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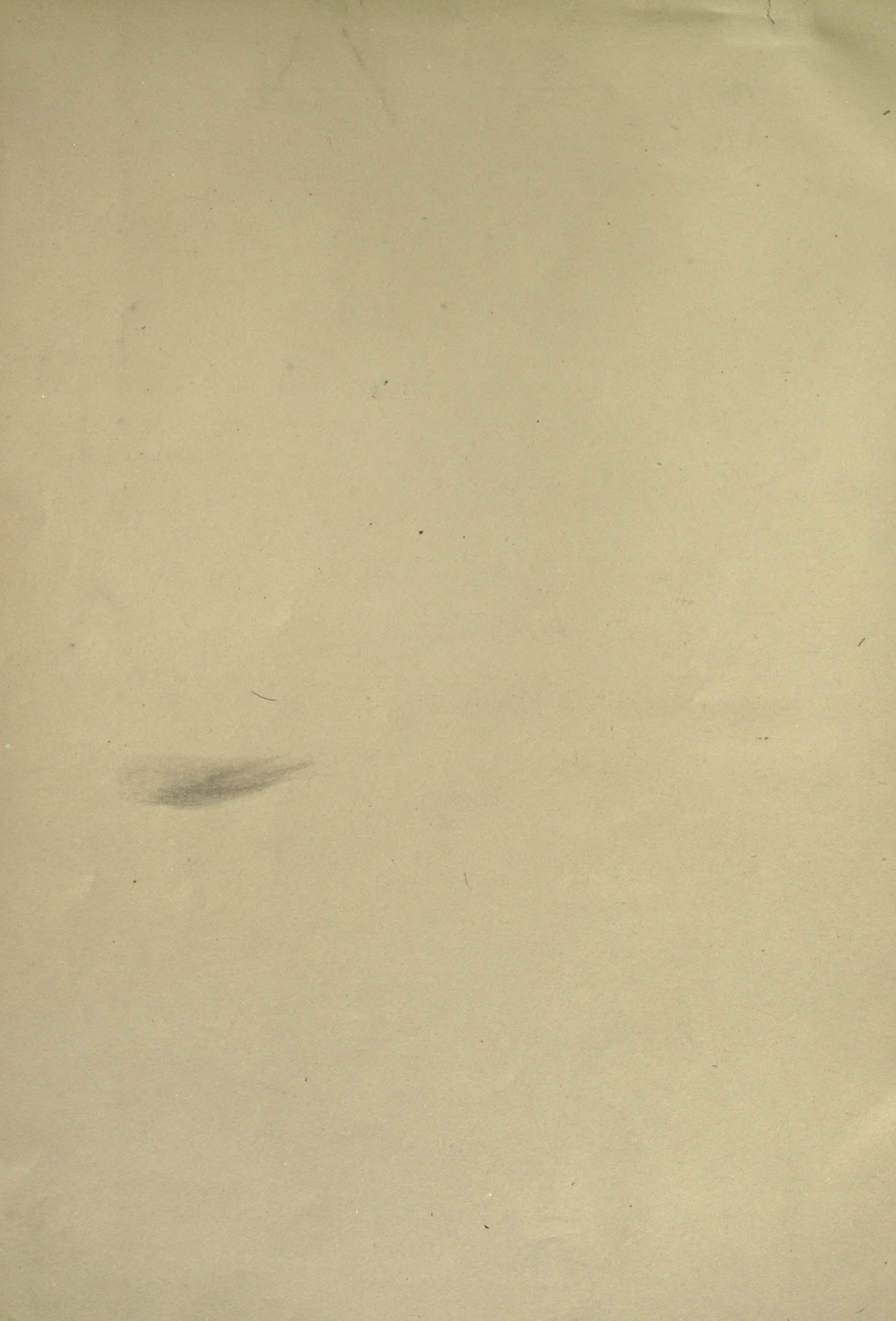
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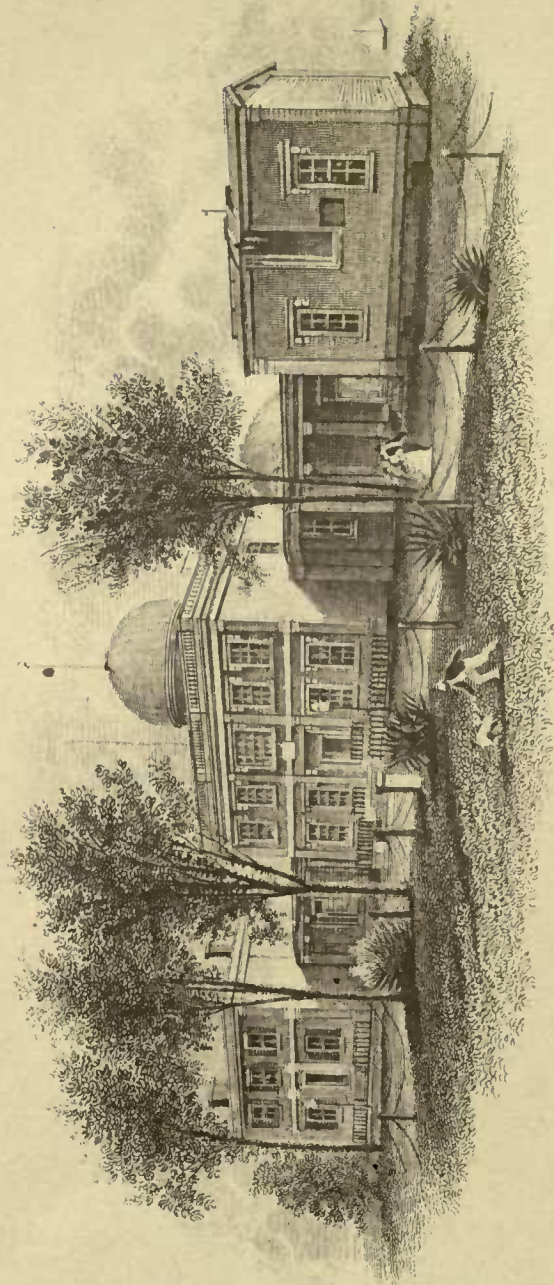
GIFT OF

Rear Admiral C. H. Davis

1876.

