LICK OBSERVATORY BULLETIN

NUMBER 402

A DETERMINATION OF THE LONGITUDE OF THE LICK OBSERVATORY

BY

H. M. JEFFERS

Advantage was taken of the Radio Time Signals for the World Longitude Determination in October and November, 1926, to effect a re-determination of the longitude of the Lick Observatory. The work was undertaken, first, to obtain an improved value of the longitude of this place, one consistent with the results of the other observatories cooperating in the International scheme, and second, to examine into the performance of the Meridian Circle as an instrument for the determination of time.

The Repsold Meridian Circle has been amply described in previous *Publications*. The only important change made was the substitution of a self-registering micrometer for the fixed wire arrangement. A spring driven clock-work for driving the transit wire was available but was not used, since it did not seem advisable to add so much unsymmetrically placed weight to the telescope tube. A single transit thread was used. The micrometer produces ten breaks per revolution, with two additional ones to locate the beginning of a revolution. Usually twenty breaks were measured on each star. The value of one revolution of the micrometer is $3^{\circ}.206$. It conveniently happens that the correction for one-half the width of the micrometer contact strip almost exactly cancels the correction for diurnal aberration.

The level error was obtained from nadir observations only, as there was no spirit level to give an independent check. The collimation was obtained from the collimators, and also from the nadir at reversal. Twenty-seven determinations of collimation were made, and the two methods gave results in satisfactory accord. The

azimuth was usually obtained by using one circumpolar in combination with several time stars. A time determination consisted of six or seven stars, usually, with a similar set after reversal. On seven nights observations were made in both positions of the instrument, and on four other nights in but one position.

There is decided evidence that the time determinations are affected by a reversing error, such as has been found elsewhere. An inspection of the clock correction diagram will show that observations made with the telescope in the position clamp west indicate the clock to be several hundredths of a second faster, usually, than similar observations made in the position clamp east. The pivots of the instrument have not been investigated for inequality or imperfections of figure, though possibly the source of the error does not lie here. At any rate it is hoped to look into the effect more closely as opportunity allows. The best that can be done now appears to be to take a reasonable average between the results in the two positions. The separate determinations of clock correction were plotted on a large scale, and the curve was then drawn which seemed best to indicate the state of the clock. This procedure leads, of course, to a "smoothed" clock rate. From the curve were read off the values of the clock corrections for the times of the radio signals.

The Riefler Clock was used as the time keeper. Shortly before this work it was taken apart and cleaned, and some leaks in the containing cylinder were stopped. There was no temperature control in the clock room, but in the thick-walled basement, where the clock is mounted, the variations in temperature are quite

slow, with scarcely any diurnal fluctuations. The rate seems to have been fairly good, though the series was not long enough to give an effective test of clock performance. The series, moreover, was interrupted by an earthquake which seems to have changed the correction several hundredths of a second. This earthquake stopped the Hohwü clock, the pendulum of which swings at right angles to that of the Riefler.

For the reception of the short wave signals a "Grebe Short Wave Receiver" was used, Type CR-18. It comprises a regenerative detector and one stage of audio frequency amplification, two tubes. An antenna about fifty feet long was used with it. The quickly changed

times with good intensity, but the interference would scarcely have permitted automatic records, had the attempt been made.

The recording apparatus was similar to that described in the U. S. Naval Observatory circular, with the differences that one more stage of low frequency amplification was used, and that a "tone filter" or "tuned by pass" was used at the input to the apparatus. This simple contrivance, made from such material as happened to be at hand, assisted considerably in reducing both static and interference, and it also had the unexpected effect of making the system more stable. Relay chattering, which sometimes causes trouble in

coils and stability made this receiver very convenient to handle. For the reception of long waves, an amplifier was constructed in our shop, after a design furnished through the courtesy of the Bureau of Standards. This amplifier contained four stages of resistance coupled amplification, followed by an autodyne detector using honeycomb coils, and one stage of low frequency amplification, a total of six tubes. For the input to the amplifier an arrangement of honeycomb coils was tried, but the selectivity was insufficient. In the latter part of October, a United States Navy Type SE-1899 tuner was lent by courtesy of the Naval authorities in San Francisco. With this tuner between antenna and amplifier, the recording of Annapolis (NSS) and Honolulu (NPM) was quite successful. An antenna about 300 feet long was used. Undoubtedly a loop collector would have still further increased the selectivity, but this was not tried. With the arrangement used, Saigon and Bordeaux signals were heard at

such installations, was nearly, if not quite, suppressed. The relay was a standard telegraph type, with the coils wound to a high resistance. The output of either the short or long wave set was fed into the recorder, so that in receiving short wave signals, a total of five tubes was used, while nine tubes were used for long waves. The long waves gave the better records, but the long wave set was not in reliable operation till most of the good observing weather had passed. No attempt was made to use the numerous records of time signals obtained which were not favorably situated with respect to observations for time.

