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INTERNATIONAL POLAR EXPEDITION.

REPORT

ON THE

PROCEEDINGS OF THE UNITED STATES EXPEDITION

TO

LADY FRANKLIN BAY, GRINNELL LAND,

BY

ADOLPHUS W. GREELY,
FIRST LIEUTENANT, FIFTH CAVALRY, ACTING SIGNAL OFFICER AND ASSISTANT, COMMANDING THE EXPEDITION.

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PENDULUM OBSERVATIONS.

APPENDIX 141.

A pendulum furnished by the U. S. Coast and Geodetic Survey was swung forty-eight times under favorable conditions, as regards equable temperature, and corresponding sets of time observations were made.

Detailed information on this point has been given the Coast Survey, to which office these observations were sent September 24, 1886.

A. W. G.

PENDULUM OBSERVATIONS.

Report by C. S. PEIRCE.

In 1881 the Chief Signal Officer applied to the Superintendent of the Coast and Geodetic Survey for pendulum apparatus, instructions, etc., to enable Lieutenant Greely to determine the acceleration of gravity at Lady Franklin Bay. Mr. Carlisle P. Patterson, then Superintendent of the Survey, was a man of high intelligence, and though he did not class himself among scientific men, yet had for so many years conducted investigations in association with them that he understood most of the conditions of success in scientific work. He at once put me into personal communication with Lieutenant Greely, and instructed me to do what was necessary to further the end in view, without hampering the business by requiring the observance of intricate forms. We were just then commencing the construction of the series of Peirce pendulums. These instruments will be elsewhere described, and it is only necessary to say here that they are invariable reversible pendulums of nearly cylindrical contour, so that the effects of viscosity can be theoretically ascertained.

It was agreed that Lieutenant Greely should take with him No. 1 of this series of pendulums, and that he should send me one of his companions, Mr. E. Israel, to be instructed in the use of the instrument. Very little time remained, however, after the completion of the pendulum before it was necessary to pack it up for transportation. The preliminary operations in Washington were therefore somewhat hurried. Eight swingings of the pendulum were made in room No. 6, in the basement of the Coast Survey building. This station had never been used before, and I unhappily found out, too late, that the sandstone piers had the peculiarity of bending back and forth by a considerable amount under the oscillating pendulum, without elastic restoration. Accordingly, it became of the very highest moment for the success of the whole work that these piers, or rather the entire dolmen, should be preserved intact, so that the pendulum could be again swung on the same support after its return. Unfortunately, while I was afterwards in the field, a naval officer was permitted to remove the stone capping the piers, to carry with him to South America, in order, apparently, to save the trouble of cutting a hole in a plank. The result is that these preliminary swingings must be regarded as of no value. The position of the center of mass of the pendulum was determined by me before it was sent out; and the distance between the knife-edges was carefully compared with the German normal meter, No. 49, to which I have referred the lengths of all the reversible pendulums used by me.

The pendulum was finally placed in a wooden box having holes bored in it in such a way as to permit air to be blown through it and through the hollow stem of the pendulum; and a current of air, thoroughly dried with chloride of calcium, was passed for a long time through the box, which was then stoppered, placed in a tin case, and soldered up. The object of this proceeding was to prevent the pendulum being found covered with frost when wanted for use in its arctic destination. Then

the pendulum was carried to Fort Conger, by far the most northerly station which ever has been or is ever likely to be occupied for exact scientific observations, and it was there swung on sixteen days by Lieutenant Greely, aided by Mr. Israel, with a remarkable degree of skill and energy.

The directions accompanying the instrument were that the pendulum should be swung on eight days, once each day with heavy end down and twice with heavy end up, the one swinging in the former position being intermediate in time between the two in the latter. After these eight days' swingings the knives were to be removed and interchanged, and eight days more work was to be done in the same manner in the new position of the knives. This programme was faithfully carried out; but after the interchange of knives the periods of oscillation show a large change, and this is of such a character as not to be eliminated by the formula for the reversible pendulum. This seems to have been due to a difference in the cylindricity of the edges, combined with the effect of some accident to the pendulum. The result is that only the observations made after the interchange of knives can be used.

On the abandonment of Fort Conger the head upon which the pendulum had been supported in its oscillations (the bearings of the knife-edges forming a part of it) was left behind; but the pendulum itself was courageously brought away and carried down to the camp, from which the survivors of the party, of whom the lamented Israel was not one, were rescued. It seems almost inconceivable that any instrument could have gone through that terrible journey over ice hummocks, etc., intact. The chronometer brought back at the same time arrived almost smashed to pieces. Nevertheless, a remeasurement of the pendulum after its return to Washington shows that it had only undergone an increase of $\frac{1}{30000}$, a change which might almost be expected without any special accident: namely, in June, 1881, the pendulum was found 397.2 microns longer than Meter 49, and in December, 1884, it was found 429.3 microns longer, both at 20° C. The pendulum was oscillated at the Smithsonian Institution, and, using the formula for the reversible pendulum, these experiments give a value for gravity at that station agreeing closely with that given by our best pendulum, Peirce No. 2, and in accordance with other results: namely, the period of oscillation of a meter pendulum (subject to some small corrections) was, according to No. 1, 1.0063191^s, while according to No. 2 it was 1.0063186^s. This shows that the knives of Pendulum No. 1 never underwent any permanent damage.

But, though there was so little change in the length of the pendulum, there is evidence that it lost a large part of its mass. In 1881 illness prevented my weighing the pendulum myself, and it was not weighed at all in its finished state. But my assistant reported that while still symmetrical, and after having been polished, its mass was 6477 grams, that the added load was 3985 grams, and that in the adjustment 4.6 grams were deducted, so that its total mass must have been 10457 grams. My experience in the construction of other pendulums shows that the mass so calculated was probably in excess by 5 or 10 grams, owing to the operation of polishing. But the pendulum now weighs only 10436 grams, so that it would seem to have lost from 10 to 15 grams, probably on the journey from Fort Conger to Camp Clay. The center of mass, too, was apparently moved 0.32 millimeter toward the center of figure. Namely, I found in 1881 that the distance from the center of mass to the nearest knife-edge was 25.105 centimeters, while Mr. Farquhar now finds that with the same arrangement of the knives the same distance is 25.137 centimeters; yet as economical considerations have always prevented our expending the sum of $50 required for a suitable instrument to measure this quantity, I should not think these measures by themselves conclusively proved a change. This, however, is not all. The excess of the period of oscillation with the heavy end down over that with the heavy end up, corrected for flexure and brought to the standard pressure and temperature (one absolute atmosphere and 15° C.), was $+0.0006514^s$, while the corresponding difference at Washington, after the return, was found to be $+0.0007009^s$. The difference between these corrected for difference of gravity is $+0.0000494^s$. This result, not depending upon the coefficient of expansion, is probably nearly correct. But there is an equation to be satisfied between the loss of weight, the shifting of the center of mass, and the change of period. Moreover, any two of these quantities determine the point (supposed on the axis of the pendulum) where the loss took place; and the question arises whether this was a point at which such a loss could take place. Now, there are but three points where the loss was possible. One of these is 3 centimeters outside of the knife-edge at the heavy end. If 12 grams were lost at that point the center of mass would be shifted by 0.32 millimeter, the amount observed; and the excess of the period with heavy end down over that with heavy end up would be increased by $+0.0000472^s$, or very nearly the amount observed. The agreement of these numbers tends to show that the alteration which the pendulum underwent during its homeward journey did not involve any difference in the distance between the knife-edges, so that the pendulum may still be treated as invariably reversible, though not as two invariable pendulums.

Having thus narrated the history of the instrument, I proceed to consider the difficulties of deducing any result from the observations. The atmospheric pressure at Fort Conger exhibits no great range, and does not differ much from that at Washington, so that the small corrections can be satisfactorily calculated from theory. The [illegible] otherwise with the temperature corrections. The difference of temperature between the two stations was ab[illegible]ld make so much difference in the effect of the atmosphere as to involve it in some doubt. Still, as [illegible] the [illegible] treated as reversible, but not as invariable, except as to the distance between the knife-edges (a [illegible] circumstances just narrated), this is a matter of little consequence.

The coefficient of expansion of this pendulum, and of another, Peirce No. 4, constructed of brass purchased at the same time as the material of No. 1, was determined by comparisons of those pendulums with a meter marked U. S. C. S.—C. S. P.—1878—B., at different temperatures. This bar was made at the same time as and is in every respect a match with the meter A, whose coefficient of expansion was carefully determined by me and published in my Measurements of Gravity at Initial Stations.* This meter B has a series of different lines at one end. The mean of ten skillful comparisons by Mr. D. C. Chapman, on five days of December, 1884, between pendulum No. 1, and meter B, taken at its outer line, makes the pendulum longer by $+251.6^{\mu} \pm 0.3^{\mu}$ at 18.46°; and the mean of five comparisons on two days by the same observer during the same month makes the same excess $242.7^{\mu} \pm 0.1^{\mu}$ at 30.99° C. The expansion of the pendulum was, according to these measures, 0.71^{μ} less than that of the meter per degree. Six comparisons of pendulum Peirce No. 4 with the same meter at the third line from the end, made in the previous October, on three days, make the excess of the pendulum $-0.9^{\mu} \pm 0.3^{\mu}$ at 16.83°, and six comparisons on four days in the same month, all by the same excellent observer, make the excess $-6.5^{\mu} \pm 0.4^{\mu}$ at 25.42°. This gives for the excess of the expansion per degree centigrade of the pendulum over meter B, -0.65^{μ}; but I prefer to use the comparisons of Pendulum No. 1; and since the coefficient of meter A was found to be 18.95^{μ} we assume 18.24^{μ} for the pendulum. At an extremely low temperature this coefficient would, of course, be smaller. The coefficient 18.24^{μ} is for the temperature of 24.6° C. Now, Fizeau (*Comptes rendus*, LXVIII, p. 1125) examined a specimen of brass whose coefficient of expansion at 24.6° C. was 18.28 millionths; and this coefficient was found to increase 1.96 millionths per 100° C. of elevation of temperature. As the first coefficient was so nearly the same as that of Pendulum No. 1, we may assume that the second would be so, too. The observations at Fort Conger after the interchange of the knives were at a mean temperature of −30.4° C. To reduce them to +15° C. we must use the coefficient for −7.7° C., and since this is 32.3° below the temperature for which the coefficient was observed, we calculate the coefficient to be used as follows:

Coefficient of expansion at 24.6° = 18.24 microns per degree C.
Correction to −7.7° C. = 1.96 × .323 = .63
∴ Coefficient of expansion at −7.7° C. = 17.61

Experiments at different stations, especially in Washington and in Ithaca, show, however, conclusively, that while the effects of temperature calculated from the expansion and the atmospheric theory answer well enough for heavy end up (in which position the atmospheric effects, being three times as great as with heavy end down, greatly reduce the effect of expansion), yet with heavy end down the effect of temperature on the period is much larger in fact than the theory indicates. Similar phenomena have presented themselves to many experimenters; and the later Repsold pendulums may be said to be almost exceptional in not showing anything of the sort to any marked extent. The cause of the phenomenon can only be surmised. In order to determine the proper value of the expansion to be used in reducing the periods it would be necessary to leave a pendulum support undisturbed for six months and re-occupy the same station at the end of that time; and in order to understand the effect sufficiently to allow for it with certainty it should be studied through a large range of temperature. For this purpose a station like Minneapolis should be chosen. But in the present state of our knowledge, and in a case like this, the expansion deduced from linear measures must be used.

Elaborate observations upon the descent of the arc were made by Mr. Israel, and these have been reduced by Mr. H. Farquhar, of the Coast and Geodetic Survey, according to the method given in my "Measurements of Gravity at Initial Stations," with some improvements in detail. In the following tables these observations with the reductions are first given, and are followed by the observations of periods, and then by the measure of flexure. In these Mr. Israel says he used "the weight of 2.5 pounds;" but I think that this must have been the weight which in the Coast Survey Report for 1881, p. 377, is said to weigh 1.0818k = 2.38 lb., and I have so treated it in the reductions.

*U. S. Coast Survey Report for 1876, Appendix 15.

Decrement of arc.—Observed $D_\phi t$ in swings with heavy end up.

φ	1		3		4		6		7		9		10		13		16		18		19	
.030	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.
.029	---	---	---	---	---	---	1.0	1.1	---	---	---	1.5	---	---	---	---	---	---	---	---	---	---
.028	---	---	---	---	---	---	1.0	1.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.027	---	---	---	---	---	---	---	1.3	1.3	1.1	---	---	---	---	---	---	---	---	---	---	.9	1.0
.026	---	---	---	---	---	---	---	---	1.1	1.0	---	---	---	---	---	---	---	---	---	---	---	---
.025	---	---	---	---	1.0	---	---	---	.9	.9	---	---	---	---	---	---	---	---	.9	---	---	---
.024	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.023	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.022	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.021	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.020	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.5	---	---	---
.019	---	---	---	1.9	---	---	1.1	1.0	1.5	1.5	1.7	---	---	---	---	---	---	---	1.3	1.3	---	---
.018	---	---	1.2	1.3	---	---	1.6	1.6	1.6	1.6	2.1	2.2	1.3	---	---	---	---	2.0	2.0	1.7	1.7	1.8
.017	---	---	1.7	1.7	1.5	---	1.5	1.9	1.8	1.7	2.5	1.8	2.1	1.9	---	1.9	1.8	2.0	2.0	1.8	1.8	1.8
.016	---	---	1.7	1.9	1.7	---	2.3	1.5	1.7	1.7	2.0	2.2	1.8	1.8	---	2.2	1.9	1.9	1.9	1.8	1.7	2.0
.015	---	---	2.0	2.2	1.8	1.3	2.1	2.2	2.0	2.1	2.1	2.0	2.1	2.1	---	2.5	2.1	2.1	2.0	2.1	1.9	2.0
.014	---	---	2.4	2.6	2.5	2.2	2.0	1.9	2.1	2.0	1.9	2.0	2.1	2.0	2.0	2.3	2.1	2.1	2.5	2.1	2.3	2.5
.013	---	---	2.4	2.2	2.1	2.0	2.5	2.2	2.3	2.6	2.3	1.9	2.2	2.1	2.3	2.7	2.4	2.5	2.4	2.2	2.6	2.5
.012	---	---	2.1	2.2	2.7	2.0	2.7	2.7	2.6	2.7	2.5	2.3	2.8	2.7	2.2	2.7	2.3	2.4	2.8	2.8	2.6	3.1
.011	---	3.3	2.5	3.0	2.8	2.2	3.2	2.9	2.8	2.9	3.2	2.6	3.1	3.0	2.3	3.2	3.1	3.1	3.5	3.2	2.9	3.2
.010	2.7	2.8	3.7	3.2	3.3	3.4	3.9	3.9	2.9	2.8	3.5	3.4	3.1	3.0	2.5	4.0	3.2	3.4	3.6	3.2	3.0	3.1
.009	2.7	3.0	3.7	3.9	3.4	3.2	3.5	3.4	3.6	3.9	4.1	3.5	3.7	3.3	2.8	4.9	3.9	3.8	3.6	3.8	3.2	3.7
.008	3.7	3.8	3.6	4.1	4.4	3.9	4.4	4.0	4.1	4.2	4.9	3.9	3.9	3.6	3.6	5.3	4.7	4.0	4.1	4.1	4.1	5.2
.007	4.2	4.8	4.5	4.9	5.1	4.2	4.9	4.2	4.5	5.0	4.9	5.0	4.5	4.1	4.5	5.6	5.1	4.9	5.0	4.2	4.8	4.7
.006	5.0	4.8	5.3	4.7	5.2	4.2	5.2	5.4	5.2	5.6	5.7	5.1	5.5	5.4	4.7	7.0	5.0	5.7	5.9	5.5	4.9	6.4
.005	4.9	5.8	[5.3]	---	5.8	5.7	6.6	5.6	[6.4]	---	5.8	5.6	---	[7.1]	[5.2]	---	[5.9]	---	---	[6.3]	6.3	7.1
.004	[7.8]	[7.8]	[7.7]	---	---	---	[6.9]	---	[6.3]	---	---	---	---	---	---	---	[6.5]	---	---	[7.0]	---	---

φ	21		22		23		28		31		33		36		39		43		46	
.030	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.
.029	---	---	---	---	---	---	.9	.9	---	---	---	---	.9	---	---	---	---	---	---	---
.028	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.027	---	---	---	---	---	---	---	---	---	---	---	.8	---	---	---	---	---	---	---	---
.026	---	---	---	---	---	---	1.2	1.0	---	---	---	---	---	---	---	---	---	---	---	---
.025	---	---	---	---	---	---	[illegible]	.8	---	1.0	---	---	---	---	---	---	---	---	---	---
.024	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.023	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.022	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.021	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.020	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.019	1.6	1.5	2.0	---	---	1.7	---	---	---	---	1.8	---	---	---	---	1.5	---	---	---	---
.018	1.4	1.6	---	2.0	1.5	1.6	1.5	1.9	---	---	1.7	---	---	---	1.6	2.1	---	---	1.7	---
.017	1.6	1.7	---	---	1.6	1.8	1.9	1.7	---	---	1.9	1.7	---	---	2.1	1.8	---	1.6	---	1.9
.016	1.9	1.8	---	---	1.7	1.9	1.6	1.8	---	---	2.0	1.9	---	---	1.8	2.2	1.9	1.9	---	---
.015	2.0	2.0	---	---	2.0	2.1	1.8	2.1	---	---	2.3	2.0	---	---	2.0	2.2	1.9	2.2	---	---
.014	2.0	2.3	2.0	2.5	2.3	2.2	2.1	2.1	---	---	2.3	2.1	---	---	2.1	2.6	2.0	2.2	---	---
.013	2.2	2.6	2.2	2.1	2.4	2.5	2.1	2.4	---	---	2.6	2.3	---	---	2.5	2.3	2.4	2.4	2.4	---
.012	2.7	2.5	2.8	2.4	2.9	2.8	2.5	2.9	2.7	2.7	2.8	2.6	---	---	2.3	2.8	2.5	2.8	3.1	3.1
.011	2.9	2.6	3.6	2.9	3.1	3.1	2.9	3.0	2.8	3.0	3.6	2.9	---	---	2.5	3.2	3.0	2.9	3.2	2.7
.010	3.1	3.1	3.4	3.4	3.0	3.8	2.9	3.2	3.1	3.5	3.7	3.1	---	3.8	3.3	4.0	2.9	3.3	3.2	3.2
.009	3.7	3.5	4.4	3.5	3.6	4.0	2.3	3.9	3.4	3.7	4.3	3.6	---	4.7	3.8	4.3	3.3	3.5	3.9	3.8
.008	3.5	4.2	4.5	4.5	3.9	4.2	3.8	4.1	3.7	4.2	4.5	3.4	---	5.2	4.0	4.9	3.6	4.5	4.5	4.6
.007	3.9	5.3	5.3	4.6	4.2	4.8	4.5	5.1	4.3	5.1	5.4	4.3	3.5	---	4.5	4.8	4.6	4.5	4.5	4.3
.006	5.1	5.3	5.5	5.1	5.0	5.8	4.8	5.8	5.1	5.8	---	5.4	4.1	---	4.8	6.3	5.0	5.2	6.1	5.5
.005	[5.7]	---	6.4	5.7	6.2	6.7	5.9	6.8	6.4	6.9	---	[5.8]	[5.1]	---	[5.6]	---	5.3	7.0	---	[5.9]
.004	[6.2]	---	---	---	---	---	---	---	---	---	---	[6.1]	[5.2]	---	[7.4]	---	---	---	---	[8.4]

NOTE.—The notation is that of "Measurements of Gravity at Initial Stations."

