OBSERVATIONS OF LONG PERIOD VARIABLE STARS

at the

LEANDER McCORMICK OBSERVATORY

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By

HAROLD LEE ALDEN

A.B. Wheaton College, '12.
M.S. University of Chicago, '13.

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OBSERVATIONS OF LONG PERIOD VARIABLE STARS AT THE LEANDER McCORMICK OBSERVATORY.

I. INTRODUCTION.

(a) Number and Nature of the Observations.

During the years 1901 - 1912 one of the principal lines of investigation at the Leander McCormick Observatory was the observation of variable stars of long period. In that time nearly four thousand estimates of brightness were made on one hundred and twenty-five variables. From July 1915 to April 1917 twenty-three hundred additional observations have been made on this interesting class of variable stars, sixteen - hundred of which were on ninety-two of the stars previously observed. None of the results from these measures has ever been published. The purpose of this paper is to describe briefly the data, methods of observation, instruments, observers, etc and make a beginning in rendering available to astronomers the valuable data that has accumulated here. As soon as possible all the observations to date will be published.

The observations are of considerable value because the large aperture of the McCormick telescope enables the variables to be observed when they are very faint and when they are beyond the reach of observers with small instruments. The original purpose was to observe these stars only at and near minimum. While this plan was not strictly adhered to, much information can be derived from the observations regarding the light-curves of the stars near minimum, thus adding greatly to the history of the light- variation of the stars observed.

The value of the data is somewhat impaired by the fact that so many separate observers were engaged in making the observations and by the comparative inexperience of most of these observers when first undertaking this line of research. The latter difficulty applies only to limited portions of the observations and as two men frequently worked together at the telescope the mean of the two estimates would not be very discordant. Furthermore with a large number of observers personal equations would average out, giving in general better determinations of the mean curves of the variables and better values of the magnitudes of the comparison stars.

Most of the variables on the observing list become fainter at minimum than comparison stars whose magnitudes are determined on some well defined scale. The observations supply the data necessary for determining the relative brightness of faint stars used as comparison stars and will thus enable the adopted scale to be materially extended.

It is to be regretted that on many of the variables the observations are scattering and fragmentary. Of the one hundred and twenty-five stars observed prior to 1912,

25	have	10	observations
18	"	10 - 24	"
48	"	25 - 49	"
28	"	50 - 74	"
6	"	75 -100	"

Since 1915 the observations have accumulated more rapidly, averaging over a hundred a month. The average for the last five months has been two hundred and fifty per month, a maximum of three hundred and twenty-five being recorded for December 1916. Unfortunately the demands of the photographic parallax program are such that the telescope is available for variable star observations only during limited hours of the night and hence the choice of the stars to be observed on a given night is somewhat restricted.

The greatest value of the McCormick observations will undoubtedly be in combination with results obtained elsewhere, the data secured here supplying, as before stated, important information regarding the light-variations and limiting magnitudes of the variables when faint.

(b) Observers.

The earlier observations were made by Professor Ormond Stone, at that time director of the Observatory, and under his direction by graduate students of the University of Virginia who were holders of the Vanderbilt Fellowships. Since 1915 the work has been under the supervision of Professor S.A.Mitchell, the present director. All members of the Observatory staff have taken part in making the observations.

The following list gives the name of each observer together with his present location, the period during which he observed and the letter or letters by which he is designated in the tables of observations that follow. The names are given in the order in which they appear in the observing records.

ObserVers.

Name	Present location	Observed	Designation
O.Stone,	Manassas, Va.	1903-1911	S
G.F.Paddock,	Lick Observatory, Cal.	1903-1906	P
C.P.Olivier,	McCormick Observatory.	1903- -	O
F.W.Reed,	University of Illinois.	1905-1907	R
R.E.Wilson,	Lick Obs. Station, Chili.	1907-1910	W
W.N.Neff,	Y.M.C.A., University of Virginia.	1907-1909	N
J.B.Smith,	Hampden-Sidney College, Va.	1909-1911	B
C.N.Wunder,	Georgetown College, Texas.	1909-1912	Wn
H.H.Gaver,	Instructor, University of Virginia	1910-1911	Ga
P.H.Graham,	Agnes Scott College, Ga.	1911-1916	Gr
F.P.Guthrie,	Charleston, S.C.	1911-1912	Gu
H.L.Alden,	McCormick Observatory.	1915- -	A
R.C.Lamb,	McCormick Observatory.	1916- -	L
S.A.Mitchell,	McCormick Observatory.	1916- -	M

(c) Instrument.

The observations were made with the twenty-six inch Clark refractor of this Observatory. When the variables were bright, estimates were occasionally made with the five inch finder attached to the large telescope.

The theoretical limit of the twenty-six inch telescope being in the neighborhood of the sixteenth magnitude, under average conditions of seeing and transparency variable stars can be followed down to the fifteenth magnitude. Only when the moon is near full and the seeing very poor does the limit of visibility become higher than magnitude thirteen.

For the earlier observations a low power eyepiece magnifying about eighty diameters was usually employed. This eyepiece has the advantage of giving a comparatively large field but on the other hand difficulty is experienced in distinguishing the variable from neighboring stars when very faint on account of the small scale.

In 1913 a photographic plate-holder attachment replaced the former tail-piece of the telescope and, since 1915, practically all of the observations have been made with a "finding eyepiece" having a magnifying power of two hundred and eighty. This eyepiece can either be clamped to the telescope in place of the plate-holder or held against the plate-holder attachment by the observer. The latter method is preferred by most of the present observers on account of its convenience and the facility with which the field of the variable can be located. By sliding the eyepiece around while holding it firmly against the plate-holder attachment, a region of the sky covering the five by seven inch photographic plate or an extent of one degree in right ascension and forty-three minutes in declination can readily be examined and stars can be brought to any desired position in the field of the eyepiece without affecting the focus or necessitating the use of the slow motions.

II. METHOD OF OBSERVING.

(a) Observing List.

The stars selected for observation were those contained in the first three series of Hagen's Atlas Stellarum Variabilium. Eight stars from the sixth series were included but were observed only a few times. Most of the variables which did not become as faint as the thirteenth magnitude were later dropped from the observing list. This accounts for the fact that on a number of the regions comparatively few observations have been made.

During the past year the number of stars under observation has been nearly doubled by the addition to the observing list of other stars with faint minima. This paper is concerned however only with those variables on which observations were begun prior to 1912. Details concerning methods of observation, reduction, derivation of magnitudes of the comparison stars, etc given here do not necessarily apply to the stars recently added to the program.

(b) Charts.

Hagen's charts were used for all the stars under discussion, these charts being occasionally supplemented by photographs obtained from Yerkes Observatory. Recently photographs of a few of the regions have been received from Harvard College Observatory. In all cases the original Hagen chart is still used at the telescope.

In addition to the stars printed on the Hagen charts, faint stars were necessary to identify the variables when faint and to serve as comparison stars. These were marked on the charts in pencil by the various observers.

(c) Comparison Stars.

No systematic sequences of comparison stars were adopted in any of the fields, each observer following his own judgment in selecting his comparison stars for a given observation. If any star selected was not already on the chart, it was inserted and a designation assigned to it. Such methods insured the independence of each separate observation but, in too many cases, stars selected thus at random have been observed so seldom that no reliable values of their magnitudes can be derived, thus depreciating materially the value of such observations.

Originally the comparison stars on the charts were designated only by letters or numbers. In September 1904 a system was adopted whereby a double check was established on the identity of each comparison star used. As a result the errors in recording can be readily recognized and corrected. The system was as follows:-

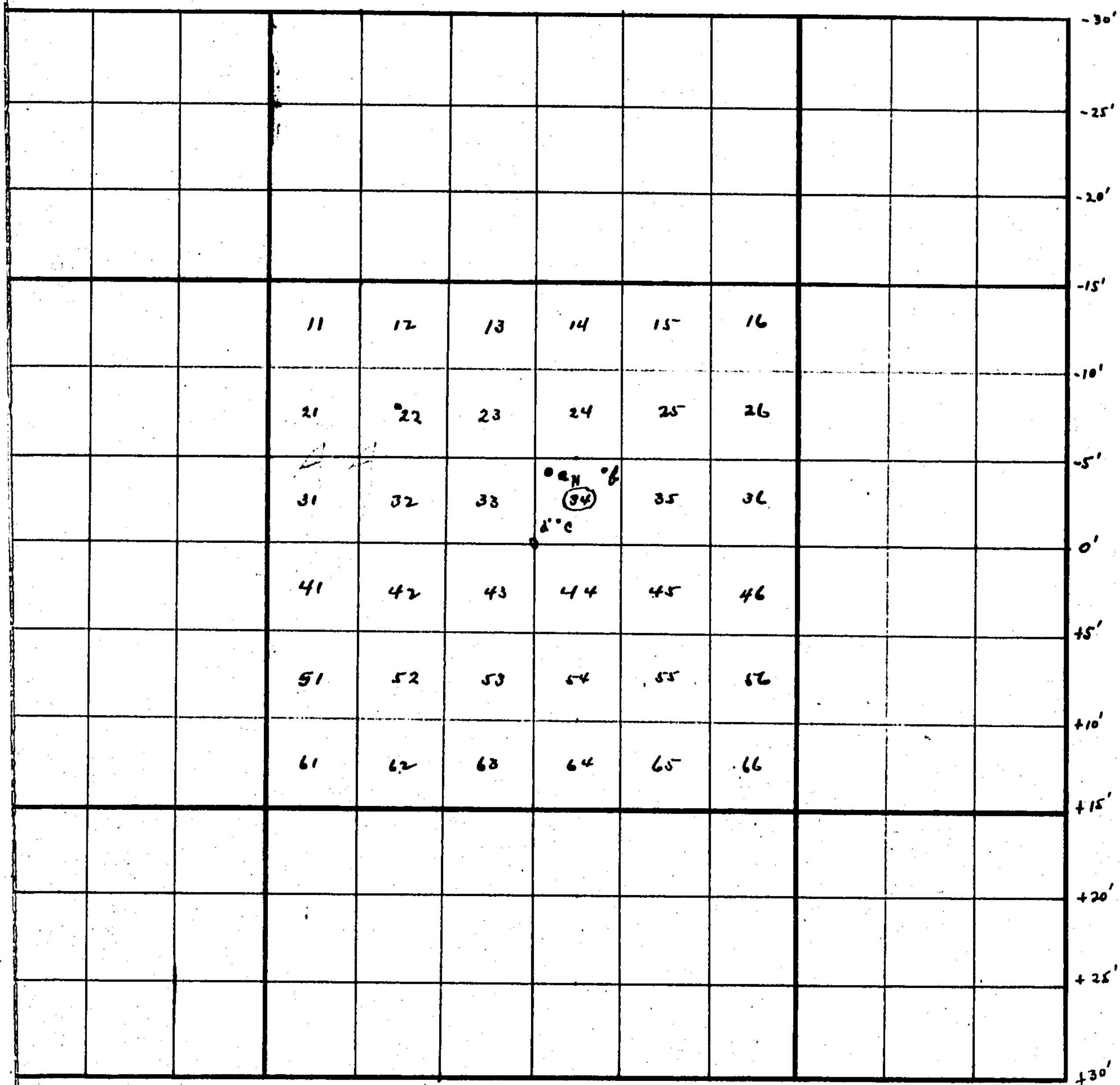
> Each star within one of the small squares on the Hagen chart was assigned a number or letter to distinguish it from the other stars in the same square, this designation being given only to those stars used as comparison stars. The square in which a given star was located was then designated by a number of two figures. The first figure gave the number of the horizontal row and the second that of the vertical column of small squares within the larger thirty minute square bounded by the heavy line, counting in each case from the upper left-hand corner of the large square.
>
> In recording, the number of the square is first given and the designation of the star within the square is appended as a subscript. Thus 84_a means the star marked a in the square which is in the third row down from the top and the fourth column from the left-hand side of the large square. In other words a is in the square immediately above and to the right of the variable.
>
> A sketch of a Hagen chart is given to better illustrate the system. The numbers assigned to the different squares are written within them.

Outside of the thirty minute square only bright stars were needed and these were designated by letters only- either capitals or Greek.

The comparison stars given in Harvard Annals, 37 were marked on the charts with the Harvard letter and a subscript H. Thus 84_{a_H} signified that the star was located as described above and that it was star a in the Harvard sequence for that field.

As the magnitudes of none of the comparison stars were derived until the present reductions, the details concerning them will be reserved for a later section.

Hagen Chart.


-30'
-25'
-20'
-15'
11 12 13 14 15 16
-10'
21 22 23 24 25 26
-5'
a
b
31 32 33 34 35 36
d
c
0'
41 42 43 44 45 46
+5'
51 52 53 54 55 56
+10'
61 62 63 64 65 66
+15'
+20'
+25'
+30'

(d) Observations and Records.

The observations were made according to a modified Argelander method. Three or more stars were arranged with the variable in the order of brightness and steps inserted to show the relative differences between the successive stars. These short sequences were expected to provide the data necessary for deriving the magnitudes of all the comparison stars used, after which the magnitude of the variable itself could be determined.

The method is entirely independent since the observer had no knowledge regarding the final adopted magnitudes of any of the comparison stars. It is subject however to two objections. In the first place , there is no check as the work proceeds on the possible variations in the brightness of some of the comparison stars. Secondly, the final reduction of the observations on a given star must be postponed until sufficient observations have accumulated in the course of several years to enable the magnitudes of the comparison stars of all brightnesses to be accurately determined.

The method in use at present of securing provisional values of the magnitudes of a selected sequence of comparison stars as soon as possible after a star has been put upon the observing list proves much more satisfactory without affecting to any appreciable extent the independence of the observations.

The steps used by the different observers varied greatly. Stone's intervals were approximately the same as the grades of Hagen, while other observers employed steps ranging from one or two hundredths to half a magnitude in extreme cases. The ideal step is a tenth of a magnitude but since the magnitudes of none of the comparison stars other than those contained in the sequences given in Volume 87 of the Harvard Annals were known to the observers, little opportunity was given for standardizing the steps.

The manner of keeping the records was in general as follows. For each night's work the date is recorded at the top of the page in the record book. For each observation is given the name of the variable together with the Chandler number given on the Hagen chart, the time of the observation (either the hour in Eastern Standard Time or the hour angle from which the time can be computed if necessary), the observation itself with any remarks that may be necessary, a rough estimate of the ~~stars~~ magnitude of the variable, and finally the observer's initials.

The observations were recorded by all the observers in the same record book in the order in which they were made. A list of the observations of a given star was kept on the back of the chart, giving the date, observer and the brightness of the variable, estimated to the nearest whole magnitude. The approximate magnitudes were merely for the purpose of showing whether the variable was faint enough to make further observations worth while and not to give the observer any information as to the change to be expected in the variable since the last observation.

III. MAGNITUDES OF COMPARISON STARS.

As already stated the observations were made in such a manner that the relative brightness of all the comparison stars could be determined after sufficient observations on stars of all magnitudes had been obtained. These differences of brightness must be reduced to some recognized scale and zero point. Since so much data is to be found in the Harvard Annals (37,57,63,74 et al.) regarding the magnitudes of comparison stars for long period variables, the Harvard photometric scale has been adopted and the Harvard magnitudes of all comparison stars, wherever known, used to form the basis for extending this scale to the fainter stars. The extension of the scale was effected by means of the observations themselves and by photometric measures made here. The latter results will not necessarily coincide with the Harvard scale extended but in the relatively small range covered, i.e. twelfth to fifteenth magnitudes, the departure will not be very great. The photometer results will be discussed separately as they were made independent of the observing program and only deal with certain fields.

For the brighter comparison stars which were not included in the Harvard sequences, magnitudes were obtained by interpolation between known stars from the data provided by the observations. If necessary to fit the observations better the Harvard magnitudes were adjusted slightly. This was seldom necessary though occasional large differences were found among the fainter stars. The mean of half a dozen observations usually gave a sufficiently accurate value of the magnitudes of the brighter stars.

The magnitudes of the fainter stars were obtained by extrapolation beyond the limits of the Harvard sequences or by interpolation between the Harvard magnitudes and the photometer magnitudes in the fields where these were available. The latter method proved quite satisfactory but the results obtained by extrapolation proved very discordant and the mean of a dozen or more observations was needed to insure values of the magnitudes which were sufficiently accurate. In many cases it has seemed best to postpone the reductions until new and independent estimates could be made of the magnitudes of all of the faint comparison stars.

As no detailed description concerning the derivation of the magnitudes of comparison stars will apply to all the fields which have been observed here and which are now being reduced, all necessary particulars will be given in connection with the results for a given field. variable.

IV. PHOTOMETER RESULTS.

(a) Description of Photometer and Calibration Curve.

The photometer employed here was one of the equalizing wedge photometers constructed at Harvard College Observatory under the Rumford appropriation and sent out to various observatories in 1900. The instrument has been so well described by Parkhurst (Astrophysical Journal, 13, 249, May 1901.) that details need not be repeated here.

The incandescent lamp which served as the source of light was supplied with current from wet cell batteries in the basement of the Observatory. No rheostat was used to maintain a constant current, the series of observations being always repeated in reverse order so as to average out the effects of progressive changes in the brightness of the artificial star.

The use of a photographic wedge to cut down the light of an artificial star to match that of a real star in the field of the telescope is attended by many difficulties. The greatest of these is the calibration of the wedge, or in other words the determination of the relative absorption of the different portions of the wedge expressed in stellar magnitudes. (See Harvard Annals, <u>41</u>, 237-247, and also <u>72</u>, 79 et seq.) The various methods of effecting this calibration are sufficiently well known that they need not be described in detail.

