	1656·1	70 08 51·86	1198·2
East Dennis, cupola.	41 44 53·61	1654·0	70 09 04·90	113·2
Old house.	41 44 30·31	935·1	70 08 37·18	859·1
Quivett Creek.	41 44 34·40	1061·3	70 08 51·86	1198·3
Brewster, corner 2, peg.	41 44 37·76	1165·0	70 08 45·30	1046·7
Brewster, corner 2.	41 44 37·56	1158·8	70 08 45·08	1041·7
Baxter's wharf.	41 38 55·50	1712·2	70 16 24·40	564·6
Barnstable, corner 10.	41 38 53·20	1641·3	70 16 28·71	664·4
German Hill 2. 1887.	41 41 19·04	587·4	70 12 56·61	1309·2
German Hill 3. 1887.	41 41 28·04	865·1	70 12 35·60	823·3
Meridian, north stone.	41 42 30·99	956·1	70 17 41·89	968·5
Meridian, middle stone.	41 42 28·71	885·8	70 17 41·92	969·2
Meridian, south stone.	41 42 26·57	819·7	70 17 41·95	969·9
Hallett Pond.	41 42 08·78	270·9	70 15 38·77	896·4
Black Ball Hill.	41 43 48·04	1482·1	70 11 27·14	627·2
Nobscussett flagstaff. 1887.	41 44 38·42	1185·3	70 12 27·34	631·7
Nobscussett, water tank.	41 44 41·68	1285·9	70 12 26·91	621·8
Garden River.	41 43 24·79	764·8	70 11 59·19	1368·1
Dennis, corner 6.	41 43 17·92	552·9	70 11 51·14	1182·1

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
123 28 32	303 28 21	Black	475·0	2·676 65
38 38 45	218 38 39	Black, base 1.	361·9	2·558 57
326 29 36	146 29 37	Brewster, corner 12, peg	44·135	1·644 78
121 12 00	301 11 49	Black.	434·7	2·638 16
173 14 58	353 14 57	Black	400·3	2·602 35
248 46 56	68 47 06	Brewster, corner 12, peg.	374·5	2·573 46
198 41 33	18 41 33	Brewster, corner 13, peg	17·235	1·236 41
174 16 10	354 16 09	Black.	415·9	2·618 99
20 23 57	200 23 55	Kelly	178·6	2·251 85
1 00 20	181 00 20	Kelly	194·3	2·288 52
294 34 17	114 34 19	Dennis, corner 1, base 1.	64·695	1·810 87
284 10 20	104 10 25	Dennis, corner 1, base 2	164·855	2·217 10
326 18 38	146 18 42	Kelly.	282·0	2·450 28
70 30 41	250 29 22	Scargo Observatory	2 890·9	3·461 03
285 15 04	105 16 14	West Brewster.	2 539·4	3·404 73
68 20 29	248 19 19	Scargo Observatory	2 608·1	3·416 33
283 36 21	103 37 40	West Brewster.	2 830·7	3·451 90
85 27 41	265 26 13	Scargo Observatory	3 074·0	3·487 71
154 49 01	334 48 51	East Dennis Methodist church.	796·8	2·901 36
180 00 04	0 00 04	East Dennis Methodist church	595·0	2·774 50
290 23 49	110 23 59	Old house.	361·8	2·558 48
320 44 15	140 44 20	Old house	296·6	2·472 13
55 38 31	235 38 27	Quivett Creek.	183·4	2·263 42
140 44 16	320 44 16	Brewster, corner 2, peg	8·0	0·903 09
55 53 12	235 51 51	Hyannis	3 418·6	3·533 85
128 27 04	308 26 43	Hyannis Universalist church.	936·2	2·971 36
234 30 27	54 30 30	Baxter's wharf	122·475	2·088 05
207 23 17	27 24 41	Scargo Observatory	6 372·1	3·804 28
267 04 18	87 13 42	Chatham.	19 639·0	4·293 13
86 50 45	266 45 16	Shootflying	11 445·9	4·058 65
120 31 42	300 28 51	Sandy Neck light-house.	6 911·0	3·839 54
215 44 34	35 45 06	Sandy Neck light-house	1 929·7	3·285 49
273 14 32	93 16 45	Yarmouth Congregational church.	4 635·5	3·666 10
180 32 13	0 32 13	Meridian, north stone	70·42	1·847 70
180 32 13	0 32 13	Meridian, north stone	136·37	2·134 72
256 41 18	76 42 09	Yarmouth Congregational church	1 830·9	3·262 67
142 38 35	322 37 46	Sandy Neck light-house.	2 832·4	3·452 16
83 53 14	263 49 37	Sandy Neck light-house	7 578·1	3·879 56
56 48 59	236 47 03	Yarmouth Congregational church.	4 822·8	3·683 30
318 09 32	138 10 12	Black Ball Hill	2 085·9	3·319 30
32 13 38	212 12 22	Yarmouth Congregational church.	4 958·6	3·695 36
320 08 11	140 08 51	Black Ball Hill	2 155·6	3·333 57
31 42 50	211 41 34	Yarmouth Congregational church.	5 049·2	3·703 22
164 53 16	344 52 58	Nobscussett water tank	2 457·2	3·390 44
225 55 06	45 55 27	Black Ball Hill.	1 031·3	3·013 37
138 43 36	318 43 31	Garden River	281·9	2·450 14
210 50 24	30 50 40	Black Ball Hill.	1 082·4	3·034 37

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Dennis, corner 7.	41 43 22·40	691·1	70 11 57·59	1331·2
Poverty, peg.	41 43 17·26	532·5	70 12 08·05	186·1
Dennis, corner 5, peg.	41 43 07·05	217·5	70 11 56·53	1306·7
Dennis, corner 5.	41 43 06·80	209·8	70 11 56·00	1294·5
Pine Knoll.	41 42 34·89	1076·4	70 12 30·04	694·5
Rock.	41 42 03·44	106·1	70 11 25·30	584·9
Dennis, corner 4, flag.	41 42 45·55	1405·3	70 11 10·36	239·5
Dennis, corner 4.	41 42 46·09	1421·9	70 11 10·93	252·7
Dennis, corner 3, flag.	41 42 32·94	1016·2	70 10 51·15	1182·5
Dennis, corner 3, peg.	41 42 32·67	1007·9	70 10 48·69	1125·7
Dennis, corner 3.	41 42 32·64	1007·0	70 10 45·80	1058·9
Rock, base 1.	41 42 11·60	357·9	70 11 32·23	745·2
Rock, base 2.	41 42 11·60	357·9	70 11 32·23	745·2
Dennis, corner 2.	41 42 27·09	835·8	70 10 50·98	1178·6
Barnstable, corner 9.	41 41 32·44	1000·8	70 15 36·46	843·1
Barnstable, corner 8, peg.	41 42 04·38	135·1	70 15 40·79	943·2
Barnstable, corner 8.	41 42 04·50	138·8	70 15 38·91	899·7
Barnstable, corner 2.	41 38 33·14	1022·4	70 27 07·95	184·0
Santuit.	41 38 57·92	1786·9	79 27 01·08	25·0
Folger.	41 39 02·45	75·6	70 26 43·06	996·4
Lovell.	41 38 54·13	1670·0	70 26 47·96	1109·8
Birch.	41 38 59·48	1835·0	70 26 49·58	1147·3
Holmes.	41 39 27·52	849·0	70 27 06·64	153·6
Barnstable, corner 3.	41 39 01·43	44·1	70 26 49·24	1139·4
Harlow.	41 40 01·56	48·1	70 28 22·61	523·1
Harlow, base 1.	41 40 00·48	14·8	70 28 17·81	412·0

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
153 22 50	333 22 49	Garden River	82·5	1·916 68
221 39 16	41 39 36	Black Ball Hill.	1 059·0	3·024 88
170 29 59	350 29 46	Nobscussett water tank	2 640·7	3·421 72
224 52 38	44 53 05	Black Ball Hill.	1 340·2	3·127 13
139 47 16	319 47 08	Poverty, peg	412·6	2·615 56
208 14 14	28 14 34	Black Ball Hill.	1 435·5	3·157 00
122 17 40	302 17 40	Dennis, corner 5, peg	14·40	1·158 36
81 32 55	261 31 41	Yarmouth Congregational church	2 610·2	3·416 68
212 47 30	32 48 12	Black Ball Hill.	2 684·7	3·428 89
98 11 48	278 09 50	Yarmouth Congregational church.	4 120·9	3·614 99
179 14 46	359 14 45	Black Ball Hill.	3 227·5	3·508 86
14 53 24	194 53 14	Rock	1 344·4	3·128 54
80 51 51	260 49 44	Yarmouth Congregational church.	4 481·1	3·651 38
321 42 14	141 42 14	Dennis, corner 4, flag	21·36	1·329 60
40 56 20	220 55 57	Rock	1 205·1	3·081 01
86 12 45	266 10 25	Yarmouth Congregational church.	4 879·0	3·688 33
98 11 35	278 11 33	Dennis, corner 3, flag	57·495	1·759 63
94 18 39	274 18 35	Dennis, corner 3, flag	124·1	2·093 60
90 58 11	270 58 09	Dennis, corner 3, peg.	66·80	1·824 78
235 15 24	55 15 51	Dennis, corner 3, flag	1 155·7	3·062 85
327 32 14	147 32 19	Rock.	298·4	2·474 80
327 30 12	147 30 17	Rock	298·4	2·474 80
235 15 23	55 15 50	Dennis, corner 3, flag.	1 155·9	3·062 91
47 24 33	227 24 10	Rock	1 078·0	3·032 62
63 23 37	243 23 10	Rock, base 1.	1 066·7	3·028 04
228 14 43	48 15 33	Yarmouth Congregational church	2 316·6	3·364 86
177 16 09	357 16 08	Hallett Pond.	1 122·5	3·050 18
199 00 45	19 00 46	Hallett Pond	143·4	2·156 68
181 24 20	1 24 20	Hallett Pond	132·1	2·120 77
85 16 21	265 16 20	Barnstable, corner 8, peg.	43·64	1·639 88
154 30 55	334 30 23	Ames	2 602·4	3·415 38
169 50 28	349 50 27	Crocker.	251·86	2·401 16
21 29 29	201 29 23	Crocker	555·3	2·744 56
141 05 52	321 05 15	Ames.	2 036·2	3·308 82
43 23 26	223 23 08	Crocker	903·3	2·955 84
71 28 51	251 28 39	Santuit.	439·8	2·643 29
111 03 14	291 03 05	Santuit	325·3	2·512 30
203 51 20	23 51 23	Folger.	280·5	2·448 00
238 45 19	58 45 23	Folger	176·7	2·247 14
347 09 53	167 09 54	Lovell.	169·2	2·228 32
324 48 47	144 49 03	Folger	946·8	2·976 25
337 15 02	157 15 14	Lovell.	1 117·0	3·048 05
257 35 08	77 35 12	Folger	146·5	2·165 86
7 32 04	187 32 04	Birch.	60·7	1·782 90
120 44 02	300 40 19	Pine Hill	9 037·3	3·956 04
171 16 29	351 15 56	Bourne Hill.	7 468·6	3·873 24
106 41 10	286 41 07	Harlow	115·9	2·063 94

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Harlow, base 2.	41 40 02·74	84·5	70 28 17·53	405·5
Corn.	41 40 09·31	287·2	70 28 30·20	698·6
Extra flag.	41 40 06·16	190·0	70 28 16·34	378·0
Extra peg.	41 40 19·90	613·9	70 28 23·94	553·9
Long peg.	41 40 24·56	757·7	70 28 23·88	552·4
Canaumet.	41 40 07·40	228·3	70 29 12·49	288·9
Indian flagstaff. 1887.	41 40 47·31	1459·6	70 28 39·84	921·4
Wakeby.	41 40 36·85	1136·9	70 29 42·84	990·9
Mashpee, peg.	41 40 37·25	1149·2	70 28 32·49	751·6
Sandwich, corner 14.	41 40 36·66	1131·0	70 28 32·06	741·5
Quail.	41 40 12·46	384·4	70 29 56·63	1310·0
Sandwich, corner 12.	41 39 57·71	1780·4	70 28 57·60	1332·5
Sandwich, corner 11.	41 39 39·89	1230·7	70 28 51·78	1198·0
House chimney.	41 39 20·35	627·8	70 29 34·53	799·0
Peters Pond.	41 40 59·24	1827·6	70 29 56·38	1304·0
Sandwich, corner 22.	41 40 34·08	1051·4	70 30 42·53	983·8
Barnstable, corner 6.	41 44 03·83	118·2	70 23 21·34	493·2
Sandwich, corner 17.	41 41 06·67	205·8	70 28 42·80	989·8
Sandwich, corner 20.	41 40 37·11	1144·9	70 29 40·41	934·7
Flat Rock. 1887–1889.	41 45 17·10	527·6	70 32 20·31	469·2
Sandwich, corner 5.	41 47 28·84	889·8	70 31 11·84	273·4
Dwarf.	41 46 01·52	46·9	70 31 30·42	702·7
Sandwich, peg.	41 46 03·29	101·5	70 31 09·56	220·8

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
72 45 50	252 45 47	Harlow	123·1	2·090 10
5 21 49	185 21 49	Harlow, base 1.	70·035	1·845 32
304 40 06	124 40 14	Harlow, base 2	356·3	2·551 86
323 43 15	143 43 20	Harlow.	296·7	2·472 28
14 39 46	194 39 45	Harlow, base 2	108·9	2·037 18
45 38 58	225 38 54	Harlow.	202·9	2·307 30
356 53 47	176 53 48	Harlow	566·5	2·753 21
344 21 16	164 21 20	Harlow, base 2.	549·6	2·740 03
342 54 18	162 54 23	Extra flag	593·9	2·773 68
357 37 16	117 37 17	Harlow.	709·9	2·851 21
244 46 35	64 47 07	Long peg	1 242·9	3·094 42
278 50 59	98 51 32	Harlow.	1 167·9	3·067 39
344 13 28	164 13 39	Harlow	1 466·5	3·166 28
31 30 55	211 30 33	Canaumet.	1 444·7	3·159 79
257 30 05	77 30 47	Indian flagstaff	1 492·6	3·173 94
322 18 01	142 18 21	Canaumet.	1 148·5	3·060 15
333 02 15	153 02 21	Long peg	439·2	2·642 62
45 08 08	225 07 42	Canaumet.	1 305·5	3·115 78
151 18 53	331 18 53	Mashpee, peg	20·73	1·316 60
46 00 47	226 00 20	Canaumet.	1 299·9	3·113 91
238 48 23	58 49 14	Indian flagstaff	2 076·3	3·317 28
278 42 24	98 42 53	Canaumet.	1 033·1	3·014 15
130 57 10	310 57 00	Canaumet	456·0	2·658 97
195 01 18	15 01 30	Indian flagstaff.	1 584·6	3·199 93
150 32 59	330 32 45	Canaumet	974·5	2·988 77
166 13 40	346 13 36	Sandwich, corner 12.	566·0	2·752 80
199 21 00	19 21 15	Canaumet	1 538·5	3·187 11
216 32 17	36 32 42	Sandwich, corner 12.	1 434·8	3·156 79
116 51 56	296 49 15	Pine Hill	6 277·7	3·797 80
190 27 40	10 28 10	Bourne Hill.	5 696·7	3·755 62
128 33 06	308 30 56	Pine Hill	5 796·8	3·763 19
198 13 38	18 14 38	Bourne Hill.	6 715·8	3·827 10
327 13 08	147 14 49	Shootflying	6 475·7	3·811 29
89 22 29	269 18 36	Bourne Hill.	8 095·8	3·908 26
109 39 58	289 36 28	Pine Hill	7 753·5	3·889 50
172 55 52	352 55 33	Bourne Hill.	5 414·0	3·733 52
257 19 25	77 20 05	Indian flagstaff	1 435·9	3·157 13
324 49 43	144 50 02	Canaumet.	1 121·5	3·049 78
298 20 36	118 22 42	Bourne Hill	4 954·5	3·695 00
23 55 59	203 54 54	Pine Hill.	5 602·0	3·748 34
336 35 30	156 36 50	Bourne Hill	6 992·9	3·844 66
21 16 03	201 15 17	Flat Rock.	4 361·2	3·639 61
189 03 15	9 03 27	Sandwich, corner 5	2 727·9	3·435 83
319 15 09	139 16 41	Bourne Hill.	4 913·8	3·691 42
83 32 06	263 31 52	Dwarf	484·9	2·685 69
178 51 46	358 51 44	Sandwich, corner 5.	2 639·8	3·421 57

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Sandwich, corner 4.	41 46 17·04	525·7	70 31 16·17	373·5
Bourne, peg.	41 46 07·88	243·1	70 31 28·98	669·4
Sandwich, corner 3.	41 46 06·12	188·8	70 31 25·48	588·6
Cliff. 1887–88.	41 48 34·96	1078·6	70 32 18·38	424·3
Bourne and Plymouth corner.	41 48 35·97	1109·7	70 32 20·17	465·6
Cove school.	41 48 23·09	712·4	69 58 34·40	794·1
Sagamore church spire. 1887.	41 46 50·52	1558·6	70 32 10·55	243·6
Barnstable, corner 1.	41 38 30·53	941·9	70 27 13·05	302·0
Barnstable, corner 4.	41 39 25·09	774·1	70 27 05·60	129·6
Sandwich, corner 9.	41 39 57·69	1779·8	70 28 18·13	419·4
Sandwich, corner 10.	41 39 35·39	1091·8	70 28 33·44	773·7
Sandwich, corner 15.	41 40 47·91	1478·1	70 28 32·87	760·2
Sandwich, corner 16.	41 40 56·92	1756·0	70 28 33·78	781·2
Sandwich, corner 19.	41 40 41·32	1274·7	70 29 50·16	1160·2
Sandwich, corner 13.	41 40 36·50	1126·0	70 28 34·95	808·4
Sandwich, corner 21.	41 40 14·89	459·4	70 29 52·59	1216·6
Sandwich, corner 18.	41 41 00·74	22·8	70 29 51·71	1196·0
Brewster, corner 6.	41 44 52·29	1613·2	69 59 37·42	864·6
Brewster, corner 9.	41 44 08·66	267·2	70 00 09·85	227·6
Brewster, corner 11.	41 43 24·34	750·9	70 01 35·39	818·0
Barnstable, corner 7.	41 42 11·91	367·4	70 15 39·20	906·4
Barnstable, corner 5.	41 39 50·75	1565·7	70 27 33·24	769·0
Herring Pond. 1888–89.	41 47 21·72	670·1	70 33 32·72	755·5
Round Rock.	41 45 10·36	319·6	70 32 18·16	419·5
Jeannette.	41 43 16·42	506·6	70 32 12·00	277·4
Old Board	41 47 23·24	717·0	70 34 17·02	392·9
Parker.	41 47 07·74	238·8	70 34 08·50	196·3
Notice.	41 47 28·40	876·2	70 33 39·80	919·0
Easton, flagstaff. 1888.	41 48 05·46	168·4	70 33 42·17	973·6
Bourne, corner 6.	41 47 08·31	256·4	70 34 08·74	201·8
Bourne, corner 7.	41 47 26·87	829·0	70 33 40·55	936·3
Bourne, corner 12.	41 43 14·25	439·6	70 32 15·43	356·6
Tarkiln Hill.	41 46 14·64	451·7	70 38 45·89	1060·0

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
340 12 20	160 12 24	Sandwich, peg	450·9	2·654 04
34 30 26	214 30 17	Dwarf.	581·1	2·764 22
9 37 09	189 37 08	Dwarf	199·1	2·299 01
38 46 04	218 46 01	Dwarf	182·3	2·260 67
123 49 22	303 49 20	Bourne, peg.	97·325	1·988 22
323 00 21	143 01 05	Sandwich, corner 5	2 553·3	3·407 11
0 25 08	180 25 07	Flat Rock.	6 104·5	3·785 65
306 53 44	126 53 45	Cliff	51·785	1·714 20
0 01 47	180 01 47	Flat Rock.	6 135·5	3·787 85
56 26 22	236 25 22	Neck	2 497·0	3·397 41
63 49 24	243 47 53	Orleans 2.	3 530·1	3·547 79
321 41 28	141 43 27	Bourne Hill	6 670·2	3·824 14
328 28 59	148 29 26	Dwarf.	1 773·1	3·248 73
135 55 18	315 55 09	King Hill	470·9	2·672 92
354 10 53	174 10 53	Hallet Pond	96·98	1·986 67
85 08 52	265 08 37	Ames	536·55	2·729 61
336 28 58	156 29 46	Flat Rock	4 192·9	3·622 51
3 49 09	183 48 52	Pine Hill.	8 985·0	3·953 52
296 26 40	116 28 44	Bourne Hill	4 814·7	3·682 57
25 18 07	205 17 00	Pine Hill.	5 433·8	3·735 10
251 47 31	71 49 31	Bourne Hill	4 388·2	3·642 29
177 40 51	357 40 47	Round Rock.	3 518·3	3·546 33
272 36 37	92 37 07	Herring Pond	1 023·9	3·010 26
325 16 41	145 17 59	Flat Rock.	4 734·0	3·675 23
157 38 23	337 38 17	Old Board	517·0	2·713 51
242 25 19	62 25 43	Herring Pond.	932·0	2·969 43
46 06 19	226 06 00	Parker	919·5	2·963 54
79 29 42	259 29 17	Old Board.	873·9	2·941 45
357 15 47	177 15 49	Notice	1 144·8	3·058 72
18 50 49	198 50 32	Parker.	1 881·8	3·274 58
342 34 46	162 34 46	Parker	18·30	1·262 45
200 14 40	20 14 41	Notice	50·31	1·701 65
254 00 06	74 03 35	Herring Pond	7 522·6	3·876 37
316 03 38	136 06 49	Pine Hill.	9 571·7	3·980 99

CAPE COD BAY AND PENINSULA—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Ryder.	41 45 58·20	1795·5	70 37 19·72	455·5
Dead pine.	41 47 22·23	685·8	70 37 46·40	1071·4
White Island Pond.	41 48 26·24	809·5	70 37 54·08	1248·3
Ryder, peg 1.	41 45 56·44	1741·3	70 37 32·44	749·4
Plymouth, corner 1.	41 45 46·54	1435·8	70 37 59·32	1370·2
Plymouth, corner 2.	41 47 16·45	507·5	70 37 40·12	926·4
Plymouth, corner 3.	41 48 19·69	607·5	70 37 01·68	38·8
Plymouth, corner 4.	41 48 23·00	709·6	70 37 56·56	1305·6

CAPE COD BAY TO BOSTON BAY.

Monk Hill. (C. & G. S. & Bdn.), 1835–1890.	41 57 39·108	1206·7	70 43 23·398	538·8
Carolina Hill. 1848–1889.	42 06 58·520	1805·4	70 43 52·853	1214·2
Prospect Hingham. (C. & G. S. & Bdn.), 1834–1885.	42 11 34·686	1070·2	70 51 27·166	623·3
Sprague. (C. & G. S. & Bdn.), 1834–1848.	42 00 17·896	552·2	70 58 00·109	2·5
Gurnet.	42 00 11·398	351·7	70 36 06·055	139·4
Brant.	42 05 17·319	534·4	70 38 28·702	659·7
White. 1848–49.	42 07 05·938	183·2	70 41 24·595	565·0
Alden. (C. & G. S. & Bdn.), 1835–1889.	41 49 48·328	1491·1	70 57 02·790	64·4
Telegraph Hill. (Borden.)	42 06 53·638	1654·9	70 41 50·218	1153·6
Scituate light-house. (C. & G. S. & Bdn.), 1834–1849.	42 12 17·316	534·3	70 42 58·736	1347·4
Standish monument. 1877–1889.	42 00 50·236	1549·9	70 40 57·642	1326·3
Middleboro town hall, flagstaff on dome. 1885–1890.	41 53 31·128	960·4	70 54 41·409	954·6
Pasture. 1887–1890.	41 49 19·512	602·0	70 53 08·359	192·9
Bridgewater waterworks. 1888–1890.	42 00 17·816	549·7	70 57 59·814	1376·5
South Abington waterworks. 1885–1890.	42 04 49·669	1532·5	70 56 34·247	787·2

CAPE COD BAY AND PENINSULA—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
280 21 34	100 24 53	Flat Rock	7 031·9	3·847 07
323 56 43	143 58 57	Pine Hill.	7 900·2	3·897 64
329 36 28	149 39 00	Pine Hill	10 409·3	4·017 42
33 23 11	213 22 31	Tarkiln Hill.	2 497·3	3·397 47
333 34 20	153 36 57	Pine Hill	12 231·5	4·087 48
16 25 30	196 24 56	Tarkiln Hill.	4 232·6	3·626 61
259 29 35	79 29 43	Ryder	298·7	2·475 20
322 01 15	142 03 37	Pine Hill.	8 033·6	3·904 91
243 47 30	63 47 48	Ryder, peg 1	692·0	2·840 11
140 50 38	320 50 34	Dead pine	229·8	2·361 35
338 30 47	158 32 49	Pine Hill	11 555·3	4·062 78
31 57 40	211 56 31	Tarkiln Hill.	4 546·9	3·657 72
209 46 16	29 46 18	White Island Pond	115·3	2·061 81

CAPE COD BAY TO BOSTON BAY.

288 41 59·6	108 47 17·3	Manomet	11 560·9	4·062 992
130 53 24·9	310 37 40·4	Blue Hill.	42 760·3	4·631 041
357 44 58·0	177 45 17·7	Monk Hill	17 273·1	4·237 371
108 43 33·0	288 28 06·8	Blue Hill.	33 418·6	4·523 988
309 12 12·3	129 17 17·2	Carolina Hill	13 468·5	4·129 319
95 50 00·1	275 39 38·4	Blue Hill.	21 339·0	4·329 175
283 33 45·4	103 43 31·8	Monk Hill	20 768·8	4·317 410
152 03 25·9	331 57 28·8	Blue Hill.	26 068·1	4·416 109
65 01 23·1	244 56 30·6	Monk Hill	11 110·6	4·045 737
139 31 49·6	319 26 36·9	Carolina Hill.	16 522·3	4·218 069
346 52 48·7	166 54 49·5	Manomet	18 329·6	4·263 152
25 38 52·9	205 35 35·6	Monk Hill.	15 679·0	4·195 317
338 49 17·8	158 53 16·4	Manomet	22 734·4	4·356 683
8 53 29·3	188 52 09·7	Monk Hill.	17 700·8	4·247 994
249 58 27·9	70 12 52·2	Manomet	31 749·7	4·501 739
232 21 54·6	52 31 01·8	Monk Hill.	23 827·8	4·377 083
337 04 39·9	157 08 55·7	Manomet	22 603·6	4·354 178
7 08 55·9	187 07 53·5	Monk Hill.	17 242·9	4·236 610
347 18 50·1	167 19 53·3	White	9 847·4	3·993 321
110 58 42·6	290 54 05·4	Scituate.	10 129·5	4·005 586
321 41 00·6	141 44 41·0	Manomet	12 245·5	4·087 978
29 39 08·9	209 37 31·4	Monk Hill.	6 784·6	3·831 524
243 50 38·6	63 58 11·6	Monk Hill	17 395·1	4·240 427
25 23 31·6	205 21 57·3	Alden.	7 608·2	3·881 282
99 21 13·5	279 18 37·2	Alden	5 482·6	3·738 986
164 33 12·7	344 32 10·6	Middleboro town hall.	8 054·2	3.906 024
237 30 42·6	57 40 10·0	Carolina Hill	23 067·0	4·362 992
283 33 37·2	103 43 23·5	Monk Hill.	20 761·6	4·317 261
135 55 10·2	315 48 15·2	Blue Hill	20 390·1	4·309 419
209 24 33·6	29 27 59·6	Prospect Hingham.	14 349·0	4·156 822

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Brockton First Congregational church spire. 1885–1890.	42 05 06·758	208·5	71 01 14·772	339·5
East Bridgewater Unitarian church spire. 1885–1890.	42 01 46·040	1420·5	70 57 11·308	260·1
Bridgewater Unitarian church spire. 1885–1889.	41 59 18·248	563·0	70 58 27·958	643·5
Cochesett Methodist church spire. 1889–90.	42 00 55·913	1725·1	71 02 27·798	639·6
Scotland Congregational church belfry. 1889.	41 58 16·039	494·8	71 00 29·820	686·6
North Easton high school. 1889–90.	42 03 56·334	1738·1	71 06 16·838	387·1
Halifax Congregational church spire. 1885–1890.	41 59 28·110	867·3	70 51 42·790	984·9
Plympton Congregational church spire. 1885–1889.	41 57 21·245	655·5	70 48 56·149	1293·2
Kingston Unitarian church spire. 1886–1889.	41 59 36·679	1131·7	70 43 59·102	1360·4
Rockland waterworks. 1889–90.	42 05 45·946	1417·6	70 54 23·622	542·8
Hanover Center Congregational church spire. 1885–1889.	42 07 00·225	6·9	70 50 41·462	952·5
Rockland Congregational church spire. 1885–1890.	42 07 48·982	1511·3	70 54 56·626	1300·6
Round Top observatory.	42 05 38·225	1179·4	70 53 18·330	421·2
South Weymouth Unitarian church spire. 1885.	42 10 30·856	952·0	70 57 06·726	154·4
Mount Hope. 1885.	42 11 34·966	1078·9	70 49 18·000	413·0
Scituate Orthodox church spire. 1885.	42 12 02·370	73·1	70 45 36·908	846·8
Scituate Unitarian church spire. 1885.	42 12 00·436	13·4	70 45 22·116	507·3
Pigeon Hill. 1884–1890.	41 50 58·246	1797·0	70 59 44·574	1028·2
Standish.	42 00 50·77	1566·4	70 40 58·21	1339·4
Plymouth.	41 57 24·78	764·5	70 40 07·93	182·6
Plymouth pier head.	41 58 46·50	1434·6	70 39 13·38	308·0
Plymouth court-house. (Borden) 1835.	41 57 26·37	813·5	70 40 02·23	51·4
Plymouth National Monument. 1877–1888.	41 57 36·70	1132·2	70 40 34·94	804·7

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
299 09 50·1	119 21 47·3	Monk Hill	28 254·3	4·451 085
261 42 25·4	81 54 03·9	Carolina Hill.	24 188·7	4·383 613
291 42 54·5	111 52 08·4	Monk Hill	20 522·1	4·312 222
359 29 29·0	179 29 34·7	Alden.	22 144·4	4·345 263
160 22 38·2	340 20 46·5	Brockton First Congregational church.	11 416·8	4·057 545
194 20 16·0	14 21 32·1	South Abington waterworks.	10 554·8	4·023 448
192 14 08·9	12 14 57·8	Brockton First Congregational church	7 919·6	3·898 701
298 36 29·9	118 39 10·4	Bridgewater Unitarian church.	6 288·6	3·798 556
151 10 38·0	331 09 19·1	Cochesett Methodist church	5 630·7	3·750 563
175 20 20·2	355 19 50·1	Brockton First Congregational church.	12 714·2	4·104 289
252 35 44·8	72 39 07·2	Brockton First Congregational church	7 275·8	3·861 880
322 42 58·3	142 46 50·6	Scotland Congregational church.	13 190·2	4·120 252
286 15 27·6	106 21 01·6	Monk Hill	11 979·5	4·078 437
20 30 05·2	200 28 05·8	Middleboro town hall.	11 757·4	4·070 312
265 51 19·6	85 55 02·1	Monk Hill	7 683·0	3·885 529
135 35 15·4	315 33 24·0	Halifax Congregational church.	5 481·0	3·738 863
301 54 55·5	122 00 37·2	Manomet	13 870·0	4·142 078
347 13 41·4	167 14 05·3	Monk Hill.	3 719·4	3·570 470
314 37 15·2	134 44 37·2	Monk Hill	21 361·2	4·329 625
261 09 30·6	81 16 33·6	Carolina Hill.	14 664·8	4·166 277
329 45 35·5	149 50 28·8	Monk Hill	20 031·0	4·301 703
63 36 37·6	243 32 41·1	South Abington waterworks.	9 052·3	3·956 761
348 42 04·7	168 42 26·8	Rockland waterworks	3 871·1	3·587 835
22 04 39·3	202 03 33·9	South Abington waterworks.	5 969·9	3·775 996
150 46 13·6	330 45 07·7	Rockland Congregational church	4 623·4	3·664 966
71 36 55·9	251 34 44·6	South Abington waterworks.	4 745·5	3·676 281
235 18 32·1	55 23 24·8	Scituate	12 144·4	4·084 377
255 47 04·5	75 50 52·5	Prospect Hingham.	8 037·4	3·905 113
171 12 35·2	351 12 12·9	Scituate	4 985·5	3·697 706
89 50 41·0	269 49 14·2	Prospect Hingham.	2 963·7	3·471 837
129 52 33·1	309 50 45·4	Walnut Hill	4 791·0	3·680 422
188 59 36·7	8 59 47·6	Tank 1885.	2 382·3	3·376 988
127 56 43·9	307 54 46·3	Walnut Hill	5 092·6	3·706 936
180 47 12·1	0 47 13·1	Tank 1885.	2 412·9	3·382 535
175 28 20·3	355 27 20·0	Brockton First Congregational church.	26 261·5	4·419 319
241 14 08·7	61 25 04·0	Monk Hill.	25 775·9	4·411 214
280 12 52	100 16 08	Gurnet	6 831·7	3·834 53
321 41 01	141 44 42	Manomet.	12 266·5	4·088 72
227 15 55	47 18 37	Gurnet	7 578·4	3·879 58
95 37 36	275 35 25	Monk Hill.	4 523·1	3·655 44
318 08 22	138 10 53	Manomet	7 777·5	3·890 84
238 42 27	58 44 32	Gurnet.	5 045·1	3·702 87
297 43 29	117 46 32	Manomet	7 134·8	3·853 38
171 55 58	351 54 46	Telegraph Hill.	17 677·5	4·247 42
297 13 49	117 17 14	Manomet	7 950·4	3·900 39
91 07 00	271 05 07	Monk Hill.	3 880·4	3·588 88

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Plymouth (Gurnet) light-house. (Borden) 1835.	42 00 12·10	373·3	70 36 04·33	99·6
Plymouth (Gurnet) light-house. 1848–1870.	42 00 12·30	379·5	70 36 04·03	92·7
North Plymouth rope works.	41 58 47·50	1465·5	70 41 20·16	464·1
Kingston.	41 58 53·29	1644·1	70 41 54·63	1257·6
Kingston church spire. 1848.	41 59 36·08	1113·2	70 43 52·77	1214·6
East Duxbury church belfry. 1848.	42 02 08·10	249·9	70 40 24·05	553·2
South Duxbury Unitarian church spire. 1848–1888.	42 02 06·65	205·2	70 41 33·44	769·2
Duxbury, astronomical longitude station, transit. 1869–70.	42 02 55·18	1702·5	70 40 10·96	252·1
Duxbury pier light-house. 1877–1888.	41 59 14·94	461·0	70 38 56·57	1302·2
Powder Point.	42 02 49·15	1516·4	70 39 10·75	247·2
Eel River church spire. 1848.	41 56 15·18	468·3	70 37 49·12	1131·6
Webster's flagstaff. 1848.	42 04 39·21	1209·8	70 40 13·77	316·5
Webster's (Hon. Daniel) house, west chimney.	42 04 48·26	1489·0	70 40 47·07	1081·9
Lewis.	42 08 09·45	291·6	70 43 13·69	314·4
Hatch.	42 08 08·48	261·6	70 42 11·36	260·9
Third Cliff.	42 10 49·78	1536·0	70 43 01·94	44·5
Briggs.	42 10 02·49	76·8	70 44 57·31	1315·5
North Marshfield Unitarian church spire. 1849.	42 08 30·15	930·2	70 44 29·46	676·5
Scituate Unitarian church spire. 1848–49.	42 12 00·69	21·3	70 45 22·19	509·0
Studley.	42 08 13·49	416·2	70 48 07·38	168·5
Bonney.	42 03 10·50	324·0	70 52 34·01	782·1
Coleman.	42 10 42·14	1300·2	70 43 38·65	887·0
Boot Pond.	41 53 07·44	229·5	70 40 00·08	1·8

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
354 21 10	174 21 34	Manomet	8 476·6	3·928 22
65 00 30	244 55 36	Monk Hill.	11 155·8	4·047 50
354 24 32	174 24 56	Manomet	8 482·2	3·928 51
64 59 38	244 54 44	Monk Hill.	11 164·0	4·047 82
305 39 47	125 43 43	Manomet	9 983·4	3·999 28
250 16 20	70 19 50	Gurnet.	7 679·4	3·885 33
303 57 44	124 02 02	Manomet	10 737·2	4·030 89
253 15 01	73 18 54	Gurnet.	8 377·4	3·923 11
264 09 52	84 15 04	Gurnet	10 796·7	4·033 29
349 23 13	169 23 33	Monk Hill.	3 672·0	3·564 90
330 25 04	150 28 22	Manomet	13 811·5	4·140 24
26 27 35	206 25 35	Monk Hill.	9 269·2	3·967 04
324 52 26	144 56 30	Manomet	14 628·8	4·165 21
17 03 18	197 02 05	Monk Hill.	8 633·8	3·936 20
334 10 20	154 13 29	Manomet	14 957·9	4·174 87
51 43 52	231 42 57	South Duxbury Unitarian church.	2 416·6	3·383 20
324 14 45	144 17 04	Manomet	8 219·2	3·914 83
64 19 25	244 16 27	Monk Hill.	6 818·0	3·833 66
158 47 31	338 46 01	White	8 499·4	3·929 39
191 56 15	11 56 43	Brant.	4 672·5	3·669 55
198 01 36	18 02 45	Gurnet	7 664·8	3·884 50
108 37 14	288 33 31	Monk Hill.	8 123·3	3·909 73
338 27 38	158 30 49	Manomet	17 925·9	4·253 48
18 37 16	198 35 09	Monk Hill.	13 676·3	4·135 97
168 31 40	348 31 15	White	4 334·8	3·636 97
328 55 09	148 56 14	Powder Point.	4 290·9	3·632 55
182 34 05	2 34 15	Scituate light-house	7 655·6	3·883 98
308 00 48	128 02 01	White.	3 181·0	3·502 56
315 53 32	135 56 01	Brant	7 352·4	3·866 43
330 53 39	150 54 10	White.	2 208·5	3·344 10
3 07 15	183 07 07	Lewis	4 954·6	3·695 01
342 03 27	162 04 32	White.	7 259·1	3·860 88
241 07 54	61 09 11	Third Cliff	3 023·3	3·480 48
325 41 36	145 42 45	Lewis.	4 222·2	3·625 54
167 21 18	347 20 59	Briggs	2 920·1	3·465 40
204 59 33	25 00 32	Third Cliff.	4 753·7	3·677 03
261 07 41	81 09 17	Scituate light-house	3 330·9	3·522 56
329 01 24	149 04 04	White.	10 604·5	4·025 49
143 33 42	323 31 28	Prospect Hingham	7 717·7	3·887 49
208 23 25	28 25 16	Scituate Unitarian church.	7 970·0	3·901 46
185 37 46	5 38 31	Prospect Hingham	15 631·8	4·194 01
239 31 24	59 37 13	Carolina Hill.	13 891·5	4·142 75
197 19 06	17 19 33	Scituate light-house	3 076·0	3·487 98
135 34 38	315 33 28	Scituate Unitarian church.	3 393·9	3·530 70
233 18 31	53 21 33	Manomet	7 814·5	3·892 90
150 49 00	330 46 44	Monk Hill.	9 602·6	3·982 39

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Carver Center Baptist church spire. 1886.	41 53 14·94	460·9	70 46 07·90	182·1
North Carver, white church spire. 1886.	41 55 12·62	389·3	70 48 03·07	70·7
South Carver, Union chapel spire. 1886.	41 51 28·10	866·9	70 45 31·96	737·2
Furnace.	41 52 23·16	714·5	70 43 14·20	327·4
Telegraph. 1886.	41 53 47·04	1451·2	70 35 46·62	1074·7
Table Land. 1886–1889.	41 50 46·02	1419·7	70 39 07·33	169·1
Tank. 1886.	41 51 27·71	854·9	70 35 38·32	883·9
Sampson's (Mrs. Aaron) house chimney.	41 54 17·00	524·5	70 38 14·32	330·1
Exchange.	41 53 29·52	910·7	70 38 45·75	1054·7
College Pond.	41 52 10·88	335·7	70 39 21·22	489·5
Ridge.	41 53 02·56	79·0	70 39 54·02	1245·5
Plympton, cupola. 1888–89.	42 00 16·87	520·5	70 47 42·16	970·3
Crooked oak.	41 58 29·58	912·6	70 45 29·68	683·3
Rickard Pond.	41 56 46·21	1425·7	70 45 57·06	1314·3
Kingston, corner 2.	41 56 51·23	1580·6	70 45 33·08	762·0
Plymouth (Gurnet) north light-house. 1888.	42 00 12·56	387·5	70 36 04·28	98·5
Duxbury, corner 13.	42 00 47·76	1473·5	70 36 40·10	922·7
Clarke Island.	42 00 46·66	1439·6	70 38 11·04	254·0
Clarke Island, base 1.	42 00 46·35	1430·0	70 38 11·61	267·1
Clarke Island, base 2.	42 00 46·59	1437·4	70 38 10·38	238·8
Duxbury, corner 14.	42 00 47·86	1476·6	70 38 10·75	247·4
Cordage works, chimney.	41 58 46·90	1447·0	70 41 17·66	406·5
Carolina Hill 2. 1888.	42 06 54·70	1687·7	70 43 52·28	1201·0
Peterson.	42 04 49·30	1521·1	70 41 15·77	362·4

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
253 11 56	73 19 04	Manomet	15 398·2	4·187 47
204 55 31	24 57 21	Monk Hill.	8 988·6	3·953 69
267 16 51	87 25 16	Manomet	17 414·1	4·240 90
234 55 20	54 58 27	Monk Hill.	7 869·7	3·895 96
240 53 43	61 00 27	Manomet	15 923·6	4·202 04
194 30 03	14 31 29	Monk Hill.	11 824·2	4·072 77
240 38 25	60 43 35	Manomet	12 321·1	4·090 65
178 45 17	358 45 11	Monk Hill.	9 750·1	3·989 01
124 16 16	304 11 11	Monk Hill	12 729·2	4·104 80
78 12 38	258 09 49	Boot Pond.	5 969·5	3·775 94
164 25 26	344 24 51	Boot Pond	4 529·6	3·656 06
219 37 42	39 39 56	Telegraph.	7 253·7	3·860 56
117 01 48	296 58 53	Boot Pond	6 775·3	3·830 93
177 26 49	357 26 43	Telegraph.	4 303·1	3·633 78
236 37 58	56 39 49	Manomet	4 585·0	3·661 34
131 14 16	311 10 49	Monk Hill.	9 465·4	3·976 14
140 18 24	320 15 18	Monk Hill	10 011·5	4·000 50
68 19 16	248 18 26	Boot Pond.	1 844·0	3·265 76
219 56 35	39 59 11	Manomet	8 365·5	3·922 49
152 49 30	332 49 04	Boot Pond.	1 961·8	3·292 65
231 48 28	51 51 26	Manomet	7 795·4	3·891 84
137 05 23	317 05 19	Boot Pond.	205·5	2·312 85
263 39 12	83 43 43	Standish monument	9 365·5	3·971 53
309 13 40	129 16 33	Monk Hill.	7 692·2	3·886 05
225 12 00	45 13 01	Kingston Unitarian church spire	2 938·2	3·468 08
298 09 30	118 10 54	Monk Hill.	3 298·7	3·518 34
159 35 22	339 34 12	Plympton, cupola	6 935·1	3·841 05
245 13 34	65 15 17	Monk Hill.	3 896·9	3·590 72
74 20 09	254 19 53	Rickard Pond	573·79	2·758 75
354 22 13	174 22 37	Manomet	8 490·4	3·928 93
64 56 45	244 51 51	Monk Hill.	11 162·7	4·047 77
350 08 00	170 08 48	Manomet	9 678·1	3·985 79
57 57 07	237 52 37	Monk Hill.	10 957·2	4·039 70
51 12 09	231 08 40	Monk Hill	9 229·5	3·96[illegible]
91 39 42	271 37 50	Standish monument.	3 835·1	3·58[illegible]
233 28 09	53 28 09	Clarke Island	16·25	1·21[illegible]
75 20 43	255 20 42	Clarke Island, base 1	29·3	1·467 18
98 22 41	278 22 40	Clarke Island.	15·475	1·189 63
347 35 26	167 35 26	Clarke Island, base 2	40·2	1·603 95
10 14 02	190 14 02	Clarke Island.	37·6	1·574 95
54 10 10	234 08 46	Monk Hill	3 571·4	3·552 84
186 54 01	6 54 14	Standish monument.	3 833·2	3·583 56
330 52 27	150 58 05	Manomet	23 865·5	4·377 77
357 46 40	177 46 59	Monk Hill.	17 154·6	4·234 38
12 29 11	192 27 45	Monk Hill	13 593·5	4·133 33
137 06 01	317 04 16	Carolina Hill 2.	5 282·1	3·722 81

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Gotham Hill.	42 04 38·14	1176·8	70 40 09·00	206·9
Float Hill.	42 03 57·06	1760·5	70 41 25·07	576·4
Marshfield, corner 1.	42 03 27·08	835·5	70 40 59·72	1373·1
Marshfield, corner 13.	42 04 16·62	512·8	70 39 06·48	149·0
Arnold Brook.	42 04 02·08	64·2	70 41 49·84	1145·8
Walker's flag.	42 04 14·12	435·7	70 41 56·98	1309·9
Cove.	42 00 10·35	319·3	70 42 46·08	1060·5
West Duxbury Methodist church spire. 1888.	42 03 23·67	730·3	70 46 32·20	740·4
Barker.	42 06 59·17	1825·6	70 47 32·98	757·7
Loring's flagstaff. 1888.	42 00 25·20	777·5	70 43 15·58	358·5
Loring's Flats.	42 00 10·23	315·6	70 43 20·28	466·7
Seaside.	41 59 01·17	36·1	70 41 35·04	806·6
Kingston, corner 15.	41 59 01·17	36·1	70 41 36·41	838·2
Marshfield First Baptist church spire. 1888.	42 06 25·91	799·4	70 45 29·08	668·2
White Birch.	42 06 37·00	1141·6	70 46 37·88	870·3
North River. 1888.	42 06 58·00	1789·5	70 46 31·30	719·1
Nicks Rock. 1888.	41 57 35·92	1108·2	70 42 59·76	1376·2
Kingston, corner 16.	41 57 15·59	481·0	70 43 19·94	459·2
Tussuck Brook.	42 00 31·42	969·4	70 43 26·94	620·0
Tobey.	42 01 05·40	166·6	70 43 58·48	1345·5
Lean.	42 06 35·30	1089·2	70 45 59·94	1377·1
Birch, east base.	42 06 33·77	1041·9	70 45 33·92	779·4
Birch, west base.	42 06 33·92	1046·6	70 45 35·16	807·9
Birch stake.	42 06 31·54	973·1	70 45 35·74	821·2

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
9 02 37	189 02 04	Standish monument	7 119·8	3·852 47
129 24 47	309 22 17	Carolina Hill 2.	6 639·3	3·822 12
234 04 00	54 04 51	Gotham Hill	2 159·5	3·334 36
353 45 00	173 45 18	Standish monument.	5 798·3	3·763 30
359 26 04	179 26 05	Standish monument	4 839·2	3·684 77
17 07 50	197 06 14	Monk Hill.	11 233·4	4·050 51
21 53 11	201 51 57	Standish monument	6 861·2	3·836 40
59 35 23	239 34 07	Marshfield, corner 1.	3 019·3	3·479 90
152 09 39	332 08 17	Carolina Hill 2	6 023·2	3·779 83
208 15 40	28 16 03	Peterson	1 654·2	3·218 60
221 06 37	41 07 05	Peterson	1 440·7	3·158 56
336 11 18	156 11 23	Arnold Brook.	406·2	2·608 75
243 44 03	63 45 16	Standish monument	2 782·3	3·444 41
10 26 11	190 25 46	Monk Hill.	4 744·6	3·676 20
209 25 53	29 27 40	Carolina Hill 2	7 476·7	3·873 71
301 33 53	121 37 37	Standish monument.	9 034·8	3·955 92
271 32 30	91 34 58	Carolina Hill 2	5 071·8	3·705 16
341 35 56	161 38 43	Monk Hill.	18 208·7	4·260 28
2 00 47	182 00 42	Monk Hill	5 127·7	3·709 92
33 47 28	213 46 59	Kingston Unitarian church.	1 801·2	3·255 55
269 43 16	89 43 39	Cove	787·1	2·896 02
40 48 41	220 48 15	Kingston Unitarian church.	1 367·5	3·135 94
235 15 06	55 17 22	Clarke Island	5 712·9	3·756 86
306 26 20	126 30 26	Manomet.	10 508·7	4·021 55
269 51 56	89 51 57	Seaside	31·49	1·498 17
349 54 12	169 55 36	Monk Hill	16 509·0	4·217 72
109 50 04	289 48 41	Barker.	3 026·4	3·480 92
358 44 50	178 44 54	West Duxbury Methodist church	5 966·4	3·775 71
118 24 10	298 23 33	Barker.	1 438·7	3·157 97
13 08 33	193 08 29	White Birch	665·2	2·822 97
91 28 41	271 28 00	Barker.	1 417·2	3·151 44
100 15 31	280 15 15	Monk Hill	553·1	2·742 79
205 06 37	25 07 59	Standish monument.	6 621·4	3·820 95
173 43 30	353 43 28	Monk Hill	730·0	2·863 30
216 31 29	36 31 42	Nicks Rock.	780·4	2·892 31
359 07 08	179 07 10	Monk Hill	5 316·9	3·725 66
23 39 42	203 39 21	Kingston Unitarian church.	1 844·1	3·265 79
276 23 51	96 25 52	Standish monument	4 187·2	3·621 92
0 17 48	180 17 48	Kingston Unitarian church.	2 737·3	3·437 33
258 27 29	78 28 55	Carolina Hill 2	2 993·1	3·476 12
292 14 25	112 14 46	Marshfield First Baptist church.	766·1	2·884 26
335 23 58	155 24 01	Marshfield First Baptist church	266·9	2·426 28
279 19 35	99 19 36	Birch, east base	28·790	1·459 24
330 34 28	150 34 32	Marshfield First Baptist church.	283·9	2·453 16
190 22 32	10 22 32	Birch, west base	74·5	1·872 30
318 41 17	138 41 21	Marshfield First Baptist church.	231·6	2·364 79

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Marshfield, corner 6.	42 06 34·75	1072·2	70 45 35·87	824·2
Marshfield, corner 5.	42 06 12·14	374·6	70 45 46·15	1060·4
Duxbury, corner 8.	42 05 49·32	1521·7	70 45 00·76	17·5
Big pine.	42 02 45·20	1394·6	70 46 50·10	1152·2
Marshfield, corner 2.	42 04 00·75	23·1	70 41 46·96	1079·6
Marshfield, corner 3.	42 04 14·09	434·7	70 41 56·46	1297·9
Duxbury, corner 5.	42 01 03·96	122·2	70 43 54·25	1248·2
Pine tree. 1888.	41 58 02·53	78·0	70 45 51·62	1188·6
Silver Lake.	42 01 13·83	426·7	70 47 47·13	1084·6
Meadow, peg	42 00 16·70	515·3	70 47 45·99	1058·4
Pitch pine.	42 01 17·99	555·0	70 46 19·38	445·9
Kingston, corner 9.	42 01 19·50	601·6	70 46 10·65	245·0
Kingston, corner 5.	42 00 15·54	479·5	70 47 45·65	1050·6
Rock.	42 00 47·50	1465·5	70 38 12·23	281·4
Kingston, corner 6.	42 00 59·38	1832·1	70 48 03·67	84·5
Kingston, corner 7.	42 01 14·33	442·1	70 47 49·99	1150·1
Kingston, corner 8.	42 01 23·62	728·8	70 46 33·68	774·9
Duxbury, corner 3.	42 00 34·15	1053·6	70 43 28·92	665·5
Duxbury, corner 4.	42 00 59·24	1827·7	70 43 50·79	1168·6
Marshfield, corner 7.	42 06 35·66	1100·2	70 45 59·05	1356·7
Duxbury, corner 1.	42 00 08·89	274·3	70 42 44·08	1014·5
Duxbury, corner 2.	42 00 10·31	318·1	70 43 20·27	466·5
Marshfield, corner 8.	42 06 50·70	1564·3	70 46 01·36	31·2
Marshfield, corner 9.	42 06 46·48	1434·1	70 46 35·30	811·0
Marshfield, corner 10.	42 06 48·46	1495·2	70 46 40·02	919·4
Marshfield, corner 11.	42 06 48·59	1499·2	70 46 35·99	826·8
Marshfield, corner 12.	42 06 55·40	1709·3	70 46 32·02	735·6
Duxbury, corner 7.	42 02 48·63	1500·4	70 46 54·97	1264·2
Kingston, corner 3.	41 58 01·36	42·0	70 45 57·70	1328·6
Randolph Orthodox church spire. 1885.	42 09 45·46	1402·6	71 02 32·40	743·7
Holbrook church spire. 1885.	42 09 21·88	675·1	71 00 34·26	786·5
Randolph Baptist church spire. 1885.	42 10 28·36	875·0	71 02 57·56	1321·1
Avon Baptist church spire. 1885–1890.	42 07 59·92	1848·8	71 02 27·48	631·1