Observed D_ϕ t in swings with heavy end down.

ϕ	2		5		8		11		17		23		38		41		44	
	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.
.030	3.0	----	----	----	----	1.6	----	2.5	2.3	2.3	----	2.4	----	2.0	----	----	----	----
.029	3.0	----	2.8	----	----	2.3	2.1	2.7	2.4	2.3	2.6	2.5	2.2	2.5	----	----	----	----
.028	3.1	----	2.2	1.9	2.1	3.0	2.7	2.5	2.5	2.7	2.2	2.6	2.7	2.7	----	----	1.8	----
.027	3.1	3.0	3.2	3.5	3.0	3.3	3.0	2.7	2.7	3.1	2.8	2.6	2.9	3.3	----	----	3.1	2.3
.026	----	2.9	3.5	3.4	3.5	----	2.5	2.8	2.7	----	3.0	3.1	3.3	2.9	----	----	2.4	3.0
.025	----	3.2	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
.024	----	----	----	----	----	3.3	----	----	----	----	----	----	----	----	----	----	----	----
.023	4.0	----	3.7	3.3	2.9	2.8	2.5	2.4	3.9	3.6	3.3	3.3	----	3.6	----	----	----	----
.022	4.4	3.8	3.2	3.4	3.3	4.5	2.9	3.4	3.8	3.8	3.5	3.9	3.8	3.6	----	----	4.3	3.8
.021	3.7	4.1	4.0	3.8	4.1	4.7	4.4	4.5	3.9	4.6	4.1	4.1	3.8	4.4	4.1	----	3.9	4.0
.020	4.4	3.7	4.0	3.9	5.0	5.0	4.3	5.3	4.5	4.6	4.2	4.0	4.3	5.6	3.9	3.5	3.9	4.2
.019	4.5	4.3	5.0	5.1	4.9	5.3	5.8	4.6	4.4	5.2	4.2	4.4	5.5	5.1	4.8	3.9	4.1	4.1
.018	4.7	4.7	4.9	4.7	5.1	5.1	4.0	4.1	5.5	6.2	4.6	4.8	5.3	5.9	5.2	5.4	4.1	4.9
.017	5.5	4.7	5.1	4.7	5.1	5.1	4.9	6.1	6.1	5.1	5.0	5.1	6.0	6.2	4.9	4.9	5.1	6.0
.016	4.6	5.5	5.4	5.0	5.2	6.5	5.1	6.1	5.1	6.0	5.4	5.7	6.3	6.1	5.1	5.8	6.2	6.3
.015	5.9	4.5	5.5	6.2	6.5	6.1	6.0	5.7	5.8	7.3	5.9	6.1	6.1	6.1	5.7	5.6	6.4	6.8
.014	8.2	6.2	8.7	6.5	6.3	8.1	6.9	7.0	7.6	7.0	6.3	6.6	6.6	7.3	6.0	5.9	7.0	7.7
.013	6.9	8.0	7.8	8.3	7.9	7.8	6.3	7.7	6.7	7.9	8.6	8.5	7.0	7.5	6.1	6.0	7.5	7.8
.012	8.1	7.0	8.5	9.1	7.7	9.0	9.0	9.1	7.8	9.3	8.7	8.6	9.0	9.1	7.5	7.1	7.7	8.4
.011	9.6	9.1	8.2	9.3	9.1	9.8	8.9	10.0	9.9	10.3	9.5	9.4	9.1	10.6	8.3	7.9	8.4	8.8
.010	11.0	10.1	10.9	10.1	9.9	11.7	10.3	11.1	9.8	11.1	10.5	12.5	9.5	12.0	9.4	8.7	9.0	10.6
.009	11.9	11.4	10.6	11.1	11.5	12.1	11.4	11.8	11.2	13.1	11.7	12.6	12.5	11.8	10.4	10.0	11.1	11.6
.008	12.5	11.7	11.8	11.3	12.4	14.4	12.2	13.8	13.9	13.8	11.6	12.4	11.7	14.7	12.5	12.5	12.6	13.9
.007	15.9	13.8	14.7	13.7	14.4	15.0	14.8	15.1	12.9	14.2	13.4	16.5	14.8	15.9	13.7	12.7	14.1	15.3
.006	23.4	16.3	18.8	16.3	15.0	17.7	17.4	21.2	14.1	17.0	17.3	21.4	16.7	20.3	16.7	15.6	15.1	17.6
.005																		

Calculation of time of infinite arc from approximate $\frac{1}{b}$.

ϕ	(1) 10^h		(2) 11^h		(3) 4^h		(4) 9^h		(5) 10^h		(6) 3^h		(7) 9^h		(8) 9^h	
	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.
.030	----	53.7	60.5	----	----	42.0	----	----	----	19.2	26.1	25.4	----	20.2	44.1	46.8
.029	----	----	61.1	----	42.1	----	----	----	19.1	----	26.3	25.7	----	----	----	46.0
.028	----	----	61.5	----	----	42.2	----	----	19.3	18.4	26.4	25.8	19.2	20.0	44.1	45.7
.027	53.1	----	61.8	55.2	42.1	----	----	----	18.7	17.5	----	26.1	19.5	20.1	43.4	45.9
.026	----	53.5	62.1	55.4	----	42.1	39.7	38.5	19.1	18.2	26.0	----	19.6	20.1	43.6	46.4
.025	53.0	----	----	55.2	41.9	----	39.7	----	19.5	18.5	----	26.2	19.5	20.0	44.0	----
.024	----	----	----	55.3	----	----	----	----	----	----	----	----	----	----	----	46.1
.023	----	----	59.3	----	----	----	----	----	19.3	18.5	----	----	----	----	43.4	46.0
.022	----	----	59.7	56.6	----	----	----	----	19.4	18.2	----	----	----	----	42.7	45.2
.021	----	----	60.4	56.7	----	----	----	----	18.9	17.9	----	----	----	----	42.3	46.0
.020	----	52.8	60.1	56.8	----	41.9	39.1	----	18.9	17.7	25.9	25.3	18.6	19.6	42.4	46.7
.019	52.5	----	60.2	56.2	41.7	42.4	----	----	18.6	17.3	25.6	24.9	18.7	19.7	43.1	47.4
.018	----	52.8	60.2	56.0	41.3	42.1	39.6	37.4	19.1	17.9	25.6	24.9	18.7	19.7	43.5	48.2
.017	52.3	----	60.0	55.8	41.3	42.1	39.4	----	19.1	17.7	25.4	25.1	18.8	19.7	43.7	48.4
.016	----	52.7	60.2	55.2	41.1	42.1	39.2	36.8	18.9	17.1	25.8	24.7	18.6	19.5	43.5	48.2
.015	52.1	----	59.2	55.1	41.2	42.4	39.1	36.2	18.7	16.5	26.0	25.0	18.7	19.7	43.1	49.1
.014	----	52.6	58.9	53.4	41.4	42.8	39.4	36.2	18.0	16.5	25.8	24.7	18.6	19.5	43.4	49.0
.013	51.7	----	60.5	53.0	41.5	42.7	39.2	35.9	20.1	16.4	26.0	24.6	18.6	19.8	43.1	50.5
.012	----	52.6	60.0	53.6	41.1	42.4	39.4	35.4	20.5	17.3	26.2	24.8	18.7	20.0	44.6	50.9
.011	52.5	53.0	60.0	52.5	40.7	42.5	39.3	34.7	20.9	18.3	26.5	24.8	18.6	20.0	43.2	51.8
.010	52.1	52.7	60.6	52.6	41.3	42.6	39.5	35.0	20.1	18.6	27.3	25.6	18.4	19.7	43.3	52.6
.009	51.3	52.2	61.6	52.7	41.5	43.0	39.4	34.7	21.0	18.7	27.3	25.5	18.5	20.1	43.2	54.3
.008	51.0	52.0	62.0	52.6	41.1	43.1	39.8	34.6	20.1	18.3	27.7	25.5	18.6	20.3	43.2	54.9
.007	50.6	52.2	61.3	51.1	41.0	43.4	40.3	34.2	18.7	16.4	28.0	25.1	18.5	20.7	42.4	56.1
.006	50.2	51.6	61.7	49.4	40.9	43.7	40.1	33.0	17.9	14.6	27.8	25.1	18.3	20.9	41.3	55.6
.005	48.6	50.9	66.5	47.1	39.7	----	39.4	32.2	18.1	12.3	27.9	24.2	18.2	----	37.7	54.7
.004	48.4	50.7	----	----	39.4	----	----	----	----	----	26.8	----	16.5	----	----	----
.003	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Summary. .0280	53.1	53.6	61.2	55.2	42.0	42.1	39.7	38.5	19.1	18.4	26.2	25.8	19.5	20.1	43.8	46.1
.0148	52.2	52.7	59.9	54.7	41.3	42.4	39.3	36.4	19.2	17.2	25.9	24.9	18.7	19.7	43.3	49.0
.0084	51.2	52.2	61.2	52.4	41.1	43.0	39.7	34.6	20.0	18.0	27.4	25.3	18.5	20.2	43.1	54.3
.0050	49.0	51.0	64.9	47.1	39.9	42.9	39.5	32.2	18.0	12.3	27.6	24.4	17.9	21.1	38.5	54.8

ϕ	(9) 2^h		(10) 9^h		(11) 9^h		(12) 1^h		(13) 11^h		(14) 10^h		(15) 3^h		(16) 10^h	
	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.
.030	9.7	8.8	----	28.4	----	49.8	----	----	----	34.6	104.7	107.7	----	55.2	35.1	----
.029	----	9.5	28.6	----	48.8	49.9	----	----	----	----	103.3	106.6	55.2	----	----	35.2
.028	----	----	----	----	48.3	50.0	----	----	----	34.5	101.8	105.4	----	----	35.2	----
.027	10.1	----	----	28.0	48.2	49.7	----	----	----	----	100.3	104.0	----	54.2	----	35.0
.026	----	----	28.5	----	48.4	49.6	----	----	31.9	34.0	99.2	102.4	53.9	----	35.0	----
.025	----	9.1	----	27.7	47.8	49.3	----	----	----	----	97.3	----	----	53.4	----	35.1
.024	----	----	----	----	----	----	----	----	31.0	----	95.6	----	----	----	----	----
.023	----	----	----	----	47.6	48.8	----	----	----	----	----	----	----	----	----	----
.022	----	----	----	----	46.5	47.6	----	----	----	----	----	----	----	----	----	----
.021	----	----	----	----	45.7	47.3	----	----	----	----	----	----	----	----	----	----
.020	9.4	----	----	----	46.1	47.8	----	----	----	----	87.5	92.0	----	----	34.8	----
.019	9.7	8.8	28.0	----	46.1	48.8	----	----	----	----	85.0	90.0	----	----	----	35.0
.018	10.2	9.4	27.7	27.0	47.4	48.9	----	----	----	33.6	82.5	88.2	----	49.4	34.9	35.4
.017	11.0	9.5	28.1	27.2	46.5	48.1	----	----	----	33.8	79.7	86.2	48.9	----	35.0	35.7
.016	11.1	9.8	28.0	27.1	46.1	48.9	----	----	----	34.1	77.3	83.7	----	47.8	35.0	35.7
.015	11.3	9.9	28.2	27.3	45.6	49.4	----	----	29.1	34.7	74.4	81.1	47.0	----	35.2	35.9
.014	11.0	9.7	28.1	27.1	45.4	48.9	68.8	----	28.9	34.8	71.1	78.3	----	45.6	35.1	35.8
.013	11.0	9.3	28.0	26.9	45.7	49.3	----	67.7	28.9	35.2	67.5	76.4	44.3	----	35.2	36.0
.012	11.0	9.1	28.3	27.1	44.6	49.6	66.5	----	28.6	35.4	63.4	72.6	----	42.6	35.0	35.9
.011	11.3	8.8	28.5	27.2	45.5	50.6	----	65.2	28.0	35.7	59.7	70.1	41.2	----	35.2	36.1
.010	11.7	9.1	28.5	27.1	45.4	51.6	64.5	----	27.4	36.6	54.1	67.0	39.5	39.1	35.3	36.4
.009	12.3	9.1	28.7	26.9	45.7	52.7	----	62.0	26.7	38.0	48.4	64.5	37.4	37.1	35.7	36.7
.008	12.2	9.0	28.6	26.5	45.6	53.0	60.5	----	26.3	39.3	42.0	63.4	34.8	34.5	35.4	36.7
.007	13.5	9.4	28.5	26.0	44.6	53.6	----	58.0	26.2	40.3	35.7	62.2	31.5	31.1	35.9	37.0
.006	13.8	9.1	28.6	26.0	43.9	53.2	55.8	57.1	25.5	41.9	29.1	63.3	27.6	27.3	35.5	37.3
.005	13.1	8.2	----	26.6	42.7	55.8	53.6	----	24.2	----	21.5	----	22.8	22.4	34.9	----
.004	----	----	----	----	----	----	51.6	----	----	----	12.7	----	----	----	33.4	----
.003	----	----	----	23.7	----	----	----	----	----	----	9.1	----	9.0	----	----	----
Summary. .0280	9.8	9.1	28.5	28.0	48.3	49.7	----	----	32.6	34.4	101.9	105.3	54.8	54.5	35.1	35.1
.0148	10.8	9.4	28.1	27.1	45.9	49.0	69.6	69.6	29.2	34.6	73.7	80.4	46.6	46.3	35.1	35.8
.0084	12.2	9.1	28.6	26.7	45.4	52.6	61.5	60.9	26.7	38.4	44.7	64.2	35.9	35.5	35.5	36.6
.0050	13.4	8.4	28.6	26.0	42.9	55.0	53.8	54.1	24.4	43.5	21.7	61.9	22.9	22.4	34.7	37.6

Calculation of time of infinite arc, etc.—Continued.

φ	(17) 10^h		(18) 3^h		(19) 11^h		(20) 11^h		(21) 4^h		(22) 11^h		(23) 0^h		(24) 4^h	
	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.
.030	50.2	51.7	24.7	----	----	38.2	54.3	----	40.4	----	----	----	----	4.9	----	34.1
.029	50.1	51.6	----	----	----	----	----	53.9	----	40.5	----	----	3.6	4.9	----	----
.028	49.9	51.3	24.9	24.0	37.6	38.2	53.6	----	40.3	----	----	----	3.6	4.8	----	34.1
.027	49.6	51.2	----	----	37.5	38.2	----	53.0	----	40.5	----	----	3.0	4.6	----	----
.026	49.5	51.5	25.0	23.9	----	----	52.9	----	40.0	----	----	----	3.0	4.4	32.9	34.0
.025	49.1	----	24.9	----	37.3	----	----	52.4	----	40.5	52.2	----	2.9	4.4	----	34.2
.024	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
.023	48.5	51.7	----	----	----	----	----	52.6	----	----	----	----	3.5	5.3	----	----
.022	48.8	51.7	----	----	----	----	52.4	----	----	----	----	----	3.2	5.0	----	----
.021	48.9	51.8	25.1	----	----	----	----	52.8	----	----	----	----	3.0	5.2	----	----
.020	48.8	52.4	25.2	24.1	----	----	52.3	----	39.6	40.5	51.9	----	3.1	5.3	----	----
.019	49.0	52.7	25.1	24.0	37.0	38.1	----	52.7	39.8	40.6	52.5	51.4	3.0	5.0	32.9	34.6
.018	48.9	53.4	25.5	24.1	37.1	38.3	52.5	----	39.6	40.6	----	51.8	2.7	4.9	----	----
.017	49.5	54.7	25.8	24.2	37.2	38.4	----	52.7	39.5	40.6	53.5	----	2.4	4.8	32.8	35.6
.016	50.3	54.5	25.8	24.1	37.0	38.5	52.5	----	39.5	40.5	----	----	2.1	4.6	----	----
.015	49.8	54.9	25.9	24.3	37.0	38.6	----	52.4	39.6	40.6	53.7	51.4	1.9	4.7	33.2	35.7
.014	49.4	56.0	26.2	24.2	37.1	38.9	51.9	----	39.4	40.7	53.5	51.7	1.6	4.6	----	----
.013	50.4	56.4	26.3	24.1	37.4	39.1	----	53.4	39.3	41.0	53.4	51.5	1.3	4.6	33.5	35.9
.012	49.7	56.9	26.6	24.4	37.5	39.7	54.7	----	39.5	41.0	53.7	51.4	2.5	5.7	----	----
.011	49.4	58.1	27.2	24.7	37.5	40.0	----	55.5	39.5	40.7	54.4	51.4	3.1	6.2	33.3	36.2
.010	50.3	59.4	27.7	24.8	37.4	40.0	55.7	----	39.5	40.7	54.7	51.7	3.6	6.6	----	----
.009	50.1	60.5	27.8	25.1	37.1	40.2	----	55.8	39.7	40.7	55.6	51.7	4.1	9.1	34.0	37.2
.008	49.8	62.1	27.9	25.2	37.2	41.4	54.6	----	39.2	40.9	56.1	52.2	4.3	10.2	----	----
.007	50.5	62.7	28.3	24.8	37.4	41.5	----	56.9	38.5	41.6	56.8	52.2	2.7	9.4	33.7	38.8
.006	47.9	61.4	28.8	24.9	36.9	42.5	54.0	----	38.2	41.5	56.9	51.9	0.6	10.4	----	----
.005	43.4	59.8	----	24.7	36.5	43.1	----	55.8	37.4	----	56.8	51.1	59.3	13.2	33.2	39.7
.004	----	----	----	23.7	----	----	50.4	----	35.6	----	----	----	----	----	----	----
.003	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Summary .0280	49.7	51.5	24.9	24.0	37.5	38.2	53.6	53.1	40.2	40.5	----	----	3.2	4.7	32.9	34.1
Summary .0148	49.5	55.0	26.0	24.2	37.2	38.7	53.0	52.9	39.5	40.7	53.4	51.5	2.4	5.0	33.1	35.7
Summary .0084	50.0	61.1	27.8	24.9	37.3	40.7	54.6	55.9	39.3	40.9	55.8	51.9	3.7	8.8	33.7	37.7
Summary .0050	43.8	59.9	29.1	24.5	36.5	43.2	52.4	56.2	37.2	41.5	56.9	51.3	59.0	12.8	33.2	39.7