Two lags needed to be considered, that of the transit micrometer relay, which changed the "makes" of the transit micrometer to "breaks" in the chronograph circuit, and that of the radio and recording apparatus. On most of the observing nights, the lag of the recorder alone was measured, by putting the clock relay, in series with about three volts of dry cells, directly into the

recorder. This amounted to about 0^s.03, and the variation from this was small. Later a more careful investigation was made, using both a high frequency buzzer and a tube oscillator. These gave a signal which passed through the radio apparatus, and thus measured the entire lag, not that of the recorder alone. The buzzer and tube oscillator were arranged to run continuously, the clock relay being adjusted to suppress the signal in one case, and change the frequency in the other. The buzzer, which gave a rough note in the oscillating receiver, gave a slightly larger lag than the tube oscillator. Various trials showed a negligible difference in lag for short and long wave signals, 0^s.045, and 0^s.048 respectively. In the reductions the value 0^s.046 was used for both. It was scarcely to be hoped that the lag would stay constant for varying conditions of signal strength and apparatus adjustment, but it is believed that the variations were not important. An effort was made to keep the adjustments uniform, and the measures of recorder lag during the reception of signals are quite consistent. The determination of the lag of the transit micrometer relay, which breaks the circuit when there is current through the coils, yielded a value of 0^s.011, which was used in the reductions. The lag was measured by putting this relay alternately in and out of the circuit controlling the tube oscillator, and measuring the difference on the chronograph as recorded through the radio apparatus.

Using the reference numbers of the U. S. Naval Observatory, signals observed here were as follows:

No.	GCT	Meters	
1	02:55—03:00	17,145	Annapolis
4	03:20—03:25	75	Bellevue
5	03:30—03:35	11,500	Honolulu
6	03:40—03:45	37	Honolulu
13	10:10—10:15	17,145	Annapolis
15	10:20—10:25	75	Bellevue
16	10:30—10:35	11,500	Honolulu
17	10:40—10:45	37	Honolulu

All signals were of the Rhythmic type except No. 1, Annapolis, which was the American code. Thirty or forty ticks were measured, in general, distributed over the record. The times were reduced to that of the last tick, using the Naval Observatory values for the rates of the radio signals. The clock times of reception of the last tick, corrected for a transit micrometer relay lag of +0^s.011, a radio apparatus lag of -0^s.046, and for the errors of the clock, are:

	No.	
Oct. 17	4	20 ^h 57 ^m 55 ^s .9
	6	21 18 05.5
	17	3 19 13.4
19	6	21 26 49.630
22	4	21 17 38.770

	No.	
Oct. 22	6	21 ^h 38 ^m 27 ^s .444
23	4	21 21 35.319
25	15	4 30 37.459
26	6	21 53 57.500
30	6	22 09 28.545
	15	4 50 20.155
31	4	21 53 07.741
	6	22 13 21.351
Nov. 3	4	22 04 57.371
	15	5 06 6.390
	16	5 16 15.915
	17	5 26 7.696
4	5	22 19 00.971
	6	22 29 51.957
17	1	22 35 17.031*
	13	5 51 16.508
	15	6 01 18.134
	16	6 06 40.004
	17	6 21 27.683
Nov. 18	1	22 39 13.638*

* Clock time as observed, no corrections. These were used only to get the clock rate. The time observation Nov. 17 was with telescope clamp E only, and the clock correction used includes -0^s.020 for reversing error.

The times of reception of the signals at Washington and San Diego were obtained from the Naval Observatory Circular, the U. S. Coast and Geodetic Survey Circular gives the times observed at Honolulu, and those observed at Vancouver and Ottawa have been published by the Dominion Observatory at Ottawa. The times as published were corrected for transmission time to reduce them to consistency with the times observed here, assuming a transmission velocity of 180,000 miles per second.

The following table gives the concluded difference in longitude between the Meridian Circle of the Lick Observatory and the various other stations.