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
304 02 15	124 02 16	Birch, east base	54·0	1·732 68
327 23 05	147 23 05	Birch, west base.	30·4	1·482 43
11 30 58	191 30 27	West Duxbury Methodist church	5 304·9	3·724 68
120 36 12	300 35 00	Barker.	2 851·0	3·454 99
351 34 04	171 35 09	Monk Hill	15 289·0	4·184 38
25 04 27	205 03 26	West Duxbury Methodist church.	4 961·5	3·695 61
199 07 58	19 08 10	West Duxbury Methodist church	1 255·9	3·098 94
333 14 46	153 17 04	Monk Hill.	10 574·0	4·024 24
121 49 48	301 49 46	Arnold Brook	78·054	1·892 40
94 28 57	274 28 57	Walker's flag	11·97	1·078 09
114 26 25	294 26 22	Tobey	106·88	2·028 90
211 10 20	31 10 35	Crooked oak	975·6	2·989 25
281 56 22	101 58 01	Monk Hill.	3 488·9	3·542 69
317 28 31	137 31 27	Monk Hill	8 985·0	3·953 52
356 15 55	176 15 58	Plympton, cupola.	1 761·5	3·245 89
266 31 30	86 31 35	Plympton, cupola	88·4	1·946 43
329 01 34	149 03 32	Monk Hill	7 875·0	3·896 25
347 34 46	167 35 19	Crooked oak.	5 320·3	3·725 94
76 55 40	256 55 34	Pitch pine	206·08	2·314 04
167 30 06	347 30 06	Meadow, peg	36·622	1·563 74
242 53 32	62 53 34	Plympton, cupola.	90·2	1·955 26
337 55 40	157 55 40	Clarke Island, base 1	38·2	1·582 56
313 12 44	133 12 45	Clarke Island.	37·6	1·575 58
220 29 36	40 29 47	Silver Lake.	586·16	2·768 02
283 12 40	103 12 42	Silver Lake	67·62	1·830 08
297 48 14	117 48 24	Pitch pine	372·04	2·570 59
344 39 09	164 39 52	Crooked oak.	5 567·9	3·745 69
331 39 02	151 39 03	Tussock Brook	95·75	1·981 12
137 02 47	317 02 42	Tobey	259·75	2·414 55
61 19 50	241 19 49	Lean	23·28	1·366 98
134 18 24	314 18 23	Cove	64·47	1·809 36
3 38 29	183 38 29	Loring's Flats	2·396	0·379 49
356 03 35	176 03 36	Lean	476·42	2·677 99
194 30 46	14 30 49	North River, 1888	367·16	2·564 85
214 15 08	34 15 14	North River, 1888	355·92	2·551 35
200 21 44	20 21 47	North River, 1888	309·54	2·490 72
191 33 59	11 33 59	North River, 1888	82·01	1·913 87
313 24 59	133 25 02	Big pine	154·11	2·187 84
255 30 48	75 30 52	Pine tree, 1888	144·62	2·160 23
132 42 24	312 39 29	Blue Hill	8 141·6	3·909 71
178 40 58	358 40 53	Round Top.	7 481·9	3·874 01
160 39 32	340 38 08	Round Top	8 699·0	3·939 47
251 52 34	71 58 41	Prospect Hingham.	13 208·7	4·120 86
127 49 09	307 46 31	Blue Hill	6 826·2	3·834 18
183 45 49	3 46 01	Round Top.	6 169·1	3·790 22
145 14 44	325 11 46	Blue Hill	10 669·6	4·028 15
178 28 49	358 28 41	Round Top.	10 739·2	4·030 97

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Neary Mount.	42 09 51·04	1574·8	71 03 46·13	1058·9
Ladder. 1885.	42 10 33·03	1019·1	71 01 14·31	328·4
Ladder 2. 1885.	42 10 13·72	423·3	71 01 21·13	485·0
Ladder 3. 1885.	42 10 09·98	307·9	71 01 22·54	517·4
Braintree, corner 1.	42 10 08·63	266·3	71 01 20·95	480·9
Cochato. 1885.	42 11 23·83	735·3	71 01 12·17	279·3
Cochato 2. 1885.	42 11 13·68	422·1	71 01 09·91	227·4
Braintree, corner 2.	42 11 12·87	397·1	71 01 10·70	245·5
Blanchard. 1885.	42 08 03·34	103·0	71 02 09·88	226·9
Blanchard 2. 1885.	42 07 59·38	1832·1	71 02 10·39	238·7
Randolph, corner 1.	42 07 59·22	1827·2	71 02 11·47	263·2
Curran. 1885.	42 09 38·87	1199·3	71 03 51·77	1188·5
Curran 2. 1885.	42 09 48·94	1510·0	71 04 01·70	39·0
North corner of Stoughton.	42 09 50·81	1567·7	71 04 01·61	36·9
Pine Hill. 1885.	42 07 08·72	269·1	71 01 16·66	382·7
Pine Hill 2. 1885.	42 07 09·18	283·2	71 01 19·43	446·3
Holbrook, corner 1.	42 07 07·70	237·6	71 01 20·47	470·3
Rockland Catholic church spire. 1885–1889.	42 08 01·65	50·9	70 55 00·74	17·0
Board. 1885.	42 11 39·53	1219·7	70 49 07·31	167·7
Board, base end.	42 11 41·73	1287·6	70 49 08·51	195·3
Board 2. 1885.	42 11 41·21	1271·5	70 48 54·71	1255·3
Scituate, corner 3.	42 11 43·56	1344·0	70 48 50·41	1156·6
Pincin Hill. 1885.	42 11 21·07	650·1	70 46 45·40	1041·7
Pincin Hill 2. 1885.	42 11 00·39	12·0	70 46 39·43	904·9
Scituate, corner 2.	42 11 00·15	4·6	70 46 39·49	906·3
Hollis. 1885.	42 10 01·40	43·2	70 58 36·64	841·0
Hollis 2. 1885.	42 10 03·19	98·4	70 58 35·81	822·0
Hollis 3. 1885.	42 10 04·91	151·5	70 58 37·02	849·7

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
141 16 56	321 14 51	Blue Hill	6 839·6	3·835 03
191 44 29	11 45 13	Round Top.	7 463·1	3·872 92
50 41 54	230 41 02	Randolph Orthodox church	2 316·6	3·364 86
161 55 16	341 54 19	Round Top.	6 324·6	3·801 03
61 57 19	241 56 31	Randolph Orthodox church	1 853·7	3·268 04
194 43 33	14 43 38	Ladder.	616·1	2·789 66
195 37 36	15 37 37	Ladder 2	119·78	2·078 38
138 45 57	318 45 56	Ladder 3	55·29	1·742 65
155 38 56	335 37 57	Round Top	4 879·1	3·688 34
222 18 52	42 19 21	South Braintree church.	1 447·1	3·160 51
170 35 20	350 35 18	Cochato	317·4	2·501 58
213 41 44	33 42 11	South Braintree church.	1 662·5	3·220 76
215 54 12	35 54 13	Cochato 2	30·80	1·488 56
174 17 03	354 17 02	Cochato.	339·8	2·531 16
75 24 34	255 24 22	Avon Baptist church	417·7	2·620 90
176 17 40	356 17 20	Round Top.	10 652·2	4·027 44
92 27 26	272 27 15	Avon Baptist church	392·9	2·594 24
185 30 22	5 30 22	Blanchard.	122·6	2·088 64
259 01 24	79 01 25	Blanchard 2	25·29	1·402 95
323 36 26	143 37 00	Holbrook, corner 1.	1 974·6	3·295 48
144 00 28	323 58 27	Blue Hill	7 059·6	3·848 78
199 01 51	19 01 55	Neary Mount.	397·1	2·598 89
259 43 00	79 43 10	Neary Mount	363·2	2·560 20
323 43 17	143 43 24	Curran.	385·2	2·585 71
2 07 23	182 07 23	Curran 2	57·69	1·761 10
323 39 32	143 41 20	Holbrook, corner 1.	6 246·5	3·795 64
144 02 40	324 02 04	Blanchard	2 081·7	3·318 42
160 13 29	340 12 38	Randolph Orthodox church.	5 139·4	3·710 91
282 41 57	102 41 59	Pine Hill	65·26	1·814 65
207 34 15	27 34 16	Pine Hill 2	51·61	1·712 73
147 52 11	327 50 46	South Weymouth Unitarian church	5 437·1	3·735 37
216 41 48	36 44 11	Prospect Hingham.	8 200·1	3·913 82
168 07 04	348 06 35	Scituate	4 891·0	3·689 40
262 51 44	82 54 15	Scituate Unitarian church.	5 206·8	3·716 57
337 59 41	157 59 42	Board	73·30	1·865 10
79 51 05	259 50 57	Board	293·8	2·468 00
92 55 43	272 55 34	Board, base end.	317·0	2·501 12
53 37 04	233 37 01	Board 2	122·45	2·087 96
208 10 38	28 11 35	Tank	4 115·4	3·614 41
237 32 57	57 33 53	Scituate Unitarian church.	2 264·4	3·354 96
167 52 52	347 52 48	Pincin Hill	652·5	2·814 59
223 45 02	43 45 54	Scituate Unitarian church.	2 565·1	3·409 11
189 57 49	9 57 49	Pincin Hill 2	7·42	0·870 40
246 12 57	66 13 57	South Weymouth Unitarian church	2 255·2	3·353 18
306 40 35	126 43 00	Rockland Catholic church.	6 182·6	3·791 17
19 06 26	199 06 25	Hollis	58·44	1·766 71
332 26 30	152 26 31	Hollis 2	60·01	1·778 22

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Holbrook, corner 6.	42 10 06·19	191·0	70 58 37·11	851·8
Scituate Point.	42 12 17·14	528·8	70 43 00·65	14·9
Coleman Hill.	42 10 45·46	1402·7	70 44 17·34	398·0
Clift street.	42 09 29·08	897·2	70 45 05·24	120·3
Stoddard's barn cupola.	42 09 25·13	775·4	70 44 33·32	764·9
North River. 1885.	42 09 55·46	1711·2	70 45 10·35	237·5
Scituate, corner 1.	42 09 55·88	1724·1	70 45 17·03	390·9
Mount Hope 2. 1885.	42 11 17·42	537·5	70 49 42·96	985·8
Mount Hope 3. 1885.	42 11 41·08	1267·5	70 50 22·76	522·2
Scituate, corner 4.	42 11 41·52	1281·1	70 50 21·71	498·1
Cohasset, corner 1.	42 12 03·07	94·7	70 49 39·00	894·8
Hersey. 1885.	42 11 17·82	549·8	70 51 49·21	1129·2
Hill 1. 1885.	42 11 33·32	1028·1	70 51 29·08	667·2
Hersey, base end. 1885.	42 11 11·59	357·6	70 51 43·61	1000·7
Hill 2. 1885.	42 11 34·17	1054·3	70 51 16·28	373·5
Hill 3. 1885.	42 11 33·16	1023·1	70 51 24·04	551·6
South Scituate, corner 3.	42 11 11·54	356·1	70 51 43·64	1001·4
South Scituate, corner 4.	42 11 25·88	798·5	70 51 09·59	220·1
Accord Pond. 1885.	42 10 24·24	747·9	70 53 14·67	336·7
Accord Pond, base end. 1885.	42 10 15·10	465·9	70 53 45·53	1045·0
Accord Pond 3. 1885.	42 10 11·12	343·1	70 53 40·39	927·1
Accord Pond 4. 1885.	42 10 23·97	739·6	70 53 36·07	827·9
Accord Pond 2. 1885.	42 10 01·76	54·3	70 53 24·44	561·0
South Scituate, corner 2.	42 10 02·03	62·6	70 53 21·38	490·8
South Scituate, corner 2′.	42 10 24·28	749·1	70 53 17·07	391·8
Rockland, corner 4, peg.	42 10 11·49	354·5	70 53 38·43	882·1
Rockland, corner 4.	42 10 11·55	356·4	70 53 38·45	882·5

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
356 54 40	176 54 40	Hollis 3	39·58	1·597 48
6 12 02	186 11 50	Weymouth, corner 1.	3 665·9	3·564 18
80 59 33	260 57 58	Scituate Unitarian church	3 286·1	3·516 68
120 35 12	300 33 38	Tank.	3 730·4	3·571 74
147 17 14	327 16 31	Scituate Unitarian church	2 749·9	3·439 32
211 52 32	31 53 24	Scituate Point.	3 331·5	3·522 64
175 15 40	355 15 29	Scituate Unitarian church	4 686·2	3·670 82
205 00 31	25 01 03	Coleman Hill	2 600·4	3·415 04
99 27 07	279 26 46	Clift street	742·9	2·870 93
188 25 02	8 25 13	Coleman Hill.	2 505·5	3·398 89
317 44 33	137 44 58	Stoddard's barn, cupola	1 264·2	3·101 81
351 47 53	171 47 56	Clift street.	822·2	2·914 95
274 56 00	94 56 05	North River, 1885	153·9	2·187 22
341 52 44	161 52 52	Clift street.	870·1	2·939 58
102 34 17	282 33 07	Prospect Hingham	2 449·9	3·389 14
226 35 53	46 36 10	Mount Hope.	788·1	2·896 57
308 37 54	128 38 21	Mount Hope 2	1 169·1	3·067 84
82 24 33	262 23 50	Prospect Hingham.	1 491·0	3·173 47
60 50 46	240 50 45	Mount Hope 3	27·70	1·442 48
330 55 47	150 56 01	Mount Hope	992·0	2·996 52
70 34 22	250 33 09	Prospect Hingham.	2 631·7	3·420 23
224 10 33	44 10 48	Prospect Hingham	725·6	2·860 72
226 05 46	46 05 47	Prospect Hingham	60·71	1·783 26
44 00 17	224 00 03	Hersey.	665·0	2·822 79
206 26 29	26 26 39	Hill 1	748·9	2·874 45
146 15 35	326 15 31	Hersey.	231·24	2·364 06
93 39 58	273 39 51	Prospect Hingham	250·4	2·398 56
260 04 39	80 04 44	Hill 2	180·7	2·256 97
123 16 16	303 16 14	Prospect Hingham	85·93	1·934 14
206 26 28	26 26 38	Hill 1	750·40	2·875 29
149 00 51	329 00 47	Hill 2	298·3	2·474 68
124 06 50	304 06 40	Hill 3.	400·5	2·602 61
184 17 40	4 17 54	Hingham Plains church	6 182·6	3·791 17
228 36 19	48 37 31	Prospect Hingham.	3 288·1	3·516 94
248 16 33	68 16 54	Accord Pond	762·3	2·882 15
235 33 36	55 33 53	Accord Pond	715·8	2·854 79
136 08 34	316 08 31	Accord Pond, base end.	170·11	2·230 73
269 01 45	89 01 59	Accord Pond	491·2	2·691 25
14 02 57	194 02 54	Accord Pond 3.	408·7	2·611 42
197 54 42	17 54 49	Accord Pond	729·0	2·862 72
158 43 14	338 43 06	Accord Pond 4.	735·5	2·866 58
83 09 22	263 09 20	Accord Pond 2	70·73	1·849 60
271 26 22	91 26 24	Accord Pond	55·16	1·741 62
75 48 52	255 48 51	Accord Pond 3	46·40	1·666 52
345 48 52	165 48 52	Rockland, corner 4, peg	1·80	0·255 27
61 54 40	241 49 30	Holbrook, corner 1.	12 030·4	4·080 28

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Jones. 1885.	42 09 28·84	889·8	70 50 01·89	43·4
Jones, base end.	42 09 24·53	756·8	70 50 38·71	888·7
Jones 2. 1885.	42 09 29·64	914·6	70 50 37·72	865·9
Jones 3. 1885.	42 09 30·17	930·9	70 50 40·68	933·9
Jones 4. 1885.	42 09 30·04	926·9	70 50 51·88	1191·0
Hanover, corner 4.	42 09 30·13	929·6	70 50 51·88	1191·0
West Scituate church spire. 1885.	42 09 28·33	874·1	70 51 10·24	235·1
Grose.	42 09 53·90	1663·1	70 52 43·52	999·0
Pine tree. 1885.	42 09 13·78	425·2	70 53 06·06	139·1
South Scituate, corner 1, peg.	42 09 13·87	427·9	70 53 05·37	123·3
South Scituate, corner 1.	42 09 13·61	419·9	70 53 05·31	121·9
Remington. 1885.	42 08 14·56	449·2	70 58 22·68	520·8
Remington, base end.	42 08 16·73	516·2	70 58 23·08	530·0
Remington 3. 1885.	42 08 15·12	466·5	70 58 14·69	337·4
Remington 2. 1885.	42 08 04·91	151·5	70 58 26·16	600·8
Weymouth, corner 1.	42 08 08·07	249·0	70 58 54·35	1248·2
Russell.	42 09 25·16	776·3	70 55 37·46	860·0
Hingham, corner 1.	42 09 27·51	848·8	70 55 31·35	719·7
Hayden.	42 11 30·81	950·6	71 01 50·92	1168·4
Braintree, corner 3.	42 11 29·72	917·0	71 01 48·30	1108·2
McGaughey.	42 10 12·49	385·4	71 01 00·03	0·7
Holbrook, corner 4.	42 10 08·08	249·3	71 01 03·06	70·2
Blue Rock.	42 10 08·01	247·1	71 00 28·18	646·9
Holbrook, corner 5.	42 10 06·36	196·2	71 00 26·24	604·6
Pine street.	42 10 15·19	468·7	70 55 26·28	603·2
Weymouth–Hingham line stone A.	42 10 13·56	418·4	70 55 24·32	558·2
Monument. 1885–86.	42 00 17·86	551·0	70 57 59·76	1375·2
Middleboro Baptist church spire. 1885.	41 53 33·03	1019·1	70 54 41·56	958·1

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
65 33 00	245 29 42	Rockland Congregational church	7 436·4	3·871 36
153 15 27	333 14 30	Prospect Hingham.	4 348·2	3·638 31
261 03 13	81 03 38	Jones	855·7	2·932 33
271 43 20	91 43 44	Jones	822·8	2·915 32
8 14 04	188 14 03	Jones, base end.	159·44	2·202 60
283 28 56	103 28 58	Jones, 2	69·89	1·844 42
269 07 13	89 07 21	Jones, 3	257·10	2·410 10
359 07 13	179 07 13	Jones, 4	2·76	0·440 91
269 24 59	89 25 45	Jones	1 569·1	3·195 66
59 29 44	239 27 12	Rockland Congregational church.	6 035·0	3·780 68
290 13 03	110 14 06	West Scituate church	2 282·2	3·358 35
38 25 32	218 24 03	Rockland Congregational church.	4 919·5	3·691 92
202 40 55	22 41 10	Grose	1 341·8	3·127 69
260 24 18	80 25 36	West Scituate church.	2 696·8	3·430 85
80 24 18	260 24 18	Pine tree, 1885	16·00	1·204 12
260 24 19	80 25 36	West Scituate church.	2 680·8	3·428 26
170 24 19	350 24 19	South Scituate, corner 1, peg	8·07	0·906 87
202 30 53	22 31 44	South Weymouth Unitarian church	4 552·6	3·658 26
124 30 58	304 29 30	Holbrook church.	3 666·3	3·564 23
352 17 26	172 17 26	Remington	67·62	1·830 08
84 39 42	264 39 37	Remington	184·3	2·265 43
104 31 15	284 31 09	Remington, base end.	198·9	2·298 60
195 00 21	15 00 23	Remington	308·4	2·489 12
219 53 21	39 53 29	Remington 3.	410·6	2·613 40
254 36 03	74 36 24	Remington	754·5	2·877 67
278 33 54	98 34 13	Remington 2.	654·8	2·816 14
341 52 30	161 52 55	Rockland Catholic church.	2 711·1	3·433 15
134 41 55	314 40 55	South Weymouth Unitarian church.	2 882·5	3·459 77
62 41 34	242 41 30	Russell	157·95	2·198 52
61 45 03	241 41 09	Holbrook, corner 1.	9 104·4	3·959 25
165 07 36	345 07 03	Round Top	4 375·9	3·641 07
245 21 21	65 22 16	South Braintree church.	2 049·9	3·311 74
119 17 34	299 17 32	Hayden	68·91	1·838 28
339 15 01	159 15 18	Holbrook church	1 670·2	3·222 76
68 33 11	248 32 09	Randolph Orthodox church.	2 277·8	3·357 52
207 04 39	27 04 41	McGaughey	152·95	2·184 55
5 36 38	185 36 34	Holbrook church	1 430·7	3·155 55
76 18 40	256 17 17	Randolph Orthodox church.	2 935·1	3·467 62
140 13 39	320 13 38	Blue Rock	66·13	1·820 40
351 53 51	171 54 08	Rockland Catholic church	4 161·8	3·619 28
101 51 17	281 50 10	South Weymouth Unitarian church.	2 355·8	3·372 14
138 09 48	318 09 47	Pine street	67·38	1·828 53
6 28 51	186 28 46	Hingham, corner 1.	1 429·9	3·155 32
283 33 53	103 43 39	Monk Hill	20 760·6	4·317 24
356 07 37	176 08 15	Alden.	19 467·0	4·289 30
159 56 26	339 54 14	Monument	13 298·1	4·123 79
244 01 18	64 08 51	Monk Hill.	17 372·4	4·239 86

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
East Stoughton Catholic church spire. 1885.	42 07 55·19	1702·8	71 02 28·22	648·1
Middleboro Green church spire. 1885–1890.	41 54 31·36	967·6	70 53 06·83	157·4
Whitman Congregational church spire. 1885–1889.	42 04 44·81	1382·6	70 56 12·96	297·9
Titicut church spire. 1885–1889.	41 55 57·17	1763·9	70 58 51·49	1186·2
Bryantville Baptist church spire. 1885–1889.	42 02 34·76	1072·4	70 51 01·77	40·7
State Farm waterworks.	41 56 35·00	1079·9	70 57 08·26	190·3
Howard Institute.	42 01 12·01	370·5	71 00 44·28	1018·8
Fulton.	42 00 39·85	1229·5	70 58 48·16	1108·3
Holmes Knoll.	41 58 57·05	1760·2	70 54 37·36	860·0
Easton Congregational church spire. 1889.	42 02 10·95	337·9	71 05 52·02	1196·5
North Raynham church spire. 1889.	41 57 20·11	620·4	71 04 14·88	342·7
Nippenicket.	41 57 31·16	961·4	71 02 42·59	980·8
Brockton Heights Methodist church spire. 1889.	42 04 30·50	941·0	71 03 57·20	1314·9
Campello South Congregational church spire. 1889.	42 03 49·32	1521·7	71 00 58·95	1355·3
Elmwood church spire. 1889.	42 00 51·58	1591·4	70 57 47·80	1099·9
Elmwood, engine house.	42 00 51·11	1576·9	70 57 47·01	1081·7
Desmond.	42 00 29·50	910·2	70 56 38·96	896·5
Cedar.	41 59 20·33	627·2	70 54 01·00	23·0
Union.	41 59 47·48	1464·9	70 53 53·70	1235·9
Washburn.	42 00 30·59	943·8	70 53 48·55	1117·3
Harding.	42 01 31·90	984·2	70 53 47·82	1100·2
Two-dollar tree.	42 03 38·28	1181·1	70 54 29·68	682·4
Hanson Congregational church spire. 1889.	42 03 32·92	1015·7	70 52 31·33	720·4

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
239 08 41	59 08 53	Blanchard	490·5	2·690 68
311 05 05	131 05 53	Pine Hill.	2 180·9	3·338 63
147 46 26	327 43 10	Monument	12 641·5	4·101 80
246 37 44	66 44 14	Monk Hill.	14 636·3	4·165 43
306 29 51	126 38 26	Monk Hill	22 045·5	4·343 32
16 37 06	196 35 55	Monument.	8 594·9	3·934 24
236 33 56	56 38 43	Halifax Congregational church	11 824·7	4·072 79
307 59 40	128 02 27	Middleboro town hall.	7 315·4	3·864 24
310 48 32	130 53 39	Monk Hill	13 946·0	4·144 45
9 18 44	189 18 17	Halifax Congregational church.	5 835·4	3·766 07
234 29 42	54 33 20	Halifax Congregational church	9 203·0	3·963 93
329 10 14	149 11 52	Middleboro town hall.	6 606·0	3·819 94
220 32 44	40 35 31	South Abington waterworks	8 841·0	3·946 50
318 12 01	138 13 32	Bridgewater Unitarian church.	4 707·5	3·672 79
349 32 00	169 32 14	Bridgewater Unitarian church	2 560·3	3·408 28
95 37 14	275 34 47	Cochesett Methodist church.	5 078·1	3·705 70
38 25 32	218 23 51	State Farm waterworks	5 593·1	3·747 65
97 02 47	277 00 13	Bridgewater Unitarian church.	5 348·4	3·728 22
229 34 45	49 37 51	Brockton First Congregational church	8 370·1	3·922 73
296 12 44	116 15 01	Cochesett Methodist church.	5 237·7	3·719 14
200 18 22	20 19 34	Cochesett Methodist church	7 099·7	3·851 24
251 33 54	71 36 25	Scotland Congregational church.	5 462·4	3·737 38
183 05 00	3 05 10	Cochesett Methodist church	6 326·4	3·801 16
245 37 08	65 38 37	Scotland Congregational church.	3 356·3	3·525 86
266 38 02	86 42 59	South Abington waterworks	10 199·1	4·008 56
313 27 05	133 31 04	Bridgewater waterworks.	11 329·2	4·054 20
91 43 27	271 39 54	North Easton high school	7 311·7	3·864 02
171 20 44	351 20 33	Brockton First Congregational church.	2 416·7	3·383 22
14 51 36	194 51 28	Bridgewater waterworks	1 077·5	3·032 42
75 24 18	255 23 38	Fulton.	1 435·1	3·156 89
16 00 23	196 00 14	Bridgewater waterworks	1 068·5	3·028 76
76 08 13	256 07 32	Fulton.	1 449·3	3·161 17
79 03 02	259 02 08	Bridgewater waterworks	1 894·9	3·277 58
113 16 46	293 16 00	Elmwood church.	1 724·3	3·236 61
265 40 49	85 42 21	Halifax Congregational church	3 190·2	3·503 82
40 13 34	220 11 29	State Farm waterworks.	6 679·4	3·824 74
81 53 46	261 50 42	Bridgewater Unitarian church	6 376·8	3·804 60
158 24 29	338 22 41	South Abington waterworks.	10 028·6	4·001 24
21 16 28	201 15 55	Holmes Knoll	3 097·0	3·490 94
86 07 38	266 04 50	Bridgewater waterworks.	5 795·8	3·763 11
68 30 32	248 27 43	Bridgewater waterworks	6 232·5	3·794 66
147 55 14	327 53 23	South Abington waterworks.	7 202·8	3·857 50
47 02 41	227 00 53	East Bridgewater Unitarian church	5 080·4	3·705 90
127 34 51	307 33 28	South Abington waterworks.	3 613·0	3·557 87
113 00 08	292 57 25	South Abington waterworks	6 066·0	3·782 90
147 50 41	327 49 26	Rockland waterworks.	4 848·9	3·685 84

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Harris.	42 06 44·10	1360·7	70 59 56·75	1303·8
Holbrook waterworks. 1889–90.	42 09 23·64	729·4	70 59 27·79	638·0
Cleveland Pond.	42 06 51·56	1590·8	70 58 45·45	1044·1
Abington, corner 2.	42 06 50·79	1567·1	70 58 47·40	1089·0
Abington Swedenborgian church spire. 1889.	42 06 26·66	822·6	70 56 38·73	889·9
Bowker.	42 07 00·69	21·3	70 55 55·17	1267·4
Rockland, corner 14.	42 06 59·80	1845·1	70 55 55·14	1266·7
Pembroke Unitarian church spire. 1889.	42 04 18·32	565·2	70 48 38·22	878·6
Rye Hill.	42 05 08·87	273·7	70 54 22·29	512·4
West Crook, liberty pole. 1889.	42 04 13·76	424·6	70 56 54·18	1245·5
Whitman, corner 1, peg.	42 03 39·34	1213·8	70 57 05·02	115·4
Whitman, corner 1.	42 03 39·31	1212·9	70 57 05·54	127·4
Humble.	42 03 59·72	1842·6	70 55 08·06	185·3
Whitman, corner 9.	42 03 54·28	1674·8	70 54 48·21	1108·4
Baldwin.	42 04 03·92	121·0	70 55 47·48	1091·6
Whitman, corner 10.	42 03 58·73	1812·1	70 55 46·49	1068·8
Foster.	42 03 40·95	1263·5	70 50 32·49	747·0
Hanson, corner 19.	42 03 37·67	1162·3	70 50 29·41	676·2
Foster, peg 1.	42 03 39·31	1212·9	70 50 23·00	528·8
Foster, peg 2.	42 03 36·92	1139·1	70 50 24·52	563·8
Hanson, corner 18.	42 03 40·76	1257·6	70 50 25·83	593·9
Hanson, corner 20.	42 03 34·00	1049·0	70 50 22·21	510·7
Hanson, corner 21.	42 03 33·64	1037·9	70 50 22·40	515·0
Hanson, corner 22.	42 03 33·15	1022·8	70 50 13·40	308·1
Foster, peg 3.	42 03 44·70	1379·2	70 50 27·20	625·4
Foster, peg 4.	42 03 49·80	1536·5	70 50 20·01	460·0
Hanson, corner 17.	42 03 50·19	1548·6	70 50 19·37	445·3

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
283 09 33	103 13 16	Rockland waterworks	7 861·8	3·895 52
307 09 57	127 12 13	South Abington waterworks.	5 841·4	3·766 52
295 06 16	115 09 18	Rockland Congregational church	6 877·6	3·837 44
334 44 06	154 46 02	South Abington waterworks.	9 345·9	3·970 62
288 34 28	108 37 23	Rockland waterworks	6 347·5	3·802 60
81 59 39	261 58 51	Harris.	1 654·1	3·218 55
242 09 57	62 09 58	Cleveland Pond	50·77	1·705 61
292 00 52	112 02 23	Rockland waterworks	3 348·9	3·524 90
358 01 32	178 01 35	South Abington waterworks.	2 994·2	3·476 28
222 03 29	42 04 08	Rockland Congregational church	2 007·2	3·302 60
317 37 16	137 38 17	Rockland waterworks.	3 121·3	3·494 33
178 38 49	358 38 49	Bowker	27·44	1·438 31
95 05 46	275 00 27	South Abington waterworks	10 985·3	4·040 81
150 27 34	330 26 11	Hanover Center Congregational church.	5 742·6	3·759 11
78 57 40	258 56 12	South Abington waterworks	3 090·3	3·490 00
178 27 57	358 27 56	Rockland waterworks.	1 144·4	3·058 58
4 56 30	184 56 19	East Bridgewater Unitarian church	4 574·7	3·660 36
105 17 35	285 14 40	Brockton First Congregational church.	6 209·4	3·793 05
193 12 21	13 12 28	West Crook, liberty pole	1 090·77	3·037 73
193 48 03	13 48 11	West Crook, liberty pole	1 094·5	3·039 23
265 11 51	85 11 51	Whitman, corner 1, peg.	11·95	1·077 52
127 53 24	307 52 25	South Abington waterworks	2 510·2	3·399 71
197 18 17	17 18 47	Rockland waterworks.	3 433·1	3·535 69
110 12 13	290 12 00	Humble	486·17	2·686 79
142 42 41	322 42 10	South Abington waterworks	1 774·4	3·249 04
211 28 16	31 29 12	Rockland waterworks.	3 691·1	3·567 15
171 56 52	351 56 51	Baldwin	161·80	2·208 99
104 20 07	284 16 05	South Abington waterworks	8 582·6	3·933 62
133 31 15	313 29 24	Round Top observatory.	5 256·1	3·720 66
145 04 54	325 04 52	Foster	123·55	2·091 86
103 03 14	283 03 08	Foster	224·1	2·350 42
124 11 12	304 11 07	Foster	221·4	2·345 25
205 26 50	25 26 51	Foster, peg 1.	81·74	1·912 44
345 45 36	165 45 37	Foster, peg 2	122·4	2·087 64
92 10 41	272 10 37	Foster.	153·2	2·185 22
149 27 17	329 27 15	Foster, peg 2	104·6	2·019 61
173 43 02	353 43 01	Foster, peg 1.	164·9	2·217 23
154 15 21	334 15 20	Foster, peg 2	112·3	2·050 55
175 31 56	355 31 56	Foster, peg 1.	175·5	2·244 37
114 24 57	294 24 50	Foster, peg 2	281·1	2·448 80
130 42 37	310 42 31	Foster, peg 1.	291·3	2·464 32
345 27 40	165 27 41	Hanson, corner 18	125·6	2·098 83
46 24 40	226 24 37	Foster.	167·8	2·224 86
46 24 45	226 24 40	Foster, peg 3	228·35	2·358 61
46 24 45	226 24 37	Foster.	396·18	2·597 89
50 30 45	230 30 45	Foster, peg 4	19·11	1·281 35

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Bryantville Methodist church spire. 1889.	42 02 44·96	1387·2	70 50 28·84	663·2
Hanson, corner 24, peg 1.	42 02 45·85	1414·6	70 50 39·85	916·5
Hanson, corner 24, peg 2.	42 02 49·36	1522·9	70 50 38·99	896·7
Hanson, corner 24.	42 02 46·36	1430·4	70 50 46·12	1060·7
Hanson, corner 25, peg 2.	42 02 42·51	1311·6	70 50 25·54	587·4
Hanson, corner 25.	42 02 41·71	1286·9	70 50 29·24	672·4
Hanson, corner 25, peg 1.	42 02 41·57	1282·6	70 50 29·11	669·5
Hanson, corner 27.	42 02 36·80	1135·5	70 50 33·02	759·5
Hanson, corner 28, peg.	42 02 34·62	1068·2	70 50 42·34	973·6
Hanson, corner 28.	42 02 33·89	1045·6	70 50 42·93	987·1
Hanson, corner 26.	42 02 37·16	1146·5	70 50 33·34	766·8
Chapman.	42 05 20·15	621·7	70 50 52·59	1208·6
Hanson, corner 15.	42 05 19·36	597·3	70 50 35·41	813·8
Grover's cupola.	41 59 42·22	1302·6	70 50 35·93	826·9
South Halifax Baptist church spire. 1889.	41 57 19·89	613·6	70 51 59·67	1374·2
Bridgewater, corner 3.	41 56 34·14	1053·3	71 00 55·10	1269·2
Halifax, corner 1.	41 56 54·00	1666·0	70 52 10·64	245·0
Churchill.	41 54 58·08	1791·8	70 49 03·80	87·6
Churchill, peg 1.	41 54 52·58	1622·2	70 48 59·68	1375·3
Churchill, peg 2.	41 54 53·72	1657·4	70 48 56·75	1307·8
Carver, corner 19.	41 54 49·26	1519·8	70 48 57·60	1327·4
Richmond.	41 55 51·43	1586·7	71 00 11·36	261·7
Richmond, peg.	41 55 47·94	1479·1	71 00 02·06	47·5
Bridgewater, corner 1.	41 55 47·73	1472·6	71 00 01·58	36·4
Bridgewater, corner 2.	41 56 07·73	238·5	71 00 22·25	512·6
Rockland, corner 10.	42 09 06·50	200·5	70 54 02·22	51·0
Rockland, corner 11.	42 07 05·13	158·3	70 53 23·86	548·2
Hanson, corner 13.	42 05 16·86	520·2	70 53 16·97	390·0
Hanson, corner 14.	42 05 21·11	651·3	70 52 46·95	1079·1

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
67 24 31	247 24 09	Bryantville Baptist church	819·7	2·913 67
117 43 37	297 42 15	Hanson Congregational church.	3 182·0	3·502 70
276 12 03	96 12 10	Bryantville Methodist church	254·2	2·405 22
55 48 58	235 48 43	Bryantville Baptist church.	609·3	2·784 80
300 11 08	120 11 15	Bryantville Methodist church	269·7	2·430 88
10 17 23	190 17 22	Hanson, corner 24, peg 1.	109·91	2·041 04
240 33 38	60 33 43	Hanson, corner 24, peg 2	188·1	2·274 50
276 11 58	96 12 02	Hanson, corner 24, peg 1.	145·1	2·161 59
134 53 03	314 53 01	Bryantville Methodist church	107·1	2·029 66
253 49 21	73 49 23	Hanson, corner 25, peg 2	88·52	1·947 06
185 13 11	5 13 11	Bryantville Methodist church.	100·6	2·002 74
183 25 53	3 25 53	Bryantville Methodist church	104·7	2·019 84
145 55 07	325 55 07	Hanson, corner 25.	5·16	0·712 42
211 25 50	31 25 53	Hanson, corner 25, peg 1	172·59	2·237 02
252 37 14	72 37 20	Hanson, corner 27	224·72	2·351 64
211 15 14	31 15 14	Hanson, corner 28, peg	26·30	1·420 93
326 06 10	146 06 10	Hanson, corner 27	13·29	1·123 40
83 12 11	263 08 22	South Abington waterworks	7 909·0	3·898 12
99 20 27	279 18 06	Rockland waterworks.	4 914·7	3·691 50
93 32 40	273 32 28	Chapman.	395·56	2·597 21
332 08 42	152 09 49	Plympton Congregational church	4 918·8	3·691 86
74 13 00	254 12 15	Halifax Congregational church.	1 599·4	3·203 96
269 24 59	89 27 02	Plympton Congregational church	4 226·8	3·626 01
185 36 34	5 36 45	Halifax Congregational church.	3 975·1	3·599 35
269 41 16	89 43 48	State Farm waterworks	5 225·4	3·718 12
291 48 57	111 50 20	Titicut church.	3 067·8	3·486 83
197 33 00	17 33 07	South Halifax Baptist church	837·76	2·923 12
71 00 30	250 56 44	Middleboro town hall	8 231·0	3·915 45
156 17 20	336 15 34	Halifax Congregational church.	9 100·4	3·959 06
150 44 53	330 44 50	Churchill	194·4	2·288 64
62 28 55	242 28 53	Churchill, peg 1	76·22	1·882 09
129 34 25	309 34 20	Churchill.	210·9	2·324 12
154 54 14	334 54 13	Churchill, peg 1	113·1	2·053 44
188 07 04	8 07 05	Churchill, peg 2.	139·0	2·143 10
252 18 25	72 20 27	State Farm waterworks	4 427·0	3·646 11
264 29 54	84 30 47	Titicut church.	1 848·7	3·266 87
116 41 14	296 41 08	Richmond	240·0	2·380 18
260 03 28	80 04 15	Titicut church.	1 650·6	3·217 64
120 15 28	300 15 28	Richmond, peg	12·845	1·108 73
333 29 04	153 29 11	Richmond	561·98	2·749 72
4 32 38	184 32 24	Rockland waterworks	6 207·1	3·792 89
23 47 54	203 46 12	South Abington waterworks.	8 659·8	3·937 51
29 20 22	209 19 42	Rockland waterworks	2 802·5	3·447 55
22 25 24	302 24 22	Rockland Congregational church.	2 523·9	3·402 07
120 22 12	300 21 27	Rockland waterworks	1 775·4	3·249 29
177 17 00	357 16 59	Round Top observatory.	659·88	2·819 47
79 14 20	259 14 00	Hanson, corner 13	702·38	2·846 57

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Hanson, corner 11.	42 05 04·16	128·4	70 54 48·44	1113·4
Hanson, corner 23.	42 03 18·47	569·9	70 50 46·76	1075·2
Hanson, corner 1.	42 00 56·81	1752·8	70 50 58·96	1356·6
Monponsett, peg 1.	42 00 58·88	1816·6	70 51 00·75	17·3
Monponsett, peg 2.	42 00 51·64	1593·2	70 51 13·17	303·0
Monponsett, peg 3.	42 00 59·79	1844·7	70 51 19·38	445·9
Monponsett, peg 4.	42 00 53·21	1641·7	70 51 35·03	806·1
Hanson, corner 2.	42 00 58·38	1801·2	70 51 38·36	882·6
Hanson, corner 29.	42 01 10·59	326·7	70 50 02·20	50·6
Halifax, corner 16.	42 00 46·48	1434·1	70 48 28·59	657·9
Halifax, corner 17.	42 00 36·42	1123·7	70 48 25·95	597·2
Halifax, corner 18.	41 59 48·42	1493·9	70 49 09·10	209·4
Halifax, corner 19.	41 59 04·42	136·4	70 49 24·17	556·4
Bridgewater, corner 9.	42 00 21·26	655·9	70 57 14·97	344·5
Bridgewater, corner 13.	41 58 58·33	1799·6	70 54 06·82	157·0
Bridgewater, corner 15.	41 57 58·85	1815·7	70 54 31·83	732·9
Nippenicket, peg.	41 57 45·28	1397·0	71 02 59·72	1375·2
Bridgewater, corner 5.	41 57 47·32	1459·9	71 02 59·90	1379·4
Bridgewater, corner 4.	41 57 37·21	1148·0	71 02 39·83	917·2
Fulton, peg 1.	42 00 33·84	1044·1	70 58 49·47	1138·4
Fulton, peg 2.	42 00 31·06	958·3	70 58 50·32	1157·9
Chimney corner.	42 00 32·64	1007·0	70 58 41·80	961·9
Bridgewater, corner 7.	42 00 26·82	827·5	70 58 45·41	1045·0
Bridgewater, corner 8.	42 00 39·80	1227·9	70 58 48·29	1111·3
Holmes Knoll, peg.	41 58 48·85	1507·1	70 54 38·86	894·6
Bridgewater, corner 14.	41 58 49·24	1519·2	70 54 42·07	968·5

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
203 51 19	23 51 36	Rockland waterworks	1 410·0	3·149 22
256 23 26	76 23 44	Rye Hill.	618·3	2·791 21
100 30 40	280 29 30	Hanson Congregational church	2 445·3	3·388 33
141 04 26	321 02 44	Round Top observatory.	5 543·8	3·743 81
20 14 05	200 13 36	Halifax Congregational church	2 916·8	3·464 90
133 00 29	312 56 45	South Abington waterworks.	10 539·3	4·022 81
327 05 56	147 05 57	Hanson, corner 1	75·97	1·880 63
232 00 02	52 00 10	Monponsett, peg 1	362·6	2·559 44
244 00 17	64 00 26	Hanson, corner 1.	363·8	2·560 88
273 45 02	93 45 14	Monponsett, peg 1	429·3	2·632 78
330 23 26	150 23 30	Monponsett, peg 2.	289·1	2·461 04
240 34 55	60 35 06	Monponsett, peg 3	413·5	2·616 50
257 28 58	77 29 21	Monponsett, peg 1.	807·9	2·907 35
264 19 00	84 19 13	Monponsett, peg 3	439·0	2·642 50
334 20 33	154 20 35	Monponsett, peg 4.	177·1	2·248 24
36 12 45	216 11 38	Halifax Congregational church	3 918·1	3·593 08
126 53 44	306 49 22	South Abington waterworks.	11 268·9	4·051 88
228 29 40	48 30 08	Silver Lake	1 273·6	3·105 02
310 31 53	130 32 24	Plympton, cupola.	1 406·1	3·148 03
217 43 24	37 43 50	Silver Lake	1 459·5	3·164 20
300 54 13	120 54 42	Plympton, cupola.	1 174·7	3·069 94
356 14 19	176 14 28	Plympton Congregational church	4 550·4	3·658 05
79 58 13	259 56 30	Halifax Congregational church.	3 592·5	3·555 40
348 32 22	168 32 41	Plympton Congregational church	3 248·0	3·511 62
102 54 47	282 53 14	Halifax Congregational church.	3 273·5	3·515 01
84 08 06	264 07 36	Bridgewater waterworks	1·037·3	3·015 89
181 50 46	1 50 48	East Bridgewater Unitarian church.	2 617·3	3·417 85
49 34 38	229 31 28	Titicut church	8 615·1	3·935 26
95 51 43	275 48 48	Bridgewater Unitarian church.	6 042·8	3·781 24
54 20 11	234 18 26	State Farm waterworks	4 435·3	3·646 92
175 56 38	355 56 34	Holmes Knoll.	1 800·2	3·255 33
254 36 49	74 38 29	Scotland Congregational church	3 579·8	3·553 86
317 50 41	137 50 52	Nippenicket.	587·9	2·769 32
356 16 49	176 16 49	Nippenicket, peg	63·173	1·800 53
18 48 06	198 48 04	Nippenicket	197·33	2·295 20
189 16 12	9 16 13	Fulton	187·7	2·273 55
293 23 14	113 23 47	Bridgewater waterworks.	1 245·2	3·095 23
192 45 12	12 45 13	Fulton, peg 1	88·2	1·945 39
289 21 10	109 21 44	Bridgewater waterworks.	1 232·0	3·090 60
76 02 20	256 02 14	Fulton, peg 2	202·1	2·305 57
101 54 21	281 54 16	Fulton, peg 1.	180·5	2·256 59
139 10 12	319 10 09	Fulton, peg 2	172·9	2·237 87
204 49 13	24 49 15	Chimney corner.	197·9	2·296 42
244 45 55	64 45 55	Fulton	3·341	0·523 88
187 45 46	7 45 47	Holmes Knoll	255·3	2·407 11
204 13 34	24 13 37	Holmes Knoll	264·3	2·422 13
279 10 42	99 10 44	Holmes Knoll, peg.	74·935	1·874 68

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Bridgewater, corner 6.	41 58 57·97	1788·4	71 03 16·82	387·2
Bridgewater, corner 10.	42 00 23·80	734·3	70 56 35·79	823·6
Bridgewater, corner 11.	41 59 46·96	1448·8	70 53 58·84	1354·2
Bridgewater, corner 12.	41 59 18·01	555·7	70 54 00·98	22·6
Halifax, corner 20, peg.	41 57 22·60	697·3	70 51 48·04	1106·3
Halifax, corner 20.	41 57 24·69	761·7	70 51 48·82	1124·3
Halifax, corner 21, peg.	41 57 16·02	494·3	70 51 44·24	1018·9
Halifax, corner 21.	41 57 18·15	560·0	70 51 40·95	943·1
Nicks Rock 2. 1889–90.	41 57 35·95	1109·1	70 42 59·64	1373·4
Denham's barn cupola. 1886–1889.	41 55 41·98	1295·2	70 44 48·18	1110·1
Denham.	41 55 39·23	1210·3	70 44 55·47	1278·0
Denham, peg 1.	41 55 42·12	1299·5	70 44 51·94	1196·7
Denham, peg 2.	41 55 44·43	1370·8	70 44 58·38	1345·1
Carver, corner 23.	41 55 59·87	1847·1	70 45 14·49	333·8
Carver, corner 24. 1889.	41 55 33·87	1044·9	70 45 04·38	100·9
Campello, peg 1.	42 03 49·62	1531·0	71 00 57·31	1317·6
Campello, peg 3.	42 03 14·82	457·3	71 00 45·80	1053·2
West Bridgewater, corner 4, eccentric.	42 03 17·23	531·6	71 00 35·91	825·7
West Bridgewater, corner 6.	42 03 16·94	522·7	71 00 25·26	580·8
West Bridgewater, corner 4.	42 03 17·27	532·8	71 00 36·22	832·9
Campello, peg 2.	42 03 24·66	760·9	71 00 49·06	1128·1
West Bridgewater, corner 5.	42 03 19·36	597·3	71 00 27·78	638·8
West Bridgewater, corner 7, peg.	42 03 05·25	162·0	71 00 18·03	414·6
West Bridgewater, corner 7.	42 03 04·18	129·0	71 00 23·08	530·7
Whitman, corner 4.	42 05 40·54	1250·8	70 56 50·40	1158·2
Hanson, corner 16.	42 04 38·08	1174·9	70 50 39·80	914·8
Hanson, corner 10.	42 03 42·20	1302·0	70 54 30·96	711·8
Halifax, corner 15, peg.	42 01 28·88	891·1	70 48 56·40	1297·5
Halifax, corner 15.	42 01 26·52	818·3	70 48 55·69	1281·1

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
251 18 33	71 22 05	Bridgewater waterworks	7 699·5	3·886 46
288 34 51	108 36 43	Scotland Congregational church.	4 055·6	3·608 06
157 27 33	337 27 31	Desmond	190·43	2·279 74
262 12 47	82 12 50	Union	119·48	2·077 29
179 39 46	359 39 46	Cedar	71·68	1·855 41
72 38 43	252 38 35	South Halifax Baptist church.	280·7	2·448 19
344 19 08	164 19 09	Halifax, corner 20, peg	66·83	1·825 00
59 20 43	239 20 36	South Halifax Baptist church.	290·4	2·463 00
108 34 53	288 34 43	South Halifax Baptist church	374·9	2·573 89
49 06 57	229 06 55	Halifax, corner 21, peg	100·27	2·001 17
97 07 00	277 06 48	South Halifax Baptist church.	434·5	2·637 98
69 25 50	249 23 51	Rickard Pond	4 364·9	3·639 97
100 05 04	280 04 48	Monk Hill.	556·0	2·745 05
208 22 34	28 23 31	Monk Hill	4 107·7	3·613 60
215 24 09	35 25 22	Nicks Rock 2.	4 314·8	3·634 96
209 49 16	29 50 18	Monk Hill	4 263·6	3·629 78
243 14 00	63 14 05	Denham's barn cupola.	188·3	2·274 84
42 22 31	222 22 29	Denham	120·65	2·081 52
295 42 39	115 42 43	Denham, peg 1	164·6	2·216 50
337 20 39	157 20 41	Denham.	174·0	2·240 49
322 03 46	142 03 57	Denham, peg 2	603·88	2·780 95
231 09 15	51 09 21	Denham	263·68	2·421 08
76 11 15	256 11 14	Campello South Congregational church	38·76	1·588 37
164 08 45	344 08 36	Campello South Congregational church	1 106·5	3·043 95
166 09 12	346 09 04	Campello, peg 1.	1 105·78	3·043 67
71 53 28	251 53 22	Campello, peg 3	239·28	2·378 91
151 51 10	331 50 55	Campello South Congregational church.	1 122·8	3·050 31
92 04 53	272 04 44	West Bridgewater, corner 4, eccentric	245·05	2·389 26
142 12 44	322 12 21	Campello South Congregational church.	1 264·1	3·101 77
280 02 28	100 02 28	West Bridgewater, corner 4, eccentric	7·19	0·856 93
163 21 18	343 21 11	Campello South Congregational church	794·1	2·899 87
166 09 10	346 09 04	Campello, peg 1.	793·12	2·899 34
142 12 42	322 12 21	Campello South Congregational church	1 169·63	3·068 05
322 12 42	142 12 44	West Bridgewater, corner 6.	94·44	1·975 17
155 13 49	335 13 44	West Bridgewater, corner 6	397·07	2·598 87
254 04 46	74 04 49	West Bridgewater, corner 7, peg	120·82	2·082 13
213 23 50	33 25 06	Rockland Congregational church	4 747·4	3·676 46
267 09 16	87 10 54	Rockland waterworks.	3 377·2	3·528 56
7 33 42	187 33 27	Bryantville Baptist church	3 838·6	3·584 17
92 32 50	272 28 52	South Abington waterworks.	8 155·7	3·911 46
346 22 41	166 22 42	Two-dollar tree	124·87	2·096 46
126 18 23	306 17 00	South Abington waterworks.	3 516·7	3·546 13
286 14 14	106 15 00	Silver Lake	1 659·6	3·220 01
322 26 24	142 27 14	Plympton, cupola.	2 802·6	3·447 56
167 26 24	347 26 24	Halifax, corner 15, peg	74·7	1·873 08
283 55 47	103 56 33	Silver Lake.	1 625·0	3·210 85