The data for deriving the calibration curve of the McCormick wedge consists of two groups:-

1. Observations made in the years 1900 - 1905.
2. Observations made since 1913.

No reductions of the earlier data were available so all of the original observations have been reduced by the writer. As each group consisted of a number of independent series, it seemed best, in order to combine the separate results, to determine from each the slope (σ) of the calibration curve at a number of points along the wedge and then take the mean of these slopes for a ~~at a~~ given interval ~~point~~ on the wedge. The slope, σ, at any scale-reading along the wedge is defined as the change in absorption, (expressed in stellar magnitudes) per scale division at the given scale-reading. Having derived mean values of the slope for every five scale divisions these values were plotted as ordinates against the scale-readings as abscissae. A smooth curve drawn through these points then shows the manner in which the value of the slope varies with the scale reading. The calibration curve by which scale-readings are converted into differences of magnitude is then obtained by integration from the known values of the quantity σ. This is represented by

$$\Delta \text{ Mag.} = \sum_{S=0}^{S=n} \sigma \cdot \delta S \qquad (\delta S = 1)$$

where S stands for scale-reading, Δ Mag. represents the absorption of the wedge in magnitudes for a given scale-reading S = n as compared with the absorption at S equal to zero.

1. Earlier calibration data.

The first group of observations contains seven independent series for determining the form of the calibration curve, three of which were made in the laboratory and four at the telescope. Briefly they are as follows:-

A. Observations in the laboratory with a Lummer- Brodhun photometer.

(1) The distances of the light-sources were varied to produce equality of brightness for different settings of the wedge placed in front of one of the light-sources. Some of the observations were made with artificial stars and some with illuminated surfaces as light-sources. The latter required the use of the ratio of the fourth powers of the distances to reduce the absorption to stellar magnitudes since the absorption of the wedge for a point-source is the square of that for an illuminated area. (Astronomishe Nachrichten, 172.314 and references given there.) Settings were made for every five divisions on the scale and the average slope between these points was assumed to be the slope for the mean scale-reading. A total of approximately twelve hundred settings were made by Stone, Paddock, Reed and T.McN. Simpson(now of the University of Chicago.

(2) The light-sources were kept fixed and the wedge setting varied so as to match the two artificial stars, before one of which a shade-glass of known magnitude absorption was placed for the alternate settings. Two shade-glasses were used, designated by a and b or I and II respectively. From more than two hundred accordant settings by H.D.Curtis (now of the Lick Observatory) on the Lummer-Brodhun photometer, the absorption of these shades was found to be

$$\underline{a} = 0^{M}.837 \pm 0.006 \text{ p.e.}$$
$$\underline{b} = 0.859 \pm 0.003 \text{ p.e.}$$

The two shades together therefore gave a magnitude interval of 1.696. By varying the relative positions of the light-sources, data regarding the various portions of the wedge was obtained. Nine hundred settings were made by Stone, Paddock and Olivier.

(3) Polarizing prisms were used to give known magnitude intervals but as the zero-points from which to count the angles are uncertain, the observations were not reduced. Several hundred settings were made by this method.

B. Observations at the telescope.

(4) Using the same shade-glasses as in (2), settings were made on real stars with and without the shade-glass placed in front of the star-image. The absorption of the shade divided by the difference in the scale-readings gave the average slope as before. Extra weight was assigned to these observations in the final combination of results becausecthey were made under the same conditions as actual measures. Six hundred settings by Stone, Paddock and Reed were available.

(5) This series was made in a manner similar to the previous one but the results are entitled to less weight. Instead of measuring the the same star alternately with and without the shade-glass, a number of stars in the Pleiades were measured without and then with the shade-glass placed in front of the real stars. As of necessity some time elapsed between the two sets of measures on a given star, the results could be affected by changes of different sorts. Hence the decrease in weight. There are eight hundred settings by the same observers as in the preceding series.

(6) The same shade-glasses were used by Curtis during some of his photometer measures on the Rumford fields to be described later, the settings being made approximately as in (4). There are about a thousand settings available but unfortunately they fall for the most part on a limited portion of the scale between settings 15 and 35.

(7) The aperture of the lens was partially limited by placing over the objective a curtain in which sectors had been cut. The ratio of the area of the sectors to that of the objective gives a known magnitude interval. Professor Stone's description of the sectors and their use may be of interest. The following is taken from an unpublished manuscript.

> " In order to determine, in terms of stellar magnitudes, the values of the scale-readings of the wedge of the Rumford photometer attached to the 26-inch equatorial of the Leander McCormick Observatory, a shutter was constructed having three equal apertures (A) in the form of sectors of a circle having the same diameter as that of the uncovered object-glass (O). The ratio of the absorption of the light of a star passing through A to that passing through O was thus equal to the ratio of the area of A to that of O. These apertures were arranged at equal distances from one another like the spokes of a wheel, their apexes meeting at a common point. The arcs of the sectors were made of such lenghth as to reduce the light of a star as nearly as possible two magnitudes, or in a ratio the logarithm of which is 0.800. At the center of the circle of which the sectors formed a part, a circular area two inches in diameter was left covered in order to give strength. As a

> result the actual reduction when the shutter was closed was 2.00645 magnitudes. The shutter was arranged to close by pulling a cord from the eye-end of the telescope, and to open (leaving the full aperture of the telescope unobstructed) by means of a Hartshorn shade roller.
>
> σ, the ratio of 2.00645 divided by the difference of the readings "closed" minus "open", i.e. reduced minus full aperture, is the observed value of a scale division in terms of stellar magnitudes. "

The magnitude interval is somewhat large so that the average value of σ obtained may not correspond exactly with that at the mean of the scale-readings. Nevertheless the results were given extra weight. About six hundred settings were made by Stone and Paddock.

Table I gives the results of six of the seven series. The headings of the various columns are self-explanatory. One discordant value for scale-reading 12.5 has been included. Its weight however is so low that it does not seriously affect the results. The weights of the different series have been assigned arbitrarily by the writer according to his idea of the reliability of the separate results. The weights of the values of σ are such that, in a series of unit weight, unit weight was given to ten settings, to five settings in a series of double weight, to twenty settings in a series of half weight and so on.

At the foot of the appropriate columns are given the sums of the weights, the weighted means of the scale-readings and values of σ,
and the average deviations of the latter taken
and the average deviations of the latter taken without regard to weight.

(Table I.)

The full line in Figure I. shows the mean values of σ obtained from Table I plotted against the scale-readings. If a smooth curve were drawn through the points shown, it would indicate the manner in which σ varied along the scale and give the information necessary to construct the calibration curve.

(Figure I.)

Table I.

Slope of Calibration Curve. 1900-1905

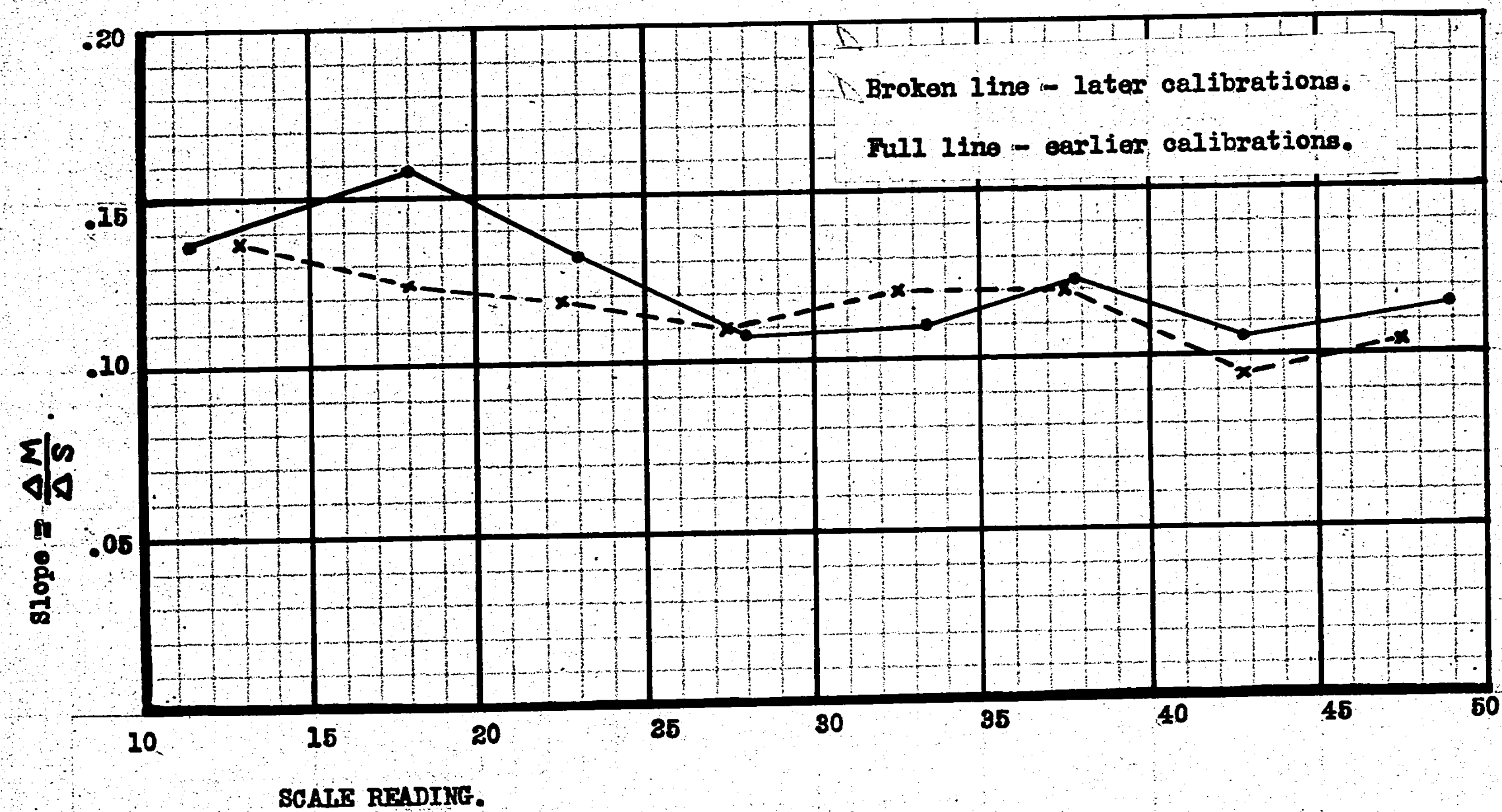
McCormick Wedge.

Series	Number of settings	Weight of series	Scale-reading < 15 Scale	σ	weight	15 - 20 S	σ	W	20 - 25 S	σ	W	25 - 30 S	σ	W
A. In laboratory (1)	1200	1	10.0	M 0.094	19	17.5	M 0.149	19	22.5	M 0.129	18	27.5	M 0.113	17
(2)	900	2/3	11.6	.130	20	17.5	.144	18	22.4	.124	11	26.9	.097	9
B. At telescope (4)	600	1 1/3	11.7	.168	9	18.1	.148	7	22.5	.129	21	27.0	.113	9
(5)	800	1/2	12.2	.168	3	17.8	.170	3	22.8	.135	8	27.9	.126	4
(6)	1000	1	12.5	.278	4	18.5	.176	30	23.5	.127	18	28.5	.100	27
(7)	600	2	14.1	.136	4	17.3	.149	6	23.4	.148	10	27.3	.121	6
Totals	5100				59			83			86			72
Weighted Mean			11.4	M 0.137		17.9	M 0.158		22.8	M 0.131		27.7	M 0.108	
Average residual				±.042			±.012			±.006			±.010	

Series	30-35 S	σ	W	35-40 S	σ	W	40-45 S	σ	W	45-50. S	σ	W
A. In laboratory (1)	32.5	M 0.119	16	37.5	M 0.131	16	42.5	M 0.091	9			
(2)	31.7	.110	8	38.0	.114	6	42.8	.114	6			
B. At telescope (4)	34.9	.104	5				41.0	.100	7	45.0	.107	1
(5)	32.1	.120	4	37.0	.096	2	42.3	.110	2	51.6	.096	2
(6)	33.5	.094	17	38.5	.092	4						
(7)	32.9	.133	6	36.7	.129	10	42.8	.116	8	47.9	.121	8
Totals			56			38			32			11
Weighted Mean	32.9	M 0.110		37.4	M 0.122		42.3	M 0.105		48.3	M 0.115	
Average residual		±.011			±.016			±.009			±.011	

Figure I.

Slope of Curves.



2. Later calibration data.

During the summer and fall of 1915 the photometer wedge was recalibrated in the laboratory by Dr. Mitchell and the writer. Two independent methods were employed. Known magnitude intervals were obtained (A) by polarizing prisms, the zero-angle or point of extinction being carefully determined each time a set of measures was made, and (B) by a rotating sector.

In each case the entire photometer was used exactly as it is employed at the telescope. A second artificial star was projected into the eye-piece of the photometer by a lens properly arranged and focussed. Storage batteries furnished the current for the lamps for the two artificial stars. These lamps were connected in series so that changes in current would affect both in the same manner.

The rotating sector was cut from a piece of heavy tin with two sets of steps designed to give a magnitude range extending over the whole usable length of the wedge. An outline of the sector is given to show its form. The angles were measured very carefully on the circle of a spectrometer and the relative absorption of the various steps computed from the formula

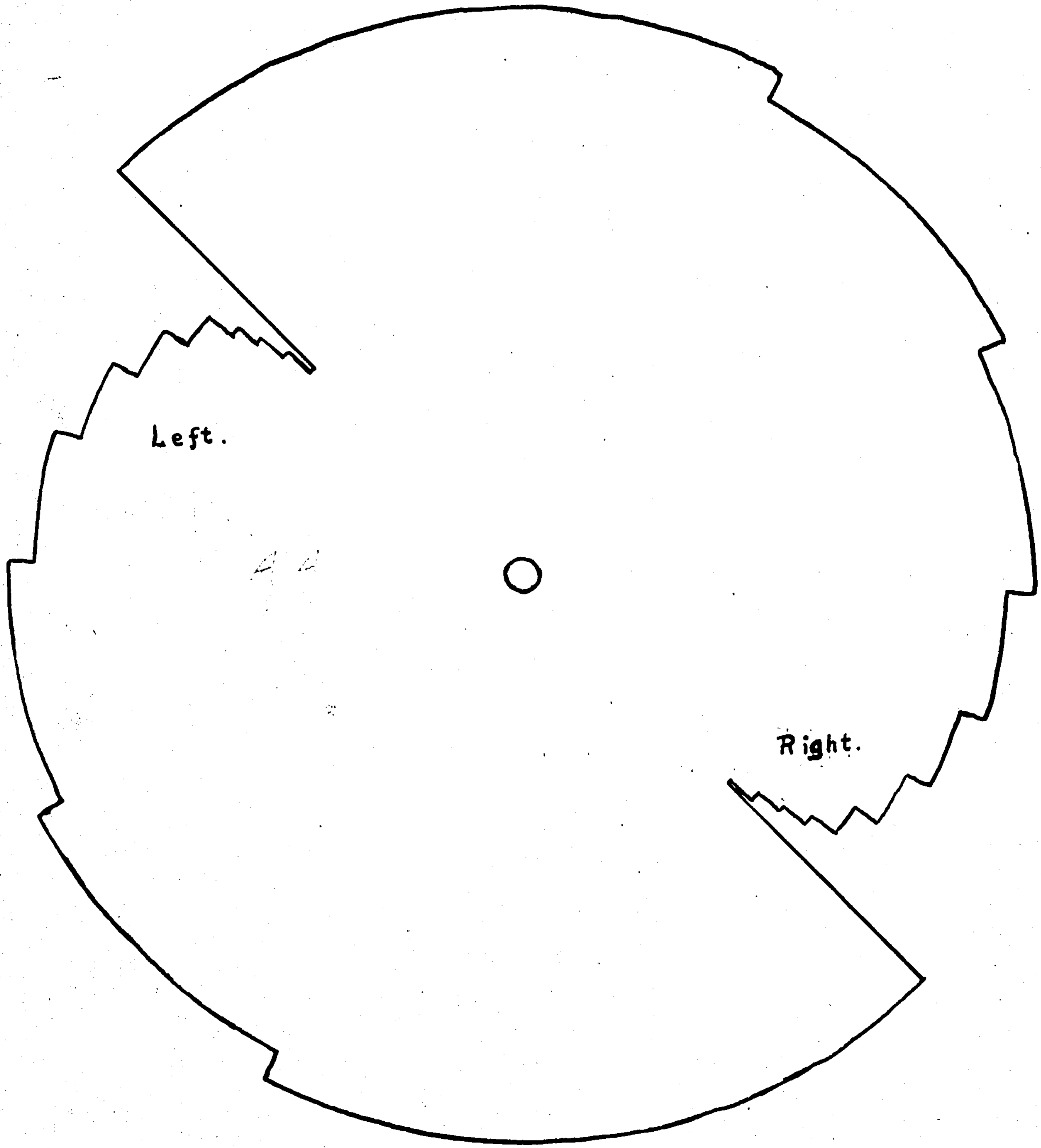
$$\Delta \text{ mag.} = 2.5 \log \frac{360}{\theta}$$

where θ represents the angular opening of the sector expressed in degrees. The measures, each of which is the mean of several settings, together with the resulting Δ mags are given in Table II.

(Table II.)

Table II.

Step Number.	Opening of Sector			Δ mag.
	Right	Left	Sum	
1	-	-	360° 00′	0.000
2	108° 17′	108° 03′	216 20	0.553
3	72 04	72 05	144 09	0.994
4	44 13	44 11	88 24	1.525
5	28 42	28 40	57 22	1.994
6	18 30	18 18	36 48	2.476
7	11 00	11 08	22 08	3.028
8	6 00	6 07	12 07	3.683
9	4 15	4 26	8 41	4.044
10	3 09	3 09	6 18	4.417
11	1 11	1 37	2 48	5.273



Rotating Sector.