φ	(25) 0^h		(26) 0^h		(27) 5^h		(28) 11^h		(29) 0^h		(30) 5^h		(31) 11^h		(32) 11^h	
	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.
.030	21.7	----	34.3	----	28.2	29.1	55.4	55.8	6.5	----	9.4	----	53.5	54.4	64.5	67.6
.029	----	22.3	----	----	----	----	55.5	55.9	----	6.6	----	9.7	----	----	----	----
.028	----	----	33.7	31.6	28.4	29.2	----	----	6.6	----	9.4	----	53.7	54.4	64.3	67.4
.027	21.7	22.7	----	----	----	----	55.1	55.8	----	6.1	----	9.4	----	----	----	----
.026	----	----	32.9	30.5	28.4	29.4	55.3	55.8	6.1	----	9.2	----	53.3	54.2	64.3	----
.025	21.8	----	32.4	----	----	29.4	----	55.6	----	5.3	----	9.4	----	54.2	63.8	----
.024	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
.023	----	----	----	----	----	----	----	----	4.8	----	----	----	----	----	----	----
.022	----	----	----	----	----	----	----	----	----	5.4	----	----	----	----	62.8	67.7
.021	----	----	31.6	27.5	----	----	----	54.4	6.5	----	----	----	----	----	----	----
.020	----	22.4	----	----	28.3	29.7	----	----	----	6.5	8.9	----	----	----	62.6	68.2
.019	21.7	22.7	31.4	27.5	----	----	54.1	55.2	6.5	----	----	9.5	53.0	54.4	----	----
.018	21.6	22.7	----	----	28.3	29.9	54.0	55.5	----	6.4	9.4	----	----	----	61.6	68.7
.017	21.5	22.8	31.7	27.2	----	----	54.2	55.5	6.0	----	----	9.8	52.7	54.5	----	----
.016	21.3	22.8	----	----	28.1	30.4	53.9	55.4	----	5.8	9.7	----	----	----	61.3	69.6
.015	21.4	23.0	31.6	26.8	----	----	53.8	55.6	4.9	----	----	10.1	52.6	54.7	----	----
.014	21.5	23.0	----	----	28.3	30.8	53.7	55.5	----	6.1	9.7	----	----	----	60.7	70.9
.013	21.6	23.2	32.8	26.2	----	----	53.5	55.6	5.6	----	----	10.1	52.6	55.0	----	----
.012	22.0	23.5	----	----	28.5	31.5	53.5	56.0	----	7.2	9.6	----	52.8	55.2	60.3	72.3
.011	22.2	23.7	33.6	27.4	----	----	53.5	56.1	7.7	----	----	10.5	52.7	55.3	----	----
.010	22.1	24.4	----	----	28.5	31.9	53.3	56.2	----	7.9	9.9	----	52.7	55.7	58.5	72.0
.009	22.2	24.9	36.7	26.5	----	----	53.1	56.6	8.8	----	----	10.6	52.6	55.9	----	----
.008	22.1	25.1	----	----	28.9	33.2	52.9	56.7	----	7.1	10.1	----	52.3	56.1	55.1	77.1
.007	21.7	25.3	37.4	25.4	----	----	52.8	57.2	7.8	----	----	10.3	52.0	56.6	----	----
.006	21.3	25.7	40.5	23.7	29.0	----	52.2	57.6	----	9.1	9.8	----	51.7	57.0	53.5	81.4
.005	21.0	25.9	43.0	23.8	28.5	34.9	51.6	57.9	8.7	----	----	9.9	51.6	57.4	51.9	83.3
.004	----	----	----	----	----	----	----	----	----	7.3	8.1	----	----	----	----	----
.003	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Summary .0280	21.7	22.5	33.5	31.5	28.3	29.3	55.3	55.8	6.3	5.9	9.3	9.5	53.5	54.3	64.2	67.6
Summary .0148	21.6	23.0	32.2	27.0	28.3	30.7	53.8	55.6	6.1	6.3	9.6	10.0	52.7	54.8	60.9	70.3
Summary .0084	22.0	24.9	36.3	26.2	28.7	32.9	53.0	56.7	8.1	7.4	10.0	10.5	52.4	56.1	56.0	75.8
Summary .0050	21.0	25.9	43.3	23.3	28.6	34.9	51.6	58.0	8.7	8.3	9.0	9.9	51.5	57.4	51.9	83.3

Calculation of time of infinite arc, etc.—Continued.

φ	(33) 4^h		(34) 11^h		(35) 0^h		(36) 4^h		(37) 1^h		(38) 2^h		(39) 7^h		(40) 0^h	
	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.
.030	45.1	----	51.4	----	16.5	----	----	39.7	46.7	47.7	----	10.6	----	14.9	----	----
.029	----	----	----	51.4	----	17.9	----	39.8	----	----	9.0	10.2	----	----	50.2	----
.028	----	43.9	51.4	----	16.4	----	----	----	46.7	----	8.6	10.1	----	15.2	----	50.0
.027	45.2	43.7	----	51.4	----	17.2	----	----	46.5	47.9	8.5	10.0	13.5	----	50.0	----
.026	----	----	51.2	----	16.0	----	----	40.1	----	----	8.6	10.5	----	----	----	49.8
.025	----	43.7	----	51.2	----	17.1	38.4	----	46.4	----	8.8	10.3	13.5	15.1	49.9	----
.024	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
.023	----	----	----	----	----	----	----	----	----	----	----	11.2	----	----	----	----
.022	----	----	----	----	----	17.5	----	----	----	----	8.5	11.2	----	----	----	----
.021	----	----	----	----	15.8	----	----	40.7	----	----	8.6	11.1	----	----	----	----
.020	45.8	43.6	50.8	----	----	18.0	----	----	46.4	48.1	8.4	11.5	----	15.8	----	49.3
.019	46.2	----	----	50.9	15.7	----	----	40.9	----	----	8.4	12.8	13.6	15.9	49.3	----
.018	46.3	43.6	50.7	----	----	17.7	35.4	----	46.3	48.7	9.4	13.4	13.6	16.4	----	49.0
.017	46.5	43.6	----	51.0	14.9	----	----	41.7	----	----	9.8	14.4	14.0	16.5	48.7	----
.016	46.6	43.6	51.0	----	----	19.0	34.8	----	46.5	49.4	10.5	15.3	13.9	16.8	----	49.1
.015	47.0	43.7	----	51.2	15.9	----	----	42.6	----	----	11.2	15.8	14.0	17.1	48.9	----
.014	47.1	43.6	50.8	----	----	19.3	34.7	----	46.5	49.6	11.1	15.7	13.9	17.5	----	49.2
.013	47.4	43.6	----	51.2	15.4	----	----	43.1	----	----	11.1	16.4	14.1	17.5	49.0	----
.012	47.7	43.7	50.7	----	----	19.7	34.4	----	46.3	50.4	10.7	16.5	13.9	17.8	----	49.2
.011	48.4	43.7	----	50.8	14.5	----	----	44.0	----	----	11.6	17.5	13.5	18.1	49.2	----
.010	49.0	43.7	51.1	----	----	20.5	33.7	44.7	46.1	51.5	11.7	19.1	13.7	19.0	----	49.1
.009	49.8	43.8	----	51.5	14.7	----	----	45.9	----	----	11.2	21.1	14.0	19.8	49.3	----
.008	50.3	43.2	50.9	----	----	23.6	31.9	47.1	46.2	52.9	12.2	21.4	14.0	20.7	----	49.5
.007	51.1	42.9	----	51.0	15.4	----	30.8	----	----	54.0	10.7	22.9	13.9	20.9	49.3	----
.006	----	42.9	50.8	----	----	24.3	29.5	48.6	44.6	----	10.0	23.3	13.3	21.8	----	49.2
.005	----	42.2	----	50.5	10.9	20.5	28.1	----	45.6	55.2	8.1	25.0	12.4	----	48.4	----
.004	----	40.3	49.6	----	----	----	25.3	----	----	----	----	----	11.8	----	----	----
.003	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Summary .0280	45.2	43.8	51.3	51.4	16.3	17.4	38.4	39.9	46.6	47.8	8.7	10.3	13.5	15.1	50.1	49.9
Summary .0148	47.0	43.6	50.8	51.0	15.3	19.0	34.8	42.5	46.4	49.6	10.8	15.5	13.8	17.1	49.0	49.1
Summary .0084	50.1	43.4	50.9	51.3	14.9	22.8	32.3	46.4	46.1	52.6	11.4	21.1	13.9	20.1	49.3	49.4
Summary .0050	52.9	42.0	50.3	50.5	10.9	21.5	27.9	49.6	45.3	55.2	8.2	24.7	12.5	22.9	48.4	49.0

φ	(41) 0^h		(42) 5^h		(43) 0^h		(44) 0^h		(45) 4^h		(46) 0^h		(47) 0^h		(48) 5^h	
	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.
.030	----	60.4	9.5	----	23.7	----	37.1	----	59.2	----	----	40.3	57.7	----	5.2	----
.029	60.4	----	----	9.5	----	24.2	----	39.1	----	59.9	40.6	----	----	57.1	----	5.3
.028	----	60.2	9.4	----	23.7	----	37.0	----	----	59.9	----	----	56.4	----	5.3	----
.027	60.9	----	----	9.4	----	23.9	36.0	38.7	----	----	----	40.2	----	55.2	----	5.3
.026	----	59.8	9.4	----	22.3	----	36.3	38.2	58.9	59.8	40.4	----	55.0	----	5.3	----
.025	60.9	----	----	9.4	----	23.6	35.6	38.1	----	60.0	----	40.2	----	53.7	----	5.4
.024	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
.023	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
.022	----	58.9	----	----	----	----	35.2	38.9	----	----	----	----	----	----	----	----
.021	60.5	----	----	----	----	----	35.8	39.0	----	----	----	----	----	----	----	5.7
.020	60.6	59.3	9.3	----	----	24.0	35.7	39.0	----	----	----	----	50.5	----	5.6	----
.019	60.2	58.5	----	9.4	23.0	----	35.3	38.9	58.6	60.2	41.1	----	----	49.7	----	5.6
.018	60.5	57.9	9.5	----	----	24.1	34.9	38.5	----	----	41.2	40.6	49.6	----	5.8	----
.017	60.8	58.4	----	9.6	22.7	24.0	34.1	38.5	58.5	60.5	----	40.8	----	49.5	----	6.2
.016	60.4	58.0	9.5	----	22.7	24.0	33.9	39.2	----	----	41.3	----	48.9	----	5.9	----
.015	59.9	58.2	----	10.2	22.7	24.3	34.5	39.9	58.4	60.4	----	41.0	----	49.4	----	6.5
.014	59.4	57.6	10.1	----	22.5	24.3	34.7	40.5	----	----	41.6	----	49.2	----	6.2	----
.013	58.8	56.9	----	10.4	22.6	24.4	35.1	41.6	58.2	60.5	41.7	41.1	----	48.5	----	6.9
.012	57.5	55.5	10.5	----	22.6	24.7	35.2	42.0	----	----	42.3	41.7	47.2	----	7.0	----
.011	55.9	54.5	----	10.6	22.7	24.7	34.8	42.3	58.3	61.1	42.6	41.5	----	47.8	----	7.0
.010	56.2	53.4	10.6	----	22.5	24.9	34.2	42.1	----	----	42.7	41.6	47.9	----	7.2	----
.009	55.6	52.1	----	11.1	22.3	24.9	33.2	42.7	57.9	61.5	43.1	41.9	----	48.7	----	7.6
.008	54.5	50.6	10.5	----	21.9	25.4	32.8	42.8	----	----	43.6	42.5	47.2	----	7.6	----
.007	53.8	49.9	----	11.8	21.9	25.3	32.2	43.5	57.6	62.1	43.5	42.2	----	46.1	----	7.8
.006	52.0	47.1	10.2	----	21.5	25.1	30.8	43.3	----	----	44.2	42.3	47.6	----	7.3	----
.005	50.1	44.1	----	11.2	20.3	25.6	27.3	42.3	55.9	63.6	----	41.7	49.6	45.6	----	7.9
.004	----	----	----	----	----	----	----	----	----	----	----	42.1	----	----	6.4	----
.003	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Summary .0280	60.9	60.1	9.4	9.4	23.4	23.9	36.6	38.6	59.1	59.9	40.5	40.2	56.4	55.8	5.3	5.3
Summary .0148	59.6	57.7	9.9	10.0	22.7	24.3	34.7	40.2	58.4	60.5	41.7	41.0	48.9	49.0	6.2	6.5
Summary .0084	55.0	51.5	10.5	11.3	22.2	25.1	33.1	42.8	57.8	61.7	43.2	42.0	47.4	47.4	7.4	7.5
Summary .0050	50.0	44.0	10.0	11.5	20.6	25.4	27.8	42.6	55.9	63.6	44.5	42.0	49.2	45.6	6.9	7.9

Values of $\frac{1}{b}$ and of the ratio heavy end down to heavy end up.

No. of swings.	$\frac{1}{b}$ Heavy end down.	$\frac{1}{b}$ Heavy end up.		Ratio, down : up.
	m.	m.	m.	
1, 2, 3	110.3	37.0	38.7	2.91
4, 5, 6	111.1	36.6	38.6	.95
7, 8, 9	114.9	38.3	40.3	.92
10, 11, 12	110.7	38.1	[21.5]	.91
13, 14, 15	[59.3]	37.3	[19.3]	
16, 17, 18	115.7	39.9	40.7	.87
19, 20, 21	112.6	39.9	38.5	.87
22, 23, 24	113.1	41.5	41.1	.74
25, 26, 27	109.1	39.9	40.9	.70
28, 29, 30	113.1	37.9	39.7	.91
31, 32, 33	112.0	39.1	41.1	.79
34, 35, 36	113.0	38.4	38.6	.94
37, 38, 39	119.0	41.0	41.6	.88
40, 41, 42	105.4	37.7	40.3	.70
43, 44, 45	111.7	38.8	39.1	.87
46, 47, 48	100.9	41.2	41.1	.45

FORT CONGER. PENDULUM, PEIRCE NO. 1.

HEAVY END DOWN.

No. of swing and face.	Temperature (F).	Pressure.	Mean instant, first transits.	Mean instant, last transits.	Arc correction.	Interval.	No. of oscillations.	Uncorrected period.	Rate.
	°	in.	h. m. s.	h. m. s.	s.	s.		s.	
2 B	−9.5	29.892	8 01 50.956	10 18 58.229	0.085	8227.187	8190	1.0045405	+293
5 F	−10.1	29.936	6 21 54.677	8 43 25.124	0.087	8490.360	8452	1.0045337	+293
8 F	−10.8	29.825	5 45 40.006	8 07 51.636	0.096	8531.535	8493	1.0045372	+293
11 F	−14.6	29.919	5 51 16.941	8 12 45.177	0.088	8488.148	8450	1.0045145	+293
14 B	−18.3	30.041	7 41 37.613	9 16 14.876	0.044	5677.219	5652	1.0044619	+293
17 B	−16.1	29.841	6 51 10.445	9 14 29.119	0.096	8598.578	8560	1.0045068	+293
20 B	−16.0	29.286	7 53 56.610	10 25 41.479	0.093	9104.7[illegible]	9064	1.0044986	+293
23 F	−15.4	29.789	8 05 37.325	10 28 47.998	0.090	8590.58[illegible]	8552	1.0045117	+293
26 F	−18.9	29.717	8 35 09.007	10 53 36.815	0.083	8307.725	8271	1.0044402	+294
29 F	−20.8	29.975	8 06 30.184	10 37 34.324	0.093	9064.047	9024	1.0044378	+294
32 B	−21.3	29.776	8 05 19.742	10 32 42.974	0.094	8843.138	8804	1.0044455	+294
35 F	−21.5	29.999	8 18 25.331	10 41 07.292	0.090	8561.871	8524	1.0044429	+294
38 B	−21.6	29.446	10 11 28.548	12 37 41.455	0.095	8772.812	8734	1.0044438	+340
41 F	−25.0	29.872	9 01 36.205	11 13 17.033	0.084	7900.744	7866	1.0044170	+340
44 F	−26.6	29.821	8 38 44.315	10 56 14.706	0.089	8250.302	8214	1.0044195	+340
47 B	−25.9	29.287	9 01 45.782	11 08 54.270	0.068	7628.420	7595	1.0044003	+340

FORT CONGER. PENDULUM, PEIRCE NO. 1—Continued.

HEAVY END UP.