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Whitman, corner 5.	42 06 00·66	20·4	70 54 59·04	1356·6
West Bridgewater, corner 2.	42 02 59·14	1824·8	71 04 12;32	283·4
Norton, corner 5.	41 59 35·63	1099·3	71 06 04·82	110·9
Taunton, corner 12.	41 59 27·18	838·6	71 05 15·50	356·7
Taunton, corner 13.	41 58 56·62	1746·9	71 05 08·95	206·0
West Bridgewater, corner 3.	42 03 25·36	782·5	71 00 39·28	903·2
Old cross.	42 03 17·32	534·4	71 00 36·33	835·4
Plympton, corner 1.	41 55 39·92	1231·6	70 49 49·16	1132·7
Plympton, corner 2.	41 56 34·00	1049·0	70 50 46·10	1061·9
Plympton, corner 10.	41 58 42·31	1305·3	70 47 16·71	384·7
Hanson, corner 6.	42 01 24·04	741·7	70 53 49·60	1141·1
Hanson, corner 5.	42 01 09·26	285·7	70 53 50·54	1162·8
Hanson, corner 4.	42 01 35·39	1091·9	70 53 42·04	967·2
Hanson, corner 7.	42 01 27·42	846·0	70 53 53·31	1226·4
Hanson, corner 8.	42 01 30·00	925·6	70 53 52·48	1207·3
Hanson, corner 9.	42 01 31·29	965·4	70 54 00·80	18·4
Hanson, corner 12.	42 05 09·41	290·3	70 54 10·41	239·2
Halifax, corner 7.	42 00 10·92	336·9	70 54 00·24	5·5
Halifax, corner 8.	42 00 59·43	1833·6	70 53 53·66	1234·6
Abington, corner 3.	42 06 42·07	1298·1	70 59 56·86	1306·3
Easton, corner 1.	41 59 06·40	197·5	71 03 18·75	431·6
Rattlesnake Hill.	42 05 03·13	96·6	71 09 03·36	77·2
Centerville church spire. 1889.	42 01 19·07	588·4	71 00 41·43	953·2
North Easton waterworks.	42 04 00·39	12·0	71 06 44·08	1013·4
Bridgewater Congregational church spire. 1889.	41 59 21·53	664·2	70 58 38·26	880·6
Whitman Catholic church spire. 1889.	42 04 41·61	1283·8	70 56 12·90	296·5
Harris, south.	42 06 43·52	1342·8	70 59 56·81	1305·2
South Raynham Baptist church spire. 1890.	41 53 52·23	1611·4	71 00 13·15	303·1

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
332 08 42	152 09 07	Rye Hill	1 807·4	3·257 06
44 58 50	224 57 46	South Abington waterworks.	3 096·1	3·490 81
226 00 48	46 02 47	Brockton First Congregational church.	5 671·5	3·753 70
252 00 50	72 05 57	South Abington waterworks.	11 070·1	4·044 15
243 36 08	63 38 33	Cochesett Methodist church	5 574·9	3·746 24
287 37 52	107 41 36	Scotland Congregational church.	8 093·6	3·908 14
234 37 59	54 39 51	Cochesett Methodist church	4 731·7	3·675 02
288 25 36	108 28 47	Scotland Congregational church.	6 933·3	3·840 94
170 25 11	350 24 25	North Easton high school	9 378·0	3·972 11
225 12 22	45 14 10	Cochesett Methodist church.	5 225·0	3·718 09
84 30 16	264 30 10	Campello, peg 2	225·81	2·353 74
148 32 38	328 32 25	Campello South Congregational church.	866·6	2·937 80
285 55 28	105 55 28	West Bridgewater, corner 4, eccentric	10·06	1·002 53
159 37 19	339 36 03	Halifax Congregational church	7 510·7	3·875 68
247 28 52	67 33 10	Monk Hill.	9 617·0	3·983 04
166 20 48	346 20 10	Halifax Congregational church	5 528·3	3·742 59
240 03 47	60 05 00	Plympton Congregational church.	2 922·0	3·465 68
42 29 10	222 28 03	Plympton Congregational church	3 390·9	3·530 32
103 01 00	282 58 02	Halifax Congregational church.	6 286·2	3·798 39
98 20 36	278 18 21	East Bridgewater Unitarian church	4 689·5	3·671 13
189 36 19	9 36 20	Harding.	245·92	2·390 79
103 49 18	283 47 03	East Bridgewater Unitarian church	4 756·2	3·677 26
182 41 54	2 41 55	Hanson, corner 6.	456·28	2·659 23
50 57 55	230 57 51	Harding	171·16	2·233 40
222 24 36	42 24 40	Harding	187·17	2·272 24
241 16 41	61 16 44	Harding	122·19	2·087 03
266 24 04	86 24 13	Harding	299·21	2·475 98
86 30 02	266 29 54	Rye Hill	273·57	2·437 06
203 53 41	23 53 49	Washburn	663·85	2·822 07
107 34 07	287 31 55	East Bridgewater Unitarian church	4 769·1	3·678 44
193 18 25	13 18 27	Hanson, corner 5.	311·75	2·493 81
182 22 27	2 22 27	Harris	62·76	1·797 67
222 30 54	42 32 38	Howard Institute	5 258·5	3·720 86
253 15 43	73 19 17	Bridgewater waterworks.	7 665·0	3·884 51
269 21 40	89 26 54	Brockton First Congregational church	10 770·1	4·032 22
281 30 45	101 36 09	Campello South Congregational church.	11 366·3	4·055 62
357 17 23	177 17 31	Scotland Congregational church	5 653·5	3·752 32
73 44 11	253 43 00	Cochesett Methodist church.	2 549·5	3·406 45
254 49 55	74 53 35	Brockton First Congregational church	7 841·9	3·894 42
313 58 27	134 01 19	Cochesett Methodist church.	8 193·7	3·913 48
204 09 48	24 10 46	East Bridgewater Unitarian church.	4 887·1	3·689 05
207 00 04	27 00 30	Bridgewater waterworks.	1 949·1	3·289 84
16 49 17	196 48 05	Bridgewater waterworks	8 502·4	3·929 54
116 52 37	296 52 23	South Abington waterworks.	550·2	2·740 50
184 22 17	4 22 17	Harris	17·80	1·250 43
274 50 07	94 53 49	Middleboro town hall	7 675·0	3·885 08
352 59 54	173 00 13	Pigeon Hill.	5 408·4	3·733 07

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Split Rock.	41 58 45·26	1396·4	71 04 36·17	832·8
Banana.	41 53 49·40	1524·1	70 59 38·26	881·9
Pineapple.	41 53 27·09	835·8	70 59 37·49	864·3
Spruce.	41 53 03·40	104·9	70 59 53·40	1231·2
Spruce, south base.	41 52 59·08	1822·8	71 00 00·21	4·8
Spruce, north base.	41 53 01·82	56·2	71 00 01·77	40·8
Ned Deane.	41 53 51·55	1590·5	71 00 59·22	1365·1
Tomasso.	41 53 13·74	423·9	71 00 17·54	404·4
High pine.	41 53 28·96	893·5	71 00 25·68	592·0
Mann, peg	41 53 06·53	201·5	70 59 42·98	991·0
Corn, peg.	41 54 02·01	62·0	71 00 14·35	330·8
Taunton, corner 32.	41 53 24·34	750·9	71 00 44·52	1026·4
Deane, peg.	41 53 37·49	1156·7	71 00 56·19	1295·3
Taunton, corner 46.	41 53 48·99	1511·5	70 59 59·48	1371·1
Le Baron.	41 51 57·69	1779·9	70 58 36·53	842·5
Williams.	41 51 07·23	223·1	70 59 13·82	318·8
Precinct Congregational church spire. 1890.	41 51 22·07	680·9	70 58 50·64	1168·1
Lakeville, corner 26.	41 54 20·09	619·8	70 59 15·54	358·2
Lakeville, corner 14.	41 51 06·93	213·8	70 59 18·08	417·2
Lakeville, corner 17.	41 51 14·44	445·5	70 59 11·93	275·3
Precinct, peg 6.	41 51 04·49	138·5	70 59 20·98	484·0
Precinct, peg 1.	41 50 52·93	1633·0	70 59 41·22	950·9
Precinct, peg 2.	41 50 56·30	1737·0	70 59 35·11	810·0
Precinct, peg 3.	41 50 50·35	1553·4	70 59 45·66	1053·3

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
166 26 32	346 25 25	North Easton high school	9 873·0	3·994 45
216 13 41	36 15 07	Cochesett Methodist church.	4 997·7	3·698 77
1 34 44	181 34 40	Pigeon Hill	5 282·5	3·722 84
118 59 08	298 55 02	Prospect Taunton.	9 678·5	3·985 81
268 55 34	88 58 52	Middleboro town hall	6 827·0	3·834 23
2 02 17	182 02 12	Pigeon Hill.	4 595·0	3·662 29
163 11 08	343 10 55	South Raynham Baptist church	1 573·7	3·196 93
206 39 24	26 39 35	Pineapple.	817·7	2·912 61
211 13 11	31 13 26	Pineapple	1 010·6	3·004 57
229 38 12	49 38 17	Spruce.	206·0	2·313 83
255 46 18	75 46 24	Spruce	199·0	2·298 93
336 55 45	156 55 46	Spruce, south base.	91·826	1·962 97
268 52 01	88 52 32	South Raynham Baptist church	1 062·2	3·026 19
342 08 55	162 09 45	Pigeon Hill.	5 617·2	3·749 52
266 00 33	86 04 17	Middleboro town hall	7 768·0	3·890 31
349 41 20	169 41 42	Pigeon Hill.	4 248·9	3·628 28
132 02 46	312 02 24	Ned Deane	1 041·0	3·017 44
201 55 03	21 55 11	South Raynham Baptist church.	774·0	2·888 75
153 44 44	333 44 24	South Raynham Baptist church	1 572·2	3·196 50
191 17 24	11 17 28	Pineapple.	646·8	2·810 74
295 03 48	115 04 12	Banana	918·4	2·963 05
354 44 42	174 44 43	South Raynham Baptist church.	303·0	2·481 44
158 01 26	338 01 16	Ned Deane	905·2	2·956 76
220 02 55	40 03 16	South Raynham Baptist church.	1 124·0	3·050 76
170 51 49	350 51 47	Ned Deane	439·6	2·643 05
290 30 29	110 30 49	High pine.	750·9	2·875 57
107 34 54	287 34 45	South Raynham Baptist church	330·6	2·519 33
139 30 24	319 30 14	Corn, peg.	528·1	2·722 70
129 27 17	309 22 30	Prospect Taunton	12 806·5	4·107 43
241 58 35	62 01 12	Middleboro town hall.	6 140·2	3·788 18
137 02 00	316 57 38	Prospect Taunton	13 247·7	4·122 14
234 43 22	54 46 24	Middleboro town hall.	7 692·4	3·886 06
134 00 19	313 55 42	Prospect Taunton	13 295·4	4·123 70
235 15 38	55 18 24	Middleboro town hall.	6 992·0	3·844 60
283 25 02	103 28 05	Middleboro town hall	6 497·1	3·812 72
6 08 17	186 07 58	Pigeon Hill.	6 263·1	3·796 79
233 33 49	53 34 07	Precinct Congregational church	786·7	2·895 83
264 42 03	84 42 06	Williams.	98·8	1·994 86
11 05 46	191 05 45	Williams	226·6	2·355 31
31 31 33	211 31 29	Lakeville, corner 14.	271·6	2·433 93
221 33 34	41 33 36	Lakeville, corner 14	100·80	2·003 46
242 54 19	62 54 24	Williams.	185·6	2·268 69
154 46 46	334 46 44	Pigeon Hill	181·5	2·258 99
53 35 36	233 35 32	Precinct, peg 1	175·06	2·243 19
105 27 20	285 27 14	Pigeon Hill.	226·4	2·354 95
232 11 38	52 11 41	Precinct, peg 1	129·80	2·113 28
232 59 47	52 59 54	Precinct, peg 2.	304·8	2·484 07

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Precinct, peg 4.	41 50 58·11	1792·8	70 59 31·15	949·2
Precinct, peg 5.	41 51 00·05	1·5	70 59 27·77	640·6
Lakeville, corner 12.	41 50 59·94	1849·3	70 59 27·77	640·6
Lakeville, corner 15.	41 51 07·90	243·7	70 59 17·19	396·6
Lakeville, corner 16.	41 51 08·12	250·5	70 59 17·60	406·0
Precinct, peg e.	41 51 19·74	609·0	70 59 00·05	1·2
Precinct, peg f.	41 51 13·41	413·7	70 59 07·04	162·4
Precinct, peg c.	41 51 21·38	659·6	70 58 51·09	1178·4
Precinct, peg d.	41 51 21·94	676·9	70 58 53·00	1222·5
Precinct, peg b.	41 51 22·45	692·6	70 58 49·46	1140·8
Pigeon, peg 1.	41 50 35·66	1100·2	71 00 06·27	144·7
Pigeon, peg 2.	41 50 43·99	1357·2	71 00 08·78	202·6
Middleboro waterworks.	41 53 41·63	1284·4	70 54 58·30	1343·9
Leonard.	41 53 46·58	1437·1	70 57 54·50	1256·3
Leonard, peg 1.	41 53 47·29	1459·0	70 57 46·38	1069·1
Leonard, peg 2.	41 53 52·56	1621·6	70 57 46·08	1062·2
Lakeville, corner 27	41 53 46·61	1438·0	70 57 48·56	1119·4
Curve.	41 52 40·10	1237·2	70 55 06·08	140·2
Long Point.	41 49 04·69	144·7	70 53 58·00	1338·6
Long Point, peg.	41 48 56·56	1745·0	70 54 00·46	10·6
Lakeville, corner 30.	41 48 54·05	1667·6	70 53 56·87	1312·6
Shaw.	41 51 41·37	1276·4	70 48 18·79	433·4
Carver, peg 12.	41 51 38·69	1193·7	70 48 01·35	31·1
Carver, peg 11.	41 51 39·49	1218·4	70 47 52·56	1212·2
Carver, peg 9.	41 51 48·35	1491·7	70 48 00·46	10·6

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
58 29 39	238 29 36	Precinct, peg 2	107·09	2·029 73
90 48 44	270 48 35	Pigeon Hill.	309·6	2·490 77
52 30 31	232 30 29	Precinct, peg 4	98·32	1·992 64
228 52 01	48 52 06	Precinct, peg 6.	208·04	2·318 14
54 04 15	234 04 13	Precinct, peg 4	96·4	1·984 19
178 48 01	358 48 01	Precinct, peg 5.	3·26	0·513 40
285 00 51	105 00 53	Williams	80·5	1·905 77
34 33 46	214 33 45	Lakeville, corner 14.	36·4	1·561 16
287 31 35	107 31 38	Williams	91·5	1·961 32
16 56 17	196 56 17	Lakeville, corner 14.	38·3	1·583 63
39 27 54	219 27 45	Williams	499·7	2·698 73
59 11 24	239 11 16	Lakeville, corner 17.	319·0	2·503 83
105 44 07	285 44 04	Lakeville, corner 17	117·07	2·068 45
219 34 36	39 34 41	Precinct, peg e.	253·2	2·403 47
76 09 58	256 09 52	Precinct, peg e	212·8	2·327 88
205 42 38	25 42 38	Precinct Congregational church.	23·8	1·376 88
291 13 48	111 13 49	Precinct, peg c	47·10	1·673 03
67 20 12	247 20 07	Precinct, peg e.	176·3	2·246 24
48 31 49	228 31 48	Precinct, peg c	50·12	1·700 05
66 40 59	246 40 58	Precinct Congregational church.	29·6	1·471 99
215 41 02	35 41 16	Pigeon Hill	858·2	2·933 59
231 46 30	51 46 46	Pigeon Hill	711·0	2·851 87
347 17 52	167 17 54	Pigeon, peg 1.	263·59	2·420 93
61 16 50	241 08 20	Richmond Hill	20 137·2	4·304 00
108 19 27	288 12 14	Prospect Taunton.	15 712·7	4·196 25
276 05 51	96 08 00	Middleboro town hall	4 476·6	3·650 95
16 05 37	196 05 09	Le Baron.	3 496·6	3·543 64
83 22 11	263 22 06	Leonard	188·5	2·275 28
2 24 14	182 24 14	Leonard, peg 1	162·84	2·211 76
46 27 09	226 27 03	Leonard.	267·7	2·427 71
197 16 18	17 16 20	Leonard, peg 2	192·2	2·283 76
247 28 12	67 28 13	Leonard, peg 1.	54·4	1·735 50
199 51 28	19 51 44	Middleboro town hall	1 674·1	3·223 77
218 40 48	38 42 08	Middleboro Green church.	4 397·3	3·643 19
248 13 55	68 14 28	Pasture	1 233·6	3·091 16
192 48 10	12 48 12	Long Point	257·0	2·409 97
239 30 30	59 31 05	Pasture.	1 395·5	3·144 72
175 27 45	355 27 44	Long Point	329·4	2·517 70
234 56 06	54 56 38	Pasture.	1 367·8	3·136 03
211 38 20	31 41 37	Monk Hill	12 967·9	4·112 87
247 31 46	67 40 20	Manomet.	19 215·9	4·283 66
101 35 52	281 35 40	Shaw	410·7	2·613 52
83 04 38	263 04 32	Carver, peg 12	204·29	2·310 25
95 28 15	275 27 57	Shaw.	607·9	2·783 82
3 57 07	183 57 06	Carver, peg 12	298·6	2·475 04
63 01 11	243 00 59	Shaw.	474·5	2·676 27

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Carver, corner 13.	41 51 44·39	1369·5	70 48 07·37	170·0
Carver, corner 12.	41 51 40·45	1248·0	70 47 58·20	1342·4
Carver, peg 10.	41 51 52·26	1612·4	70 48 10·97	253·0
Carver, peg 8.	41 52 03·23	99·7	70 48 18·36	423·4
Carver, peg 7.	41 51 59·15	1824·9	70 48 00·35	8·1
Carver, peg 6.	41 52 06·42	198·1	70 48 05·52	127·3
Carver, peg 5.	41 52 09·28	286·3	70 47 59·91	1381·7
Carver, peg 4.	41 52 15·59	481·0	70 48 07·62	175·7
Carver, peg 3.	41 52 16·63	513·1	70 48 03·88	89·5
Carver, peg 2.	41 52 27·27	841·3	70 48 12·32	284·1
Carver, peg 1.	41 52 27·24	840·4	70 48 09·35	215·6
Carver, corner 17.	41 52 31·29	965·4	70 48 10·68	246·3
Carver, peg 21.	41 52 02·02	62·3	70 48 34·92	805·4
Carver, peg 22.	41 52 04·08	125·9	70 48 33·50	772·6
Carver, peg 23.	41 52 05·03	155·2	70 48 39·67	914·9
Carver, peg 24.	41 52 11·30	348·6	70 48 43·35	999·7
Carver, peg 25.	41 52 11·15	344·0	70 48 47·46	1094·5
Carver, peg 13.	41 51 41·90	1292·7	70 47 44·01	1015·0
Carver, peg 14.	41 51 34·52	1065·0	70 47 37·66	868·7
Carver, peg 15.	41 51 29·76	918·2	70 47 40·42	932·3
Carver, peg 16.	41 51 17·88	551·6	70 47 34·13	787·4
Carver, peg 17.	41 51 16·58	511·5	70 47 37·63	868·1
Carver, peg 18.	41 51 05·74	177·1	70 47 34·47	795·2
Carver, peg 19.	41 51 03·03	93·5	70 47 40·30	929·6

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
321 40 58	141 41 02	Carver, peg 12	224·1	2·350 44
70 29 56	250 29 48	Shaw.	279·4	2·446 21
53 19 27	233 19 25	Carver, peg 12	90·44	1·956 38
93 26 26	273 26 12	Shaw	475·7	2·677 34
332 04 00	152 04 06	Carver, peg 12	473·8	2·675 56
28 13 42	208 13 37	Shaw.	381·4	2·581 34
333 14 50	153 14 55	Carver, peg 10	378·9	2·578 47
0 50 08	180 50 08	Shaw.	674·4	2·828 91
0 25 27	180 25 27	Carver, peg 9	333·3	2·522 80
37 47 24	217 47 12	Shaw.	694·2	2·841 46
332 00 18	152 00 21	Carver, peg 7	254·1	2·405 08
21 36 04	201 35 55	Shaw.	831·4	2·919 79
1 51 40	181 51 40	Carver, peg 7	312·7	2·495 18
55 44 04	235 44 00	Carver, peg 6.	156·6	2·194 88
317 34 57	137 35 02	Carver, peg 5	263·6	2·420 87
350 18 01	170 18 02	Carver, peg 6.	286·9	2·457 67
338 00 46	158 00 49	Carver, peg 5	244·5	2·388 35
69 31 43	249 31 41	Carver, peg 4.	92·0	1·963 92
329 20 34	149 20 40	Carver, peg 3	381·6	2·581 64
343 16 00	163 16 03	Carver, peg 4.	376·4	2·575 67
353 40 26	173 40 27	Carver, peg 4	361·7	2·558 34
90 49 02	270 49 00	Carver, peg 2.	68·53	1·835 85
346 14 56	166 14 57	Carver, peg 1	128·7	2·109 57
17 00 09	197 00 08	Carver, peg 2.	129·7	2·112 94
264 26 06	84 26 17	Carver, peg 8	383·8	2·584 09
274 19 21	94 19 31	Carver, peg 8	350·2	2·544 31
27 15 43	207 15 42	Carver, peg 21.	71·56	1·854 66
281 35 42	101 35 46	Carver, peg 22	145·3	2·162 16
310 16 38	130 16 41	Carver, peg 21.	143·6	2·157 02
336 17 48	156 17 50	Carver, peg 23	211·2	2·324 79
267 11 51	87 11 54	Carver, peg 24	95·00	1·977 71
316 23 40	136 23 45	Carver, peg 23.	260·7	2·416 16
69 18 40	249 18 34	Carver, peg 11	210·8	2·323 77
117 39 09	297 38 58	Carver, peg 9.	428·3	2·631 76
114 02 50	294 02 40	Carver, peg 11	376·3	2·575 53
147 15 29	327 15 25	Carver, peg 13.	270·8	2·432 68
167 32 42	347 32 40	Carver, peg 13	383·5	2·583 78
203 29 33	23 29 35	Carver, peg 14.	160·0	2·204 00
158 23 27	338 23 23	Carver, peg 15	394·2	2·595 71
170 59 11	350 59 09	Carver, peg 14.	519·6	2·715 67
171 00 46	351 00 44	Carver, peg 15	411·8	2·614 67
243 32 21	63 32 23	Carver, peg 16.	90·3	1·955 74
167 40 21	347 40 19	Carver, peg 17	342·3	2·534 39
181 11 19	1 11 19	Carver, peg 16.	374·7	2·573 70
188 23 42	8 23 44	Carver, peg 17	422·5	2·625 79
238 12 19	58 12 23	Carver, peg 18.	158·5	2·200 14

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Carver, corner 9.	41 51 10·40	320·9	70 47 38·97	899·0
Carver, peg 18½.	41 50 56·98	1758·0	70 47 39·69	915·6
Carver, peg 20.	41 50 51·47	1588·0	70 47 31·54	727·6
Taunton, corner 14.	41 58 49·22	1518·6	71 05 01·21	27·9
Taunton, corner 15.	41 58 47·78	1474·2	71 04 58·53	1347·5
Taunton, corner 16.	41 58 33·74	1041·0	71 04 41·84	963·3
Taunton, corner 31.	41 53 31·71	978·3	71 00 48·35	1114·6
Taunton, corner 33.	41 53 26·02	802·8	71 00 32·80	756·1
Taunton, corner 34.	41 53 05·82	179·6	71 00 22·18	511·4
Taunton, corner 35.	41 53 06·30	194·4	71 00 14·21	327·7
Taunton, corner 36.	41 52 59·05	1821·8	71 00 14·72	339·4
Taunton, corner 37.	41 53 02·36	72·8	71 00 02·93	67·6
Taunton, corner 38.	41 53 03·44	106·1	70 59 53·59	1235·6
Taunton, corner 39.	41 53 04·92	151·8	70 59 49·87	1149·8
Taunton, corner 40.	41 53 06·57	202·7	70 59 43·71	1007·8
Taunton, corner 41.	41 53 23·24	717·0	70 59 33·38	769·5
Taunton, corner 42.	41 53 28·21	870·3	70 59 39·18	903·2
Taunton, corner 43.	41 53 32·80	1012·0	70 59 39·48	910·1
Taunton, corner 44.	41 53 39·84	1229·2	70 59 38·84	895·4
Taunton, corner 45.	41 53 49·51	1527·5	70 59 41·80	963·5
Lakeville, corner 5.	41 50 35·07	1082·0	71 00 06·88	158·7
Lakeville, corner 6.	41 50 35·54	1096·5	71 00 06·26	144·4
Lakeville, corner 7.	41 50 48·10	1484·0	70 59 48·45	1117·7
Lakeville, corner 8.	41 50 48·83	1506·5	70 59 47·02	1084·7
Lakeville, corner 9.	41 50 50·21	1549·1	70 59 45·41	1047·6
Lakeville, corner 10.	41 50 56·10	1730·8	70 59 35·32	814·8
Lakeville, corner 11.	41 50 58·55	1806·4	70 59 30·13	695·1
Lakeville, corner 13.	41 51 04·55	140·4	70 59 20·79	479·6
Lakeville, corner 18.	41 51 16·20	499·9	70 59 08·19	188·9
Lakeville, corner 19.	41 51 19·73	608·7	70 59 00·14	3·2
Lakeville, corner 20.	41 51 23·49	724·7	70 58 49·08	1132·1
Lakeville, corner 21.	41 51 26·27	810·5	70 58 43·68	1007·5
Lakeville, corner 22.	41 51 28·93	892·6	70 58 39·87	919·6
Lakeville, corner 23.	41 51 31·41	969·1	70 58 37·08	855·3
Precinct, peg a.	41 51 37·66	1161·9	70 58 28·75	663·2
Lakeville, corner 24.	41 51 39·35	1214·0	70 58 27·15	626·2
Lakeville, corner 24½.	41 52 24·96	770·1	70 58 38·51	888·0
Lakeville, corner 25.	41 52 34·45	1062·9	70 58 40·92	943·6
Lakeville, corner 28.	41 52 44·67	1378·2	70 55 10·91	251·6
Lakeville, corner 29	41 52 38·03	1173·3	70 55 02·08	48·0
Carver, peg 7½.	41 51 58·52	1805·5	70 48 01·81	41·7
Carver, peg 11½.	41 51 39·63	1222·7	70 47 51·70	1192·4
Carver, peg 26.	41 52 13·89	428·5	70 48 51·57	1189·2
Carver, corner 14.	41 51 57·43	1771·9	70 48 10·09	232·7

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
324 10 03	144 10 06	Carver, peg 18	177·3	2·248 80
7 44 58	187 44 57	Carver, peg 19.	229·4	2·360 59
175 37 45	355 37 45	Carver, peg 19	187·3	2·272 64
204 01 12	24 01 15	Carver, peg 18.	296·0	2·471 23
150 25 10	330 25 04	Carver, peg 19	410·0	2·612 76
171 15 47	351 15 45	Carver, peg 18.	445·3	2·648 64
281 56 58	101 57 15	Split Rock	589·14	2·770 22
278 35 52	98 36 07	Split Rock	520·64	2·716 54
204 10 43	20 10 47	Split Rock	378·53	2·578 10
134 35 32	314 35 27	Deane, peg	253·91	2·404 68
241 02 21	61 02 26	High pine	187·55	2·273 11
203 39 20	23 39 23	Tomasso	266·78	2·426 15
161 31 28	341 31 26	Tomasso	241·92	2·383 67
269 48 58	89 49 08	Spruce, south base	334·51	2·524 41
301 41 15	121 41 16	Spruce, north base	31·465	1·497 83
286 45 13	106 45 13	Spruce	4·568	0·659 73
60 05 25	240 05 23	Spruce	93·789	1·972 15
274 41 09	94 41 09	Mann, peg	16·896	1·227 78
141 24 49	321 24 46	Pineapple	151·95	2·181 69
311 40 47	131 40 48	Pineapple	52·08	1·716 64
345 22 40	165 22 41	Pineapple	181·91	2·259 85
182 34 56	2 34 56	Banana	295·19	2·470 10
272 24 17	92 24 19	Banana	81·62	1·911 79
217 54 42	37 54 42	Pigeon, peg 1	23·03	1·362 37
176 13 32	356 13 32	Pigeon, peg 1	3·58	0·553 68
222 50 06	42 50 08	Precinct, peg 3	94·58	1·975 80
213 46 07	33 46 08	Precinct, peg 3	56·30	1·750 51
127 16 28	307 16 28	Precinct, peg 3	7·21	0·857 70
217 50 26	37 50 26	Precinct, peg 2	7·76	0·889 70
59 56 35	239 56 34	Precinct, peg 4	27·30	1·436 13
68 21 11	248 21 11	Precinct, peg 6	4·63	0·665 29
342 54 14	162 54 15	Precinct, peg f	90·05	1·954 46
263 55 32	83 55 32	Precinct, peg e	2·04	0·308 79
15 08 59	195 08 59	Precinct, peg b	33·34	1·523 03
48 31 53	228 31 49	Precinct, peg b	178·04	2·250 52
46 59 06	226 59 03	Lakeville, corner 21	120·25	2·080 10
40 04 28	220 04 26	Lakeville, corner 22	99·95	1·999 80
44 54 04	224 53 58	Lakeville, corner 23	272·32	2·435 08
35 18 20	215 18 19	Precinct, peg a	63·76	1·804 58
356 53 37	176 53 38	Le Baron	842·62	2·925 63
354 54 12	174 54 15	Le Baron	138·68	3·056 40
321 40 54	141 40 57	Curve	179·74	2·254 64
124 37 56	304 37 53	Curve	112·20	2·050 01
239 53 16	59 53 17	Carver, peg 7	38·94	1·590 38
77 54 26	257 54 25	Carver, peg 11	20·35	1·308 53
311 43 05	131 43 08	Carver, peg 25	127·00	2·103 82
260 00 05	80 00 06	Carver, peg 7½	194·00	2·287 79

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Oak tree.	41 51 38·24	1179·8	70 48 01·24	28·6
Carver, corner 5.	41 50 46·61	1438·0	70 47 27·58	636·3
Carver, corner 6.	41 50 46·82	1444·5	70 47 29·57	682·2
Carver, corner 7.	41 50 57·37	1770·0	70 47 41·86	965·6
Carver, corner 8.	41 51 03·17	97·8	70 47 43·24	997·4
Carver, corner 10.	41 51 26·38	813·9	70 47 39·92	920·8
Carver, corner 11.	41 51 40·70	1255·7	70 47 51·70	1177·9
Carver, corner 15.	41 52 01·28	39·5	70 48 35·62	821·5
Carver, corner 16.	41 52 13·66	421·4	70 48 54·80	1263·7
Turner flagstaff. 1890.	41 50 23·75	732·7	70 41 39·92	921·0
Turner's barn cupola.	41 50 20·46	631·2	70 41 34·91	805·4
Turner flagstaff, east base.	41 50 25·35	782·1	70 41 38·61	890·8
Turner flagstaff, west base.	41 50 25·04	772·5	70 41 39·37	908·4
Turner's barn gable.	41 50 20·19	622·9	70 41 34·89	805·0
Turner observatory, peg 1.	41 50 24·00	740·4	70 41 37·40	862·9
Turner observatory, peg 2.	41 50 20·49	632·2	70 41 28·28	652·5
Turner observatory.	41 50 37·55	1158·5	70 41 43·85	1011·6
Carver, corner 24. 1890.	41 50 56·28	1736·4	70 41 02·70	62·3
Trout.	41 56 46·32	1429·1	70 46 23·93	551·2
Trout, peg 1.	41 56 43·34	1337·1	70 46 18·99	437·5
Carver, corner 20.	41 56 46·34	1429·7	70 46 19·94	459·4
Stoughton Congregational church spire. 1890.	42 07 23·70	731·2	71 06 08·09	185·8
Drake jr.	42 06 12·52	386·3	71 04 45·68	1049·6
Savery.	42 06 28·04	865·1	71 03 35·00	804·2
West.	42 07 24·87	767·3	71 00 07·11	163·3
Curtis.	42 06 56·77	1751·6	71 02 12·26	282·1
Brown.	42 05 20·26	625·1	70 58 48·48	1114·2
Drake.	42 06 15·56	480·1	71 04 44·67	1026·4
Brown, peg 1.	42 05 19·91	614·3	70 58 39·27	902·5

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
167 56 52	347 56 52	Carver, peg 12	14·20	1·152 40
148 37 50	328 37 47	Carver, peg 20	175·67	2·244 69
162 26 33	342 26 32	Carver, peg 20	150·63	2·177 90
283 22 24	103 22 25	Carver, peg 18½	51·55	1·712 21
273 41 55	93 41 57	Carver, peg 19	68·08	1·833 00
173 42 48	353 42 48	Carver, peg 15	104·83	2·020 49
359 52 16	179 52 16	Carver, peg 11½	33·09	1·519 73
215 28 06	35 28 06	Carver, peg 21	27·92	1·445 91
264 36 33	84 36 35	Carver, peg 26	74·85	1·874 21
221 23 01	41 27 09	Manomet	12 957·8	4·112 53
323 48 06	143 53 14	Pine Hill.	18 058·8	4·256 69
220 42 17	40 46 22	Manomet	12 958·4	4·112 55
323 54 34	143 59 39	Pine Hill.	17 908·9	4·253 07
330 24 38	150 24 40	Turner's barn cupola	173·0	2·238 08
31 29 04	211 29 03	Turner flagstaff.	58·0	1·763 52
241 41 52	61 41 53	Turner flagstaff, east base	20·02	1·301 46
17 35 07	197 35 07	Turner flagstaff.	41·9	1·622 63
133 22 29	313 22 26	Turner flagstaff	159·8	2·203 46
151 40 07	331 40 05	Turner flagstaff, east base.	180·9	2·257 32
332 07 34	152 07 36	Turner's barn cupola	123·2	2·090 52
82 15 20	262 15 18	Turner flagstaff.	58·7	1·768 45
110 29 44	290 29 36	Turner flagstaff	286·8	2·457 57
117 13 48	297 13 42	Turner observatory, peg 1.	236·7	2·374 26
325 40 29	145 40 39	Turner observatory, peg 2	637·0	2·804 14
340 24 28	160 24 32	Turner observatory, peg 1.	443·6	2·647 04
28 07 25	208 07 08	Turner observatory, peg 2	1 252·0	3·097 61
58 39 38	238 39 11	Turner observatory.	1 111·5	3·045 90
62 20 00	242 14 28	Middleboro town hall	12 949·4	4·112 25
124 14 24	304 10 51	Halifax Congregational church.	8 878·5	3·948 34
128 56 29	308 56 26	Trout	146·3	2·165 16
346 39 06	166 39 07	Trout, peg 1	94·99	1·977 67
89 41 46	269 41 43	Trout.	91·8	1·963 03
302 03 21	122 06 37	Brockton First Congregational church	7 954·4	3·900 61
1 48 04	181 47 58	North Easton high school.	6 401·2	3·806 26
26 30 43	206 29 42	North Easton high school	4 695·5	3·671 68
139 15 02	319 14 07	Stoughton Congregational church.	2 899·7	3·462 36
287 23 16	107 27 57	South Abington waterworks	10 134·4	4·005 80
314 34 20	134 38 36	East Bridgewater Unitarian church.	12 389·7	4·093 06
55 22 05	235 17 40	North Easton waterworks	11 092·0	4·045 01
108 33 42	288 32 08	Avon Baptist church.	3 400·5	3·531 54
169 49 08	349 48 58	Avon Baptist church	1 980·5	3·296 77
219 48 08	39 49 58	Holbrook waterworks.	5 899·2	3·770 79
286 59 37	107 01 07	South Abington waterworks	3 226·5	3·508 73
353 09 20	173 09 53	Bridgewater waterworks.	9 398·1	3·973 04
13 55 23	193 55 22	Drake jr	96·49	1·984 46
92 54 41	272 54 45	Brown	211·8	2·326 00

CAPE COD BAY TO BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Brown, peg 2.	42 05 17·21	531·0	70 58 44·75	1028·5
Whitman, corner 3.	42 05 14·12	435·7	70 58 37·28	856·8
Whitman, corner 2.	42 04 16·45	507·6	70 58 32·61	749·6
Brockton, corner 15.	42 04 08·10	249·9	70 58 52·62	1209·7
Brockton, corner 16.	42 03 34·36	1060·2	70 59 25·49	586·1
West Bridgewater, corner 8.	42 03 11·59	357·6	70 59 20·42	469·6
Brockton city farm barn cupola.	42 04 23·70	731·2	70 59 40·23	924·8
S. H. Hill.	42 00 14·69	453·2	70 53 07·85	180·6
Hanson, corner 3.	42 01 15·70	484·4	70 51 53·73	1236·1
Abington, corner 6.	42 09 05·16	159·2	70 56 28·54	655·3
Brockton, corner 7.	42 05 44·15	1362·2	71 04 51·52	1183·9
Brockton, corner 8.	42 06 11·63	358·8	71 03 42·51	976·8
Avon–Stoughton, corner 2.	42 06 25·28	780·0	71 03 38·99	896·2
Abington, corner 4, (1835).	42 07 35·72	1102·1	71 00 08·89	204·2
Abington, corner 4, (1862).	42 07 38·52	1188·5	71 00 09·53	218·9
Avon–Brockton, road stone.	42 06 50·17	1547·9	71 02 05·23	120·1

BOSTON BAY.

Nahant. 1847.	42 25 04·764	147·0	70 54 18·232	416·8
Dorchester Heights. 1846–47.	42 20 03·428	105·8	71 02 35·910	822·1
Deer Island. 1846.	42 21 01·282	39·6	70 57 30·989	709·3
Governor Island. 1846.	42 21 08·312	256·5	71 00 39·030	893·3
Boston State House dome. (C. & G. S. & Bdn.) 1834–1890.	42 21 29·596	913·2	71 03 51·040	1168·1
Long Island Head light-house. 1846–1860.	42 19 48·132	1485·0	70 57 24·123	552·3
Powderhorn 2. 1877–78.	42 24 04·564	140·8	71 01 52·055	1190·5
Blind Asylum. 1861–1878.	42 20 07·037	217·1	71 02 32·861	752·3

CAPE COD BAY TO BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
137 38 32	317 38 30	Brown	127·2	2·104 53
236 31 07	56 31 11	Brown, peg 1.	150·89	2·178 65
119 01 20	299 01 15	Brown, peg 2	196·4	2·293 10
165 35 20	345 35 19	Brown, peg 1.	184·3	2·265 55
112 37 20	292 35 31	Brockton First Congregational church	4 037·8	3·606 14
249 20 56	69 22 15	South Abington waterworks.	2 907·6	3·463 53
248 01 35	68 03 08	South Abington waterworks	3 429·6	3·535 24
331 59 56	152 01 04	East Bridgewater Unitarian church.	4 963·9	3·695 82
239 25 51	59 27 46	South Abington waterworks	4 571·3	3·660 04
317 16 05	137 17 35	East Bridgewater Unitarian church.	4 548·7	3·657 89
231 36 02	51 37 53	South Abington waterworks	4 873·6	3·687 85
311 37 09	131 38 35	East Bridgewater Unitarian church.	3 972·9	3·599 11
259 21 57	79 24 02	South Abington waterworks	4 349·5	3·638 44
324 50 25	144 52 05	East Bridgewater Unitarian church.	5 948·9	3·774 44
76 43 49	256 40 15	Bridgewater Unitarian church	7 570·8	3·879 14
150 47 28	330 45 10	South Abington waterworks.	9 722·1	3·987 76
42 11 25	222 10 35	S. H. Hill	2 540·2	3·404 87
135 41 16	315 38 08	South Abington waterworks.	9 230·6	3·965 23
0 57 10	180 57 06	South Abington waterworks	7 883·9	3·896 74
97 54 17	277 52 17	Holbrook waterworks.	4 154·8	3·618 55
188 43 05	8 43 09	Drake jr	885·56	2·947 22
198 48 53	18 48 58	Savery	534·86	2·728 24
227 08 33	47 08 36	Savery	125·01	2·096 94
353 02 49	173 02 50	West	337·36	2·528 09
352 28 59	172 29 01	West	424·74	2·628 12
141 35 08	321 35 04	Curtis	259·96	2·414 90

BOSTON BAY.

37 09 11·4	217 00 43·5	Blue Hill	28 652·6	4·457 164
83 37 52·4	263 23 44·7	Prospect Waltham.	28 933·7	4·461 404
23 28 40·0	203 25 47·3	Blue Hill	14 781·5	4·169 719
109 12 15·5	289 03 43·8	Prospect Waltham.	18 394·8	4·264 695
40 02 12·6	219 55 54·7	Blue Hill	20 027·3	4·301 623
99 59 07·6	279 47 10·3	Prospect Waltham.	24 720·4	4·393 056
162 57 02·7	342 56 13·5	Powderhorn	5 692·4	3·755 292
301 31 02·6	121 35 17·7	Nantasket.	10 178·5	4·007 682
209 37 54·4	29 39 14·6	Powderhorn	5 505·9	3·740 825
14 24 17·8	194 22 15·6	Blue Hill.	16 744·1	4·223 863
304 05 21·5	124 07 25·3	Nantasket	5 086·7	3·706 439
44 55 19·1	224 48 56·7	Blue Hill.	18 467·4	4·266 407
18 10 42·7	198 07 20·4	Blue Hill	22 100·3	4·344 397
85 40 59·6	265 31 58·0	Prospect Waltham.	18 426·6	4·265 445
108 48 23·3	288 39 49·5	Prospect Waltham	18 424·5	4·265 397
187 15 23·6	7 15 51·1	Powderhorn 2.	7 388·2	3·868 539

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Whites Hill.	42 12 52·466	1618·8	70 58 39·300	901·4
Great Quincy.	42 16 29·026	895·6	70 57 06·869	157·4
Scituate. (C. & G. S. & Bdn.) 1834–1885.	42 14 14·646	451·9	70 49 51·228	1174·6
Hayden's Hotel (Ocean House).	42 15 10·370	320·0	70 46 20·130	461·4
Cat Hill.	42 13 19·178	591·8	70 45 20·317	466·0
Blue Hill. (Borden) 1834–35.	42 12 43·676	1347·5	71 06 52·709	1209·0
Cambridge Observatory, west transit, astronomical azimuth station. 1867–1869.	42 22 53·481	1650·3	71 07 44·478	1017·4
Dorchester (Dr. Deems', formerly Dr. Codman's) church spire. 1846–1885.	42 17 26·864	828·9	71 04 17·981	411·9
Milton Orthodox church spire 1846–1885.	42 15 12·366	381·5	71 04 50·372	1154·7
Cohasset, church spire. 1847–1885.	42 14 35·632	1099·4	70 48 14·016	321·3
East Weymouth, church spire. 1846–1885.	42 12 50·396	1555·0	70 55 31·079	712·9
Round Top.	42 13 47·878	1477·3	71 02 39·900	915·0
Fuller.	42 14 39·604	1222·0	71 02 56·408	1293·2
Stetson observatory.	42 14 02·161	66·7	70 59 44·007	1009·1
Captain Johns Hill.	42 16 15·690	484·1	71 07 47·012	1077·3
Totman Mountain.	42 13 15·948	492·1	70 54 46·448	1065·3
Castle Hill. (Borden.)	42 29 19·576	604·0	71 02 42·106	961·5
Turkey Hill 2. 1885.	42 14 25·263	779·5	70 51 14·655	336·0
Hingham Catholic church spire. 1885.	42 14 33·702	1039·9	70 53 24·778	568·1
Walnut Hill.	42 13 41·890	1292·5	70 48 17·239	395·3
Tank. 1885.	42 13 18·630	574·8	70 45 20·672	474·1
Mount Auburn, tower. 1860–1890.	42 22 10·949	337·8	71 08 40·367	923·6
Cambridge Observatory, meridian mark (east transit or meridian circle), 1845–1847.	42 25 47·43	1463·5	71 07 43·52	994·8

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
88 42 52·3	268 37 20·8	Blue Hill	11 319·1	4·053 812
210 44 56·2	30 47 50·4	Nantasket.	11 607·3	4·064 731
229 13 32·3	49 15 24·4	Nantasket	5 040·9	3·702 512
17 36 16·5	197 35 14·4	Whites Hill.	7 009·9	3·845 710
140 22 23·2	320 19 22·3	Nantasket	9 659·7	3·984 962
78 13 24·3	258 07 29·4	Whites Hill.	12 372·9	4·092 473
70 27 43·3	250 25 21·4	Scituate	5 136·0	3·710 626
117 40 36·5	297 25 13·5	Nantasket.	12 397·8	4·093 344
105 25 39·1	285 22 37·0	Scituate	6 443·9	3·809 150
158 12 59·8	338 12 19·6	Hayden's Hotel.	3 694·7	3·567 583
116 03 16·0	295 32 02·3	Wachusett	70 702·2	4·849 433
180 45 45·0	0 46 03·8	Holt.	47 656·1	4·678 118
268 47·9	88 47·9	Cambridge Observatory	13·571	1·132 62
205 48 45·3	25 49 54·0	Dorchester Heights	5 366·7	3·729 706
125 52 44·8	305 45 22·0	Prospect Waltham.	18 557·6	4·268 521
156 05 37·0	336 03 27·9	Corey	10 835·7	4·034 856
198 55 09·5	18 56 40·0	Dorchester Heights.	9 494·3	3·977 461
247 40 10·2	67 41 26·8	Hayden's Hotel	2 822·3	3·450 603
300 37 10·8	120 39 07·6	Cat Hill.	4 629·2	3·665 502
189 11 15·3	9 12 03·0	Nantasket	10 167·5	4·007 213
292 38 10·0	112 40 53·8	Prospect Hingham.	6 063·7	3·782 737
284 50 58·0	104 58 30·0	Prospect Hingham	15 969·3	4·203 285
71 13 45·0	251 10 55·1	Blue Hill.	6 123·0	3·786 966
289 46 52·5	109 54 35·6	Prospect Hingham	16 806·4	4·225 476
56 38 48·0	236 36 09·3	Blue Hill.	6 487·2	3·812 054
291 43 07·8	111 48 41·6	Prospect Hingham	12 271·2	4·088 887
83 46 52·2	263 44 54·0	Round Top.	4 057·4	3·608 247
293 57 55·1	114 01 10·6	Fuller	7 291·1	3·862 792
349 11 31·5	169 12 08·0	Blue Hill.	6 651·3	3·822 905
86 40 29·0	266 32 21·1	Blue Hill	16 685·5	4·222 339
304 19 53·9	124 22 07·8	Prospect Hingham.	5 537·2	3·743 289
327 38 38·7	147 47 18·1	Scituate	33 027·4	4·518 874
10 35 47·8	190 32 59·0	Blue Hill (Borden).	31 259·4	4·494 980
279 42 32·8	99 43 28·9	Scituate	1 940·7	3·287 956
3 07 19·6	183 07 11·2	Prospect Hingham.	5 270·9	3·721 884
333 57 31·8	153 58 50·8	Prospect Hingham	6 147·0	3·788 661
79 42 57·9	259 33 55·0	Blue Hill.	18 833·3	4·274 926
48 00 09·4	227 58 01·8	Prospect Hingham	5 863·9	3·768 185
115 07 57·1	295 06 53·9	Scituate.	2 380·4	3·376 657
100 04 01·2	280 02 02·6	Walnut Hill	4 112·4	3·614 097
105 35 29·7	285 32 27·8	Scituate.	6 440·6	3·808 926
249 22 18·6	69 26 53·9	Powderhorn	9 978·8	3·999 079
280 52 52·5	100 56 07·5	Boston State House.	6 742·6	3·828 825
291 29 34	111 33 31	Powderhorn	8 639·7	3·936 50
2 31 33	182 31 20	Corey.	9 699·3	3·986 74

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Nahant. (Borden) 1834.	42 25 40·22	1241·0	70 55 16·96	387·6
Ballard. 1847–48.	42 27 17·56	541·9	70 59 32·57	744·3
Waite 1. 1847.	42 26 00·85	25·6	71 03 57·96	1324·8
Waite 2. 1847.	42 26 20·43	630·6	71 01 13·14	300·3
Little Nahant. 1847–48.	42 26 13·27	409·6	70 55 52·09	1190·5
Dread Ledge Beacon. 1847.	42 27 23·19	715·6	70 53 43·54	994·8
Swampscott church spire. 1847.	42 28 06·14	189·4	70 54 58·40	1334·0
Grover Cliff.	42 23 22·79	703·4	70 58 08·65	197·9
Lynn, east church, green tower. 1847.	42 28 07·12	219·7	70 56 16·41	374·9
Lynn, west church, turret. 1847.	42 27 45·71	1410·4	70 57 37·00	845·3
Lynn, high rock, pole near swing.	42 28 04·96	153·0	70 56 52·10	1190·2
Egg Rock.	42 26 00·40	12·3	70 53 53·34	1219·2
Crusoe House, flagstaff.	42 26 10·65	328·6	70 58 07·58	173·3
South Boston Point. 1846–1861.	42 20 13·02	401·7	71 01 33·45	765·8
Castle Island.	42 20 19·26	594·5	71 00 45·65	1045·0
Nahant 2. 1860.	42 25 04·80	148·1	70 54 18·33	419·1
Winthrop Head. 1860.	42 22 04·07	125·6	70 58 06·04	138·2
Winthrop Head 2. 1877–78.	42 22 04·36	134·5	70 58 08·25	188·8
Tuft's College.	42 24 26·84	828·2	71 07 13·85	316·7
Ten Hill Farm, flag. 1847.	42 23 50·88	1569·8	71 05 15·26	349·0
Ten Hill Farm 2. 1860.	42 23 50·48	1557·6	71 05 15·44	353·1
Governor Island 2. 1860–61.	42 21 09·10	280·8	71 00 42·86	980·9
Governor Island 3. 1877–78.	42 21 08·84	272·8	71 00 41·12	941·1

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
340 32 58	160 36 37	Scituate	22 429·0	4·350 81
33 41 13	213 33 25	Blue Hill (Borden).	28 773·6	4·458 99
299 39 55	119 43 27	Nahant	8 270·8	3·917 55
28 11 17	208 09 43	Powderhorn.	6 751·0	3·829 37
321 12 13	141 13 38	Powderhorn	4 597·3	3·662 50
358 54 57	178 55 02	Boston State House.	8 370·3	3·922 74
283 47 28	103 52 08	Nahant	9 767·9	3·989 80
11 59 02	191 58 36	Powderhorn.	4 281·9	3·631 64
314 34 00	134 35 03	Nahant	3 012·0	3·478 86
64 17 28	244 13 25	Powderhorn.	9 135·7	3·960 74
10 31 16	190 30 53	Nahant	4 344·1	3·637 90
88 47 00	268 43 04	Ballard.	7 977·2	3·901 85
19 24 43	199 24 07	Little Nahant	3 691·9	3·567 25
76 34 05	256 31 00	Ballard.	6 440·8	3·808 94
348 50 00	168 50 25	Deer Island	4 450·5	3·648 41
104 13 09	284 10 39	Powderhorn.	5 269·6	3·721 78
16 18 44	196 17 28	Grover Cliff	9 140·5	3·960 97
71 10 38	251 08 26	Ballard.	4 735·4	3·675 36
5 05 56	185 05 35	Grover Cliff	8 144·8	3·910 88
71 47 35	251 46 17	Ballard.	2 779·8	3·444 02
11 22 15	191 21 23	Grover Cliff	8 880·6	3·948 44
68 16 00	248 14 12	Ballard.	3 947·2	3·596 29
18 20 18	198 20 01	Nahant	1 808·7	3·257 37
98 20 14	278 18 54	Little Nahant.	2 743·1	3·438 24
0 16 06	180 16 05	Grover Cliff	5 179·3	3·714 27
52 52 37	232 50 06	Powderhorn.	6 437·1	3·808 69
126 53 40	306 52 07	Boston State House	3 937·1	3·595 18
176 36 10	356 35 58	Powderhorn.	7 160·8	3·854 96
117 06 13	297 04 08	Boston State House	4 766·1	3·678 16
167 41 31	347 40 46	Powderhorn.	7 119·0	3·852 42
0 11 37	180 11 36	Nantasket	12 623·2	4·101 17
79 54 21	259 49 16	Powderhorn.	10 538·5	4·022 78
125 46 32	305 44 00	Powderhorn	6 369·4	3·804 10
223 01 26	43 03 59	Nahant 2.	7 630·4	3·882 55
59 09 16	239 06 18	Blind Asylum	7 055·7	3·848 54
125 56 30	305 53 59	Powderhorn 2.	6 322·1	3·800 86
275 16 38	95 20 15	Powderhorn	7 391·8	3·868 75
319 40 15	139 42 32	Boston State House.	7 171·8	3·855 63
264 44 49	84 47 06	Powderhorn	4 667·9	3·669 12
336 08 53	156 09 50	Boston State House.	4 766·2	3·678 17
336 02 33	156 03 30	Boston State House	4 756·6	3·677 30
112 30 50	292 29 30	Tuft's College.	2 931·3	3·467 06
52 45 12	232 43 58	Blind Asylum	3 163·6	3·500 18
163 43 45	343 42 58	Powderhorn.	5 643·8	3·751 57
53 18 13	233 16 58	Blind Asylum	3 190·4	3·503 84
163 20 40	343 19 52	Powderhorn 2.	5 659·9	3·752 81