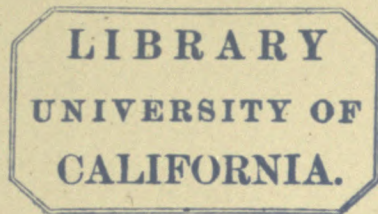


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INSTRUMENTS AND PUBLICATIONS

OF THE



UNITED STATES NAVAL OBSERVATORY.

" FOUNDED A. D. 1842.

JOHN TYLER,

PRESIDENT OF THE U. S.

ABEL P. UPSHUR,

SECRETARY OF THE NAVY."

[Inscription on the Tablet over the door of the Observatory.]

PUBLISHED BY AUTHORITY OF THE HON. SECRETARY OF THE NAVY.

REAR-ADMIRAL C. H. DAVIS, SUPERINTENDENT.

WASHINGTON:

1845-1876.

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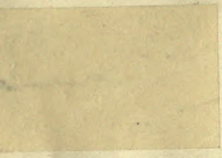
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TABLE OF CONTENTS.

	Page.
I. Founding of the Observatory.....	3
II. Position of the Observatory	6
III. Superintendents of the Observatory	7
IV. Publications of the Observatory.....	8
INSTRUMENTS OF THE OBSERVATORY:	
i. The Mural Circle.....	13
ii. The Transit Instrument	16
iii. The Prime Vertical Transit	18
iv. The 9.6-inch Equatorial	19
v. The Transit Circle.....	21
vi. The XXVI-inch Equatorial	26

PLATES.

General view of the Observatory	Frontispiece.
Plate I. The Transit Instrument and Mural Circle	to face page 13
Plate II. The 9.6-inch Equatorial.....	to face page 19
Plate III. The Transit Circle.....	to face page 21
Plate IV. The XXVI-inch Equatorial, (general view).....	to face page 29
Plate V. The XXVI-inch Equatorial, (eye-end).....	to face page 33
Plate VI. Astronomical drawings	to follow page 45



BOARD OF GOVERNORS

I.—FOUNDING OF THE OBSERVATORY.

[Condensed from Appendix IV of the volume of Observations for 1871: "Founding and Progress of the Observatory,"
By Prof. J. E. NOURSE, U. S. N.]

Congressional action for instituting a National Observatory originated in the earliest movements for establishing a first meridian in the United States.

Memorials towards this object, offered by Mr. William Lambert of Virginia, were presented in the House of Representatives as early as the years 1810, 1815, and 1818. They were approved by the House, and Mr. Lambert was appointed to make astronomical observations, in order to ascertain the longitude of the Capitol from Greenwich. In his reports of these observations, transmitted to Congress by President Monroe in 1822 and 1823, he took strong grounds in advocacy of the founding of an Observatory.¹

Mr. F. R. Hassler, the first Superintendent of the United States Coast Survey, in his report made on returning from the purchase of his instruments in London, 1816, recommended the establishment of an Observatory in the city of Washington "as a national object, a scientific ornament, and a means for nourishing an interest for science in general."² Mr. Hassler's views were supported by many eminent men, and particularly by President Madison and Secretary Dallas, who were desirous that this part of his plans, in connection with the work of the Coast Survey, should receive immediate execution. Mr. Hassler submitted a detailed plan for an Observatory, and selected for it a site north of the Capitol.

In 1825 President John Quincy Adams, in his first message to Congress, urged the establishment of an Astronomical Institution, referring in his recommendation to the expectations entertained by the first President of the United States, and his selection of a site for a Scientific Institution at the Capital.

In 1838 Mr. Adams, then a member of the House of Representatives, renewed his efforts for the object by urging on President Van Buren to incorporate the idea of an Observatory within the plans for the appropriation of the Smithsonian Fund. In 1842 he made an extended report from the committee appointed upon this bequest, advocating for this purpose the appropriation of a large part of the interest accruing from the fund.

¹ Journal of the House of Representatives, Eighteenth Congress, First Session; Message of the President of the United States, February 25, 1824.

² Transactions of American Philosophical Society for 1825.

Recommendations for the founding of an Observatory had also been made by the Secretary of the Navy, Mr. Branch, in 1830, when communicating the wishes of the Board of Navy Commissioners, and by his successors, Mr. Dickerson, in 1835, and Mr. Paulding, in 1838.

In the year last named, a series of astronomical and meteorological observations was commenced, by orders of the Navy Department, in the small Observatory connected with the Depot of Charts, under charge of Lieut. James M. Gilliss, U. S. N., near the Capitol. These observations, undertaken in connection with the interests of the Exploring Expedition to the Southern Hemisphere, then sailing under Captain Wilkes, U. S. N., were continued to the year 1842. They brought about the establishment of the present Institution.¹

The Naval Observatory was authorized by the act of Congress approved by the President August 18, 1842. The full purposes of this act were declared in the report of the committee of Congress² recommending the appropriation, which report was unanimously accepted, and their bill passed without discussion. In this report astronomical work in its full scope was provided for in express terms.

The Secretary of the Navy, Hon. A. P. Upshur, directed Lieut. J. M. Gilliss, U. S. N., who had been in charge of the astronomical and meteorological observations before named, to prepare a plan for an Observatory. His report, presented November 23, 1843, was accepted by the Department, and the construction of a building, with its equipments for astronomical and meteorological work, was placed in his charge. The act of Congress provided for its erection at a cost not exceeding the sum of \$25,000.

The act further provided that the institution might be located on any portion of the public land in the District of Columbia which the President of the United States should deem suited to the purpose. On the recommendation of Lieutenant Gilliss, reservation No. 4, as marked on the original plan of Washington City, was selected by President Tyler as the site of the Observatory:

This reservation, which has otherwise a marked historic interest, had long been recognized as the proposed seat of a scientific institution. For this purpose it was designated by General Washington, in his letter of October 21, 1796, to the Commissioners appointed to lay out the Capital. It had been, therefore, known in Washington City as "University Square."

It lies on the north bank of the Potomac, in the southwestern section of the city, the north front on E street, being 810 feet in length; the east, on Twenty-third street, 1,103 feet; and the west, on Twenty-fifth street, 620 feet. The area inclosed embraces a little more than nineteen acres.

