LICK OBSERVATORY BULLETIN

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THE POSITION OF THE MIRE, LICK OBSERVATORY MERIDIAN CIRCLE

The Mire has been regularly observed during meridian circle work, and in general has been used as a check, during short periods of time, upon the azimuth derived from the circumpolar stars. In 1905, observations of a fundamental character were begun, and it became necessary to follow the Mire determinations more closely. Evidence of variation in the position of the mark, with respect to the meridian, became evident in the discussion, and this evidence will be presented here in detail.

The plan of observation during the first year, 1905-06, included two full programmes of stars, each of four hours duration, twelve hours apart. Each programme included *Polaris* and β *Ursae Minoris*, and four North stars between 60° and 70° Declination, two at each culmination. Two zenith stars, two South stars between -36° and -43° Declination, and a group of clock stars made up the balance of each programme. In one, α *Andromedae* was always included. Ample material is supplied in these programmes for the discussion of the azimuth from stars at various zenith distances, for the refraction determination, and for the zenith correction to transits and zenith distances. Both programmes were observed throughout the year.

When the epoch of a programme was close to noon, it was not possible to observe it entire, and in fact but few of the stars, even of the brightest, could be observed at high noon. In this case *Polaris* and β *Ursae Minoris* were always observed, if possible, and α *Andromedae* in its respective programme. During this first year three successive culminations of *Polaris* are taken to form a set of azimuth and Mire values, though sometimes as many as five are counted in one set.

In the period following, beginning in October, 1906, programmes of four hours duration were observed, mainly in the evening hours preceding mid-

night, and *Polaris* was regularly observed at both culminations, with α *Andromedae* each day. Four successive culminations of *Polaris* are taken to form a set, in this period, though occasionally a transit was lost by cloudiness, and in some sets five successive transits have been included. Excluding some transits, not utilized on account of failure to complete the desired succession, there are 209 transits of *Polaris*, in the period of 32 months, in 21 of which the fundamental observations were made. The combination gives 55 sets, of three to five successive transits in a set.

The original results are presented in Table I, containing the consecutive monthly record of azimuth and Mire from upper and lower culminations, and the positions of the Mire, thus derived. The variations in ΔM , the observed position of the Mire, can be seen, by inspection, to be somewhat systematic in nature. The material gives determinations at every hour of the day, from the same star, and except for the portion of the year lost by unfavorable weather, the distribution is good, every month being represented at least once.

From the consecutive record the material is next condensed into monthly values, in Table II. Inspection of this table shows the occurrence of large azimuths in March and September, but the variations during the remaining months seem to be accidental, and to follow no law. The changes in the position of the instrument can be discussed in another place; and here the azimuth will be abandoned for the present as a factor, only noting that since *Polaris* is used exclusively for this table and for Tables III and IV, the systematic errors of standard Right Ascension do not affect the results.

It will, however, be evident that annual variations in ΔM , the position of the Mire with respect to the meridian, are entangled in effect with daily variations, since *Polaris* comes to transit successively at a different mean time in each month.