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
East Boston.	42 22 53·13	1639·9	71 02 11·74	268·5
East Boston Point, flag.	42 21 58·24	1796·9	71 01 44·75	1023·9
East Boston Iron Works, chimney.	42 22 55·76	1720·4	71 01 48·44	1108·1
East Boston Reservoir. 1861.	42 22 52·76	1627·9	71 02 09·84	225·1
East Boston Reservoir 2. 1877.	42 22 52·56	1621·8	71 02 09·91	226·7
East Boston Elevator. 1877–78.	42 21 47·59	1468·4	71 02 15·51	354·9
East Boston Dry Dock, post.	42 21 44·76	1381·1	71 01 54·81	1254·2
East Boston ship-yard, east wharf, post.	42 21 50·12	1546·5	71 01 41·59	951·7
East Boston, brick church, dark spire. 1861.	42 22 26·77	826·0	71 02 21·89	500·8
East Boston, granite church, dark spire. 1861.	42 22 16·06	495·5	71 02 28·44	650·7
Long wharf. 1846.	42 21 37·65	1162·0	71 02 53·75	1229·7
Long wharf 2, post. 1860–61.	42 21 36·45	1124·7	71 02 53·54	1225·2
Neptune House, flagstaff.	42 25 43·48	1341·5	70 58 46·76	1068·9
Naval Hospital.	42 23 22·58	696·7	71 02 55·94	1279·6
Cushman's house, cupola.	42 24 59·35	1831·2	71 00 44·60	1019·7
Nahant Hotel, cupola.	42 25 09·20	283·9	70 54 19·84	453·6
Stone powder house.	42 24 00·40	12·3	71 07 00·17	3·9
Grain mill near turnpike, west chimney.	42 24 05·18	159·8	71 05 51·68	1181·8
Brick factory near Mystic River, cupola.	42 24 32·76	1010·8	71 05 27·07	619·0
Tall chimney, north side of Mystic River.	42 24 36·17	1116·1	71 05 21·94	501·7
Chelsea, church spire. 1847.	42 24 32·98	1017·5	71 00 26·28	600·8
Chelsea, bridge.	42 22 56·55	1744·8	71 02 55·67	1273·5
Chelsea, dark church spire, cross. 1860.	42 23 40·47	1248·7	71 01 54·68	1250·6

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
298 13 01	118 16 10	Deer Island	7 292·4	3·862 87
6 02 02	186 01 46	Dorchester Heights.	5 265·0	3·721 40
315 40 50	135 41 34	Governor Island	2 153·1	3·333 07
336 06 12	156 06 52	Castle Island.	3 340·3	3·523 78
177 48 15	357 48 13	Powderhorn	2 128·2	3·328 01
260 33 37	80 36 05	Grover Cliff.	5 096·6	3·707 28
112 46 26	292 44 21	Ten Hill Farm 2	4 603·4	3·663 08
190 24 22	10 24 34	Powderhorn.	2 256·5	3·353 44
327 35 18	147 36 18	Governor Island 3	3 790·7	3·578 72
5 52 42	185 52 27	Blind Asylum.	5 134·0	3·710 46
264 44 59	84 47 46	Winthrop Head 2	5 681·5	3·754 46
7 17 54	187 17 42	Blind Asylum.	3 128·1	3·495 28
350 11 57	170 12 11	South Boston Point	2 872·6	3·458 28
16 06 58	196 06 32	Blind Asylum.	3 139·0	3·496 79
356 26 17	176 26 22	South Boston Point	3 061·9	3·477 40
20 15 25	200 14 50	Blind Asylum.	3 390·6	3·530 28
192 44 50	12 45 10	Powderhorn	3 097·6	3·491 03
198 58 51	18 58 59	East Boston Reservoir.	847·8	2·928 29
193 57 33	13 57 58	Powderhorn	3 453·6	3·538 27
200 35 15	20 35 28	East Boston Reservoir.	1 209·4	3·082 58
197 17 16	17 17 58	Powderhorn	4 751·5	3·676 83
286 21 06	106 22 37	Governor Island.	3 213·4	3·506 97
197 06 04	17 06 45	Powderhorn	4 785·5	3·679 93
350 15 36	170 15 50	Blind Asylum.	2 799·4	3·447 06
348 38 43	168 39 09	Grover Cliff	4 427·5	3·646 16
54 16 33	234 14 28	Powderhorn.	5 218·6	3·717 55
323 12 37	143 14 08	Governor Island 3	5 152·3	3·712 00
354 59 41	174 59 57	Blind Asylum.	6 056·8	3·782 24
201 05 59	21 06 48	Ballard	4 571·0	3·660 01
309 51 38	129 53 23	Grover Cliff.	4 647·1	3·667 18
50 18 35	230 13 00	Dorchester Heights	14 758·4	4·169 04
79 08 42	259 03 37	Powderhorn.	10 529·1	4·022 39
268 53 55	88 57 23	Powderhorn	7 048·7	3·848 11
12 31 59	192 31 17	Corey.	6 543·6	3·815 82
270 08 13	90 10 55	Powderhorn	5 481·1	3·738 87
298 40 39	118 41 03	Ten Hill Farm 2.	944·8	2·975 34
279 58 15	100 00 40	Powderhorn	4 993·8	3·698 43
85 43 56	265 42 44	Tuft's College.	2 448·7	3·388 94
281 25 17	101 27 39	Powderhorn	4 898·1	3·690 03
83 35 40	263 34 24	Tuft's College.	2 575·1	3·410 79
66 00 00	245 59 02	Powderhorn	2 146·1	3·331 65
19 38 22	199 36 55	Dorchester Heights.	8 830·2	3·945 97
179 32 09	359 32 09	Naval Hospital	803·4	2·904 92
276 42 49	96 43 20	East Boston Reservoir 2.	1 054·2	3·022 93
93 52 08	273 49 52	Ten Hill Farm 2	4 601·7	3·662 92
101 07 14	281 03 39	Tuft's College.	7 438·4	3·871 48

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Chelsea, white church spire, with martin-hole windows. 1860.	42 23 24·55	757·5	71 02 19·91	455·6
Chelsea, white church spire, with clock. 1860.	42 23 27·33	843·3	71 02 18·18	415·8
Chelsea, white church spire, with three tiers of windows. 1860.	42 23 36·20	1117·0	71 02 16·13	368·9
Chelsea, tall dark church spire. 1861.	42 23 30·56	942·9	71 02 16·88	386·1
Chelsea, brown tower.	42 23 28·98	894·2	71 01 46·40	1061·3
Edgeworth Mills, round chimney.	42 25 01·38	42·6	71 04 30·87	705·8
Malden church, tall spire. 1847.	42 25 38·84	1198·3	71 04 01·56	35·6
Malden, yellow church spire. 1860.	42 25 38·75	1195·6	71 04 01·45	33·1
Malden Bridge, yellow house chimney, at toll-gate.	42 23 34·58	1066·9	71 04 09·58	219·1
Malden Bridge.	42 23 11·41	352·1	71 04 13·50	308·8
Medford Unitarian church spire. 1860.	42 25 13·97	431·0	71 06 56·23	1285·5
Medford, tall square chimney, near bridge.	42 24 52·20	1610·6	71 06 31·54	721·1
Winnisimmet, church spire with clock. 1847.	42 23 27·35	843·9	71 02 18·18	415·8
Somerville, church spire on hill. 1846–47.	42 23 12·18	375·8	71 05 52·37	1197·8
Somerville, red church spire. 1860.	42 23 11·98	369·6	71 05 52·46	1200·0
Somerville, church spire, near Malden Bridge. 1847.	42 23 07·43	229·3	71 04 36·63	837·9
Cambridge Baptist church spire. 1847–1865.	42 22 34·42	1061·9	71 07 07·71	176·4
Cambridge Unitarian church spire. 1847–1865.	42 22 28·70	885·5	71 07 10·78	246·6
Cambridge, gas works chimney.	42 22 24·35	751·3	71 07 36·78	841·5
Cambridgeport, Universalist church spire. 1846–1861.	42 21 47·52	1466·2	71 06 00·88	20·1
Cambridgeport Observatory dome.	42 21 19·06	588·1	71 06 35·85	820·5
Cambridgeport, redoubt, flagstaff. 1861.	42 21 23·89	737·1	71 06 17·21	393·9
Cambridgeport, flagstaff near engine-house. 1861.	42 21 45·58	1406·4	71 05 15·64	357·9

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
101 17 10	281 15 12	Ten Hill Farm 2	4 093·6	3·612 11
105 59 02	285 55 44	Tuft's College.	6 992·0	3·844 60
100 00 36	279 58 36	Ten Hill Farm 2	4 116·8	3·614 56
349 50 57	169 51 03	East Boston Reservoir.	1 083·7	3·034 89
96 09 07	276 07 06	Ten Hill Farm 2	4 124·9	3·615 41
353 52 27	173 52 31	East Boston Reservoir.	1 348·2	3·129 74
352 07 33	172 07 38	East Boston Reservoir	1 177·8	3·071 08
104 22 14	284 18 54	Tuft's College.	7 010·4	3·845 74
25 36 51	205 36 41	East Boston Reservoir	1 239·8	3·093 34
173 21 32	353 21 28	Powderhorn.	1 109·1	3·044 97
295 41 53	115 43 40	Powderhorn	4 031·9	3·605 51
74 03 28	254 01 38	Tuft's College.	3 876·1	3·588 39
314 25 49	134 27 16	Powderhorn	4 148·9	3·617 93
30 18 36	210 15 54	Corey.	10 914·7	4·038 01
26 51 52	206 51 02	Ten Hill Farm 2	3 744·6	3·573 40
63 15 04	243 12 54	Tuft's College.	4 926·9	3·692 57
183 22 12	3 22 20	Waite 1	4 520·5	3·655 19
253 32 07	73 33 40	Powderhorn.	3 280·9	3·515 99
243 06 02	63 07 38	Powderhorn 2	3 627·1	3·559 56
281 36 35	101 37 58	East Boston Reservoir 2.	2 886·6	3·460 38
287 03 16	107 06 41	Powderhorn	7 277·8	3·862 00
9 53 45	189 53 01	Corey.	8 788·2	3·943 90
282 53 30	102 56 38	Powderhorn	6 558·1	3·816 78
51 02 48	231 02 19	Tuft's College.	1 244·3	3·094 92
154 17 08	334 16 01	Waite 1	5 256·5	3·720 70
207 26 36	27 26 54	Powderhorn.	1 298·4	3·113 41
322 18 52	142 21 04	Dorchester Heights	7 357·3	3·866 72
31 14 29	211 13 02	Corey.	5 730·1	3·758 16
215 28 48	35 29 13	Ten Hill Farm 2	1 458·8	3·164 00
253 30 26	73 33 08	Powderhorn.	5 735·0	3·758 53
334 02 24	154 03 45	Dorchester Heights	6 313·8	3·800 29
44 43 16	224 40 57	Corey.	6 687·3	3·825 25
248 52 47	68 56 20	Powderhorn	7 739·8	3·888 73
306 48 18	126 51 21	Dorchester Heights.	7 771·6	3·890 51
247 51 56	67 55 31	Powderhorn	7 870·3	3·895 99
305 26 41	125 29 46	Dorchester Heights.	7 724·3	3·887 86
9 38 39	189 38 22	Corey	3 473·2	3·540 73
187 53 52	7 54 07	Tuft's College.	3 815·8	3·581 58
101 12 49	281 11 02	Mount Auburn	3 720·1	3·570 56
233 21 10	53 23 58	Powderhorn.	7 094·0	3·850 89
54 30 43	234 29 45	Corey	2 427·6	3·385 17
171 28 10	351 27 44	Tuft's College.	5 859·1	3 767 83
57 02 27	237 01 16	Corey	2 864·3	3 457 02
113 54 54	293 53 18	Mount Auburn.	3 583·5	3·554 31
59 42 43	239 40 51	Corey	4 415·4	3·644 97
151 29 10	331 27 50	Tuft's College.	5 663·2	3·753 06

BOSTON BAY—Continued

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
East Cambridge, court-house cupola. 1860–61.	42 22 11·95	368·7	71 04 48·56	1111·1
East Cambridge, church spire near court-house. 1847.	42 22 11·46	353·5	71 04 50·78	1161·9
West Cambridge, tall church spire with clock. 1846.	42 24 55·63	1716·6	71 09 15·82	361·8
Graves.	42 21 53·66	1655·7	70 52 12·61	288·5
Great Brewster. 1846.	42 20 01·96	60·5	70 53 45·18	1034·3
Great Brewster 2. 1860.	42 20 01·68	51·8	70 53 45·22	1035·3
Point Shirley foundry chimney. 1846–1860.	42 21 31·80	981·2	70 58 20·22	462·7
Battery wharf.	42 22 01·32	40·8	71 02 59·22	1355·0
Guide Post, west end of milldam.	42 20 55·63	1716·4	71 05 51·00	1167·2
Belle Isle.	42 22 57·30	1767·9	70 59 56·35	1289·0
Navy-yard, battery near flagstaff.	42 22 23·97	739·6	71 03 06·32	144·6
Bird Island.	42 21 22·80	703·4	71 01 15·97	365·5
Bird Island Beacon. 1861.	42 21 18·06	557·2	71 01 15·96	365·3
Navy-yard chimney.	42 22 30·04	926·9	71 03 09·16	209·6
Apple Island, flag.	42 21 31·55	973·5	70 59 32·43	742·1
Bluff Head, flag.	42 22 03·82	117·9	70 58 04·53	103·6
Lewis' wharf, cupola. 1846–1861.	42 21 47·44	1463·8	71 03 00·02	0·5
Faneuil Hall, grasshopper.	42 21 36·38	1122·4	71 03 23·70	542·4
Bunker Hill Monument.	42 22 35·05	1081·4	71 03 40·56	927·9
Bunker Hill Catholic church spire, cross. 1860.	42 22 53·34	1645·7	71 04 00·70	16·0
Green Island, flag. 1846.	42 21 11·16	344·3	70 53 33·05	756·4
Green Island 2. 1860.	42 21 11·14	343·7	70 53 33·02	755·7
McLean's Asylum, north dome.	42 22 37·26	1149·7	71 04 54·69	1251·1

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
55 33 41	235 31 31	Corey	5 375·0	3·730 38
89 40 36	269 38 00	Mount Auburn.	5 303·8	3·724 59
189 40 48	9 41 24	Waite 1	7 179·6	3·856 10
229 28 28	49 30 29	Powderhorn.	5 378·5	3·730 66
278 45 50	98 50 49	Powderhorn	10 269·7	4·011 56
348 14 01	168 14 51	Corey.	8 265·5	3·917 27
77 31 26	257 27 51	Deer Island	7 463·5	3·872 94
154 01 54	334 00 29	Nahant.	6 559·5	3·816 87
13 45 10	193 44 46	Nantasket	3 375·5	3·528 34
109 31 15	289 28 43	Deer Island.	5 483·8	3·739 08
123 59 32	303 54 05	Powderhorn	13 427·0	4·127 98
175 22 23	355 22 01	Nahant 2.	9 383·4	3·972 36
65 02 36	244 59 44	Dorchester Heights	6 456·5	3·810 00
134 15 15	314 12 52	Powderhorn.	6 762·4	3·830 10
201 59 27	22 00 12	Powderhorn	4 104·8	3·613 29
297 00 24	117 01 59	Governor Island.	3 601·2	3·556 45
223 07 36	43 10 17	Powderhorn	7 995·2	3·902 83
289 48 56	109 51 07	Dorchester Heights.	4 747·4	3·676 46
63 16 21	243 13 43	Boston State House	6 013·3	3·779 11
128 10 07	308 08 49	Powderhorn.	3 364·7	3·526 94
208 40 14	28 41 04	Powderhorn	3 541·9	3·549 24
304 41 40	124 43 19	Governor Island.	4 100·0	3·612 78
93 24 16	273 22 32	Boston State House	3 555·2	3·550 86
155 24 18	335 23 40	East Boston.	3 065·6	3·486 51
11 16 52	191 16 40	South Boston Point	2 046·3	3·310 96
38 46 46	218 45 54	Blind Asylum.	2 810·9	3·448 84
122 48 05	302 45 20	Tuft's College	6 656·7	3·823 26
130 41 06	310 39 41	Ten Hill Farm 2.	3 808·4	3·580 74
288 34 24	108 35 46	Deer Island	2 932·2	3·467 19
57 05 29	237 03 25	Dorchester Heights.	5 003·3	3·699 26
323 51 53	143 54 24	Nantasket	8 713·4	3·940 19
59 08 37	239 05 34	Dorchester Heights.	7 237·4	3·859 58
200 10 00	20 10 46	Powderhorn	4 511·5	3·654 32
290 30 07	110 31 42	Governor Island.	3 445·2	3·537 22
204 37 00	24 38 02	Powderhorn	5 033·7	3·701 89
282 55 34	102 57 25	Governor Island.	3 867·1	3·587 38
221 54 21	41 55 34	Powderhorn	3 716·8	3·570 17
302 46 31	122 48 33	Governor Island.	4 941·4	3·693 85
123 09 36	303 07 26	Tuft's College	5 276·5	3·722 35
270 23 39	90 24 54	East Boston Reservoir.	2 536·6	3·404 26
11 16 48	191 16 16	Nantasket	5 520·9	3·742 01
86 49 02	266 46 22	Deer Island.	5 454·3	3·736 74
11 17 26	191 16 54	Nantasket	5 520·3	3·741 96
115 10 34	295 04 57	Powderhorn.	12 609·6	4·100 70
191 39 48	11 40 26	Waite 1	6 413·9	3·807 12
237 08 18	57 10 21	Powderhorn.	4 973·5	3·696 66

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Watertown United States Arsenal, flagstaff. 1846.	42 21 42·72	1318·1	71 09 45·97	1051·9
Cushing's (J. P.) house, skylight.	42 22 48·57	1498·6	71 10 10·24	234·2
Breed Island.	42 23 28·04	865·2	71 00 30·28	692·6
State Street Block. 1877–78.	42 21 33·64	1038·0	71 03 08·13	186·0
Prospect Somerville. 1877–78.	42 22 54·62	1685·3	71 05 37·88	866·6
Waverly House. 1877–78.	42 22 17·56	541·8	71 03 46·42	1062·1
Fitchburg Depot.	42 22 00·36	11·1	71 03 41·64	952·8
Lowell Roundhouse.	42 22 09·74	300·5	71 04 23·39	535·2
Lowell draw, flagstaff. 1877.	42 22 05·14	158·6	71 04 08·40	192·2
Lowell Depot, flagstaff. 1877.	42 21 53·81	1660·3	71 03 47·12	1078·2
Organ Factory. 1877–78.	42 21 44·45	1371·5	71 04 58·17	1331·1
Nealy's house.	42 21 22·37	690·2	71 06 27·13	620·9
Otter street.	42 21 21·48	662·8	71 04 24·91	570·1
Standard Sugar Refinery.	42 20 44·00	1357·6	71 03 15·58	356·6
South Boston sea wall. 1877–78.	42 21 18·40	567·7	71 02 43·48	995·1
Point Curve.	42 21 14·02	432·6	71 02 56·28	1288·0
Center.	42 21 09·74	300·5	71 02 46·38	1061·5
Two-story house, smoke pipe.	42 20 56·31	1737·5	71 05 52·96	1212·2
Powers & Mellville's elevator, southwest gable.	42 22 59·03	1821·5	71 04 40·01	915·3
Coal shed, flagstaff.	42 23 06·56	202·4	71 02 39·20	896·7
Octagonal building.	42 21 37·37	1153·0	71 04 19·02	435·3
Shed, upper gable.	42 21 57·42	1771·7	71 04 11·87	271·6
Iron smokestack.	42 23 14·06	433·8	71 02 26·10	597·0

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
247 57 29	68 02 48	Powderhorn	11 693·9	4·067 96
287 14 53	107 19 43	Dorchester Heights.	10 309·3	4·013 23
258 18 34	78 24 10	Powderhorn	11 635·6	4·065 79
324 54 20	144 55 46	Corey.	5 097·4	3·707 35
308 27 30	128 29 06	Winthrop Head 2	4 150·1	3·618 06
121 04 34	301 03 39	Powderhorn 2.	2 183·5	3·339 15
282 48 12	102 49 51	Governor Island 3	3 450·0	3·537 82
343 11 42	163 12 06	Blind Asylum.	2 791·4	3·445 82
247 18 24	67 20 56	Powderhorn 2	5 598·2	3·748 05
256 52 16	76 54 05	Naval Hospital.	3 803·3	3·580 16
209 55 13	29 55 47	Naval Hospital	2 314·9	3·364 54
293 57 00	113 58 01	East Boston Elevator.	2 276·5	3·357 26
213 10 52	33 12 06	Powderhorn 2	4 579·2	3·660 79
281 18 00	101 18 58	East Boston Elevator.	2 009·6	3·303 12
224 19 13	44 20 55	Powderhorn 2	4 953·6	3·694 92
302 53 11	122 54 02	State Street Block.	2 051·0	3·311 97
232 42 17	52 42 31	Waverly House	632·1	2·800 76
283 31 40	103 31 58	Fitchburg Depot.	630·1	2·799 43
275 13 09	95 14 11	East Boston Elevator	2 104·8	3·323 21
304 53 26	124 53 52	State Street Block.	1 088·1	3·036 66
238 06 08	58 06 56	Waverly House	1 933·3	3·286 29
254 19 55	74 20 47	Fitchburg Depot.	1 818·9	3·259 82
201 35 37	21 36 10	Prospect Somerville	3 061·2	3·485 88
251 28 54	71 29 54	Organ Factory.	2 146·9	3·331 81
90 34 20	270 32 58	Nealy's house	2 797·4	3·446 75
181 20 39	1 20 40	Lowell Roundhouse.	1 489·9	3·173 17
186 21 28	6 21 33	State Street Block	1 541·1	3·187 82
319 23 35	139 24 04	Blind Asylum.	1 502·2	3·176 74
215 23 57	35 24 16	East Boston Elevator	1 104·8	3·043 30
276 00 32	96 01 54	Governor Island 3.	2 815·8	3·449 60
155 51 41	335 51 33	State Street Block	663·1	2·821 60
245 12 19	65 12 28	South Boston sea wall.	322·4	2·508 45
120 16 50	300 16 43	Point Curve	262·1	2·418 48
193 56 28	13 56 30	South Boston sea wall.	275·5	2·440 10
135 47 35	315 47 12	Nealy's house	1 121·6	3·049 84
220 09 43	40 10 20	Organ Factory.	1 944·0	3·288 69
316 13 35	136 14 11	Waverly House	1 771·8	3·248 41
345 56 58	165 57 09	Lowell Roundhouse.	1 567·6	3·195 24
302 48 49	122 49 09	East Boston Reservoir 2	797·5	2·901 75
142 13 40	322 13 29	Naval Hospital.	625·5	2·796 25
103 42 42	283 42 16	Organ Factory	922·4	2·964 92
174 17 53	354 17 50	Lowell Roundhouse.	1 003·8	3·001 66
69 19 23	249 18 52	Organ Factory	1 132·8	3·054 15
145 16 59	325 16 51	Lowell Roundhouse.	462·6	2·665 16
330 49 39	150 49 50	East Boston Reservoir 2	760·0	2·880 82
51 23 24	231 23 04	Chelsea Bridge.	865·8	2·937 40

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Glassworks, east gable of main building.	42 22 22·65	698·9	71 04 41·86	957·8
New England Glass Company's chimney.	42 22 21·35	658·8	71 04 40·30	922·1
Peck's chimney.	42 22 51·09	1576·4	71 03 03·64	83·3
Fitchburg Roundhouse flagstaff. 1877.	42 22 23·43	722·9	71 04 10·02	229·3
Round building, ventilator.	42 20 50·28	1551·4	71 03 27·19	622·4
Round brick building, iron rod.	42 23 14·81	457·0	71 04 29·82	682·4
Brick Factory.	42 23 45·12	1392·2	71 04 12·89	294·8
Marine Hospital cupola, flagstaff. 1861–1877.	42 23 21·22	654·8	71 02 43·70	999·6
Winslow's factory, corner.	42 23 02·22	68·5	71 03 53·96	1234·4
Holmes' factory.	42 22 45·76	1412·0	71 03 29·36	671·7
Crossing, signal pole. 1877.	42 22 27·27	841·4	71 04 15·52	355·1
Gambrel roof, northeast gable.	42 22 18·38	567·1	71 03 26·45	605·2
Tudor cupola.	42 22 14·98	462·2	71 03 39·81	910·9
Gray's wharf, long brick building, northeast corner.	42 22 09·48	292·5	71 03 16·38	374·8
Prince street draw tender's house, pole. 1877.	42 22 07·79	240·4	71 03 35·91	821·7
Draw, northwest corner, iron crane.	42 22 05·92	182·7	71 03 56·41	1290·7
Car shed, northeast ventilator.	42 22 09·94	306·7	71 04 00·51	11·7
One story red building, southwest end.	42 22 07·93	244·7	71 04 17·38	397·7
National Dock building, southeast corner.	42 22 02·92	90·1	71 02 33·56	767·9
Long wharf building, lightning rod.	42 21 37·08	1144·1	71 02 57·46	1314·9
Cunard wharf, flagstaff. 1846.	42 21 50·08	1545·8	71 02 26·90	615·5
Cunard wharf, flagstaff. 1877.	42 21 49·98	1542·2	71 02 27·98	640·3
Cunard wharf, pole. 1860.	42 21 50·37	1554·2	71 02 29·04	664·5

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
277 03 24	97 04 01	Waverly House	1 278·0	3·106 52
296 30 27	116 31 08	Fitchburg Depot.	1 540·1	3·187 55
54 13 31	234 11 15	Corey	5 696·4	3·755 60
230 21 08	50 23 02	Powderhorn.	4 998·5	3·698 84
215 49 48	35 50 36	Powderhorn 2	2 796·4	3·446 60
190 15 36	10 15 41	Naval Hospital.	987·7	2·994 63
288 33 03	108 33 19	Waverly House	569·1	2·755 17
35 53 55	215 53 46	Lowell Roundhouse.	521·3	2·717 08
198 03 40	18 03 53	State Street Block	1 407·5	3·148 44
261 24 53	81 26 45	Governor Island 3.	3 843·7	3·584 75
246 56 18	66 58 04	Powderhorn 2	3 921·3	3·593 43
282 05 40	102 07 14	East Boston Reservoir 2.	3 273·6	3·515 02
259 26 14	79 27 49	Powderhorn 2	3 276·2	3·515 37
299 57 14	119 58 37	East Boston Reservoir 2.	3 247·3	3·511 52
221 26 38	41 27 13	Powderhorn 2	1 784·3	3·251 46
318 50 05	138 50 28	East Boston Reservoir 2.	1 174·6	3·069 90
235 23 09	55 24 31	Powderhorn 2	3 387·5	3·529 88
277 07 37	97 08 47	East Boston Reservoir 2.	2 399·1	3·380 05
213 55 07	33 55 29	Naval Hospital	1 369·5	3·136 56
222 27 36	42 28 42	Powderhorn 2.	3 296·3	3·518 03
294 13 42	114 14 02	Waverly House	729·8	2·863 19
18 22 53	198 22 48	Lowell Roundhouse.	569·8	2·755 73
32 00 48	212 00 38	Fitchburg Depot	655·4	2·816 49
86 49 48	266 49 35	Waverly House.	457·9	2·660 76
5 16 56	185 16 55	Fitchburg Depot	452·8	2·655 94
117 41 06	297 41 02	Waverly House.	171·1	2·233 14
64 02 03	244 01 46	Fitchburg Depot	642·7	2·808 03
109 54 20	289 54 00	Waverly House.	731·3	2·864 09
29 45 18	209 45 14	Fitchburg Depot	263·9	2·421 43
141 22 23	321 22 16	Waverly House.	385·7	2·586 20
212 26 57	32 27 04	Waverly House	425·6	2·628 98
296 51 29	116 51 39	Fitchburg Depot.	379·0	2·578 69
233 54 38	53 54 47	Waverly House	398·8	2·600 72
304 22 06	124 22 19	Fitchburg Depot.	523·4	2·718 87
247 14 31	67 14 52	Waverly House	767·9	2·885 28
285 55 18	105 55 42	Fitchburg Depot.	850·6	2·929 70
9 23 06	189 22 59	South Boston sea wall	1 392·4	3·143 75
41 11 24	221 11 01	State Street Block.	1 201·0	3·079 53
330 58 35	150 58 44	South Boston sea wall	659·1	2·818 93
66 27 19	246 27 12	State Street Block.	266·3	2·425 39
297 33 28	117 34 41	Governor Island	2 784·7	3·444 78
3 35 13	183 35 07	Dorchester Heights.	3 297·2	3·518 15
20 00 27	200 00 17	South Boston sea wall	1 036·9	3·015 73
61 13 56	241 13 29	State Street Block.	1 048·0	3·020 34
337 02 08	157 02 45	South Boston Point	3 262·1	3·513 50
1 34 18	181 34 15	Blind Asylum.	3 189·9	3·503 78

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Fawn Beacon. 1860.	42 21 17·58	542·4	70 56 32·87	752·5
Deer Island Beacon. 1846.	42 20 23·44	723·2	70 57 18·41	421·4
Deer Island Hospital cupola.	42 21 12·39	382·3	70 57 53·15	1216·4
Deer Island, flag. 1860.	42 21 01·24	38·3	70 57 30·95	708·4
Lincoln's wharf, post.	42 21 57·73	1781·3	71 02 58·15	1330·6
Eastern avenue wharf, post.	42 21 50·10	1545·9	71 02 56·18	1285·6
Loring's machine shop, wharf.	42 20 31·60	975·0	71 02 02·70	61·8
Foster's wharf, post.	42 21 21·15	652·6	71 03 01·36	31·1
South Bay, tripod. 1860–61.	42 19 31·09	959·3	71 03 46·58	1066·6
Prentice's coal wharf, post.	42 21 08·76	270·3	71 03 11·59	265·2
Sailors' Home cupola.	42 21 19·10	589·3	71 03 08·40	192·2
Boylston School cupola.	42 21 21·51	663·7	71 03 09·02	206·4
Fort Hill wharf, post.	42 21 15·74	485·7	71 03 05·16	118·1
Central wharf, cupola.	42 21 32·55	1004·3	71 03 05·21	119·2
India wharf, cupola.	42 21 29·10	897·9	71 02 59·70	1366·2
India wharf, post.	42 21 28·04	865·2	71 02 59·09	1352·2
Grand Junction wharf, shears.	42 21 47·40	1462·5	71 02 22·93	524·7
Bay State Iron Works, north gable.	42 20 24·77	764·3	71 02 22·31	510·7
Bay State Steam Engine Works wharf, post.	42 21 45·52	1404·5	71 02 09·69	221·7
Adams school, flagstaff. 1861.	42 21 57·86	1785·2	71 01 59·08	1351·9
Hog Island, tripod.	42 23 30·16	930·6	71 00 39·69	907·8
Gas Works, north end of Boston, chimney.	42 22 01·90	58·6	71 03 28·38	649·4
Gas Works, near Malden Bridge, chimney.	42 23 18·75	578·5	71 04 29·70	679·4

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
203 41 31	23 43 02	Nahant 2	7 657·0	3·884 06
331 33 28	151 34 57	Nantasket.	6 382·0	3·804 96
106 47 40	286 45 25	Governor Island	4 796·2	3·680 90
166 08 48	346 08 40	Deer Island.	1 202·4	3·080 06
134 14 04	314 11 23	Powderhorn	7 624·1	3·882 19
214 24 06	34 26 31	Nahant 2.	8 693·2	3·939 18
133 29 12	313 26 16	Powderhorn	8 228·9	3·915 34
210 21 58	30 24 08	Nahant 2.	8 711·6	3·940 10
201 06 28	21 07 13	Powderhorn	4 199·3	3·623 18
350 22 35	170 22 52	Blind Asylum.	3 464·4	3·539 63
199 27 40	19 28 23	Powderhorn	4 404·3	3·643 88
350 28 12	170 28 28	Blind Asylum.	3 224·9	3·508 52
42 19 59	222 19 39	Blind Asylum	1 025·2	3·010 82
237 39 07	57 40 01	Governor Island 2.	2 163·0	3·335 06
276 40 45	96 42 18	Governor Island 2	3 191·9	3·504 04
344 04 37	164 04 56	Blind Asylum.	2 378·2	3·376 24
178 23 53	358 23 50	Boston State House	3 658·0	3·563 24
236 40 43	56 41 33	Blind Asylum.	2 019·5	3·305 25
269 48 30	89 50 10	Governor Island 2	3 404·2	3·532 01
306 00 41	126 01 27	Loring's machine shop.	1 949·3	3·289 87
275 16 49	95 18 27	Governor Island 2	3 345·3	3·524 44
339 54 17	159 54 41	Blind Asylum.	2 367·8	3·374 34
340 11 10	160 11 34	Blind Asylum	2 442·8	3·387 88
314 00 08	134 01 12	South Boston Point.	3 041·6	3·483 10
273 35 38	93 37 14	Governor Island 2	3 263·6	3·513 70
313 36 22	133 37 04	Loring's machine shop.	1 974·6	3·295 47
322 43 43	142 44 25	Loring's machine shop	2 362·9	3·373 45
344 19 19	164 19 41	Blind Asylum.	2 740·6	3·437 84
319 55 36	139 56 34	South Boston Point	3 067·0	3·486 72
346 21 24	166 21 42	Blind Asylum.	2 605·7	3·415 92
319 44 02	139 45 00	South Boston Point	3 033·1	3·481 89
346 29 22	166 29 40	Blind Asylum.	2 570·6	3·410 04
338 44 39	158 45 12	South Boston Point	3 124·4	3·494 76
4 12 02	184 11 55	Blind Asylum.	3 105·2	3·492 09
153 44 39	333 44 08	State Street Block	2 369·7	3·374 70
239 34 19	59 35 27	Governor Island 3.	2 685·7	3·429 06
343 47 22	163 47 46	South Boston Point	2 972·1	3·473 06
9 54 10	189 53 54	Blind Asylum.	3 084·9	3·489 24
349 43 14	169 43 31	South Boston Point	3 287·4	3·516 85
12 44 48	192 44 25	Blind Asylum.	3 506·0	3·544 81
60 46 02	240 45 01	East Boston Reservoir	2 363·0	3·373 46
122 46 44	302 45 55	Powderhorn.	1 967·3	3·293 87
66 28 25	246 25 21	Corey	6 836·0	3·834 80
92 15 59	272 12 29	Mount Auburn.	7 144·1	3·853 95
133 06 00	313 05 29	Ten Hill Farm 2	1 433·1	3·156 29
284 03 28	104 05 02	East Boston Reservoir.	3 298·5	3·518 32

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Millers River, head of, church spire. 1860.	42 22 44·08	1360·1	71 05 48·79	1116·2
Carpet cleaning factory, ventilator. 1860–61.	42 21 16·62	512·8	71 04 39·93	913·9
Milldam, yellow house chimney.	42 20 56·22	1734·7	71 05 51·67	1182·7
Milldam, regatta house flagstaff. 1861.	42 21 04·89	150·9	71 05 19·01	435·1
Planing mill, chimney.	42 22 16·17	498·9	71 07 17·17	392·9
Varnish factory, chimney.	42 21 49·54	1528·6	71 07 06·33	144·9
Riverside Press, chimney.	42 21 46·03	1420·2	71 06 57·05	1305·5
Charles River tripod.	42 21 09·41	290·3	71 07 00·28	6·4
Small red house on marsh, chimney.	42 24 45·88	1415·6	71 06 07·72	176·5
Cloverden.	42 22 47·54	1466·9	71 07 18·42	421·4
Cloverden observatory, astronomic latitude station (zenith telescope). 1855–1864.	42 22 46·29	1428·3	71 07 17·60	402·6
Agassiz Museum.	42 22 44·52	1373·7	71 06 56·04	1282·0
Gould Transitory. 1865.	42 22 41·01	1265·4	71 06 57·87	1323·8
Boston, Hollis street church spire. 1847.	42 20 59·42	1833·3	71 03 53·15	1216·4
Boston, Hanover street brick church spire. 1847.	42 21 49·90	1539·6	71 03 17·44	399·1
Boston, St. Mary's church, north spire. 1877.	42 21 54·82	1691·5	71 03 29·69	679·4
Boston Neck, dark church spire with clock. 1860–61.	42 20 26·77	826·0	71 04 25·27	578·5
Boston Catholic cathedral, statue. 1861.	42 20 12·67	390·9	71 04 25·14	575·5
Boston, Berkley street yellow church spire. 1860–61.	42 20 44·13	1361·6	71 04 15·42	353·0
Boston jail, cupola.	42 21 43·26	1334·5	71 04 14·44	330·4
Boston, State prison cupola.	42 22 28·23	871·0	71 04 08·84	202·2
Boston light-house. (C & G. S. & Bdn) 1834–1847.	42 19 40·74	1257·0	70 53 26·18	599·4
South Boston flats, A.	42 20 21·44	661·5	71 01 39·28	899·1
South Boston flats, B.	42 20 21·59	666·2	71 02 14·82	339·3

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
245 18 43	65 21 23	Powderhorn	5 959·5	3·775 21
75 25 20	255 23 24	Mount Auburn.	4 056·5	3·608 15
73 56 29	253 54 13	Corey	4 818·3	3·682 89
106 57 54	286 55 12	Mount Auburn.	5 751·9	3·759 81
120 51 39	300 49 45	Mount Auburn	4 496·8	3·652 90
163 52 18	343 51 23	Tuft's College.	6 765·5	3·830 29
75 25 22	255 23 32	Corey	3 859·8	3·586 57
113 52 40	293 50 24	Mount Auburn.	5 038·6	3·702 31
17 59 52	197 59 22	Corey	3 334·7	3·523 06
181 04 15	1 04 17	Tuft's College.	4 032·7	3·605 60
28 33 18	208 32 40	Corey	2 675·3	3·427 38
107 04 15	287 03 12	Mount Auburn.	2 250·8	3·352 34
33 37 59	213 37 15	Corey	2 692·2	3·430 11
175 34 21	355 34 10	Tuft's College.	4 976·9	3·696 96
129 39 54	309 38 47	Mount Auburn	2 974·9	3·473 47
177 05 02	357 04 53	Tuft's College.	6 099·7	3·785 31
325 01 36	145 02 11	Ten Hill Farm 2	2 086·0	3·319 32
68 46 32	248 45 47	Tuft's College.	1 622·4	3·210 17
249 00 39	69 01 37	Somerville church, 1860	2 106·2	3·323 50
107 30 10	287 29 53	Cambridge Observatory.	610·7	2·785 82
154 01·1	334 01·1	Cloverden	42·98	1·633 23
239 46 25	59 47 08	Somerville church, 1860	1 683·3	3·226 16
104 11 43	284 11 11	Cambridge Observatory.	1 128·9	3·052 64
201 09	21 09	Agassiz Museum	116·2	2·065 34
266 26 51	86 29 02	Governor Island	4 451·1	3·648 47
314 19 47	134 20 39	Dorchester Heights.	2 471·9	3·393 03
289 28 50	109 30 37	Governor Island	3 845·5	3·584 95
343 51 41	163 52 09	Dorchester Heights.	3 420·1	3·534 04
209 08 56	29 10 02	Powderhorn 2	4 584·2	3·661 26
277 28 18	97 29 08	East Boston Elevator.	1 711·9	3·233 49
332 43 11	152 43 37	South Bay tripod	1 933·0	3·286 23
118 51 24	298 48 32	Mount Auburn.	6 664·4	3·823 76
273 51 19	93 52 35	Blind Asylum	2 576·3	3·411 00
325 27 19	145 27 45	South Bay tripod.	1 557·4	3·192 41
343 40 01	163 40 20	South Bay tripod	2 348·4	3·370 78
86 21 40	266 19 07	Corey.	5 201·6	3·716 14
67 33 03	247 30 30	Corey	5 641·1	3·751 36
98 00 50	277 57 51	Mount Auburn.	6 144·7	3·788 50
130 52 14	310 50 09	Tuft's College	5 594·7	3·747 78
149 01 56	329 01 11	Ten Hill Farm 2.	2 959·9	3·471 28
125 10 34	305 04 53	Powderhorn	14 152·5	4·150 83
173 12 42	353 12 07	Nahant.	10 068·1	4·002 95
273 07 09	93 07 45	Castle Island	1 229·4	3·089 69
223 37 47	43 38 28	Governor Island.	1 998·4	3·300 68
133 37 36	313 36 31	Boston State House	3 041·9	3·483 14
236 40 03	56 41 08	Governor Island.	2 624·2	3·419 00

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
South Boston flats, C.	42 20 15·97	492·8	71 02 35·44	811·3
South Boston flats, D.	42 20 30·32	935·5	71 03 06·10	139·6
South Boston flats, E.	42 20 34·38	1060·7	71 03 15·65	358·2
South Boston Reservoir, flagstaff. 1860–61.	42 19 58·48	1804·4	71 02 46·56	1066·0
South Boston, dark church spire with turrets, cross. 1860–61.	42 20 31·87	983·3	71 03 24·44	559·5
West Boston Bridge, pole on draw. 1860–61.	42 21 41·49	1280·2	71 04 26·12	597·7
Charlestown brick church, spire, cross. 1861.	42 22 21·96	677·6	71 03 48·32	1105·5
Outer Brewster. 1846.	42 20 29·40	907·2	70 52 41·28	945·0
Outer Brewster 2. 1860.	42 20 29·33	905·0	70 52 41·21	943·3
Brighton, east church, spire.* 1847.	42 20 57·83	1784·3	71 09 13·03	298·3
Brighton, west church, spire with clock.† 1847.	42 20 56·25	1735·5	71 09 20·29	464·4
East Brighton, dark church spire.‡ 1861.	42 21 13·69	422·4	71 08 12·35	282·6
Moon Head 1. 1847.	42 18 22·20	684·9	70 59 23·06	528·1
Moon Head 2. 1860.	42 18 22·04	680·0	70 59 23·13	529·8
Weeks' house, chimney.	42 20 21·21	654·4	70 53 49·02	1122·2
Weeks' barn, center chimney.	42 20 23·48	724·5	70 53 52·86	1210·1
Kimbal's house, center chimney.	42 20 19·12	590·0	70 53 26·75	612·4
Machine shop, tall chimney on ridge pole.	42 20 28·60	882·5	71 03 59·10	1352·9
Gas works, ventilator.	42 20 50·28	1551·4	71 03 27·18	622·1
Fulton Wire Works, south chimney.	42 20 08·04	248·1	71 03 29·56	676·7
Lawrence school, cupola.	42 20 28·78	888·0	71 03 12·88	294·8
Railroad tripod.	42 20 52·37	1615·9	71 02 57·82	1323·5
Fort Independence flagstaff. 1861.	42 20 18·90	583·2	71 00 44·92	1028·3

* Removed in 1893. † Torn down in 1890 and new and taller spire erected on same site. ‡ Position changed in 1890.

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
142 42 44	322 41 53	Boston State House	2 855·8	3·455 73
238 46 04	58 47 22	Governor Island.	3 115·9	3·493 59
150 39 04	330 38 34	Boston State House	2 098·4	3·321 88
250 47 13	70 48 52	Governor Island.	3 564·7	3·552 02
154 34 42	334 34 18	Boston State House	1 886·5	3·275 66
253 42 12	73 43 58	Governor Island.	3 734·7	3·572 26
58 23 19	238 22 39	South Bay tripod	1 613·4	3·207 75
188 52 41	8 53 06	East Boston Reservoir.	5 443·6	3·735 89
252 43 28	72 45 17	Governor Island 2	3 872·8	3·588 02
15 06 56	195 06 41	South Bay tripod.	1 942·7	3·288 41
66 59 46	246 57 20	Corey	5 373·7	3·730 27
98 54 04	278 51 13	Mount Auburn.	5 888·4	3·770 00
219 59 52	40 01 10	Powderhorn	4 138·0	3·616 79
247 07 33	67 08 39	East Boston Reservoir.	2 445·1	3·388 30
28 46 41	208 45 34	Nantasket	4 706·5	3·672 70
98 28 05	278 24 50	Deer Island.	6 703·8	3·826 32
117 51 07	297 44 56	Powderhorn	14 246·9	4·153 72
165 21 30	345 20 25	Nahant 2.	8 785·0	3·943 74
240 12 54	60 17 51	Powderhorn	11 620·9	4·065 24
280 25 27	100 29 54	Dorchester Heights.	9 244·0	3·965 86
240 24 36	60 29 39	Powderhorn	11 789·6	4·071 50
291 32 25	111 33 18	Corey.	1 921·8	3·283 71
160 03 03	340 02 44	Mount Auburn	1 879·4	3·274 02
349 25 19	169 25 26	Corey.	1 265·3	3·102 21
207 35 18	27 36 33	Deer Island	5 538·9	3·743 42
271 37 45	91 41 09	Nantasket.	6 939·7	3·841 34
162 09 04	342 07 24	Powderhorn	11 107·8	4·045 63
271 35 23	91 38 47	Nantasket.	6 941·3	3·841 44
10 26 44	190 26 23	Nantasket	3 938·2	3·595 30
64 21 41	244 17 56	Moon Head 2.	8 488·3	3·928 82
9 01 20	189 01 02	Nantasket	3 992·4	3·601 23
63 40 25	243 36 43	Moon Head 2.	8 440·0	3·926 34
17 49 11	197 48 35	Nantasket	4 000·3	3·602 09
121 05 47	301 00 06	Powderhorn.	13 494·3	4·130 15
288 37 06	108 38 04	Blind Asylum	2 083·1	3·318 72
350 49 29	170 49 37	South Bay tripod.	1 797·5	3·254 68
261 12 23	81 14 14	Governor Island 2	3 805·6	3·580 42
10 18 00	190 17 47	South Bay tripod.	2 483·6	3·395 08
271 21 22	91 22 00	Blind Asylum	1 298·3	3·113 38
18 52 08	198 51 57	South Bay tripod.	1 204·8	3·080 90
250 03 59	70 05 40	Governor Island 2	3 652·5	3·562 59
23 25 56	203 25 33	South Bay tripod.	1 940·0	3·287 79
260 29 57	80 31 28	Governor Island 2	3 131·8	3·495 79
337 46 47	157 47 04	Blind Asylum.	1 511·0	3·179 26
80 43 26	260 42 53	South Boston Point	1 125·6	3·051 39
157 44 51	337 43 54	East Boston Reservoir.	5 129·9	3·710 11

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
George Island.	42 19 11·16	344·3	70 55 42·32	969·1
Barrel Beacon. 1846.	42 19 22·27	687·1	70 55 09·18	210·2
Brookline, Dr. Pierce's church spire. 1847.	42 19 38·17	1177·7	71 07 52·48	1201·5
Gallop Island, flag. 1846.	42 19 37·30	1150·9	70 56 21·48	491·7
Gallop Island 2. 1860.	42 19 37·97	1171·5	70 56 23·16	530·3
Lovel Island, pole.	42 19 48·60	1499·4	70 55 50·36	1152·9
Nix Mate.	42 19 53·55	1652·2	70 56 40·94	937·2
Sargent Observatory.	42 18 42·75	1319·0	71 05 41·40	948·1
Roxbury, Jamaica Plains, tall church spire. 1847.	42 18 36·44	1124·3	71 06 59·36	1359·4
Roxbury, laboratory chimney.	42 19 24·52	756·5	71 05 52·98	1213·1
Roxbury, Dr. Putnam's church spire. 1847.	42 19 47·81	1475·1	71 05 24·96	571·4
Roxbury, new Unitarian church spire. 1847.	42 19 42·11	1299·2	71 04 51·72	1184·1
Roxbury Oil Works, chimney.	42 19 55·40	1709·4	71 03 55·14	1262·4
Spectacle Island, flag.	42 19 38·90	1200·3	70 59 16·66	381·4
Squantum. 1847–1860.	42 18 13·89	428·7	71 00 41·57	952·1
Thompson Island, flag. 1847.	42 19 14·60	450·5	71 00 16·12	369·2
Thompson Island, pole near farm school. 1847.	42 19 07·56	233·3	71 00 26·01	595·6
Thompson Island 2. 1860.	42 19 07·88	243·1	71 00 25·65	587·4
Long Island, south end, flag. 1846.	42 18 39·52	1219·4	70 58 37·16	851·0
Long Island, south end, 2. 1860.	42 18 39·60	1221·9	70 58 36·88	844·6
Long Island Hotel, cupola.	42 19 27·40	845·4	70 57 53·39	1222·5
Farm schoolhouse, southeast gable.	42 19 05·26	162·3	71 00 27·55	630·9
Fort Warren, west gable of house.	42 19 13·10	404·2	70 55 42·40	970·9

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
312 17 29	132 18 24	Nantasket	2 542·8	3·405 31
21 10 17	201 09 20	Great Quincy.	5 364·3	3·729 51
237 30 32	57 31 29	Great Brewster	2 280·0	3·357 93
331 21 57	151 22 30	Nantasket.	2 340·4	3·369 29
172 33 44	352 33 37	Corey	1 717·9	3·235 00
225 03 19	45 07 22	Powderhorn.	11 647·4	4·066 23
148 27 02	328 26 15	Deer Island	3 040·9	3·483 00
257 59 01	78 00 46	Great Brewster.	3 658·6	3·563 31
312 01 34	132 02 57	Nantasket	3 791·1	3·578 77
60 24 12	240 22 11	Moon Head 2.	4 740·8	3·675 85
134 14 23	314 13 15	Deer Island	3 214·9	3·507 17
261 48 27	81 49 51	Great Brewster.	2 895·6	3·461 74
266 17 44	86 19 42	Great Brewster	4 032·3	3·605 55
313 07 28	133 09 03	Nantasket.	4 416·0	3·645 03
136 39 04	316 37 29	Corey	4 695·1	3·671 64
239 36 20	59 38 25	Dorchester Heights.	4 923·1	3·692 24
158 15 58	338 15 16	Corey	3 884·5	3·589 33
263 46 33	83 47 25	Sargent Observatory.	1 796·1	3·254 34
212 30 40	32 33 22	Powderhorn	10 253·4	4·010 87
255 04 54	75 07 07	Dorchester Heights.	4 669·0	3·669 22
111 20 56	291 19 10	Corey	3 864·5	3·587 09
211 33 50	31 36 14	Powderhorn.	9 304·2	3·968 68
109 57 24	289 55 16	Corey	4 639·0	3·666 42
258 02 18	78 03 49	Dorchester Heights.	3 178·2	3·502 18
259 11 56	79 12 51	Blind Asylum	1 917·6	3·282 75
345 20 51	165 20 57	South Bay tripod.	775·3	2·889 46
99 26 00	279 23 46	Dorchester Heights	4 623·3	3·665 01
145 38 57	325 38 02	Governor Island.	3 341·4	3·523 93
142 14 36	322 13 19	Dorchester Heights	4 275·0	3·630 94
269 36 06	89 40 23	Nantasket.	8 735·3	3·941 28
115 13 04	295 11 30	Dorchester Heights	3 537·4	3·548 68
171 30 00	351 29 45	Governor Island.	3 547·4	3·549 91
12 08 47	192 08 37	Squantum	1 693·5	3·228 79
120 06 31	300 05 04	Dorchester Heights.	3 437·6	3·536 26
167 49 45	347 48 47	Powderhorn	9 368·7	3·971 68
280 51 22	100 55 28	Nantasket.	8 522·8	3·930 58
199 05 54	19 06 39	Deer Island	4 629·0	3·665 49
277 05 50	97 08 43	Nantasket.	5 931·0	3·773 13
156 01 13	335 59 02	Powderhorn	10 979·4	4·040 58
206 26 25	26 29 19	Nahant 2.	13 276·4	4·123 08
147 28 37	327 25 56	Powderhorn	10 149·9	4·006 46
205 16 44	25 19 09	Nahant 2.	11 514·9	4·061 26
168 11 30	348 10 33	Powderhorn	9 438·9	3·974 92
280 16 09	100 20 16	Nantasket.	8 551·1	3·932 02
313 15 05	133 16 00	Nantasket	2 584·8	3·412 42
72 42 46	252 40 17	Moon Head 2.	5 295·0	3·723 87

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Flagstaff, corner of Dorchester street and turnpike. 1861.	42 19 47·62	1469·3	71 03 26·50	606·7
Suffolk Cordage Factory, ball.	42 19 38·04	1173·7	71 04 20·24	463·4
Point Allerton, flag. 1846.	42 18 37·12	1145·3	70 52 59·36	1359·4
Point Allerton Beacon. 1860.	42 18 47·08	1452·6	70 53 00·29	6·6
Commercial Point wharf, flag.	42 18 00·28	8·6	71 02 38·24	875·9
Dorchester church spire, with clock. 1846.	42 18 29·60	913·3	71 03 45·81	1049·2
Dorchester, summer house on hill.	42 18 09·13	281·8	71 04 35·65	816·6
North Pettick Island, flag. 1846.	42 18 06·28	193·8	70 55 47·57	1089·6
North Pettick Island 2. 1860.	42 18 06·32	195·0	70 55 47·73	1093·3
South Pettick Island.	42 17 23·84	735·6	70 56 51·70	1184·4
Rainsford Island, flagstaff. 1846.	42 18 46·83	1444·9	70 57 07·41	169·7
Rainsford Island, flag. 1860.	42 18 46·91	1447·4	70 57 07·12	163·0
Hull, Oregon House cupola.	42 18 12·14	374·6	70 54 47·44	1086·6
Hull, Steamboat Hotel cupola.	42 18 16·26	501·7	70 55 08·29	189·9
Strawberry Hill, barn.	42 17 22·52	694·8	70 52 49·47	1133·4
Neponset church spire. 1846.	42 17 11·62	358·5	71 02 52·87	1211·3
Hangman Ledge Beacon. 1846.	42 17 44·75	1380·8	70 57 39·22	898·4
Forbes.	42 15 27·87	859·9	71 01 38·94	892·5
Crow Point.	42 15 41·98	1295·3	70 53 46·47	1065·1
Sagamore Head.	42 16 24·46	754·7	70 51 50·04	1146·6
Turkey Hill. 1847.	42 14 25·68	792·4	70 51 14·22	326·0
Eaton Hill, flag.	42 15 44·08	1360·0	70 59 53·43	1224·5
Parker Hill.	42 13 45·60	1406·9	70 46 49·45	1133·8