"The site of the main building has a north horizontal range of 1.25 miles, and a south range of 8 miles. It is 267 feet from the north, 320 feet from the east, 490 feet from the west, and 900 feet from the south inclosure." The hill is of gravel formation, with a surface-stratum of dry, brittle clay.

¹ The two volumes of these Observations, published by order of Congress, were the subjects of the highest commendation by astronomers in Europe as well as in the United States.

² Report of Naval Committee, House of Representatives, No. 449, Twenty-seventh Congress, Second Session.

The central building is 50 feet 8 inches square on the outside from the foundation to a height of 2 feet 6 inches above ground, and thence to the top of the walls, 50 feet square. All the foundations to the ground-line are of blue rock, 2 feet thick; the remainder of the outside walls are of brick, 18 inches thick, finished in the best manner; and the partition-walls of brick, 14 inches thick. It is two stories and a basement high, with a parapet and balustrade of wood around the top, and is surmounted by a revolving dome, 23 feet in diameter, resting on a circular wall built up to a height of 7 feet above the roof.

To the east, west, and south sides of this central building wings were built by Lieutenant Gilliss, the eastern and the western being each 26 feet in length and 21 feet in width, and the south wing being 21 feet long, with the same breadth and height as the others.

Additions to the Observatory, as thus originally constructed, have been made at different periods, in accordance with the extension of its astronomical work. In the year 1847 quarters for the Superintendent were erected east of the main building. In 1848 the east wing was extended 24 feet, connecting these quarters with the main building and furnishing a store-room for chronometers. The rating and daily care of these, and their dispatch to United States vessels when put in commission, are intrusted to the officer in charge of this room.

Further extensions of the building have been made by the erection of the observing-room for the Transit Circle, in 1868, and that of the large dome for the 26-inch Equatorial, completed, with its adjoining offices for computers, &c., in 1873.

Each of these latest extensions is described in connection with its instrument.

THE LIBRARY.

During the official visit of inquiry made by Lieutenant Gilliss, in 1843, to the Observatories in Europe, donations of nearly three hundred Astronomical and other Scientific volumes were offered to the Observatory then being founded at Washington.

The chief donors were, the Royal Astronomical Society, the Royal Society, the Admiralty, the East India Company, and the Directors of the Observatories at Greenwich, Berlin, Brussels, and Munich. More than seven hundred volumes were purchased by Lieutenant Gilliss.

The annual Exchanges of Publications made by the Observatory with most of the scientific Institutions of the world, and with authors of distinguished scientific treatises, have been the principal sources of increase up to the present date, at which the numbers in the Library exceed six thousand. These exchanges are building up a scientific Treasury, largely repaying the Government for its outlay in the publication of the Astronomical volumes.

In transmitting its foreign exchanges the Institution is indebted for the courteous offices of the Smithsonian, and for those of the Resident Legations.

II.—POSITION OF THE OBSERVATORY.¹

The latitude deduced from observations made with the Mural Circle in 1845 and 1846 was, $+38^{\circ} 53' 39''.25$;² and that value has been employed in the reduction of all observations made with the Mural Circle down to the present time.

The observations made with the same instrument from 1861 to 1864, inclusive, give a latitude $0''.47$ less, viz, $+38^{\circ} 53' 38''.8$;³ and this latter value is the one which has always been used in computing the published "Apparent North Polar Distances, obtained from Observations made with the Transit Circle." It should be remarked, however, that in the published tables of "Right Ascension, North Polar Distances, and Semi-diameters of the Sun, Moon, and Planets, deduced from Observations with the Transit Circle," and of "Corrections to the Right Ascensions and North Polar Distances of the American Ephemeris, given by Individual Observations of Stars with the Transit Circle," the final north polar distances depend upon the position of the pole determined, from all the observations of circumpolar stars made with the Transit Circle during the same year as those contained in the tables in question. In interpolating tabular positions of the moon and planets, the longitude of the Observatory from Greenwich is assumed to be $5^{\text{h}} 8^{\text{m}} 12^{\text{s}}.0$.

The point to which all differences of longitude, measured from the Observatory, are referred is the center of the dome. The most probable value of its latitude is $+38^{\circ} 53' 38''.8$, which has been determined from discussions of all the observations of circumpolar stars observed, both above and below the pole, with the Mural and Transit Circles during the years between 1861 and the present time.

For the determination of its longitude from Greenwich by the telegraph, the following data were communicated in an official letter of the Superintendent of the Coast Survey, dated August 10, 1872:

	<i>h.</i>	<i>m.</i>	<i>s.</i>
Determined in 1867 - - - - -	5	8	12.11
Determined in 1870 - - - - -			12.16
Determined in 1872 - - - - -			12.10
Mean - - - - -	5	8	12.12

¹ The astronomical position of the Observatory here given appears in the "General Introduction" to each of the recent volumes.

² Washington Observations 1845, Appendix, page 116.

³ Washington Observations 1864, Introduction, page 44.

III.—SUPERINTENDENTS OF THE OBSERVATORY.

Commander M. F. MAURY, from October 1, 1844, to April 20, 1861.

Captain J. M. GILLISS, from April 22, 1861, to February 9, 1865.

Rear-Admiral C. H. DAVIS, from April 28, 1865, to May 8, 1867.

Rear-Admiral B. F. SANDS, from May 8, 1867, to February 23, 1874.

Rear-Admiral C. H. DAVIS, from February 23, 1874, —.

OFFICERS IN CHARGE OF INSTRUMENTS SINCE 1861.

The 9.6-inch Equatorial. Assistant Astronomer J. Ferguson; Professors Newcomb; Hall; Eastman.

The Prime Vertical.—Professors Hubbard; Newcomb.

The Transit Instrument.—Professor Yarnall.

The Mural Circle.—Professors Hubbard; Newcomb; Yarnall.

The Transit Circle.—Professors Newcomb; Hall; Harkness; Eastman.

The XXVI-inch Equatorial.—Professors Newcomb; Hall.

The Meteorological Instruments.—Professor J. R. Eastman.

The Chronometers and Nautical Instruments.—Very frequent changes have occurred in the orders of the officers of the line on duty at the Observatory in charge of the naval instruments and the charts.