TABLE I

MONTHLY RECORD OF DETERMINATIONS OF ΔM BY OBSERVATIONS OF POLARIS

Month	No.	<i>a</i> U. C.	Mire	ΔM	No.	<i>a</i> L. C.	Mire	ΔM	Mean <i>a</i>	Mire	ΔM	Sets
1905												
July	6	+ $\bar{s}356$	1 $\bar{s}220$	0 $\bar{s}864$	6	+ $\bar{s}431$	1 $\bar{s}337$	0 $\bar{s}906$	+ $\bar{s}394$	1 $\bar{s}278$	0 $\bar{s}884$	4
Aug.	8	.378	.260	.882	7	.397	.351	.954	.388	.305	.917	5
Sept.	6	.486	.404	.918	3	.572	.485	.913	.529	.444	.915	3
Oct.	8	.577	.385	.808	8	.524	.353	.829	.550	.369	.819	4
Nov.	2	.439	.258	.819	3	.412	.249	.837	.425	.253	.828	1
1906												
Jan.	5	.406	.278	.872	4	.320	.193	.873	.363	.235	.872	3
Mar.	1	.540	.342	.802	3	.529	.293	.764	.534	.317	.784	1
May	4	.336	.129	.793	4	.302	.115	.813	.319	.122	.803	2
June	7	.190	.037	.847	6	.264	.129	.865	.227	.083	.856	4
July	3	.232	.059	.827	3	.248	.172	.924	.240	.116	.876	2
Oct.	6	.325	.153	.828	10	.340	.194	.854	.332	.173	.841	3
Nov.	4	.296	.073	.777	5	.253	.042	.789	.275	.058	.783	3
Dec.	4	.365	.121	.756	4	.310	.097	.787	.337	.109	.772	2
1907												
Feb.	2	.231	.104	.873	2	.229	0.990	.761	.230	.047	.817	1
April	9	.276	.046	.770	8	.258	.029	.771	.267	.037	.770	4
May	9	.289	.058	.769	6	.270	.031	.761	.279	.044	.765	3
June	4	.318	.010	.692	3	.370	.079	.709	.344	.044	.700	2
July	6	.211	0.997	.786	4	.174	.124	.950	.192	.060	.868	2
Aug.	6	.278	.096	.818	7	.293	.237	.944	.285	.166	.881	3
Nov.	4	.340	.028	.688	4	.297	.004	.707	.318	.016	.698	2
1908												
Feb.	3	.421	.134	.713	2	.399	.050	.651	.410	.092	.682	1
Sum	107				102							55
Mean		+ $\bar{s}347$	1.152	0.805		+ $\bar{s}343$	1.169	0.826	+ $\bar{s}345$	1.161	0.816	
v				$\pm .048$				$\pm .072$			$\pm .056$	

TABLE II

POLARIS OBSERVATIONS, COMBINED BY MONTHS

Month	No.	<i>a</i> U. C.	Mire	ΔM	<i>a</i> L. C.	Mire	ΔM	Mean <i>a</i>	Mire	ΔM	Sets
July	3	+ $\bar{s}266$	1 $\bar{s}092$	0 $\bar{s}826$	+ $\bar{s}284$	1 $\bar{s}211$	0 $\bar{s}927$	+ $\bar{s}275$	1 $\bar{s}151$	0 $\bar{s}876$	8
Aug.	2	.328	.178	.850	.345	.294	.949	.336	.235	.899	8
Sept.	1	.486	.404	.918	.572	.485	.913	.529	.444	.915	3
Oct.	2	.451	.269	.818	.432	.273	.841	.441	.271	.830	7
Nov.	3	.358	.120	.762	.320	.098	.778	.339	.109	.770	6
Dec.	1	.365	.121	.756	.310	.097	.787	.337	.109	.772	2
Jan.	1	.406	.278	.872	.320	.193	.873	.363	.235	.872	3
Feb.	2	.326	.119	.793	.314	.020	.706	.320	.069	.749	2
Mar.	1	.540	.342	.802	.529	.293	.764	.534	.317	.783	1
Apr.	1	.276	.046	.770	.258	.029	.771	.267	.037	.770	4
May	2	.312	.093	.781	.286	.073	.787	.299	.083	.784	5
June	2	.254	.023	.769	.317	.104	.787	.285	.063	.778	6
Sum	21										55
Mean		+ $\bar{s}364$	1.174	0.810	+ $\bar{s}357$	1.181	0.824	+ $\bar{s}360$	1.177	0.817	
v				$\pm .039$			$\pm .064$			$\pm .052$	

In the first tabulation of results there is some evidence of a progressive change, masked to some extent by the periodic variation. By comparison of the values for the same calendar months that occur more than once, a progressive change of $-0^s.048$ per year has been derived for ΔM , and the original values of Table I have accordingly been corrected for a rate of $0^s.004$ per month, dating from the mean epoch of the table, November 1, 1906. The effect of this cor-

rection has been to reduce the average residual of ΔM from $\pm 0^s.048$ U. C. to $\pm 0^s.034$; and from $\pm 0^s.072$ L. C. to $\pm 0^s.058$; and for the mean from $\pm 0^s.056$ to $\pm 0^s.044$.