The sector was mounted on the shaft of an electric motor which in turn was mounted on a screw base so that any desired step of the sector could be brought accurately in front of the artificial star.

Four independent series, each consisting of a number of separate sets of measures made on different days, were obtained as follows:-

	Settings	Weight
A. Polarizing prisms.		
(1) Mitchell	300	1
(2) Alden	1100	3
B. Rotating sector.		
(3) Mitchell	800	2
(4) Alden	500	3

The results of these four series are given in Table III in the same form as in Table I, the observations being weighted as above. Prior to the reduction of the earlier calibration data a mean calibration curve had been derived from the recent observations by direct combination of the curves obtained for the separate series, weighted the same as in the above list. Mean values of σ taken from this mean curve are entitled to the same weight as those obtained directly from the original series. Hence they have been entered in Table III and the mean of the two values of σ taken for each portion of the wedge. The final values thus obtained are plotted in Figure I,(dotted line).

The two curves in Figure I show a marked difference in slope between the scale-readings 15 and 25. Since the wedge was placed in a new carrier prior to the 1915 measures, the scale-readings do not necessarily correspond but the zero-points are probably not greatly different. The agreement between the curves would be improved slightly if the zero of the present scale coincided with scale-reading 3 or 4 of the earlier scale . Unfortunately there is no direct

Table III.

Slope of Calibration Curve 1915

McCormick Wedge.

Series	No. of settings	Weight of series	Scale-reading < 15			15 – 20			20 – 25			25 – 30			30 – 35			35 – 40			40 – 45			> 45		
			Scale	σ	Weight	S	σ	W	S	σ	W	S	σ	W	S	σ	W	S	σ	W	S	σ	W	S	σ	W
A. Polarizing prisms (1) Mitchell	300	1	13.8	M 0.108	1	–	–	–	20.1 24.6	0.146 0.091	1 1	29.6	0.095	1	34.8	0.185	1	39.8	0.101	1	44.6	0.098	1	50.5	0.086	1
(2) Alden	1100	3	14.8	.142	3	18.2	.136	3	22.0	.105	3	26.0	.129	3	30.2 34.1	.085 .114	3 3	38.0	.102	3	41.8	.073	3	45.8	.098	3
B. Rotating sector (3) Mitchell	800	2	10.6 14.3	.147 .120	2 2	18.8	.102	2	23.0	.132	2	27.8	.090	2	34.2	.097	2	39.2	.116	2	42.8	.090	2	48.0	.135	2
(4) Alden	500	3	11.4 14.6	.152 .147	3 3	18.4	.121	3	22.3	.122	3	26.8	.112	3	31.6	.135	3	35.6 38.4	.112 .158	3 3	44.0	.098	3			
Total	2700				14			8			10			9			12			12			9			6
Weighted mean Average deviation			13.3	.140 (.013)		18.4	.122 (.012)		22.4	.118 (.017)		27.1	.111 (.014)		32.6	.115 (.028)		37.8	.121 (.018)		43.1	.088 (.009)		47.3	.108 (.020)	
Value of σ from Mean Curve	same	same	12.5	.136		17.5	.126		22.5	.120		27.5	.108		32.5	.124		37.5	.118		42.5	.099		47.5	.100	
Final value			12.9	.138		18.0	.124		22.5	.119		27.3	.110		32.5	.120		37.6	.120		42.8	.094		47.4	.104	

method of determining this relation. A marked difference would still remain between the slopes even if this adjustment were made. The effect of this difference on the calibration curve itself is shown by Figure II, which gives the curves obtained by integration from smooth curves drawn through the points shown in Figure I. (Scale-readings are used as ordinates and Δ mags as abscissae so that the slope $\underline{\sigma}$ as defined is the slope with respect to the vertical axis and not the conventional " slope of the curve ".)

(Figure II.)

In the most used portion of the wedge between scale-readings 20 and 45 the two curves are practically identical, the greatest difference being 0.05 magnitude. Above 45 on the scale the observations for determining the form of the curves are relatively few in number. Below 20 the increasing difference in the curves is probably real. There is further evidence on this point.

In the winter of 1914-1915 the wedge was sent to Yerkes Observatory and there calibrated by Parkhurst according to methods that he has described. (Researches in Stellar Photometry. Published by the Carnegie Institution of Washington.) The results of all three calibrations are given in Table IV for every five scale divisions. The columns of differences show that the Yerkes results agree very satisfactorily with the McCormick curves between the points 25 and 45 on the scale but in the thinner portions of the wedge the deviation from the early McCormick curve is even greater than for the recent McCormick results. (Table IV.)

To what shall we attribute this difference between the two McCormick reduction curves? Parkhurst has found that his wedge

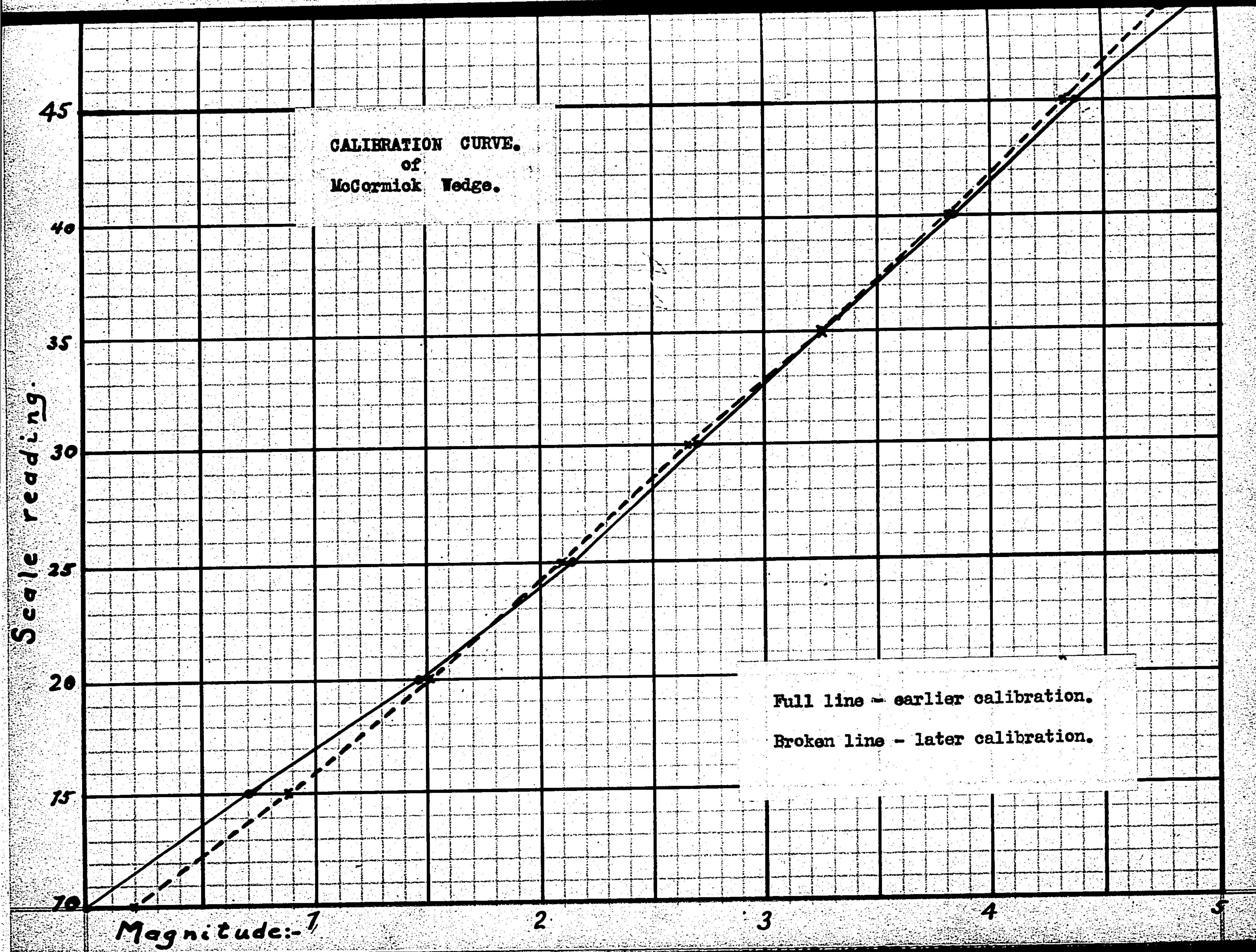

CALIBRATION CURVE.
of
McCormick Wedge.
Full line - earlier calibration.
Broken line - later calibration.
Scale reading.
45
40
35
30
25
20
15
10
Magnitude:-
1
2
3
4
5

Table IV.

CALIBRATION CURVES.					
Scale Reading.	McCormick.		Yerkes Parkhurst.	McCormick New - Old.	McC. New minus Park.
	Old	New			
10	0.00	0.20	0.30	+ 0.20	- 0.10
15	0.70	0.88	0.98	+ 0.18	- 0.10
20	1.46	1.51	1.62	+ 0.05	- 0.11
25	2.14	2.10	2.08	- 0.04	+ 0.02
30	2.70	2.66	2.66	- 0.04	0.00
35	3.25	3.25	3.30	0.00	- 0.05
40	3.84	3.82	3.84	- 0.02	- 0.02
45	4.38	4.32	4.32	- 0.06	0.00
50	5.00	4.83	4.79	- 0.17	+ 0.04

has not changed appreciably in ten years, since a recent calibration reproduced his former reduction curve. (Popular Astronomy, 22, 1914, 635.) His wedge however has been kept in its original carrier and carefully preserved. This has not been true of the McCormick wedge. It was placed in the new carrier about 1907 and at some subsequent date the cover-glass was removed and the film exposed to the deteriorating influences of moisture, dust, etc until the cover-glass was replaced in the fall of 1914. Parkhurst's experience therefore is no argument against an actual change in the McCormick wedge.

Any deterioration of the wedge would probably tend to make it less "contrasty" and thus decrease the slope of the calibration curve. Such a change would be most effective in the thinner portions of the wedge. This is in accord with what has actually taken place so that the evidence for a real deterioration of the film of the wedge is very strong.

Consequently all photometer measures made in the years 1900 - 1905 have been reduced by means of the curve derived from the calibration data obtained in the same period. Measures made since 1914 have been reduced with the later McCormick curve.

(b) Photometer Magnitudes.

The photometer measures with which this paper is most concerned were those made on faint stars in certain regions known as the Rumford fields and in twenty other fields selected here. These will be considered in the order in which the measures were made.

1. Rumford fields.

By means of appropriations from the Rumford fund of the American Academy of Arts and Sciences several observatories were provided with wedge photometers in order that they might cooperate in the determination of standards forfaint stellar magnitudes in certain selected variable star fields. To each observatory was assigned stars near the limit of visibility for its telescope. The McCormick Observatory undertook the measurement of the fifteenth magnitude standards and later a complete set of measures was also made on the fourteenth magnitude stars selected at Princeton Observatory. The results are here published for the first time.

The Rumford fields included twelve regions from each of the first three series of Hagen's Atlas. Five stars of the twelfth magnitude (designated a,b,c,d,and e) were selected at the Harvard College Observatory and the magnitudes determined on the Harvard photometric scale. These stars were to be used for determining the "zero-point" for the measures made on the fainter stars. Table V gives the positions of these twelfth magnitude standards as given in Hagen's catalog.

(Table V.)

Table VI gives the Hagen numbers and the Harvard magnitudes for these same stars. The stars are arranged according to brightness and not according to their designation as in Table V. The designations follow the order of the Hagen numbers.

(Table VI.)

In each of the Rumford fields five stars were selected here to serve as fifteenth magnitude standards and designated by the letters l,m,n,o and p. The positions of these stars are given in Table VII as determined here. (Table VII.)

STANDARDS FOR FAINT STELLAR MAGNITUDES (RUMFORD APPROPRIATION).

TABLE V.

POSITIONS OF TWELFTH MAGNITUDE STANDARDS.

				a		b		c		d		e		
Design.	Variable.	α 1900.	δ 1900.	Δα	Δδ	Δα	Δδ	Δα	Δδ	Δα	Δδ	Δα	Δδ	
		h m	° ′	s	′	s	′	s	′	s	′	s	′	
001909	S Ceti	0 19.0	− 9 53	00	− 3.4	− 62	− 2.2	+ 1	+11.1	+ 36	+10.9	− 49	− 6.1	
004047	U Cassiopeiae	0 40.8	+47 43	+ 27	+ 5.1	+ 3	+11.4	+ 71	− 2.1	+ 35	+ 3.0	+ 14	− 2.9	
011208	S Piscium	1 12.4	+ 8 24	+ 28	−12.3	− 73	− 4.8	+ 50	+ 5.7	+ 14	− 1.8	+ 58	+12.0	
011272	S Cassiopeiae	1 12.3	+72 5	+190	+ 7.6	+ 65	+14.0	+120	+11.7	+ 40	− 7.2	− 5	− 4.7	
022000	R Ceti	2 20.9	− 0 38	+ 28	+14.2	− 22	+ 6.3	+ 17	+13.0	+ 52	+ 4.2	+ 25	+12.0	
030514	U Arietis	3 5.5	+14 25	− 2	−11.4	− 26	+ 8.2	+ 34	+ 6.9	+ 12	+ 3.0	− 11	− 7.2	
032335	R Persei	3 23.7	+35 20	+ 42	+12.8	+ 28	+ 4.8	− 16	+ 8.7	− 14	+ 6.6	+ 1	+ 5.4	
044617	V Tauri	4 46.2	+17 22	− 17	+ 8.4	+ 22	+10.2	+ 12	+ 4.2	+ 29	− 0.9	+ 11	+10.3	
052404	S Orionis	5 24.1	− 4 46	− 29	+ 8.1	+ 15	− 0.9	+ 27	− 7.5	+ 03	+ 3.3	+ 58	− 4.2	
061647	V Aurigae	6 16.3	+47 42	− 18	− 6.4	− 18	−10.8	− 14	− 3.9	− 5	+ 7.8	− 14	+ 7.5	
070122	R Geminorum	7 1.3	+22 52	− 33	− 9.1	− 18	− 7.3	+ 7	−13.8	− 4	− 6.1	+ 15	−11.4	
075612	U Puppis	7 56.1	−12 34	− 26	+ 3.3	− 42	− 4.2	− 4	− 4.5	+ 22	− 4.5	+ 7	− 8.4	
081617	V Cancri	8 16.0	+17 36	+ 18	+ 0.4	+ 37	− 6.3	− 36	+ 0.9	+ 5	+ 8.1	+ 26	+ 8.1	
085008	T Hydrae	8 50.8	− 8 46	+ 33	0.0	− 28	+ 9.6	− 38	− 1.5	− 21	− 3.3	+ 46	+ 2.4	
093934	R Leonis Min.	9 39.6	+34 58	+ 35	+ 4.3	− 70	−11.2	+ 16	− 5.8	+ 23	− 5.6	− 46	− 8.1	
104814	W Leonis	10 48.4	+14 15	+ 57	− 5.7	+ 51	+ 2.7	+ 34	− 6.6	+ 16	− 2.1	+ 16	− 8.1	
120905	T Virginis	12 9.5	− 5 29	+ 47	−14.2	+ 39	+ 2.9	+ 18	− 7.9	− 11	−14.2	+ 15	− 6.4	
123160	T Ursae Majoris	12 31.8	+60 2	− 33	+ 1.8	+ 57	− 3.7	~~− 5~~	~~−12.1~~	− 40	−14.1	+ 4	+ 8.5	+0 9 +14.4
124606	U Virginis	12 46.0	+ 6 6	+ 59	+ 5.7	+ 24	+ 0.7	+ 47	− 0.6	− 59	+ 2.1	− 17	− 8.7	
132706	S Virginis	13 27.8	− 6 41	+ 8	+11.7	− 43	+ 6.6	− 56	+14.1	− 50	+ 8.7	− 15	+ 4.2	
141954	S Bootis	14 19.5	+54 16	+ 68	+ 7.2	− 5	+ 3.8	− 68	− 6.4	− 72	+14.4	+ 17	− 4.2	
142584	R Camelop.	14 25.1	+84 17	+235	+ 6.1	+515	+ 8.5	−295	+12.0	−415	+11.7	+380	+ 3.5	
154615	R Serpentis	15 46.1	+15 26	− 28	− 6.5	− 42	−11.9	− 38	− 3.1	− 49	+ 4.2	− 36	+ 6.2	
155018	RR Librae	15 50.6	−18 1	− 64	− 3.0	− 41	− 0.9	− 4	+ 8.7	− 57	− 5.8	− 14	+ 7.2	
161122	RS Scorpii	16 11.7	−22 40	+ 30	− 1.6	+ 41	+ 8.1	+ 53	− 1.5	− 14	+ 6.3	+ 49	+ 3.3	
163137	W Herculis	16 31.7	+37 32	+ 22	− 0.8	− 45	− 9.6	+ 60	−14.1	+113	− 8.5	+ 94	−10.0	
163266	R Draconis	16 32.4	+66 58	+ 28	− 9.5	− 4	−10.1	− 25	−11.5	−143	−11.3	+108	+ 0.4	
164715	S Herculis	16 47.4	+15 7	+ 40	−11.4	+ 50	− 3.1	+ 23	− 7.8	+ 16	− 6.0	+ 25	−12.2	
190108	R Aquilae	19 1.6	+ 8 5	− 12	+ 5.8	+ 54	+ 3.3	− 53	+ 6.4	− 34	+ 6.5	− 55	− 9.7	
191321	Z Sagittarii	19 13.8	−21 7	− 20	− 5.3	− 45	− 1.6	− 55	− 5.7	− 17	− 2.0	+ 27	+ 5.5	
* *194632*	χ Cygni	19 46.7	+32 40	+ 24	− 2.2	+ 40	+ 0.3	+ 28	+ 3.6	+ 15	+ 2.6	+ 3	+ 7.9	