At the date of the organization of the Hydrographic Office, 1866, after the transfer of the charts and other naval instruments, Commander A. W. Johnson was placed in charge of the *chronometers*. At the present date Lieutenant-Commander Charles H. Davis is in charge.

IV.—PUBLICATIONS OF THE OBSERVATORY.

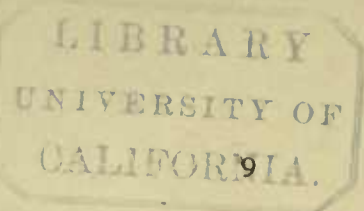
1. VOLUMES OF OBSERVATIONS.

Vol. I.	Astronomical Observations for the year	1845	published in	1864
II.	Do. do.	1846	do.	1851
III.	Do. do.	1847	do.	1853
IV.	Do. do.	1848	do.	1856
V.	Do. do.	1849-1850	do.	1859
VI.	Do. do.	1851-1852	do.	1867
* VII.	Results of Astronomical Observations for the years	1853-1860	do.	1872
VIII.	Astronomical and Meteorological Observations for	1861	do.	1862
IX.	Do. do.	1862	do.	1863
X.	Do. do.	1863	do.	1865
XI.	Do. do.	1864	do.	1866
XII.	Do. do.	1865	do.	1867
XIII.	Do. do.	1866	do.	1868
XIV.	Do. do.	1867	do.	1870
XV.	Do. do.	1868	do.	1871
XVI.	Do. do.	1869	do.	1872
XVII.	Do. do.	1870	do.	1873
XVIII.	Do. do.	1871	do.	1873
XIX.	Do. do.	1872	do.	1874
XX.	Do. do.	1873	do.	1875
XXI.	Do. do.	1874	in press.	

2. SPECIAL OBSERVATIONS AND REPORTS.

Observation or report.	Author.	Appendix to volume for the year—
<i>Superintendency of Commander Maury.</i>		
A.—Observations on sun-spots.....	Rev. B. Sestini, S. J.	} 1847
B.—Observations on the Mississippi River, at Memphis.....	Passed Midshipman R. A. Marr	
C.—Tables for facilitating reduction of apparent places of fixed stars to their mean places. (Zones of stars observed at the National Observatory in 1846, reduced by Assistant Astronomer James Ferguson, published in 1860.)	Professors J. H. C. Coffin and J. S. Hubbard. Lieutenant L. Maynard and Professor J. S. Hubbard.	
<i>Superintendency of Captain Gilliss.</i>		
Longitude of United States Naval Observatory from moon culminations.	Professor S. Newcomb.....	1862
A.—Solar parallax from observations on the planet Mars, made near the opposition, 1862, with the equatorial.	Professor A. Hall.....	} 1863
A.—Solar parallax from observations on the planet Mars, made near the opposition, 1862, with the meridian-instrument.	Assistant Astronomer J. Ferguson....	
B.—Orbit of Nemausa.....	Professor A. Hall.....	} 1864
Investigation of the latitude and longitude of the Observatory, and of the declination of certain circumpolar stars.	Professor S. Newcomb.....	

* This volume was published as Appendix II to the volume of Observations for the year 1871.



PUBLICATIONS OF THE OBSERVATORY.

2. SPECIAL OBSERVATIONS AND REPORTS—Continued.

Observation or report.	Author.	Appendix to volume for the year—
<i>Superintendency of Rear-Admiral Davis.</i>		
Description of the Transit Circle	Professor S. Newcomb.....	} 1865
Investigation of the distance of the sun		
Discussion of the meteorological observations from 1842 to 1867.....		
Report on interoceanic canals and railroads.....		
Report on November meteors of 1866.....	Rear-Admiral C. H. Davis.....	1866
<i>Superintendency of Rear-Admiral Sands.</i>		
I.—Report on the difference of longitude between Washington and Havana.	Professor W. Harkness.....	} 1867
II.—Reports on the total solar eclipse in the United States, August 7, 1869.	Professors S. Newcomb, A. Hall, W. Harkness, J. R. Eastman, and others.	
III.—Positions of fundamental stars deduced from Washington observations, 1862-'67.	Professor S. Newcomb	
IV.—Catalogue of 151 stars in Præsepe.....	Professor A. Hall.....	} 1868
Catalogue of stars observed by the United States Astronomical Expedition to the Southern Hemisphere, 1850-'52.	Lieutenant James M. Gilliss, Superintendent; Lieutenant A. McRae, Master S. Ledyard Phelps, and Mr. E. R. Smith, assistants.	
I.—Reports on total solar eclipse in Europe of December 22, 1870....	Professors Newcomb, Hall, Harkness, and Eastman.	} 1869
II.—Zones of stars observed with the Mural Circle in the years 1846, 1847, 1848, and 1849.	Professor J. H. C. Coffin, Lieutenant T. J. Page, Lieutenant C. Steedman.	
I.—Report on the difference of longitude between Washington and Saint Louis.	Professor W. Harkness.....	} 1870
II.—Reports on observations of Encke's Comet, during its return in 1871.	Professors Hall and Harkness.....	
III.—Right ascensions of the equatorial fundamental stars, and corrections necessary for reduction of right ascensions of different catalogues to a mean homogeneous system.	Professor S. Newcomb	
IV.—Zones of Stars observed at the United States Naval Observatory with the Meridian Transit Instrument, in years 1846, 1847, 1848, and 1849.	Lieutenant J. J. Almy, Lieutenant W. A. Parker, Professors R. Keith, Mark H. Beecher, J. S. Hubbard.	} 1871
Report on November meteors of 1867	Professors Newcomb, Harkness, and Eastman.	
Discussions of West India Cyclone of October 29 and 30, 1867.....	Professor J. R. Eastman.....	} 1872
Report on November meteors of 1868.....	Observers: Professor J. Major, Lieutenant L. Maynard, Lieutenant W. B. Muse.	
I.—Zones of stars observed at the United States Naval Observatory with the Meridian Circle, in the years 1847, 1848, and 1849. [This Appendix, edited by Professor A. Hall, U. S. N., completes the Zone Observations commenced in 1847, and embraces those published in 1860, 1869, 1870, and 1871; those published in 1869, 1870, 1871 were reduced by Dr. B. A. Gould.]	Professor M. Yarnall.....	
II.—Results of observations made at the United States Naval Observatory with the Transit Instrument and Mural Circle, in the years 1853 to 1860, inclusive.	Professor M. Yarnall	} 1873
III.—Catalogue of stars observed at the United States Naval Observatory during the years 1845 to 1871.	Professor J. E. Nourse	
IV.—Memoir of the founding and progress of the United States Naval Observatory.	Professor J. R. Eastman.....	} 1874
I.—Tables of instrumental constants and corrections for the reduction of Transit observations.	Professor J. R. Eastman.....	
II.—Difference of longitude between Washington and Detroit, Mich.; Carlin, Nevada, and Anstin, Nevada.	S. W. Burnham.....	
<i>Superintendency of Rear-Admiral Davis.</i>		
I.—The Uranian and Neptunian systems investigated with the 26-inch Equatorial.	Professor S. Newcomb	} 1873
II.—The Instruments and the Publications of the United States Naval Observatory.	Professors M. Yarnall, J. R. Eastman, and E. S. Holden.	
III.—Report on the difference of longitude between Washington and Ogden, Utah.	Professor J. R. Eastman	} 1874
IV.—Catalogue of Double Stars.....	S. W. Burnham.....	