These corrected monthly values of ΔM are now combined in Table III, and the diminished residuals of this table, as compared with Table II, are confirmatory evidence of the improvement resulting from the application of the correction for progressive or secular change.

TABLE III
DETERMINATIONS OF ΔM , FROM POLARIS, CORRECTED FOR SECULAR CHANGE

Month	U. C.	M. T.	Comp.	O-C	L. C.	M. T.	Comp.	O-C	Mean	Comp.	O-C
July	$+.812$	17h7	$+.857$	$-.045$	$+.913$	5h7	$+.871$	$+.042$	$+.862$	$+.864$	$-.002$
Aug.	.840	15.7	.879	$-.039$	.939	3.7	.893	$+.046$	.889	.886	$+.003$
Sept.	.864	13.7	.856	$+.008$	.859	1.7	.870	$-.011$	.861	.863	$-.002$
Oct.	.792	11.7	.806	$-.014$	.815	23.7	.820	$-.005$	.804	.813	$-.009$
Nov.	.763	9.7	.767	$-.004$	.780	21.7	.781	$-.001$	.772	.774	$-.002$
Dec.	.762	7.7	.761	$+.001$	.793	19.7	.775	$+.018$	.778	.768	$+.010$
Jan.	.834	5.7	.781	$+.053$	.835	17.7	.795	$+.040$	.834	.788	$+.046$
Feb.	.831	3.7	.791	$+.040$	.744	15.7	.805	$-.061$	.787	.798	$-.011$
Mar.	.772	1.7	.782	$-.010$	.734	13.7	.796	$-.062$	.753	.789	$-.036$
April	.792	23.7	.764	$+.028$	.793	11.7	.778	$+.015$	.793	.771	$+.022$
May	.783	21.7	.771	$+.012$	.789	9.7	.785	$+.004$	.786	.778	$+.008$
June	.775	19.7	.809	$-.034$	.793	7.7	.823	$-.030$	.784	.816	$-.032$
Mean	$+.802$		.802	$\pm .024$	$+.816$		.816	$\pm .028$	$+.809$	.809	$\pm .015$
v	$\pm .029$				$\pm .047$				$\pm .035$		

The values of ΔM , in the columns of Table III headed U. C., L. C. and Mean have been treated for periodic variations, with results of similar form in the three cases. The expressions representing the corrections required by the Mire readings are as follows:

$$\begin{aligned}\text{U. C.} & +0^s.006 \sin \Delta t - 0^s.014 \cos \Delta t - 0^s.036 \sin 2\Delta t \\ \text{L. C.} & +0^s.053 \sin \Delta t - 0^s.050 \cos \Delta t - 0^s.033 \sin 2\Delta t \\ \text{Mean} & +0^s.030 \sin \Delta t - 0^s.032 \cos \Delta t - 0^s.034 \sin 2\Delta t\end{aligned}$$

In these expressions, Δt is the angle representing the difference between the time of transit of *Polaris* in any month, and the time of transit on January 1, which is 6.7 P.M. for upper culmination and 6.7 A.M. for lower.

The similarity of the expressions representing the variations at both upper and lower culminations, and consequently of the mean, show that there is either a six-month periodic term or a twelve-hour periodic term, represented by the last term in the expressions above.