No. of swing and face.	Temperature (F).	Pressure.	Mean instant, first transits.	Mean instant, last transits.	Arc correction.	Interval.	No. of oscillations.	Uncorrected period.	Rate.
	°	in.	h. m. s.	h. m. s.	s.	s.		s.	
1 B	−9.9	29.873	5 29 15.364	6 18 43.118	0.027	2967.727	2956	1.0039671	+293
3 F	−10.1	29.908	11 18 41.202	12 08 01.892	0.027	2960.663	2949	1.0039550	+293
4 F	−10.0	29.942	4 15 55.413	5 02 06.354	0.024	2770.917	2760	1.0039553	+293
6 B	−9.2	29.928	10 02 43.028	10 55 39.548	0.027	3176.493	3164	1.0039485	+293
7 B	−11.5	29.829	3 55 39.382	4 46 01.286	0.028	3021.876	3010	1.0039455	+293
9 B	−10.8	29.830	8 46 03.706	9 35 21.373	0.028	2957.639	2946	1.0039509	+293
10 B	−15.5	29.900	4 06 24.949	5 00 13.573	0.024	3228.600	3216	1.0039179	+293
12 F	−13.8	29.948	8 56 31.588	9 21 12.127	0.008	1480.531	1476	1.0030699	+293
13 F	−16.8	30.043	6 13 57.083	6 56 51.168	0.019	2574.067	2564	1.0039261	+293
15 F	−15.0	30.036	10 29 25.625	10 50 40.955	0.011	1275.218	1271	1.0033190	+293
16 F	−16.5	29.892	5 11 23.928	6 10 35.691	0.029	3551.735	3538	1.0038821	+293
18 B	−15.6	29.780	10 00 37.269	10 52 11.182	0.029	3093.884	3082	1.0038559	+293
19 B	−16.6	29.338	6 13 05.985	7 04 07.873	0.029	3061.859	3050	1.0038881	+293
21 B	−16.0	29.267	11 15 58.320	12 05 21.808	0.028	2963.460	2952	1.0038822	+293
22 B	−15.8	29.796	6 28 32.893	7 18 06.475	0.027	2973.555	2962	1.0039010	+293
24 F	−16.0	29.786	11 09 37.201	12 00 37.098	0.029	3059.868	3048	1.0038938	+293
25 B	−18.5	29.665	6 57 23.116	7 47 58.915	0.029	3035.770	3024	1.0038921	+293
27 F	−18.2	29.755	12 04 34.987	12 55 40.873	0.029	3065.857	3054	1.0038825	+293
28 F	−20.3	29.969	6 30 42.121	7 18 43.286	0.027	2881.138	2870	1.0038807	+293
30 B	−20.2	29.958	11 44 29.864	12 37 02.015	0.029	3152.122	3140	1.0038605	+293
31 B	−21.5	29.766	6 29 20.535	7 19 48.195	0.028	3027.633	3016	1.0038571	+293
33 B	−21.1	29.793	11 18 57.889	12 09 35.592	0.031	3037.672	3026	1.0038572	+293
34 B	−22.4	29.997	6 26 13.701	7 17 17.528	0.028	3063.799	3052	1.0038661	+293
36 B	−22.2	29.996	11 14 31.568	12 00 54.307	0.027	2782.713	2772	1.0038647	+293
37 B	21.0	29.485	8 22 01.236	9 12 33.904	0.030	3032.638	3021	1.0038523	+340
39 B	−21.4	29.393	13 50 29.471	14 41 55.326	0.028	3085.826	3074	1.0038471	+340
40 B	−25.4	29.842	7 24 44.646	8 09 22.960	0.026	2678.287	2668	1.0038558	+340
42 F	−25.0	29.899	11 44 32.245	12 30 30.926	0.028	2758.653	2748	1.0038767	+340
43 F	−26.1	29.834	6 58 38.207	7 46 15.284	0.028	2857.050	2846	1.0038825	+340
45 F	−25.9	29.830	11 34 56.301	12 22 43.212	0.025	2806.886	2796	1.0038933	+340
46 F	−26.4	29.373	7 14 59.632	8 08 09.968	0.031	3190.275	3178	1.0038625	+340
48	−26.4	29.218	11 40 04.803	12 35 03.470	0.030	3298.636	3286	1.0038455	+340

PENDULUM, PEIRCE NO. 1.

HEAVY END DOWN.

Before interchange of knives.

No. of swing.	Temperature, +13.2° F.	Pressure, −29.784 in.	Period corrected for rate.	Temperature correction.	Pressure correction.	Period corrected to mean pressure and temperature.
	°	In.	s			s
2	+3.7	+0.108	1.0045698	−174	−15	1.0045509
5	+3.1	+0.152	5630	−146	−22	5462
8	+2.4	+0.041	5665	−113	−6	5546
11	−1.4	+0.135	5438	+66	−19	5485
14*	. .	. . .	. .	. .	. .	. .
17	−2.9	+0.057	5361	+136	−8	5489
20	−2.8	−0.498	5279	+132	+71	5482
23	−2.2	+0.005	5410	+103	−1	5512
Mean						1.0045498

*Necessarily rejected on account of irregular descent of the arc.

PENDULUM, PEIRCE No. 1—Continued.

HEAVY END DOWN—Continued.

After interchange of knives.

No. of swing.	Temperature, +22.7° F.	Pressure, —29.737 in.	Period corrected for rate.	Temperature correction.	Pressure correction.	Period corrected to mean pressure and temperature.
	°	In.	s			s
26	+ 3.8	- 0.020	1.0044696	—179	+ 3	1.0044520
29	+ 1.9	+0.238	4672	— 89	— 34	4549
32	+ 1.4	+0.039	4749	— 66	— 6	4677
35	+ 1.2	+0.262	4723	— 56	— 37	4630
38	+ 1.1	—0.291	4778	— 52	+ 41	4767
41	— 2.3	+0.135	4510	+108	— 19	4599
44	— 3.9	+0.084	4535	+183	— 12	4706
47	— 3.2	—0.450	4343	+150	+ 64	4557
Time of oscillation at —22.7° F. and 29.737in pressure.						1.0044626
Correction to standard atmosphere						— 681
Expansion to 15° C.						+4014
Flexure						— 655
Elevation, 23 feet.						— 11
Corrected period.						1.0047293

HEAVY END UP.

Before interchange of knives.

No. of swing.	Temperature, +13.6° F.	Pressure, —29.794 in.	Period corrected for rate.	Temperature correction.	Pressure correction.	Period corrected to mean pressure and temperature.
	°	In.	s			s
1	+ 3.7	+.079	1.0039964	—106	— 33	1.0039825
3	+ 3.5	+.114	9843	—100	— 48	9695
4	+ 3.6	+.148	9846	—103	— 63	9680
6	+ 4.4	+.134	9778	—126	— 57	9595
7	+ 2.1	+.035	9748	—60	— 15	9673
9	+ 2.8	+.036	9802	— 80	— 15	9707
10	— 1.9	+.106	9472	+ 55	— 45	9482
12*	..	..	..	..	..	..
13	— 3.2	+.249	9554	+ 92	—106	9540
15*	..	..	..	..	..	..
16	— 2.9	+.098	9114	+ 83	— 42	9155
18	— 2.0	—.014	8852	+ 57	+ 6	8915
19	— 3.0	—.456	9174	+ 86	+193	9453
21	— 2.4	—.527	9115	+ 69	+223	9407
22	— 2.2	+.002	9303	+ 63	— 1	9365
24	— 2.4	—.008	9231	+ 69	+ 3	9303
Mean						1.0039485

* Necessarily rejected on account of irregular descent of the arc.

PENDULUM, PEIRCE No. 1—Continued.

HEAVY END UP—Continued.

After interchange of knives.

No. of swing.	Temperature, +22.6° F.	Pressure, —29.736 in.	Period corrected for rate.	Temperature correction.	Pressure correction.	Period corrected to mean pressure and temperature.
	°	In.	s			s
25	+ 4.1	—.071	1.0039214	—118	+ 30	1.0039126
27	+ 4.4	+.019	9118	—126	— 8	8984
28	+ 2.3	+.233	9100	— 63	— 99	8938
30	+ 2.4	+.222	8898	— 69	— 94	8735
31	+ 1.1	+.030	8864	— 32	— 13	8819
33	+ 1.5	+.057	8865	— 43	— 24	8798
34	+ 0.2	+.261	8954	— 6	—111	8837
36	+ 0.4	+.260	8940	— 11	—110	8819
37	+ 1.6	—.251	8863	— 46	+106	8923
39	+ 1.2	—.343	8811	— 34	+145	8922
40	— 2.8	+.106	8898	+ 80	— 45	8933
42	— 2.4	+.163	9107	+ 69	— 69	9107
43	— 3.5	+.098	9165	+100	— 42	9223
45	— 3.3	+.094	9273	+ 95	— 40	9328
46	— 3.8	—.363	8965	+109	+154	9228
48	— 3.8	—.518	8795	+109	+220	9124
Time of oscillation at —22.6° F. and 29.736in pressure						1.0038990
Correction to standard atmosphere						—2026
Expansion to 15° C.						+4006
Flexure						— 220
Elevation, 23 feet.						— 11
Corrected period.						1.0040739

Flexure of Pendulum Piers.

Observer, E. ISRAEL, 1882.

Deflecting force, the weight of 2.5 pounds. [Treated as 2.38 lb.]

1 rev. micr. at —12° F.	=0.001704in
	Flexure. r.
Scale 7.843in forward	0.299
Scale 15.858 back	0.656
At center knife-edge	0.414
	=0.000710in
Wt. pend. 23.0 lb. ∴ *MS*	=0.00686in=174.2m

PENDULUM, PEIRCE No. 1.

1881, June 11-14.

Comparison with Meter No. 49, middle plugs.

Temperature F. Mean pendulum and meter.	Temperature F. Excess pendulum over meter.	Length, observed excess pendulum.	Correction for mean to 70°.	Correction for difference.	Excess, corrected.
°	°	μ	μ	μ	μ
70.3	+0.2	399.5	+0.1	−2.1	397.5
69.3	−0.1	397.5	−0.2	+1.0	398.3
69.5	0.0	398.0	−0.2	0.0	397.8
69.6	−0.2	400.0	−0.1	+2.1	402.0
69.8	0.0	397.5	−0.1	0.0	397.4
70.0	−0.2	393.5	0.0	+2.1	395.6
70.2	−0.1	396.5	+0.1	+1.0	397.6
69.9	−0.4	390.0	0.0	+4.1	394.1
69.9	−0.2	391.5	0.0	+2.1	393.6
70.0	−0.2	393.0	0.0	+2.1	395.1
70.1	−0.2	396.5	0.0	+2.1	398.6
70.2	−0.2	393.0	+0.1	+2.1	395.2
70.3	−0.2	394.0	+0.1	+2.1	396.2
69.5	−0.1	400.0	−0.2	+1.0	400.8
69.6	−0.1	393.0	−0.1	+1.0	392.9
69.8	−0.2	395.5	−0.1	+2.1	397.5
					396.9
Corr. error of thermometers					396.6
At 68°					397.2

PENDULUM, PEIRCE No. 1.

1884, December 1-10.

Comparison with outer line of Meter B.

Temperature C.	Pendulum —meter.	Reduced to 20° C.
°	μ	μ
17.24	+252.4	+251.1
18.11	+252.8	251.6
17.98	+253.2	250.1
18.19	+252.7	253.9
18.38	+252.3	252.5
18.82	+251.4	251.7
19.00	+249.0	250.3
19.74	+249.8	250.9
19.32	+249.6	251.1
19.83	+248.0	250.9
30.30	+242.5	250.7
30.57	+241.9	250.9
30.92	+242.1	250.7
31.45	+241.9	250.4
31.71	+242.2	250.9

Mean pendulum — *B* 1st line	+251.2
1st line — 3rd line	+199.4
B 3rd line — No. 49	− 12.0
Correction to thermometers	+ 0.7
	+429.3

I now give a summary of the observations made with this pendulum in Washington in 1884-'85 by me, with the assistance of Mr. W. B. Fairfield.

PENDULUM No. 1.

1884-'85.

At Smithsonian Institution, Washington, D. C.

Heavy end down. No. of swing.	Temperature.	Pressure.	*nT*.	Heavy end up. No. of swing.	Temperature.	Pressure.	*nT*.
	°	In.	s.		°	In.	s.
1	20.15	29.711	15095.265	1	20.75	30.256	5028.101
2	20.58	29.643	.230	2	21.02	30.266	.043
3	20.63	29.753	.212	3	21.23	30.282	.106
4	20.53	30.044	.229	4	21.21	30.300	.093
5	20.20	29.624	.274	5	20.96	30.348	.028
6	20.69	29.618	.232	6	20.98	30.336	.061
7	21.04	29.866	.216	7	21.00	30.344	.048
8	21.18	30.078	.202	8	20.99	30.402	.084
9	20.33	30.681	.251	Means	21.02	30.317	5028.070
10	20.54	30.640	.276	Corr. to stand. atmos.			−.033
11	20.48	30.608	.282	Expansion to 15° C.			−.273
12	20.10	30.462	.246	Flexure			−.116
Means	20.54	30.061	15095.243	Corrected time			5027.648
Corr. to stand. atmos.			+.005				
Expansion to 15° C.			−.752				
Flexure			−1.037				
Corrected time			15093.459				

10,000 osc. simple pendulum 10065.819.

In comparing the observations made at Fort Conger with those at Washington I shall make use of a figure of the earth which I have deduced from the totality of the experiments with Kater invariable pendulums down to and including the expedition of Mr. Edwin Smith. In this discussion I have ascertained by least squares that the correction for elevation is 0.00406^s.* The coefficient of $\sin^2 \varphi$ is 225.94^s, and I have also introduced a term in $\sin^3 \varphi - \frac{3}{5} \sin \varphi$, the coefficient of which is 1.22^s, this operating to increase the last effect at the north pole. According to this discussion gravity is in excess at Washington by $+0.76^s$.

Inasmuch as it is certain that the pendulum underwent some alteration between its last swinging at Fort Conger and its swinging at Washington, but of such a nature that the distance between the knife-edges was not altered, we have to compare the periods of the pendulum at the two stations, reduced according to the principle of the reversible pendulum. This period for this pendulum is obtained by adding 8 in the seventh place of decimals to $\frac{3}{2}$ the period of heavy end down, minus $\frac{1}{2}$ the period of heavy end up. This gives, at Fort Conger, 1.0050578^s as the period of oscillation of the simple pendulum of the same length between the knife-edges. We now proceed as follows:

2 log. of period at Fort Conger	+0.0043821
Correction to equator	+0.0022174
Correction from equator and sea-level to Washington	−0.0008904
—station error at Washington	−76
—2 log. period at Washington	−0.0056982
—station error at Fort Conger	+0.0000033

It appears from this that gravity is slightly in deficiency at Fort Conger, by only -0.33^s; and since a careful scrutiny of these observations has fully convinced me that they are by far the best that ever have been made within the arctic circle, it is gratifying to find that they satisfy so well the figure already deduced by me, and that they go to confirm the reality of some small harmonic function of the third order, such as that which I have introduced.

*Here, as elsewhere, by 1 second in such a connection I mean one unit in the fifth place of the common logarithm of gravity.

MEMORANDUM BY THE OFFICER COMMANDING THE EXPEDITION.

It only appears proper, in a matter of such importance to the scientific world as the pendulum observations of the Lady Franklin Bay Expedition, that its commanding officer should make some brief statements bearing on the opinions of Professor C. S. Peirce, which are believed to be erroneous. An opinion is expressed on page 702, as follows: "This seems to have been due to a difference of cylindricity of the edges, combined with the effect of some accident to the pendulum." No accident in any way, shape, or manner, occurred to this pendulum. It was never handled by any one in reversion or suspension excepting by myself; so that I can speak with a personal and positive knowledge that the pendulum was never harmed while at Fort Conger. As soon as the series of observations was completed, the pendulum was carefully removed, wiped dry, and again soldered up in the original tin box.

The statement is also made, that "on the abandonment of Fort Conger, the head upon which the pendulum had been supported in its oscillations (the bearings of the knife-edge forming part of it) was left behind." The metal piece referred to never was, in any way, shape, or manner, alluded to by either the Superintendent of the Coast Survey, the late Carlisle P. Patterson, or Professor Peirce, as being of the slightest utility, and the instructions given me were to the effect that the only important part to be brought back was the pendulum, then soldered in a tin box. If the omission to bring back the plate has any bearing upon these observations, as does not plainly appear from Professor Peirce's remarks, it is simply the fault of either the late Mr. Patterson or Professor Peirce himself.

Later the statement is made, "But, though there was little change in the length of the pendulum, it is evident it lost a large part of its mass." In the very next line it is admitted by Professor Peirce that the pendulum was not weighed at all in its finished state, and that the loss in adjustment, 4.6 grams, was calculated. Consequently the statement that "It (the pendulum) would seem to have lost from ten to fifteen grams, probably on the journey from Fort Conger to Camp Clay," rests on a surmise and an estimate. The pendulum was brought back to Camp Clay soldered in the original metal box, in which it was so carefully packed that no vibratory motion could occur in such manner as to cause loss of weight. The pendulum, although handled hundreds of times, was always treated with special consideration, as was also a box containing photographic negatives; and as an instance of the care exercised with these packages, may be mentioned the fact, that out of forty-eight glass negatives only four were fractured, although necessarily handled scores of times, under circumstances when a moment's delay apparently entailed a loss of boats and life.

It is possible, as suggested in the following Supplementary Report, that during the observations the screws holding one of the pendulum edges in place might have been loosened or tightened, and this seems very probable, as the wrong screw might easily have been touched under the extremely disadvantageous circumstances in connection with the swinging of the pendulum, which was done in an ice-house, where one's breath congealed the moment it left the mouth, and the darkness was broken simply by the light from a single candle so that the temperature of the pendulum might not be affected. On one occasion something of this kind undoubtedly occurred, for the pendulum was stopped after swinging a few minutes, as its arc of oscillation decreased so rapidly as to show conclusively that its vibrations would cease in about one-quarter of the usual time.

It seems but justice to the late Mr. Israel, the astronomer of the expedition, who had charge of the pendulum, both during our stay at Fort Conger and our retreat later, that these statements should be made. Besides, they may have a bearing in other scientific discussions of these observations and so be of a certain importance. It would not be just to those who consult these results to deprive them of the fullest and most complete information on this point. The commanding officer of the expedition has had too much experience with physical observations not to realize the importance of a full and free statement of all the facts in any case. He realizes clearly that accidents and mishaps may occur in any set of observations. While a full statement of such accidents and mishaps enables those discussing the observations to apply suitable corrections, on the other hand any misstatements or denials might result in misleading the zealous student of such observations.

It is admitted that the preliminary observations with this pendulum in Washington, under conditions left entirely to Professor Peirce, were practically failures, through whose fault I know not. To the embarrassments, discomforts, and privations which Mr. Israel and myself (the former very indifferently instructed in pendulum work, and myself without any definite verbal and no written instructions) experienced in making these observations should not be added the charge of having injured the pendulum (which was *never weighed in its finished state until after its return*) and caused a considerable loss of mass without adducing the clearest proof that such mass had been lost while in our possession. These statements of Professor Peirce have been maturely made after being assured by me that no injury came to the pendulum and that no such loss of mass was possible. I leave it to the scientific world to pass on this matter.

A. W. GREELY,
Late Commanding Lady Franklin Bay Expedition.

WASHINGTON, D. C., *July*, 1888.

ON THE PENDULUM OBSERVATIONS AT FORT CONGER.

SUPPLEMENTARY REPORT BY HENRY FARQUHAR.

U. S. COAST SURVEY OFFICE, *May* 11, 1887.

F. M. THORN, Esq.,
Superintendent U. S. Coast Survey:

DEAR SIR: At your verbal request for a statement of such facts within my personal knowledge as might help to clear up the question of responsibility with regard to certain charges explicitly or implicitly made by Assistant C. S. Peirce against the management of this office in his report on the Pendulum Observations at Fort Conger, I here undertake the task, joining with such statement a presentation, for what it is worth, of conclusions at variance with his on two or three points, and a few notes and additional data that seem to me necessary to make the results of the work as clear as they should be. Mr. Peirce's long familiarity with every detail of gravity determinations, the real additions to general knowledge of the subject that are due to him, the fact that this important part of the activity of the Survey has been from its first inception under his control (all work being performed either by himself or, according to his methods, by observers and computers trained under him), and the further fact that the discussion of this Fort Conger work was expressly given into his charge, have, in your judgment, entitled him to the courtesy of transmitting his report through your hands without amendment. But for the very reason that these causes will give an increased weight both to his reflections on the Bureau and to the conclusions drawn by him from the observations the advisability of testing them by pertinent facts will be recognized.