CHAPTER I. THE EARLY HISTORY OF THE UNITED STATES

1776	The Declaration of Independence is signed.	The Continental Congress meets in Philadelphia.
1777	The Battle of Brandywine is fought.	The British occupy Philadelphia.
1778	The Battle of the Clouds is fought.	The British evacuate Philadelphia.
1781	The Battle of Red Bank is fought.	The British evacuate the area.
1783	The Treaty of Paris is signed.	The British recognize American independence.
1787	The Constitution is drafted.	The Constitution is signed.
1789	The Bill of Rights is adopted.	The Bill of Rights is signed.
1791	The Bill of Rights is ratified.	The Bill of Rights is signed.
1793	The Bill of Rights is ratified.	The Bill of Rights is signed.

THE INSTRUMENTS
OF THE
OBSERVATORY.

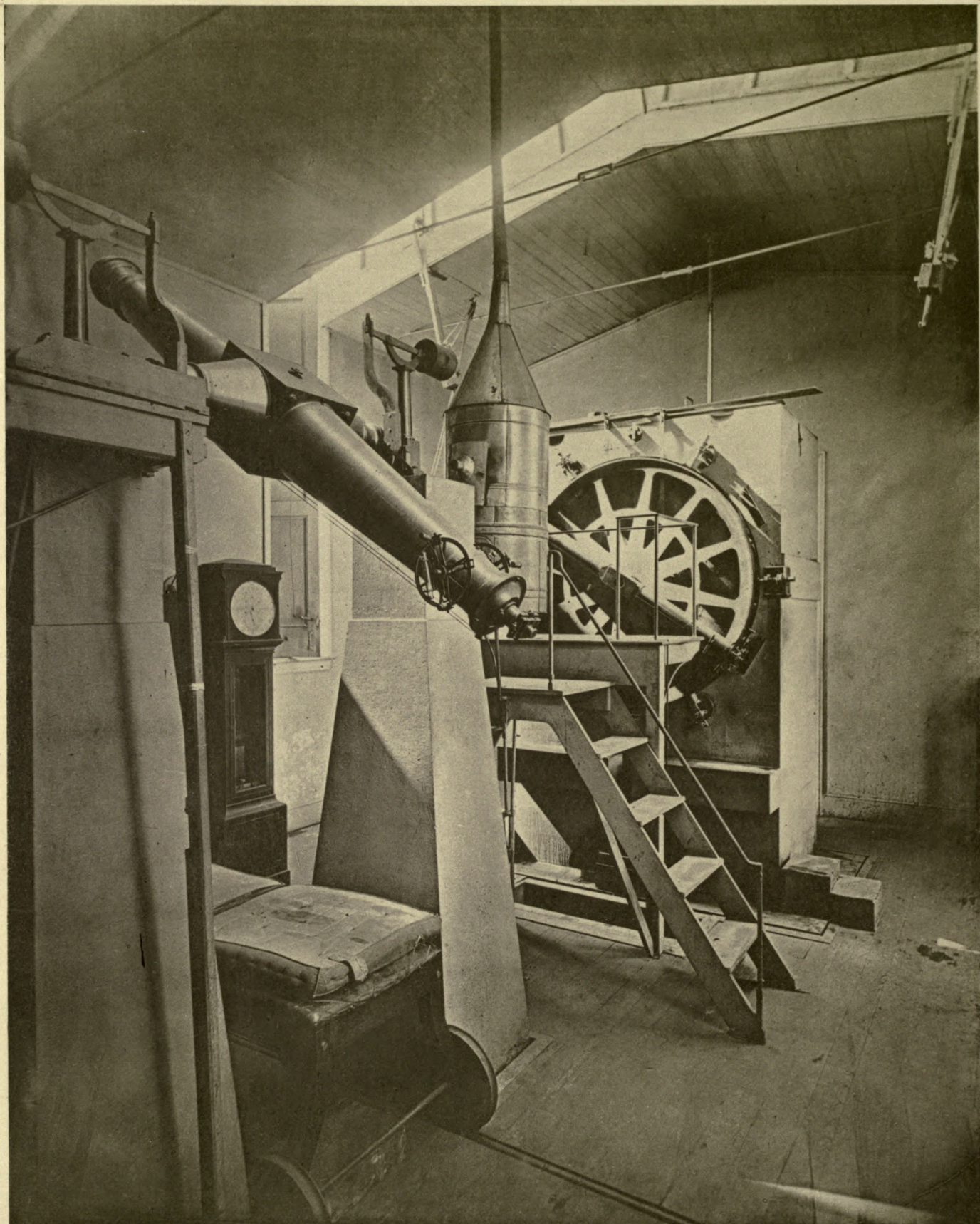
I.—The MURAL CIRCLE	- - - - -	Mounted in	1844.
II.—The TRANSIT INSTRUMENT	- - - - -	do	1844.
III.—The PRIME-VERTICAL TRANSIT-INSTRUMENT	-	do	1845.
IV.—The 9.6-INCH EQUATORIAL	- - - - -	do	1845.
V.—The TRANSIT CIRCLE	- - - - -	do	1865.
VI.—The XXVI-INCH EQUATORIAL	- - - - -	do	1873.