The twelve-month periodic variation, or the twenty-four-hour periodic variation, can be eliminated by combining values in Table III which differ six months in epoch, and this process has been followed in deriving the test values of Table IV, which gives the corresponding mean times of such a combination. The

values of Table IV give an expression for the correction of the Mire reading of the form: $-0^s.034 \sin 2\Delta t$, the origin for reckoning Δt being as above, the time of transit on January 1. The comparison of observed minus computed values, with the mean residual, shows how effective the expression has been in representing the periodic variation.

TABLE IV
 ΔM FROM POLARIS; MEAN TIME COMBINATION

				M. T.	Mean	Comp.	O-C
Jan.	U. C.	July	L. C.	5h7	$0^s.873$	$0^s.826$	$+.047$
Feb.	U. C.	Aug.	L. C.	3.7	.885	.843	$+.042$
Mar.	U. C.	Sept.	L. C.	1.7	.816	.826	$-.010$
April	U. C.	Oct.	L. C.	23.7	.803	.792	$+.011$
May	U. C.	Nov.	L. C.	21.7	.782	.775	$+.007$
June	U. C.	Dec.	L. C.	19.7	.784	.792	$-.008$
July	U. C.	Jan.	L. C.	17.7	.823	.826	$-.003$
Aug.	U. C.	Feb.	L. C.	15.7	.792	.843	$-.051$
Sept.	U. C.	Mar.	L. C.	13.7	.799	.826	$-.027$
Oct.	U. C.	April	L. C.	11.7	.793	.792	$+.001$
Nov.	U. C.	May	L. C.	9.7	.776	.775	$+.001$
Dec.	U. C.	June	L. C.	7.7	.777	.792	$-.015$
Mean					0.809		$\pm .019$
v						$\pm .027$	

To return again to Table III, the values of ΔM for the two culminations differ by 0^s014 , and this may be assumed to be the systematic error in computing the azimuth of the instrument, depending upon the error in the standard Right Ascension of *Polaris*. Half the difference, or 0^s007 , should be applied to the ΔM from each culmination, corresponding to an error of about a quarter of a second in the adopted Right Ascension.

The mean values of the terms in the expression derived from the periodic variation have been applied to each mean result, giving the computed columns of Table III. The comparison of the means of these columns, with the respective average residuals before the application of periodic corrections, indicates the improvement introduced by the latter. The results in the columns observed minus computed would of course be smaller if each separate culmination were corrected with the coefficients derived for that series. It appears more consistent to adopt the mean value as representing, as nearly as may be, the effect of daily and annual terms in the variation in the position of the Mire. To derive the ΔM corresponding to the reading of the Mire at the time of any transit of *Polaris*, the following corrections would then be necessary:

Systematic correction depending upon the error in Right Ascension of *Polaris*:

$$\text{U. C.} + 0^s007; \quad \text{L. C.} - 0^s007.$$

Correction due to progressive change in ΔM :
 $+0^s004 \Delta$ (Date—Nov. 1, 1906),
 where this difference is given in months.

Correction for periodic variation in ΔM :
 $-0^s030 \sin \Delta t + 0^s032 \cos \Delta t + 0^s034 \sin 2\Delta t$.
 The Δt is reckoned from the mean time of transit of *Polaris* on January 1, and the corrections are tabulated below, in Table V, with the mean time of transit as argument. The secular change is also tabulated here.

The application of these two tabular variations to the individual monthly values will be found to reduce the residuals of Table I, as follows: U. C. from $\pm 0^s048$ to $\pm 0^s037$; L. C. from $\pm 0^s072$ to $\pm 0^s037$; mean from $\pm 0^s056$ to $\pm 0^s028$.

The determinations at U. C. would appear to be the more precise, originally; and the decrease in the average residual is less marked. The probable error of a determination of the Mire position from the double culminations of *Polaris*, in one month of the series of twenty-one, is quite precisely $\pm 0^s020$.

The range of variation in the periodic term amounts to 0^s12 (1^m8), in the position of the Mire, and this is equivalent to an actual movement of quite precisely one hundredth of an inch, at the distance of the Mire from the meridian circle. The secular change in two and a half years amounts to the same quantity, one hundredth of an inch.