I. The failure, probably complete, of the observations in room 6 of this building is correctly ascribed to the absence of a reliable determination of the flexure of the support. That the deficiency has been irremediable since the removal of the cap-stone is not denied, though, as the flexure must be largely due to the unfortunate situation of the piers over a brick archway, even this is doubtful. But when it is remembered that in such researches large corrections are usually, especially where their exact determination is difficult, variable corrections, that in this case the yielding is described as having been of such a character as would naturally be produced by a cause like imperfectly-hardened mortar under the recently erected piers, and that it might have become essentially changed by a settling of the archway beneath, an accurate measurement of the flexure at the time of the observations is seen to have been the chief desideratum, and the maintenance of this confessedly unreliable stand to have been of far less importance. Results from a later swinging on the same support would not improbably have been misleading. That observations of flexure were not prevented by lack of time, notwithstanding Professor Peirce's illness at the most unfortunate point, is clear, for the stone was removed in August or September, 1882, the pendulum having been swung from it in June, 1881. And as if to fix the responsibility beyond possible question, Mr. Peirce in this report calls especial attention to the liberal discretion allowed him by Mr. Patterson, who was Superintendent until August, 1881. It is certain that Superintendent Hilgard would not have permitted the removal of the stone had not Mr. Peirce failed to impress upon him the importance of retaining it, or had it been given him to understand that observations essential to the availability of work done months before were yet unmade. The simple truth I believe to be, that because of the want of time for proper preparations, the unsuitability of the place, and the newness of the observer, Mr. Peirce expected no valuable results at the time from the swingings in room 6, and attached no such importance to them as he now appears to attach.

The loss to the service from the necessity of using for the Peirce pendulums a center-of-mass apparatus adapted to a smaller stem Professor Peirce slightly overrates. In consequence of the forced removal of parts of the apparatus the measure is rendered more difficult with the new pendulums; but as two independent determinations of the distance h_m, made last January, gave (when reduced to edge 9 at heavy end) 25.140^{cm} and 25.135^{cm}, it is improbable that the uncertainty of the result can be so great as to admit the earlier value, 25.105^{cm}, as an equally exact observation of the same quantity. I have not examined the 1881 observations with care, but I believe them to have been less complete than those of 1887.

II. The evidence that the pendulum lost half an ounce in weight between 1881 and 1887 is not conclusive. In the first place, the weight of the brass added in construction at the heavy end was originally estimated from its density and calculated dimensions, not found by the balance, and it was pretty certainly less than was intended. By the calculation the center of mass was to have been at one-fourth the distance between the edges, a result which would have been more nearly attained with a heavier load. Secondly, the atmospheric correction applied in the Fort Conger reduction, on which the difference between heavy end down and up depends, is, a few lines below, said to be "involved in some doubt," and is not improbably too small. Thirdly, it is incredible that so considerable a loss could have escaped the notice of Messrs. Peirce and W. B. Fairfield at the time of the Smithsonian experiments. Fourthly, a recent careful examination by Mr. Fairfield and myself shows no sign of it. There was, it may be said, certainly no such loss within 5^{cm} of the knife-edge if the instrument was originally symmetrical. Finally, General Greely is positive in his disbelief that any such disaster could have befallen the pendulum while in his charge.

To show more clearly the true character of the change in the period of oscillation after the interchange of knife-edges, the following table of periods free from difference of edges and atmospheric corrections in general, those of a simple pendulum of length equal to the distance between the two suspensions, as deduced from each set of three swings, is given. This period is equal to

$$\frac{T_d h_d - T_u h_u}{h_d - h_u}\sqrt{1-\frac{(T_d-T_u)^2 h_d h_u}{(T_d h_d - T_u h_u)^2}}$$

in which the factor under the radical may usually be neglected, T_d and T_u being nearly equal. The temperature here equals $\frac{2}{3}$ that at the "down" swings, $-\frac{1}{3}$ the mean at the two "up," in Fahrenheit degrees $+22°$. Three reductions are made: T [illegible] being values obtained from Mr. Peirce's table of "Period corrected" reduced to one temperature and pressure, T [illegible] resulting from the substitution of a higher rate of expansion, found by least squares on the theory that the change was due to fall of temperature, and T [illegible] resulting from the use of the coefficient of expansion 17.49^{μ}, 18.24^{μ} being taken as true at $+8°$ C. and reduced to $-30°$ C. by Fizeau's equation:

Swings.	Temperature.	T [illegible]	Δ	T [illegible]	Δ	T [illegible]	Δ
	°	s.		s.		s.	
2— 1, 3	+12.8	1.0047912	—122	1.0047412	—194	1.0048006	—094
5— 4, 6	+11.6	7903	—131	7447	—161	7988	—112
8— 7, 9	+11.4	8004	—030	7558	—050	8088	—012
11—10, 13	+ 8.2	8001	—033	7680	+072	8061	—039
17—16, 18	+ 5.9	8247	+213	8017	+409	8291	+191
20—19, 21	+ 6.2	8038	+004	7796	+188	8084	—016
23—22, 24	+ 6.8	8131	+097	7865	+257	8181	+081
26—25, 27	+ 2.8	7325	—191	7216	—392	7346	—165
29—28, 30	+ 0.9	7479	—037	7444	—164	7486	—025
32—31, 33	+ 0.7	7685	+169	7658	+050	7690	+179
35—34, 36	+ 0.9	7605	+089	7570	—038	7612	+101
38—37, 39	+ 0.2	7763	+247	7755	+147	7764	+253
41—40, 42	— 2.9	7461	—055	7574	—034	7440	—071
44—43, 45	— 4.9	7493	—023	7673	+065	7459	—052
47—46, 48	— 3.6	7319	—197	7460	—148	7293	—218
Means	{ + 9.0 / — 0.7	1.0048034±031 / 47516±038		} 1.0047608±037		{ 1.0048100±027 / 47511±039	
Probable error 1 set			±096		±142		±095

In view of the huge value, almost equal to the expansion itself, that has to be given the supposed unknown factor depending on the temperature and not on the vis-viva in order to reconcile the two series of observations, and of its failure to bring them to a satisfactory accord (two swings having less weight, the factor being introduced, than one without it), it appears that the hypothesis of large unknown effects of temperature operating in this way is of no assistance. It is plain, also, that the same difficulties, improbably large hypothetical corrections and greatly increased residuals, must meet any other assumed cause which is gradual and continuous in its operation. "Improvement in the rigidity of the supporting piers," unless by a tightening of screw-taps, etc., at the time of the change (which did not occur), is thus equally excluded as an explanation; also defective elasticity in the brass of the pendulum, through which it does not at once respond to change of temperature. That the change took place abruptly at the time of the transposition, and not a little before and a little after, is about as evident,

indeed, as that it took place at all. The progression that appears in the former half of the results (belonging, it should be observed, entirely to the heavy-end-up swings) is in the wrong direction for continuity, and there is no steady progression in the latter half. The hypothesis of a "difference in the cylindricity of the edges" is suggested by Professor Peirce. If we regard the edges as cylindric, and suppose No. 9 to have had a radius of curvature 29.5^{μ} greater, the difference between first and last values of T [illegible] disappears. Observations of decrement of arc show a slightly greater friction on edge 9. But this hypothesis requires (see formulæ in Coast Survey Report for 1876, p. 276 [77 of Appendix 15]) a difference between the two edges of 87.4^{μ}, about half the measured difference. The supposition of another "accident" at the time of the interchange of edges appears untenable, partly because it is difficult to understand how the instrument could have had two serious accidents without afterward showing a trace of either, and partly because General Greely, in whose presence the interchange was carefully made, testifies confidently that there is no possibility of any such accident.

One explanation remains: That there was a real difference in the length of the pendulum, as swung before and after the interchange. The mean periods in the two positions were for temperature $-22°$ F. and pressure 29.75^{in} (using the coefficient .00000489):

	s.	s.
First days	T_d=1.0045145±10	T_u=1.0039287±47
Last days	T_d=1.0044656±20	T_u=1.0039009±29
Differences	.0000489±22	.0000278±55
Differences, calculated	.0000560	.0001672

The distance of edge 9 from its bearing-plane, as measured by Dr. J. J. Clark in January, 1887, is 504.0μ, and that of edge 10 is 670.6μ; difference, 166.6μ. Hence is calculated the theoretical decrease in period, entered above; nearly the observed amount for heavy end down and very different for heavy end up. It seems highly probable, therefore, that the edge at the heavy end was farther from the center of mass at the earlier observations than at the later. This edge, that is to say, was loose, so as to have a play of an eighth of a millimeter on the average until the transposition was made, and was properly tightened after it. Inspection of the earlier heavy-end-up corrected periods plainly suggests (when the lower expansion-coefficient is used more plainly yet) that the play of this edge may have increased progressively, as they show a pretty steady diminution. The effect of removing the heavy-end knife-edge, of a mass equal to $\frac{150}{10436}$ that of the pendulum, by a distance $\frac{1}{2}(h_d+h_u)=x$ from the other edge will be to increase h_d by $150x : 10436$ and h_u by $10286x : 10436$; $\Delta(r_c^2)$ may be taken equal to $150 : 10436$ of $2r\Delta r$ (r being the distance of the center of the shifted mass from the other edge) and hence to $100.9\times150x : 5218$; $\Delta(r_e^2)=\Delta(r_c^2-h_d^2+h_u^2)$ will then be $[(100.9-h_d)150+10286h_u]x : 5218$. Substituting these values in

$$\Delta T=\frac{T}{2}\left(\frac{\Delta(r^2)}{r^2}-\frac{\Delta h}{h}\right)$$

we find $\Delta T_d=+.00010x$ and $\Delta T_u=-.00963x$. Taking $x=0.01188^{cm}$, and correcting the periods before interchange accordingly, we have $T_d=1.0045133^s$, $T_u=1.0040431^s$, and T [illegible] the same as the later value 1.0047511^s. The differences between the periods for first and last days will thus become 0.0000477^s and 0.0001422^s, one-seventh less than those calculated from measurement of the edges.

A loosening of the heavy-end edge, after the measures made in 1881, might have taken place in one of several conceivable ways. The observer, whose zeal and industry surpassed his experience, could have turned one of the screws holding this edge in place, about the beginning of the experiments, mistaking it for a similar screw by which the pendulum is raised or lowered. An artisan, in packing the instrument, could accidentally have touched the screw. Dirt of some kind could have remained on one of the brass slides holding the edge in place (a recent examination shows that the slide at the same end of the heavy edge-holder is considerably stained with rust, verdigris, etc., over its inner surface, which may be a trace of it) and this dirt not have been squeezed out till after the measures of length (June 11 to 14, 1881, before the pendulum had been swung even in Washington), but become so, gradually perhaps, before the edges were transposed. Without committing ourselves to any one of these possible explanations, we must admit that the hypothesis of a slight loosening of one edge during the first swings is the only one yet suggested that seems to meet the facts.

Attention should be called to a point that seems to be plainly brought out in these swingings: The considerable difference between the atmospheric viscosity, as deduced *a priori* by Professor Peirce, and used in correcting for pressure, and the resistance proportional to first power of amplitude deduced from the observations. For the Repsold pendulum, at widely different pressures and temperatures, the coefficient of this resistance for "heavy end up" was found to agree with the formula $b=.0013\tau^{\frac{1}{2}}+.02368p\tau^{-1}$, the unit of p being a standard atmosphere, of τ 288° C., the temperature having been increased by 273°, and of b the reciprocal of a minute. The second coefficient, divided by 60π, was used as the coefficient of the effect of the viscosity on the period. In this reduction the viscosity coefficient for heavy end up is 0.0000994, and the average b is .02536 (min)$^{-1}$; $\pi l = 0.8885$, $\tau^{-1} = 1.020$ and $\rho l = 1.004$. $0.0000994 \times 60\pi \times 1.020 \times 1.004 = 0.01921$, a value for the second part of b little over four-fifths of that in the Repsold pendulum, which seems to require that the first coefficient be 0.0069, more than five times as great, to produce 0.02536. As such a difference between the two pendulums, due to atmospheric viscosity alone, is not easily credible, it seems clear that an important part of this resistance is due to some other cause, as indeed Professor Peirce suspects. In the Fort Conger observations, although, as the table of calculated $1:b$ shows, nearly uniform throughout, the resistance was certainly greater than in this building seven months before, where this quantity was 41^m or 43^m with heavy end up, and 123^m or 130^m with heavy end down. Much of this difference is due to the value of the quantity c, the coefficient of resistance proportional to square of velocity, employed. The heavy-end-up swings at Fort Conger gave 0.075 for $b:c$, and the heavy-end-down 0.048; the constant value 0.056, a weighted mean, was used in the reduction. Substituting the value 0.0413, used in the earlier reductions, these swings are best satisfied by taking $1:b = 42.2^m$ and 120.7^m on the average, the heavy-end-down value showing a decidedly more rapid rate of decrement. Mr. Peirce deduces for the pendulums of this pattern, using $b:c = 0.0413$, a value of 130.3^m with heavy end down, thus making the Fort Conger decrement appear still more abnormally rapid. That the higher degree of resistance thus unmistakably indicated may have had some influence on the period of oscillation is altogether probable. Supposing that the period was thereby shortened, and applying to each heavy-end-down period, except in swing 14, a plus correction of 0.013^s times the excess of the b deduced for each swing over a standard value, the agreement of the separate results is perceptibly improved. To bring swing 14 into agreement with the others a coefficient of $+0.050^s$ is required. The heavy-end-up swings, after the interchange of edges, are improved by a correction in this direction; not so those before interchange, except the aberrant swings 12 and 15. The former of these indicates a correction of $+0.041^s\,\Delta b$, while the arc observations in swing 15, not being satisfied by increase of the coefficients b and c, as are 14 and 12, show that the resistance, whatever it was, was in this swing irregular. The calculated values of $1:b$ are in general smaller, indicating greater resistance when the pendulum is suspended from edge No. 9 in either position, but very slightly so, so that no empirical correction of this nature is found to have an appreciable effect in explaining away the apparent decrease of length in the pendulum at the time of the change of edges, and we are left to believe that such decrease actually occurred.

The probability of a loose knife-edge is the real justification of the course properly followed by Mr. Peirce in depending on the latter half of the observations alone for a value of gravity. One correction to his final result appears, however, to be needed: An increase of the expansion allowance by 0.0000074^s. He states that his expansion "coefficient 18.24^μ is for the temperature of 24.6° C.," apparently because the comparisons between Pendulum No. 1 and Meter B were made about that temperature. But the observations of Meter A, on which the adopted coefficient for B depends, were made (1876 Report, page 274) about 8° C.; taking this as the temperature at which the coefficient 18.24^μ holds good, we have as the value for −7.7° C. 17.93^μ. Increasing T_d, T_u, and the "reversible pendulum" period by 0.0000074^s, we must increase the double logarithm by 0.0000064, when the "station error" becomes −0.0000097, and the conclusion in favor of a term in odd powers of the sine of the latitude is correspondingly weakened. It should be remembered that this result is subject to three uncertainties: Whether the latter observations were alone made with a pendulum of the length found in 1884; whether, in correcting periods of the simple pendulum for temperature, allowance for the expansion of the metal is sufficient, and whether the unusually rapid decrement of arc at this station was due to a cause that left the period unaffected. Another point, which does not appreciably affect this result, is nevertheless worth noting. If the reversible-pendulum period equals $(74.914\,T_d - 25.160\,T_u) \div 49.754$, $\frac{3}{2}T_d - \frac{1}{2}T_u$ must be increased by $0.0057(T_d - T_u) = 0.0000040^s$ at the Smithsonian, 0.0000037^s at Fort Conger. This might be diminished by 2 in the seventh place to allow for the factor under the radical in the first formula above. Professor Peirce, at the end of his report, uses a quite different correction.

III. The additional tables here submitted are:

(1) A discussion of the time observations on which depends the rate of the chronometer used.

(2) The times of reaching successive thousandths of radius in observations of decrement of arc. These are taken directly from the records left by Mr. Israel.

(3) A general summary of the results for time of infinite arc, mean of right and left readings, for four arcs at about equal intervals of time, by preliminary assumed values of b^{-1} and by corrected values of b^{-1}; t_∞ having weights equal to 35, 42, 6, and 1 for the four arc-readings selected the correction to b^{-1} is found from the excesses of the separate t_∞ over their weighted mean, being $\frac{1}{7}$ the last excess $+\frac{3}{7}$ the third $+\frac{4}{7}$ the second $-\frac{10}{7}$ the first. The agreement of the four values of t_∞ would obviously be improved if a correction of bc^{-1} (the constant value 0.056 being used in the calculation) were also introduced; but the exactness attained is sufficient for the arc correction.

(4) A more complete presentation of the center-of-mass observations made in January last.

Yours, very respectfully,

HENRY FARQUHAR.

COMPUTATION OF TIME FROM TRANSIT OBSERVATIONS AT FORT CONGER.

(December 28, 1881, to February 4, 1882, inclusive.)

Two independent computations have been made. In the second computation the azimuth was assumed constant for several sets during five periods, the weighted mean of the values obtained separately for each set being used in reducing all sets in the period. In the least-square work the weights multiplied by $\sec^2\delta$ (wC^2) were first found, and the weight of the star-observation in determining the time correction (w) obtained by multiplying this by $\cos^2\delta$. The weights were obtained by the method of Mr. Schott's pamphlet (U. S. Coast Survey Report for 1880, Appendix 14).

As the errors of observation and of reading the sheets (in most of the observations; in a few cases the sheets were accessible and the latter class of errors corrected by a second reading) were abnormally large, a special computation of the error of transit over a thread was required; for that purpose all the incomplete transits in which the star was observed across 2—4 threads (the mean of the threads having been calculated separately for each thread observed) were taken and the $\overline{me}^2$ for the star found by dividing the sum of the squares of the individual discrepancies by the number of threads observed, less one. Means of values of $\overline{me}^2$ were found, if there was more than one for a given value of $\sec^2\delta$. Reductions for the observer's reading of chronograph sheets and for the second reading were made separately.

The following table shows the results of this work, the column "do. calc'd" being derived from the formula

$$\overline{me}^2 = 0.1 + 0.3\sec^2\delta.$$

The values for "second readings" correspond to about one-third of these, as is also shown in the table. Second readings were therefore given treble weight without further investigation. The number of cases in which these readings showed an error of one or two entire seconds in the observer's readings proved that there ought to be a considerable difference in the weight allowed the two.