THE INSTRUMENTS

OF THE REVOLUTION

1. The Declaration of Independence
2. The Constitution
3. The Bill of Rights
4. The Judiciary Act
5. The Federal Reserve Act
6. The National Bank Act
7. The National Currency Act
8. The National Banking Act
9. The National Bankruptcy Act
10. The National Labor Relations Act

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James R. Osgood & Co., Boston.

TRANSIT INSTRUMENT.

U. S. NAVAL OBSERVATORY, WASHINGTON.

MOUNTED 1845.

OBJECT GLASS { Focal Length, 7 ft. 0.4 in.
Clear Aperture, 5.33 in.

MURAL CIRCLE.

U. S. NAVAL OBSERVATORY, WASHINGTON.

MOUNTED 1845.

OBJECT GLASS { Focal Length, 5 ft. 3.8 in.
Clear Aperture, 4.10 in.

I.—THE MURAL CIRCLE.

[Prepared by Professor M. YARNALL, U. S. N., in charge.]

The Mural Circle was constructed by Troughton & Simms, of London. It was mounted August 12, 1844, in the room which is now used as the Library, but was removed during the latter part of 1845 to the Observing Room in the east wing of the building, and there mounted on the eastern face of a sandstone pier. This pier is 9 feet 4 inches high, 6 feet from north to south, and 3 feet 3 inches from east to west.

The axis of the instrument reaches entirely across the pier, through an archway of 32 inches span and 21 inches pitch.

The Circle is placed upon the eastern end of the axis, which is sustained in part on friction-rollers, supported by counterpoises. It is 5 feet in diameter. The divisions are upon the periphery of the rim, cut upon a band of gold, and 5' apart. They are read off by means of six of "Troughton's Reading Microscopes," mounted firmly upon the face of the pier, and adjusted, as nearly as practicable, 60° from each other. These microscopes are designated by the letters A, B, C, D, E, F; A being on the north side of the pier, and the line through the center, joining A and B, being horizontal.

By this arrangement—

(The reading for) B =	(the reading for) A +	180°
Do. C =	do. A +	300°
Do. D =	do. A +	120°
Do. E =	do. A +	240°
Do. F =	do. A +	60°

approximatively.

These microscopes are adjusted, as to focal length, so that five revolutions of the micrometer-screw of each may measure one space, or 5' of the circle. The micrometer-heads are divided into sixty parts, reading, therefore, directly to *seconds*, or, by subdivisions easily made, to *tenths* of seconds. In general, in making readings of the Circle, the *seconds* and *parts* are read from each of the six microscopes, and to these are prefixed the *degrees* and *minutes* from A alone. The mean of these six readings constitutes the "Circle Reading."

For illuminating the graduated limb, an argand gas-burner is placed behind the pier, in a line with the axis of the instrument. The light from this burner passes through six holes, bored through the pier, directly to the reflectors attached to the several microscopes. In this way a less variable illumination is secured than by means of lamps carried in the hand.

III.—THE PRIME-VERTICAL TRANSIT INSTRUMENT.

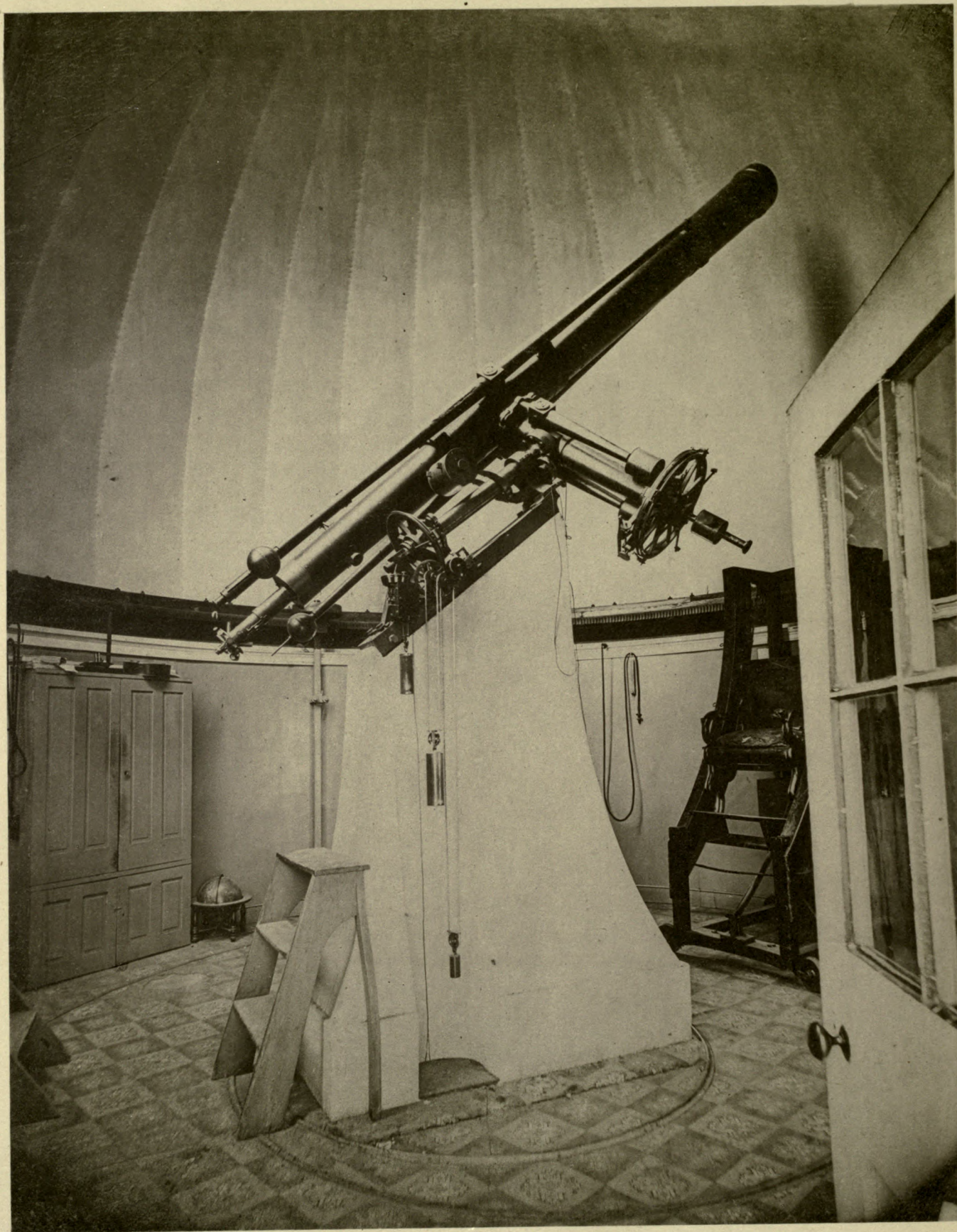
This instrument being for the present out of use, no detailed description of it is required, further than that given in *Washington Astronomical Observations*, vol. i, 1845, page li *et seq.*, and Plate IV.