TABLE V
CORRECTIONS TO MIRE; 1905-1908

Secular Change.		Periodic Variation.			
1905	Correc.	Polaris U. C.		Polaris L. C.	
				Correc.	
July 1	—0 ^s 064				
Aug. 1	.060				
Sept. 1	.056				
Oct. 1	.052	M. T.			M. T.
Nov. 1	.048	0 ^h 0	+0 ^s 035		12 ^h 0
Dec. 1	.044	1.0	+ .027		13.0
1906		2.0	+ .017		14.0
Jan. 1	.040	3.0	+ .011		15.0
Feb. 1	.036	4.0	+ .010		16.0
Mar 1	.032	5.0	+ .016		17.0
April 1	.028				
May 1	.024	6.0	+0.025		18.0
June 1	.020	7.0	+ .035		19.0
July 1	.016	8.0	+ .042		20.0
Aug. 1	.012	9.0	+ .041		21.0
Sept. 1	.008	10.0	+ .031		22.0
Oct. 1	— .004	11.0	+ .012		23.0
Nov. 1	0.000				
Dec. 1	+ .004	12.0	—0.012		0.0
1907		13.0	— .039		1.0
Jan. 1	.008	14.0	— .061		2.0
Feb. 1	.012	15.0	— .075		3.0
Mar. 1	.016	16.0	— .077		4.0
April 1	.020	17.0	— .068		5.0
May 1	.024				
June 1	.028	18.0	—0.048		6.0
July 1	.032	19.0	— .023		7.0
Aug. 1	.036	20.0	— .002		8.0
Sept. 1	.040	21.0	+ .023		9.0
Oct. 1	.044	22.0	+ .036		10.0
Nov. 1	.048	23.0	+ .040		11.0
Dec. 1	.052				
1908		0.0	+0.035		12.0
Jan. 1	.056				
Feb. 1	+0.060				

No explanation can be given here to account for these changes, beyond the influence of the change in temperature with the season, and with the hour of the day. The pier supporting the mark is covered by a small house and roof, and the foundation is the rock of the mountain top. The variation in the monthly values of azimuth during the same series is included in a range of 0^s4 . Single values of a show a total range of 0^s6 , which would be less than one thousandth of an inch, at the axis of the instrument.

The discussion of the material from other years, preceding the fundamental series, will have interest in this connection, and fortunately this material exists in easily available form. The record in detail is given in Volumes IV, VI and X of the *L. O. Publications*,

from which it has been condensed here, in Table VI. Each monthly value of this table has on the average seven determinations of ΔM , made nearly uniformly in the hours of the early night. The average mean time is close to 10 P.M. The azimuth of the instrument was computed from observations of from one to three pairs of circumpolar stars per night, during this

period. Any systematic error in the standard Right Ascension of the circumpolar stars, depending upon the hour of Right Ascension, would be reproduced in the ΔM of the table, which in this important condition differs from the preceding discussion of ΔM from observations of *Polaris* alone. Nearly fifty circumpolar stars have been observed.