120905	T Virginis	12	9.5	− 5	29	+ 47	−14.2	+ 39	+ 2.9	+ 18	− 7.9	− 11	−14.2	+ 15	− 6.4	
123160	T Ursae Majoris	12	31.8	+60	2	− 33	+ 1.8	+ 57	− 3.7	~~− 5~~	~~−12.1~~	− 40	−14.1	+ 4	+ 8.5	+0 9 +14.4
124606	U Virginis	12	46.0	+ 6	6	+ 59	+ 5.7	+ 24	+ 0.7	+ 47	− 0.6	− 59	+ 2.1	− 17	− 8.7	
132706	S Virginis	13	27.8	− 6	41	+ 8	+11.7	− 43	+ 6.6	− 56	+14.1	− 50	+ 8.7	− 15	+ 4.2	
141954	S Bootis	14	19.5	+54	16	+ 68	+ 7.2	− 5	+ 3.8	− 68	− 6.4	− 72	+14.4	+ 17	− 4.2	
142584	R Camelop.	14	25.1	+84	17	+235	+ 6.1	+515	+ 8.5	−295	+12.0	−415	+11.7	+380	+ 3.5	
154615	R Serpentis	15	46.1	+15	26	− 28	− 6.5	− 42	−11.9	− 38	− 3.1	− 49	+ 4.2	− 36	+ 6.2	
155018	RR Librae	15	50.6	−18	1	− 64	− 3.0	− 41	− 0.9	− 4	+ 8.7	− 57	− 5.8	− 14	+ 7.2	
161122	RS Scorpii	16	11.7	−22	40	+ 30	− 1.6	+ 41	+ 8.1	+ 53	− 1.5	− 14	+ 6.3	+ 49	+ 3.3	
163137	W Herculis	16	31.7	+37	32	+ 22	− 0.8	− 45	− 9.6	+ 60	−14.1	+113	− 8.5	+ 94	−10.0	
163266	R Draconis	16	32.4	+66	58	+ 28	− 9.5	− 4	−10.1	− 25	−11.5	−143	−11.3	+108	+ 0.4	
164715	S Herculis	16	47.4	+15	7	+ 40	−11.4	+ 50	− 3.1	+ 23	− 7.8	+ 16	− 6.0	+ 25	−12.2	
190108	R Aquilae	19	1.6	+ 8	5	− 12	+ 5.8	+ 54	+ 3.3	− 53	+ 6.4	− 34	+ 6.5	− 55	− 9.7	
191321	Z Sagittarii	19	13.8	−21	7	− 20	− 5.3	− 45	− 1.6	− 55	− 5.7	− 17	− 2.0	+ 27	+ 5.5	
* *194632*	χ Cygni	19	46.7	+32	40	+ 24	− 2.2	+ 40	+ 0.3	+ 28	+ 3.6	+ 15	+ 2.6	+ 3	+ 7.9	
205923	R Vulpeculae	20	59.9	+23	26	+ 49	+ 5.4	+ 34	+ 5.7	− 18	+ 4.2	+ 62	+ 4.2	− 15	− 6.3	
210124	V Capricorni	21	1.8	−24	19	+ 22	− 6.8	+ 44	− 2.4	− 13	−23.6	+ 48	+ 8.1	+ 13	−20.3	
223841	R Lacertae	22	38.8	+41	51	+ 79	+ 9.8	+ 24	− 3.3	+ 34	−11.9	+ 85	+ 5.3	− 13	+ 3.5	
225120	S Aquarii	22	51.8	−20	53	− 51	+15.6	+ 34	−11.1	+ 37	+12.0	− 23	−12.6	− 21	−10.8	
230110	R Pegasi	23	1.6	+10	0	− 31	− 4.8	+ 9	+14.8	+ 43	− 0.3	+ 20	− 5.1	+ 55	+12.1	

These tables are for the use of observers, and not for publication.

The designation in the first column gives the right ascension in hours and minutes, and the declination in degrees. Southern declinations are indicated by Italics. Thus the designation of S Ceti should be read zero, nineteen, nine, south.

EDWARD C. PICKERING.

* not south. +32° 40'

STANDARDS FOR FAINT STELLAR MAGNITUDES (RUMFORD APPROPRIATION).

TABLE ~~V~~ VI.

Magnitudes ~~POSITIONS~~ OF TWELFTH MAGNITUDE STANDARDS.

Design.	Variable.	α 1900.	δ 1900.	Hagen ~~Δα~~ No	Photom ~~Δδ~~ Mag	Δα	Δδ	Δα	Δδ	Δα	Δδ	Δα	Δδ
		h m	° ′	s		s	′	s	′	s	′	s	′
001909	S Ceti	0 19.0	− 9 53	23	12.32	24	12.50	26	12.64	25	12.67	27	12.91
004047	U Cassiopeiae	0 40.8	+47 43	55	11.48	60	12.07	58	12.12	54	12.24	63	12.40
011208	S Piscium	1 12.4	+ 8 24	12	11.22	13	11.59	14	11.75	15	11.96	16	12.50
011272	S Cassiopeiae	1 12.3	+72 5	20	11.46	22	11.64	25	11.65	27	11.67	35	12.44
022000	R Ceti	2 20.9	− 0 38	14	12.03	15	12.43	17	12.60	18	12.62	20	12.93
030514	U Arietis	3 5.5	+14 25	17	12.60	19	13.04	22	13.08	21	13.19	23	13.26
032335	R Persei	3 23.7	+35 20	23	10.86	34	11.72	35	11.78	33	11.84	36	11.85
044617	V Tauri	4 46.2	+17 22	27	12.36	22	12.44	30	12.44	25	12.48	24	12.52
052404	S Orionis	5 24.1	− 4 46	36	11.54	35	11.56	34	11.94	40	11.98	37	12.12
061647	V Aurigae	6 16.3	+47 42	22	11.64	27	12.27	31	12.35	30	12.61	35	12.62
070122	R Geminorum	7 1.3	+22 52	28	11.46	27	11.93	38	12.14	37	12.27	44	12.84
075612	U Puppis	7 56.1	−12 34	53	11.13	56	11.36	45	11.43	51	11.76	82~~44~~	12.23
081617	V Cancri	8 16.0	+17 36	24	11.33	26	11.74	27	12.05	39	12.55	38	12.59
085008	T Hydrae	8 50.8	− 8 46	24	11.42	25	11.91	29	12.13	30	12.16	27	12.29
093934	R Leonis Min.	9 39.6	+34 58	26	12.29	27	12.63	30	12.97	29	13.03	31	13.35
104814	W Leonis	10 48.4	+14 15	20	12.30	22	12.32	24	12.71	23	12.72	27	12.88 31, 13.20
120905	T Virginis	12 9.5	− 5 29	19	11.46	18	11.62	22	12.21	24	12.24	23	12.25
123160	T Ursae Majoris	12 31.8	+60 2	20	12.51	21	12.71	26	13.15	24	13.24	23	13.39
124606	U Virginis	12 46.0	+ 6 6	15	11.22	16	11.39	17	12.19	18	12.63	19	13.00
132706	S Virginis	13 27.8	− 6 41	19	11.97	18	12.06	20	12.31	22	12.92	24	12.95
141954	S Bootis	14 19.5	+54 16	21	12.30	22	12.40	23	12.64	24	12.84	25	12.84
142584	R Camelop.	14 25.1	+84 17	13	11.55	16	12.29	19	12.43	14	12.49	18	12.54
154615	R Serpentis	15 46.1	+15 26	16	11.24	15	11.36	17	11.59	20	12.22	21	12.29
155018	RR Librae	15 50.6	−18 1	19	11.51	18	11.58	22	11.59	17	11.61	21	11.76
161122	RS Scorpii	16 11.7	−22 40	26	11.81	27	12.00	29	12.09	38	12.29	35	12.34
163137	W Herculis	16 31.7	+37 32	21	11.33	19	11.57	20	11.62	22	11.96	24	12.20
163266	R Draconis	16 32.4	+66 58	18	11.12	19	11.82	20	12.20	21	12.38	22	12.67
164715	S Herculis	16 47.4	+15 7	15	11.25	16	11.41	17	11.61	21	11.66	18	12.07
190108	R Aquilae	19 1.6	+ 8 5	24	11.52	26	11.67	31	11.70	29	11.85	33	12.16
191321	Z Sagittarii	19 13.8	−21 7	25	10.59	29	10.78	27	10.93	30	11.51	35	11.63
194632	χ Cygni	19 46.7	+32 40	59	10.78	67	11.16	63	11.17	64	11.23	81	11.25
205923	R Vulpeculae	20 59.9	+23 26	24	10.39	23	10.51	29	10.72	25	10.83	26	11.02
210124	V Capricorni	21 1.8	−24 19	9	10.58	14	11.20	16	11.24	19	11.33	18	11.48
223841	R Lacertae	22 38.8	+41 51	45	11.76	67	12.35	52	12.39	56	12.40	54	12.50

075612	U Puppis	7 56.1	−12 34	53	11.73	56	11.36	45	11.43	51	11.76	[illegible]	12.23
081617	V Cancri	8 16.0	+17 36	24	11.33	26	11.74	27	12.05	39	12.55	38	12.57
085008	T Hydrae	8 50.8	− 8 46	24	11.42	25	11.91	29	12.13	30	12.16	27	12.29
093934	R Leonis Min.	9 39.6	+34 58	26	12.29	27	12.63	30	12.97	29	13.03	31	13.35
104814	W Leonis	10 48.4	+14 15	20	12.30	22	12.32	24	12.71	23	12.72	27	12.88 31, 1320.
120905	T Virginis	12 9.5	− 5 29	19	11.46	18	11.62	22	12.21	24	12.24	23	12.25
123160	T Ursae Majoris	12 31.8	+60 2	20	12.51	21	12.71	26	13.15	24	13.24	23	13.39
124606	U Virginis	12 46.0	+ 6 6	15	11.22	16	11.39	17	12.19	18	12.63	19	13.00
132706	S Virginis	13 27.8	− 6 41	19	11.97	18	12.06	20	12.31	22	12.92	24	12.95
141954	S Bootis	14 19.5	+54 16	21	12.30	22	12.40	23	12.64	24	12.84	25	12.84
142584	R Camelop.	14 25.1	+84 17	13	11.55	16	12.29	19	12.43	14	12.49	18	12.54
154615	R Serpentis	15 46.1	+15 26	16	11.24	15	11.36	17	11.59	20	12.22	21	12.29
155018	RR Librae	15 50.6	−18 1	19	11.51	18	11.58	22	11.59	17	11.61	21	11.76
161122	RS Scorpii	16 11.7	−22 40	26	11.81	27	12.00	29	12.09	38	12.29	35	12.34
163137	W Herculis	16 31.7	+37 32	21	11.33	19	11.57	20	11.62	22	11.96	24	12.20
163266	R Draconis	16 32.4	+66 58	18	11.12	19	11.82	20	12.20	21	12.38	22	12.67
164715	S Herculis	16 47.4	+15 7	15	11.25	16	11.41	17	11.61	21	11.66	18	12.07
190108	R Aquilae	19 1.6	+ 8 5	24	11.52	26	11.67	31	11.70	29	11.85	33	12.16
191321	Z Sagittarii	19 13.8	−21 7	25	10.59	29	10.78	27	10.93	30	11.57	35	11.63
194632 *	χ Cygni	19 46.7	+32 40	59	10.78	67	11.16	63	11.17	64	11.23	81	11.25
205923	R Vulpeculae	20 59.9	+23 26	24	10.39	23	10.51	29	10.72	25	10.83	26	11.02
210124	V Capricorni	21 1.8	−24 19	9	10.58	14	11.20	16	11.24	19	11.33	18	11.48
223841	R Lacertae	22 38.8	+41 51	45	11.76	57	12.35	52	12.39	56	12.40	54	12.50
225120	S Aquarii	22 51.8	−20 53	16	11.03	17	11.10	20	11.75	19	11.91	21	12.01
230110	R Pegasi	23 1.6	+10 0	17	11.48	21	11.88	20	11.93	19	12.10	23	12.29
	36												

These tables are for the use of observers, and not for publication.

The designation in the first column gives the right ascension in hours and minutes, and the declination in degrees. Southern declinations are indicated by Italics. Thus the designation of S Ceti should be read zero, nineteen, nine, south.

* not south.

EDWARD C. PICKERING.

STANDARDS FOR FAINT STELLAR MAGNITUDES (RUMFORD APPROPRIATION).

TABLE ~~IX~~ VII.

POSITIONS OF FIFTEENTH MAGNITUDE STANDARDS.

Design.	Variable.	α 1900.	δ 1900.	Δα	Δδ	Δα	Δδ	Δα	Δδ	Δα	Δδ	Δα	Δδ
		h m	° ′	s	′	s	′	s	′	s	′	s	′
001909	S Ceti	0 19.0	− 9 53	+ 12	+15.8	+ 32	+16.0	+ 38	+16.0	+ 37	+14.2	+ 28	+ 3.0
004047	U Cassiopeiae	0 40.8	+47 43	+ 42	+ 8.3	+ 34	+ 3.6	+ 63	+ 1.9	+ 31	− 0.8	+ 66	− 1.9
011272	S Cassiopeiae	1 12.3	+72 5	+148	− 1.4	+162	+ 6.4	+ 73	+16.3	+127	+10.6	+138	+12.6
011208	S Piscium	1 12.4	+ 8 24	+ 10	−11.0	+ 6	−10.1	− 21	−12.4	− 6	−13.7	− 68	− 3.3
022000	R Ceti	2 20.9	− 0 38	+ 9	+13.0	− 10	+12.6	− 2	+12.1	+ 39	+ 3.7	+ 78	+ 7.0
030514	U Arietis	3 5.5	+14 25	− 21	+ 4.9	− 30	+ 4.7	− 24	+ 4.8	+ 32	+11.3	+ 28	+ 7.8
032335	R Persei	3 23.7	+35 20	− 16	+ 9.5	+ 35	+13.1	− 1	+10.6	− 22	+ 6.0	− 4	+ 3.5
044617	V Tauri	4 46.2	+17 22	− 11	+ 4.2	+ 16	+10.4	− 3	+ 9.0	0	+ 9.4	+ 4	+ 9.7
052404	S Orionis	5 24.1	− 4 46	+ 51	− 3.7	+ 48	− 1.0	+ 53	− 0.9	+ 73	− 0.7	+ 55	− 4.1
061647	V Aurigae	6 16.5	+47 45	− 1	− 7.4	− 12	− 9.9	− 19	− 8.3	− 6	+ 9.3	− 14	+ 9.3
070122	R Geminorum	7 1.3	+22 52	+ 50	+ 3.0	+ 46	+ 6.8	+ 42	+ 2.8	+ 38	+ 3.9	+ 47	+ 8.6
075612	U Puppis	7 56.1	−12 34	+ 35	− 2.2	+ 19	− 2.4	+ 22	− 0.4	+ 29	− 1.0	+ 32	− 3.0
081617	V Cancri	8 16.0	+17 36	+ 32	− 4.8	+ 32	− 1.0	+ 29	− 6.0	+ 41	− 2.5	+ 28	− 6.8
085008	T Hydrae	8 50.8	− 8 46	+ 44	+ 6.3	+ 37	+ 6.4	+ 41	+ 2.0	+ 43	+ 3.3	+ 51	+ 6.0
093934	R Leonis Min.	9 39.6	+34 58	+ 11	− 7.1	+ 25	− 2.7	+ 19	− 1.0	+ 18	− 7.9	+ 24	− 9.3
104814	W Leonis	10 48.4	+14 15	+ 71	+ 1.9	+ 62	− 4.8	+ 41	− 4.8	+ 25	− 5.4	+ 47	− 3.6
120905	T Virginis	12 9.5	− 5 29	− 3	+ 8.6	+ 49	+ 6.1	+ 5	+ 6.3	+ 36	+ 8.5	+ 50	+ 8.6
123160	T Ursae Majoris	12 31.8	+60 2	+104	−11.0	+ 65	− 2.9	+ 69	− 6.0	+130	− 9.1	+123	−12.4
124606	U Virginis	12 46.0	+ 6 6	+ 26	+ 2.0	+ 29	0.0	+ 33	+ 1.2	+ 44	+ 1.3	+ 27	− 0.2
132706	S Virginis	13 27.8	− 6 41	+ 51	− 3.4	+ 41	− 4.2	+ 44	− 4.6	+ 52	− 9.4	+ 39	−14.3
141954	S Bootis	14 19.5	+54 16	+ 48	+ 2.9	+ 46	− 0.5	+ 53	− 3.1	+ 54	− 4.5	+ 48	− 2.5
142584	R Camelop.	14 25.1	+84 17	+485	+ 0.8	+560	+ 1.1	+465	− 1.5	+420	+ 0.3	+120	− 7.7
154615	R Serpentis	15 46.1	+15 26	− 53	− 8.3	− 45	−10.0	− 39	− 4.7	− 54	+ 1.9	− 38	+ 6.0
155018	RR Librae	15 50.6	−18 1	+ 30	− 4.2	+ 55	− 6.7	+ 62	− 5.9	+ 48	− 4.4	+ 40	− 3.9
161122	R, S Scorpii	16 11.7	−22 40	+ 17	− 2.5	+ 13	− 3.4	+ 14	− 3.9	+ 22	− 3.4	+ 12	− 2.7
163137	W Herculis	16 31.7	+37 32	+ 61	−10.4	+ 62	−11.3	+ 65	−15.2	+ 79	−14.8	+ 83	−14.1
163266	R Draconis	16 32.4	+66 58	+ 29	− 6.3	− 40	−13.7	− 28	− 9.5	+ 19	−11.2	− 12	− 8.4
164715	S Herculis	16 47.4	+15 7	+ 72	− 6.1	+ 29	−13.5	+ 9	− 8.5	+ 62	− 6.0	+ 89	+ 0.2
190108	R Aquilae	19 1.6	+ 8 5	+ 42	− 0.5	+ 41	+ 0.1	+ 43	− 4.6	+ 68	− 1.4	+ 76	− 2.2
191321	Z Sagittarii	19 13.8	−21 7	+ 40	− 3.2	+ 28	− 2.5	+ 26	− 1.6	+ 32	− 6.2	+ 57	− 1.8
194632	χ Cygni	19 46.7	+32 40	+ 16	+ 9.0	+ 16	+ 5.4	+ 46	+ 3.8	+ 48	− 0.3	+ 38	− 5.3
205923	R Vulpeculae	20 59.9	+23 26	+ 17	− 3.4	+ 25	− 4.0	+ 35	− 4.4	+ 31	− 3.3	+ 25	+ 1.9
210124	V Capricorni	21 1.8	−24 19	+ 25	− 3.4	+ 37	− 3.9	+ 33	− 7.0	+ 50	−16.1	+ 32	− 5.6
223841	R Lacertae	22 38.8	+41 51	+ 62	+ 5.5	+ 48	+ 7.0	+ 74	+ 8.9	[illegible]	[illegible]	[illegible]	[illegible]