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
42 03 44	222 03 30	South Bay tripod	686·4	2·836 60
243 58 08	63 58 44	Blind Asylum.	1 366·5	3·135 60
249 59 19	70 00 31	Blind Asylum	2 616·3	3·417 69
285 31 53	105 32 16	South Bay tripod.	800·2	2·903 18
70 21 32	250 20 38	Nantasket	1 965·9	3·293 57
158 10 17	338 09 46	Great Brewster.	2 820·1	3·450 26
85 00 04	264 55 46	Moon Head 2	8 802·0	3·944 58
128 53 46	308 47 48	Powderhorn.	15 623·9	4·193 79
180 48 11	0 48 13	Dorchester Heights	3 800·0	3·579 78
261 03 06	81 04 25	Squantum.	2 705·1	3·432 19
208 55 54	28 56 41	Dorchester Heights	3 308·0	3·519 56
276 32 06	96 34 10	Squantum.	4 247·5	3·628 13
217 51 19	37 52 40	Dorchester Heights	4 467·0	3·650 02
268 24 26	88 27 04	Squantum.	5 363·6	3·729 46
261 44 14	81 45 13	Nantasket	2 022·2	3·305 82
156 19 52	336 18 42	Deer Island.	5 896·0	3·770 56
95 38 01	275 35 36	Moon Head 2	4 957·5	3·695 26
143 01 03	322 56 58	Powderhorn.	13 848·4	4·141 40
117 22 37	297 20 55	Moon Head 2	3 905·2	3·591 64
193 50 51	13 52 34	Nahant 2.	14 650·1	4·165 84
172 35 15	352 34 59	Deer Island	4 183·6	3·621 55
284 04 03	104 05 55	Nantasket.	3 948·2	3·596 40
76 10 22	256 08 50	Moon Head 2	3 208·2	3·506 26
146 24 19	326 21 07	Powderhorn.	11 774·7	4·070 95
138 15 57	318 11 11	Powderhorn	14 585·8	4·163 93
182 59 34	2 59 54	Nahant 2.	12 750·0	4·105 51
91 46 25	271 43 34	Moon Head 2	5 839·7	3·766 39
139 21 34	319 17 02	Powderhorn.	14 175·6	4·151 54
74 23 16	254 20 23	Great Quincy	6 124·2	3·787 05
128 17 29	308 16 28	Nantasket.	2 648·3	3·422 97
184 11 19	4 11 30	Dorchester Heights	5 315·3	3·725 53
237 24 42	57 26 10	Squantum.	3 569·3	3·552 58
122 13 42	302 19 22	Dorchester Heights	8 029·7	3·904 70
181 46 36	1 46 42	Deer Island.	6 066·7	3·782 95
171 16 48	351 16 10	Dorchester Heights	8 602·4	3·934 62
242 42 23	62 47 18	Nantasket.	11 308·4	4·053 40
52 06 28	232 03 11	Whites Hill	8 510·8	3·929 97
107 33 39	287 31 24	Great Quincy.	4 817·0	3·682 78
91 08 35	271 05 02	Great Quincy	7 261·4	3·861 02
134 56 45	314 55 04	Nantasket.	4 859·6	3·686 60
74 18 26	254 13 27	Whites Hill	10 604·0	4·025 47
149 02 02	328 59 57	Nantasket.	8 277·9	3·917 92
238 28 21	58 32 05	Nantasket	8 953·9	3·952 01
342 11 42	162 12 32	Whites Hill.	5 561·1	3·745 16
57 38 54	237 35 47	Prospect Hingham	7 542·9	3·877 54
102 09 14	282 07 12	Scituate.	4 263·4	3·629 76

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Paine Hill Observatory.	42 14 01·56	48·2	70 59 42·96	985·1
Thayer Hill, yellow house, chimney.	42 13 51·49	1588·7	70 58 10·55	241·9
Bumkin Island, flag.	42 16 51·86	1600·1	70 54 02·85	65·3
Black Rock.	42 16 08·55	263·8	70 49 28·42	651·3
Grape Island, flag.	42 16 07·28	224·4	70 55 27·21	623·6
Baker Hill.	42 14 35·94	1108·9	70 54 28·47	652·7
Hingham church spire, with clock. 1847.	42 14 34·32	1058·9	70 53 29·43	674·7
Hingham, old church spire. 1847.	42 14 28·68	884·9	70 53 14·96	343·0
Hingham, Old Colony House cupola.	42 14 51·75	1596·7	70 52 22·62	518·5
Hingham, Great Plains church spire. 1847.	42 12 38·35	1183·2	70 53 04·50	103·2
Milton Mills, tall church spire. 1846.	42 16 26·49	817·3	71 04 07·96	182·4
Wellington Hill, flag.	42 16 59·24	1827·8	71 05 44·08	1010·0
Atlantic House, chimney.	42 16 03·02	93·3	70 50 53·05	1215·7
Rockland House cupola.	42 15 56·90	1755·5	70 51 10·05	230·3
Pig Rock Beacon. 1847.	42 16 44·04	1358·8	70 56 22·65	519·0
Quincy, Bents Point church spire. 1847.	42 14 45·75	1411·6	70 58 31·97	732·9
Quincy, stone church spire. 1847.	42 15 04·25	131·1	71 00 12·98	297·5
Quincy, black top church spire. 1847.	42 15 00·66	20·4	70 59 49·90	1143·8
Minot Ledge light-house. 1847–1877.	42 16 11·16	344·3	70 45 34·71	795·4
Weymouth, Great Hill, flag.	42 14 59·38	1832·1	70 56 33·50	767·8
North Weymouth church spire. 1847.	42 13 46·46	1433·4	70 56 42·94	984·6
King Oak Hill, pole. 1847.	42 13 38·94	1201·4	70 56 25·32	580·5
James & Pope's timber dock, post.	42 20 32·51	1003·1	71 02 39·68	908·3

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
218 09 50	38 11 35	Great Quincy	5 788·6	3·762 57
325 35 44	145 36 27	Whites Hill.	2 583·7	3·412 24
196 42 21	16 43 04	Great Quincy	5 075·2	3·705 45
266 22 55	86 28 31	Scituate.	11 471·5	4·059 62
80 31 42	260 29 38	Great Quincy	4 275·2	3·630 96
171 15 41	351 15 29	Nantasket.	2 617·0	3·417 80
93 29 04	273 23 56	Great Quincy	10 525·0	4·022 22
120 25 58	300 22 42	Nantasket.	7 751·4	3·889 38
201 10 25	21 11 10	Nantasket	4 249·1	3·628 30
263 54 08	83 56 34	Sagamore Head.	5 005·0	3·699 40
133 52 31	313 50 44	Great Quincy	5 035·6	3·702 05
181 36 04	1 36 10	Nantasket.	6 782·7	3·831 40
125 23 58	305 21 32	Great Quincy	6 112·7	3·786 23
213 49 45	33 50 52	Sagamore Head.	4 090·9	3·611 82
124 57 22	304 54 46	Great Quincy	6 484·1	3·811 85
162 17 38	342 17 17	Crow Point.	2 373·6	3·375 41
128 52 51	308 51 55	Crow Point	2 469·3	3·392 57
194 37 39	14 38 01	Sagamore Head.	2 956·2	3·470 73
236 08 45	56 10 55	Scituate	5 336·1	3·727 22
311 19 53	131 20 58	Prospect Hingham.	2 973·9	3·473 32
197 28 34	17 29 36	Dorchester Heights	7 017·3	3·846 17
234 57 19	54 59 38	Squantum.	5 774·3	3·761 50
154 25 49	334 24 16	Corey	7 325·5	3·864 84
217 09 14	37 11 21	Dorchester Heights.	7 132·3	3·853 23
95 23 14	275 19 03	Great Quincy	8 604·4	3·934 72
130 47 57	310 45 38	Nantasket.	6 267·6	3·797 10
330 11 22	150 12 15	Scituate	3 635·6	3·560 58
1 57 01	181 56 58	Turkey Hill.	2 816·4	3·449 70
168 51 04	348 50 18	Deer Island	8 090·0	3·907 95
224 45 27	44 46 49	Nantasket.	3 983·3	3·600 24
221 39 51	41 42 40	Nantasket	8 674·0	3·938 22
301 08 21	121 13 07	Prospect Hingham.	11 387·5	4·056 43
233 48 32	53 52 29	Nantasket	10 012·0	4·000 52
298 09 03	118 14 56	Prospect Hingham.	13 683·3	4·136 19
233 51 57	53 53 47	Great Quincy	4 625·6	3·665 17
337 44 08	157 44 55	Whites Hill.	4 273·8	3·630 81
58 34 57	238 32 05	Scituate	6 892·1	3·838 35
107 44 55	287 39 03	Nantasket.	12 637·7	4·101 67
206 44 50	26 46 20	Nantasket	6 783·6	3·831 46
311 55 34	131 59 00	Prospect Hingham.	9 447·1	3·975 30
58 02 11	238 00 53	Whites Hill	3 145·9	3·497 75
173 45 40	353 45 24	Great Quincy.	5 045·8	3·702 93
64 59 51	244 58 21	Whites Hill	3 390·7	3·530 29
169 43 06	349 42 38	Great Quincy.	5 334·0	3·727 05
271 53 30	91 53 55	Loring's machine shop	847·0	2·927 90
348 45 22	168 45 27	Blind Asylum.	801·3	2·903 80

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Egg Rock light-house. 1877–1894.	42 26 00·748	23·1	70 53 54·014	1234·7
Light-house Hill.	42 13 29·02	895·4	70 58 21·11	484·1
Hole in rock. 1885.	42 12 40·44	1247·8	71 03 04·44	101·9
Fenno Peak.	42 13 20·30	626·4	71 03 43·40	995·5
High Service, apex of water tower in Dorchester.	42 19 31·37	968·0	71 05 42·30	968·6
Petty Rock.	42 16 16·06	495·5	71 06 49·62	1137·1
Gravel Bank 1885.	42 14 28·72	886·2	71 07 30·32	695·1
West Dedham church, white spire. 1885.	42 12 51·94	1602·7	71 12 47·44	1088·2
Hyde Park Catholic church spire. 1885.	42 15 18·58	573·3	71 07 23·15	530·7
Forest Hill Cemetery, bell tower. 1885.	42 17 50·83	1568·4	71 06 30·82	706·0
Jewish Cemetery. 1885.	42 15 35·39	1092·0	71 09 15·08	345·6
Sumner.	42 15 21·08	650·4	71 09 32·22	738·5
Jewish Cemetery 2. 1885.	42 15 30·39	937·7	71 09 10·54	241·6
Reservoir.	42 14 55·10	1700·2	71 06 36·10	827·5
Barn cupola.	42 14 11·39	351·4	71 07 43·59	999·5
Knoll.	42 14 20·46	631·3	71 07 27·43	628·9
Hyde Park, corner 1.	42 13 40·36	1245·3	71 07 52·15	1195·9
Hyde Park, corner 2.	42 14 09·72	299·9	71 08 35·40	811·7
Jerusalem	42 15 20·76	640·5	71 08 49·02	1123·7
Ashland street.	42 16 37·44	1155·2	71 06 52·84	1210·8
River street. 1885.	42 15 43·34	1337·3	71 06 10·76	246·6
River street 2. 1885.	42 15 46·11	1422·8	71 06 03·23	74·0
River street 3. 1885.	42 15 47·67	1470·9	71 06 05·82	133·4
River street 4. 1885.	42 15 48·73	1503·6	71 05 57·15	1309·8

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
144 30 59·8	324 28 17·5	Orne	9 457·6	3·975 782
201 12 10·4	21 13 56·1	Coddon.	9 877·5	3·994 646
290 20 29	110 25 07	Prospect Hingham	10 129·1	4·005 57
342 44 35	162 45 25	South Weymouth Unitarian church.	5 756·0	3·760 12
195 07 37	15 07 54	Round Top	2 155·1	3·333 47
241 14 13	61 16 28	Stetson Observatory.	5 242·9	3·719 57
75 31 20	255 29 13	Blue Hill	4 482·8	3·651 55
139 25 46	319 18 00	Prospect Waltham.	24 335·5	4·386 24
7 18 50	187 18 03	Blue Hill	12 674·5	4·102 93
118 12 33	298 06 07	Prospect Waltham.	14 874·1	4·172 43
321 46 19	141 48 24	Fenno Peak	6 901·4	3·838 94
0 36 21	180 36 19	Blue Hill.	6 545·0	3·815 91
292 03 41	112 06 13	Fenno Peak	5 615·3	3·749 37
345 01 48	165 02 13	Blue Hill.	3 346·7	3·524 62
227 35 05	47 38 27	Captain Johns Hill	9 325·5	3·969 67
271 42 11	91 46 09	Blue Hill.	8 142·2	3·910 74
203 25 29	23 25 52	Petty Rock	1 933·0	3·286 23
305 53 39	125 56 07	Fenno Peak.	6 221·0	3·793 86
3 01 29	183 01 14	Blue Hill	9 482·2	3·976 91
30 45 05	210 44 14	Captain Johns Hill.	3 415·1	3·533 40
281 25 02	101 26 17	Hyde Park Catholic church	2 617·6	3·417 90
328 17 34	148 19 10	Blue Hill.	6 216·8	3·793 57
221 39 37	41 39 48	Jewish Cemetery	591·1	2·771 68
322 56 21	142 58 08	Blue Hill.	6 074·2	3·783 49
59 58 00	239 57 45	Sumner	574·0	2·758 89
146 02 10	326 02 07	Jewish Cemetery.	186·1	2·269 67
5 21 22	185 21 11	Blue Hill	4 064·6	3·609 02
65 59 07	245 54 57	West Dedham church.	9 324·8	3·969 64
228 54 56	48 55 41	Reservoir	2 052·6	3·312 31
336 34 52	156 35 26	Blue Hill.	2 940·4	3·468 40
345 00 03	165 00 26	Blue Hill	3 083·1	3·488 99
52 56 23	232 56 12	Barn cupola.	464·4	2·666 86
204 36 35	24 36 52	Knoll	1 361·1	3·133 89
321 53 43	141 54 23	Blue Hill.	2 211·9	3·344 77
248 31 55	68 32 39	Gravel Bank	1 603·1	3·204 97
318 18 26	138 19 35	Blue Hill.	3 543·8	3·549 47
331 06 41	151 07 59	Blue Hill	5 525·5	3·742 37
49 59 47	229 57 07	West Dedham church.	7 139·5	3·853 67
61 37 14	241 36 38	Captain Johns Hill	1 411·2	3·149 59
192 33 28	12 33 43	Forest Hill Cemetery, bell tower.	2 319·8	3·365 45
114 21 37	294 20 32	Captain Johns Hill	2 421·4	3·384 06
138 34 57	318 34 31	Petty Rock.	1 346·3	3·129 14
63 38 59	243 38 54	River street	192·6	2·284 68
309 03 25	129 03 27	River street 2	76·53	1·883 83
40 14 35	220 14 32	River street.	175·2	2·243 47
59 52 51	239 52 47	River street 2	161·0	2·206 93

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
River street 5. 1885.	42 15 47·08	1452·7	71 05 55·20	1265·1
Peg. 1885.	42 15 23·24	717·1	71 06 37·06	849·5
Peg 2. 1885.	42 15 27·38	844·8	71 06 43·11	988·1
Peg 3. 1885.	42 15 30·76	949·1	71 06 47·32	1084·6
Gravel Bank 2. 1885.	42 14 21·88	675·1	71 07 34·04	780·4
Dedham waterworks.	42 14 34·26	1057·1	71 09 31·82	729·5
Dedham court-house.	42 14 55·48	1711·9	71 10 35·86	822·0
North Weymouth church, tall spire. 1885.	42 14 34·38	1060·8	70 56 44·52	1020·6
South Braintree church, slender yellow spire. 1885.	42 11 58·51	1805·4	71 00 29·71	681·6
South Braintree high school, tower. 1885.	42 12 29·97	924·7	71 00 21·48	492·7
Braintree Orthodox church, large brown spire. 1885.	42 13 17·02	525·2	71 00 13·80	316·5
Weymouth Landing church spire. 1885.	42 12 58·60	1808·2	70 57 51·78	1187·6
Corliss. 1885.	42 14 34·14	1053·4	71 03 48·57	1113·6
Yellow pine.	42 12 47·27	1458·6	71 05 14·12	323·9
Mitchell.	42 12 57·54	1775·4	71 05 43·65	1001·2
Webster. 1885.	42 15 29·28	903·5	71 01 48·35	1108·3
Evans. 1885.	42 16 13·42	414·1	71 02 40·62	930·9
Evans 2. 1885.	42 16 00·22	6·8	71 02 30·02	688·0
Quincy, corner 8.	42 16 06·32	195·0	71 02 31·63	724·8
Stone wharf.	42 16 29·93	923·5	71 02 35·40	811·2
Willard street.	42 13 40·08	1236·7	71 01 43·95	1007·9
Braintree, corner 4.	42 11 40·74	1257·1	71 02 51·94	1191·7
Braintree, corner 6.	42 12 55·59	1715·3	71 02 43·54	998·7

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
80 47 34	260 47 27	River street 2	186·3	2·270 24
138 49 02	318 49 01	River street 4.	67·76	1·830 97
82 15 23	262 14 52	Hyde Park Catholic church	1 066·1	3·027 81
169 59 24	349 59 16	Petty Rock.	1 654·9	3·218 78
312 36 58	132 37 02	Peg	188·5	2·275 38
73 31 44	253 31 17	Hyde Park Catholic church.	956·9	2·980 88
317 12 24	137 12 27	Peg 2	142·1	2·152 53
65 25 13	245 24 49	Hyde Park Catholic church.	902·9	2·955 66
201 56 30	21 56 33	Gravel Bank	227·6	2·357 10
342 33 23	162 33 51	Blue Hill.	3 167·7	3·500 75
278 28 43	98 30 07	Knoll	2 883·7	3·459 95
312 59 00	133 00 47	Blue Hill.	4 991·4	3·698 22
157 37 50	337 34 42	Prospect Waltham	16 797·7	4·225 25
287 12 51	107 17 28	Fenno Peak.	9 903·3	3·995 78
311 46 38	131 47 57	Totman Mountain	3 631·4	3·560 08
80 02 49	259 58 50	Round Top.	8 274·1	3·917 72
138 30 23	318 28 56	Round Top	4 506·2	3·653 81
195 21 27	15 21 58	Stetson Observatory.	3 956·6	3·597 32
127 08 46	307 07 13	Round Top	3 982·3	3·600 13
196 48 21	16 48 46	Stetson Observatory.	2 971·6	3·472 99
105 52 29	285 50 51	Round Top	3 483·5	3·542 01
206 07 42	26 08 02	Stetson Observatory.	1 551·2	3·190 68
253 35 55	73 40 22	Turkey Hill 2	9 491·4	3·977 33
286 18 59	106 23 17	Prospect Hingham.	9 195·4	3·963 57
312 11 15	132 12 01	Round Top	2 125·2	3·327 41
51 10 01	231 07 57	Blue Hill.	5 420·4	3·734 03
87 24 11	267 23 05	Blue Hill	2 262·1	3·354 51
210 44 49	30 45 47	Corliss.	3 836·9	3·583 98
295 04 24	115 04 44	Yellow pine	747·7	2·873 75
75 08 59	255 08 13	Blue Hill.	1 637·1	3·214 08
20 42 04	200 41 29	Round Top	3 344·4	3·524 32
45 31 16	225 30 30	Fuller.	2 187·0	3·339 84
7 07 38	187 07 27	Fuller	2 917·7	3·465 04
41 49 12	221 46 23	Blue Hill.	8 669·6	3·938 00
44 51 32	224 48 36	Blue Hill	8 540·4	3·931 48
149 12 18	329 12 11	Evans.	474·6	2·676 34
348 55 55	168 55 56	Evans 2	192·0	2·283 39
136 45 53	316 45 47	Evans.	300·9	2·478 44
13 12 27	193 12 23	Evans	523·2	2·718 68
40 14 55	220 12 02	Blue Hill.	9 132·7	3·960 59
100 38 07	280 37 29	Round Top	1 305·4	3·115 76
137 52 40	317 51 51	Fuller.	2 476·8	3·393 89
171 09 23	351 09 15	Hole in rock	1 864·1	3·270 46
184 01 24	4 01 32	Round Top.	3 932·1	3·594 62
182 57 32	2 57 34	Round Top	1 615·5	3·208 30
224 52 11	44 52 51	Willard street.	1 936·9	3·287 10

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Pierce. 1885.	42 11 59·34	1831·0	71 06 12·79	293·4
Pierce 2. 1885.	42 11 53·24	1642·8	71 06 22·68	520·3
Pierce 3. 1885.	42 12 02·18	67·3	71 06 15·32	351·4
Milton, corner 1.	42 12 02·74	84·5	71 06 12·43	285·2
Plains 2. 1885.	42 12 13·28	409·8	71 05 34·11	782·6
Plains. 1885.	42 12 20·76	640·6	71 05 21·74	498·7
Plains 3. 1885.	42 12 17·47	539·0	71 05 18·90	433·6
Plains 4. 1885.	42 12 16·49	508·8	71 05 11·38	261·0
Plains 5. 1885.	42 12 15·98	493·1	71 05 07·48	171·6
Corliss, base end.	42 14 32·83	1013·0	71 03 47·37	1086·1
Corliss 2. 1885.	42 14 33·56	1035·5	71 03 44·72	1025·3
Quincy, corner 3.	42 13 45·23	1395·6	71 03 12·63	289·6
Harris.	42 13 46·28	1428·0	71 01 44·18	1013·1
Wood street.	42 13 41·01	1265·4	71 02 01·80	41·3
Hole in rock, base end.	42 12 21·68	669·0	71 03 04·07	93·4
Hole in rock 2. 1885.	42 12 22·22	685·6	71 03 01·62	37·2
Braintree, corner 5.	42 12 24·04	741·8	71 02 59·89	1373·8
Fields.	42 13 56·42	1740·9	71 00 12·86	294·9
Braintree, corner 8.	42 13 43·42	1339·8	71 00 40·53	929·4
Heywood Observatory.	42 14 07·90	243·8	70 58 42·10	965·3
Heywood.	42 14 10·43	321·8	70 58 52·96	1214·3
Hingham Plains church, tall, slender, gray spire. 1885.	42 13 44·06	1359·5	70 52 54·48	1249·3
Turkey Hill 3. 1885.	42 14 27·30	842·4	70 51 14·77	338·6
Turkey Hill, base end.	42 14 37·27	1150·0	70 51 17·02	390·2
Turkey Hill 4. 1885.	42 14 37·44	1155·3	70 51 20·35	466·6
Totman Mountain 2. 1885.	42 13 32·38	999·1	70 54 55·46	1271·9
Border street.	42 14 02·57	79·3	70 47 05·24	120·2

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
146 24 30	326 24 03	Blue Hill	1 652·2	3·218 07
222 17 31	42 18 10	Yellow pine.	1 999·7	3·300 97
230 21 40	50 21 47	Pierce	294·8	2·469 59
156 17 14	336 16 54	Blue Hill.	1 708·6	3·232 65
326 24 28	146 24 30	Pierce	105·3	2·022 46
31 27 40	211 27 35	Pierce 2.	323·4	2·509 71
4 27 44	184 27 44	Pierce	105·4	2·023 04
75 19 30	255 19 28	Pierce 3.	68·7	1·837 01
117 42 33	297 41 40	Blue Hill	2 034·7	3·308 49
203 36 41	23 36 54	Yellow pine.	1 144·5	3·058 63
50 53 05	230 52 57	Plains 2	365·8	2·563 22
108 56 13	288 55 12	Blue Hill.	2 204·4	3·343 29
147 19 52	327 19 50	Plains	120·53	2·081 10
99 59 25	279 59 20	Plains 3	175·13	2·243 36
100 00 17	280 00 14	Plains 4	90·96	1·958 85
145 45 14	325 45 13	Corliss	48·71	1·687 62
69 36 02	249 36 00	Corliss, base end	64·8	1·811 28
101 21 18	281 21 15	Corliss.	89·9	1·953 59
151 21 50	331 21 26	Corliss	1 719·4	3·235 37
263 47 26	83 47 48	Round Top.	755·0	2·877 92
358 27 16	178 27 16	Willard street	191·6	2·282 31
92 12 55	272 12 18	Round Top.	1 278·9	3·106 82
248 03 41	68 03 53	Harris	435·5	2·638 96
274 01 34	94 01 46	Willard street.	410·1	2·612 92
179 09 56	359 09 56	Hole in rock	578·8	2·762 50
73 33 09	253 33 07	Hole in rock, base end	58·61	1·767 97
173 26 26	353 26 24	Hole in rock.	565·8	2·752 67
35 09 52	215 09 51	Hole in rock 2	68·8	1·837 74
168 21 10	348 21 07	Hole in rock.	516·5	2·713 05
59 13 56	239 12 01	Hole in rock	4 580·4	3·660 90
85 32 26	265 30 47	Round Top.	3 382·5	3·529 24
245 57 43	65 58 21	Stetson Observatory	1 419·2	3·152 04
323 01 55	143 02 13	Braintree Orthodox church.	1 019·6	3·008 43
53 16 15	233 15 13	Braintree Orthodox church	2 624·3	3·419 01
82 53 52	262 53 10	Stetson Observatory.	1 430·7	3·155 55
287 23 14	107 23 21	Heywood Observatory	261·0	2·416 63
77 42 51	257 42 17	Stetson Observatory.	1 198·1	3·078 49
240 56 20	60 57 27	Turkey Hill 2	2 618·4	3·418 03
333 20 45	153 21 44	Prospect Hingham.	4 465·8	3·649 90
357 47 12	177 47 12	Turkey Hill 2	63·00	1·799 34
350 28 37	170 28 39	Turkey Hill 3	312·0	2·494 09
273 55 41	93 55 43	Turkey Hill, base end	76·55	1·883 95
337 45 15	157 45 19	Turkey Hill 3.	338·1	2·529 00
337 49 06	157 49 12	Totman Mountain	547·5	2·738 41
32 14 23	212 13 59	East Weymouth church.	1 531·4	3·185 10
68 52 32	248 51 44	Walnut Hill	1 770·1	3·248 00
122 54 12	302 53 26	Cohasset church.	1 878·1	3·273 71

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Elm. 1885.	42 13 22·66	699·2	70 47 44·72	1025·6
Elm 2. 1885.	42 13 23·37	721·1	70 47 16·88	387·1
Wright Hill.	42 13 16·59	511·9	70 58 01·69	38·8
Weymouth, corner 2.	42 13 11·99	370·0	70 58 09·08	208·2
Cohasset, corner 2.	42 12 47·44	1463·8	70 50 28·68	657·8
Whiting street. 1885.	42 11 37·84	1167·6	70 55 04·03	92·5
Whiting street 2. 1885.	42 11 37·26	1149·7	70 55 04·69	107·6
Whiting street 3. 1885.	42 11 36·34	1121·3	70 55 08·04	184·5
High street.	42 12 55·02	1697·7	70 54 52·88	1212·9
Boston, corner 1.	42 15 18·73	577·9	71 09 32·70	749·5
Hyde Park, corner 3.	42 15 20·92	645·5	71 08 49·68	1138·8
Hyde Park, corner 4.	42 15 30·21	932·2	71 09 10·09	231·3
Hyde Park, corner 5.	42 16 39·19	1209·2	71 06 54·30	1244·2
Hyde Park, corner 6.	42 15 48·46	1495·3	71 05 52·58	1205·1
Milton, corner 3.	42 14 22·00	678·8	71 07 35·15	805·9
Milton, corner 4.	42 14 52·97	1634·4	71 06 35·42	812·0
Milton, corner 5.	42 15 19·69	607·6	71 06 36·13	828·1
Milton, corner 6.	42 15 31·72	978·8	71 06 48·85	1119·7
Quincy, corner 1.	42 12 16·64	513·4	71 05 00·55	12·6
Quincy, corner 4.	42 14 32·75	1010·5	71 03 41·65	954·9
Webster 2. 1885.	42 15 33·38	1030·0	71 01 54·58	1251·0
Quincy, corner 5.	42 15 30·01	926·0	71 01 57·70	1322·5
Quincy, corner 6.	42 15 33·47	1032·8	71 01 54·89	1258·1
Quincy, corner 7.	42 15 59·37	1831·9	71 02 31·77	728·1
Quincy, corner 9.	42 16 30·66	946·0	71 02 35·06	803·4
Braintree, corner 7.	42 13 40·59	1252·4	71 02 00·56	12·8
Braintree, corner 9.	42 13 56·16	1732·9	71 00 09·58	219·7
Weymouth-Hingham line stone C (?).	42 12 53·95	1664·7	70 55 00·44	10·1
Weymouth-Hingham line stone B.	42 11 37·68	1162·7	70 55 11·43	262·2
Cohasset, corner 3.	42 14 22·79	703·2	70 51 13·99	320·7
Cohasset, corner 4.	42 14 38·16	1177·5	70 51 19·76	453·0
Hingham, corner 2.	42 13 30·90	953·5	70 54 54·83	1257·4
Elm 3. 1885.	42 13 23·69	731·0	70 47 18·77	430·5
Elm 4. 1885.	42 13 23·73	732·2	70 47 20·17	462·5
Scituate, corner 5.	42 13 23·81	734·7	70 47 20·17	462·5
Scituate, corner 6.	42 14 05·60	172·8	70 47 05·90	135·3

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
128 30 34	308 30 12	Walnut Hill	953·1	2·979 12
216 19 08	36 19 34	Border street.	1 528·4	3·184 25
88 02 30	268 02 11	Elm	638·9	2·805 45
192 26 24	12 26 32	Border street.	1 238·7	3·092 96
98 37 52	278 34 45	Round Top	6 453·0	3·809 76
130 44 10	310 43 57	Light-house Hill.	587·9	2·769 30
152 18 20	332 18 12	Light house Hill	593·5	2·773 40
230 06 05	50 06 10	Wright Hill.	221·1	2·344 67
324 02 46	144 03 33	Mount Hope	2 762·1	3·441 24
30 52 25	210 51 46	Prospect Hingham.	2 615·2	3·417 50
53 44 00	233 42 38	South Weymouth Unitarian church	3 492·8	3·543 17
164 30 27	344 30 09	East Weymouth, church.	2 323·1	3·366 07
220 18 26	40 18 26	Whiting street	23·57	1·372 36
249 39 35	69 39 37	Whiting street 2	82·03	1·913 97
213 33 22	33 34 21	Hingham Cathólic church	3 654·2	3·562 79
297 41 22	117 43 40	Prospect Hingham.	5 330·5	3·726 77
188 34 52	8 34 52	Sumner	73·21	1·864 57
288 07 18	108 07 18	Jerusalem	16·03	1·204 93
118 12 29	298 12 29	Jewish Cemetery 2	11·58	1·063 71
328 19 55	148 19 56	Ashland street	63·57	1·803 25
54 37 10	234 37 08	River street 5	73·57	1·866 70
278 29 05	98 29 06	Gravel bank 2	25·82	1·411 96
166 39 11	346 39 11	Reservoir	67·39	1·828 60
169 02 38	349 02 37	Peg	111·57	2·047 55
310 08 20	130 08 21	Peg 3	45·78	1·660 68
82 43 36	262 43 31	Plains 5	160·21	2·204 69
109 28 48	289 28 46	Corliss 2	74·60	1·872 74
311 32 31	131 32 35	Webster	190·85	2·280 69
214 28 51	34 28 53	Webster 2	126·30	2·101 40
290 40 24	110 40 24	Webster 2	7·65	0·883 66
236 52 47	56 52 48	Evans 2	47·90	1·680 34
19 02 57	199 02 57	Stone wharf	23·78	1·376 21
114 41 32	294 41 31	Wood street	31·25	1·494 85
96 05 53	276 05 51	Fields	75·54	1·878 18
259 15 26	79 15 31	High street	176·51	2·246 77
6 21 26	186 21 05	Hingham, corner 1.	6 408·8	3·806 78
297 58 27	117 58 29	Whiting street 3	88·02	1·944 58
6 29 46	186 29 33	Hingham, corner 1.	4 042·1	3·606 61
168 34 01	348 34 01	Turkey Hill 2	77·61	1·889 92
31 16 47	211 16 47	Turkey Hill 4	25·88	1·412 96
162 19 43	342 19 43	Totman Mountain 2	47·80	1·679 40
6 22 14	186 21 49	Hingham, corner 1.	7 556·1	3·878 30
282 42 09	102 42 10	Elm 2	44·54	1·648 75
272 12 57	92 12 58	Elm 3	32·09	1·506 37
2 12 57	182 12 57	Elm 4	2·58	0·411 62
350 44 43	170 44 43	Border street	94·69	1·976 30

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Heywood, base end.	42 14 09·29	286·7	70 58 54·30	1245·0
Braintree, corner 10.	42 14 08·91	274·9	70 58 53·76	1232·7
Mitchell, base end.	42 12 15·51	478·6	71 05 35·22	808·0
Quincy, corner 2.	42 12 50·37	1554·2	71 05 37·24	854·2
Sanitarium pole.	42 24 58·27	1798·0	71 10 56·18	1284·5
Sullivan's barn, cupola.	42 21 18·12	559·1	71 09 56·65	1296·5
Barker's house.	42 21 09·29	286·6	71 11 34·57	791·2
Belmont, corner 6.	42 24 53·59	1653·6	71 12 11·28	257·9
Fence.	42 22 47·43	1463·5	71 11 17·77	406·6
Fence, east base.	42 22 50·22	1549·6	71 11 17·73	405·7
Fence, west base.	42 22 50·24	1550·2	71 11 20·51	469·2
Belmont, corner 2.	42 22 50·72	1565·0	71 11 22·95	525·0
Waltham Baptist church spire. 1890.	42 22 30·01	926·0	71 14 15·14	346·4
Precipice.	42 22 39·42	1216·3	71 16 41·55	950·6
Precipice, north base.	42 22 34·89	1076·6	71 16 45·19	1033·9
Precipice, south base.	42 22 32·39	999·4	71 16 40·59	928·6
Waltham, corner 2.	42 22 31·48	971·3	71 16 36·43	833·5
Swine.	42 24 21·94	677·0	71 12 42·08	962·3
Beaver Brook.	42 23 07·63	235·4	71 11 47·95	1096·8
Beaver Brook base, peg.	42 23 05·32	164·2	71 11 46·96	1074·2
Beaver Brook, peg.	42 23 08·68	267·8	71 11 41·98	960·3
Watertown, corner 5.	42 23 09·92	306·1	71 11 40·79	933·1
Woodland.	42 23 14·60	450·5	71 11 42·20	965·3
Belmont, corner 3.	42 23 15·51	478·6	71 11 46·35	1060·2
Brown Knoll.	42 24 09·23	284·8	71 11 59·68	1364·8
Lexington, corner 1.	42 24 22·07	681·0	71 12 42·31	967·6
Brown Knoll, south base.	42 24 10·93	337·3	71 12 09·05	207·0
Brown Knoll north base.	42 24 13·72	423·3	71 12 08·75	200·1

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
221 15 46	41 15 47	Heywood	46·7	1·669 32
133 39 50	313 39 50	Heywood, base end	17·12	1·233 50
201 25 36	21 25 37	Heywood.	50·4	1·702 50
133 55 17	313 55 11	Mitchell	268·3	2·428 60
146 26 13	326 26 09	Mitchell	265·6	2·424 22
232 48 50	52 48 51	Mitchell, base end.	58·26	1·765 37
303 28 07	123 32 54	Boston State House	11 663·3	4·066 82
62 39 13	242 36 18	Prospect Waltham.	6 673·9	3·824 38
168 40 18	348 39 38	Sanitarium pole	6 928·2	3·840 62
267 32 28	87 36 34	Boston State House.	8 374·7	3·922 97
128 22 26	308 19 57	Prospect Waltham	6 441·4	3·808 98
187 05 00	7 05 26	Sanitarium pole.	7 119·5	3·852 45
353 04 40	173 05 05	Barker's house	6 971·4	3·843 32
55 13 51	235 11 47	Prospect Waltham.	5 125·2	3·709 71
7 14 11	187 14 00	Barker's house	3 052·4	3·484 64
100 07 49	280 05 09	Prospect Waltham.	5 520·1	3·741 95
0 34 32	180 34 32	Fence	86·1	1·935 05
270 31 33	90 31 35	Fence, east base	63·654	1·803 83
324 05 03	144 05 05	Fence.	107·0	2·029 54
284 48 42	104 48 44	Fence, west base	57·680	1·761 03
137 34 32	317 33 51	Prospect Waltham	2 040·8	3·309 80
224 49 55	44 52 09	Sanitarium pole.	6 452·7	3·809 74
238 20 21	58 21 19	Prospect Waltham	2 317·0	3·364 92
291 34 11	111 37 38	Barker's house.	7 555·1	3·878 24
210 45 52	30 45 54	Precipice	162·7	2·211 38
126 16 07	306 16 04	Precipice, north base	130·390	2·115 24
174 14 05	354 14 04	Precipice.	218·0	2·338 53
106 23 36	286 23 33	Precipice, south base	99·167	1·996 37
245 08 49	65 10 00	Sanitarium, pole	2 668·6	3·426 28
326 16 15	146 18 07	Sullivan's barn, cupola.	6 818·5	3·833 69
70 59 33	250 57 54	Waltham Baptist church	3 561·9	3·551 68
94 11 03	274 08 43	Prospect Waltham.	4 756·4	3·677 28
162 26 50	342 26 49	Beaver Brook	74·858	1·874 24
47 44 05	227 44 02	Beaver Brook base, peg	154·1	2·187 94
76 42 01	256 41 57	Beaver Brook.	140·4	2·147 42
35 27 27	215 27 26	Beaver Brook, peg	46·99	1·672 01
358 24 54	178 24 54	Beaver Brook, peg	182·7	2·261 81
31 28 27	211 28 23	Beaver Brook.	252·0	2·401 48
286 24 23	106 24 26	Woodland	99·0	1·995 83
334 35 19	154 35 22	Beaver Brook, peg.	233·2	2·367 73
112 01 48	292 01 19	Swine	1 045·7	3·019 41
169 02 13	349 02 05	Belmont, corner 6.	1 394·2	3·144 33
307 10 42	127 10 42	Swine	6·620	0·820 86
283 45 18	103 45 24	Brown Knoll	220·7	2·343 81
303 43 54	123 44 00	Brown Knoll	249·5	2·397 01
4 35 22	184 35 22	Brown Knoll, south base.	86·329	1·936 16

BOSTON BAY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Browns Knoll, traverse 1.	42 24 13·90	428·9	71 12 10·07	230·3
Belmont, corner 4.	42 24 13·53	417·5	71 12 11·23	256·8
St. John's Seminary.	42 20 30·00	925·7	71 09 54·45	1246·4
Ridge.	42 21 56·02	1728·5	71 08 37·08	848·5
Ridge, base.	42 21 55·93	1725·7	71 08 39·37	900·9
Winchester, peg.	42 21 59·11	1823·9	71 08 40·55	927·9
Watertown, corner 14.	42 21 59·09	1823·3	71 08 41·00	938·2
Watertown, corner 15.	42 21 59·45	1834·4	71 08 41·15	941·6
Watertown, corner 16.	42 21 55·92	1725·4	71 08 39·57	905·5
Cambridge Congregational church spire. 1890.	42 23 12·14	374·6	71 07 09·48	216·9
Cambridge waterworks, tower.	42 22 46·06	1421·2	71 08 11·88	271·8
Corey Hill electric light.	42 20 33·00	1018·2	71 08 02·00	45·8
High Rock.	42 28 04·93	152·1	70 56 48·76	1113·9
Little Nahant 2. 1894.	42 26 13·22	407·9	70 55 52·25	1194·3
Marsh.	42 26 55·81	1722·1	70 58 53·19	1215·5
Yellow house, east chimney. 1894.	42 27 48·63	1500·5	70 53 49·20	1124·1
Dread Ledge Beacon. 1894.	42 27 23·06	711·5	70 53 43·57	995·5
High School. 1894.	42 28 12·13	374·3	70 54 39·39	899·8
Lincoln House, cupola. 1894.	42 27 47·39	1462·3	70 54 29·06	663·9
Nahant, church steeple. 1894.	42 25 29·30	904·1	70 55 02·18	49·8
Nahant, church cupola. 1894.	42 25 36·32	1120·7	70 55 19·61	448·3
Gasworks, chimney. 1894.	42 27 16·97	523·6	70 57 07·82	178·7
Point Pines House, chimney. 1894.	42 26 14·60	450·5	70 58 05·20	118·9

BOSTON BAY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
280 38 31	100 38 32	Browns Knoll, north base	30·745	1·487 77
345 44 35	165 44 36	Browns Knoll, south base.	94·6	1·976 10
246 31 30	66 31 31	Browns Knoll, traverse 1	28·830	1·459 84
178 03 16	358 03 15	Sullivan's barn, cupola	1 485·1	3·171 75
208 32 54	28 33 44	Mount Auburn.	3 546·5	3·549 80
57 17 12	237 16 18	Sullivan's barn, cupola	2 164·1	3·335 28
170 43 16	350 43 14	Mount Auburn.	466·9	2·669 20
266 57 54	86 57 56	Ridge	52·362	1·719 02
320 16 52	140 16 54	Ridge	124·1	2·093 69
344 37 44	164 37 45	Ridge base.	101·9	2·007 98
267 19 34	87 19 34	Winchester, peg	10·327	1·013 97
307 27 04	127 27 04	Winchester, peg	17·165	1·234 64
266 54 30	86 54 32	Ridge	57·112	1·756 73
304 51 10	124 53 24	Boston State House	5 533·8	3·743 02
47 24 33	227 21 41	Sullivan's barn, cupola.	5 196·6	3·715 72
31 02 43	211 02	Mount Auburn	1 264·0	3·101 74
41 28 00	221 26	Sullivan's barn, cupola.	3 620·6	3·558 78
163 48 12	343 47	Mount Auburn	3 147·4	3·497 95
253 03 51	73 06 40	Boston State House.	6 003·6	3·778 41
241 50 26	61 52 40	Legg Hill	5 127·2	3·709 88
313 48 05	133 50 03	Egg Rock light-house.	5 534·3	3·743 06
159 28 14	339 27 36	High Rock	3 680·9	3·565 95
278 05 27	98 06 47	Egg Rock light-house.	2 730·0	3·436 16
233 06 40	53 08 04	High Rock	3 554·3	3·550 75
287 36 42	107 38 44	Little Nahant 2.	4 339·0	3·637 39
43 41 42	223 40 19	Little Nahant 2	4 071·1	3·609 71
97 00 25	276 58 24	High Rock.	4 132·8	3·616 24
106 59 57	286 57 52	High Rock	4 423·8	3·645 80
53 46 44	233 45 17	Little Nahant 2.	3 645·8	3·561 79
24 24 48	204 23 59	Little Nahant 2	4 029·2	3·605 22
85 42 49	265 41 22	High Rock.	2 963·7	3·471 83
33 12 07	213 11 11	Little Nahant 2	3 472·5	3·540 64
99 38 11	279 36 37	High Rock.	3 237·1	3·510 15
153 06 52	333 05 40	High Rock	5 384·3	3·731 13
196 07 01	16 08 03	Legg Hill.	7 515·9	3·875 98
116 41 42	296 39 18	Marsh	5 463·0	3·737 43
156 03 13	336 02 13	High Rock.	5 018·1	3·700 54
74 50 14	254 49 03	Marsh	2 494·8	3·397 04
196 23 48	16 24 01	High Rock.	1 542·7	3·188 29
139 13 04	319 12 32	Marsh	1 679·2	3·225 10
207 09 12	27 10 04	High Rock.	3 826·3	3·582 78

SALEM AND VICINITY.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Brown Hill.	42 36 45·688	1409·7	70 50 49·984	1139·3
Coddon.	42 30 59·166	1825·7	70 51 17·520	399·9
Bolles.	42 35 05·95	183·6	70 47 35·44	808·3
Folly Hill.	42 33 59·108	1823·9	70 54 48·202	1099·5
Beverly Rocks.	42 33 58·78	1813·8	70 50 14·98	341·7
Beverly, powderhouse.	42 33 12·60	388·7	70 52 33·13	755·9
Beverly, tall spire with turrets.	42 32 51·06	1575·6	70 52 43·52	993·8
Beverly Point, flag in tree.	42 32 59·04	1821·8	70 54 15·46	352·7
Baker Island light-house. 1834–1877.	42 32 11·53	355·8	70 47 11·22	256·1
Kettle Island.	42 34 01·26	38·9	70 43 22·00	501·8
Fort Lee.	42 31 54·71	1688·2	70 52 28·94	660·4
Legg Hill. 1848–189x.	42 29 23·300	719·0	70 53 30·826	704·0
Manchester church, dark spire.	42 34 30·28	934·3	70 46 20·82	474·8
Danvers Insane Asylum, tower.	42 34 51·74	1596·6	70 58 30·82	702·8
Danvers Plain, tall spire.	42 34 03·32	102·5	70 56 18·26	416·5
Danvers, new mills, tall spire.	42 33 20·70	638·8	70 55 30·55	696·9
South Danvers, tall spire.	42 31 35·38	1091·7	70 55 40·55	925·5
Dexter Point.	42 32 53·80	1660·1	70 50 44·26	1009·8
Bowditch Ledge Beacon.	42 32 25·38	783·2	70 48 43·19	985·5
Great Misery, flag.	42 32 50·20	1549·0	70 47 49·23	1123·2
Great Haste.	42 32 05·29	163·3	70 50 32·51	741·9
Little Haste Beacon.	42 32 07·71	237·9	70 50 35·95	820·4
Hardy Rock Beacon.	42 32 11·36	350·5	70 48 01·62	37·0

SALEM AND VICINITY.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
98 31 09·8	278 20 36·7	Holt	21 536·5	4·333 174
38 28 34·0	218 23 46·9	Orne.	15 576·8	4·192 479
123 52 53·2	303 42 39·3	Holt	24 899·7	4·396 194
223 59 47·4	44 04 50·7	Thompson.	14 712·3	4·167 681
124 46 28	304 44 16	Brown Hill	5 398·5	3·732 27
240 07 13	60 09 46	Thompson.	5 948·3	3·774 39
319 05 33·5	139 07 55·9	Coddon	7 344·4	3·865 958
31 03 45·3	211 01 39·4	Orne.	8 241·8	3·916 022
14 26 43	194 26 01	Coddon	5 723·0	3·757 62
56 07 28	236 02 18	Orne.	12 635·7	4·101 60
337 14 56	157 15 47	Coddon	4 464·3	3·649 75
52 32 04	232 28 26	Orne.	9 242·8	3·965 80
330 22 30	150 23 28	Coddon	3 971·5	3·598 95
55 04 17	235 00 47	Orne.	8 659·1	3·937 48
312 18 45	132 20 45	Coddon	5 493·0	3·739 81
43 50 40	223 48 12	Orne.	7 218·4	3·858 44
68 21 47	248 19 01	Coddon	6 048·7	3·781 66
107 42 21	287 37 12	Folly Hill.	10 941·6	4·039 08
62 40 15	242 34 54	Coddon	12 218·0	4·087 00
57 06 08	237 03 33	Baker Island light-house.	6 230·9	3·794 55
140 23 59	320 22 25	Folly Hill	4 982·9	3·697 48
66 35 04	246 31 24	Orne.	8 099·2	3·908 44
103 33 35·3	283 30 37·2	Orne	6 191·9	3·791 821
225 48 19·5	45 49 49·6	Coddon.	4 244·3	3·627 809
46 03 15	225 58 25	Legg Hill	13 638·6	4·134 77
60 16 54	240 12 45	Fort Lee.	9 673·6	3·985 59
305 56 10	126 01 03	Coddon	12 216·0	4·086 93
354 32 21	174 32 46	Orne.	8 724·9	3·940 76
307 09 31	127 12 06	Fort Lee	6 566·6	3·817 34
273 36 19	93 37 20	Folly Hill.	2 058·4	3·313 52
307 04 40	127 07 31	Coddon	7 239·9	3·859 73
29 12 50	209 11 13	Orne.	6 731·8	3·828 13
195 04 03	15 04 38	Folly Hill	4 593·0	3·662 10
280 30 58	100 33 56	Coddon.	6 106·9	3·785 82
285 00 00	105 02 24	Baker Island light-house	5 033·3	3·701 85
12 06 52	192 06 30	Coddon.	3 617·2	3·558 37
52 57 21	232 55 37	Coddon	4 413·8	3·644 82
79 36 48	259 34 15	Fort Lee.	5 237·8	3·719 15
54 14 29	234 12 08	Coddon	5 858·8	3·767 81
75 00 35	254 57 26	Fort Lee.	6 608·8	3·820 12
26 43 46	206 43 16	Coddon	2 284·0	3·358 69
83 00 24	262 59 05	Fort Lee.	2 676·9	3·427 64
24 10 03	204 09 35	Coddon	2 318·0	3·365 12
81 09 48	261 08 32	Fort Lee.	2 609·8	3·416 60
85 12 52	265 09 51	Fort Lee	6 122·2	3·786 91
109 45 35	289 41 00	Folly Hill.	9 853·9	3·993 61

SALEM AND VICINITY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Dodge's Hotel, cupola.	42 32 02·86	88·2	70 53 49·30	1125·1
Hospital Point light-house. 1877.	42 32 47·60	1468·8	70 51 23·29	531·3
Fort Pickering light-house. 1877.	42 31 35·57	1097·6	70 52 01·07	24·4
Great Aquavitæ, stone beacon.	42 31 34·58	1067·0	70 51 28·24	644·5
Little Aquavitæ, pole.	42 31 34·78	1073·2	70 51 13·10	299·0
Abbott Rock, stone beacon.	42 31 49·48	1526·8	70 51 46·34	1057·5
North Gooseberry Island, flag.	42 31 35·97	1109·9	70 47 39·19	894·4
Eagle Island, flag.	42 31 31·21	963·1	70 48 49·24	1123·8
Coney Island, flag.	42 31 42·89	1323·4	70 50 14·78	337·3
Salem, south church, corner of Cambridge and Chestnut streets.	42 31 12·02	370·9	70 53 59·36	1354·8
Salem, Howard street church.	42 31 28·12	867·7	70 53 34·04	776·9
Derby wharf light-house. 1877.	42 30 59·91	1848·7	70 53 02·54	58·0
Marblehead light-house. 1848–1877.	42 30 19·76	609·7	70 50 03·02	68·9
Marblehead, black top church.	42 30 25·66	791·8	70 50 54·11	1235·3
Marblehead Rock Beacon.	42 30 11·95	367·7	70 49 34·48	787·2
Marblehead Neck, flag.	42 29 46·94	1448·7	70 50 29·04	663·1
Cat Island, flagstaff. 1848.	42 30 43·52	1342·9	70 48 55·42	1265·1
Cat Island, east rock.	42 30 32·61	1006·2	70 48 45·00	1027·3
Boulder west of Salem turnpike.	42 30 21·92	676·4	70 56 07·38	168·5
Ware Hill, flagstaff. 1848.	42 30 40·60	1252·7	70 54 32·79	748·5
Halfway Rock Beacon.	42 30 09·38	289·5	70 46 31·40	716·9
Brookhouse's house.	42 29 08·56	264·1	70 53 13·76	314·3
Ocean House cupola.	42 28 53·73	1658·0	70 52 33·64	768·3

SALEM AND VICINITY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
159 28 06	339 27 26	Folly Hill	3 830·5	3·583 25
277 48 22	97 49 16	Fort Lee.	1 851·0	3·267 40
357 44 44	177 44 48	Coddon	3 348·4	3·524 84
61 30 05	241 25 41	Orne.	10 162·5	4·007 00
318 28 55	138 29 24	Coddon	1 499·8	3·176 03
26 40 14	206 39 13	Legg Hill.	4 566·6	3·659 59
347 22 34	167 22 41	Coddon	1 119·6	3·049 07
114 08 54	294 08 13	Fort Lee.	1 518·2	3·181 34
5 14 47	185 14 44	Coddon	1 103·4	3·042 75
109 33 29	289 32 38	Fort Lee.	1 836·8	3·264 07
337 02 09	157 02 28	Coddon	1 685·9	3·226 83
27 53 02	207 51 51	Legg Hill.	5 102·3	3·707 77
77 11 02	257 08 34	Coddon	5 111·4	3·708 54
141 07 20	321 05 35	Beverly Rocks.	5 661·5	3·752 93
73 43 39	253 41 59	Coddon	3 526·1	3·547 30
156 45 24	336 44 26	Beverly Rocks.	4 955·9	3·695 12
46 43 17	226 42 35	Coddon	1 967·2	3·293 84
96 48 27	276 46 56	Fort Lee.	3 083·5	3·489 04
276 06 36	96 08 25	Coddon	3 715·5	3·570 02
349 00 26	169 00 45	Legg Hill.	3 417·0	3·533 65
160 02 50	340 02 00	Folly Hill	4 957·0	3·695 22
241 04 41	61 05 25	Fort Lee.	1 697·1	3·229 72
270 31 50	90 33 01	Coddon	2 397·5	3·379 76
12 13 36	192 13 17	Legg Hill.	3 049·7	3·484 26
125 34 26	305 33 36	Coddon	2 090·7	3·320 30
228 39 22	48 41 18	Baker Island light-house.	5 222·3	3·717 86
87 12 26	267 07 42	Orne	9 608·6	3·982 66
140 58 41	320 56 03	Folly Hill.	8 480·5	3·928 42
121 47 05	301 45 55	Coddon	2 767·1	3·442 03
134 25 24	314 21 52	Folly Hill.	10 019·6	4·000 85
94 05 21	274 00 20	Orne	10 195·5	4·008 41
153 35 42	333 35 09	Coddon.	2 488·3	3·395 90
98 29 02	278 27 26	Coddon	3 279·9	3·515 86
114 16 59	294 14 35	Fort Lee.	5 345·4	3·727 98
103 15 34	283 13 51	Coddon	3 577·1	3·553 54
162 07 16	342 06 15	Beverly Rocks.	6 684·8	3·825 09
260 07 08	80 10 24	Coddon	6 716·5	3·827 14
195 04 59	15 05 53	Folly Hill.	6 941·3	3·841 44
262 39 34	82 41 46	Coddon	4 494·4	3·652 67
329 19 10	149 19 52	Legg Hill.	2 773·3	3·442 99
90 09 53	270 02 11	Orne	15 595·5	4·193 00
103 15 46	283 12 33	Coddon.	6 710·1	3·826 73
106 34 15	286 31 05	Orne	6 686·4	3·825 19
166 29 29	346 28 25	Folly Hill.	9 220·8	3·964 77
204 10 29	24 11 20	Coddon	4 242·8	3·627 65
107 53 47	287 50 10	Orne.	7 697·3	3·886 34

SALEM AND VICINITY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Tinker Island, pole on house.	42 28 57·71	1780·8	70 50 07·28	166·3
Church spire summer house.	42 28 55·14	1701·5	70 53 03·45	78·8
Summer house on high rock.	42 28 05·06	156·2	70 56 48·86	1116·1

CAPE ANN AND VICINITY.