TABLE VI
MONTHLY RECORD OF ΔM ; NIGHT OBSERVATIONS OF CIRCUMPOLAR STARS

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Means
1893											0 ^s 942	0 ^s 901	0 ^s 922
1894	0 ^s 850	0 ^s 843	0 ^s 822	0 ^s 894	0 ^s 930	0 ^s 929	0 ^s 945		0 ^s 983	0 ^s 963	.975	.900	.917
1895	.890	.927	.913	.936	.978		1.040	1 ^s 076	1.020	1.053	.960	.943	.977
1896	.953	.937	.957	.940	.923	.999							.985
1897									.979	.970	.906	.858	.903
1898	.930	.876	.871	.933	.919	.932	.960		.975	.958	.928	.879	.929
1899	.892	.913	.888	.893	.910		1.029	.954	.984				.940
1900	.856	.860		.870	.911	.928	.973		.975	.943	.942	.902	.916
1901	.873	.910	.900			.977	1.008	1.023			.961	.969	.958
1902	.897			.852	.814	.888	.948	.939	.994	.947	.920	.875	.896
1903	.904	.858	.825	.902	.935	.977				.915	.905	.899	.920
1904	.908	.800	.805	.784									.875
Means.	0.895	0.880	0.873	0.889	0.915	0.947	0.986	0.998	0.987	0.964	0.938	0.903	0 ^s 931
Computed	.888	.873	.873	.888	.916	.946	.974	.989	.989	.974	.946	.916	
Obs.—C.	+ .007	+ .007	.000	+ .001	— .001	+ .001	+ .012	+ .009	— .002	— .010	— .008	— .013	± .006
1906										0.828	0.756	0.749	0.763
1907		0.781		0.737	0.806	0.728	0.844	0.803			0.684		.767
1908		0.660											.718
Computed		.708		.723	.751	.781	.809	.824		.809	.781	.751	
Obs.—C.		+ .012		+ .014	+ .055	— .053	+ .035	— .021		+ .019	— .061	— .002	± .030

The record of nearly eleven consecutive years, 1893 to 1904, shows but very slight indication of any progressive change, though a rate of -0^s005 per year might be assumed during this period. There is, however, a distinct periodic annual variation, which can be expressed in the form: $0^s931 - 0^s060 \sin \Delta \alpha$; where $\Delta \alpha$ is the difference between the Right Ascension at 10 P.M. in any month and the Right Ascension 2^h6, corresponding to that hour of the night on December first. The above expression resembles that derived for the annual term from *Polaris* and may thus be tentatively assumed as due to a variation in the position of the Mire, rather than to systematic error in Right Ascension in the polar stars used. The application of the above expression to the monthly means of Table VI reduces the average residual from $\pm 0^s029$ to the computed minus observed mean of $\pm 0^s006$, which is very distinct evidence of the faithfulness of the curve in reproducing the original values. The last column of Table VI gives the annual values of ΔM after the separate months have been corrected for the periodic variation.

The fundamental observations of 1906–1908, made in the early night as a rule, are also included in Table VI, and the same periodic variation has been assumed to be applicable in this series, in which *Polaris* appears only when it falls within the four hours of observation on any night. The average residual of the monthly values has been reduced from $\pm 0^s044$ to the observed minus computed $\pm 0^s030$, by correcting for the periodic variation in this form.

The secular change in ΔM developed in the discussion of the fundamental observations appears to have begun in 1904. Between 1903 and 1907 it amounts to 0^s04 per year, which is in fair accord with the value for 1905 to 1908, derived from *Polaris* observations. And the most recent determinations of ΔM give a value close to 0^s55 for the four months with mean epoch 1912.0, showing a continuation of the progressive change amounting to 0^s05 per year.

Both the annual period in the position of the Mire and the daily variation are referred to in *L. O. Publications*, Vol. X, pages 259 and 260, where the values at different seasons, and the hourly change in ΔM are

noted. As will be seen in Table V, above, hourly changes may amount to $0^{\circ}02$, and these have been often noted, when the successive azimuth determinations do not confirm the entire change in Mire readings.

The corrections to the Mire readings, necessary to reduce the observations of the early hours of the night to a standard value, may be tabulated here for convenient reference. They may be taken to represent the annual period in the position of the Mire, combined with the systematic error in the Right Ascension of the polar stars. The corrections are derived from the same expression from which the values of Table VI are obtained, though this may be conveniently written in the form: $-0^{\circ}060 \sin(a - 2^h6)$; and the argument of the tabular corrections will be the Right Ascension at the time of observation.