	Signal No.	Washington	San Diego	Honolulu	Ottawa	Vancouver
Oct. 19	6	.....	.....	20 ^h 35	.....	53 ^h 40
22	4	19 ^h 19	46 ^m 54	.....	43 ^m 01	.....
22	6	.....	.....	.....	.....	.43
23	4	.....	.56	.....	42.99	.....
25	15	.18	.55	.....	43.02	.43
26	6	.....	.....	.34	.....	.38
30	6	.....	.....	.32	.....	.39
30	15	.23	.60	.....	.04	.37
31	4	.20	.59	.....	.03	.36
31	6	.23	.....	.....	.....	.36
Nov. 3	4	.19	.57	.....	.00	.39
3	15	.21	.58	.....	.02	.36
3	16	.....	.58	.33	.01	.36
3	17	.....	.....	.....	.....	.....
4	5	.....	.57	.36	.....	.43
4	6	.....	.....	.43	.....	.42
17	13	.25	.61	.....	.03	.34
17	15	.....	.58	.....	.05	.31
17	16	.....	.55	.....	.06	.35
17	17	.....	.....	.....	.....	.32

AVERAGE DIFFERENCES

Lick—Washington	= +2 ^h 58 ^m 19 ^s .210
Lick—San Diego	= +0 17 46.573
Lick—Honolulu	= -2 24 20.355
Lick—Ottawa	= +3 03 43.024
Lick—Vancouver	= -0 05 53.376

The comparison with the Coast and Geodetic Survey results for Honolulu is based largely on short wave signals, upon which the Honolulu observer does not place much dependence, and the comparisons are few. Longitudes have not at this date been announced for Ottawa and Vancouver, so no immediate use can be made of our comparison with these places.

It will be noted that the figures above for the difference San Diego-Washington differ by 0^s.012 from the Naval Observatory value for this quantity. An examination of the published times of reception of the radio signals at these two places shows that the greater part of the discrepancy is due to the accumulation of normal small errors in these quantities, since the radio observations upon which our value depends are comparatively few. The rest of the discrepancy arises from the accumulation of small errors in our reductions and in the reading of the chronograph records. At any rate, considering the Naval Observatory results, it is advisable to diminish the observed difference Lick-Washington by 0^s.006, and to increase the difference Lick-San Diego by the same amount, assigning equal weight to each. This gives: Lick-Washington = +2^h58^m19^s.204 and, adopting the Naval Observatory result for the longitude of Washington with respect to Greenwich, 5^h08^m15^s.753, we have the following longitude for the Meridian Circle referred to Greenwich:

$$8^{\text{h}}06^{\text{m}}34^{\text{s}}.96$$

which is the longitude to be used until further notice. For the latitude of the Meridian Circle, reference may be made to Professor Tucker's value, in the Appendix to Volume XV of the *Publications of the Lick Observatory*. This value is:

$$+37^{\circ}20'25''.62.$$

PREVIOUS DETERMINATIONS OF LONGITUDE

The earliest value given for the longitude of the Lick Observatory is 2^h58^m22^s.2 for the position of "Observa-

tory Peak" from Washington. This is recorded in Volume I of the *Publications of the Lick Observatory*, and the authority for it is not known.

In the addendum to Volume I is given the value 8^h06^m34^s.35, which is the position of the small dome with respect to Greenwich. It was derived by the U. S. Coast and Geodetic Survey by triangulation, but the addendum does not give complete details.

In 1888, the U. S. Coast and Geodetic Survey measured by telegraphic exchange of signals the difference between the Coast Survey Station, about ¼ mile east of the Observatory, and the Lafayette Park Observatory in San Francisco. This difference was 3^m09^s.047. The Coast Survey Station on Mt. Hamilton was connected with the Transit Meridian by triangulation, the resulting difference, referred to the Transit Meridian, being 3^m07^s.966. This value has not been remeasured or changed, though readjustments have changed the adopted value for the longitude of the Lafayette Park Observatory.

The U. S. Coast and Geodetic Survey Report for 1889 gives 8^h09^m42^s.77 for the longitude of Lafayette Park, and 8^h06^m34^s.807 for the longitude of the Transit Meridian.

The Report for 1897 includes the results of a readjustment of the Lafayette Park longitude to 8^h09^m42^s.861, yielding 8^h06^m34^s.895 for the Transit Meridian. This is the value adopted until the results for the World Longitude Determination of 1926 became available.

It may be added that it now seems desirable to adopt the Meridian of the Meridian Circle as that of reference, since the recent observations were made with this instrument, and since the Transit instrument has been removed to Berkeley. The Transit was 37.3 feet (0^s.031) west of the Meridian Circle, and the present U. S. Coast and Geodetic Survey Bench Mark on the terrace west of the 12-inch dome is 158.4 feet (0^s.131) west, and 34.1 feet (0^s.34) north of the Meridian Circle.

In conclusion, I should like to express my thanks to the U. S. Navy personnel, who made possible the loan to us of the SE-1899 tuner, to the Director of the Bureau of Standards, who furnished the design for the long wave amplifier, and to various members of the U. S. Naval Observatory and of the U. S. Coast and Geodetic Survey, for information and helpful discussion.

May 12, 1928.