052404	S Orionis	5 24.1	− 4 46	+ 51	− 3.7	+ 48	− 1.0	+ 53	− 0.9	+ 73	− 0.7	+ 55	− 4.1
061647	V Aurigae	6 16.5	+47 45	− 1	− 7.4	− 12	− 9.9	− 19	− 8.3	− 6	+ 9.3	− 14	+ 9.3
070122	R Geminorum	7 1.3	+22 52	+ 50	+ 3.0	+ 46	+ 6.8	+ 42	+ 2.8	+ 38	+ 3.9	+ 47	+ 8.6
075612	U Puppis	7 56.1	−12 34	+ 35	− 2.2	+ 19	− 2.4	+ 22	− 0.4	+ 29	− 1.0	+ 32	− 3.0
081617	V Cancri	8 16.0	+17 36	+ 32	− 4.8	+ 32	− 1.0	+ 29	− 6.0	+ 41	− 2.5	+ 28	− 6.8
085008	T Hydrae	8 50.8	− 8 46	+ 44	+ 6.3	+ 37	+ 6.4	+ 41	+ 2.0	+ 43	+ 3.3	+ 51	+ 6.0
093934	R Leonis Min.	9 39.6	+34 58	+ 11	− 7.1	+ 25	− 2.7	+ 19	− 1.0	+ 18	− 7.9	+ 24	− 9.3
104814	W Leonis	10 48.4	+14 15	+ 71	+ 1.9	+ 62	− 4.8	+ 41	− 4.8	+ 25	− 5.4	+ 47	− 3.6
120905	T Virginis	12 9.5	− 5 29	− 3	+ 8.6	+ 49	+ 6.1	+ 5	+ 6.3	+ 36	+ 8.5	+ 50	+ 8.6
123160	T Ursae Majoris	12 31.8	+60 2	+104	−11.0	+ 65	− 2.9	+ 69	− 6.0	+130	− 9.1	+123	−12.4
124606	U Virginis	12 46.0	+ 6 6	+ 26	+ 2.0	+ 29	0.0	+ 33	+ 1.2	+ 44	+ 1.3	+ 27	− 0.2
132706	S Virginis	13 27.8	− 6 41	+ 51	− 3.4	+ 41	− 4.2	+ 44	− 4.6	+ 52	− 9.4	+ 39	−14.3
141954	S Bootis	14 19.5	+54 16	+ 48	+ 2.9	+ 46	− 0.5	+ 53	− 3.1	+ 54	− 4.5	+ 48	− 2.5
142584	R Camelop.	14 25.1	+84 17	+485	+ 0.8	+560	+ 1.1	+465	− 1.5	+420	+ 0.3	+120	− 7.7
154615	R Serpentis	15 46.1	+15 26	− 53	− 8.3	− 45	−10.0	− 39	− 4.7	− 54	+ 1.9	− 38	+ 6.0
155018	RR Librae	15 50.6	−18 1	+ 30	− 4.2	+ 55	− 6.7	+ 62	− 5.9	+ 48	− 4.4	+ 40	− 3.9
161122	R, S Scorpii	16 11.7	−22 40	+ 17	− 2.5	+ 13	− 3.4	+ 14	− 3.9	+ 22	− 3.4	+ 12	− 2.7
163137	W Herculis	16 31.7	+37 32	+ 61	−10.4	+ 62	−11.3	+ 65	−15.2	+ 79	−14.8	+ 83	−14.1
163266	R Draconis	16 32.4	+66 58	+ 29	− 6.3	− 40	−13.7	− 28	− 9.5	+ 19	−11.2	− 12	− 8.4
164715	S Herculis	16 47.4	+15 7	+ 72	− 6.1	+ 29	−13.5	+ 9	− 8.5	+ 62	− 6.0	+ 89	+ 0.2
190108	R Aquilae	19 1.6	+ 8 5	+ 42	− 0.5	+ 41	+ 0.1	+ 43	− 4.6	+ 68	− 1.4	+ 76	− 2.2
191321	Z Sagittarii	19 13.8	−21 7	+ 40	− 3.2	+ 28	− 2.5	+ 26	− 1.6	+ 32	− 6.2	+ 57	− 1.8
194632	χ Cygni	19 46.7	+32 40	+ 16	+ 9.0	+ 16	+ 5.4	+ 46	+ 3.8	+ 48	− 0.3	+ 38	− 5.3
205923	R Vulpeculae	20 59.9	+23 26	+ 17	− 3.4	+ 25	− 4.0	+ 35	− 4.4	+ 31	− 3.3	+ 25	+ 1.9
210124	V Capricorni	21 1.8	−24 19	+ 25	− 3.4	+ 37	− 3.9	+ 33	− 7.0	+ 50	−16.1	+ 32	− 5.6
223841	R Lacertae	22 38.8	+41 51	+ 62	+ 5.5	+ 48	+ 7.0	+ 74	+ 8.9	+ 20	− 2.9	+ 83	+ 9.4
225120	S Aquarii	22 51.8	−20 53	+ 21	+ 2.7	+ 44	+ 0.2	+ 50	+ 2.2	+ 33	+ 7.5	+ 51	+ 6.4
230110	R Pegasi	23 1.6	+10 0	+ 38	+ 2.4	+ 38	+ 4.0	+ 32	+ 4.6	+ 12	+ 4.9	+ 49	− 2.3

These tables are for the use of observers, and not for publication.

The designation in the first column gives the right ascension in hours and minutes, and the declination in degrees. Southern declinations are indicated by Italics. Thus the designation of S Ceti should be read zero, nineteen, nine, south.

EDWARD C. PICKERING.

The measures of both twelfth and fifteenth magnitude stars were carried out by Curtis in the years 1901 - 1902. Each night three series of four settings each were made on the faint stars and two series of the same number of settings on the brighter twelfth magnitude standards. These were taken in the order faint, bright, faint, bright, faint so as to take care of progressive changes in seeing, transparency of the sky, brightness of the photometer lamp and to some extent accidental errors of observation.

In reducing the observations, the mean of all the settings was taken for each star. The scale-readings thus obtained were converted into Δ mags by means of a table constructed from the earlier calibration curve shown in Figure II. The magnitude of any star is then given by the formula

$$\text{Magnitude} = M_0 + \Delta \text{ mag.}$$

where M_0 is the magnitude corresponding to the scale-reading for which Δ mag is equal to zero. M_0 was obtained by subtracting from the Harvard magnitudes of the twelfth magnitude standards the corresponding Δ mags derived from the observations. The mean of the five values thus obtained was then added to the Δ mag of each star to give its magnitude. This was done for each nights observations separately and the results for the different nights combined to give the final magnitude of each star. A sample reduction beginning with the mean scale-readings is given for the region S Ceti to show the form of reduction and the general agreement of the results. (Sample reduction.) ?

Each field was observed on at least three nights and the resulting mean magnitudes are given in Table VIII. As the magnitudes of the twelfth magnitude standards were also obtained they are included

Sample Reduction.

001909 S Ceti.

Date	a	b	c	d	e		l	m	n	o	p
Scale-readings	31.7	30.9	33.5	34.3	32.7		33.2	47.4	48.0	45.8	58.3
	24.7	26.4	28.6	33.0	29.3		35.5	47.7	46.0	44.4	57.3
	23.8	23.6	24.7	27.2	28.0		32.9	44.4	44.4	41.9	55.9
Δ Mags	2.87	2.78	3.06	3.16	2.98		3.03	4.63	4.70	4.46	[6.00]*
	2.07	2.26	2.51	3.01	2.60		3.30	4.66	4.48	4.30	[6.10]
	1.96	1.95	2.07	2.35	2.44		3.00	4.30	4.30	4.05	[5.81]
Harvard Magnitude	12.32	12.50	12.67	12.64	12.91	Mean Mo					
Mo	9.45	9.72	9.61	9.48	9.93	9.64 ± 0.06 p.e.					
	10.25	10.24	10.16	9.63	10.31	10.12 ± .08 "					
	10.36	10.55	10.60	10.29	10.47	10.45 ± .04 "					
McCormick magnitude	12.51	12.42	12.70	12.80	12.62		12.67	14.27	14.34	14.16	[15.64]
	12.19	12.38	12.63	13.13	12.72		13.42	14.78	14.60	14.42	[16.22]
	12.41	12.40	12.52	12.80	12.89		13.45	14.75	14.75	14.50	[16.26]
Mean	12.37	12.40	12.62	12.91	12.74		13.18	14.60	14.56	14.34	[16.04]
Average residual	0.12	0.01	0.06	0.15	0.10		0.34	0.22	0.15	0.16	0.27

* Values bracketed because Δ mags are uncertain in this portion of wedge.

in the table. Their mean magnitude will necessarily be the same as that of the Harvard magnitudes for the same stars.

Average residuals are also given for each star so as to give an idea of the consistency of the measures on separate nights without publishing all the details of the measures. The average residual for the twelfth magnitude stars is $0^{M}.10$ and for the fainter stars $0^{M}.16$. These values are not large considering the faintness of the stars measured.

(Table VIII.)

Remarks on Table VIII.

1.- measures made near end of scale, therefore magnitude doubtful.
2.- observed on two nights only.
3.- Hagen 30 observed instead of Harvard d, mag. 13.08.
4.- Hagen 50 probably observed by mistake for d on one night, $12^{M}.92$.
5.- misidentified? on one night, therefore two nights only.
6.- not a but Hagen 5. mag. 9.76. a not measured.
7.- 12-th mags. mean of five nights, 15-th mean of four.
8.- d misidentified on one night, therefore mean of three. All others mean of four. Low weight assigned to faint stars on one night because near end of scale.
9.- four nights on each, some incomplete.
10- not star a, mag 11.46.
11- This field was measured completely on six nights. All of the stars have the mean of six independent values except o and p which were changed for the last three. The position of (the first) o′ is $+0^{m}47^{s}$ $-16'.5$ mag. 13.77
p′ is +0 42 $-14'.6$ mag. 14.26

12.- Not e but Hagen 20. Mag 11.24.

Sixteenth magnitude standards in the same fields were selected at the Lick and Yerkes Observatories. Those selected at Yerkes Observatory are in a number of cases the same as the fifteenth magnitude standards selected here. Parkhurst's measures of the sixteenth magnitude stars are now in press. As soon as they appear, a comparison of the common stars will throw interesting light on the reliability of measures made with the wedge photometer.

A movement is on foot to publish charts of the Rumford

Table VIII.

Twelfth magnitude standards. Fifteenth magnitude standards.

Field	Star →	a		b		c		d		e		l		m		n		o		p	
		Mag	[illegible]	Mag	a.r.	Mag.	a.r.	Mag	a.r.	Mag	a.r.	Mag	a.r.	Mag	a.r.	Mag	a.r.	Mag	a.r.	Mag	a.r.
001909	S Ceti	12.37	0.12	12.40	.01	12.62	.06	12.91	.15	12.74	.10	13.18	34	14.60	.22	14.56	.15	14.34	.16	[16.04](1)	.27
004047	U Cassiopeiae	12.22	09	11.72	12	12.20	16	12.00	05	12.17	12	[13.51]	38	14.56	.16	15.24(2)	06	13.63	25	15.66(2)	24
011208	S Piscium	11.75	14	11.64	14	11.95	08	(3)		12.50	02	14.10	00	15.24	18	15.00	07	15.61	09	15.33	10
011272	S Cassiopeiae	11.44	06	11.76	03	11.72	22	11.76(4)	05	12.12	12	14.15	26	14.68	23	13.85	10	14.92	20	14.56	26
022000	R Ceti	12.24	08	12.40	10	12.23	01	12.69	12	13.07	02	14.50	16	14.50	19	14.59	18	15.88(2)	21	15.98(2)	08
030514	U Arietis (2)	12.58	18	12.95	08	13.12	01	13.14	12	13.37	10	14.54	01	15.00	20	15.12	23	15.46	11	15.28	18
032335	R Persei	11.12	16	11.75	09	11.70	10	11.73	04	11.77	11	14.29	03	13.96	04	14.48	16	14.43	13	15.77(5)	06
044617	V Tauri	(6)		12.90	08	12.18	14	12.06	07	12.66	03	14.52	19	14.58	24	15.43	12	15.34	05	15.55	04
052404	S Orionis (7)	11.92	10	11.77	14	11.52	10	12.09	16	11.83	16	15.36	23	15.39	26	15.28	19	15.06	24	15.63	25
061647	V Aurigae	11.67	12	12.33	12	12.43	19	12.43	15	12.54	19	14.55	16	14.77	21	15.12	10	15.50	24	15.22	20
070122	R Geminorum	11.91	09	11.68	06	12.29	09	12.22	11	12.53	10	13.80	01	14.29	10	14.87	06	14.93	07	15.37	08
075612	U Puppis (8)	11.46	10	12.03	15	11.62	06	11.41	07	11.30	15	14.26	18	14.69	30	14.86	34	14.88	30	14.95	30
081617	V Cancri	11.46	14	11.80	24	12.10	22	12.46	16	12.45	10	14.60	28	14.59	08	[15.27]	64	15.40	32	15.85	23
085008	T Hydrae	11.57	06	12.02	10	12.20	09	12.14	06	11.99	05	15.15	07	15.61	04	15.37	05	15.61	10	16.07	06
093934	R Leonis Minoris	12.38	06	12.53	02	13.33	06	12.87	18	13.16	15	15.21	11	15.22	07	15.65	18	15.68	18	15.93	20
104814	W Leonis	12.40	12	12.20	08	12.70	21	12.69	18	13.03	31	14.72(5)	06	15.22	20	15.39	23	15.68	23	15.35(2)	25
120905	T Virginis	11.50	09	11.50	17	12.45	18	12.35	14	12.00	19	14.60	11	13.88	05	14.83	03	14.99	04	15.56	10
123160	T Ursae Majoris	12.58	09	12.46	15	13.36	07	13.34	03	13.26	09	14.53	10	15.05	08	15.92	13	15.76	15	16.06	15
124606	U Virginis	11.51	08	11.49	07	12.20	16	12.65	10	12.75	07	14.65	12	15.00	31	15.58	12	15.77	18	15.86	13
132706	S Virginis	12.20	03	12.07	12	12.16	05	12.80	17	12.99	06	14.96	10	15.44(5)	06	15.83	16	15.92	19	15.95	16
141954	S Boötis (9)	12.24	07	12.36	07	12.75	06	12.86	17	12.79	06	14.78	04	15.28	06	15.43	17	15.64	12	16.35	12
142584	R Camelop.	(10)		12.20	07	12.22	01	12.93	07	(10)		14.18	20	14.67	19	15.37(1)	24	15.86	21	15.74	10
154615	R Serpentis (9)	11.52	08	11.36	07	11.58	07	11.96	02	12.26	12	14.40	16	15.12	16	[15.40]	40	15.33	08	15.45	06
155018	RR Librae (9)	11.65	10	11.54	10	11.62	07	11.73	10	11.53	08	14.76	17	14.51	17	15.42	18	15.25	20	15.54	22
161122	RS Scorpii	11.54	06	12.18	05	12.00	02	12.19	06	12.63	05	14.63	12	14.67	23	15.03	03	14.97	05	15.80	13
163137	W Herculis	11.54	10	11.58	15	11.50	11	11.86	18	12.13	17	13.93	10	14.40	07	[16.28](2)	34	15.37	27	15.52	16
163266	R Draconis (9)	11.29	36	11.68	08	12.29	16	12.58	16	12.33	12	14.37	18	14.42	12	14.58	22	14.97	25	15.32	15
164715	S Herculis	11.38	04	11.41	08	11.46	17	11.81	02	11.94	09	14.40	04	14.55	10	14.65	08	15.16	06	15.52	19
190108	R Aquilae	11.49	02	11.69	04	11.71	06	11.85	13	(12)		14.86	05	15.03	07	15.24	15	14.72	11	15.05	09
191321	X Sagittarii	10.50	07	10.87	13	10.92	03	11.52	08	11.63	09	14.22	24	14.20	30	14.21	19	14.51	24	14.66	23
194632	X Cygni	10.83	03	11.25	20	10.94	07	11.32	13	11.23	12	14.47(5)	03	13.35	08	13.75	10	14.93	16	14.72	21
205923	R Vulpeculae	10.51	07	10.40	12	10.67	04	10.97	03	10.93	19	14.12	02	14.32	08	13.92	16	14.87	26	14.71	26
210124	V Capricorni (11)	10.75	04	11.24	05	11.20	04	11.30	07	11.35	08	14.24	23	13.98	21	14.80	17	14.96	18	15.93	20
223841	R Lacertae	11.73	23	12.29	10	12.37	09	12.60	10	12.40	06	13.95	18	14.74	36	15.02	25	14.85	30	15.99	20
225120	S Aquarii	11.06	04	11.25	04	11.82	06	11.81	06	11.93	03	13.73	11	14.48	09	14.90	04	15.06	10	15.27	11
230110	R Pegasi	11.73	02	12.16	05	11.95	08	11.76	12	12.11	23	14.96	02	15.42	13	15.14	05	14.09	04	15.06	12

([illegible] at end of table.)

fields showing the positions of all the standard stars from the twelfth to the sixteenth magnitude. Owing to the large number of faint stars, identifications will be difficult without these charts.