TABLE VII

CORRECTIONS TO MIRE: 1893 TO 1908. NIGHT OBSERVATIONS

Sid. T.	Correc.	Sid. T.	Correc.
0 ^h 0	+0 ^s 038	12 ^h 0	-0 ^s 038
1.0	+ .024	13.0	- .024
2.0	+ .009	14.0	- .009
3.0	- .006	15.0	+ .006
4.0	- .021	16.0	+ .021
5.0	- .035	17.0	+ .035
6.0	- .047	18.0	+ .047
7.0	- .055	19.0	+ .055
8.0	- .059	20.0	+ .059
9.0	- .060	21.0	+ .060
10.0	- .056	22.0	+ .056
11.0	- .049	23.0	+ .049

The application of these corrections to the single values of Table VI reduces the average residual of single months from $\pm 0^{\circ}030$ to $\pm 0^{\circ}019$. The range of the periodic term is closely one hundredth of an inch, in the position of the meridian mark, during a year. It appears probable that both progressive change and periodic variation may be expected in measuring the position of the Mire, until observations indicate a check in the former. The periodic variation may be expected to continue.

The first part of this discussion includes the variations which may have periods of a year, and of a day, and being based upon *Polaris* alone, the results are not affected by errors of Right Ascension. Table IV may be assumed to have the annual period eliminated. In Table VI the daily period does not enter, but systematic errors of Right Ascension may be included. There remain some observations, made during fundamental work which may contribute to the question of the daily period, though not independent of systematic

Right Ascension errors. On three occasions continuous observations were made on a list of stars for at least forty-eight hours consecutively, including azimuth and Mire readings, these last being taken hourly.

The values of ΔM during these sets of observations are given below in Table VIII. The observing programme was the same in each set, two observers, Mr. R. F. Sanford and myself, alternating each six hours. The September and October sets were observed with opposite assignments, so that the systematic errors of the two observers could be derived and could be eliminated in the results. The April series was long delayed, on account of bad weather, and was the last observing that I carried out before taking up the work of the Carnegie Institution at San Luis. In this set the observers changed assignment half way through, so that the distribution of errors is the same as for the other two combined. The last set is separated by six months from the other two, so that the Right Ascensions may be taken as differing twelve hours in mean time. This was another feature planned for the elimination of systematic errors.

Polaris, β *Ursae Minoris* and α *Andromedae* were observed in these programmes, and all the brighter stars that could be included for daytime observations. There are eight North stars used for azimuth, some of them being below 70° Declination, in order to give large zenith distances at lower culmination, both culminations having been observed.

The first series of Table VIII included fifty-two hours of continuous observing, with forty-eight readings on the Mire. The azimuth was determined in each six-hour group of stars, and the values interpolated to correspond to the Mire readings. The values of ΔM for the same hours of Right Ascension are combined in the table following. The periodic daily variation is given by the expression: $-0^{\circ}060 \sin \Delta \alpha$, where $\Delta \alpha$ is reckoned from 23^h0 R.A. which corresponds to 10^h7 P.M. in this series.

The October series included forty-eight hours continuous observing, with forty-five Mire readings. The daily periodic variation is of the form: $-0^{\circ}037 \sin \Delta \alpha$, where $\Delta \alpha$ is reckoned from 0^h0 R.A. corresponding to 10^h9 P.M. at the date of observation.

The series in April, 1908, was much broken by clouds, one six-hour group having been lost entirely from that cause. There are thirty-five Mire readings, extending over a period of fifty-four hours, of which only thirty-six were actually used. The periodic variation is of the form $-0^{\circ}024 \sin \Delta \alpha$, where $\Delta \alpha$ is reckoned from 13^h0 R.A. corresponding to 10^h6 P.M. in the April series. The signs of the periodic variations confirm the existence of the daily period, with mean time argument.