For an equatorial star $\overline{me}^2 = 0.4 \therefore \epsilon^2 = 0.18$; and assuming for ϵ four times the Naval Observatory value (Appendix 14, page 38) we have $\epsilon_1 = 0.136^s$ and $\epsilon_1^2 = 0.018$.

Hence the weight of an incompletely-observed star appears to be inversely as $0.018 + \frac{0.18}{N}$ or $1 + \frac{10}{N}$. In the case of second readings this quantity becomes $1 + \frac{10}{3N}$.

The weights used in computation were

$$wC^2 = \frac{12}{(3+\cos^2\delta)\left(1+\frac{10}{N} \text{ or } 1+\frac{10}{3N}\right)}$$

Transit observations at Fort Conger. Mean error of a single thread.

$Sec^2\delta$.	First reading.		do. calc'd.	÷3	Second reading.	
	No. obs.	$\overline{me}^2$			$\overline{me}^2$	No. obs.
1.0	2	0.41	0.40	0.13	0.05	1
1.1	2	0.58	0.43	0.14	0.18	2
1.2	5	0.73	0.46			
1.3	5	0.30	0.49			
1.4	1	0.24	0.52	0.17	0.45	1
1.6	1	0.01	0.58			
1.7	2	0.26	0.61			
1.8	1	0.64	0.64			
2.0	5	0.91	0.70	0.23	0.03	2
2.1	3	1.06	0.73	0.24	0.14	2
2.2	3	0.75	0.76			
2.3	1	0.76	0.79			
2.7			0.91	0.30	0.41	1
4.6	1	0.39	1.48			
6.1	2	0.28	1.93			
6.9	1	0.40	2.17			
8.0	1	1.37	2.50			
8.5	1	0.88	2.65			
10.8	1	1.65	3.34			
13.5	1	4.95	4.15			
14.2	3	6.25	4.36			
20.9	1	6.39	6.37			
33.9	1	13.36	10.27			

The thread intervals were deduced from a discussion of all the stars completely observed during the period, second readings being given treble weight. They are, for illumination west:

	s.
1	−44.455
2	−22.019
3	− 0.162
4	+21.919
5	+44.717

The following tables show the residuals in detail, with the value of the inclination for each star:

Date.	Star.	Level.	wC^2	Res.
		s.		s.
Dec. 28	α Cygni	−.18	1.1	−1.31
	Gr. 3373	−.13	.7	+9.01
	α Cephei	−.45	1.1	+ .63
	ε Pegasi	−.23	1.0	+ .42
Jan. 6	κ Cephei	−.11	.9	−1.82
	ε Cygni	−.07	1.0	+ .08
	ζ Cygni	+.01	1.1	+ .52
	α Cephei	[+.01]	1.2	−1.23
Jan. 7	α Persei	+.03	1.2	− .49
	η Tauri	+.06	1.0	+ .72
	α Tauri II	−.05	1.8	− .55
	α Camelop. II	−.59	2.3	+1.20
Jan. 7	η Urs. Maj. II	−.06	2.1	− .72
	η Bootis II	[−.06]	1.9	+ .42
	α Drac. II	−.10	.9	−1.56
	α Bootis II	−.16	1.9	+ .16
Jan. 8	θ Persei	−.05	1.2	+ .11
	α Ceti	−.02	.7	.00
	α Persei	+.35	1.2	+ .67
	η Tauri	+.68	.9	− .40
Jan. 8	20 Can. Ven	−.28	1.0	
Jan. 9	α Persei	−.14	1.2	+ .28
	η Tauri	+.05	1.0	− .20
	ε Persei	+.21	.8	+ .10
Jan. 10	α Aurigæ II	+.59	1.9	− .77
	α Orionis II	−.23	1.8	+ .57
	β Aurigæ II	[−.23]	1.6	− .16
	γ Gemin. II	+.07	1.9	− .04
	ε Bootis	−.01	1.1	.00
	β Urs. Maj	−.03	.9	+ .08
	δ Bootis	+.03	.9	+ .07
Jan. 11	δ Persei	−.15	1.2	− .54
	ε Persei	+.19	.9	+ .57
	α Tauri	+.05	1.0	+ .36
	α Aurigæ	+.05	1.1	− .49
Jan. 11	η Urs. Maj. II	+.03	2.1	+ .23
	α Drac. II	−.10	2.3	+ .95
	α Bootis II	[−.10]	1.2	− .51
Jan. 13	α Tauri	−.02	1.5	+ .99
	α Aurigæ II	−.07	1.9	−1.20
	β Tauri II	+.05	1.9	− .34
	22 Camelop. II	+.02	2.3	+ .66
Jan. 13	ε Bootis	−.26	1.1	− .33
	β Ursæ Maj	−.41	1.1	+3.02
	δ Bootis	[−.41]	1.1	− .19
	α Coron. B	−.10	.9	+ .37
Jan. 17	α Tauri	−.08	.3	−1.45
	α Camelop	−.04	.9	+2.84
	ι Herculis L.	+.24	1.2	+1.60
	α Orionis	[−.05]	1.0	+ .18
	β Aurigæ	−.05	.6	−1.16
	α Lyræ L.	[−.17]	1.1	− .19
	ε Geminorum	−.30	.9	− .85
Jan. 17	ε Bootis	−.15	1.1	+ .03
	β Ursæ Min	−.17	1.1	+1.79
	α Persei L.	−.67	1.2	+ .63
	α Coron. B	−.46	1.1	− .31
	τ Herculis	−.58	1.2	− .41
Jan. 18	γ Tauri	+.11	.9	+1.15
	α Tauri	[+.33]	1.0	+ .78
	α Camelop	+.55	1.3	−1.39
	ι Herculis L. II	−.01	2.1	−1.05
	α Orionis II	[−.02]	1.4	− .19
	β Aurigæ II	−.03	1.6	− .15
Jan. 18	α Coron. B. II	−.23	1.9	− .42
	ζ Persei L. II	−.10	1.2	+ .72
	φ Herculis II	+.14	2.1	− .29
	η Herculis II	+.38	2.0	+ .27
Jan. 19	θ Tauri II	−.06	1.9	− .32
	β Draconis L. II	−.37	1.9	+ .83
	α Orionis II	+.01	1.8	+ .68
	β Aurigæ II	[+.01]	.8	− .64
	ε Herculis L. II	+.21	1.9	− .12
	μ Geminorum II	+.03	1.9	− .55

Date.	Star.	Level.	wC^2	Res.
		s.		s.
Jan. 19	γ^2 Urs. Min	[−.19]	1.3	+4.11
	α Coron. B	−.19	1.1	−1.08
	ζ Persei L.	−.36	1.1	+ .40
	τ Herculis	+.07	1.0	+ .24
Jan. 20	ν Orionis	−.43	1.0	− .05
	η Geminorum	[−.29]	1.0	+ .22
	μ Geminorum	−.14	.9	− .19
	γ Geminorum	+.23	.7	− .03
Jan. 20	β Persei L.	+.06	1.1	− .08
	γ^2 Urs. Min	−.22	1.1	+3.12
	α Coron. B.	[−.22]	1.1	− .65
	δ Persei L.	−.10	.8	− .03
	ε Coron. B	−.10	.7	+ .23
	τ Herculis	−.10	.8	+ .43
Jan. 21	ι Herculis L.	−.23	1.2	− .85
	α Orionis	+.25	1.0	− .53
	β Aurigæ	−.10	.8	+ .91
	ν Orionis	+.07	1.0	+ .42
	η Geminorum	[−.03]	.7	− .57
	μ Geminorum	−.14	1.0	+ .72
Jan. 21	δ Bootis	+.11	1.1	− .55
	γ^2 Urs. Min	−.35	1.3	+ .67
	α Coron. B.	−.38	1.1	+ .20
	δ Persei L.	−.02	1.0	+ .10
	ε Serpentis	[+.11]	.9	+ .13
	ε Coron. B	+.23	.7	− .01
Jan. 23	β Geminorum	+.09	.8	+ .08
	ε Draconis L	−.13	1.3	+1.16
	κ Hydræ	+.13	1.0	+ .05
	ι Urs. Maj	+.03	1.2	− .38
Jan. 23	γ Draconis	−.33	1.2	+ .01
	μ Geminorum L	−.22	1.0	+ .01
	α Lyræ	−.53	.8	− .02
	β Lyræ	[−.53]	1.1	+ .05
Jan. 25	α Camelop.	+.64	.6	−1.42
	α Aurigæ	+.55	1.1	− .47
	β Tauri	+.58	.9	+ .67
	α Orionis	[+.69]	1.0	+ .01
	β Aurigæ	+.69	.6	− .46
Jan. 25	δ Bootis	−.02	1.1	− .24
	γ^2 Urs. Min	+.17	1.3	+1.16
	α Coron. B	−.05	1.1	+ .05
	ε Coron. B.	−.27	1.1	+ .03
	ε Persei L.	−.27	1.2	− .22
	τ Herculis	−.22	1.0	+ .08
Jan. 26	ι Herculis L.	−.24	1.2	+ .22
	α Orionis	−.11	1.0	+ .15
	β Aurigæ	−.22	.6	−1.10
	22 Camelop	−.03	.9	+3.93
	μ Geminorum	+.19	.5	−1.60
	χ Draconis L	−.02	1.3	+2.53
Jan. 26	β Bootis	−.05	.6	+ .17
	β Persei L.	[−.02]	1.1	− .44
	δ Bootis	+.01	1.1	− .32
	γ^2 Urs. Min	−.44	1.3	+2.34
	α Coron. B	−.11	1.1	− .28
	δ Persei L.	[−.11]	1.2	+ .73
Jan. 29	α Geminorum	−.49	1.1	− .03
	α Canis Min	[−.49]	1.0	+ .27
	β Geminorum	[−.09]	1.1	− .48
	Gr. 1374	−.09	.9	+2.79
Feb. 4	σ^2 Ursæ Maj	−.39	.6	+ .20
	α Cephei L	−.34	1.2	+1.36
	ε Leonis	[−.32]	1.0	+ .04
	α Leonis	−.31	1.0	+ .20
	γ^1 Leonis	−.21	1.0	+ .19
	δ Leonis	−.65	1.0	−1.34
	λ Drac.	−.85	1.1	+1.33
	λ Androm. L.	[−.80]	1.2	− .01
	χ Ursæ Maj.	−.75	1.0	+ .44

Time observations. Summary of results.

Epoch, sidereal time.			Azimuth. Computed.	Azimuth. Used.	Collimation.	Correction to 2490.	Rate + 0.1ˢ applied.	Rates applied { +.1052ˢ / +.122ˢ	Residuals.
		h.	*s.*	*s.*	*s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*s.*
Dec.	28	21.4	−467.5	−440.2	−6.28	+1 48 59.11	+1 49 4.17	+1 49 4.73	−1.72
Jan.	6	20.8	434.2	440.2	6.08	49 21.70	5.22	4.36	−2.09
	7	4.0	445.3	440.2	5.65	26.25	9.05	8.16	+1.71
	7	13.9	429.0	440.2	5.68	26.77	8.56	7.61	+1.16
	8	3.1	444.8	440.2	5.42	28.82	9.31	8.30	+1.85
	8	13.2		440.2	5.6	30.03	9.51	8.44	+1.99
	9	3.7	445.3	440.2	5.81	34.46	12.49	11.35	+4.90
	10	5.9	−454.8	−461.8	−5.46	31.67	7.08	5.80	−.65
	10	15.0	462.0	461.8	5.66	32.49	6.99	5.66	−.79
	11	4.3	453.1	461.8	5.87	33.37	6.54	5.14	−1.31
	11	13.9	467.6	461.8	2.31	35.20	7.41	5.96	−.49
	13	5.2	458.6	461.8	3.33	38.91	7.19	5.54	−.91
	13	15.2	470.9	461.8	3.84	39.84	7.12	5.42	−1.03
	17	5.6	−495.4	−497.3	−2.97	52.95	11.59	9.44	+2.99
	17	15.7	496.2	497.3	3.24	52.67	10.30	8.10	+1.65
	18	5.1	499.2	497.3	2.55	52.89	9.18	6.91	+.46
	18	15.8	490.3	497.3	3.57	52.33	7.55	5.22	−1.23
	19	5.9	493.4	497.3	3.21	54.03	7.84	5.44	−1.01
	19	15.9	502.6	497.3	3.73	55.14	7.95	5.50	−.95
	20	6.3	485.2	497.3	3.32	56.00	7.37	4.84	−1.61
	20	15.6	499.8	497.3	3.31	58.04	8.48	5.90	−.55
	21	5.9	504.5	497.3	3.35	50 1.10	10.11	7.46	+1.01
	21	15.5	497.7	497.3	3.85	0.15	8.20	5.50	−.95
	23	8.5	494.4	497.3	3.76	5.65	9.60	48 57.27	−.27
	23	18.4	497.6	497.3	3.31	6.52	9.48	56.93	−.61
	25	5.4	−480.9	−487.8	−4.25	11.85	11.31	57.99	+.45
	25	15.7	489.2	487.8	3.44	12.75	11.18	57.63	+.09
	26	6.0	486.5	487.8	3.89	14.94	11.94	58.08	+.54
	26	15.3	488.9	487.8	3.72	15.03	11.10	57.04	−.50
	29	7.6	−503.9	−497.6	−4.16	24.70	14.34	58.86	+1.32
Feb.	4	10.5	496.8	497.6	3.55	40.79	15.74	57.03	−.51

The correction to 2490, the chronometer used in the time observations, has, first, the uniform hourly rate of +0.1ˢ applied, and a more exact rate is found by a least-square calculation. The observations are divided into two parts, those up to and those after the second set on January 21. The results

$$\text{cor} = \begin{cases} +1^h\,49^m\,6.45^s + 0.1052^s \text{ (time in hours from January 0, } 0^h\text{) to January 22, at } 2^h \text{ sid. t.} \\ +1^h\,48^m\,57.54^s + 0.122^s \text{ (time in hours from January 0, } 0^h\text{) after January 22, at } 2^h \text{ sid. t.} \end{cases}$$

are tested by comparisons with the observations on the last column above.

The residuals found do not generally exceed the probable errors of observation, and the irregularities indicated are shown by comparison of other chronometers to be either (1) the effect of some cause affecting all of them nearly equally in the same way, or (2) errors in the time observations themselves. The second view is preferred, and the two uniform rates of +0.1052ˢ and +0.122ˢ therefore adopted.

In working out the chronometer comparisons the mean chronometer (No. 124) was treated as a sidereal chronometer having a high rate, and the corrections of all the chronometers were reduced to something near constancy by the application of uniform rates. The going of all five chronometers after the application of these uniform rates, as also the changes in the azimuth, are shown in the accompanying illustration.

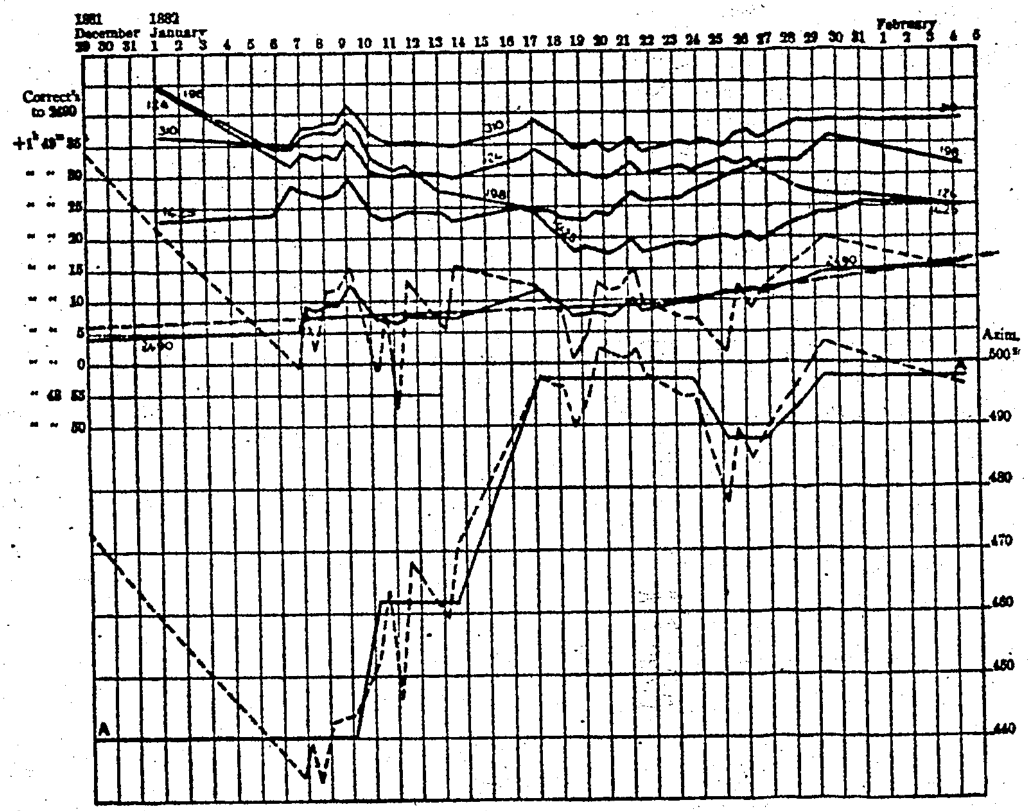
Seven errors in the comparisons receive hypothetical corrections in the reduction.

Time observations, errors of chronometers, and application of uniform rates.