The fourteenth magnitude standards were measured in 1903 - 1904 by Reed and Simpson in the same manner as the fifteenth magnitude stars. The two observers measured each field on two separate nights thus giving four independent determinations of the magnitude of each star. The positions of the fourteenth magnitude standards are given in Table IX.

(Table IX.)

The resulting magnitudes for the twelfth and fourteenth magnitude standards are given in Table X in the same form as in Table VIII. The average residual for all the twelfth magnitude stars is $0^{M}.10$ as before. For the fourteenth magnitude stars it is $0^{M}.17$. In each case however the probable error would be smaller than for the fifteenth magnitude stars because of the extra night's observation.

(Table X.)

Remarks on Table X.

1.- measured on three nights only.
2.- discordant value discarded.
3.- identification doubtful.

2. Other fields.

In 1904 - 1905 measures were made by Reed and Simpson on twelve stars in each of twenty ~~other~~ variable star fields. The measures were made on two nights each in the same manner as the preceding except that all stars received the same number of settings. The original records are lost. The charts used and a list of the mean scale-readings for each star are preserved so that the stars can be identified and their

STANDARDS FOR FAINT STELLAR MAGNITUDES (RUMFORD APPROPRIATION).

TABLE IX.

POSITIONS OF FOURTEENTH MAGNITUDE STANDARDS.

Design.	Variable.	α 1900.	δ 1900.	Δα	Δδ	Δα	Δδ	Δα	Δδ	Δα	Δδ	Δα	Δδ
		h m	° ′	s	′	s	′	s	′	s	′	s	′
001909	S Ceti	0 19.0	−9 53	−4	+5.5	+45	+7.7	−18	+2.4	+45	+4.7	+30	0.0
004047	U Cassiopeiae	0 40.8	+47 43	+40	−6.4	+42	−3.6	+54	−4.3	+4	+4.6	+32	−1.9
011272	S Cassiopeiae	1 12.3	+72 5	−41	+4.4	−67	+1.4	−83	−0.6	−88	+2.6	−96	+2.4
011208	S Piscium	1 12.4	+8 24	−16	+3.2	−14	−9.0	+9	−10.0	+14	−4.6	+32	−9.1
022000	R Ceti	2 20.9	−0 38	−16	−2.4	−10	−4.8	+14	+10.0	+17	+9.0	+26	+2.2
030514	U Arietis	3 5.5	+14 25	−33	−2.2	+18	−10.0	+23	+7.8	+30	−6.0	+67	+3.0
032335	R Persei	3 23.7	+35 20	+14	−9.5	+46	−3.5	+54	−1.8	+59	−5.8	+60	−7.7
044617	V Tauri	4 46.2	+17 22	+39	−4.6	+48	+2.6	+57	+4.8	+58	+2.3	+63	−2.0
052404	S Orionis	5 24.1	−4 46	−12	+2.3	+3	−7.7	+6	+9.1	+28	+3.9	+28	+0.7
061647	V Aurigae	6 16.5	+47 45	+11	+2.9	+20	+1.0	+25	−5.0	+46	−4.2	+39	−0.8
070122	R Geminorum	7 1.3	+22 52	+63	+3.5	+66	+2.1	+71	+5.8	+82	+5.8	+66	+2.6
075612	U Puppis	7 56.1	−12 34	−21	+0.1	−11	−3.7	+1	−3.6	+19	+0.7	+24	−0.8
081617	V Cancri	8 16.0	+17 36	−21	+0.3	+2	−7.7	+4	+6.0	+18	+2.2	+32	+5.3
085008	T Hydrae	8 50.8	−8 46	−26	−2.2	−6	−6.1	+15	−6.9	+24	+3.9	+32	−5.2
093934	R Leonis Min.	9 39.6	+34 58	−32	+5.1	+5	+9.0	+18	−2.7	+33	+8.2	+34	+12.5
104814	W Leonis	10 48.4	+14 15	+22	+3.7	+22	+6.2	+38	+5.3	+82	+5.8	+90	+6.3
120905	T Virginis	12 9.5	−5 29	+28	−2.0	−22	−4.8	+39	−2.1	−32	−5.6	+22	+3.3
123160	T Ursae Majoris	12 31.8	+60 2	+73	−3.8	+23	−1.1	+36	−0.2	+71	+6.2	+82	+7.1
124606	U Virginis	12 46.0	+6 6	−30	−5.2	−20	+7.2	−2	+4.3	−1	+6.0	+51	+2.2
132706	S Virginis	13 27.8	−6 41	−26	+2.0	+23	+3.0	+37	+7.7	+81	−0.1	+98	+2.0
141954	S Bootis	14 19.5	+54 16	+54	−1.2	+72	+1.9	+79	−1.1	+129	+9.8	+131	+2.5
142584	R Camelop.	14 25.1	+84 17	+368	+0.3	−348	+1.7	−40	−6.2	−32	−9.7	+93	−4.9
154615	R Serpentis	15 46.1	+15 26	+27	+9.2	+44	+7.3	+49	+4.2	+52	+5.0	+33	−2.8
155018	RR Librae	15 50.6	−18 1	−7	−8.0	+13	−0.4	+47	−7.1	+53	+4.9	+59	−0.3
161122	R, S Scorpii	16 11.7	−22 40	+19	−3.6	+24	+2.3	+27	+3.1	+39	−1.3	+47	+0.7
163137	W Herculis	16 31.7	+37 32	+29	−5.4	+40	−1.8	+56	+4.7	+63	0.0	+64	−4.7
163266	R Draconis	16 32.4	+66 58	−9	+5.2	+52	−7.6	+68	−5.5	+131	−4.2	+135	+0.2
164715	S Herculis	16 47.4	+15 7	−46	−4.2	−44	−5.1	−49	−2.2	−67	+2.3	−50	+1.7
190108	R Aquilae	19 1.6	+8 5	+36	+4.3	+46	−2.5	+17	+5.5	+37	−5.7	+37	+0.8
191321	Z Sagittarii	19 13.8	−21 7	+38	−2.5	+34	−5.5	+44	−1.6	+20	−7.5	+42	+1.7
194632	χ Cygni	19 46.7	+32 40	+43	+5.0	+47	+0.2	+51	+6.9	+54	+2.8	+66	+4.7
205923	R Vulpeculae	20 59.9	+23 26	+27	−9.5	+35	+2.3	+23	−9.2	+44	−10.0	+57	−4.8
210124	V Capricorni	21 1.8	−24 19	+70	0.0	+63	+3.0	+48	0.0	+56	+0.4	+34	+5.0
223841	R Lacertae	22 38.8	+41 51	+49	+3.8	+41	+2.6	+78	+1.8	+88	−3.3	+56	−4.5

022000	R Ceti	2	20.9	− 0	38	− 16	− 2.4	− 10	− 4.8	+ 14	+10.0	+ 17	[illegible]	+ 26	+ 2.2
030514	U Arietis	3	5.5	+14	25	− 33	− 2.2	+ 18	−10.0	+ 23	+ 7.8	+ 30	− 6.0	+ 67	+ 3.0
032335	R Persei	3	23.7	+35	20	+ 14	− 9.5	+ 46	− 3.5	+ 54	− 1.8	+ 59	− 5.8	+ 60	− 7.7
044617	V Tauri	4	46.2	+17	22	+ 39	− 4.6	+ 48	+ 2.6	+ 57	+ 4.8	+ 58	+ 2.3	+ 63	− 2.0
052404	S Orionis	5	24.1	− 4	46	− 12	+ 2.3	+ 3	− 7.7	+ 6	+ 9.1	+ 28	+ 3.9	+ 28	+ 0.7
061647	V Aurigae	6	16.5	+47	45	+ 11	+ 2.9	+ 20	+ 1.0	+ 25	− 5.0	+ 46	− 4.2	+ 39	− 0.8
070122	R Geminorum	7	1.3	+22	52	+ 63	+ 3.5	+ 66	+ 2.1	+ 71	+ 5.8	+ 82	+ 5.8	+ 66	+ 2.6
075612	U Puppis	7	56.1	−12	34	− 21	+ 0.1	− 11	− 3.7	+ 1	− 3.6	+ 19	+ 0.7	+ 24	− 0.8
081617	V Cancri	8	16.0	+17	36	− 21	+ 0.3	+ 2	− 7.7	+ 4	+ 6.0	+ 18	+ 2.2	+ 32	+ 5.3
085008	T Hydrae	8	50.8	− 8	46	− 26	− 2.2	− 6	− 6.1	+ 15	− 6.9	+ 24	+ 3.9	+ 32	− 5.2
093934	R Leonis Min.	9	39.6	+34	58	− 32	+ 5.1	+ 5	+ 9.0	+ 18	− 2.7	+ 33	+ 8.2	+ 34	+12.5
104814	W Leonis	10	48.4	+14	15	+ 22	+ 3.7	+ 22	+ 6.2	+ 38	+ 5.3	+ 82	+ 5.8	+ 90	+ 6.3
120905	T Virginis	12	9.5	− 5	29	+ 28	− 2.0	− 22	− 4.8	+ 39	− 2.1	− 32	− 5.6	+ 22	+ 3.3
123160	T Ursae Majoris	12	31.8	+60	2	+ 73	− 3.8	+ 23	− 1.1	+ 36	− 0.2	+ 71	+ 6.2	+ 82	+ 7.1
124606	U Virginis	12	46.0	+ 6	6	− 30	− 5.2	+ 20	+ 7.2	− 2	+ 4.3	− 1	+ 6.0	+ 51	+ 2.2
132706	S Virginis	13	27.8	− 6	41	− 26	+ 2.0	+ 23	+ 3.0	+ 37	+ 7.7	+ 81	− 0.1	+ 98	+ 2.0
141954	S Bootis	14	19.5	+54	16	+ 54	− 1.2	+ 72	+ 1.9	+ 79	− 1.1	+129	+ 9.8	+131	+ 2.5
142584	R Camelop.	14	25.1	+84	17	+368	+ 0.3	−348	+ 1.7	− 40	− 6.2	− 32	− 9.7	+ 93	− 4.9
154615	R Serpentis	15	46.1	+15	26	+ 27	+ 9.2	+ 44	+ 7.3	+ 49	+ 4.2	+ 52	+ 5.0	+ 33	− 2.8
155018	RR Librae	15	50.6	−18	1	− 7	− 8.0	+ 13	− 0.4	+ 47	− 7.1	+ 53	+ 4.9	+ 59	− 0.3
161122	R, S Scorpii	16	11.7	−22	40	+ 19	− 3.6	+ 24	+ 2.3	+ 27	+ 3.1	+ 39	− 1.3	+ 47	+ 0.7
163137	W Herculis	16	31.7	+37	32	+ 29	− 5.4	+ 40	− 1.8	+ 56	+ 4.7	+ 63	0.0	+ 64	− 4.7
163266	R Draconis	16	32.4	+66	58	− 9	+ 5.2	+ 52	− 7.6	+ 68	− 5.5	+131	− 4.2	+135	+ 0.2
164715	S Herculis	16	47.4	+15	7	− 46	− 4.2	− 44	− 5.1	− 49	− 2.2	− 67	+ 2.3	− 50	+ 1.7
190108	R Aquilae	19	1.6	+ 8	5	+ 36	+ 4.3	+ 46	− 2.5	+ 17	+ 5.5	+ 37	− 5.7	+ 37	+ 0.8
191321	Z Sagittarii	19	13.8	−21	7	+ 38	− 2.5	+ 34	− 5.5	+ 44	− 1.6	+ 20	− 7.5	+ 42	+ 1.7
194632	χ Cygni	19	46.7	+32	40	+ 43	+ 5.0	+ 47	+ 0.2	+ 51	+ 6.9	+ 54	+ 2.8	+ 66	+ 4.7
205923	R Vulpeculae	20	59.9	+23	26	+ 27	− 9.5	+ 35	+ 2.3	+ 23	− 9.2	+ 44	−10.0	+ 57	− 4.8
210124	V Capricorni	21	1.8	−24	19	+ 70	0.0	+ 63	+ 3.0	+ 48	0.0	+ 56	+ 0.4	+ 34	+ 5.0
223841	R Lacertae	22	38.8	+41	51	+ 49	+ 3.8	+ 41	+ 2.6	+ 78	+ 1.8	+ 88	− 3.3	+ 56	− 4.5
225120	S Aquarii	22	51.8	−20	53	− 46	− 2.7	+ 44	− 8.0	− 50	− 5.2	+ 30	− 8.2	− 49	− 4.1
230110	R Pegasi	23	1.6	+10	0	+ 14	− 1.8	+ 23	+ 5.0	+ 11	+ 5.1	+ 58	− 3.0	+ 32	− 8.2

These tables are for the use of observers, and not for publication.

The designation in the first column gives the right ascension in hours and minutes, and the declination in degrees. Southern declinations are indicated by Italics. Thus the designation of S Ceti should be read zero, nineteen, nine, south. In Table II, the stars are not arranged in the order of brightness.

EDWARD C. PICKERING.

Table X.

Twelfth magnitude standards. Fourteenth magnitude standards.

Field	Star →	a mag	a a.r.	b mag	b a.r.	c mag	c a.r.	d mag	d a.r.	e mag	e a.r.	f mag	f a.r.	g mag	g a.r.	h mag	h a.r.	i mag	i a.r.	k mag	k a.r.
001909	S Ceti	12.31	.09	12.51	.10	12.53	06	12.76	11	12.94	07	13.81	.15	14.08	.12	14.16	.13	14.38	.18	14.33	18
004047	U Cassiopeiae	12.07	08	11.72	10	12.23	05	12.02	13	12.28	10	13.14	14	13.48	09	13.74	10	13.46	12	13.52	16
011208	S Piscium	11.36	07	11.66	14	11.95	16	11.85	13	12.21	10	14.06	14	13.97	05	13.75	19	14.32	06	13.38	06
011272	S Cassiopeiae	11.60	13	11.60	12	11.57	06	11.75	11	12.34	08	13.40	08	13.56	14	13.94	16	13.41	07	13.51	16
022000	R Ceti	12.22	10	12.38	07	12.48	02	12.67	12	12.86	08	14.86	16	15.09	23	14.87	31	15.04	25	14.34	12
030514	U Arietis	12.70	10	12.93	08	13.25	13	13.18	04	13.13	15	14.19	14	14.10	10	14.18	12	14.66	03	13.98	14
032335	R Persei	11.36	12	11.88	09	11.76	06	11.70	07	11.85	12	13.64	18	13.58	16	13.56	14	13.34	16	13.98	12
044617	V Tauri	12.40	08	12.72	13	12.39	14	12.27	08	12.45	10	13.75	19	14.08	09	13.94	13	14.24	08	13.72	11
052404	S Orionis	12.04	11	11.61	04	11.68	05	12.00	03	11.80	06	13.25	11	13.44	20	13.34	10	13.39	12	13.39	17
061647	V Aurigae	11.98	16	12.58	12	12.22	08	12.49	09	12.48	11	13.54	22	13.68	21	13.70	16	13.58	17	13.77	25
070122	R Geminorum	12.01	10	11.81	16	12.33	09	12.20	07	12.52	06	14.44	10	12.92	16	13.30	08	13.11	06	12.98	15
075612	U Puppis	11.31	05	11.97	19	11.76	05	11.30	09	11.43	12	13.68	11	13.57	12	13.44	10	13.48	12	13.86	10
081617	V Cancri	11.64	04	12.02	07	11.88	03	12.30	08	12.42	12	13.63	10	13.81	20	13.19	10	13.58	10	13.27	13
085008	T Hydrae	11.73	11	11.89	08	12.08	07	11.98	04	12.23	11	13.78	07	14.03	18	13.98	15	14.22	08	13.77	18
093934	R Leonis Minoris	12.40	04	12.60	13	13.07	10	12.96	10	13.29	03	14.65	13	14.69	13	13.89	07	13.66	06	13.67	08
104814	W Leonis	12.41	09	12.36	05	12.56	07	12.68	06	12.90	10	13.74	07	13.99	06	14.52	12	14.40	12	14.02	10
120905	T Virginis	11.66	06	11.76	14	11.99	08	12.03	13	12.34	12	14.13	25	13.52	12	14.22	24	13.56	14	14.28	18
123160	T Ursae Majoris	12.56	22	12.61	12	(13.56)(3)	57	13.24	26	13.26	23	13.44	12	14.01	24	14.72	14	13.92	19	14.52	16
124606	U Virginis	11.58	08	11.50	13	12.30	14	12.42	08	12.67	15	14.30	35	13.64	18	13.68	15	14.12	19	13.51	18
132706	S Virginis	12.06	12	12.24	13	12.33	08	12.66	06	12.93	10	13.91	07	13.74	12	14.12(1)	06	14.21	09	14.46	08
141954	S Boötis	12.27	12	12.48	08	12.67	09	12.82	10	12.78	12	13.99	06	14.26	14	14.36	11	13.96	14	13.96	14
142584	R Camelop.	11.69	04	12.19	09	12.25	14	12.63	02	12.70	16	14.20	17	14.08	27	14.11	18	13.64	12	14.18	24
154615	R Serpentis	11.55	63	11.35	14	11.55	08	11.96	11	12.31	10	13.46	24	13.67	22	14.06	18	14.01	23	13.98	13
155018	RR Librae	11.54	10	11.64	05	11.59	08	11.66	09	11.63	13	13.78	10	13.36	12	13.04	12	14.38	09	13.96	13
161122	R S Scorpii	11.90	12	12.05	11	11.91	07	12.19	10	12.48	04	13.53	10	13.25	16	13.38	12	13.35	11	13.90	03
163137	W Herculis	11.57	06	11.70	07	11.50	04	11.77	09	12.08	09	13.84	16	14.17	11	14.08	06	14.17	10	14.15	12
163266	R Draconis	11.38	14	11.74	21	12.34	22	12.54	12	12.43	23	14.38(2)	14	13.80	20	14.29(2)	22	14.37	26	14.82(2)	32
164715	S Herculis	11.25	08	11.38	09	11.53	07	12.20	10	11.58	16	13.24	13	13.28	11	13.59	03	13.58	08	14.16	14
190108	R Aquilae	11.52	12	11.88	04	11.72	10	11.85	07	11.93	04	13.77	34	13.30	13	13.76	23	13.28	28	13.10	21
191321	T Sagittarii	10.55	14	10.96	12	11.12	08	11.36	18	11.46	15	12.36	28	12.90	27	13.01	25	12.90	23	13.84	24
194632	χ Cygni	10.87	09	10.98	10	11.06	19	11.28	03	11.40	18	12.34	12	12.84	10	12.99	08	12.04	12	12.39	04
205923	R Vulpeculae	10.69	03	10.45	11	10.55	09	11.00	04	10.76	06	12.64	31	12.41	08	12.55	15	12.80	14	12.96	12
210124	V Capricorni	10.72	07	11.18	05	11.28	08	11.32	09	11.22	12	13.40	10	13.58	10	13.65	12	13.90	07	13.94	16
223841	R Lacertae	12.04	03	12.32	04	12.28	08	12.44	14	12.34	08	13.13	11	13.08	07	13.27	08	13.58	17	13.54	22
225120	S Aquarii	11.13	13	10.88	13	11.95	13	11.88	06	11.97	06	14.30	10	13.42	21	13.93	07	14.05	12	14.20	10
230110	R Pegasi	11.64	05	12.00	20	11.99	08	11.77	07	12.30	08	13.59	15	13.59	08	13.57	05	13.74	13	13.65	18