Its objective has an aperture of 4.86 inches, and a focal length of 6 feet 5 inches. Its four eye-pieces magnify—

No. 1	-	-	-	-	-	-	74 diameters.
No. 2	-	-	-	-	-	-	106 diameters.
No. 3	-	-	-	-	-	-	140 diameters.
No. 4	-	-	-	-	-	-	221 diameters.

The observations made with this instrument may be found in the annual volumes.

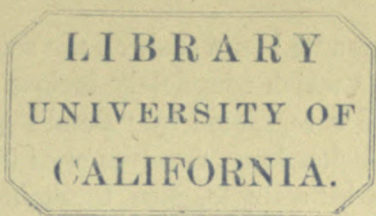
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Heliotype.

James R. Osgood & Co., Boston.

THE 9.6 INCH EQUATORIAL.
U. S. NAVAL OBSERVATORY, WASHINGTON. MOUNTED 1844.



IV.—THE 9.6-INCH EQUATORIAL.

[Prepared by Professor J. R. EASTMAN, in charge, 1876.]

This instrument was made by Merz & Mahler, of Munich. Its object-glass has a clear aperture of 9.62 inches, and a focal length of 14 feet 4.5 inches. It is mounted in the German style, and is provided with a finder, hour and declination circles, a micrometer, with a position-circle, and a driving-clock.

The finder has an object-glass 2.6 inches in diameter, with a focal length of 32 inches.

The hour-circle is 15 inches in diameter, is divided to single minutes, and may be read by means of a vernier to 2^s.

The declination-circle is 21 inches in diameter, is divided to 5 minutes of arc, and may be read by means of a vernier to 4^{''}.

The micrometer is provided with three *fixed* transit-wires, and a *movable* declination system consisting of five wires. The transit-wire nearest to the comb of the micrometer is called wire A, and the others are known as B and C. The equatorial interval of B—A is 12^s.03, and of C—B is 11^s.98.

The approximate intervals of the declination system in micrometer-revolutions are, numbering the wires from the head of the micrometer :

1 to 2	-	-	-	-	16.86 revolutions.
2 to 3	-	-	-	-	13.06 revolutions.
3 to 4	-	-	-	-	13.10 revolutions.
4 to 5	-	-	-	-	16.06 revolutions.

The value of one revolution of the micrometer-screw was found in 1872 to be 15^{''}.31.

The position-circle is divided to 15', and may be read by a vernier to 1'.

The illumination of the field or of the wires is accomplished by directing the light from a gas-burner through openings in the side of the tube and toward the eye-piece, in the usual manner.

The clock-work for moving the instrument in right ascension is regulated by a Fraunhofer centrifugal pendulum, but it is scarcely powerful enough to properly control the motion.

This instrument is provided with eight eye-pieces, magnifying, respectively, 90, 132, 209, 296, 433, 562, 734, and 899 diameters. One eye-piece is fitted with a single-ring micrometer and one with a double-ring.

There is a chronograph mounted on a shelf on the southwest side of the observing-room, and protected by doors which completely inclose it when not in use. It was made by Bond, of Boston, and is regulated by "Bond's spring governor." The barrel is 6 inches in diameter, 13.5 inches long, revolves once in a minute, and the record of both clock and key is effected by a single, glass, fountain-pen. This chronograph can be connected with any clock which it is desirable to use.

THE COMET SEEKER.