Epoch, sidereal time.		No. 124. Correction (from 2490).	No. 124. Rate +9.88ˢ applied.	No. 310. Correction (from 124).	No. 310. Rate +0.05ˢ applied.	No. 198. Correction (from 124).	No. 198. Rate −0.04ˢ applied.	No. 1425. Correction (from 124).	No. 1425. Rate +0.26ˢ applied.
	h.	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
Jan. 1	3.7	+2 31 37.79	+2 26 64.11	+2 35 37.80	+2 35 36.42	−4 22 46.60	−4 22 45.49	−4 2 9.88	−4 2 17.10
6	19.2	49 48.68	53.38	42.07	35.11	61.05	55.48	1 40.12	16.32
6	14.5	52 57.63	51.65	42.80	34.88	61.94	55.60	30.28	11.52
7	2.0	54 53.14	53.54	46.03	37.53	60.71	53.91	28.33	12.54
7	14.7	56 57.94	52.86	46.78	37.65	60.35	53.04	25.51	13.04
8	1.9	58 49.01	53.28	47.96	38.27	60.77	53.01	23.05	13.48
8	13.7	+3 0 45.10	52.78	48.68	38.40	61.32	53.09	19.41	12.89
9	2.6	2 55.37	55.60	52.23	41.30	59.94	51.20	13.91	10.77
9	16.1	5 6.31	53.16	[1]50.81	39.21	23 2.82	53.54	12.99	13.35
10	2.5	6 46.57	50.67	48.83	36.71	6.99	57.29	13.25	16.32
10	15.8	8 57.30	50.00	48.24	35.45	8.70	58.47	10.41	16.94
11	2.7	10 44.82	49.82	48.42	35.09	9.76	59.09	7.40	16.77
11	14.6	12 42.93	50.36	49.33	35.40	9.53	58.39	[2]3.50	15.96
13	3.2	18 44.47	50.29	50.67	34.91	15.23	62.62	0 54.02	16.00
13	15.9	20 49.36	49.71	51.12	34.73	16.02	62.90	51.99	17.24
16	6.5	31 11.01	52.87	56.82	37.30	20.64	65.02	33.54	15.11
17	2.7	34 31.75	54.03	59.32	38.79	22.02	65.59	29.24	16.03
17	17.7	36 58.46	52.54	58.36	37.08	22.85	65.82	28.09	18.78
18	2.9	38 28.76	51.95	58.13	36.39	24.13	66.73	26.66	19.75
18	17.8	40 53.98	49.96	56.70	34.21	25.20	67.21	25.15	22.10
19	4.8	42 42.95	50.25	57.47	34.43	25.60	67.17	21.78	21.62
19	17.0	44 42.93	49.69	58.82	35.17	24.89	65.97	18.99	21.97
20	5.5	[3]46 46.20	49.46	57.98	33.71	25.92	66.50	16.25	22.48
20	17.1	48 41.80	50.45	59.34	34.49	24.49	64.61	12.59	21.86
21	4.8	50 38.93	51.99	[4]61.24	35.80	23.36	63.01	7.97	20.28
21	16.2	[5]52 29.55	49.97	59.61	33.60	24.91	64.10	7.22	22.49
23	7.2	58 56.15	51.25	[6]36 3.10	35.14	26.14	63.77	3 59 55.48	20.91
23	19.1	+4 0 53.04	50.57	3.32	34.77	25.60	62.76	52.67	21.17
24	5.6	2 37.36	51.15	4.51	35.43	25.29	62.03	49.19	20.44
25	4.0	6 20.00	52.48	4.74	34.54	24.68	60.52	42.97	20.02
25	16.6	8 23.70	51.69	7.04	36.21	24.25	59.59	[7]39.95	20.29
26	4.8	10 25.01	52.47	8.41	36.97	24.13	58.98	35.89	19.40
26	16.2	12 16.19	51.01	7.86	35.85	23.57	57.96	34.01	20.47
28	6.6	−[8]2 31 3.36	−4 22 47.93	12.53	38.60	25.06	57.92	20.94	17.38
29	5.9	27 12.20	46.97	13.43	38.34	23.11	55.03	13.69	16.23
29	15.4	25 38.20	46.83	14.06	38.49	22.55	54.09	11.19	16.16
31	6.8	19 8.81	46.71	16.23	38.69	25.24	55.21	58 59.03	14.26
Feb. 4	8.2	3 4.76	44.98	21.21	38.80	32.40	58.47	34.52	15.07

[1] 310 supposed 20ᵐ out.
[2] 1425 supposed 5ᵐ out.
[3] Seconds of chronometers supposed interchanged.
[4] 310 supposed 10ˢ out.
[5] 124 supposed 20ˢ out.
[6] 310 supposed 1ᵐ out.
[7] 1425 1ʰ out.
[8] 124 allowed to run down on the 27th.

Diagram, showing the errors of five chronometers after applying uniform rates, also the value of the azimuth, during observations for gravity, at Fort Conger, Grinnell Land, January, 1882.



——— *Azimuths uniform during five Periods, Corrections to Chronometer 2490 found on this Assumption, and Corrections to the other Chronometers on the Assumption that 2490 moves uniformly between Star-Observations, as then determined.*

- - - - - *Azimuths as originally calculated, and Corrections to 2490 on this Assumption. Also calculated Corrections to 2490, on the Supposition of uniform Rates before and after Jan. 22, 2h B. T.*

Pendulum at Fort Conger. Arc observations. Times of reaching successive thousandths of radius on each side.

Swing and face	1 *B*		2 *B*		3 *F*		4 *F*		5 *F*		6 *B*		7 *B*		8 *F*	
Date	Jan. 6, 11h to 12h.		Jan. 6, 1h to 4h.		Jan. 6, 5h to 6h.		Jan. 7, 10h to 11h.		Jan. 7, 12h to 2h.		Jan. 7, 4h to 5h.		Jan. 8, 10h to 11h.		Jan. 8, 11h to 2h.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
	m.	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*
.030	----	34.8	58.5	----	----	23.1	----	----	----	17.2	07.2	06.5	----	01.3	42.3	44.8
.029	----	----	01.5	----	24.0	----	----	----	19.5	----	08.2	07.6	----	----	----	46.4
.028	----	----	04.5	----	----	25.0	----	----	22.3	21.4	09.2	08.6	02.0	02.8	47.1	48.7
.027	36.9	----	07.6	01.0	25.9	----	----	----	24.5	23.3	----	09.9	03.3	03.9	49.2	51.7
.026	----	38.3	10.7	04.0	----	26.9	24.5	23.3	27.7	26.8	10.8	----	04.4	04.9	52.2	55.0
.025	38.8	----	----	06.9	27.7	----	25.5	----	31.2	30.2	----	12.0	05.3	05.8	55.7	----
.024	----	----	----	10.1	----	----	----	----	----	----	----	----	----	----	----	00.9
.023	----	----	17.5	----	----	----	----	----	37.5	36.7	----	----	----	----	01.6	04.2
.022	----	----	21.5	18.4	----	----	----	----	41.2	40.0	----	----	----	----	04.5	07.0
.021	----	----	25.9	22.2	----	----	----	----	44.4	43.4	----	----	----	----	07.8	11.5
.020	----	44.9	29.6	26.3	----	34.0	31.2	----	48.4	47.2	18.0	17.4	10.7	11.7	11.9	16.2
.019	46.0	----	34.0	30.0	35.2	35.9	----	----	52.4	51.1	19.1	18.4	12.2	13.2	16.9	21.2
.018	----	47.9	38.5	34.3	36.4	37.2	34.7	32.5	57.4	56.2	20.7	20.0	13.8	14.8	21.8	26.5
.017	49.1	----	43.2	39.0	38.1	38.9	36.2	----	02.3	00.9	22.2	21.9	15.6	16.5	26.9	31.6
.016	----	51.4	48.7	43.7	39.8	40.8	37.9	35.5	07.4	05.6	24.5	23.4	17.3	18.2	32.0	36.7
.015	52.7	----	53.3	49.2	41.8	43.0	39.7	36.8	12.8	10.6	26.6	25.6	19.3	20.3	37.2	43.2
.014	----	55.4	59.2	53.7	44.2	45.6	42.2	39.0	18.3	16.8	28.6	27.5	21.4	22.3	43.7	49.3
.013	56.8	----	07.4	59.9	46.6	47.8	44.3	41.0	27.0	23.3	31.1	29.7	23.7	24.9	50.0	57.4
.012	----	00.2	14.3	07.9	48.7	50.0	47.0	43.0	34.8	31.6	33.8	32.4	26.3	27.6	57.9	05.2
.011	03.0	03.5	22.4	14.9	51.2	53.0	49.8	45.2	43.3	40.7	37.0	35.3	29.1	30.5	05.6	14.2
.010	05.7	06.3	32.0	24.0	54.9	56.2	53.1	48.6	51.5	50.0	40.9	39.2	32.0	33.3	14.7	24.0
.009	08.4	09.3	43.0	34.1	58.6	00.1	56.5	51.8	02.4	00.1	44.4	42.6	35.6	37.2	24.6	35.7
.008	12.1	13.1	54.9	45.5	02.2	04.2	00.9	55.7	13.0	11.2	48.8	46.6	39.7	41.4	36.1	47.8
.007	16.3	17.9	07.4	57.2	06.7	09.1	06.0	59.9	24.8	22.5	53.7	50.8	44.2	46.4	48.5	02.2
.006	21.3	22.7	23.3	11.0	12.0	13.8	11.2	04.1	39.5	36.2	58.9	56.2	49.4	52.0	02.9	17.2
.005	26.2	28.5	46.7	27.3	17.3	----	17.0	09.8	58.3	52.5	05.5	01.8	55.8	----	17.9	34.9
.004	34.0	36.3	----	----	25.0	----	----	----	----	----	12.4	----	02.1	----	----	----
.003	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Swing and face	9 *B*		10 *B*		11 *F*		12 *F*		13 *F*		14 *B*		15 *F*		16 *F*	
Date	Jan. 8, 2h to 3h.		Jan. 9, 10h to 11h.		Jan. 9, 11h to 2h.		Jan. 9, 3h.		Jan. 10, 12h to 1h.		Jan. 10, 1h to 3h.		Jan. 10, 4h to 5h.		Jan. 11, 11h to 12h.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
	m.	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*
.030	50.8	49.9	----	09.5	----	47.8	----	----	----	15.7	42.7	45.7	----	36.3	16.2	----
.029	----	51.4	10.5	----	49.2	50.3	----	----	----	----	43.7	47.0	37.1	----	----	17.1
.028	----	----	----	----	51.3	53.0	----	----	----	17.3	44.8	48.4	----	----	18.0	----
.027	53.9	----	----	11.8	54.0	55.5	----	----	----	----	46.1	49.8	----	38.0	----	18.8
.026	----	----	13.3	----	57.0	58.2	----	----	16.7	18.8	47.8	51.0	38.7	----	19.8	----
.025	----	54.9	----	13.5	59.5	01.0	----	----	----	----	49.0	----	----	39.2	----	20.9
.024	----	----	----	----	----	----	----	----	18.0	----	50.4	----	----	----	----	----
.023	----	----	----	----	05.8	07.0	----	----	----	----	----	----	----	----	----	----
.022	----	----	----	----	08.3	09.4	----	----	----	----	----	----	----	----	----	----
.021	----	----	----	----	11.2	12.8	----	----	----	----	----	----	----	----	----	----
.020	01.5	----	----	----	15.6	17.3	----	----	----	----	57.0	01.5	----	----	26.9	----
.019	03.2	02.3	21.5	----	19.9	22.6	----	----	----	----	58.8	03.8	----	----	----	28.5
.018	05.3	04.5	22.8	22.1	25.7	27.2	----	----	----	28.7	00.8	06.5	----	44.5	30.0	30.5
.017	07.8	06.3	24.9	24.0	29.7	31.3	----	----	----	30.6	02.9	09.4	45.7	----	31.8	32.5
.016	09.8	08.5	26.7	25.8	34.6	37.4	----	----	----	32.8	05.8	12.2	----	46.5	33.7	34.4
.015	11.9	10.5	28.8	27.9	39.7	43.5	----	----	29.7	35.3	08.5	15.2	47.6	----	35.8	36.5
.014	13.8	12.5	30.9	29.9	45.7	49.2	11.6	----	31.7	37.6	11.4	18.6	----	48.4	37.9	38.6
.013	16.1	14.4	33.1	32.0	52.6	56.2	----	12.8	34.0	40.3	14.4	23.3	49.4	----	40.3	41.1
.012	18.6	16.7	35.9	34.7	58.9	03.9	14.1	----	36.2	43.0	17.7	26.9	----	50.2	42.6	43.5
.011	21.8	19.3	39.0	37.7	07.9	13.0	----	15.7	38.5	46.2	22.1	32.5	51.7	----	45.7	46.6
.010	25.3	22.7	42.1	40.7	16.8	23.0	17.1	----	41.0	50.2	25.5	38.4	53.1	52.7	48.9	50.0
.009	29.4	26.2	45.8	44.0	27.1	34.1	----	19.1	43.8	55.1	29.8	45.9	54.5	54.2	52.8	53.8
.008	34.3	30.1	49.7	47.6	38.5	45.9	21.6	----	47.4	00.4	34.9	56.3	55.9	55.6	56.5	57.8
.007	39.2	35.1	54.2	51.7	50.7	59.7	----	23.7	51.9	06.0	41.8	08.3	57.2	56.8	01.6	02.7
.006	44.9	40.2	59.7	57.1	05.5	14.8	26.9	28.2	56.6	13.0	50.7	24.9	58.7	58.4	06.6	08.4
.005	50.7	45.8	----	04.2	22.9	36.0	31.2	----	01.8	----	01.7	----	00.4	00.0	12.5	----
.004	----	----	----	----	----	----	37.2	----	----	----	16.0	----	----	----	19.0	----
.003	----	----	----	19.9	----	----	----	----	----	----	32.7	----	05.2	----	----	----

Pendulum at Fort Conger. Arc observations. Times of reaching successive thousandths of radius on each side—Continued.

Swing and face	17 *B*		18 *B*		19 *B*		20 *B*		21 *B*		22 *B*		23 *F*		24 *F*	
Date	Jan. 11, 12^{h} to 3^{h}.		Jan. 11, 4^{h} to 5^{h}.		Jan. 13, 12^{h} to 1^{h}.		Jan. 13, 1^{h} to 4^{h}.		Jan. 13, 5^{h} to 6^{h}.		Jan. 17, 12^{h} to 1^{h}.		Jan. 17, 2^{h} to 4^{h}.		Jan. 17, 5^{h} to 6^{h}.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
	m.	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*
.030	48.2	49.7	05.8	----	----	19.3	52.3	----	21.5	----	----	----	----	02.9	----	15.2
.029	50.5	52.0	----	----	----	----	----	54.3	----	22.4	----	----	04.0	05.3	----	----
.028	52.9	54.3	07.7	06.8	20.4	21.0	56.6	----	23.1	----	----	----	06.6	07.8	----	16.9
.027	55.4	57.0	----	----	21.3	22.0	----	58.8	----	24.3	----	----	08.8	10.4	----	----
.026	58.1	00.1	09.8	08.7	----	----	01.5	----	24.8	----	----	----	11.6	13.0	17.7	18.8
.025	00.8	----	10.7	----	23.1	----	----	04.1	----	26.3	38.0	----	14.6	16.1	----	20.0
.024	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
.023	06.7	09.9	----	----	----	----	----	10.8	----	----	----	----	21.7	23.5	----	----
.022	10.6	13.5	----	----	----	----	14.2	----	----	----	----	----	25.0	26.8	----	----
.021	14.4	17.3	15.8	----	----	----	----	18.3	----	----	----	----	28.5	30.7	----	----
.020	18.3	21.9	17.3	16.2	----	----	21.8	----	31.7	32.6	44.0	----	32.6	34.8	----	----
.019	22.8	26.5	18.6	17.5	30.5	31.6	----	26.5	33.3	34.1	46.0	44.9	36.8	38.8	26.4	28.1
.018	27.2	31.7	20.6	19.2	32.2	33.4	30.8	----	34.7	35.7	----	46.9	41.0	43.2	----	----
.017	32.7	37.9	22.6	21.0	34.0	35.2	----	35.9	36.3	37.4	50.3	----	45.6	48.0	29.6	32.4
.016	38.8	43.0	24.5	22.8	35.7	37.2	41.0	----	38.2	39.2	----	----	50.6	53.1	----	----
.015	43.9	49.0	26.5	24.9	37.6	39.2	----	46.5	40.2	41.2	54.3	52.0	56.0	58.8	33.8	36.3
.014	49.7	56.3	29.0	27.0	39.9	41.7	52.2	----	42.2	43.5	56.3	54.5	01.9	04.9	----	----
.013	57.3	03.3	31.4	29.2	42.5	44.2	----	00.3	44.4	46.1	58.5	56.6	08.2	11.5	38.6	41.0
.012	04.0	11.2	34.2	32.0	45.1	47.3	09.0	----	47.1	48.6	01.3	59.0	16.8	20.0	----	----
.011	11.8	20.5	37.7	35.2	48.0	50.5	----	17.9	50.0	51.2	04.9	01.9	25.5	28.6	43.8	46.7
.010	21.7	30.8	41.3	38.4	51.0	53.6	27.1	----	53.1	54.3	08.3	05.3	35.0	38.0	----	----
.009	31.5	41.9	44.9	42.2	54.2	57.3	----	37.2	56.8	57.8	12.7	08.8	45.5	50.5	51.1	54.3
.008	42.7	55.0	49.0	46.3	58.3	02.5	47.5	----	00.3	02.0	17.2	13.3	57.2	03.1	----	----
.007	56.6	08.8	54.0	50.5	03.1	07.2	----	03.0	04.2	07.3	22.5	17.9	08.8	15.5	59.4	04.5
.006	09.5	23.0	59.9	56.0	08.0	13.6	15.6	----	09.3	12.6	28.0	23.0	22.2	32.0	----	----
.005	23.6	40.0	----	02.3	14.3	20.7	----	36.0	15.0	----	34.4	28.7	39.5	53.4	10.8	17.3
.004	----	----	----	09.3	----	----	53.7	----	21.2	----	----	----	----	----	----	----
.003	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Swing and face	25 *B*		26 *F*		27 *F*		28 *F*		29 *F*		30 *B*		31 *B*		32 *B*	
Date	Jan. 18, 1^{h} to 2^{h}.		Jan. 18, 2^{h} to 5^{h}.		Jan. 18, 6^{h} to 7^{h}.		Jan. 19, 12^{h} to 1^{h}.		Jan. 19, 2^{h} to 5^{h}.		Jan. 19, 5^{h} to 6^{h}.		Jan. 20, 12^{h} to 1^{h}.		Jan. 20, 2^{h} to 4^{h}.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
	m.	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*
.030	02.8	----	32.3	----	09.3	10.2	36.5	36.9	04.5	----	50.5	----	34.6	35.5	02.5	05.6
.029	----	04.2	----	----	----	----	37.4	37.8	----	07.0	----	51.6	----	----	----	----
.028	----	----	36.7	34.6	11.2	12.0	----	----	09.6	----	52.2	----	36.5	37.2	07.3	10.4
.027	05.5	06.5	----	----	----	----	38.9	39.6	----	11.9	----	53.2	----	----	----	----
.026	----	----	41.5	39.1	13.2	14.2	40.1	40.6	14.7	----	54.0	----	38.1	39.0	12.9	----
.925	07.6	----	44.1	----	----	15.2	----	41.4	----	17.0	----	55.2	----	40.0	15.5	----
.024	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
.023	----	----	----	----	----	----	----	----	23.0	----	----	----	----	----	----	----
.022	----	----	----	----	----	----	----	----	----	27.2	----	----	----	----	24.6	29.5
.021	----	----	57.1	53.0	----	----	----	45.1	32.0	----	----	----	----	----	----	----
.020	----	14.5	----	----	20.4	21.8	----	----	----	36.0	01.0	----	----	----	32.1	37.7
.019	15.2	16.2	05.2	01.3	----	----	47.6	48.7	40.3	----	----	03.0	46.5	47.9	----	----
.018	16.7	17.8	----	----	23.4	25.0	49.1	50.6	----	44.7	04.5	----	----	----	39.9	47.0
.017	18.3	19.6	14.9	10.4	----	----	51.0	52.3	49.2	----	----	06.6	49.5	51.3	----	----
.016	20.0	21.5	----	----	26.8	29.1	52.6	54.1	----	54.3	08.4	----	----	----	49.8	58.1
.015	22.0	23.6	25.7	20.9	----	----	54.4	56.2	59.0	----	----	10.7	53.2	55.3	----	----
.014	24.3	25.8	----	----	31.1	33.6	56.5	58.3	----	06.4	12.5	----	----	----	01.0	11.2
.013	26.7	28.3	39.7	33.1	----	----	58.6	00.7	12.5	----	----	15.2	57.7	00.1	----	----
.012	29.6	31.1	----	----	36.1	39.1	01.1	03.6	----	21.5	17.2	----	00.4	02.8	14.6	26.6
.011	32.7	34.2	56.0	49.8	----	----	04.0	06.6	30.1	----	----	21.0	03.2	05.8	----	----
.010	35.7	38.0	----	----	42.1	45.5	06.9	09.8	----	39.3	23.5	----	06.3	09.3	29.9	43.4
.009	39.3	42.0	18.1	07.9	----	----	10.2	13.7	50.2	----	----	27.7	09.7	13.0	----	----
.008	43.2	46.2	----	----	50.0	54.3	14.0	17.8	----	00.0	31.2	----	13.4	17.2	48.0	10.0
.007	47.4	51.0	43.5	31.5	----	----	18.5	22.9	13.9	----	----	36.0	17.7	22.3	----	----
.006	52.4	56.8	02.1	45.3	00.1	----	23.3	28.7	----	30.7	40.9	----	22.8	28.1	15.1	43.0
.005	58.6	03.5	23.2	04.0	06.1	12.5	29.2	35.5	48.9	----	----	47.5	29.2	35.0	33.1	03.5
.004	----	----	----	----	----	----	----	----	----	10.6	53.7	----	----	----	----	----
.003	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Pendulum at Fort Conger. Arc observations. Times of reaching successive thousandths of radius on each side—Continued.