Railcut.	42 37 42·872	1322·7	70 38 58·400	1330·6
Pool Hill.	42 39 24·690	762·0	70 38 05·772	131·6
Andrews Point.	42 40 58·98	1819·9	70 37 46·80	1065·4
Lanes Cove, white spire. 1849.	42 40 41·55	1282·1	70 39 15·88	361·5
Choate.	42 39 55·52	1713·2	70 45 40·80	929·1
Ipswich light-house. 1849.	42 41 06·81	210·1	70 46 07·32	166·6
Ipswich Beacon. 1849.	42 41 07·56	233·3	70 45 59·91	1363·9
Ipswich, tall dark spire.	42 40 53·18	1641·1	70 50 11·70	266·3
Butler Hill.	42 39 29·50	910·3	70 40 18·33	417·5
Burnham Brown, flag.	42 39 32·00	987·4	70 49 25·88	589·5
Burnham Essex, flag in tree.	42 39 01·50	46·3	70 47 04·48	102·0
Annisquam Harbor light-house. 1834–1849.	42 39 43·02	1327·4	70 40 55·29	1258·1
Annisquam, pole on rock.	42 39 26·92	830·7	70 40 39·62	902·4
Straitsmouth light-house. 1849.	42 39 43·65	1346·8	70 35 22·52	512·9
Straitsmouth light-house. 1851.	42 39 44·37	1369·0	70 35 19·15	436·1
Twopenny Loaf, flag.	42 39 36·80	1135·5	70 43 08·84	201·3
Rockport, red-top church.	42 39 28·80	888·7	70 37 09·70	220·9
Dogtown Methodist church.	42 38 04·86	149·9	70 40 33·09	754·0
Lufkin Hill, flag.	42 38 16·08	496·1	70 44 40·86	930·9

SALEM AND VICINITY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
99 39 40	279 37 22	Legg Hill	4 715·3	3·673 51
156 50 14	336 49 27	Coddon.	4 076·5	3·610 29
109 15 37	289 12 20	Orne	7 038·2	3·847 46
212 16 55	32 18 05	Coddon.	4 527·5	3·655 86
158 48 45	338 48 01	Orne	4 143·7	3·617 39
241 53 24	61 55 38	Legg Hill.	5 127·3	3·709 89

CAPE ANN AND VICINITY.

74 10 58·4	254 07 41·5	Thompson	6 888·2	3·838 105
113 15 06·7	293 05 13·9	Prospect Rowley.	21 667·7	4·335 812
20 53 33·8	200 52 58·1	Railcut	3 362·8	3·526 702
57 20 06·2	237 16 13·6	Thompson.	9 297·4	3·968 362
117 52 03	297 43 04	Old Town	20 422·6	4·310 11
89 17 09	269 10 31	Tilton.	13 380·8	4·126 48
40 07 29	220 04 24	Thompson	9 666·4	3·985 26
91 51 18	271 45 40	Tilton.	11 358·0	4·055 30
294 01 26	114 05 59	Railcut	10 039·2	4·001 70
336 55 35	156 56 51	Thompson.	6 492·7	3·812 43
344 38 59	164 39 17	Choate	2 281·2	3·358 16
78 01 26	258 00 27	Tilton.	2 028·7	3·307 21
340 01 03	160 02 32	Thompson	8 721·2	3·940 58
78 21 25	258 20 21	Tilton.	2 198·5	3·342 13
311 37 23	131 41 42	Thompson	11 664·3	4·066 86
6 31 01	186 30 35	Brown Hill.	7 686·5	3·885 73
331 01 55	151 02 49	Railcut	3 760·6	3·575 26
42 54 41	222 52 18	Thompson.	7 057·8	3·848 67
225 21 25	45 22 40	Tilton	3 564·6	3·552 01
304 20 44	124 24 32	Thompson.	9 294·8	3·968 24
228 49 06	48 50 03	Choate	2 532·0	3·403 46
314 02 40	134 04 52	Thompson.	6 193·3	3·791 92
35 21 06	215 19 08	Thompson	6 849·8	3·835 68
103 25 49	283 21 19	Tilton.	9 343·9	3·970 53
324 18 14	144 19 23	Railcut	3 953·0	3·596 93
40 19 23	220 17 15	Thompson.	6 676·4	3·824 54
81 04 12	261 02 21	Pool Hill	3 764·1	3·575 66
125 17 43	305 16 05	Andrews Point.	4 024·5	3·604 71
80 55 13	260 53 20	Pool Hill	3 843·2	3·584 69
124 25 05	304 23 25	Andrews Point.	4 074·6	3·610 09
9 39 48	189 39 21	Thompson	5 474·0	3·738 30
99 29 15	279 27 32	Choate.	3 508·5	3·545 12
84 19 39	264 19 01	Pool Hill	1 283·3	3·108 32
163 07 15	343 06 50	Andrews Point.	2 908·2	3·463 62
287 26 43	107 27 47	Railcut	2 261·6	3·354 42
187 19 55	7 20 05	Butler Hill.	2 633·5	3·420 54
337 55 11	157 55 46	Thompson	3 135·2	3·496 26
71 41 23	251 37 13	Brown Hill.	8 861·9	3·947 52

CAPE ANN AND VICINITY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Londoner Beacon. 1849.	42 38 06·26	193·1	70 33 59·33	1351·7
Essex powderhouse.	42 38 19·16	591·2	70 47 18·24	415·6
Essex, red-top church.	42 37 59·96	1850·1	70 46 53·16	1211·2
Beacon Hill 1.	42 36 24·94	769·6	70 38 43·01	980·3
Beacon Hill 2.	42 36 11.74	362·2	70 38 38·64	880·9
Beacon Hill Magnetic Station. 1849.	42 36 22·79	703·3	70 38 46·85	1067·9
Thatcher Island.	42 38 10·94	337·5	70 34 46·28	1054·5
Salvage.	42 40 20·24	624·6	70 34 05·94	135·2
Cape Ann north light-house. 1834–1849.	42 38 21·29	657·1	70 34 31·03	707·0
Cape Ann north light-house. 1878.	42 38 21·25	655·8	70 34 31·05	707·4
Cape Ann south light-house. 1834-1849.	42 38 12·82	395·5	70 34 31·68	721·8
Cape Ann south light-house. 1878.	42 38 12·82	395·5	70 34 31·78	724·1
Milk Island, flag.	42 37 41·64	1284·8	70 35 31·80	724·6
Salt Island, flag.	42 37 11·38	351·1	70 37 26·60	606·3
Gloucester, east church.	42 37 00·46	14·2	70 39 25·66	584·9
Gloucester Universalist church.	42 36 47·66	1470·6	70 40 00·14	3·2
Woodward Hill, flag.	42 36 59·74	1843·2	70 42 05·96	135·8
Clark Mountain, flag in tree.	42 36 59·50	1836·0	70 43 41·16	938·0
Tenpound Island light-house. 1849.	42 36 06·66	205·5	70 39 57·58	1312·6
Eastern Point light-house. 1834–1849.	42 34 49·14	1516·2	70 39 53·90	1229·1
Gloucester Catholic church spire. 1889.	42 36 57·86	1785·4	70 39 48·94	1115·4
Gloucester city hall, dome. 1889.	42 36 50·76	1566·3	70 39 48·14	1097·3

CAPE ANN AND VICINITY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
83 59 02	263 55 39	Railcut	6 852·4	3·835 84
113 20 43	293 17 56	Pool Hill.	6 113·3	3·786 28
175 33 02	355 32 51	Tilton	4 766·3	3·678 18
216 44 04	36 45 10	Choate.	3 710·2	3·569 40
252 53 13	72 57 40	Butler Hill	9 408·9	3·973 54
299 51 08	119 53 13	Thompson.	4 835·3	3·684 42
171 42 10	351 42 00	Railcut	2 430·3	3·385 66
94 19 15	274 15 48	Thompson.	6 997·9	3·844 97
170 54 12	350 53 59	Railcut	2 847·7	3·454 49
97 31 25	277 27 55	Thompson.	7 138·9	3·853 63
232 48 30	52 48 33	Beacon Hill 1	109·81	2·040 64
81 26 49	261 23 58	Railcut	5 809·3	3·764 12
55 14 21	235 11 44	Beacon Hill 2.	6 447·7	3·809 40
12 58 08	192 57 41	Thatcher Island	4 093·8	3·612 13
72 35 49	252 33 06	Pool Hill.	5 724·3	3·757 72
79 00 49	258 57 48	Railcut	6 206·4	3·792 84
111 49 03	291 46 38	Pool Hill.	5 268·1	3·721 65
58 00 48	237 57 57	Beacon Hill 1	6 771·3	3·830 67
111 50 05	291 47 40	Pool Hill.	5 268·4	3·721 68
81 22 42	261 19 41	Railcut	6 147·2	3·788 68
114 28 16	294 25 51	Pool Hill.	5 357·3	3·728 95
59 50 47	239 47 57	Beacon Hill 1	6 622·8	3·821 04
114 29 05	294 26 40	Pool Hill.	5 355·6	3·728 81
90 28 57	270 26 37	Railcut	4 707·5	3·672 79
56 56 22	236 54 15	Beacon Hill 2.	5 082·3	3·706 06
114 54 59	294 53 57	Railcut	2 306·4	3·362 94
41 44 50	221 44 01	Beacon Hill 2.	2 466·5	3·392 08
84 35 10	264 32 12	Thompson	6 033·0	3·780 53
205 23 24	25 23 42	Railcut.	1 448·8	3·161 02
175 15 22	355 15 10	Butler Hill	5 011·4	3·699 96
219 32 31	39 33 13	Railcut.	2 209·6	3·344 32
207 56 25	27 57 38	Butler Hill	5 231·4	3·718 62
252 41 17	72 43 24	Railcut.	4 476·5	3·650 94
143 37 28	323 34 50	Tilton	8 956·9	3·952 16
258 14 39	78 17 50	Railcut.	6 581·3	3·818 31
204 25 45	24 26 25	Railcut	3 260·8	3·513 32
265 00 51	85 01 44	Beacon Hill 2.	1 806·3	3·256 78
228 21 47	48 25 15	Thatcher Island	9 377·6	3·972 09
193 16 31	13 17 09	Railcut.	5 507·9	3·740 99
117 54 39	297 45 20	Prospect Rowley 2	21 224·6	4·326 84
138 01 15	317 53 39	Old Town.	22 841·3	4·358 72
118 24 23	298 15 04	Prospect Rowley 2	21 344·2	4·329 28
138 21 02	318 13 26	Old Town.	23 017·1	4·362 05

COAST NORTH OF CAPE ANN.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Great Boar Head, N. H.	42 55 05·432	167·6	70 47 45·932	1041·8
Seabrook, N. H.	42 52 29·586	913·0	70 49 06·554	148·8
Old Town. 1850–1890.	42 46 07·582	234·0	70 51 00·902	20·5
Crane Neck. 1850–1890.	42 46 13·667	421·8	70 58 31·748	721·8
Tilton. 1849–50.	42 40 53·162	1640·4	70 47 34·478	784·9
Salisbury Marsh, monument. (Borden) 1834.	42 52 18·702	577·1	70 49 14·678	333·1
Newburyport, Pleasant street Unitarian church spire. 1850–1889.	42 48 38·418	1185·4	70 52 19·206	436·4
Newburyport light-house. (Borden) 1834.	42 48 28·994	894·6	70 48 48·384	1099·3
Newburyport light-house. 1878–1889.	42 48 54·778	1690·3	70 49 10·344	235·0
Indian Hill, flagstaff. 1878–1889.	42 47 03·284	101·3	70 56 54·441	1237·4
Little Old Town. 1849–1889.	42 46 24·866	767·3	70 50 32·228	732·6
Ox Pasture Hill. 1850–1889.	42 44 17·083	527·1	70 52 55·000	1251·1
Rowley Congregational church, spire with turrets. 1849–1889.	42 42 59·016	1821·0	70 52 42·379	964·3
Byfield Congregational church, square tower. 1849–1889.	42 44 19·034	587·3	70 55 53·805	1223·9
Crane Neck 2. 1889–90.	42 46 13·801	425·8	70 58 31·688	720·4
Prospect Rowley 2. 1889.	42 42 19·017	586·8	70 53 33·084	752·9
Bald Pate 2. 1889–90.	42 42 28·752	887·2	71 00 56·022	1274·9
Isley.	42 46 34·856	1075·5	70 57 40·417	918·8
Brake Hill. 1886–1889.	42 46 46·883	1446·6	71 00 20·742	471·5
Grape.	42 53 09·934	306·5	70 54 34·912	792·3
Bald Pate. 1886.	42 42 29·260	902·9	71 00 56·455	1284·8
Beach.	42 52 18·256	563·3	70 49 04·361	99·0
South Dock, monument.	42 52 07·647	236·0	70 49 48·750	1106·6

COAST NORTH OF CAPE ANN.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
193 56 11·7	14 00 26·5	Agamenticus	34 954·4	4·543 502
242 33 32·4	62 40 59·1	Isles of Shoals.	16 737·2	4·223 682
233 05 42·0	53 14 03·5	Isles of Shoals	20 860·3	4·319 320
84 11 25·5	264 06 31·4	Powow.	9 863·0	3·994 007
26 10 38·5	206 08 55·2	Prospect Rowley	7 853·3	3·895 050
146 12 55·1	326 09 19·0	Powow.	12 977·7	4·113 199
316 47 00·5	136 50 23·1	Prospect Rowley	9 925·0	3·996 732
195 53 51·7	15 55 22·0	Powow.	11 016·7	4·042 051
296 29 39·7	116 35 29·4	Railcut	13 139·7	4·118 587
326 28 15·6	146 30 48·2	Thompson.	9 297·5	3·968 368
332 31 49·7	152 38 48·0	Railcut	30 443·9	4·483 500
17 38 22·8	197 35 27·2	Prospect Rowley.	19 410·7	4·288 042
8 10 49·9	188 09 59·7	Prospect Rowley	11 823·2	4·072 734
62 13 18·6	242 09 05·5	Crane Neck.	9 572·9	3·981 045
325 59 26·8	146 06 07·0	Railcut	24 035·8	4·380 859
29 35 47·9	209 32 34·6	Prospect Rowley.	13 121·2	4·117 975
25 58 39·4	205 57 24·3	Old Town	5 738·6	3·758 803
120 04 55·4	300 00 04·1	Powow (Borden).	11 238·7	4·050 718
282 02 18·5	102 06 18·5	Old Town.	8 218·7	3·914 803
185 06 19·7	5 06 44·0	Powow (Borden).	9 103·0	3·959 183
88 13 46·4	268 08 20·8	Crane Neck	10 907·1	4·037 710
50 42 50·4	230 42 30·9	Old Town.	842·3	2·925 461
115 11 39·4	295 07 50·7	Crane Neck	8 460·9	3·927 415
13 24 45·4	193 24 19·5	Prospect Rowley.	3 740·9	3·572 981
298 57 48·3	119 01 17·1	Tilton	8 012·3	3·903 756
43 12 03·0	223 11 28·6	Prospect Rowley.	1 687·2	3·227 172
243 16 35·3	63 19 54·1	Old Town	7 455·7	3·872 488
319 07 04·5	139 08 39·9	Prospect Rowley.	4 891·7	3·689 459
18 22	198 22	Crane Neck	4·35	0·638 74
67 59 46·5	247 51 03·4	Holt	18 964·5	4·277 941
129 47 12·0	309 40 28·3	Ayer Hill.	17 585·8	4·245 162
45 15 39·4	225 11 56·5	Holt	10 547·3	4·023 140
162 30 10·1	342 28 27·0	Ayer Hill.	11 471·7	4·059 629
190 33 33·7	10 34 29·2	Powow (Borden)	10 115·6	4·004 992
275 15 22·3	95 19 53·6	Old Town.	9 121·6	3·960 071
209 50 32·5	29 53 17·0	Powow (Borden)	11 038·9	4·042 927
275 23 24·4	95 29 44·6	Old Town.	12 784·9	4·106 696
46 22 29·6	226 21 18·9	Powow (Borden)	3 256·5	3·512 748
66 39 18·0	246 36 27·4	Eaton.	6 198·4	3·792 283
167 21 56·7	347 20 23·2	Brandybrow	14 301·2	4·155 371
199 47 00·9	19 50 09·5	Powow (Borden).	18 624·6	4·270 088
86 15 18·0	266 10 22·5	Powow (Borden)	9 881·9	3·994 841
13 02 34·7	193 01 15·5	Old Town.	11 740·6	4·069 689
8 23 55·5	188 23 06·5	Old Town	11 231·0	4·050 420
87 56 01·0	267 51 35·7	Powow (Borden).	8 858·9	3·947 382

COAST NORTH OF CAPE ANN—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
North Dock, monument.	42 51 53·109	1638·8	70 50 14·040	318·7
Pike, monument.	42 51 39·381	1215·1	70 50 53·612	1217·2
Evans, monument.	42 53 12·196	376·3	70 54 54·504	1236·8
Bagley, monument.	42 53 12·671	391·0	70 54 14·547	330·1
Morrill, monument.	42 52 58·466	1804·0	70 53 10·004	227·0
Hampton, N. H.	42 56 33·94	1047·3	70 49 37·92	859·8
Batt Hill.	42 52 15·86	489·5	70 53 32·60	739·9
Amesbury Mills, tall white spire. 1849–50.	42 51 21·34	658·5	70 55 58·56	1329·6
Bartlett.	42 50 04·46	137·6	70 55 23·76	539·6
Salisbury Beach.	42 50 49·10	1515·1	70 49 03·44	78·1
Salisbury Marsh. 1850.	42 51 06·89	212·6	70 50 11·66	264·7
Salisbury Congregational church spire. 1849–1889.	42 50 34·00	1049·2	70 51 38·97	885·0
Amesbury (formerly West Salisbury), powder house. 1850–1889.	42 51 22·09	681·7	70 54 51·36	1166·0
West Salisbury church spire. 1849–50.	42 50 39·46	1223·3	70 55 01·22	27·7
Morrill. 1878.	42 49 15·68	483·9	70 51 06·46	146·8
Mouth of Merrimac, chimney of house.	42 49 13·63	420·7	70 49 18·16	412·5
Newburyport, Belleville church spire. 1849–50.	42 49 06·77	208·9	70 53 24·84	564·3
Newbury, Upper Green, tall church spire. 1849–1851.	42 47 58·52	1805·8	70 51 46·19	1049·7
Newburyport, Harris street church spire. 1850.	42 48 31·70	978·2	70 52 23·74	539·4
Newburyport, Federal street church spire. 1850–1851.	42 48 30·56	943·1	70 51 59·57	1353·4
Newburyport Academy.	42 48 31·80	981·3	70 52 28·89	656·4
Newburyport, beacon on north pier. 1850.	42 48 49·26	1520·1	70 51 28·43	645·9
Newburyport, east light-house. 1850–51.	42 48 26·93	831·0	70 49 01·34	30·4

COAST NORTH OF CAPE ANN—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
5 42 23·4	185 41 51·5	Old Town	10 715·2	4·030 000
90 53 20·5	270 49 12·4	Powow (Borden).	8 280·1	3·918 035
0 55 39·2	180 55 34·2	Old Town	10 239·9	4·010 295
94 16 11·6	274 12 30·4	Powow (Borden).	7 401·4	3·869 312
337 55 55·0	157 58 33·8	Old Town	14 136·2	4·150 334
52 59 45·9	232 59 18·3	Brier.	1 151·9	3·061 422
30 38 40·2	210 36 56·5	Lone Tree Hill	6 795·3	3·832 208
50 25 06·0	230 23 41·5	Powow (Borden).	3 658·4	3·563 286
282 31 27·1	102 34 14·2	Beach	5 711·5	3·756 750
346 57 53·6	166 59 21·4	Old Town.	13 013·7	4·114 400
317 04 32	137 05 48	Great Boar Head	3 729·9	3·571 70
59 36 12	239 33 19	Hampton Falls.	6 677·5	3·824 68
174 32 48	354 32 35	Hampton Falls	4 603·8	3·663 12
81 15 09	261 13 16	Powow.	3 817·5	3·581 78
325 02 23	145 05 45	Old Town	11 810·0	4·072 25
348 48 33	168 50 12	Prospect Rowley.	17 054·5	4·231 84
320 43 11	140 46 10	Old Town	9 439·5	3·974 95
30 58 22	210 56 14	Crane Neck.	8 304·8	3·919 33
178 42 06	358 42 03	Seabrook	3 101·8	3·491 62
102 00 42	281 55 46	Powow.	10 104·2	4·004 50
210 04 18	30 05 02	Seabrook	2 949·2	3·469 70
289 30 46	109 31 32	Salisbury Beach.	1 643·1	3·215 67
353 59 29	173 59 55	Old Town	8 266·1	3·917 30
111 59 08	291 55 58	Powow.	6 850·3	3·835 71
118 30 18	298 29 18	Powow	2 258·8	3·353 88
192 11 45	12 12 25	Hampton Falls.	6 386·8	3·805 28
25 15 20	205 15 05	Bartlett	1 200·0	3·079 18
143 34 59	323 34 06	Powow.	2 966·9	3·472 31
358 45 14	178 45 18	Old Town	5 805·8	3·763 86
125 06 52	305 03 19	Powow (Borden).	8 666·2	3·937 83
22 08 34	202 07 24	Old Town	6 197·8	3·792 24
117 51 47	297 47 01	Powow.	10 801·1	4·033 47
52 35 03	232 31 35	Crane Neck	8 785·4	3·943 76
143 04 17	323 02 19	Powow.	6 573·1	3·817 77
70 41 31	250 36 56	Crane Neck	9 769·9	3·989 89
139 56 46	319 53 41	Powow.	9 616·6	3·983 02
63 02 45	242 58 35	Crane Neck	9 386·2	3·972 49
337 02 45	157 03 41	Old Town.	4 829·3	3·683 88
167 32 48	347 31 32	Hampton Falls	11 813·5	4·072 38
205 16 06	25 18 59	Great Boar Head.	13 476·9	4·129 59
170 42 05	350 41 09	Hampton Falls	11 650·1	4·066 33
207 50 39	27 53 52	Great Boar Head.	13 740·4	4·138 00
352 50 55	172 51 14	Old Town	5 027·9	3·701 39
131 19 43	311 16 26	Powow.	8 777·7	3·943 38
32 18 07	212 16 46	Old Town	5 086·4	3·706 41
123 09 53	303 04 56	Powow.	11 862·9	4·074 19

COAST NORTH OF CAPE ANN—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Newburyport, west light-house. 1850–51.	42 48 26·90	830·0	70 49 06·92	157·2
Upper Harbor, inner beacon. 1878.	42 48 40·74	1257·1	70 51 59·68	1356·0
Upper Harbor, outer beacon. 1878.	42 48 41·73	1287·7	70 51 55·22	1254·6
Bailey's wharf.	42 48 42·98	1326·3	70 51 56·52	1284·0
Thompson's Hotel.	42 47 57·15	1763·6	70 48 48·56	1103·4
Plum Island Magnetic Station. 1850.	42 47 59·94	1849·7	70 48 49·34	1121·1
Plum Island 1. 1849–50.	42 46 37·02	1142·4	70 48 17·72	402·8
Plum Island 2. 1849–50.	42 44 27·80	857·8	70 47 33·78	768·4
Dummer Academy. 1850.	42 45 16·28	502·4	70 53 59·58	1354·9
Wood's Hotel.	42 45 23·86	736·2	70 48 15·60	354·7
Rowley Marsh.	42 44 37·76	1165·2	70 50 16·33	371·4
Ipswich Town Farm.	42 43 03·92	121·0	70 50 52·09	1185·3
Proctor's barn.	42 43 02·03	62·6	70 46 51·51	1172·1
Manning Hill.	42 42 30·27	934·0	70 48 23·32	530·6
Stevens 2. 1889.	42 48 57·39	1770·9	70 59 25·58	581·2
Newburyport Federal Street church spire. 1886–1889.	42 48 30·58	943·6	70 51 59·52	1352·3
Newbury Congregational church spire. 1886–1889.	42 47 58·12	1793·5	70 51 47·62	1082·2
West Newbury Second Congregational church spire. 1886–1889.	42 47 49·57	1529·6	70 59 45·63	1037·0
West Newbury First Congregational church spire. 1886–1889.	42 48 35·71	1101·9	70 57 06·19	140·6
Morrill Observatory. 1886–1889.	42 51 32·39	999·5	70 54 49·26	1118·3
Moultonville schoolhouse, tower.	42 49 36·78	1135·0	70 54 02·24	50·9
Newburyport Harris Street church spire. 1886–1889.	42 48 32·38	999·2	70 52 22·38	508·5
Planting Hill.	42 48 18·00	555·4	70 55 46·12	1048·0

COAST NORTH OF CAPE ANN—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
31 04 56	211 03 39	Old Town	5 019·3	3·700 64
123 30 20	303 25 27	Powow.	11 757·4	4·070 31
135 52 06	315 49 10	Powow (Borden)	8 446·2	3·926 66
228 15 33	48 16 09	Morrill.	1 619·9	3·209 50
73 08 46	253 08 43	Upper Harbor, inner beacon	105·7	2·024 26
226 35 15	46 35 48	Morrill.	1 524·6	3·183 16
46 01 04	226 01 02	Upper Harbor, inner beacon	99·7	1·998 48
322 34 12	142 34 13	Upper Harbor, outer beacon.	48·5	1·686 06
41 40 10	221 38 40	Old Town	4 525·4	3·655 66
125 56 23	305 51 17	Powow.	12 623·5	4·101 18
40 47 09	220 45 40	Old Town	4 578·5	3·660 72
125 40 02	305 34 56	Powow.	12 558·8	4·098 95
354 42 00	174 42 29	Tilton	10 655·9	4·027 59
76 15 20	256 13 29	Old Town.	3 819·4	3·581 99
0 08 23	180 08 23	Tilton	6 623·2	3·821 07
64 08 10	244 04 06	Prospect Rowley.	9 088·7	3·958 50
105 59 32	285 56 27	Crane Neck	6 437·1	3·808 69
353 42 47	173 43 05	Prospect Rowley.	5 499·0	3·740 28
353 36 20	173 36 48	Tilton	8 405·4	3·924 56
51 45 20	231 41 44	Prospect Rowley.	9 201·3	3·963 85
331 59 51	152 01 41	Tilton	7 848·4	3·894 78
46 19 50	226 17 36	Prospect Rowley.	6 192·1	3·791 84
177 58 31	357 58 25	Old Town	5 670·9	3·753 65
69 21 43	249 19 54	Prospect Rowley.	3 916·3	3·592 88
81 47 59	261 43 27	Prospect Rowley	9 234·9	3·965 43
135 17 25	315 14 36	Old Town.	8 059·7	3·906 32
339 38 24	159 38 57	Tilton	3 196·1	3·504 62
87 14 38	267 11 08	Prospect Rowley.	7 059·1	3·848 75
217 24 01	37 26 08	Powow (Borden)	6 982·5	3·844 01
294 30 17	114 36 00	Old Town.	12 610·4	4·100 73
343 11 29	163 12 09	Old Town	4 609·4	3·663 64
65 17 16	245 13 24	Isley.	8 530·8	3·930 99
12 39 47	192 39 01	Ox Pasture Hill	6 990·8	3·844 53
70 42 04	250 37 30	Crane Neck.	9 735·1	3·988 34
101 39 55	281 37 24	Ayer Hill	5 155·1	3·712 24
211 34 36	31 36 57	Powow (Borden).	8 968·1	3·952 70
298 48 01	118 52 09	Old Town	9 477·2	3·976 68
189 49 50	9 50 22	Powow (Borden).	6 307·4	3·799 85
349 03 00	169 04 16	Ox Pasture Hill	13 681·1	4·136 12
27 13 18	207 10 47	Crane Neck.	11 058·1	4·043 68
102 13 30	282 11 38	Lone Tree Hill 2	3 820·7	3·582 14
144 24 56	324 23 23	Powow (Borden).	5 325·6	3·726 37
337 28 56	157 29 51	Old Town	4 836·6	3·684 54
63 23 00	243 19 24	Isley.	8 086·5	3·907 76
173 44 50	353 44 28	Powow (Borden)	6 802·1	3·832 64
301 48 17	121 51 31	Old Town.	7 630·4	3·882 55

COAST NORTH OF CAPE ANN—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Emery.	42 49 01·36	42·0	70 56 28·32	643·4
Adams.	42 46 53·96	1665·1	70 55 32·60	741·0
Noyes.	42 44 58·50	1805·2	70 51 46·02	1046·6
Gerrish.	42 46 12·11	373·7	70 57 04·00	90·9
Ambrose.	42 44 30·24	933·1	70 54 04·06	92·3
Poverty Rock.	42 43 34·60	1067·6	70 56 04·44	101·0
Jewett.	42 42 21·66	668·4	70 52 48·92	1113·3
Evans.	42 42 40·16	1239·2	70 52 06·78	154·3
Amesbury–Salisbury, corner 1.	42 50 50·85	1569·1	70 54 01·22	27·7
Amesbury–Salisbury, corner 2.	42 50 16·46	507·9	70 54 12·46	283·0
Newbury–Newburyport, corner 1.	42 48 25·62	790·5	70 49 05·88	133·6
Newbury–Newburyport, corner 2.	42 47 45·53	1405·0	70 50 29·58	672·2
Newbury–Newburyport, corner 3.	42 48 05·83	179·9	70 51 48·48	1101·7
Newbury–Newburyport, corner 4.	42 47 39·74	1226·2	70 53 28·70	652·2
Newbury–Newburyport, corner 5.	42 47 54·35	1677·1	70 53 54·48	1238·0
Newbury–Newburyport, corner 6.	42 47 51·04	1575·0	70 54 20·26	460·4
Newbury–Rowley, corner 1.	42 45 07·58	233·9	70 48 03·17	72·1
Ipswich–Rowley, corner 1.	42 44 10·82	333·9	70 47 37·05	842·9
Newbury–Rowley, corner 2.	42 45 04·68	144·4	70 48 16·76	381·1
Newbury–Rowley, corner 3.	42 44 56·76	1751·4	70 51 41·77	950·0
Newbury–Rowley, corner 4.	42 44 55·79	1721·5	70 52 12·34	280·6
Newbury–Rowley, corner 5.	42 44 59·16	1825·5	70 52 18·92	430·3
Newbury–Rowley, corner 6.	42 44 30·16	930·6	70 54 03·45	78·5
Newbury–Rowley, corner 7.	42 44 07·32	225·9	70 55 22·17	504·4

COAST NORTH OF CAPE ANN—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
83 00 49	262 56 04	Ayer Hill	9 603·1	3·982 41
182 17 20	2 17 26	Powow (Borden).	5 427·9	3·734 63
173 36 37	353 36 06	Powow (Borden)	9 413·5	3·973 75
283 01 10	103 04 15	Old Town.	6 340·0	3·802 09
104 09 03	284 04 28	Crane Neck	9 512·8	3·978 31
173 39 29	353 39 07	Pleasant Street Unitarian church.	6 827·9	3·834 29
183 10 09	3 10 21	Lone Tree Hill 2	7 134·4	3·853 36
270 55 56	91 00 03	Old Town.	8 256·4	3·916 79
234 11 02	54 13 06	Old Town	5 135·5	3·710 58
350 07 18	170 07 39	Prospect Rowley 2.	4 110·0	3·613 84
145 41 51	325 40 11	Crane Neck	5 942·9	3·774 00
253 03 42	73 05 50	Ox Pasture Hill.	4 504·5	3·653 65
85 21 25	265 20 55	Prospect Rowley 2	1 008·3	3·003 61
177 46 33	357 46 29	Ox Pasture Hill.	3 564·5	3·552 00
71 37 43	251 36 44	Prospect Rowley 2	2 069·5	3·315 87
159 51 38	339 51 05	Ox Pasture Hill.	3 185·5	3·503 18
68 32 31	248 30 39	Lone Tree Hill 2	4 037·0	3·606 06
123 13 27	303 11 54	Powow (Borden).	3 732·1	3·571 95
319 36 54	139 38 11	Pleasant Street Unitarian church	3 971·5	3·598 96
349 15 43	169 15 50	Moultonville schoolhouse tower.	1 246·3	3·095 62
31 33 03	211 31 45	Old Town	4 998·0	3·698 80
77 01 00	256 59 10	Newbury Congregational church.	3 771·7	3·576 54
134 25 17	314 21 20	Powow (Borden)	11 098·1	4·045 25
220 06 11	40 07 05	Newburyport light-house, 1878–1889.	2 794·3	3·446 27
355 18 46	175 18 47	Newbury Congregational church	238·6	2·377 60
70 44 15	250 41 24	Isley	6 061·8	3·782 60
154 04 46	334 02 50	Powow (Borden).	8 831·4	3·946 03
309 50 44	129 52 42	Old Town	5 140·2	3·710 98
63 47 09	243 44 01	Crane Neck.	7 026·4	3·846 73
62 41 24	242 39 08	Isley	5 121·1	3·709 36
160 29 45	340 28 25	Powow (Borden).	8 056·0	3·906 12
55 18 29	235 14 45	Prospect Rowley 2	9 131·7	3·960 55
114 37 50	294 35 49	Old Town.	4 445·6	3·647 93
66 57 59	246 53 58	Prospect Rowley 2	8 804·8	3·944 72
127 52 22	307 50 04	Old Town.	5 871·4	3·768 74
54 38 37	234 35 03	Prospect Rowley 2	8 827·3	3·945 83
117 29 35	297 27 44	Old Town.	4 206·9	3·623 96
119 00 08	299 00 05	Noyes	110·6	2·043 67
105 36 06	285 31 48	Crane Neck	8 955·7	3·952 10
216 14 44	36 15 32	Old Town.	2 747·2	3·438 89
32 18 04	212 17 39	Ox Pasture Hill	1 535·9	3·186 35
157 06 55	337 04 12	Powow (Borden).	14 000·7	4·146 15
100 00 46	280 00 46	Ambrose	14·1	1·148 09
323 23 14	143 24 28	Prospect Rowley 2	4 162·6	3·619 36
43 36 34	223 36 05	Poverty Rock.	1 394·1	3·144 30

COAST NORTH OF CAPE ANN—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Ipswich–Rowley, corner 2.	42 43 58·74	1812·5	70 48 00·02	0·5
Ipswich–Rowley, corner 3.	42 42 36·19	1116·7	70 52 03·05	69·4
Ipswich–Rowley, corner 4.	42 42 46·62	1438·6	70 52 33·55	763·4
Ipswich–Rowley, corner 5.	42 42 23·00	709·7	70 52 52·58	1196·7
Georgetown–Newbury–Rowley, corner.	42 44 09·83	303·3	70 55 28·66	652·0
Georgetown–Groveland–Newbury, corner.	42 45 14·02	432·6	70 57 36·70	834·6
Georgetown–Groveland, corner 1.	42 45 09·19	283·6	70 57 57·47	1307·0
Georgetown–Newbury–West Newbury, corner.	42 45 30·04	926·9	70 58 03·69	83·9
Newbury–West Newbury, corner 5.	42 45 37·10	1144·8	70 58 01·19	27·1
Newbury–West Newbury, corner 4.	42 45 55·60	1715·6	70 57 50·12	1139·5
Newbury–West Newbury, corner 3.	42 45 58·82	1815·0	70 57 35·83	814·6
Newbury–West Newbury, corner 2.	42 46 08·64	266·6	70 57 11·42	259·7
Newbury–West Newbury, corner 1.	42 46 51·94	1602·7	70 55 36·34	826·0
Newbury–Newburyport–West Newbury, corner.	42 47 15·14	467·2	70 55 04·42	100·5
Newburyport–West Newbury, corner 1.	42 49 09·72	299·9	70 56 16·44	373·5
Newburyport–West Newbury, corner 2.	42 48 09·94	306·7	70 55 52·74	1198·4
Georgetown–Rowley, corner 1.	42 43 34·46	1063·3	70 56 20·03	455·7
Groveland–West Newbury, corner 3.	42 46 18·17	560·7	70 59 49·16	1117·6
Groveland–West Newbury, corner 2.	42 46 22·81	703·8	70 59 54·68	1243·1
Groveland–West Newbury, corner 1, peg.	42 46 50·66	1563·2	71 01 03·18	72·3
Moulton's Castle, octagonal tower. 1886–1889.	42 50 04·29	132·4	70 55 24·58	558·2
Plum Island Hotel.	42 47 56·92	1756·4	70 48 48·18	1094·9
Dummer Academy. 1889.	42 44 56·68	1749·0	70 53 57·46	1306·8
Newburyport, Belleville church spire. 1886–1889.	42 49 06·96	214·8	70 53 25·02	568·4
Newburyport, north church spire. 1886–1889.	42 48 40·72	1256·5	70 52 28·07	637·8
Stevens. 1886.	42 48 57·44	1772·5	70 59 25·60	581·6

COAST NORTH OF CAPE ANN—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
67 55 57	247 52 11	Prospect Rowley 2	8 179·2	3·912 71
134 02 33	314 00 30	Old Town.	5 720·3	3·757 42
145 16 59	325 16 56	Evans	149·0	2·173 20
24 26 07	204 25 57	Jewett	845·7	2·927 20
57 51 06	237 50 26	Prospect Rowley 2.	1 600·2	3·204 18
296 24 23	116 24 25	Jewett	93·1	1·968 87
266 19 16	86 21 00	Ox Pasture Hill	3 502·5	3·544 38
322 25 39	142 26 57	Prospect Rowley 2.	4 313·6	3·634 84
259 33 20	79 37 48	Old Town	9 150·4	3·961 44
314 14 03	134 16 48	Prospect Rowley 2.	7 738·0	3·888 63
259 11 25	79 16 08	Old Town	9 641·8	3·984 16
311 05 42	131 08 41	Prospect Rowley 2.	7 984·7	3·902 26
154 38 56	334 38 37	Crane Neck	1 489·9	3·173 15
194 48 53	14 49 09	Isley.	2 069·0	3·315 76
148 22 29	328 22 08	Crane Neck	1 325·2	3·122 28
194 50 09	14 50 23	Isley.	1 843·7	3·265 68
120 30 00	300 29 32	Crane Neck	1 098·6	3·040 82
190 18 44	10 18 51	Isley.	1 231·2	3·090 33
109 49 52	289 49 14	Crane Neck	1 351·6	3·130 84
174 38 38	354 38 35	Isley.	1 117·0	3·048 07
94 51 47	274 50 52	Crane Neck	1 832·9	3·263 13
140 49 11	320 48 51	Isley.	1 043·6	3·018 55
233 45 54	53 45 57	Adams	105·3	2·022 28
118 01 16	297 58 19	Stevens 2	6 721·4	3·827 46
182 28 58	2 29 08	Morrill Observatory.	7 945·3	3·900 11
46 15 22	226 15 14	Emery	373·3	2·572 08
157 20 14	337 19 54	Lone Tree Hill 2.	1 780·4	3·250 51
211 08 47	31 08 51	Planting Hill	290·7	2·463 45
269 17 07	89 17 18	Poverty Rock	354·7	2·549 86
310 44 42	130 48 57	Prospect Rowley 2	11 297·4	4·052 98
12 07 41	192 06 56	Bald Pate 2.	7 240·9	3·859 79
318 46 28	138 46 32	Groveland-West Newbury, corner 3	190·6	2·280 06
193 39 52	13 40 11	Kimball	2 648·6	3·423 02
276 52 55	96 53 24	Brake Hill.	971·6	2·987 48
88 57 45	268 56 49	Lone Tree Hill	1 873·3	3·272 60
160 32 44	340 32 07	Powow (Borden).	3 692·2	3·567 28
41 49 11	221 47 41	Old Town	4 525·7	3·655 69
125 57 18	305 52 12	Powow (Borden).	12 635·7	4·101 60
166 06 49	346 05 13	Powow (Borden)	13 365·0	4·125 97
241 23 34	61 25 34	Old Town.	4 572·1	3·660 12
329 22 13	149 23 51	Old Town	6 431·9	3·808 34
65 27 06	245 22 23	Brake Hill.	10 389·2	4·016 78
337 14 49	157 15 48	Old Town	5 124·0	3·709 61
71 56 08	251 50 47	Brake Hill.	11 301·6	4·053 14
189 39 42	9 40 09	Eaton	5 409·3	3·733 14
240 35 42	60 37 30	Lone Tree Hill.	4 133·5	3·616 32

COAST NORTH OF CAPE ANN—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Curson.	42 49 24·08	743·1	70 56 06·26	142·2
Butler's Toothpick.	42 49 14·15	436·6	70 40 38·70	879·1
Newburyport Bridge, center of draw.	42 48 52·35	1615·4	70 52 18·96	430·8
Newburyport Bridge, signal.	42 48 56·75	1751·2	70 52 24·16	548·9
Groveland-West Newbury, corner 1.	42 46 57·50	1774·3	71 01 04·48	101·8
Hoxie.	42 50 11·97	369·3	70 54 40·38	917·1
Newburyport Catholic church spire. 1886.	42 48 32·32	997·3	70 52 27·40	622·6
Newburyport Baptist church spire. 1886.	42 48 38·54	1189·3	70 52 24·33	552·8
Lunt's house.	42 49 01·18	36·4	70 53 27·22	618·4
Newburyport, flagstaff. 1886.	42 49 04·65	143·5	70 53 34·14	775·6
Newburyport, liberty pole. 1886.	42 48 42·82	1321·3	70 53 07·99	181·5
Dark-colored dome. 1886.	42 48 50·72	1565·1	70 52 56·24	1277·7
West Newbury Catholic church tower, cross. 1886.	42 47 47·66	1470·7	70 59 46·90	1065·8
West Newbury, barn cupola.	42 48 34·14	1053·5	70 57 44·82	1018·4
Tall chimney.	42 48 50·90	1570·7	70 52 58·72	1334·0
First twin tree.	42 47 51·17	1579·0	70 57 48·73	1107·4
Second twin tree.	42 47 51·26	1581·7	70 57 48·72	1107·2
Centennial Hill.	42 45 29·90	922·6	71 01 21·17	481·4
Dead Hill.	42 44 29·34	905·4	71 03 33·57	763·6
Bear Hill. 1890.	42 45 18·34	565·9	71 00 09·07	206·2
Andrews Hill.	42 42 21·69	669·3	71 04 38·84	883·8
Gage Hill.	42 43 58·56	1807·0	71 05 38·34	872·2
Russell Hill.	42 44 38·82	1197·9	71 07 25·45	578·8
Red Shanks Hill.	42 42 22·86	705·4	70 59 12·73	289·7

COAST NORTH OF CAPE ANN—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
70 34 55	250 31 52	Kimball	6 490·2	3·812 26
176 33 39	356 33 31	Powow (Borden).	4 730·6	3·674 92
17 59 07	197 58 11	Old Town	6 052·4	3·781 93
119 00 13	298 55 41	Powow (Borden).	10 383·2	4·016 33
136 20 07	316 17 24	Powow (Borden)	7 884·2	3·896 76
158 47 14	338 45 42	Grape.	8 526·9	3·930 79
136 16 22	316 13 43	Powow (Borden)	7 704·4	3·886 74
159 12 16	339 10 47	Grape.	8 357·8	3·922 09
352 01 43	172 01 44	Groveland-West Newbury, corner 1, peg	213·0	2·328 46
84 37 37	264 36 11	Lone Tree Hill	2 889·6	3·460 84
145 27 46	325 26 39	Powow (Borden).	3 938·9	3·595 38
73 12 58	253 07 37	Brake Hill	11 238·5	4·050 71
140 16 49	320 14 12	Powow (Borden).	8 218·1	3·914 77
337 50 34	157 51 31	Old Town	5 029·3	3·701 51
72 23 33	252 18 09	Brake Hill.	11 361·9	4·055 45
66 14 32	246 09 51	Brake Hill	10 270·7	4·011 60
144 21 20	324 19 24	Powow (Borden).	6 681·9	3·824 90
65 19 58	245 15 22	Brake Hill	10 171·1	4·007 37
144 55 50	324 53 58	Powow (Borden).	6 503·4	3·813 14
70 03 01	249 58 07	Brake Hill	10 465·0	4·019 74
100 03 08	279 56 16	Brandybrow.	13 982·3	4·145 58
98 53 59	278 46 59	Brandybrow	14 205·6	4·152 46
141 22 26	321 20 09	Powow (Borden).	7 364·3	3·867 13
131 15 42	311 13 21	Brandybrow	6 263·1	3·796 79
211 32 14	31 34 35	Powow (Borden).	9 033·2	3·955 84
46 58 03	226 56 17	Brake Hill	4 848·9	3·685 64
109 50 20	289 46 36	Brandybrow.	7 952·2	3·900 49
98 54 41	278 47 43	Brandybrow	14 149·1	4·150 73
141 41 20	321 39 04	Powow (Borden).	7 324·9	3·864 80
97 21 44	277 17 54	Ayer Hill	7 768·7	3·890 35
118 34 09	298 30 28	Brandybrow.	8 416·5	3·925 13
97 20 32	277 16 42	Ayer Hill	7 768·7	3·890 35
118 33 07	298 29 26	Brandybrow.	8 415·3	3·925 07
250 39 45	70 41 40	Crane Neck	4 082·1	3·610 88
354 09 13	174 09 30	Bald Pate 2.	5 618·9	3·749 65
316 03 20	136 05 07	Bald Pate 2	5 166·8	3·713 22
19 17 37	199 15 41	Holt.	11 811·4	4·072 30
11 32 26	191 31 54	Bald Pate 2	5 340·8	3·727 61
72 00 36	251 58 17	Dead Hill.	4 890·7	3·689 37
200 39 06	20 39 50	Dead Hill	4 209·8	3·624 26
267 31 03	87 33 34	Bald Pate 2.	5 075·7	3·705 50
293 18 35	113 21 47	Bald Pate 2	6 995·8	3·844 84
5 56 02	185 55 30	Holt.	10 254·2	4·010 90
273 09 10	93 11 47	Dead Hill	5 282·6	3·722 85
353 07 22	173 08 03	Holt.	11 524·4	4·061 62
94 25 52	274 24 42	Bald Pate 2	2 357·8	3·372 51
187 27 10	7 27 38	Crane Neck.	7 182·7	3·856 29

COAST NORTH OF CAPE ANN—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Nason.	42 42 07·68	237·0	71 01 23·89	543·7
Orchard.	42 44 46·20	1425·6	71 02 42·28	1098·1
South Groveland Episcopal church spire. 1890.	42 44 25·61	790·3	71 02 42·90	975·8
Groveland, corner 5.	42 44 46·36	1430·5	71 02 55·83	1269·8
Groveland, corner 6.	42 44 56·76	1751·5	71 02 42·09	957·2
Groveland, corner 7.	42 45 11·81	364·4	71 02 40·55	922·2
Georgetown First Congregational church spire. 1890.	42 43 24·79	764·9	70 59 38·42	874·1
Commissioner.	42 44 04·00	123·4	71 00 45·80	1041·8
Commissioner, peg.	42 44 02·62	80·9	71 00 41·49	943·8
Georgetown, corner 4.	42 42 03·00	92·6	71 00 00·52	11·8
Georgetown, corner 6.	42 42 05·21	160·8	71 00 41·22	938·2
Georgetown, corner 12.	42 43 05·17	159·5	71 01 55·63	1265·8
Georgetown, corner 13.	42 43 56·71	1749·9	71 02 06·50	147·9
Georgetown, corner 14.	42 43 53·07	1637·6	71 01 38·99	887·0
Georgetown, corner 15.	42 44 01·18	36·4	71 01 11·61	264·1
Georgetown, corner 16.	42 44 03·30	101·8	71 00 42·32	962·7
Georgetown, corner 17.	42 44 06·95	214·5	71 00 35·88	816·2
Georgetown, corner 18.	42 44 20·98	647·4	71 00 05·49	124·9
Georgetown, corner 19.	42 44 46·54	1436·1	70 59 04·82	109·6
Georgetown, corner 20.	42 44 55·42	1710·1	70 58 47·87	1088·7
Georgetown, corner 21.	42 44 58·53	1806·1	70 58 28·48	647·7
Georgetown, corner 22.	42 45 04·61	142·3	70 58 14·62	332·5
Nason, peg 1.	42 42 05·44	198·7	71 01 27·98	636·8
Nason, peg 2.	42 42 10·74	331·4	71 01 30·57	695·8
Nason, peg 3.	42 42 12·44	383·9	71 01 34·02	774·3
Nason, peg 4.	42 42 16·61	512·5	71 01 36·35	827·3
Georgetown, corner 7.	42 42 06·03	186·1	71 01 26·90	612·2
Georgetown, corner 8.	42 42 11·32	349·3	71 01 30·52	694·6
Georgetown, corner 10.	42 42 17·12	528·3	71 01 35·88	816·6