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TABLE VIII
ΔM IN 48 HOUR PROGRAMMES

September 25 to 27, 1907				October 7 to 9, 1907				April 28 to 30, 1908			
Sid. T.	ΔM	Comp.	O-C	Sid. T.	ΔM	Comp.	O-C	Sid. T.	ΔM	Comp.	O-C
0h2	0s848	0s844	+0s004	0h2	0s825	0s818	+0s007	0h2	0s787	0s779	+0s008
1.6	.779	.824	— .045	1.6	.806	.806	.000	1.6	.793	.784	+ .009
2.8	.766	.812	— .046	2.8	.780	.796	— .016				
3.5	.800	.807	— .007	3.4	.782	.792	— .010	3.4	.771	.796	— .025
4.6	.783	.803	— .020	4.6	.779	.786	— .007	4.6	.772	.800	— .028
5.9	.819	.802	+ .017	5.3	.813	.784	+ .029	5.3	.809	.802	+ .007
6.8	.868	.808	+ .060	6.2	.756	.783	— .027	6.8	.828	.805	+ .023
7.8	.849	.817	+ .032	7.8	.801	.787	+ .014	7.8	.826	.805	+ .021
9.0	.844	.832	+ .012	8.9	.806	.793	+ .013	8.9	.825	.802	+ .023
9.6	.827	.841	— .014	9.5	.800	.798	+ .002	9.6	.795	.800	— .005
10.6	.834	.856	— .022	10.8	.796	.810	— .014	10.7	.774	.795	— .021
11.2	.922	.866	+ .056	11.6	.812	.815	— .003	11.4	.767	.790	— .023
12.7	.885	.887	— .002					12.3	.808	.785	+ .023
13.6	.912	.900	+ .012	13.6	.875	.834	+ .041	13.6	.772	.778	— .006
14.3	.943	.908	+ .035	14.1	.834	.839	— .005	14.4	.767	.772	— .005
15.7	.915	.918	— .003	15.7	.839	.850	— .011	15.8	.774	.765	+ .009
16.5	.956	.921	+ .035	16.5	.850	.854	— .004	16.5	.763	.762	+ .001
17.7	.952	.921	+ .031	17.7	.845	.857	— .012	17.8	.763	.758	+ .005
18.6	.891	.916	— .025	18.6	.858	.856	+ .002	18.6	.727	.757	— .030
19.6	.854	.909	— .055	19.5	.856	.854	+ .002	19.6	.771	.757	+ .014
20.5	.855	.898	— .043	20.4	.837	.850	— .013	20.4	.767	.759	+ .008
21.4	.844	.886	— .042	21.4	.847	.843	+ .004	21.4	.770	.762	+ .008
22.8	.885	.865	+ .020	22.7	.851	.832	+ .019	22.7	.758	.767	— .009
				23.9	.824	.821	+ .003				
Mean	0.862		± .028	0.820			± .012	0.781			± .014
v	± .044			± .026				± .020			

In the practical use of the observations of the Mire, during the fundamental work, the position of the mark will be derived from the sets of successive culminations of *Polaris* during short periods, the comparison with the computed periodic variations being used as a check. And, in current observing, the application of the corrections for the daily periodic variations may be expected to bring the Mire readings into conformity with the azimuth determination, and with the rate in azimuth, when one is found. The lack of conformity in the change had already been noted, and commented upon in Volume X.

It is possible that a meridian mark for the instrument may be established in the future, on the hills north of Mount Hamilton. The present mark, on the south, at a distance of 97 feet from the instrument, has been the only available site on the mountain itself. The hills to the north are lower, and the mark would

probably be placed at a depression of three degrees below the horizontal, which would not interfere with the use of the north collimator, the line of sight thus passing below the objective, and through a gap in the metal mounting of the tube. The establishment of such a mark presents some difficulties, as it would be several miles distant, and by road the distance would be doubled. The rough country in the mountains has few inhabitants, and the method of keeping up some source of illumination at night will need to be worked out. At a reasonably great distance from the instrument, such changes as have been found to take place in the present mark, well confirmed as they are, would be quite inappreciable in their effect upon azimuth determinations.

R. H. TUCKER.

March 13, 1912.