Swing and face	33 *B*		34 *B*		35 *F*		36 *B*		37 *B*		38 *B*		39 *B*		40 *B*	
Date	Jan. 20, 5^{h} to 6^{h}.		Jan. 21, 12^{h} to 1^{h}.		Jan. 21, 2^{h} to 5^{h}.		Jan. 21, 5^{h} to 6^{h}.		Jan. 23, 2^{h} to 3^{h}.		Jan. 23, 4^{h} to 7^{h}.		Jan. 23, 7^{h} to 8^{h}.		Jan. 25, 1^{h} to 2^{h}.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
	m.	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*
.030	26.2	----	32.5	----	14.5	----	----	20.8	27.8	28.8	----	08.6	----	56.0	----	----
.029	----	----	----	33.3	----	18.3	----	21.7	----	----	09.4	10.6	----	----	32.1	----
.028	----	26.7	34.2	----	19.4	----	----	----	29.5	----	11.6	13.1	----	58.0	----	32.8
.027	29.0	27.5	----	35.2	----	23.0	----	----	30.3	31.7	14.3	15.8	57.3	----	33.8	----
.026	----	----	36.0	----	24.6	----	----	24.9	----	----	17.2	19.1	----	----	----	34.6
.025	----	29.5	----	37.0	----	28.8	24.2	----	32.2	----	20.5	22.0	59.3	00.9	35.7	----
.024	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
.023	----	----	----	----	----	----	----	----	----	----	----	29.4	----	----	----	----
.022	----	----	----	----	----	39.3	----	----	----	----	30.3	33.0	----	----	----	----
.021	----	----	----	----	41.3	----	----	31.4	----	----	34.1	36.6	----	----	----	----
.020	37.9	35.7	42.9	----	----	47.5	----	----	38.5	40.2	37.9	41.0	----	07.9	----	41.4
.019	39.7	----	----	44.4	49.5	----	----	34.4	----	----	42.2	46.6	07.1	09.4	42.8	----
.018	41.4	38.7	45.8	----	----	56.0	30.5	----	41.4	43.8	47.7	51.7	08.7	11.5	----	44.1
.017	43.3	40.4	----	47.8	58.1	----	----	38.5	----	----	53.0	57.6	10.8	13.3	45.5	----
.016	45.3	42.3	49.7	----	----	07.5	33.5	----	45.2	48.1	59.0	03.8	12.6	15.5	----	47.8
.015	47.6	44.3	----	51.8	10.0	----	----	43.2	----	----	05.3	09.9	14.6	17.7	49.5	----
.014	49.9	46.4	53.6	----	----	19.6	37.5	----	49.3	52.4	11.4	16.0	16.7	20.3	----	52.0
.013	52.5	48.7	----	56.3	22.3	----	----	48.2	----	----	18.0	23.3	19.2	22.6	54.1	----
.012	55.3	51.3	58.3	----	----	34.0	42.0	----	53.9	58.0	25.0	30.8	21.5	25.4	----	56.8
.011	58.9	54.2	----	01.3	36.9	----	----	54.5	----	----	34.0	39.9	24.0	28.6	59.7	----
.010	02.6	57.3	04.7	----	----	51.9	47.3	58.3	59.7	05.1	43.1	50.5	27.3	32.6	----	02.7
.009	06.9	00.9	----	08.6	56.1	----	----	03.0	----	----	52.6	02.5	31.1	36.9	06.4	----
.008	11.4	04.3	12.0	----	----	16.5	53.0	08.2	07.3	14.0	05.1	14.3	35.1	41.8	----	10.6
.007	16.8	08.6	----	16.7	21.5	----	56.5	----	----	19.7	16.8	29.0	39.6	46.6	15.0	----
.006	----	14.0	21.9	----	----	45.9	00.6	19.7	16.7	----	31.6	44.9	44.4	52.9	----	20.3
.005	----	19.8	----	28.1	51.1	00.7	05.7	----	23.2	32.8	48.3	05.2	50.0	----	26.0	----
.004	----	25.9	35.2	----	----	----	10.9	----	----	----	----	----	57.4	----	----	----
.003	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Swing and face	41 *F*		42 *F*		43 *F*		44 *F*		45 *F*		46 *F*		47 *B*		48 (?)	
Date	Jan. 25, 2^{h} to 5^{h}.		Jan. 25, 5^{h} to 6^{h}.		Jan. 26, 1^{h} to 2^{h}.		Jan. 26, 2^{h} to 5^{h}.		Jan. 26, 5^{h} to 6^{h}.		Jan. 29, 1^{h} to 2^{h}.		Jan. 29, 2^{h} to 5^{h}.		Jan. 29, 5^{h} to 6^{h}.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
	m.	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*
.030	----	58.4	50.6	----	04.8	----	35.1	----	40.3	----	----	21.4	55.7	----	46.3	----
.029	01.3	----	----	51.4	----	06.1	----	39.5	----	41.8	22.5	----	----	57.5	----	47.2
.028	----	03.2	52.2	----	06.5	----	40.0	----	----	42.7	----	----	59.4	----	48.1	----
.027	06.7	----	----	53.2	----	07.7	41.8	44.5	----	----	----	24.0	----	01.0	----	49.1
.026	----	08.4	54.2	----	07.1	----	44.9	46.8	43.7	44.6	25.2	----	03.6	----	50.1	----
.025	12.6	----	----	55.2	----	09.4	47.3	49.8	----	45.8	----	26.0	----	05.4	----	51.2
.024	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
.023	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
.022	----	20.7	----	----	----	----	57.0	00.7	----	----	----	----	----	----	----	----
.021	26.0	----	----	----	----	----	01.3	04.5	----	----	----	----	----	----	----	56.4
.020	30.1	28.8	01.4	----	----	16.1	05.2	08.5	----	----	----	----	20.0	----	57.7	----
.019	34.0	32.3	----	02.9	16.5	----	09.1	12.7	52.1	53.7	34.6	----	----	23.5	----	59.1
.018	38.8	36.2	04.6	----	----	19.2	13.2	16.8	----	----	36.3	35.7	27.9	----	00.9	----
.017	44.0	41.6	----	06.4	19.5	20.8	17.3	21.7	55.3	57.3	----	37.6	----	32.7	----	03.0
.016	48.9	46.5	08.2	----	21.4	22.7	22.4	27.7	----	----	40.0	----	37.4	----	04.6	----
.015	54.0	52.3	----	10.8	23.3	24.9	28.6	34.0	59.0	01.0	----	41.6	----	43.5	----	07.1
.014	59.7	57.9	12.9	----	25.3	27.1	35.0	40.8	----	----	44.4	----	49.5	----	09.0	----
.013	05.7	03.8	----	15.5	27.7	29.5	42.0	48.5	03.3	05.6	46.8	46.2	----	55.4	----	12.0
.012	11.8	09.8	18.1	----	30.2	32.3	49.5	56.3	----	----	49.9	49.3	01.5	----	14.6	----
.011	19.3	16.9	----	21.1	33.2	35.2	57.2	04.7	08.8	11.6	53.1	52.0	----	10.2	----	17.5
.010	27.6	24.8	24.2	----	36.1	38.5	05.6	13.5	----	----	56.3	55.2	19.3	----	20.8	----
.009	37.0	33.5	----	28.2	39.4	42.0	14.6	24.1	15.0	18.6	00.2	59.0	----	30.1	----	24.7
.008	47.4	43.5	31.6	----	43.0	46.5	25.7	35.7	----	----	04.7	03.6	40.1	----	28.7	----
.007	59.9	56.0	----	37.5	47.6	51.0	38.2	49.6	23.3	27.8	09.2	07.9	----	52.2	----	33.5
.006	13.6	08.7	41.3	----	52.6	56.2	52.4	04.9	----	----	15.3	13.4	09.2	----	38.4	----
.005	30.3	24.3	----	48.8	57.9	03.2	07.5	22.5	33.5	41.2	----	19.3	29.8	25.8	----	45.5
.004	----	----	----	----	----	----	----	----	----	----	----	27.7	----	----	52.0	----
.003	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

Correction for arc. Table of mean t_m and corrected b^{-1}.

Swing.	Approx. b^{-1}	t_m for $\phi=$ .0280	.0148	.0084	.0050	t_m wt. mean.	Corr. b^{-1}	t_m for $\phi=$ .0280	.0148	.0084	.0050	t_m adopted.
	m.	h. m.	m.	m.	m.	m.	m.	h. m.	m.	m.	m.	m.
1	39	10 53.3+	52.4+	51.7	50.0	52.7+	37.0	10 55.5	55.6	55.8	55.0	55.6
2	112	11 58.2	57.3	56.8	56.0	57.6+	110.3	12 0.1	0.0	0.3	0.2	0.1
3	39	4 42.0+	41.8+	42.0+	41.4	41.9+	38.7	4 42.4	42.3	42.7	42.1	42.4
4	39	9 39.1	37.8+	37.1+	35.8+	38.3	36.6	9 41.7	41.6	42.0	41.9	41.7
5	112	10 18.7+	18.2	19.0	15.1+	18.4+	111.1	10 19.7	19.6	20.8	17.4	19.7
6	39	3 26.0	25.4	26.3+	26.0	25.7	38.6	3 26.4	26.0	27.0	27.0	26.3
7	39	9 19.8	19.2	19.3+	19.5	19.4+	38.3	9 20.6	20.3	20.8	21.2	20.5
8	112	9 44.9+	46.1+	48.7	46.6+	45.8+	114.9	9 41.8	41.8	42.8	39.4	41.8
9	39	2 9.4+	10.1	10.6+	10.9	9.8+	40.3	2 8.0	8.1	8.0	7.6	8.0
10	39	9 28.2+	27.6	27.6+	27.3	27.9	38.1	9 29.2	29.0	29.5	29.5	29.1
11	112	9 49.0	47.4+	49.0	48.9+	48.2	110.7	9 50.4	49.5	51.6	52.2	50.1
12	39	1	69.6	61.2	53.9+	68.2+	21.5	2	37.0	36.8	37.7	37.0
13	39	11 33.5	31.9	32.5+	33.9+	32.8+	37.3	11 35.4	34.6	36.0	38.2	35.1
14	112	10 103.6	77.0+	54.4+	41.8	86.1	59.3	12 41.6	39.6	41.6	53.5	40.7
15	39	3 54.6+	46.4+	35.7	22.6+	48.8	19.3	4 16.3	17.3	15.8	11.9	16.7
16	39	10 35.1	35.4+	36.0+	36.1+	35.3+	39.9	10 34.1	34.0	34.2	33.9	34.1
17	112	10 50.6	52.2+	55.5+	51.8+	51.8	115.7	10 46.5	46.5	48.0	42.6	46.6
18	39	3 24.4+	25.1	26.3+	26.8	24.9+	40.7	3 22.6	22.4	22.9	22.6	22.5
19	39	11 37.8+	37.9+	39.0	39.8+	38.0	39.9	11 36.9	36.5	37.2	37.6	36.7
20	112	11 53.3+	52.9+	55.2+	54.3	53.3	112.6	11 52.7	52.0	54.0	52.8	52.4
21	39	4 40.3+	40.1	40.1	39.3+	40.2	38.5	4 40.9	40.9	41.1	40.6	40.9
22	39	11	52.4+	53.8+	54.1	52.6+	41.5	11	48.5	48.8	47.8	48.5
23	112	0 3.9+	3.7	6.2+	5.9	4.0	113.1	0 2.7	2.0	4.0	3.2	2.4
24	39	4 33.5	34.4	35.7	36.4+	34.1+	41.1	4 31.2	31.1	31.4	31.2	31.2
25	39	0 22.1	22.3	23.4+	23.4+	22.3	39.9	0 21.1	20.9	21.6	21.2	21.0
26	112	0 32.5	29.6	31.2+	33.3	30.9+	109.1	0 35.7	34.1	37.1	42.6	35.1
27	39	5 28.8	29.5	30.8	31.7+	29.3+	40.9	5 26.7	26.5	26.9	27.0	26.6
28	39	11 55.5+	54.7	54.8+	54.8	55.0+	37.9	11 56.8	56.4	57.1	57.6	56.6
29	112	0 6.1	6.2	7.7+	8.5	6.3	113.1	0 4.9	4.5	5.5	5.7	4.8
30	39	5 9.4	9.8	10.2+	9.4+	9.6+	39.7	5 8.6	8.7	8.8	7.7	8.7
31	39	11 53.9	53.7+	54.2+	54.4+	53.8+	39.1	11 53.8	53.6	54.0	54.2	53.7
32	112	11 65.9	65.6	65.9	67.6	65.8	112.0	12 5.9	5.6	5.9	7.6	5.8
33	39	4 44.5	45.3	46.7+	47.4+	45.1	41.1	4 42.2	42.0	42.5	42.2	42.1
34	39	11 51.3+	50.9	51.1	50.4	51.1	38.4	11 52.0	51.8	52.3	51.9	51.9
35	112	0 16.8+	17.1+	18.8+	16.2	17.1+	113.0	0 15.7	15.6	16.8	13.7	15.7
36	39	4 39.1+	38.6+	39.3+	38.7+	38.9	38.6	4 39.6	39.3	40.2	39.7	39.5
37	39	1 47.2	48.0	49.3+	50.2+	47.8	41.0	1 45.0	44.9	45.3	45.2	45.0
38	112	2 9.5	13.1+	16.2+	16.4+	11.9	119.0	1 61.8	62.2	62.0	58.9	62.0
39	39	7 14.3	15.4+	17.0	17.7	15.1	41.6	7 11.4	11.4	11.7	11.2	11.4
40	39	0 50.0	49.0+	49.3+	48.7	49.4+	37.7	0 51.4	51.1	52.0	52.0	51.3
41	112	0 60.5	58.6+	53.2+	47.0	58.9	105.4	1 7.8	9.0	6.7	3.5	8.3
42	39	5 9.4	9.9+	10.9	10.7+	9.8	40.3	5 8.0	7.9	8.3	7.5	8.0
43	39	0 23.6+	23.5	23.6+	23.0	23.5+	38.8	0 23.9	23.8	24.1	23.5	23.9
44	112	0 37.6	37.4+	37.9+	35.2	37.5	111.7	0 37.9	37.9	38.6	36.0	37.9
45	39	4 59.5	59.4+	59.7+	59.7+	59.5	39.1	4 59.4	59.3	59.5	59.5	59.4
46	39	0 40.3+	41.3+	42.6	43.2+	41.0+	41.2	0 37.9	37.9	38.1	37.8	37.9
47	112	0 56.1	48.9+	47.4	47.4	51.7	100.9	1 8.3	6.3	10.0	15.2	7.5
48	39	5 5.3	6.3+	7.4+	7.4	6.0	41.1	5 3.0	3.1	3.2	2.1	3.0

PENDULUM, PEIRCE No. 1.

Center of mass.

(H. Farquhar, observer, January 10, 1887.)

In middle.	Near light end. Number down.	Near light end. Number up.	In middle.	Near heavy end. Number up.	Near heavy end. Number down.	In middle.	Near heavy end. Number up.	Near heavy end. Number down.	In middle.	Near light end. Number down.	Near light end. Number up.
	0.753	0.753		0.453	0.428		0.438	0.445		0.717	0.722
	.739	.753		.444	.438		.450	.446		.724	.724
60.067	.752	.747	10.027	.436	.435	10.027	.446	.429	60.048	.726	.725
	.741	.752		.442	.435		.443	.443		.714	.724
− 0.749	.755	.750	− 0.440	.450	.438	− 0.442	.447	.432	− 0.723	.723	.725
59.318	0.748	0.751	9.587	0.445	0.435	9.585	0.445	0.439	59.325	0.721	0.724
Difference.	....	....	49.731			Difference.	....	....	49.740		

	cm.	cm.
Adopted mean k_d-k_u	49.736	
Reduction to stop-meter at 68.3° +	.018	$k_d=74.914$
k_d-k_u in terms of stop-meter	49.754	$k_u=25.160$
k_d+k_u in terms of stop-meter	100.074	

These measures were made with edge 9 at light end and 10 at heavy end. The edges being interchanged the center of mass is moved by the ratio of the difference between the masses of 9 and 10 (found by Dr. Clark to be 0.6744^{grm}) to that of the pendulum, multiplied by the distance between the two edges in position, or $\frac{0.674}{10436}\times 101.8^{cm}=0.0066^{cm}$, and with reference to the edges by the difference between the distances of the two from the center of figure, or 0.0167^{cm}, making a total change in k_d or k_u of 0.0233^{cm}. We have then, after change of edges

$$k_d=74.914+.023=74.937 \text{ cm.}$$
$$k_u=25.160-.023=25.137$$