(Numbers in red refer to remarks at end of Table).

magnitudes determined nevertheless. Five of these fields were also in the previous lists. Additional stars have been observed in each of them however.

A list of the stars observed is given in Table XI. The numbers of the stars to be found in Hagen's catalog are given in red beneath the star's position. Positions are taken from the catalog for the Hagen stars. Positions of the others have been read off from the Hagen chart on which they had been plotted by the observers and are therefore liable to some error.

(Table XI.)

Some difficulty was experienced in securing enough standard stars in some of the fields to permit a satisfactory reduction. Harvard Annals <u>87</u>, <u>57</u>, and <u>74</u> furnished the data for standards except in the field of R Comae. For this region magnitudes were taken from Parkhurst's Researches in Stellar Photometry. Table XII gives the magnitudes of the standard stars in red on the upper line and the McCormick magnitude of all stars on the lower line, together with the average residual.

(Table XII)

Remarks on Table XII, (apply

1.- identification doubtful.
2.- misidentified on one or more nights (?).
3.- measured on three nights only.
4.- measured on two nights only.

The photometer magnitudes here given provide good standard magnitudes for faint stars in the fields selected. Additional measures willbbe made on other fields as the reduction of the variable star observations progresses and the need becomes apparent.

Table XI.
Photometer Stars.

Field	a Δα	a Δδ	b Δα	b Δδ	c Δα	c Δδ	d Δα	d Δδ	e Δα	e Δδ	f Δα	f Δδ	g Δα	g Δδ	h Δα	h Δδ	i Δα	i Δδ	k Δα	k Δδ	l Δα	l Δδ	m Δα	m Δδ
						′	s	′	s	′	s	′	s	′	s	′	s	′	s	′	s	′	s	′
T Andromedae	−0ˢ5	−5′	−29	+2	+2	+2	0	+2.5	−2	+3	+16 (33)	+1.9	+13 (32)	+7.0	−13	+8	−23 (29)	+10.2	−34	+12.5	−27	+13	−25 (39)	+14.9
R Androm. (Hagen Number)	+8 (44)	+5	−47 YN(43)	+4.6	−12 C	+2	−29 (45)W	−2.3	−22 (33)	−2	−17 (33)	−3	−6 a	−4	+6 d	−3	+7 e	−4	+15 (44)YH	−4.2	+28 (48)ZH	+0.3	+36 g	−1
U Piscium	0 (12)	−10.2	+13 (15)	−4.2	+9	−2	+7 (22)	+0.2	+8	+2	+37 (16)	+3.9	+26	+5	+21 (10)	+5.1	+17	+6	−17	+8	−24	+7.5	−28	+2.5
R Piscium	−10	+5	−12	+4	−22	+0.5	−2	±3	+6	−2.5	−45	−6	+34 (24)	+1.2	+25	+0.5	+8	+3.5	+17	+8	+21 (32)	+6.3	+32 (23)	+6.4
S Arietis	−47	−5	−34	−1	−31 (33)	+3.2	−7	+4	+8 (23)	+6.2	+17	+2	+14	−2	+25	−5	+29	−6	+20 (32)	−5.8	+14	−7.5	−8	+1.5
R Persei	−47 (41)	−1.5	−32	+2	−31	−0.5	−28	−1	−19 (53)	−2.1	−12 (58)	+0.3	+18 (62)	+1.2	+45 (52)	+1.2	+27	−2	+20	−1	+13 (40)	−2.0	+2	−4.5
V Orionis	−25	+1.5	−18	+2	−15	+3	+12 (43)	+3.1			+19	−2	+15	−0.5	+11	−1	+5 (45)	−4.2	−5	−4	−10 (21)	−3.3	−5 (40)	−0.9
T Can. Min.	−23 (38)	+3.0	−9 (47)	+4.0	−3	+1	−1 (69)	+0.3	+4 (63)	+0.2	+14	+1	+16	0	+18 (52)	+2.2	+15 (66)	−2.1	+21	−2	+21 (51)	−4.0	+35 (39)	−2.9
R Urs. Maj.	+75	0	+32	+2	+9 (14)	+3.5	−35	+1	−39 (18)	−0.6	−85 (30)	−0.2	−57 (27)	−2.9	−40	−4	−42	−6	−4 (23)	−3.3	+14 (29)	−3.9	+9	−5.5
R Comae	−30 (19)	−10.4	−32 (9)	−4.3	−60 (11)	−1.6	−37	+6	−19	+1	−32	+2	−17	+4	−7	+5	+5	+7	−3	+8	−5	+10	+29 (20)	+8.6
Y Virginis	+58 (15)	−13.7	+17 (17)	−14.0	+18	−6	+8 (20)	−7.1	−9	+7.6	−17 (12)	−7.7	−30	−6	−21	−3	−3	−4	+6 (18)	+2.3	−5	+4	−28	+6
U Virginis	+42 (5)	−12.9	+9 (10)	−6.2	−17 (19)	−8.7	−59 (18)	+2.1	−30	+1	−9 (17)	−0.5	−2	+4.3	−1	+6.0	−20	+7.2	+24 (16)	+0.7	+51	+2.2	+59 (15)	+5.7
V Virginis	−41 (17)	+0.9	−34 (14)	−0.3	−12	−2	−8	−4	−5 (21)	−6.9	0	−2.6	+3	−2.5	+19	−2	+12	0.0	−2	+1	−20 (19)	+5.4	−16 (17)	+10.2
S Virginis	+2 (23)	−2.7	−35 (12)	−2.7	−26	+2.0	−43 (19)	+6.6	−50 (22)	+8.7	−23 (26)	+12.6	−29 (28)	+8.1	−15 (24)	+4.2	+8 (18)	+11.7	+22 (29)	+4.2	+23	+3.0	+49 (25)	+5.5
S Bootis	+24 (11)	−14.7	−41 (29)	−8.4	−28 (26)	−6.0	−16 (31)	−8.1	−12 (30)	−8.7	−9 (28)	−9.5	+3	−6	+17 (25)	−4.2	−5 (22)	+3.8	−37 (27)	+2.9	−43 (69)	+4.5	−33	+6
R Serpentis	−13	−3	+3	−1	+13 (25)	+0.2	+27 (32)	+0.1	+4 (31)	+5.3	−5 (27)	+3.6	−8	+2	−27 (23)	+2.1	−49 (20)	+4.2	−43 (18)	+7.4	−36 (21)	+6.2	−17 (22)	+6.4
R Herculis	+2 (15)	−10.2	+13 (37)	−3.9	+21 (30)	+0.3	+4	+2.5	−1	+4	−6	+1	−30 (32)	−1.9	−26 (34)	−1.8	−26	−0.5	−22	+1	−24 (27)	+3.4	−21 (23)	+5.7
V Cygni	+44 (29)	−7.2	+36	−8	+31 (27)	−6.5	−18	+1	−10	+4	+4	+2	0 (43)	+0.7	+12	0	+27 (35)	−0.9	+38 (59)	+0.6	+38	+2.6	+31	+2.6
T Delphini	+35	−1	+37	−4	+34 (50)	−3.3	+10 (40)	−4.9	+7	−6	+8	−3	+14	0	+12 (21)	0	+10 (33)	+2.7	−11	0	−18	+6	−11 (26)	+7.2
V C.t.	−42	−4	+5	−5.5	+2 (28)	−3.9	+4	−1.5	−5	+0.5	−32	+3	−28 (25)	+2.1	−7 (24)	+2.1	+5 (28)	+1.5	+18	+1	+21	+3.5	+32 (27)	+1.5

Table XII
Photometer Magnitudes.

Field	Star	a		b		c		d		e		f		g		h		i		k		l		m	
		Mag	a.r.	Mag		Mag		[illegible]		13.69															
						13.76 14.42		13.96				12.58		12.33				(2)		13.03 13.30		13.30			
	T Andromedae	13.96	20	13.14	20	14.52	12	12.78	07	13.85	09	12.34	12	12.31	05	13.26	04	[12.50]	36	13.64	12	14.22	16	12.48	22
				12.87						13.94										12.38					
	R Andromedae	13.59	06	12.99	06	14.50	03	12.37	10	13.88	08	13.68	09	14.08	06	13.38	19	13.68	05	12.32	09	12.42	12	13.24	09
		(2)		12.27								12.61													
	U Piscium	[11.36]	69	12.41	04	13.19	33	13.10	29	14.44	18	12.47	05	13.66	26	11.46	07	14.33	33	13.41	12	14.00	24	13.81	19
												13.16		13.55								12.77			
	R Persei	12.34	16	13.69	08	13.86	08	15.16	12	13.75	14	13.44	06	13.57	08	12.94	16	14.20	10	14.34	04	12.47	09	14.70	16 (1)
								12.46		12.59		(2)						12.76				10.84		(12.34	
	V Orionis	13.15	18	12.92	03	13.00	17	12.48	13	12.71	14	14.02	09	15.12	06	14.58	04	12.47	13	14.53	04	10.96	10	11.62)	34
		11.42		12.09																13.68 (1)		12.35			
	T Canis Minoris	11.63	09	12.07	09	13.76	11	13.26	10	[12.82]	42	14.72	09	13.94	16	12.30	15	12.82	20	13.20	06	12.16	04	11.86	16
						11.58		14.50		12.02				13.12						12.66		13.22			
	R Ursae Majoris	13.56	06	13.97	09	11.82	18	14.28	09	12.24	06	13.12	10	13.07	08	13.56	14	13.32	18	12.67	20	13.04	12	13.94	18
		(12.29)		10.77		11.76				(14.08)		(12.83)		(14.08)		(13.19)									
	R Comae Ber.*	12.16	06	10.76 (1)	14	11.38	20	13.41	07	14.30	10	13.06	12	13.02 (1)	18	13.36	14	13.64	09	13.54	20	13.44	08	12.51	14
				11.55		13.17 (1)		12.90				11.07						13.63		11.96					
	V Virginis	11.58	04	11.76	04	13.70	06	12.49	06	12.41	09	11.08	03	13.16	06	14.07	07	13.46	09	11.80	11	13.79	20	12.76	26
		9.26		10.08				12.63				10.44 (2)		12.83 (1)		13.16 (1)				11.39				11.22	
	U Virginis	9.38	03	10.44	03	12.26	25	12.06	16	13.61	06	10.72	14	13.29	04	13.63	10	13.10	14	11.13	18	13.04	08	10.98	21
		12.04						11.74		12.92				12.34		12.95		12.06							
	S Virginis	12.49	10	11.24	17	13.77	32	11.86	08	12.59	17	12.82	25	12.82	10	12.50	18	11.81	11	12.82	12	13.30	16	12.64	08
		10.18														12.84		12.40							
	S Bootis (4)	10.64	06	13.44	03	13.18	12	13.80	12	13.66	10	13.31	12	14.16	10	12.62	02	12.16	04	12.96	06	10.90	24	13.06	04
		1																12.22				12.28			
	R Serpentis (4)	13.77	12	14.25	28	13.36	24	14.26	13	14.22	22	13.76	06	14.02	26	13.50	12	12.07	03	12.08	10	12.48	08	12.37	16
																10.90		12.17							
	T Delphini	13.19	08	12.24	13	11.50	22	11.29	17	13.38	08	13.28	11	13.11	26	10.64	15	12.43	15	13.45	17	13.12	08	11.24	17
						12.75								12.95		12.74		13.62							
	V Ceti.	14.48	24	13.89	22	12.80	08	14.56	10	14.64	13	13.32	22	13.80	06	12.75	04	13.50	11	14.46	20	14.62	15	13.19	18

* Magnitudes in parenthesis are Parkhurst's.
(1) - Numbers refer to remarks at end of table.

V. THE OBSERVATIONS.

The reduction of the variable star observations described in this paper was begun in the fall of 1916. As the observations of S Ceti had been partially reduced by a number of different methods, this field was selected for experimentation as to the best method of obtaining the magnitudes of the comparison stars and deriving the magnitude of variable. Tne result was that further reduction was held up until an additional series of photometer measures could be made on faint comparison stars to check up the values obtained from the observations. These measures gave added confidence in the magnitudes obtained by the methods described in the earlier part of this paper and the reduction was resumed.

(a) Method of Reduction.

Having obtained the magnitudes of the comparison stars, the observations were at first ~~made~~ reduced by means of a least square solution whenever a comparison of the variable had been made with more than two stars. The magnitudes of the comparison stars were used to two decimal places. It soon became evident that this method of reduction was a great deal more rigorous and laborious than the accuracy of the observations ~~would~~ warranted. It was decided therefore to drop the second decimal place in the magnitudes of the comparison stars, since it has no real significance, and to use the least square method of reduction only when (1) more than four comparison stars were used, (2) the comparison stars in the sequence of observations were unequally distributed in brightness with respect to the variable, or (3) when the steps used did not approximate the same fraction of a magnitude in all parts of the observation.

For all other observations the method of reduction in use at Harvard College Observatory and elsewhere was adopted, with the modification that any appropriate value suggested by the observation was used for each step instead of arbitrarily assuming it to be a tenth of a magnitude. The observation was then reduced as though the assumed value of a step were the true value. The differences resulting from the use of values differing not too greatly from the true values of the steps were well within the limits of accuracy of the observations.

An example taken at random wll illustrate this point. The first observation by Olivier on V Geminorum for 1906 February 23-rd is

$$33_1 - 3 - V - 2 - 43_1 - 2 - 34_2$$

Since the interval between the brightest and faintest star is 0.7 mag. and seven steps are inserted, assume each step equal to 0.1 mag. The result is

$$\begin{array}{llll} 33_1 = 13^m.4+.3 & = 13.7 & \text{mag.} \\ 43_1 = 14.0-.2 & = 13.8 & " \\ 34_2 = 14.1-.4 & = \underline{13.7} & " \\ \quad \text{Mean} & \;\; 13.73 & " \end{array}$$

The correctness of this value is confirmed by a least square solution. Let x be equal to the magnitude of the variable and y be the value of a step in fractions of a magnitude. Then the equations are

$$\begin{array}{l} x-3y = 13.4 = 13.0+0.4 \\ x+2y = 14.0 = 13.0+1.0 \\ x+4y = 14.1 = 13.0+1.1 \end{array}$$

Using only the excess above 13.0 mag. on the right hand side of the equation the normal equations become

$$\begin{array}{l} 3x + 3y = 2.5 \\ 3x + 29y = 5.2 \end{array}$$

the solution of which is $x = 0.73 + 13.0 = 13.73$ mag.
$y = 0.104$ mag.

In this case the value chosen for the step was the true one and the results are identical. If 0.15 mag. had been used as the value of a step the resulting magnitude of the variable would have been 13.68. The small difference of only 0.05 mag. from the previous result is due to the fact that approximately the same number of steps were placed between the stars of the sequence and the steps were all of about the same size.