COAST NORTH OF CAPE ANN—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
145 59 34	325 58 06	Dead Hill	5 274·0	3·722 14
224 17 00	44 17 19	Bald Pate 2.	908·3	2·958 25
63 12 38	243 12 07	Dead Hill	1 154·1	3·062 24
235 44 55	55 45 54	Centennial Hill.	2 396·4	3·379 56
95 42 33	275 41 59	Dead Hill	1 158·2	3·063 77
223 07 48	43 08 43	Centennial Hill.	2 718·6	3·434 35
335 19 42	155 19 51	South Groveland Episcopal church	704·7	2·847 98
58 32 18	238 31 52	Dead Hill.	1 006·4	3·002 78
240 56 05	60 57 00	Centennial Hill	2 105·0	3·323 26
54 08 51	234 08 16	Dead Hill.	1 444·5	3·159 72
252 48 20	72 49 14	Centennial Hill	1 889·4	3·276 33
334 41 38	154 42 49	Bald Pate 2.	5 565·1	3·745 47
342 58 57	162 59 14	Red Shanks Hill	1 998·3	3·300 66
45 36 31	225 35 38	Bald Pate 2.	2 471·3	3·392 93
308 16 40	128 17 26	Georgetown First Congregational church	1 952·8	3·290 66
4 31 30	184 31 23	Bald Pate 2.	2 948·2	3·469 55
113 25 32	293 25 29	Commissioner	106·83	2·028 70
52 52 38	232 48 17	Holt	10 982·0	4·040 68
122 10 58	302 10 20	Bald Pate 2.	1 492·4	3·173 89
155 07 19	335 07 09	Bald Pate 2	800·6	2·903 41
254 51 47	74 52 47	Red Shanks Hill.	2 086·4	3·319 40
70 09 15	250 07 24	Andrews Hill	3 949·1	3·596 50
139 23 07	319 22 01	Dead Hill.	3 422·2	3·534 30
116 57 18	296 56 19	Dead Hill	2 222·0	3·346 74
199 43 06	19 43 37	Centennial Hill.	3 054·8	3·484 98
113 14 52	293 13 34	Dead Hill	2 836·5	3·452 79
187 43 16	7 43 28	Centennial Hill.	3 015·2	3·479 32
352 54 30	172 54 41	Bald Pate 2	2 874·2	3·458 51
89 15 40	269 12 39	Gage Hill.	6 068·3	3·783 07
318 04 13	138 04 14	Commissioner, peg	28·10	1·448 70
43 40 36	223 40 32	Commissioner, peg	184·89	2·266 91
18 22 07	198 21 33	Bald Pate 2	3 648·9	3·562 16
93 08 17	273 05 56	Dead Hill.	4 740·0	3·675 78
123 53 38	303 52 54	Bear Hill	1 760·3	3·245 58
195 37 13	15 37 35	Crane Neck.	2 791·8	3·445 88
110 57 58	290 57 03	Bear Hill	1 977·6	3·296 14
188 37 46	8 37 57	Crane Neck.	2 442·2	3·387 78
104 58 14	284 57 06	Bear Hill	2 367·9	3·374 37
178 09 40	358 09 38	Crane Neck.	2 319·6	3·365 42
99 15 37	279 14 19	Bear Hill	2 637·2	3·421 14
169 38 37	349 38 25	Crane Neck.	2 166·3	3·335 72
247 38 36	67 38 39	Nason	100·5	2·002 36
301 52 38	121 52 43	Nason	179·0	2·252 77
336 02 34	156 02 36	Nason, peg 1.	145·27	2·162 18
303 41 02	123 41 04	Nason, peg 2	94·45	1·975 21
337 36 10	157 36 12	Nason, peg 3	139·20	2·143 64
233 22 22	53 22 24	Nason	85·4	1·931 37
3 47 08	183 47 08	Nason, peg 2	17·80	1·250 35
34 20 20	214 20 20	Nason, peg 4	18·95	1·277 53

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Powow. (C. & G. S. & Bdn.), 1834–1889.	42 51 57·111	1762·4	70 56 18·756	425·8
Ayer Hill. (C. & G. S. & Bdn.), 1834–1890.	42 48 23·288	718·6	71 03 27·818	632·1
Poplar Hill. (Borden.)	42 44 06·220	191·9	71 15 22·104	502·9
Gumpus, N. H. (C. & G. S. & Bdn.), 1834–1886.	42 43 32·914	1015·6	71 21 46·580	1059·8
Lowell church spire. (Borden), 1834.	42 38 48·030	1482·1	71 19 06·714	153·0
Marsh and Jones, N. H. (Borden), 1834.	42 42 43·810	1351·8	71 18 11·185	254·5
Brandybrow, monument. (C. & G. S. & Bdn.), 1834–1886.	42 50 00·025	0·8	71 03 16·194	367·8
Brandybrow. 1886.	42 50 01·473	45·5	71 03 14·181	322·0
Lone Tree Hill. 1886.	42 50 03·184	98·4	70 56 47·051	1068·6
Lone Tree Hill 2. 1888–89.	42 50 02·958	91·3	70 56 46·642	1059·4
Kimball. 1886–1889.	42 48 14·068	434·1	71 00 35·638	809·8
Eaton. 1886.	42 51 50·260	1550·9	70 58 45·609	1035·3
Silver Hill, tower. 1886–1889.	42 46 22·605	697·5	71 06 00·628	14·3
Spicket, N. H.	42 47 12·477	385·0	71 11 20·815	473·1
Midlake. 1886–1889.	42 47 53·370	1646·8	71 04 11·168	253·7
Brier.	42 52 49·727	1534·4	70 55 35·039	795·2
Lawrence Hill.	42 42 27·806	858·0	71 11 10·216	232·4
Parsonage Hill.	42 48 37·588	1159·9	71 07 21·072	478·8
Titcomb, N. H.	42 53 24·458	754·7	70 55 03·154	71·6
Reservoir Hill.	42 39 20·994	647·8	71 17 31·422	715·8
Sutton's castle.	42 40 45·162	1393·5	71 06 40·581	924·0
Chair, N. H.	42 52 55·975	1727·3	70 56 29·656	673·0
Bear Hill.	42 44 59·413	1833·3	71 10 04·386	99·8

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
317 59 21·8	138 11 08·0	Railcut	35 421·5	4·549 267
348 03 53·2	168 05 45·7	Prospect Rowley.	18 227·3	4·260 722
309 39 57·8	129 46 41·5	Prospect Rowley	17 582·3	4·245 075
12 23 11·2	192 21 11·1	Holt.	18 804·7	4·274 266
310 25 21·2	130 31 25·4	Holt	16 077·3	4·206 213
243 53 53·4	64 01 58·5	Ayer Hill.	18 073·1	4·257 032
250 09 54·8	70 22 20·9	Ayer Hill	26 540·4	4·423 907
294 03 40·7	114 14 05·6	Holt.	22 996·8	4·361 667
157 31 29·2	337 29 40·8	Gumpus	9 514·3	3·978 376
271 57 54·6	92 06 30·8	Holt.	17 366·7	4·239 717
9 51 48·6	189 51 11·0	Lowell church (Borden)	7 384·5	3·868 321
107 11 59·4	287 09 33·3	Gumpus.	5 129·9	3·710 113
11 22 57·2	191 20 49·1	Holt	21 780·3	4·338 063
5 03 23·2	185 03 15·2	Ayer Hill.	2 996·7	3·476 641
249 14 21·9	69 19 04·4	Powow (Borden)	10 085·1	4·003 680
293 20 59·9	113 29 18·1	Old Town.	18 158·8	4·259 087
38 44 06·0	218 41 40·8	Brake Hill	7 763·2	3·890 040
312 42 48·6	132 46 43·8	Old Town.	10 711·0	4·029 828
190 11 13·8	10 11 32·8	Powow (Borden)	3 579·0	3·553 758
312 43 12·4	132 47 07·3	Old Town.	10 699·4	4·029 359
220 15 44·9	40 18 39·6	Powow (Borden)	9 022·6	3·955 333
322 49 44·6	142 51 08·7	Crane Neck.	4 661·8	3·668 553
266 21 25·7	86 23 05·6	Powow (Borden)	3 340·3	3·523 789
320 49 04·4	140 50 25·0	Lone Tree Hill.	4 262·0	3·629 609
222 59 19·2	43 01 03·0	Ayer Hill	5 092·2	3·706 904
2 09 36·0	182 09 19·6	Holt.	14 654·5	4·165 972
244 42 11·4	64 47 42·1	Brandybrow	12 224·6	4·087 236
272 57 03·4	93 04 31·7	Brake Hill.	15 024·5	4·176 799
198 07 44·4	18 08 23·1	Brandybrow	4 159·6	3·619 051
291 22 13·6	111 24 50·1	Brake Hill.	5 624·7	3·750 102
31 26 07·2	211 25 37·5	Powow (Borden)	1 902·8	3·279 398
67 01 46·7	246 59 37·0	Eaton.	4 698·7	3·671 975
178 25 44·4	358 25 37·2	Spicket	8 787·5	3·943 865
241 31 02·7	61 38 23·6	Brake Hill.	16 796·7	4·225 223
245 12 05·4	65 14 53·2	Brandybrow	6 176·9	3·790 774
322 23 07·6	142 27 28·7	Bald Pate	14 341·2	4·156 584
284 03 00·0	104 07 04·1	Beach	8 395·0	3·924 022
337 46 25·9	157 49 10·6	Old Town.	14 560·7	4·163 183
143 15 23·8	323 12 30·8	Gumpus	9 703·9	3·986 945
210 03 42·2	30 07 53·6	Spicket.	16 815·7	4·225 716
80 07 20·2	259 59 59·1	Reservoir Hill	15 047·3	4·177 458
104 10 37·4	284 00 23·0	Gumpus.	21 260·2	4·327 568
260 35 46·9	80 37 05·0	Grape	2 639·3	3·421 491
352 14 34·4	172 14 41·8	Powow (Borden).	1 833·2	3·263 209
235 03 11·5	55 07 40·8	Ayer Hill	10 993·0	4·041 115
245 07 33·3	65 10 18·8	Silver Hill, tower.	6 108·3	3·785 920

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Jeremy Hill, N. H.	42 44 47·710	1472·2	71 21 21·793	495·6
Harris Hill, N. H.	42 51 43·918	1355·2	71 02 54·687	1241·5
Clark Hill, N. H.	42 44 35·483	1094·9	71 14 38·178	868·4
Williams Hill.	42 42 39·735	1226·1	71 12 57·582	1310·5
Poplar Hill, stone monument. (C. & G. S. & Bdn.) 1834–1886.	42 44 11·552	356·5	71 15 20·304	461·9
Temporary signal. (Borden.)	42 44 09·867	304·5	71 15 23·610	537·1
Leslie, monument.	42 41 50·330	1553·0	71 17 43·321	986·0
Marsh and Jones, N. H. 1886.	42 42 45·038	1389·7	71 18 06·293	143·2
Eaton 2. 1886.	42 51 47·454	1464·3	70 58 43·518	987·9
Ward Hill.	42 45 27·011	833·5	71 06 39·907	907·5
Ayer Village.	42 47 30·088	928·5	71 10 35·422	805·0
Atkinson, N. H. 1886.	42 49 20·619	636·3	71 09 14·285	324·5
Perley, monument.	42 52 07·945	245·2	70 58 03·093	70·2
Thompson, monument.	42 50 55·429	1710·3	71 02 43·534	988·4
Randall, monument.	42 53 06·376	196·8	70 55 48·371	1097·7
Smith, monument.	42 43 34·006	1049·3	71 16 06·956	158·3
Pine tree, boundary stone monument. (C. & G. S. & Bdn.) 1834–1886.	42 41 50·266	1551·1	71 19 22·004	500·8
Strongwater, monument.	42 44 14·648	452·0	71 10 56·234	1279·2
Rogers.	42 51 20·495	632·4	71 01 12·533	284·6
Janes, monument.	42 51 33·710	1040·2	71 01 54·131	1228·9
Tewksbury.	42 50 50·283	1551·6	71 00 08·552	194·2
Webster, monument.	42 44 47·573	1468·0	71 13 27·568	627·0
Noyes, monument.	42 44 41·837	1291·0	71 14 16·552	376·4

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
251 50 22·1	71 57 10·2	Spicket	14 375·8	4·157 631
332 29 59·0	152 32 35·2	Reservoir Hill.	11 363·5	4·055 513
267 22 09·0	87 26 38·3	Powow (Borden)	8 997·2	3·954 106
339 06 06·9	159 07 51·5	Brake Hill.	9 810·3	3.991 682
222 47 26·5	42 49 40·5	Spicket	6 603·5	3·819 771
309 45 49·5	129 48 10·6	Lawrence Hill.	6 157·0	3·789 367
147 21 32·3	327 20 24·0	Clark Hill	4 242·1	3·627 577
194 38 42·8	14 39 48·5	Spicket.	8 699·1	3·939 476
224 15 50·9	44 18 33·5	Spicket	7 798·9	3·892 032
232 22 35·9	52 23 04·5	Clark Hill.	1 209·7	3·082 692
235 19 23·8	55 19 26·0	Poplar Hill, monument	91·4	1·961 106
343 03 30·4	163 03 31·4	Poplar Hill (Borden).	117·653	2·070 603
356 38 02·4	176 38 10·5	Reservoir Hill	4 616·0	3·664 265
119 47 05·8	299 44 20·8	Gumpus.	6 376·9	3·804 608
342 47 24·9	162 47 40·5	Leslie	1 767·2	3·247 295
106 26 34·9	286 24 05·5	Gumpus.	5 225·5	3·718 132
245 41 52·8	65 44 42·0	Grape	6 190·0	3·791 693
264 48 16·8	84 49 55·3	Powow (Borden).	3 299·7	3·518 470
208 46 16·0	28 48 34·4	Brandybrow (Borden)	9 612·8	3·982 849
218 44 10·7	38 46 21·2	Ayer Hill.	6 975·2	3·843 555
260 22 14·3	80 27 04·8	Ayer Hill	9 854·8	3·993 649
351 22 02·8	171 22 23·9	Bear Hill.	4 702·7	3·672 347
282 38 02·6	102 41 58·1	Ayer Hill	8 067·7	3·906 751
321 16 52·2	141 19 03·8	Silver Hill, tower	7 038·6	3·847 486
247 56 23·2	67 58 44·9	Grape	5 097·4	3·707 346
278 01 29·1	98 02 40·1	Powow (Borden).	2 391·9	3·378 740
12 05 50·1	192 05 20·0	Ayer Hill	4 801·3	3·681 356
28 01 39·5	207 59 25·6	Silver Hill, tower.	9 535·6	3·979 348
329 30 12·9	149 30 22·0	Brier	596·2	2·775 421
17 53 07·0	197 52 46·3	Powow (Borden).	2 245·9	3·351 386
89 46 55·8	269 43 05·4	Gumpus	7 726·9	3·888 008
107 38 52·1	287 35 18·5	Jeremy Hill.	7 514·2	3·875 884
133 55 32·9	313 53 54·8	Gumpus	4 567·0	3·659 627
224 17 00·5	44 17 48·5	Marsh and Jones (Borden).	2 308·2	3·363 268
97 16 42·9	277 14 12·3	Clark Hill	5 089·1	3·706 643
174 11 10·7	354 10 54·0	Spicket.	5 515·7	3·741 603
249 26 52·1	69 31 22·6	Grape	9 636·4	3·983 917
260 21 24·2	80 24 44·0	Powow (Borden).	6 764·4	3·830 228
264 33 01·4	84 36 49·5	Powow (Borden)	7 647·6	3·883 527
293 21 06·5	113 21 34·8	Rogers.	1 028·7	3·012 279
225 29 19·7	45 30 16·1	Eaton	2 640·3	3·421 660
248 24 39·6	68 27 15·9	Powow (Borden).	5 609·9	3·748 958
212 47 26·9	32 48 53·0	Spicket	5 319·6	3·725 881
324 03 41·9	144 05 15·1	Lawrence Hill.	5 325·9	3·726 394
220 39 55·3	40 41 54·6	Spicket	6 129·6	3·787 435
314 16 27·6	134 18 34·0	Lawrence Hill.	5 922·6	3·772 513

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Wilson, monument.	42 42 41·011	1265·5	71 16 46·214	1051·7
Proctor, monument.	42 48 58·617	1808·8	71 08 54·021	1227·2
Harris, monument.	42 44 33·392	1030·4	71 14 45·330	1031·0
Farnsworth, monument.	42 51 52·284	1613·4	70 59 52·464	1191·0
Hoyt, monument.	42 51 42·371	1307·5	71 01 00·232	5·3
Lovers Lane, monument.	42 48 22·807	703·7	71 03 53·700	1220·2
Foote, monument.	42 49 19·418	599·2	71 08 01·235	28·0
Captain's Pond, monument.	42 48 32·196	993·5	71 10 01·744	39·6
Poor, monument.	42 47 27·589	851·3	71 11 11·907	270·6
Moulton.	42 50 26·95	831·6	70 58 39·44	895·7
Hughes.	42 49 36·22	1117·7	70 59 38·16	866·8
Amesbury–Merrimac, corner 1.	42 50 41·75	1288·2	70 58 49·08	1114·5
Amesbury–Merrimac, corner 2.	42 49 29·99	925·4	70 58 14·82	338·4
Haverhill–Merrimac, corner 1.	42 48 42·26	1304·0	71 00 10·72	243·5
Haverhill, powderhouse. 1886–1889.	42 46 21·20	654·2	71 03 22·89	520·4
Woodman, N. H.	42 52 35·86	1106·6	70 56 59·99	1361·6
French.	42 52 25·40	783·8	70 57 20·88	474·1
Hatch's house, cupola.	42 52 33·63	1037·8	70 56 48·58	1102·6
Palmer's (Mrs. Rebecca) house, chimney.	42 52 35·08	1082·5	70 56 57·64	1308·3
Lone tree.	42 50 02·88	88·9	70 56 49·81	1131·3
Merrimacport, church spire. 1886.	42 49 33·80	1043·0	70 59 12·34	280·3
Merrimac church, tall white spire. 1886.	42 50 06·51	200·9	71 00 13·83	314·1
East Haverhill flagstaff. 1886.	42 48 35·06	1081·9	71 00 09·54	216·8

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
270 24 43·2	90 27 18·3	Williams Hill	5 203·1	3·716 259
39 44 07·2	219 43 28·5	Leslie.	2 033·5	3·308 234
255 51 49·3	75 55 40·3	Brandybrow	7 959·4	3·900 882
287 22 04·0	107 25 16·2	Midlake.	6 734·8	3·828 328
223 25 45·9	43 28 04·8	Spicket	6 761·8	3·830 061
325 02 14·6	145 03 27 7	Williams Hill.	4 279·0	3·631 338
308 37 50·4	128 39 56·5	Lone Tree Hill	5 390·6	3·731 638
61 39 15·0	241 38 20·5	Rogers.	2 065·5	3·315 034
298 00 24·3	118 03 16·4	Lone Tree Hill	6 512·9	3·813 774
22 28 39·5	202 28 31·1	Rogers.	730·5	2·863 624
95 32 55·1	275 30 34·2	Parsonage Hill	4 733·8	3·675 206
196 25 30·7	16 25 57·6	B andybrow.	3 174·2	3·501 635
258 42 57·8	78 46 13·0	Brandybrow	6 648·0	3·822 694
296 54 25·2	116 57 01·6	Midlake.	5 863·0	3·768 118
215 48 30·9	35 49 03·2	Atkinson	1 842·6	3·265 433
306 05 46·8	126 08 30·6	Silver Hill, tower.	6 783·9	3·831 478
217 27 01·1	37 28 21·0	Atkinson	4 394·1	3·642 869
23 28 23·6	203 28 17·5	Spicket.	508·4	2·706 200
228 55 55	48 57 31	Powow (Borden)	4 236·0	3·626 96
286 06 31	106 07 48	Lone Tree Hill 2.	2 666·6	3·425 95
226 08 48	46 11 03	Powow (Borden)	6 277·1	3·797 76
258 01 43	78 03 38	Lone Tree Hill 2.	3 982·1	3·600 11
235 43 00	55 44 42	Powow (Borden)	4 130·0	3·615 95
334 23 40	154 23 47	Moulton.	506·4	2·704 48
162 21 08	342 20 51	Moulton	1 844·7	3·265 92
243 03 36	63 04 36	Lone Tree Hill 2.	2 246·4	3·351 49
203 56 52	23 57 14	Hughes	1 822·0	3·260 56
245 30 25	65 30 56	Stevens 2.	1 126·7	3·051 82
299 03 50	119 10 31	Prospect Rowley 2	15 357·1	4·186 31
15 51 11	195 49 08	Holt.	15 176·8	4·181 18
321 56 59	141 57 27	Powow (Borden)	1 518·5	3·181 42
59 36 01	239 34 49	Eaton.	2 780·0	3·444 04
235 44 39	55 44 53	Woodman	573·7	2·758 66
301 45 17	121 45 59	Powow (Borden).	1 658·4	3·219 69
329 00 12	149 00 32	Powow (Borden)	1 314·7	3·118 83
63 16 11	243 14 51	Eaton.	2 974·5	3·473 42
323 00 35	143 01 02	Powow (Borden)	1 467·0	3·166 42
60 34 14	240 33 01	Eaton.	2 814·2	3·449 35
312 27 00	132 30 57	Old Town	10 751·0	4·031 45
38 24 48	218 22 25	Brake Hill.	7 716·8	3·887 44
188 12 03	8 12 21	Eaton	4 254·2	3·628 82
254 37 32	74 39 11	Lone Tree Hill.	3 422·2	3·534 31
271 13 49	91 16 10	Lone Tree Hill	4 697·4	3·671 86
1 27 38	181 27 33	Brake Hill.	6 162·3	3·789 74
220 01 57	40 04 34	Powow (Borden)	8 145·0	3·910 89
4 21 36	184 21 28	Brake Hill.	3 347·8	3·524 76

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Golden Hill.	42 46 19·61	605·1	71 03 21·16	481·1
Nichols' Castle.	42 47 18·02	556·1	71 03 51·56	1171·9
Haverhill, north church spire. 1886.	42 46 48·25	1488·9	71 04 41·33	939·4
Haverhill, new Baptist church spire. 1886.	42 46 47·22	1457·1	71 04 39·46	896·9
Haverhill, North Parish church spire. 1886.	42 48 54·01	1666·6	71 06 09·76	221·7
Haverhill, West Parish church spire. 1886.	42 47 14·46	446·2	71 08 01·32	30·0
Lawrence Reservoir.	42 42 23·34	720·2	71 10 55·78	1269·4
Lawrence Reservoir, north base.	42 42 29·70	916·4	71 10 58·20	1324·5
Lawrence Reservoir, west sub-base.	42 42 22·78	702·9	71 10 57·55	1309·7
Haverhill, water tank.	42 47 16·53	510·1	71 04 20·86	474·1
Brechin Hall.	42 38 48·04	1482·4	71 08 00·37	8·4
Bartlett chapel. 1886.	42 38 52·87	1631·4	71 07 58·61	1335·1
Chapel church spire. 1886.	42 38 55·85	1723·4	71 08 02·44	55·6
Bradford, church spire. 1886.	42 46 01·19	36·7	71 04 35·43	805·6
Silver Hill, poplar tree.	42 46 22·78	702·9	71 06 00·94	21·4
Haverhill, St. James church, cross. 1886.	42 46 41·12	1268·9	71 05 05·71	129·8
Ayer Village, church spire. 1886.	42 47 14·85	458·2	71 10 07·09	161·2
Bear Hill, dead tree.	42 45 04·05	125·0	71 10 05·57	126·7
Bear Hill, wood.	42 45 00·15	4·6	71 10 00·04	0·9
Methuen, flagstaff. 1886.	42 43 52·31	1614·1	71 11 30·28	688·9
Methuen, stone church spire. 1886.	42 43 45·32	1398·4	71 11 11·24	255·7
Emery's barn, cupola.	42 42 03·08	95·0	71 11 11·70	266·3
Williams' barn, cupola.	42 42 40·18	1239·8	71 13 02·14	48·7

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
128 00 33	307 57 50	Parsonage Hill	6 918·0	3·839 98
177 44 00	357 43 55	Ayer Hill.	3 819·3	3·581 98
230 01 00	50 06 08	Powow (Borden)	13 414·7	4·127 58
281 19 08	101 21 31	Brake Hill.	4 887·1	3·689 05
132 55 09	312 53 21	Parsonage Hill	4 956·1	3·695 14
209 39 45	29 40 35	Ayer Hill.	3 375·2	3·528 30
132 51 14	312 49 24	Parsonage Hill	5 008·6	3·699 72
208 46 12	28 47 01	Ayer Hill.	3 382·0	3·529 18
284 25 55	104 27 45	Ayer Hill	3 799·4	3·579 72
72 38 22	252 37 34	Parsonage Hill.	1 697·6	3·229 84
199 37 06	19 37 33	Parsonage Hill	2 723·2	3·435 08
251 06 29	71 09 35	Ayer Hill.	6 568·3	3·817 45
58 02 47	237 58 19	Reservoir Hill	10 620·9	4·026 16
176 20 58	356 20 41	Spicket.	8 940·1	3·951 34
344 20 17	164 20 19	Lawrence Reservoir	203·75	2·309 10
77 54 05	257 53 57	Lawrence Hill.	279·9	2·447 08
118 16 35	298 16 26	Lawrence Hill	327·4	2·515 10
176 05 19	356 05 19	Lawrence Reservoir, north base.	214·3	2·331 06
121 25 51	301 23 49	Parsonage Hill	4 798·9	3·681 14
210 19 25	30 20 01	Ayer Hill.	2 386·8	3·377 82
147 30 13	327 28 04	Lawrence Hill	8 041·9	3·905 36
199 13 49	19 16 53	Ayer Hill.	18 802·7	4·274 22
146 40 58	326 38 48	Lawrence Hill	7 938·9	3·899 76
199 15 52	19 18 56	Ayer Hill.	18 649·2	4·270 66
146 50 36	326 48 29	Lawrence Hill	7 813·8	3·892 86
199 36 41	19 39 47	Ayer Hill.	18 590·9	4·269 30
142 03 30	322 01 38	Parsonage Hill	6 120·7	3·786 80
199 18 32	19 19 18	Ayer Hill.	4 646·3	3·667 11
156 21 46	336 20 52	Parsonage Hill	4 541·2	3·657 17
223 05 12	43 06 56	Ayer Hill.	5 093·1	3·706 98
139 27 04	319 25 32	Parsonage Hill	4 730·9	3·674 94
215 11 59	35 13 05	Ayer Hill.	3 858·8	3·586 45
256 51 35	76 56 06	Ayer Hill	9 316·4	3·969 25
359 09 42	179 09 44	Bear Hill.	4 179·7	3·621 15
81 56 01	261 52 56	Clark Hill	6 262·4	3·796 74
156 39 30	336 38 39	Spicket.	4 316·5	3·635 13
77 00 20	257 00 17	Bear Hill	101·5	2·006 32
244 55 37	64 58 20	Silver Hill, tower.	6 008·8	3·778 79
87 36 46	267 29 48	Gumpus	14 034·0	4·147 18
181 59 37	1 59 43	Spicket.	6 180·6	3·791 03
88 32 31	268 25 20	Gumpus	14 459·7	4·160 16
178 03 00	358 02 54	Spicket.	6 395·9	3·805 90
59 59 16	239 54 59	Reservoir Hill	9 988·5	3·999 50
182 32 01	2 32 02	Lawrence Hill.	764·0	2·883 07
44 57 06	224 54 04	Reservoir Hill	8 680·8	3·938 56
97 48 44	277 42 48	Gumpus.	12 043·7	4·080 76

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Poplar Hill. 1886.	42 44 08·03	247·8	71 15 24·64	560·6
Poplar Hill (Spofford). 1886.	42 44 06·74	208·0	71 15 22·05	501·6
Pacific Mills chimney, straight top.	42 42 13·52	417·2	71 09 55·10	1254·2
Pacific Mills chimney, swell top.	42 42 20·62	636·3	71 09 40·80	928·6
North Tewksbury, flag.	42 39 24·40	752·9	71 15 04·76	108·4
North Tewksbury, church spire. 1886.	42 38 35·00	1080·0	71 14 48·62	1107·7
Jumbo chimney.	42 39 01·12	34·6	71 18 45·30	1031·9
Lawrence Mills, new chimney.	42 39 10·74	331·4	71 18 55·20	1257·5
Robbins.	42 35 06·16	190·1	71 21 55·42	1263·8
Hillside.	42 40 12·42	383·8	71 14 42·80	974·7
Fort Hill.	42 37 58·61	1808·5	71 17 44·43	1014·3
Signal A.	42 37 50·54	1559·5	71 20 03·66	83·4
Pawtucket, church spire. 1886.	42 39 02·68	82·7	71 19 57·66	1313·5
Hillside, church spire. 1886.	42 39 53·51	1651·2	71 18 56·82	1294·0
Lawrence Mills, chimney.	42 39 00·17	5·2	71 19 02·35	53·5
Lowell court-house.	42 38 15·23	470·0	71 18 32·59	742·6
Hamilton Mills, tower.	42 38 33·00	1018·3	71 18 41·92	955·0
Highland school-house, tower.	42 37 59·36	1831·7	71 19 54·12	1233·2
Merrimac Manufacturing Company's bell tower.	42 38 54·48	1681·1	71 18 38·82	884·3
H. K. No. 1.	42 39 26·20	808·5	71 19 18·93	431·1
Lowell, St. Patrick's church spire. 1886.	42 38 43·85	1353·1	71 19 07·67	174·7
Navy-yard, chimney.	42 39 52·60	1623·1	71 19 26·57	605·1
Cupola with flag.	42 41 21·41	660·7	71 19 15·32	348·8

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
18 03 28	198 02 02	Reservoir Hill	9 315·6	3·969 21
82 55 30	262 51 11	Gumpus.	8 756·3	3·942 32
18 28 51	198 27 23	Reservoir Hill	9 296·1	3·968 30
83 13 54	263 09 33	Gumpus.	8 809·9	3·944 97
62 54 45	242 49 36	Reservoir Hill	11 674·0	4·067 22
98 40 18	278 32 16	Gumpus.	16 374·2	4·214 16
62 41 33	242 36 14	Reservoir Hill	12 063·7	4·081 48
165 50 02	345 48 54	Spicket.	9 288·8	3·967 96
88 12 23	268 10 44	Reservoir Hill	3 342·3	3·524 04
199 24 38	19 27 10	Spicket.	15 316·2	4·185 15
134 03 01	313 58 18	Gumpus	13 230·6	4·121 58
196 28 30	16 30 51	Spicket.	16 653·3	4·221 50
153 48 58	333 46 55	Gumpus	9 347·2	3·970 68
249 57 46	69 58 36	Reservoir Hill.	1 790·9	3·253 06
154 16 10	334 14 14	Gumpus	8 981·7	3·953 36
189 33 14	9 33 47	Marsh and Jones.	6 705·5	3·826 43
180 44 17	0 44 23	Gumpus	15 638·7	4·194 20
217 23 52	37 26 51	Reservoir Hill.	9 900·8	3·995 67
67 33 42	247 31 48	Reservoir Hill	4 155·2	3·618 59
229 10 46	49 13 10	Lawrence Hill.	6 393·2	3·805 72
151 54 00	331 51 16	Gumpus	11 696·3	4·068 05
186 38 56	6 39 05	Reservoir Hill.	2 559·2	3·408 11
167 30 12	347 29 02	Gumpus	10 821·3	4·034 28
231 09 39	51 11 22	Reservoir Hill.	4 451·7	3·648 53
163 26 59	343 25 45	Gumpus	8 699·2	3·939 48
260 21 30	80 23 09	Reservoir Hill.	3 378·8	3·528 76
297 16 58	117 17 56	Reservoir Hill	2 188·7	3·340 19
335 02 57	155 03 46	Fort Hill.	3 910·3	3·592 21
156 03 46	336 01 55	Gumpus	9 209·2	3·964 22
214 36 44	34 41 57	Spicket.	18 467·6	4·266 41
155 45 52	335 43 40	Gumpus	10 751·8	4·031 48
214 28 04	34 28 45	Reservoir Hill.	2 461·6	3·391 22
155 35 13	335 33 08	Gumpus	10 164·6	4·007 09
227 18 18	47 19 06	Reservoir Hill.	2 184·6	3·339 38
166 02 25	346 01 09	Gumpus	10 606·0	4·025 55
232 12 59	52 14 36	Reservoir Hill.	4 112·4	3·614 10
153 34 01	333 31 54	Gumpus	9 595·8	3·982 08
241 56 47	61 57 33	Reservoir Hill.	1 739·6	3·240 44
273 44 38	93 45 51	Reservoir Hill	2 453·7	3·389 82
315 17 21	135 17 44	Jumbo chimney.	1 089·2	3·037 09
157 56 20	337 54 32	Gumpus	9 625·2	3·983 41
242 23 33	62 24 38	Reservoir Hill.	2 473·7	3·393 34
154 53 45	334 52 10	Gumpus	7 507·8	3·875 51
290 23 33	110 24 51	Reservoir Hill.	2 798·0	3·446 84
327 31 21	147 31 31	Reservoir Hill	4 404·8	3·643 93
239 42 17	319 40 34	Gumpus.	5 321·2	3·726 01

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Croquet.	42 39 08·57	264·4	71 19 21·14	481·6
Stone monument.	42 39 13·18	406·7	71 19 18·12	412·7
H. K. No. 2.	42 39 27·02	833·8	71 19 18·21	414·7
H. K. No. 3.	42 39 29·84	920·8	71 19 12·83	292·2
Dracut, old yellow church spire. 1886.	42 40 10·35	319·4	71 18 13·40	305·1
Suffolk, chimney.	42 39 00·19	5·9	71 19 02·34	53·3
Sargent.	42 47 55·53	1713·5	71 07 19·11	434·2
Salisbury Point, church spire. 1886.	42 50 30·30	935·0	70 55 28·45	646·0
Stone monument. +	42 39 13·11	404·5	71 19 18·11	412·5
Dan.	42 39 10·73	331·1	71 19 21·93	499·6

WORCESTER AND MIDDLESEX COUNTIES.

Hasnebumskit. (Borden.)	42 18 05·114	157·8	71 53 50·811	1163·8
Fay Mountain. (Borden.)	42 14 23·786	733·9	71 37 42·540	975·3
Mugget. (Borden.)	42 08 02·120	65·4	71 57 26·236	602·6
Watatick. (Borden.)	42 41 48·553	1498·1	71 53 34·870	793·7
Hatchet. (Borden.)	42 01 39·60	1221·8	72 04 46·74	1075·2
Chandler Hill. (Borden.)	42 16 15·20	469·0	71 47 11·43	261·9
Tuft Hill. (Borden.)	42 19 01·54	47·5	72 05 04·56	104·4
Hawes Hill. (Borden.)	42 27 26·43	815·6	72 07 07·17	163·8
Pepperell. (Borden.)	42 42 12·64	390·0	71 35 12·59	286·5
Watatick, State line. (Borden.)	42 42 40·93	1263·0	71 53 55·73	1268·2

MASSACHUSETTS AND NEW HAMPSHIRE BOUNDARY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
185 19 03	5 19 04	H. K. No. 1	546·3	2·737 42
261 16 14	81 17 28	Reservoir Hill.	2 528·5	3·402 86
177 21 10	357 21 09	H. K. No. 1	402·4	2·604 65
296 27 50	116 28 12	Jumbo chimney.	835·1	2·921 72
274 21 59	94 23 11	Reservoir Hill	2 439·6	3·387 31
6 41 14	186 41 12	Croquet.	573·0	2·758 16
16 05 25	196 05 19	Croquet	683·2	2·834 55
50 57 18	230 57 14	H. K. No. 1.	178·8	2·252 26
327 52 47	147 53 15	Reservoir Hill	1 798·2	3·254 83
38 59 36	218 58 50	Croquet.	2 452·4	3·389 60
121 07 59	301 07 46	Croquet	500·4	2·699 28
154 47 35	334 47 24	H. K. No. 1.	887·3	2·948 05
260 43 15	80 45 52	Ayer Hill	5 325·1	3·726 33
76 25 41	256 22 57	Spicket.	5 651·7	3·752 18
22 47 54	202 47 28	Curson	2 216·5	3·345 66
156 54 38	336 54 04	Powow (Borden).	2 912·1	3·464 21
177 21 10	357 21 09	H. K. No. 1	404·36	2·606 77
229 48 47	49 48 50	Stone monument +	113·9	2·056 41

WORCESTER AND MIDDLESEX COUNTIES.

239 36 08·5	60 08 10·2	Holt	75 169·6	4·876 042
278 27 55·5	98 59 30·6	Blue Hill (Borden).	65 353·2	4·815 269
273 59 30·2	94 20 13·4	Blue Hill (Borden)	42 534·6	4·628 742
330 14 03·6	150 21 25·8	Beaconpole (Borden).	30 567·4	4·485 258
188 18 25·2	8 21 15·0	Wachusett	39 873·9	4.600 688
194 51 10·2	14 53 35·0	Hasnebumskit.	19 250·0	4·284 430
358 48 56·7	178 49 10·8	Wachusett	23 078·5	4·363 207
275 13 04·5	95 45 02·6	Holt.	64 741·2	4·811 181
206 17 02	26 24 22	Hasnebumskit	33 931·2	4·530 600
271 34 57	91 47 41	Alumpond.	26 272·3	4·419 498
284 42 59	104 49 22	Fay Mountain	13 485·4	4·129 863
42 53 31	222 46 38	Mugget.	20 745·5	4·316 924
220 18 51	40 26 50	Wachusett	25 082·6	4·399 372
276 22 23	96 29 56	Hasnebumskit.	15 528·8	4·191 138
91 22 49	271 13 19	Packard	19 287·6	4·285 278
143 15 31	323 05 53	Mount Grace.	32 483·4	4·511 662
46 05 29	225 53 17	Wachusett	34 279·5	4·535 034
88 24 23	268 11 56	Watatick.	25 099·7	4·399 669
271 51 06	92 03 48	Pepperell	25 575·5	4·407 824
92 13 32	271 56 22	Warwick.	34 576·3	4·538 778

CONNECTICUT RIVER VALLEY.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Mount Grace. (Borden).	42 41 29·137	899·1	72 21 20·803	473·5
Packard. (C. & G. S. & Bdn.)	42 27 40·636	1253·9	72 21 11·087	253·3
More Hill. (Borden.)	42 27 53·041	1636·7	72 47 02·631	60·1
Jilson. (Borden.)	42 44 18·050	556·9	72 52 45·496	1034·8
Colonel Mount. (Borden.)	42 14 09·353	288·6	72 13 58·354	1338·0
Hilliard Knob. (C. & G. S. & Bdn.)	42 18 20·229	624·3	72 30 38·374	878·8
Mount Lincoln. (C. & G. S. & Bdn.)	42 21 49·379	1523·6	72 25 24·533	561·4
Proven Mount. (C. & G. S. & Bdn.)	42 05 04·486	138·4	72 42 17·176	394·8
Hitchcock. (Borden.)	42 05 07·392	228·1	72 15 35·428	814·2
Dug Hill. (Borden.)	42 12 25·341	781·8	72 56 27·159	623·0
Winchell Mount. (Borden.)	42 03 29·137	899·0	72 54 08·006	184·1
Peaked Mount. (C. & G. S. and Bdn.)	42 02 50·935	1571·5	72 20 26·198	602·5
High Ridge. (C. & G. S. & Bdn.)	42 26 55·123	1700·9	72 43 06·613	151·1
Mount Esther. (C. & G. S. & Bdn.)	42 27 10·190	314·4	72 39 54·642	1248·5
Hatfield, north base. (C. & G. S. & Bdn.) 1832.	42 28 46·149	1424·0	72 36 43·569	995·2
Hatfield, south base. (Borden) 1832.	42 22 20·843	643·2	72 36 50·973	1166·2
Rock Rimmon.	42 14 23·142	714·0	72 26 29·066	666·4
Facing Rock.	42 13 08·840	272·8	72 27 34·996	802·7
Feeding Hills.	42 03 52·203	1610·7	72 40 53·754	1235·9
McCarthy.	42 04 13·049	402·6	72 30 17·177	394·9
Brush.	42 09 03·891	120·1	72 39 39·619	909·7
Crafts.	42 12 46·510	1435·1	72 38 20·460	469·3
Shingle Hill.	42 23 23·355	720·6	72 41 59·471	1360·3

CONNECTICUT RIVER VALLEY.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
300 08 27·7	120 27 29·3	Wachusett	44 545·8	4·648 807
268 56 16·8	89 15 06·4	Watatick.	37 926·2	4·578 939
265 13 52·2	85 32 44·7	Wachusett	38 434·0	4·584 715
179 30 15·6	359 30 09·0	Mount Grace.	25 565·5	4·407 654
270 28 23·4	90 45 50·9	Packard	35 450·4	4·549 622
234 14 46·6	54 32 09·8	Mount Grace.	43 248·9	4·635 975
276 45 06·5	97 06 24·9	Mount Grace	43 202·4	4·635 508
345 32 45·2	165 36 37·3	More Hill.	31 382·9	4·496 693
225 14 28·7	45 28 27·2	Wachusett	40 021·7	4·602 295
255 09 35·0	75 23 07·2	Hasnebumskit.	28 614·2	4·456 582
196 29 36·4	16 35 53·0	Mount Grace	44 707·3	4·650 378
128 13 25·3	308 02 21·8	More Hill.	28 623·7	4·456 726
48 06 01·3	228 02 29·9	Hilliard Knob	9 657·6	3·984 869
110 49 51·4	290 35 15·8	More Hill.	31 731·1	4·501 485
213 04 51·5	33 12 40·8	Hilliard Knob	29 323·7	4·467 219
171 13 15·3	351 10 03·3	More Hill.	42 730·1	4·630 734
156 26 58·0	336 20 22·1	Mount Lincoln	33 739·0	4·528 132
187 34 55·3	7 36 00·5	Colonel Mount.	16 869·6	4·227 164
252 42 49·3	73 00 10·8	Hilliard Knob	37 151·7	4·569 979
204 14 47·2	24 21 07·4	More Hill.	31 406·6	4·497 021
259 43 42·1	79 51 38·4	Proven Mount	16 604·0	4·220 212
169 04 46·2	349 03 12·8	Dug Hill.	16 849·9	4·226 597
130 24 12·2	310 11 48·1	Mount Tom	33 385·7	4·523 560
153 57 05·2	333 50 14·2	Hilliard Knob.	31 930·6	4·504 199
345 54 04·9	165 56 54·3	Mount Tom	23 677·1	4·374 328
312 47 36·5	132 56 00·8	Hilliard Knob.	23 354·8	4·368 375
296 22 08·9	116 31 55·7	Mount Lincoln	22 223·2	4·346 806
322 03 21·5	142 09 36·4	Hilliard Knob.	20 720·6	4·316 403
309 34 24·2	129 42 02·3	Mount Lincoln	20 158·7	4·304 463
336 34 37·0	156 38 43·2	Hilliard Knob.	21 042·0	4·323 086
273 28 21·7	93 36 04·3	Mount Lincoln	15 736·8	4·196 918
180 48 53·9	0 48 58·9	Hatfield, north base.	11 890·1	4·075 184
338 39 11·1	158 43 14·6	Peaked Mount	22 925·3	4·360 315
90 51 39·2	270 43 17·7	Mount Tom.	17 105·5	4·233 136
332 38 27·8	152 43 15·5	Peaked Mount	21 458·1	4·331 592
99 16 27·0	279 08 49·9	Mount Tom.	15 798·5	4·198 615
273 43 01·4	93 56 43·7	Peaked Mount	28 290·3	4·451 638
187 51 49·5	7 53 09·2	Mount Tom.	19 890·9	4·298 654
280 30 22·1	100 36 58·0	Peaked Mount	13 822·8	4·140 597
148 05 32·5	327 59 44·9	Mount Tom.	22 464·4	4·351 496
293 21 39·7	113 34 33·0	Peaked Mount	28 894·5	4·460 816
241 25 18·5	61 34 09·5	Rock Rimmon.	20 640·6	4·314 723
306 34 38·0	126 46 38·6	Peaked Mount	30 764·4	4·488 048
259 34 36·4	79 42 34·5	Rock Rimmon.	16 584·6	4·219 705
300 53 52·0	121 01 30·8	Hilliard Knob	18 180·1	4·259 595
345 34 08·7	165 36 12·9	Mount Tom.	16 966·1	4·229 581

CONNECTICUT RIVER VALLEY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Mount Warner.	42 22 48·389	1493·1	72 34 22·124	506·1
North Warner.	42 22 55·991	1727·6	72 34 17·930	410·2
Amherst College, chapel.	42 22 15·291	471·8	72 31 06·965	159·4
Dickinson.	42 25 31·485	971·5	72 30 26·662	609·5
Mount Tom. (Borden.)	42 14 30·80	950·3	72 38 55·12	1263·7
Walnut Hill. (Borden.)	42 39 06·03	186·1	72 46 29·42	670·2
Bear Mount. (Borden.)	42 35 13·62	420·3	72 25 32·89	749·9
Warwick. (Borden.)	42 43 21·57	665·6	72 19 14·26	324·4
Leyden and Guilford. (Borden.)	42 43 55·29	1706·1	72 38 24·79	563·9
Rattlesnake. (Borden.)	42 01 59·59	1838·6	72 24 28·62	658·4
Secondary signal. (Borden.)	42 02 23·04	710·8	72 54 07·82	179·9
Boundary Rock. (Borden.)	42 01 53·84	1661·1	72 16 18·42	423·8
Connecticut line, signal. (Borden.)	42 01 55·98	1727·2	72 20 46·14	1061·4
Rattle, flag in tree.	42 01 59·08	1822·8	72 24 28·67	659·5
Wigwam.	42 06 26·00	802·2	72 24 45·10	1036·2
Dumpling.	42 10 24·46	754·7	72 20 27·90	640·4
Fish Rock.	42 10 35·96	1109·5	72 47 57·78	1326·1
White, flag in tree.	42 12 02·27	70·0	72 29 47·53	1090·5
Long Meadow, Congregational church spire.	42 03 00·83	25·6	72 34 56·24	1293·3
East Long Meadow, Congregational church spire.	42 03 51·49	1588·7	72 30 45·62	1048·9
Feeding Hills, Congregational church spire.	42 04 04·15	128·0	72 40 45·48	1045·6
Feeding Hills, Methodist church spire.	42 03 58·94	1818·5	72 40 44·54	1024·0
Holland's (H.) house, chimney.	42 05 05·04	155·5	72 42 14·89	342·2
Springfield water shops, tower.	42 05 51·94	1602·6	72 33 50·44	1159·1

CONNECTICUT RIVER VALLEY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
95 55 49·6	275 50 41·3	Shingle Hill	10 517·5	4·021 914
22 10 42·2	202 07 38·5	Mount Tom.	16 576·9	4·219 502
94 36 55·7	274 31 44·6	Shingle Hill	10 591·5	4·024 958
22 10 48·9	202 07 42·3	Mount Tom.	16 830·3	4·226 091
354 50 26·6	174 50 45·9	Hilliard Knob	7 282·3	3·862 266
98 04 10·4	277 56 50·6	Shingle Hill.	15 074·5	4·178 243
1 09 17·8	181 09 09·9	Hilliard Knob	13 309·2	4·124 152
98 31 19·2	278 22 46·4	High Ridge.	17 560·6	4·244 539
273 43 13	93 43 13	Mount Tom (C. & G. S.)	1·519 5	0·181 70
2 05 27	182 05 02	More Hill	20 779·0	4·317 624
262 31 58	82 48 58	Mount Grace.	34 637·2	4·539 543
336 49 36	156 52 33	Packard	15 201·1	4·181 875
65 20 01	245 05 29	More Hill.	32 424·9	4·510 879
39 42 05	219 40 39	Mount Grace	4 508·2	3·654 000
305 57 45	126 15 21	Wachusett.	44 023·0	4·643 680
280 51 30	101 03 04	Mount Grace	23 734·9	4·375 388
312 24 16	132 32 59	Bear Mount.	23 836·5	4·377 242
103 10 15	282 58 19	Proven Mount	25 223·4	4·401 804
164 21 55	344 17 47	Hilliard Knob.	31 424·6	4·497 269
170 14 25	350 12 52	Dug Hill	18 857·3	4·275 479
252 58 43	73 06 39	Proven Mount.	17 082·3	4·232 546
107 12 20	287 09 34	Peaked Mount	5 965·5	3·775 644
189 23 30	9 23 59	Hitchcock.	6 053·7	3·782 023
230 23 30	50 26 58	Hitchcock	9 269·4	3·967 053
270 35 55	90 38 54	Boundary Rock.	6 158·9	3·789 505
117 19 00	297 15 07	McCarthy	9 017·4	3·955 08
153 58 09	74 00 52	Peaked Mount.	5 801·6	3·763 55
170 48 09	350 46 59	Rock Rimmon	14 913·9	4·173 59
318 05 16	138 08 09	Peaked Mount.	8 913·3	3·950 04
131 40 01	311 35 58	Rock Rimmon	11 085·1	4·044 74
359 50 24	179 50 25	Peaked Mount.	13 992·7	4·145 90
239 44 56	59 51 01	Mount Tom.	14 404·6	4·158 50
295 46 19	115 58 11	McCarthy.	27 075·7	4·432 58
110 06 02	289 59 55	Mount Tom	13 367·5	4·126 05
235 56 32	55 58 01	Facing Rock.	3 668·6	3·564 50
208 20 08	28 25 04	Facing Rock	21 322·6	4·328 84
250 49 33	70 52 40	McCarthy.	6 791·9	3·831 99
90 08 46	270 01 59	Feeding Hills	13 981·7	4·145 56
150 22 34	330 17 06	Mount Tom.	22 702·3	4·356 07
27 18 57	207 18 51	Feeding Hills	414·9	2·617 93
268 51 09	88 58 10	McCarthy.	14 447·1	4·159 78
45 33 07	225 33 01	Feeding Hills	297·0	2·472 77
268 12 47	88 19 48	McCarthy.	14 429·8	4·159 26
205 48 47	25 50 31	Brush	8 187·3	3·913 14
320 18 16	140 19 10	Feeding Hills.	2 920·6	3·465 47
69 14 56	249 10 12	Feeding Hills	10 407·8	4·017 36
126 28 31	306 24 37	Brush.	9 970·3	3·998 71

CONNECTICUT RIVER VALLEY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Springfield, Florence street Methodist church spire.	42 06 01·11	34·2	72 34 03·72	85·5
Springfield, Hope Congregational church tower.	42 06 38·69	1193·8	72 33 55·63	1278·1
Springfield, State Street Methodist church.	42 06 19·18	591·8	72 34 53·36	1226·1
Springfield Arsenal, clock tower.	42 06 26·48	817·0	72 34 54·70	1256·8
Springfield, South Congregational church tower.	42 06 08·04	248·1	72 35 00·10	2·3
Springfield, First Baptist church spire.	42 06 10·88	335·7	72 35 04·19	96·3
Springfield, North Congregational church spire.	42 06 21·77	671·7	72 35 13·45	309·0
Springfield, court-house tower.	42 06 01·48	45·7	72 35 21·02	483·0
Springfield, St. Michael's church spire.	42 06 15·20	469·0	72 35 05·10	117·2
Springfield, St. Joseph's Catholic church spire.	42 06 06·63	204·6	72 35 10·64	244·5
West Springfield, Park Street Congregational church spire.	42 06 23·52	725·7	72 37 11·54	265·1
West Springfield, First Congregational church spire.	42 06 52·18	1610·0	72 37 31·94	733·8
Chicopee, Catholic church spire.	42 08 40·26	1242·2	72 36 20·25	465·0
Chicopee, town hall spire.	42 08 54·65	1686·2	72 36 25·94	595·6
Chicopee, French Catholic church spire.	42 08 49·11	1515·2	72 35 34·15	784·1
Chicopee, skating rink spire.	42 08 50·25	1550·4	72 36 36·77	844·3
Chicopee Falls, Catholic church spire.	42 09 42·82	1321·2	72 34 51·06	1172·2
Chicopee Falls, Congregational church spire.	42 09 25·06	773·2	72 34 51·70	1186·9
Chicopee Falls, new Baptist church spire.	42 09 26·08	804·7	72 34 54·10	1242·0
Chicopee Falls, Methodist church spire.	42 09 25·50	786·8	72 35 00·37	8·5
Holyoke, St. Jerome's Catholic church spire.	42 12 34·10	1052·1	72 36 31·76	728·6
Holyoke, Second Congregational church tower.	42 12 18·36	566·5	72 36 39·50	906·2
Holyoke, Second Baptist church tower.	42 12 24·78	764·6	72 36 48·58	1114·4

CONNECTICUT RIVER VALLEY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
67 09 25	247 04 50	Feeding Hills	10 229·4	4·009 85
126 11 46	306 08 01	Brush.	9 556·7	3·980 31
311 48 34	131 51 00	McCarthy	6 738·0	3·828 53
61 54 44	241 50 04	Feeding Hills.	10 896·8	4·037 30
301 29 11	121 32 16	McCarthy	7 445·8	3·871 91
61 20 01	241 15 59	Feeding Hills.	9 443·4	3·975 13
126 36 16	306 33 05	Brush	8 149·3	3·911 12
159 45 30	339 42 49	Mount Tom.	15 928·9	4·202 19
298 35 32	118 38 42	McCarthy	7 407·5	3·869 67
62 45 25	242 41 28	Feeding Hills.	9 145·8	3·961 22
61 59 46	241 55 52	Feeidng Hills	9 102·9	3·959 18
130 10 57	310 07 53	Brush.	8 277·7	3·917 91
59 29 28	239 25 40	Feeding Hills	9 081·6	3·958 16
160 08 06	340 06 00	Crafts.	12 623·5	4·101 18
62 29 05	242 25 22	Feeding Hills	8 625·8	3·935 80
161 46 20	341 44 19	Crafts.	13 158·3	4·119 20
61 11 42	241 07 49	Feeding Hills	9 148·1	3·961 33
129 33 38	309 30 34	Brush.	8 175·8	3·912 53
297 25 40	117 28 57	McCarthy	7 601·0	3·880 87
62 17 27	242 13 37	Feeding Hills.	8 910·7	3·949 91
171 01 46	351 00 36	Mount Tom	15 221·2	4·182 45
172 22 48	352 22 02	Crafts.	11 922·3	4·076 36
39 53 23	219 51 08	Feeding Hills	7 235·2	3·859 45
144 11 52	324 10 26	Brush.	5 011·3	3·699 95
99 04 06	279 01 52	Brush	4 635·5	3·666 10
235 26 36	55 32 28	Facing Rock.	14 627·8	4·165 18
33 25 33	213 22 34	Feeding Hills	11 177·9	4·048 36
93 41 04	273 38 54	Brush.	4 456·4	3·648 98
94 38 54	274 36 09	Brush	5 654·7	3·752 41
152 29 31	332 27 40	Crafts.	8 259·6	3·916 96
95 44 26	275 42 23	Brush	4 219·4	3·625 25
161 55 45	341 54 36	Crafts.	7 668·3	3·884 70
79 44 58	259 41 44	Brush	6 732·9	3·828 20
139 43 38	319 41 17	Crafts.	7 430·4	3·871 01
84 23 08	264 19 55	Brush	6 642·6	3·822 34
142 23 44	322 21 24	Crafts.	7 847·8	3·894 75
142 34 33	322 32 14	Crafts	7 789·1	3·891 49
234 39 35	55 44 30	Facing Rock.	12 197·2	4·086 26
143 30 17	323 28 03	Crafts	7 716·8	3·887 44
235 58 02	56 03 01	Facing Rock.	12 326·2	4·090 83
98 44 06	278 42 53	Crafts	2 522·7	3·401 86
137 37 29	317 35 53	Mount Tom.	4 875·3	3·688 00
110 33 59	290 32 51	Crafts	2 473·4	3·393 29
142 44 57	322 43 26	Mount Tom.	5 135·1	3·710 55
107 38 49	287 37 47	Crafts	2 211·6	3·344 71
143 17 13	323 15 48	Mount Tom.	4 851·2	3·685 85

CONNECTICUT RIVER VALLEY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Holyoke, French catholic church spire.	42 11 56·88	1755·0	72 36 23·26	533·7
Holyoke, engine house tower.	42 12 46·50	1434·7	72 37 31·98	733·6
Holyoke, First Congregational church belfry.	42 12 41·16	1270·0	72 37 49·36	1132·3
Holyoke, Windsor Hotel tower.	42 12 23·07	711·8	72 36 22·72	521·2
Holyoke, city hall tower.	42 12 24·32	750·4	72 36 28·10	644·6
Baptistville, First Baptist church spire.	42 11 42·04	1297·1	72 37 49·05	1125·4
East bench mark.	42 12 53·96	1664·9	72 36 10·22	234·4
East tidal bench mark.	42 12 53·95	1664·6	72 36 10·40	238·5
West bench mark.	42 12 44·22	1364·4	72 36 14·10	323·4
South Hadley Falls, Catholic church spire.	42 13 13·03	402·0	72 36 05·58	128·0
South Hadley Falls, Methodist church spire.	42 13 00·92	28·4	72 35 56·42	1294·1
South Hadley Falls, Congregational church spire.	42 12 58·25	1797·2	72 35 56·56	1297·3
South Hadley Female Seminary, observatory.	42 15 21·78	672·0	72 34 40·88	937·1
South Hadley, Congregational church spire.	42 15 31·59	974·7	72 34 31·26	716·5
Wilbraham, Rich Hall, tower.	42 07 27·68	854·0	72 25 55·10	1265·6
Wilbraham, Congregational church spire.	42 07 16·48	508·5	72 25 54·87	1260·4
Indian Orchard church spire.	42 09 32·02	988·0	72 30 07·04	161·6
Indian Orchard, French Catholic church spire.	42 09 33·30	1027·4	72 29 59·96	1376·5
Indian Orchard, Congregational church tower.	42 09 24·98	770·7	72 30 25·45	584·3
Jenksville church tower 1.	42 09 31·91	984·6	72 29 06·70	153·8
Jenksville church tower 2.	42 09 30·19	931·5	72 28 58·94	1353·1
Wilson's (Foster) house tower.	42 12 50·94	1571·7	72 38 08·34	191·3
Ludlow, Congregational church spire.	42 11 30·41	938·3	72 27 37·86	868·7

CONNECTICUT RIVER VALLEY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
119 40 28	299 39 09	Crafts	3 094·0	3·490 52
143 46 12	323 44 30	Mount Tom.	5 889·0	3·770 04
90 01 30	270 00 57	Crafts	1 112·1	3·046 16
149 22 51	329 21 55	Mount Tom.	3 740·3	3·572 91
103 01 32	283 01 11	Crafts	732·3	2·864 70
155 59 52	335 59 08	Mount Tom.	3 703·4	3·568 60
254 43 22	74 50 01	Rock Rimmon	14 109·8	4·149 52
263 17 50	83 23 44	Facing Rock.	12 186·8	4·085 89
104 52 52	284 51 37	Crafts	2 666·9	3·426 00
139 11 47	319 10 08	Mount Tom.	5 156·6	3·712 36
160 05 32	340 05 11	Crafts	2 115·8	3·325 48
259 10 44	79 17 36	Facing Rock.	14 338·7	4·156 51
24 09 27	204 09 15	Holyoke, city hall	1 002·3	3·000 98
128 20 16	308 18 25	Mount Tom.	4 818·8	3·682 94
85 36 52	265 35 25	Crafts	2 992·1	3·475 97
128 22 27	308 20 36	Mount Tom.	4 815·4	3·682 63
131 42 45	311 40 57	Mount Tom	4 943·7	3·694 05
196 32 57	16 33 00	East bench mark.	313·5	2·496 21
75 12 24	255 10 53	Crafts	3 200·7	3·505 25
121 42 23	301 40 29	Mount Tom.	4 567·1	3·659 64
82 21 08	262 19 31	Crafts	3 333·7	3·522 93
124 06 50	304 04 50	Mount Tom.	4 947·0	3·694 34
83 45 06	263 43 29	Crafts	3 220·5	3·521 21
124 55 03	304 53 03	Mount Tom.	4 991·0	3·698 19
46 26 38	226 24 11	Crafts	6 949·8	3·841 97
74 55 02	254 52 11	Mount Tom.	6 035·6	3·780 72
45 55 11	225 52 37	Crafts	7 319·0	3·864 45
72 47 38	252 44 41	Mount Tom.	6 331·7	3·801 52
45 06 14	225 03 19	McCarthy	8 504·7	3·929 66
98 59 09	278 49 57	Brush.	19 166·8	4·282 55
100 00 08	279 50 55	Brush	19 228·7	4·283 95
168 04 21	348 03 14	Facing Rock.	11 112·2	4·045 80
127 19 10	307 13 15	Mount Tom	15 222·6	4·182 49
207 31 44	27 33 26	Facing Rock.	7 544·8	3·877 65
126 50 08	306 44 09	Mount Tom	15 327·8	4·185 48
206 33 18	26 34 55	Facing Rock.	7 436·0	3·871 34
119 44 45	299 39 26	Crafts	12 549·3	4·098 62
209 30 18	29 32 13	Facin Rock.	7 937·8	3·899 70
115 20 33	295 14 21	Crafts	14 054·3	4·147 81
197 26 40	17 27 41	Facing Rock.	7 016·2	3·846 10
115 13 46	295 07 29	Crafts	14 238·4	4·153 46
195 55 31	15 56 27	Facing Rock.	7 015·8	3·846 08
63 45 50	243 45 42	Crafts	310·0	2·491 32
160 49 44	340 49 12	Mount Tom.	3 262·1	3·513 50
181 13 57	1 13 59	Facing Rock	3 037·7	3·482 54
109 46 36	289 39 01	Mount Tom.	16 499·9	4·217 48

CONNECTICUT RIVER VALLEY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Ludlow, Methodist church tower.	42 11 29·10	897·9	72 27 09·72	223·0
Palmer, Universalist church spire.	42 09 28·06	865·8	72 19 35·91	824·4
Three Rivers, French Catholic church spire.	42 11 00·72	22·2	72 21 21·30	488·8
Granby, Congregational church spire.	42 15 22·87	705·6	72 31 04·12	94·4
Belchertown, high school tower.	42 16 37·90	1169·4	72 24 11·95	273·8
Belchertown, Baptist church tower.	42 16 40·81	1259·2	72 24 04·66	106·8
Belchertown, First Congregational church tower.	42 16 42·68	1316·9	72 24 05·98	137·0
Belchertown, Methodist church tower.	42 16 42·12	1299·6	72 24 10·26	235·1
East Hampton, Williston mill tower.	42 16 27·69	854·4	72 39 33·42	765·9
East Hampton, Methodist church tower.	42 16 15·79	487·2	72 40 22·28	510·6
East Hampton, Williston Seminary, gymnasium tower.	42 16 13·85	427·4	72 40 16·00	366·7
East Hampton, First Congregational church spire.	42 16 20·74	639·9	72 40 17·24	395·1
East Hampton, Payson Congregational church spire.	42 16 12·02	370·9	72 40 22·78	522·0
East Hampton town hall, tower.	42 16 16·66	514·1	72 40 21·85	500·7
East Hampton, Williston, Knight & Co's chimney.	42 16 00·90	27·8	72 40 11·40	261·3
West Hampton, Congregational church spire.	42 18 16·57	511·3	72 46 32·39	741·9
Northampton, First Congregational church spire.	42 19 09·25	285·4	72 37 53·14	1216·9
Northampton, Second Congregational church spire.	42 19 04·62	142·6	72 38 04·32	98·9
Northampton, Catholic church tower.	42 19 38·61	1191·3	72 38 02·98	68·2
Northampton, lunatic asylum tower.	42 18 52·16	1609·4	72 38 51·00	1168·0
Northampton, Methodist church spire.	42 19 10·72	330·8	72 37 59·58	1364·3
Northampton, Episcopal church spire.	42 19 16·38	505·4	72 37 42·57	974·8
Northampton, Round Hill, flagstaff. 1885.	42 19 27·53	849·4	72 38 22·38	512·4

CONNECTICUT RIVER VALLEY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
109 10 42	289 02 49	Mount Tom	17 121·8	4·233 55
169 19 54	349 19 37	Facing Rock.	3 131·5	3·495 75
5 23 32	185 22 58	Peaked Mount	12 306·9	4·090 15
145 33 27	325 32 52	Dumpling.	2 109·8	3·324 24
312 22 58	132 23 34	Dumpling	1 659·4	3·219 95
131 31 45	311 28 18	Rock Rimmon.	9 425·8	3·974 32
310 45 31	130 47 52	Facing Rock	6 331·8	3·801 53
45 22 21	225 16 35	Brush.	16 631·1	4·220 92
79 07 04	258 57 10	Mount Tom	20 618·6	4·314 26
130 06 58	310 00 11	North Warner.	18 126·8	4·258 32
69 51 12	249 41 38	Crafts	20 909·8	4·320 35
37 56 33	217 54 56	Rock Rimmon.	5 385·3	3·731 21
78 47 27	258 37 29	Mount Tom	20 780·7	4·317 66
136 49 58	316 45 15	Amherst College chapel.	14 079·9	4·148 60
78 47 04	258 37 08	Mount Tom	20 681·4	4·315 58
137 10 30	317 05 40	Amherst College chapel.	14 025·2	4·146 91
227 11 24	47 17 05	Amherst College chapel	15 796·1	4·198 55
346 17 23	166 17 49	Mount Tom.	3 712·4	3·569 66
214 12 44	34 16 46	Mount Warner	14 654·1	4·165 96
328 18 27	148 19 26	Mount Tom.	3 806·9	3·580 57
228 22 26	48 28 36	Amherst College chapel	16 805·8	4·225 46
329 43 44	149 44 38	Mount Tom.	3 681·4	3·566 01
214 10 30	34 14 29	Mount Warner	14 463·1	4·160 26
330 56 39	150 57 34	Mount Tom.	3 879·9	3·588 82
213 59 41	34 03 44	Mount Warner	14 757·1	4·169 00
327 12 57	147 13 56	Mount Tom.	3 714·6	3·569 91
214 14 23	34 18 25	Mount Warner	14 626·5	4·165 14
328 38 47	148 39 45	Mount Tom.	3 824·6	3·582 59
213 25 41	32 29 36	Mount Warner	14 901·2	4·173 22
327 48 01	147 48 52	Mount Tom.	3 285·1	3·516 55
303 34 06	123 39 14	Mount Tom	12 583·5	4·099 80
308 19 17	128 36 49	Peaked Mount.	45 910·3	4·661 91
144 18 16	324 15 30	Shingle Hill	9 657·2	3·984 85
215 31 06	35 33 28	Mount Warner.	8 309·4	3·919 57
216 21 12	36 23 42	Mount Warner	8 575·3	3·933 25
7 50 24	187 49 50	Mount Tom.	8 528·1	3·930 85
220 46 46	40 49 15	Mount Warner	7 735·7	3·888 50
142 03 10	322 00 31	Shingle Hill.	8 796·7	3·944 32
239 24 52	59 30 05	Amherst College chapel	12 333·4	4·091 08
0 39 28	180 39 25	Mount Tom.	8 064·7	3·906 59
144 51 55	324 49 14	Shingle Hill	9 534·5	3·979 30
238 52 18	58 56 56	Amherst College chapel.	11 029·4	4·042 55
142 22 22	322 19 29	Shingle Hill	9 625·0	3·983 40
215 01 27	35 03 42	Mount Warner.	7 290·1	3·902 55
221 33 38	41 36 20	Mount Warner	8 285·0	3·918 31
242 30 51	62 35 44	Amherst College chapel.	11 230·5	4·050 40

CONNECTICUT RIVER VALLEY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Nonotuck Hotel, tower.	42 16 47·86	1476·7	72 37 15·19	348·1
Connecticut River Lumber Company's chimney.	42 17 29·65	914·8	72 37 14·30	327·6
Mount Holyoke Hotel, flagstaff.	42 18 02·12	65·4	72 35 17·62	403·6
South Amherst, Monson's barn cupola.	42 20 36·78	1134·9	72 30 24·64	564·0
South Amherst church spire.	42 20 25·45	785·3	72 30 13·94	319·1
Smith's (Edwin) barn cupola.	42 20 56·34	1738·4	72 33 10·66	244·0
Hadley, First Congregational church spire.	42 20 30·88	952·8	72 35 20·81	476·4
Hadley, Second Congregational church spire.	42 20 33·90	1046·0	72 35 47·72	1092·3
New Braintree, Congregational church spire.	42 19 01·16	35·8	72 07 35·90	822·1
Florence, engine house tower.	42 20 04·52	139·5	72 40 19·43	444·8
Florence, Catholic church spire.	42 19 56·78	1752·0	72 40 07·03	160·9
Florence, Congregational church spire.	42 19 54·16	1671·1	72 40 30·00	686·8
Florence, schoolhouse tower.	42 19 51·98	1603·8	72 40 33·41	764·9
Florence, Methodist church spire.	42 20 07·18	221·5	72 40 25·22	577·4
Florence, Cosmian Hall, clock tower.	42 20 09·26	285·7	72 40 26·55	607·8
Florence Manufacturing Company's mill, tower.	42 19 53·57	1652·9	72 40 44·64	1022·0
Hatfield, Congregational church spire.	42 22 13·68	422·1	72 35 50·97	1166·2
Hatfield, Smith Academy, tower.	42 22 15·68	483·8	72 35 44·70	1022·8
North Hadley, Congregational church spire.	42 23 19·71	608·2	72 34 52·02	1189·9
Haydensville, Catholic church spire.	42 22 22·87	705·7	72 41 53·70	1228·6
Haydensville, Congregational church spire.	42 21 15·34	473·3	72 41 39·08	894·4
Amherst College Hall.	42 22 22·02	679·4	72 31 14·42	329·9
Amherst, Williston Hall, tower.	42 22 17·76	548·0	72 31 06·59	150·8

CONNECTICUT RIVER VALLEY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
151 57 16	331 54 05	Shingle Hill	13 829·9	4·140 82
199 35 25	19 37 21	Mount Warner.	11 808·6	4·072 20
201 49 39	21 51 35	Mount Warner	10 596·2	4·025 15
223 37 30	43 41 37	Amherst College chapel.	12 181·8	4·085 71
137 10 32	317 06 02	Shingle Hill	13 522·3	4·131 04
188 10 44	8 11 21	Mount Warner.	8 923·8	3·950 55
126 47 27	306 44 47	Mount Warner	6 784·1	3·831 49
162 19 52	342 19 24	Amherst College chapel.	3 190·1	3·503 80
127 51 18	307 48 31	Mount Warner	7 190·8	3·856 78
160 18 31	340 17 55	Amherst College chapel.	3 599·6	3·556 26
110 36 02	290 30 06	Shingle Hill	12 922·3	4·111 34
154 41 24	334 40 36	Mount Warner.	3 824·8	3·582 61
120 17 45	300 13 16	Shingle Hill	10 560·9	4·023 70
197 33 25	17 34 04	Mount Warner.	4 450·3	3·648 39
121 36 46	301 32 36	Shingle Hill	9 984·8	3·999 34
205 15 25	25 16 23	Mount Warner.	4 589·0	3·661 72
30 38 05	210 29 27	Peaked Mount	34 764·8	4·541 14
71 49 19	251 36 37	Rock Rimmon.	27 346·4	4·436 90
159 32 42	339 31 35	Shingle Hill	6 548·2	3·816 12
252 15 01	72 21 13	Amherst College chapel.	13 272·7	4·122 96
236 06 48	56 10 40	Mount Warner	9 504·7	3·977 94
350 41 06	170 41 54	Mount Tom.	10 192·5	4·008 28
237 24 20	57 28 28	Mount Warner	9 989·6	3·999 55
347 41 26	167 42 30	Mount Tom.	10 211·5	4·009 09
347 10 50	167 11 56	Mount Tom	10 162·7	4·007 01
163 12 19	343 11 21	Shingle Hill.	6 813·0	3·833 34
160 23 43	340 22 40	Shingle Hill	6 425·8	3·807 93
239 03 37	59 07 41	Mount Warner.	9 685·0	3·986 10
160 27 36	340 26 34	Shingle Hill	6 354·9	3·803 11
253 03 30	73 09 47	Amherst College chapel.	13 384·7	4·126 61
345 50 28	165 51 42	Mount Tom	10 270·7	4·011 60
165 11 14	345 10 24	Shingle Hill.	6 695·8	3·825 80
242 12 25	62 13 25	Mount Warner	2 297·6	3·361 28
131 07 17	311 02 23	High Ridge.	13 215·4	4·121 08
147 51 26	327 48 37	Mount Esther	10 735·0	4·030 80
241 52 50	61 53 46	Mount Warner.	2 141·9	3·330 80
135 49 00	315 45 36	Mount Esther	9 921·8	3·996 59
236 09 06	56 12 05	Dickinson.	7 304·5	3·863 59
175 57 26	355 57 22	Shingle Hill	1 870·9	3·272 04
344 17 34	164 19 34	Mount Tom.	15 129·3	4·179 82
192 17 42	12 18 52	Mount Esther	11 207·0	4·049 49
343 13 55	163 15 45	Mount Tom.	13 035·3	4·115 12
36 00 30	215 55 20	Mount Tom	17 963·9	4·254 40
100 44 44	280 42 38	Mount Warner.	4 370·8	3·640 56
6 21 56	186 21 56	Amherst College chapel	76·6	1·884 29
101 56 49	281 54 37	Mount Warner.	4 572·3	3·660 13

CONNECTICUT RIVER VALLEY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Amherst, Walker Hall, tower.	42 22 18·21	561·9	72 31 02·82	64·5
Amherst, Episcopal church spire.	42 22 29·76	918·2	72 31 09·06	207·3
Amherst, Congregational church spire.	42 22 32·07	989·5	72 31 00·60	13·7
Amherst Agricultural College, drill hall tower.	42 23 17·06	526·4	72 31 43·56	996·4
Amherst Agricultural College, flagstaff.	42 23 21·69	669·3	72 31 42·64	975·4
Amherst Agricultural College, belfry.	42 23 26·31	811·8	72 31 46·50	1063·6
Amherst, Lawrence Observatory.	42 22 17·06	526·4	72 31 10·05	229·9
Amherst City, Methodist church tower.	42 24 50·34	1553·2	72 30 32·79	749·7
Pelham church spire.	42 23 32·30	996·6	72 24 17·34	396·6
North Amherst, Congregational church spire.	42 24 36·74	1133·6	72 31 52·29	1195·7
Dickinson's (Charles R.) barn cupola.	42 25 23·87	736·5	72 31 49·77	1137·8
Deacon Elihu's barn tower.	42 26 06·46	199·3	72 35 22·80	521·1
Whately, Congregational church spire.	42 26 17·07	526·7	72 38 07·34	167·8
Conway township, southeast corner.	42 27 30·25	933·4	72 39 28·34	647·5
Chestnut Hill.	42 24 34·29	1058·0	72 39 40·12	917·4
Battlecock.	42 23 02·75	84·8	72 46 25·47	582·7
Leverett, Congregational church spire.	42 27 07·80	240·7	72 30 06·90	157·7
Sunderland, school-house tower.	42 28 02·32	71·6	72 34 44·74	1022·1
Sunderland, Congregational church spire.	42 27 57·91	1786·9	72 34 49·70	1135·4
Mount Toby.	42 29 16·32	503·6	72 32 16·28	371·8
Shutesbury, Congregational church spire.	42 27 11·85	365·6	72 24 37·34	853·2
Shutesbury, Baptist church.	42 27 10·31	318·1	72 24 36·46	833·1
Shutesbury house, chimney.	42 27 42·20	1302·1	72 24 41·61	950·7

CONNECTICUT RIVER VALLEY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
101 33 34	281 31 19	Mount Warner	4 653·9	3·667 82
187 53 30	7 53 54	Dickinson.	6 020·6	3·779 64
353 51 42	173 51 43	Amherst College chapel	449·1	2·652 32
97 25 58	277 23 48	Mount Warner.	4 454·0	3·648 75
15 43 02	195 42 58	Amherst College chapel	537·7	2·730 54
96 15 14	276 12 58	Mount Warner.	4 637·6	3·666 29
31 21 50	211 17 00	Mount Tom	19 008·2	4·278 94
79 35 20	259 33 36	North Warner.	3 590·7	3·555 18
338 16 30	158 16 54	Amherst College chapel	2 205·6	3·343 52
77 25 42	257 23 57	North Warner.	3 639·7	3·561 07
337 33 55	157 34 22	Amherst College chapel	2 370·8	3·374 89
74 53 59	254 52 17	North Warner.	3 587·9	3·554 84
105 37 40	285 35 34	North Warner	4 463·1	3·649 64
189 23 18	9 23 47	Dickinson.	6 080·8	3·783 96
55 36 00	235 33 28	North Warner	6 242·1	3·795 33
186 18 04	6 18 08	Dickinson.	1 277·1	3·106 24
50 20 48	230 10 58	Mount Tom	26 137·3	4·417 26
85 23 33	265 16 47	North Warner.	13 784·1	4·139 38
27 24 42	207 19 58	Mount Tom	21 053·8	4·323 33
105 32 45	285 25 10	High Ridge.	15 995·2	4·203 99
36 36 34	216 34 54	North Warner	5 683·3	3·754 60
262 56 42	82 57 38	Dickinson.	1 914·5	3·282 06
61 00 49	240 56 22	Shingle Hill	10 372·7	4·015 89
107 35 36	287 32 33	Mount Esther.	6 516·3	3·814 00
277 33 55	97 39 05	Dickinson	10 624·0	4·026 29
319 45 54	139 48 29	North Warner.	8 124·7	3·909 81
319 59 10	140 02 39	North Warner	11 044·3	4·043 14
44 09 32	224 09 14	Mount Esther.	862·5	2·935 78
55 31 54	235 30 20	Shingle Hill	3 866·2	3·587 28
132 39 07	312 36 48	High Ridge.	6 416·2	3·807 28
264 00 39	84 03 38	Shingle Hill	6 118·0	3·786 61
326 48 44	146 53 48	Mount Tom.	18 865·6	4·275 67
36 28 33	216 25 44	North Warner	9 659·6	3·984 96
88 48 56	268 40 10	High Ridge.	17 821·7	4·250 95
356 17 10	176 17 28	North Warner	9 472·0	3·976 44
79 47 51	259 42 12	High Ridge.	11 653·1	4·066 44
355 32 19	175 32 40	North Warner	9 344·2	3·970 54
78 05 46	258 02 20	Mount Esther.	7 121·1	3·852 55
13 20 26	193 19 04	North Warner	12 060·4	4·081 36
69 39 19	249 34 10	Mount Esther.	11 170·7	4·048 08
73 36 47	253 25 04	Shingle Hill	24 846·2	4·395 26
89 56 46	269 46 27	Mount Esther.	20 960·4	4·321 40
73 43 54	253 32 11	Shingle Hill	24 853·1	4·395 38
90 04 36	269 54 16	Mount Esther.	20 980·2	4·321 81
56 13 19	236 06 50	North Warner	15 861·3	4·200 34
71 29 35	251 17 55	Shingle Hill.	25 034·6	4·398 54

CONNECTICUT RIVER VALLEY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Boyden's (Colonel) barn cupola.	42 28 58·00	1789·6	72 36 51·15	1168·3
South Deerfield, Congregational church spire.	42 28 44·71	1379·6	72 36 27·16	620·4
Sugarloaf Hotel, south chimney.	42 28 13·00	401·1	72 35 32·98	753·4
Sugarloaf Hotel, north chimney.	42 28 13·30	410·4	72 35 33·08	755·7

MASSACHUSETTS, NEW YORK, AND CONNECTICUT BOUNDARY.

Saddle Mount. (Borden.)	42 38 14·125	435·8	73 09 58·908	1342·1
Becket. (Borden.)	42 18 06·712	207·1	73 08 46·817	1072·3
Alander Mount. (Borden.)	42 05 15·057	464·6	73 30 18·725	430·4
Seymore Hill. (Borden.)	42 03 27·856	859·5	73 06 14·729	338·7
Jackson Hill. (Borden.)	42 10 20·198	623·2	73 00 50·109	1150·1
Spruce Hlll. (Borden.)	42 40 12·597	388·7	73 04 09·889	225·2
Berlin Mount, N. Y. (Borden.)	42 41 31·596	974·9	73 17 10·504	239·1
Clarksburg. (Borden.)	42 44 03·571	110·2	73 09 33·739	767·5
Haines, N. Y.	41 54 37·741	1164·5	73 34 08·072	186·0
Prospect Hill, Conn.	41 58 45·109	1391·8	73 23 06·278	144·5
Northwest corner of Massachusetts. (Borden.)	42 44 45·25	1396·3	73 15 54·17	1232·1
Williamstown, Congregational church. (Borden.) 1837.	42 42 48·76	1504·6	73 12 36·94	840·6
Washington, spire. 1874–1876.	42 21 57·78	1782·7	73 08 39·78	910·2
Connecticut line. (Borden.)	42 02 58·78	1813·6	73 29 42·92	986·9
Southwest corner of Massachusetts. (Borden.)	42 02 59·61	1839·2	73 31 18·72	430·4
Brace Mount monument, N. Y.	42 02 39·91	1231·4	73 29 34·88	802·4
Iron Bolt.	42 02 58·67	1810·2	73 29 42·62	980·1
Ryant Bush.	42 03 04·05	125·0	73 28 56·63	1302·3

CONNECTICUT RIVER VALLEY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
51 34 43	231 32 39	Mount Esther	5 351·4	3·728 47
66 11 14	246 07 00	High Ridge.	9 378·4	3·972 13
344 38 12	164 39 39	North Warner	11 158·1	4·047 59
58 25 02	238 22 42	Mount Esther.	5 565·7	3·745 52
350 02 31	170 03 22	North Warner	9 930·7	3·996 98
76 59 25	256 54 19	High Ridge.	10 639·5	4·026 92
44 40 11	224 35 50	Shingle Hill	12 571·6	4·099 39
76 56 24	256 51 18	High Ridge.	10 639·5	4·026 92

MASSACHUSETTS, NEW YORK, AND CONNECTICUT BOUNDARY.

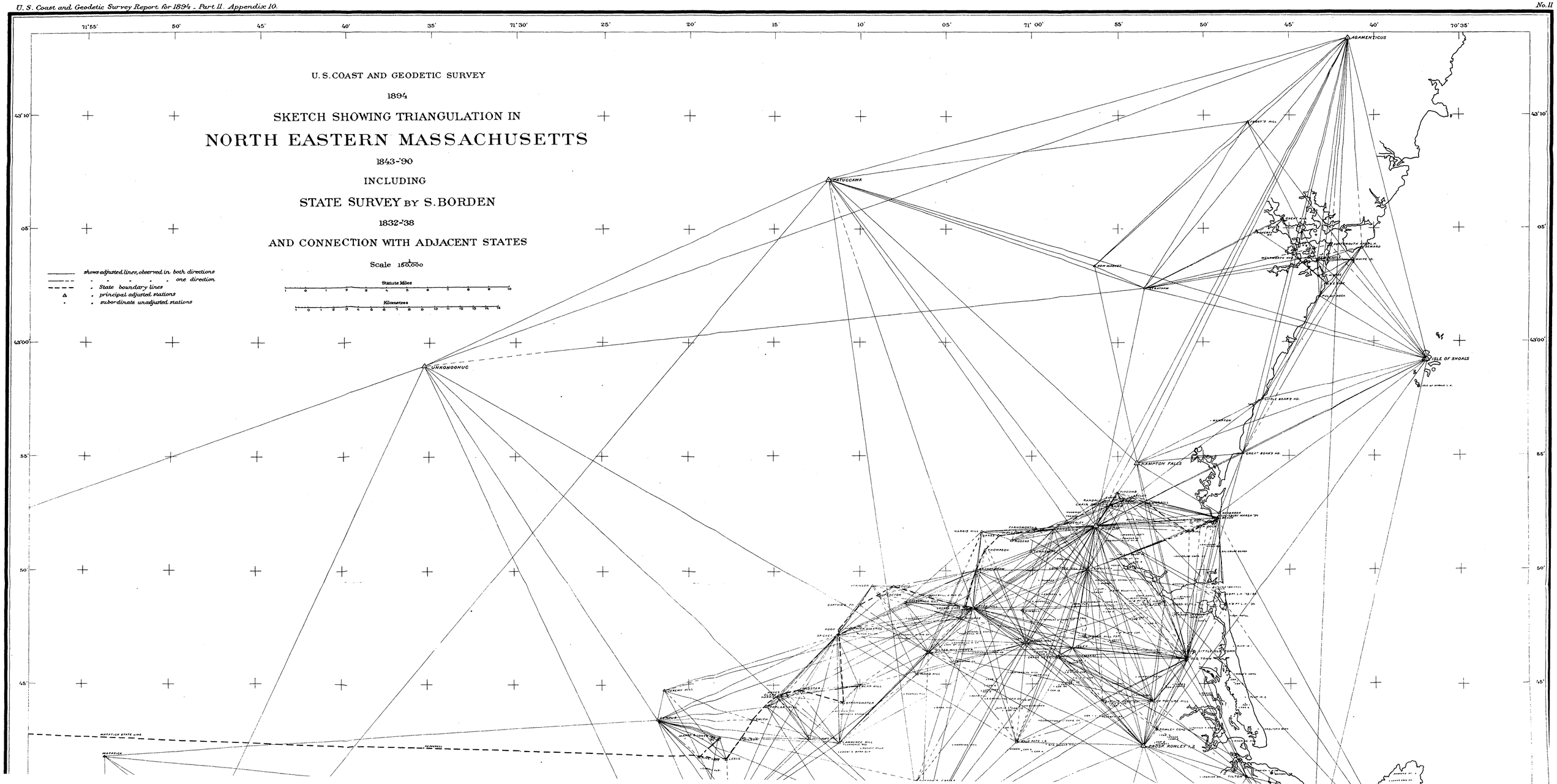
244 23 09·6	64 34 50·2	Jilson	26 068·6	4·416 117
301 16 03·2	121 31 33·9	More Hill.	36 786·1	4·565 684
124 33 50·2	304 24 22·9	Perry Peak	23 375·2	4·368 755
212 37 01·2	32 41 24·2	French Hill.	16 555·7	4·218 949
254 51 24·0	74 54 18·0	Bald Peak	6 180·0	3·790 991
231 06 28·0	51 20 55·7	Becket.	38 019·9	4·580 011
100 21 11·6	280 07 57·9	Bald Peak	27 665·0	4·441 930
172 40 46·2	352 39 04·1	Becket.	27 340·2	4·436 801
77 27 05·2	257 10 12·8	Bald Peak	35 522·1	4·550 499
142 49 56·9	322 44 36·5	Becket.	18 073·9	4·257 051
354 30 28·6	174 31 45·3	French Hill	27 096·2	4·432 908
65 20 16·3	245 16 19·8	Saddle Mount (Borden).	8 750·1	3·942 012
277 44 10·6	97 52 59·8	Spruce Hill	17 939·2	4·253 802
301 45 19·7	121 50 12·2	Saddle Mount (Borden).	11 564·5	4·063 128
314 00 24·4	134 04 04·0	Spruce Hill	10 253·1	4·010 854
3 02 39·1	183 02 22·0	Saddle Mount (Borden).	10 798·1	4·033 346
278 25 49·1	98 39 37·2	Ivy	28 911·1	4·461 065
207 49 42·6	27 55 09·8	Bald Peak.	24 067·6	4·381 432
311 46 39·1	131 53 05·5	Ivy	17 884·7	4·252 482
63 27 59·2	243 20 36·9	Haines.	17 047·9	4·231 672
278 25 05	98 29 23	Clarksburg	8 748·3	3·941 92
326 08 30	146 12 31	Saddle Mount (Borden).	14 527·9	4·162 20
292 36 43	112 42 27	Spruce Hill	12 507·8	4·097 18
69 05 53	249 02 48	Berlin Mount.	6 666·1	3·823 87
107 31 58	287 22 25	Perry Peak	20 355·8	4·308 69
176 33 56	356 33 03	Greylock.	30 179·4	4·479 71
168 55 36	348 55 12	Alander Mount	4 284·5	3·631 90
221 28 19	41 30 49	Bald Peak.	7 765·5	3·890 17
198 15 36	18 16 16	Alander Mount	4 401·0	3·643 55
270 39 05	90 40 09	Connecticut line.	2 203·3	3·343 08
308 58 39	129 02 59	Prospect Hill	11 508·2	4·061 01
22 56 37	202 53 35	Haines.	16 151·5	4·208 21
310 35 10	130 39 35	Prospect Hill	12 015·5	4·079 74
21 35 58	201 33 00	Haines.	16 619·8	4·220 63
314 42 34	134 46 28	Prospect Hill	11 349·8	4·054 99
24 41 02	204 37 34	Haines.	17 188·3	4·235 23

MASSACHUSETTS, NEW YORK, AND CONNECTICUT BOUNDARY—Continued.

Station.	Latitude.	Seconds in metres.	Longitude.	Seconds in metres.
	° ′ ″		° ′ ″	
Ball Peak (or Mount Riga), Conn.	42 00 43·33	1336·9	73 27 57·84	1330·8
Corner stone, N. Y.	42 02 58·38	1801·2	73 29 15·96	367·0
Pittsfield, First Congregational church. (Borden.)	42 26 56·1	1731·1	73 15 09·6	219·3

MASSACHUSETTS, NEW YORK, AND CONNECTICUT BOUNDARY—Continued.

Azimuth.	Back azimuth.	To station.	Distance.	Logarithm.
° ′ ″	° ′ ″		*Metres.*	
298 29 53	118 33 08	Prospect Hill	7 637·8	3·882 97
37 07 10	217 03 03	Haines.	14 139·4	4·150 43
37 22 17	217 22 04	Brace Mount, monument	717·0	2·855 53
336 39 53	156 40 45	Ball Peak.	4 537·5	3·656 82
73 35·4	253 30·2	Perry Peak	10 944	4·039 16
198 41·5	18 45·0	Saddle Mount (Borden).	22 090	4·344 19


U. S. COAST AND GEODETIC SURVEY
1894
SKETCH SHOWING TRIANGULATION IN
NORTH EASTERN MASSACHUSETTS
1843-'90
INCLUDING
STATE SURVEY BY S. BORDEN
1832-'38
AND CONNECTION WITH ADJACENT STATES
Scale 1/150,000
shows adjusted lines, observed in both directions
" " " " " one direction
" State boundary lines
" principal adjusted stations
" subordinate unadjusted stations
Statute Miles
Kilometres
AGAMENTICUS
PATUCCAWA
UNKONOONUC
ISLE OF SHOALS
HAMPTON FALLS
PROSP. ROWLEY 1,2
WATATICK STATE LINE
WATATICK
PEPPERELL

42°10'
15'
20'
25'
42°30'
35'
40'
45'
71°5.5'
50'
45'
40'
35'
71°30'
25'
20'
15'
10'
05'
71°00'
55'
50'
45'
40'
70°35'
MACHUSETT
WACHUSETT
PROSP. WALTHAM
BLUE HILL
CAM. OBS.
MONADNOCK
WOODPORT
PROSP. ROWLEY 2
PROSP. HILL
HOLT
CASTLE HILL
DANE
BALLOU
THOMPSON
BAILCUT
POOL HILL
WATATIC
WATATIC EXTENSION
NEPONSET
SPECTACLE
POOR
STRONGWATER
SMITH
PEABODY
PEABODY 2
PEABODY 3
PEABODY 4
PEABODY 5
PEABODY 6
PEABODY 7
PEABODY 8
PEABODY 9
PEABODY 10
PEABODY 11
PEABODY 12
PEABODY 13
PEABODY 14
PEABODY 15
PEABODY 16
PEABODY 17
PEABODY 18
PEABODY 19
PEABODY 20
PEABODY 21
PEABODY

U. S. COAST AND GEODETIC SURVEY

1894

SKETCH SHOWING TRIANGULATION IN

SOUTH EASTERN MASSACHUSETTS

1843-'90

INCLUDING

STATE SURVEY BY S. BORDEN

1832-'38

AND CONNECTION WITH ADJACENT STATES

Scale $\frac{1}{150\,000}$

shows adjusted lines, observed in both directions
" " " " " one direction
" State boundary lines
" principal adjusted stations
" subordinate unadjusted stations

Statute Miles 1 0 1 2 3 4 5 6 7 8 9 10

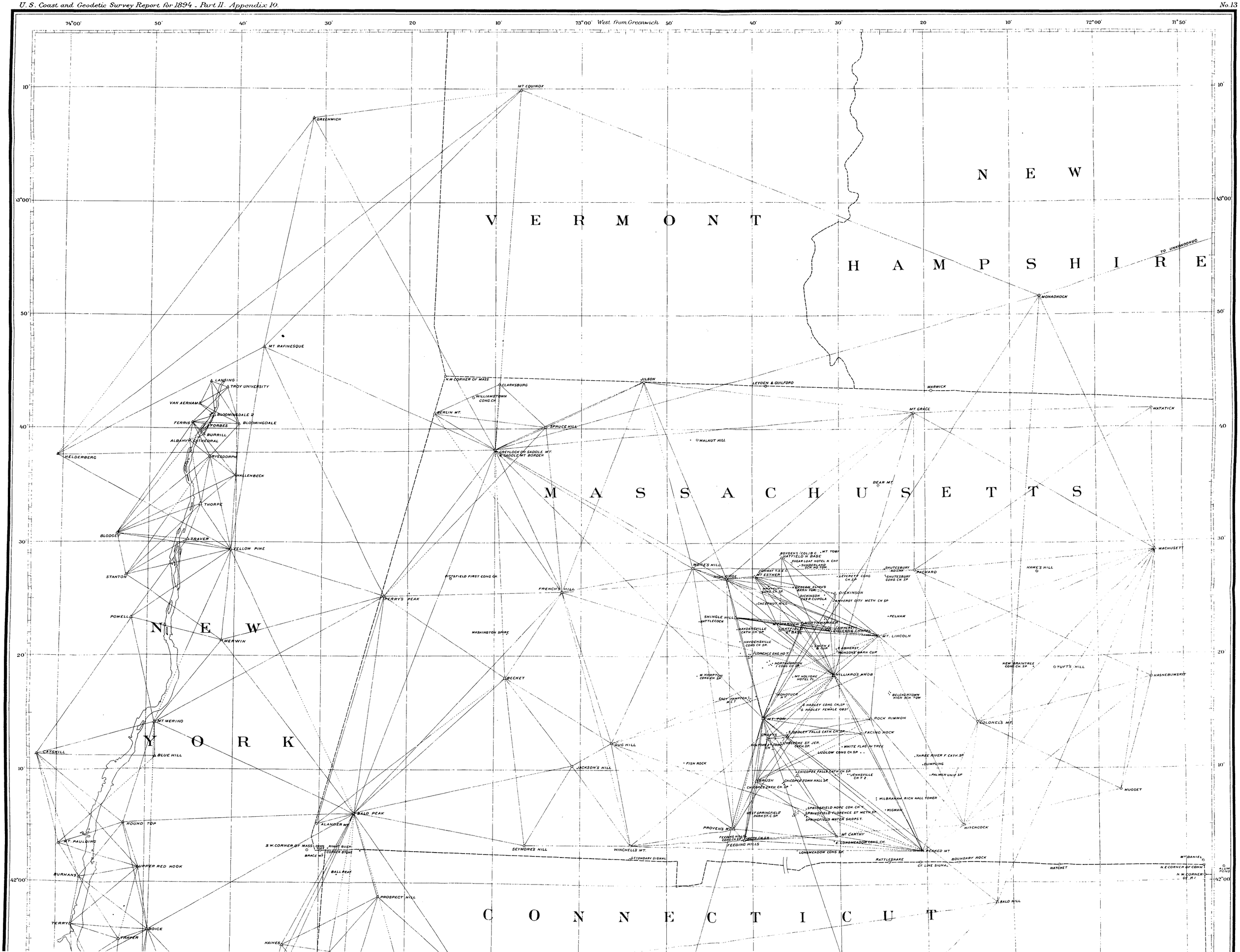
Kilometres 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

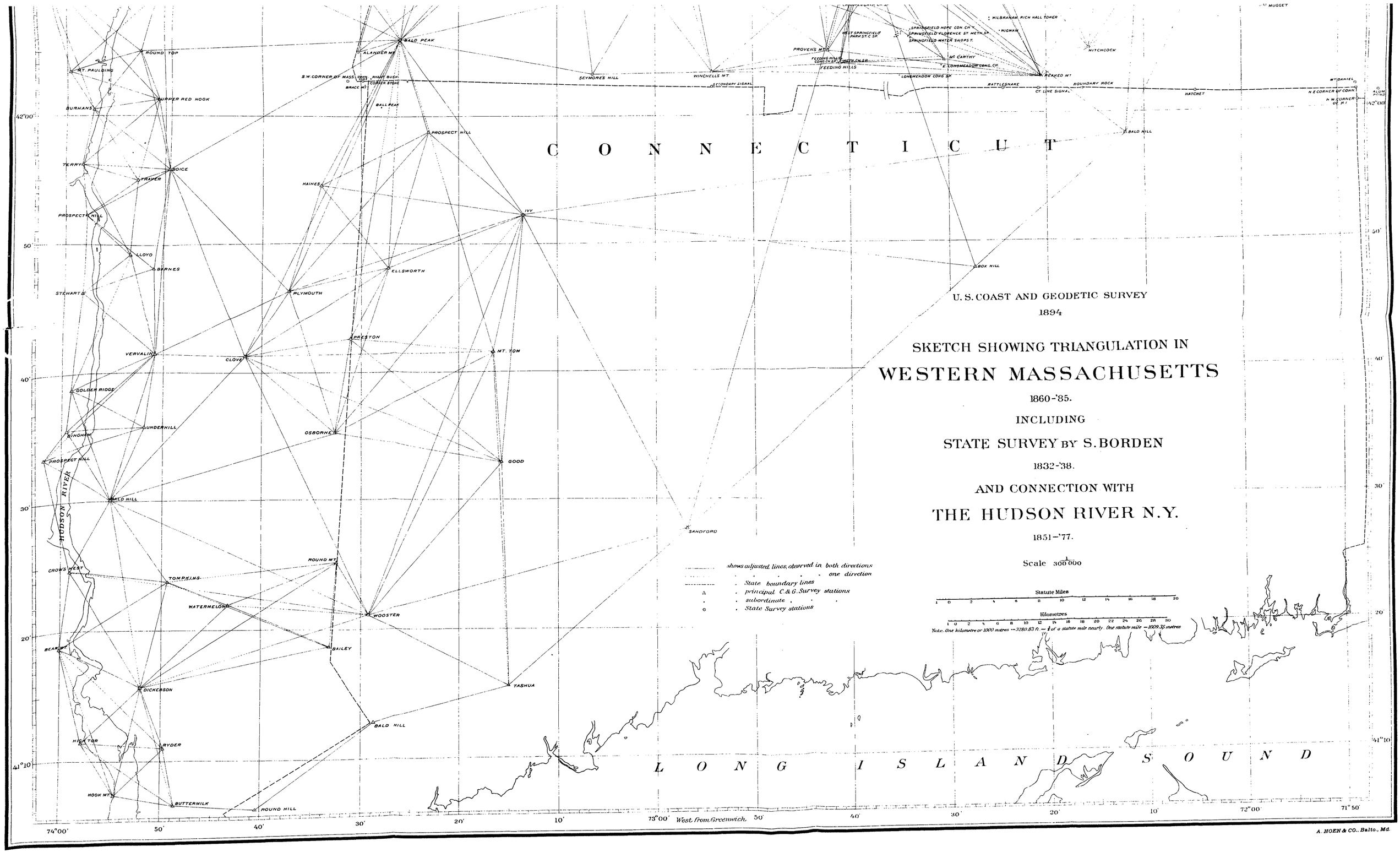
71° 30' 25' 20' 15' 10' 05' 71° 00' 55' 50' 70° 45' 70° 40' 35'

42° 10' 05' 42° 00' 41° 55' 50' 41° 45' 40' 41° 35' 30' 41° 25' 20' 41° 15'

BEACONPOLE (S. 34°)
FOXBORO CONG. CH.
MASS. N. BASE
N. EASTON H.W.
N. EASTON HIGH SCH.
BEACONPOLE
BED BRUSH
MANSFIELD CONG. CH.
MANSFIELD UNIT. CH.
N. ATTLEBORO H.W.
NORTON CONG. CH.
KOPPIN HILL
BEAR HILL
ATTLEBORO GRAM. SCH.
MASS. S. BASE
VER. N. BASE
PAWTUCKET W.W.
GREAT MEADOW
COLLEGE HILL
SPENCER
WHITMAN
MT. HOPE 1 & 2
POCASSET
WICKFORD
QUAKER
NOOTAS
MT. SPARRAN 1 & 2
EAST ROCK
BEAVERTAIL L.H.
BROCKTON CONG. CH.
ABINGTON W.W.
ROCKLAND CONG. CH.
HANOVER CENTER CONG. CH.
CAROLINA HILL
S. WEYMOUTH UNIT. CH.
PROSP. HINGHAM MT. HOPE
SCITUATE ORTH. CH.
SCITUATE L.H.
BRIDGEWATER UNIT. CH.
COHASSET METH. CH.
HAMPTON CH.
SPRAGUE'S BRIDGEWATER W.W.
BRIDGEWATER CONG. CH.
SCITLAND CONG. CH.
HALIFAX CONG. CH.
KINGSTON UNIT. CH.
DUXBURY PIER L.H.
PLYMOUTH PIER HD.
PLYMPTON CONG. CH.
MONKS HILL
EEL RIVER CH.
MANOMET
PROSPECT TAUNTON
TAUNTON UNS. ASY.
COPECUT
MIDDLEBORO T.H.
ALDEN
ROCKY WOODS
PASTURE
DUXBURY
STANDISH MON.
GURNET N. L.H.
GURNET
BRANT
PEMBROKE UNIT. CH.
W. DUXBURY METH. CH.
BRIDGEWATER W.W.
TAUNTON CONG. CH.
MIDDLEBORO CONG. CH.
WAREHAM CONG. CH.
BORDEN
HUBBARDS BARN
SWIFTS BARN
BRALEY'S BARN
ROCHESTER CONG. CH.
PERRY HILL CH.
MENDAL
PAUNCE
ACUSHNET CONG. CH.
NEW BEDFORD CH.
NEW BEDFORD H.W.
NEW BEDFORD SCH.
ROGERS SCH.
PALMER I.D.L.H.
QUANDS
CLARK PT. L.H.
SCONTICUT NECK
DARTMOUTH
NEW FALMOUTH
FALMOUTH
FALMOUTH CONG. CH.
WOODS HOLE
WOODS HOLE L.H.
NOBSKA PT. L.H.
DUMPLING RK. L.H.
NASHAWENA
CUTTYHUNK
CUTTYHUNK L.H.
INDIAN
GAY HEAD I & 2
GAY HEAD L.H.
MENEMSHA
MENEMSHA BIGHT
PROSPECT CHILMARK
TILTON
LOOKOUT PST.
LOBSTERVILLE PST.
PEAKED HILL
HANCOCK
WEQUOBOSA
NASHAQUITSA CLIFF
MAYHEW'S HD.
GAY HEAD
MOTEL PST.
BARKER'S HD.
MOLASHA HILL 2
MOLASHA HILL
GAY HD. BAPT. CH.
NO MANS LAND
NO MANS LAND L.H.
NO MANS LAND E.
NO MANS LAND I & 2
NO MANS LAND P.O.

PHOTO LITH. BY A. HOEN & CO. BALTIMORE, MD.


West from Greenwich
74°00'
50'
40'
30'
20
10'
73°00'
50'
40'
30'
20
10'
72°00'
71°50'
43°00'
42°00'
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
NEW YORK
CONNECTICUT
MT. EQUINOX
GREENWICH
MT. RAFINESQUE
LANSING
TROY UNIVERSITY
VAN AERNAM
BLOOMINGDALE 2
FERRIS
FORBES
BLOOMINGDALE
BURRILL
ALBANY
CATHEDRAL
HELDERBERG
RYESDORPH
HALLENBECK
THORPE
BLODGET
TRAVER
YELLOW PINE
STANTON
POWELL
MERWIN
MT. MERINO
CATSKILL
BLUE HILL
ROUND TOP
MT. PAULDING
UPPER RED HOOK
BURHANS
TERRY
BOICE
TRAVER
N.W. CORNER OF MASS
CLARKSBURG
WILLIAMSTOWN CONG. CH.
BERLIN MT.
SPRUCE HILL
GREYLOCK OR SADDLE MT. & SADDLE MT. BORDEN
JILSON
LEYDEN & GUILFORD
WARWICK
MT. GRACE
WATATICK
WALNUT HILL
BEAR MT.
MONADNOCK
TO UNKONOONUC
WACHUSETT
HAWE'S HILL
PACKARD
SHUTESBURY
MORE'S HILL
HIGH RIDGE
MT. ESTHER
DICKINSON
PELHAM
MT. LINCOLN
SHINGLE HILL
HATTLECOCK
HILLIARD'S KNOB
NEW BRAINTREE CONG. CH. SP.
TUFT'S HILL
HASNEBUMSKIT
BELCHERTOWN HIGH SCH. TOW.
ROCK RIMMON
COLONEL'S MT.
FACING ROCK
MT. TOM
CRAFTS
WHITE FLAG IN TREE
LUDLOW CONG. CH. SP.
THREE RIVER F. CATH. SP.
DUMPLING
PALMER UNIT SP.
FISH ROCK
CHICOPEE FALLS CATH. CH. SP.
JENKSVILLE CH. T. 2
BRUSH
CHICOPEE TOWN HALL SP.
CHICOPEE CATH. CH. SP.
WILBRAHAM RICH HALL TOWER
WIGWAM
MUGGET
HITCHCOCK
PROVEN'S MT.
FEEDING HILLS
McCARTHY
E. LONGMEADOW CONG. CH.
LONGMEADOW CONG. SP.
PEAKED MT.
RATTLESNAKE
CT. LINE SIGNAL
BOUNDARY ROCK
HATCHET
MT. DANIEL
N.E. CORNER OF CONN.
N.W. CORNER OF R.I.
BALD HILL
PITTSFIELD FIRST CONG. CH.
PERRY'S PEAK
FRENCH'S HILL
WASHINGTON SPIRE
BECKET
DUG HILL
JACKSON'S HILL
BALD PEAK
ALANDER MT.
S.W. CORNER OF MASS.
BRACE MT.
BALL PEAK
SEYMORE'S HILL
WINCHELL'S MT.
SECONDARY SIGNAL
PROSPECT HILL
HAINES


U. S. COAST AND GEODETIC SURVEY
1894
SKETCH SHOWING TRIANGULATION IN
WESTERN MASSACHUSETTS
1860-'85.
INCLUDING
STATE SURVEY BY S. BORDEN
1832-'38.
AND CONNECTION WITH
THE HUDSON RIVER N.Y.
1851-'77.
Scale 1/300 000
shows adjusted lines, observed in both directions
one direction
State boundary lines
principal C. & G. Survey stations
subordinate
State Survey stations
Statute Miles
Kilometres
Note. One kilometre or 1000 metres = 3280.83 ft. = 1/4 of a statute mile nearly. One statute mile = 1609.35 metres
C O N N E C T I C U T
L O N G I S L A N D S O U N D
HUDSON RIVER
West from Greenwich
A. HOEN & CO., Balto., Md.