After deriving the magnitudes for the variables, they were plotted as ordinates with the Julian Days as abscissae giving the light-curve in the usual manner. In general the observations are not continuous enough to allow an analysis of any degree of refinement to be made of the light-variations. In only one or two cases could a mean light curve be derived in the customary manner with any great accuracy.

(b) List of Variables.

As shown in the introduction eighty-two stars had twenty-five or more observations previous to 1912. Most of these stars are now on the observing list and additional observations are being made. For each one of these stars the data will probably be sufficient to give some information concerning magnitudes at minimum. For first reduction about thirty of these stars were selected for which Hartwig's Katalog und Ephemeriden veränderlicher Sterne (1914) gave the time of minimun or the magnitude at minimum as uncertain. From this number the following stars were taken more or less at random, S Ceti being also included for reasons mentioned above and R Comae for similar reasons.

Table XIII contains a list of these variables with the Harvard designation of each, its position for 1900, magnitudes at maximum and minimum and its period in days. This data is taken from Harvard Annals <u>63</u>, 191-205.

Table XIII.

Designation.	Star.	Position, 1900.		Magnitude.		Period.
		R.A.	Dec.	Max.	Min.	Days.
001909	S Ceti	00 19.0	−9 53	7.9	14.5	320.2
042209	R Tauri	4 22.8	+9 56	8.0	14.0	325
042309	S Tauri	4 23.7	+9 44	9.5	14.6	365
050003	V Orionis	5 0.8	+3 58	8.4	<14.5	267
071713	V Geminorum	7 17.6	+13 17	8.0	14.5	276
115919	R Comae Ber.	11 59.1	+19 20	8.0	15.0	361.8
200514	R Capricorni	20 5.7	−14 34	9.0	<13.	344
215717	U Aquarii	21 57.9	−17 6	10.	14.	258

Underscoring denotes southern declination.

(c) Results.

1. 001909 S Ceti.

Position 1900:- R.A. $0^h\ 18^m\ 58^s$
Dec. $-9^\circ\ 53'.0$

The variability of this star was first detected by Borelly in 1871 and announced in the Monthly Notices of the Royal Astronomical Society, 32, 248. Its period has been found to be variable with a difference of a pproximately twenty-four days between the longest and shortest periods and a period for this variation, which is fairly regular, of about twenty-six and one-third years. The elements for predicting the time of a maximum are given in Hartwig's 1914 Katalog as:-

$$\text{Maximum} = \text{J.D. } 2405165 + 320.6E + 12 \sin(12^\circ E + 315^\circ)$$

where E is the given epoch after the maximum on the Julian Day given.

Magnitudes for comparison stars for this variable were taken from Harvard Annals 37 and 74. This is one of the Rumford fields so that fourteenth and fifteenth magnitude standards are available as well as an extended series of photometer measures in the fall of 1916 by Mitchell, Olivier and the writer. The 1916 measures seemed to indicate a correction of - 0.19 mag. to the twelfth magnitude standards and this change of "zero-point" was applied to the fourteenth and fifteenth magnitude stars. Table XIV gives the data for the comparison stars. The first column gives the designation on the observing chart, the second the Hagen number, & the third and fourth columns the position of the star with respect to the variable. The other columns give the magnitudes obtained by the various methods, the adopted magnitude being the mean of the other columns weighted according to the writer's best judgment in each case.

The positions are taken from Hagen's catalog, from Tables VII and IX of this paper or read directly from the chart. In the latter case they are approximate only and the decimal of a minute of arc is omitted. The star 33_1 (Hagen 33) which is x in the Harvard list proved to be brighter than the Harvard magnitude and may be slightly variable.

(Table XIV)

Table XV gives the observations on this star. The first column contains the Julian Day, the second the date, the third the observation as copied from the record book, the next the designation of the observer as given in the list of observers, and finally the magnitude derived from the observation. Observations made with the finder have been marked 5. Occasional changes have been made in the comparison stars where it seemed evident that mistakes in identification had been made. The photometer measures of the variable in 1916 are of no value since the star was too bright for measurement with the photometer of the 26-inch refractor. Breaks are inserted to show when the observations were interrupted by the star coming to conjunction with the sun.

(Table XV.)

The magnitudes from Table XV are plotted in Figure III. At no time was the variable followed through a minimum far enough to determine the time of minimum very accurately. One minimum is indicated near J.D. 2417200 with a probable value for the magnitude of the variable of about 14.2. The minimum value given in Table XIII is probably correct.

Three maxima are shown by the observations but the variable is too bright at maximum for good comparisons with the large telescope. Observations with the finder are apt to be rather uncertain because so little practice has been gained by any of the observers in the use of the smaller instrument. Comparison with the computed times of maximum would mean little.

(Figure III.)

At present the minimum of this star occurs near conjunction, and cannot be observed. This field should be put on the observing list again in two or three years when it could be followed along both descending and ascending branches of its light-curve and thus determine more accurately the time and magnitude at minimum.

2. 042209 R Tauri.

Position 1900:- R.A. $4^h\ 22^m\ 49^s$
Dec. $+9\ \ 56.^{\circ}4$

This star was discovered by Hind in 1849 to be variable. An observation in 1798 together with the observations of the last sixty-five years should give a good determination of the mean period except for the uncertainty regarding the epoch of the earlier observation. Its period is given in Hartwig's Katalog only to the nearest whole day. His elements are:-

Maximum = J.D. 2401262 + 325E.

Table XVI contains the data for the comparison stars for this field in the same form as Table XIV, except that a column giving the Hagen grades is also included and also the magnitudes obtained from these grades for stars not in the Harvard lists.

R and S Tauri are near together and have many comparison stars in common. One chart for both stars is now used in observing to avoid needless multiplication of comparison stars. For reasons which will be given later a new S Tauri chart replaced the old one on February 1-st 1917 and this has been used for the observations on R Tauri also since February 20-th. Owing to the small number of observations since that date it did not seem necessary to indicate the changes in the designations of comparison stars on the new chart.

Observations for both R and S Tauri are given in Table XVII. The columns are the same as in TableXV. The magnitude of the variable is usually given only to the nearest tenth of a magnitude. A few of the observations have been made by the Harvard method of estimating the magnitude of the varible directly to the tenth of a magnitude from the known magnitudes of the comparison stars.

(Table XVII.)

The magnitudes for R Tauri are plotted in Figure IV. No maxima are recorded. The earlier observations give one determination of the time of minimum and seem to show that the magnitude at minimum varies at the other minima where the light curve is not continuous enough to determine the time. This range is from $13^{M}.5$ to $14^{M}.5$. In the last two years two minima have been observed with magnitudes of 14.0 and 14.6 respectively. Using the Julian Day given for the initial epoch the three minima give for the mean period,(assuming that the minimum occurs 140 days before the maximum. Astronomical Journal, XXIV,2.) 324.3, 323.9 and 324.0 days respectively. The mean of these is 324.1 days. The corrections to the times of minimum computed from Hartwig's elements are -39, -69 and -59 days, showing that the value of the mean period can be improved.

(Figure IV.)

3. 042309 S Tauri.

Position 1900:- R.A. $4^h\ 23^m\ 43^s$
Dec. $+9^\circ\ 43'.5$

Hartwig gives as the elements of this star:-

$$\text{Maximum} = \text{J.D. } 2400455 + 380.0\ E - 0.15\ E^2$$

which gives a value of the period agreeing with that of Harvard for the epoch occurring in 1910.

The observing chart used for S Tauri was almost unintelligible, the stars being poorly plotted and misidentifications consequently being numerous. The variable itself was misidentified when fainter than the magnitude 13.5 and hence the results for the field are of very little value for determining the light-curve at minimum. Fortunately one of the comparison stars was suspected of variability and was observed part of the time as a variable. In order to clear up the confused state of this region a new chart was inserted on which the comparison stars were correctly plotted. The comparison star which was suspected of variability proved to be the variable and some order has been brought out of the previous confusion. The star which was observed for the variable when it was faint shows a range of over a magnitude and it may have a small variation. The faint comparison stars used however are so poorly identified that the variation may be more apparent than real.

Table XVIII contains data for the comparison stars and the observations themselves are given in Table XVII with those of R Tauri.

(Table XVIII.)

Figure V shows the results obtained in Table XVII. The rise of the variable to near maximum is shown for five consecutive periods. The mean interval between successive passages of the curve through the twelfth magnitude indicates a period of about 370 days. Wherever the star S_1 was specified in the observations the points in Figure V have been enclosed in a small red circle.

This star will be kept on the observing list until better determinations of its minimum can be made.

4. 050003. V Orionis.

Position for 1900:- R.A. $5^h\ 00^m\ 47^s$
Dec. $+3^\circ\ 58'.0$

V Orionis was discovered by Boss in 1887. Hartwig gives the same period as that in Table XIII, the date of the initial epoch being J.D. 2411778. Since the period is only 267 days the star can be followed through nearly all of its light-curve between oppositions. As a result several maxima and minima have been observed.

Tables XIX andXX are the same as for the preceding stars. Figure VI shows the observed variations of the star. Four maxima and the same number of minima can be determined though the times and magnitudes at maximum are uncertain. The first three maxima are the 26-th, 27-th and 34-th epochs. Comparing their times with that of the initial epoch the mean periods come out 266.5, 266.3 and 267.7 days respectively. The mean of these is 266.8 days which is in excellent agreement with the value previously given.

Assuming that the interval between minimum and maximum to be 92 days (A.J.XXIV, 2) the times of minimum give for the mean period 264.7, 264.8, 265.1 and 266.7 respectively. The mean of these is 265.3 days,,aavalue somewhat smaller than that obtained from the maxima. The residuals obtained from the use of the 267-day period are given in Table XXIX at the end of this paper. As will be seen the magnitude at minimum varies from 14.2 to 14.6.

5. 071713. V Geminorum.

Position 1900:- R.A. $7^h\ 17^m\ 34^s$
Dec. $+13°\ 17'.0$

The variability of this star was discovered by Baxendell in 1880 and confirmed by Knott and Chandler. The period as given by Hartwig is the same as that in Table XIII. His date for the initial epoch however is 31 epochs later than that given in Harvard Annals 57, 218. The latter gives J.D.2407754. Tables XXI and XXII and Figure VII contain the data for this star.

From the light-curve one maximum can be determined with a fair degree of accuracy. The approximate date of another is shown. Only once was the variable followed completely through a minimum. Dates can be assigned to four minima however, the magnitude in each case being about 14.0. Adopting 132 days as the interval between a minimum and a maximum, the times of minimum are predicted. The differences are given in Table XXIX and seem to indicate that a slightly longer period would satisfy the observations better. The period may be lengthening slightly,

6. 115919 R Comae.

Position 1900:- $11^h\ 59^m\ 7^s$
$+19°\ 20'.3$

Schönfeld discovered this variable in 1856 and it has its period well determined as a result of the long time that it has been under obervation. The period being nearly a year, observations at successive oppositions are made in the same portion of the light-curve. This star is included in the list of those for which Parkhurst's observations are given in his Researches in Stellar Photometry. His observations extend over a period of eleven years to 1905. The observations made here began in 1903 and will form a valuable continuation of Parkhurst's work.

The elements of the light-curve of this star are:-

Maximum = J.D. 2399304 + 361.8 E.   Max. - min. = 119 days.

As will be seen from Figure VIII the variable was observed at or near twelve minima. The observations however furnish magnitudes and times for only four of these minima. The dates are approximate only owing to the flatness of the light-curve at minimum and to its assymetry. The comparison of the observed minima with those computed from the elements given shows a positive residual in each case which is fairly constant in amount. This is of the same magnitude and sign as the residuals given by Parkhurst for his observations. Therefore it seems to show that the period is correct but that the initial date may be in need of a slight correction, provided the assumption is made that the period has not changed.

The magnitude at minimum is fainter in general than the values found by Parkhurst. It varies from magnitude 13.8 to 14.3. No maxima were observed since they occurred too near conjunction. This star will be kept on the observing list for some time.

Some uncertainty exists regarding the identification of several comparison stars. Wherever this affected materially the magnitude of the variable the result was bracketed in the table and a ring put around the observation on the plotted curve. It may be that the stars 43_2 and 52_a are variable. The observations do not answer the question satisfactorily. The disagreement between Parkhurst's photometer magnitude for 43_2 and the value obtained here is so large that it can be explained only on the grounds of variability or misidentification. This star will be observed occasionally.

7. 200514 R Capricorni.

Position 1900:- R.A. $20^h\ 5^m\ 42^s$
Dec. - $14^\circ 33'.8$

R Capricorni was discovered by Hind in 1848. Its period however only to the nearest whole day. The period given in Hartwig's Katalog is the same as that in Table XIII. The Julian day of the initial epoch is 2400391. Tables XXV and XXVI give the comparison stars and the observations. The results from the latter are plotted in Figure IX.

This star is so far south that it can be observed for a limited time only each year. No maxima or minima are given by the observations. A mean light curve could not be constructed in the usual way so the following method was resorted to. Magnitudes were read of the curves drawn through the observations plotted in the figure for twenty-five day intervals before and after the star passed through the twelfth magnitude on both the descending and ascending branches of its curve. Assuming the period of 344 days it was found that the mean interval between successive passages of the curve through the twelfth magnitude on its descending and ascending portions was 210 days. For the thirteenth magnitude the interval was 110 days. With this information the two parts of the curve were fitted together and the mean curve obtained as shown in Figure X. This mean curve has been drawn in on Figure IX(in pencil) and fits the observations fairly well. The star seems to be fairly regular with a minimum magnitude of approximately 13.7. Observations will be continued until a complete minimum can be observed.

8. 215717. U Aquarii.

Position 1900:- R.A. $21^h\ 57^m\ 52^s$
Dec. $-17°6'.5$

The variability of U Aquarii was discovered in 1881 by Peters and confirmed by H.M.Parkhurst. The times of maximum are given as

Maximum = J.D. 2406105 + 258 E.

The reduction of this field proved disappointing, since the curve showed practically no variation of the star over long periods of time. It remained between the magnitudes 11.0 and 12.9 except for the minimum observed recently. It seems impossible to account for this lack of variation on the grounds of misidentification as the same chart has always been employed. The commensurability of the period with the year requires of course that the observations in successive years be made in approximately the same part of the light-curve. This explains the situation in part but does not account for the small changes noted in periods of continuous observation extending over intervals of from fifty to one hundred days.

The minimum magnitude shown by the single minimum observed was 14.1. No comparison can be made with predicted time of minimum. This star will be kept on the observing list for some time.

Tables XXVII and XXVIII and Figure XI give the data for this variable.

VI. CONCLUSION.

Table XXIX contains a summary of the maxima and minima determined from the observations given in this paper. The columns are self-explanatory. In the column for the Julian Day the number 2,400,000 has been subtracted in every case.

While the observations do not in general provide sufficient data to show the continuous light-curve for any of the stars, a glance at the above table serves to show that definite information is given regarding all of these stars at minimum. For example Table XIII gives the minimum magnitude of R Capricorni as <13.0. The observations seem to fix the magnitude at approximately 13.7.

As previously mentioned in this paper the observations will have their greatest usefulness in supplementing observations made when the stars are bright. Owing to the efficient cooperation of members of the Variable Star Section of the British Astronomical Association in England and of the American Association of Variable Star Observers in America, the long period variables are under continuous observation as long as their positions are favorable. Most of the observers however have telescopes of small aperture and hence the observations do not extend to the fainter magnitudes. Few of the larger telescopes in the world are available for continuous observations of the variables when faint. So the results obtained at this Observatory, of which those here given are quite representative, will prove very valuable in supplying information to supplement that obtained from the observations with the smaller instruments.

The knowledge of the complete light-curves of long period variables is essential for the study of these interesting objects.

Table XXIX.

Field	Maxima J.D.	Maxima Epoch	Maxima Mag.	Maxima Observed-computed	Minima J.D.	Minima Epoch	Minima Mag.	Minima Observed-computed.
042209 R Tauri					18303	53	14.4	- 39 days.
					20378	61	14.0	-369
					21213	62	14.6	- 59
050003 V Orionis	18707	26	9.3	- 13	17245	21	14.2	- 48
	18975	27	[10.0]	- 12	19100	28	14.4	- 62
	20380	34	9.5	+ 24	19373	29	14.3	- 56
	[21152]	35	[8.8]	+ 29	21295	36	14.6	- 3
071713 V Geminorum	19075	41	8.6	+ 5	18390	39	14.0	+ 4
	[21300]	49	-	+ 22	18680	40	—	+ 18
					20905	48	14.1	+ 35
					21180	49	14.0	+ 34
115919 R Comae					16940	49	13.8	27
					17290	50	14.3	15
					18380	53	14.2	20
					21280	61	14.0	25
200514 # R Capricorni					16420		[13.7]	
					17110		[13.7]	
					17810		—	
					18155		—	
					18510		[13.7]	
					21280		—	
215717 U Aquarii					21160		14.1	

derived from mean curve.

No satisfactory explanation has yet been given as to the real cause of the peculiar variations in brightness that these stars undergo. Some progress is being made however in this direction. In his address as retiring president of the British Astronomical Association in October 1916, Rev. T.E.R.Phillips, in discussing the elements of the light-curves of variables of this type, announced the discovery of some interesting relations existing between the phases and coefficients of the harmonic terms used to represent the light- curves mathematically. (Journal of B.A.A. 27, 2.) The stars examined fall into two groups (in one of which the sun takes its rightful place as a varible star) when the phases of the second and third harmonic terms are plotted as abscissae and ordinates respectively.

Statistical investigations of this sort depend upon the light-curves of individual stars just as a discussion of the distribution of stars in space depends upon the parallaxes of individual stars. Therefore the McCormick observations will not only help to determine the minima of the light-curves of individual stars but will assist also in providing more accurate data as a basis for the statistical investigations of the future into the problem of long period variation.