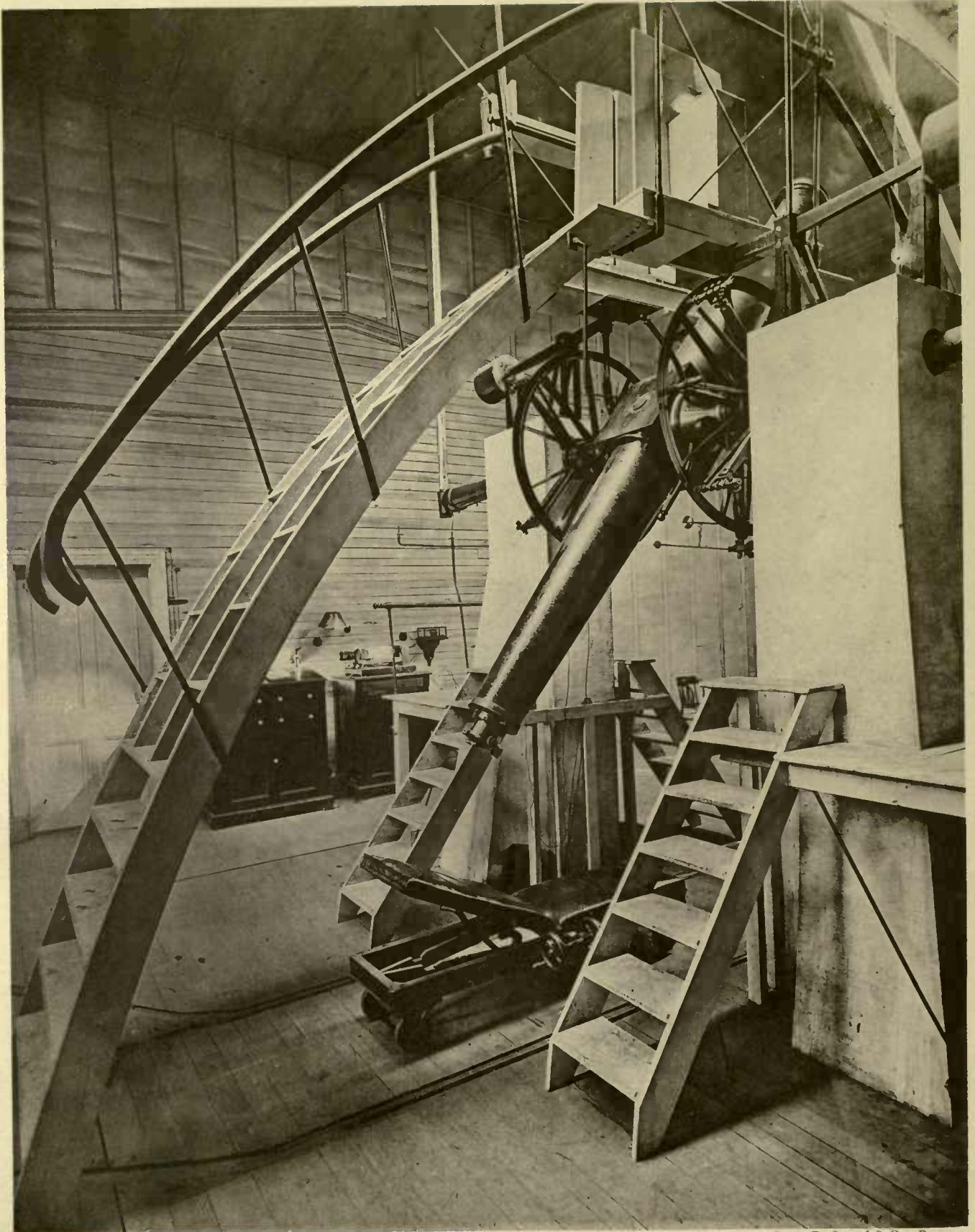
This instrument is placed on a stand in the equatorial-room when not in use. It was made by Utzschneider & Fraunhofer, is equatorially mounted, and has an object-glass of 3.96 inches diameter and 32.4 inches focal length. It has an hour-circle 5 inches in diameter, divided on silver, and reading by two verniers to $4''$, and a similar circle on the declination-axis which reads by verniers to $1'$. The instrument has five eye-pieces, whose approximate magnifying powers are, respectively, 13.6, 19.4, 40.6, 40.8, and 41.6 diameters. No. 5 is furnished with a ring micrometer. When this instrument is to be used it is placed on supports outside the dome on the roof.

THE 9.6-INCH EQUATORIAL OBSERVING-ROOM

The Equatorial is supported on a pier whose foundation is 9 feet below the surface of the ground. The diameter of the foundation is 15 feet. It is built up solid of stone laid in hydraulic cement to a height of 10.5 feet, where the diameter is 12 feet. On that foundation a conical pier 28 feet high and 7 feet in diameter at the top is built. The walls are 3 feet thick to within 10 feet of the top, where they gradually increase in thickness, and the last 3 feet is solid. The pier is capped with stone, on which rests the block of Maryland granite which supports the instrument. The room is circular and 20.1 feet in diameter, with walls 7 feet high. The hemispherical dome revolves on six equidistant, iron, 32-pound balls, moving in the groove of a cast-iron rail fastened on the top of the circular wall. The frame-work of the dome is of wood, covered with half-inch boards sheathed with copper. It is lined inside with painted canvass. The observing-slit is 20 inches wide, extends from 2 feet above the base of the dome to 2 feet beyond the center. The slit is covered by five shutters, each opening from the inside by means of a lever and pulley, the one at the top of the dome opening first. The dome is turned by means of a rack and pinion, operated by a vertical wheel 3 feet in diameter and fitted with projecting handles.

The room is furnished with an observing-chair of an obsolete pattern, which may be moved around the pier on a circular track.

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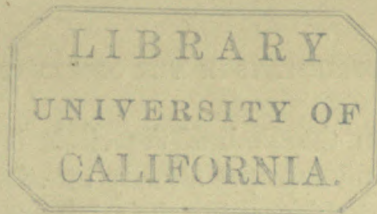
Heliotype.

James R. Osgood & Co., Boston.

TRANSIT CIRCLE.

U. S. NAVAL OBSERVATORY, WASHINGTON. MOUNTED 1866.

Focus Length 10 ft. 10 in.



V.—THE TRANSIT CIRCLE.

[Prepared by Professor J. R. EASTMAN, in charge, 1876.]

This instrument was made by Pistor & Martins, of Berlin, in 1865. It is of the reversible pattern, and is mounted upon two massive marble piers, with its axis 8 feet 2 inches above the floor.

The telescope has a clear aperture of 8.52 inches and a focal length of 12 feet and 0.7 inches. The axis is cast in a single piece, into which the steel pivots, 2.09 inches in diameter and 1.70 inches long, are screwed.

The Ys are of gun-metal, and the bearing-surfaces are 0.28 of an inch wide. The distance between them, measured from center to center of the bearing-surfaces, is 3 feet 9.1 inches. The telescope-tube is made in two similar parts, which are bolted to the opposite sides of the cube which forms the central portion of the axis. This cube measures 16.64 inches on each edge.

Attached to the two extremities of the axis are two circles identical in form and size. Each has ten radial arms, is cast in a single piece weighing about eighty pounds, is 45.30 inches in diameter at its outside edge and 43.40 inches at the graduation. The circle on the clamp-end of the axis, designated as circle A, has inlaid upon its face two bands of silver, each 0.13 of an inch wide, the inner one of which is graduated to every 2' and the outer one to every 10'. The other, designated as circle B, has inlaid upon its face a single band of silver 0.13 of an inch wide, which is graduated to every 2'.

The graduation on each of these circles is numbered from 0° to 360° , the reading increasing from left to right, and, as they face in opposite directions, when the telescope is moved in zenith-distance the reading of one circle increases while that of the other diminishes.

The circles are attached to the axis in such a manner that they may be set to give any desired reading when the telescope is pointed to the zenith.

Each pier carries four microscopes, placed at the extremities of two diameters, which intersect each other at right angles, and each of which makes an angle of 45° with the vertical. They are attached by means of metal arms, covered with wood, to the brass disk on the face of the pier which supports the Ys.

The microscopes on the western pier are marked, I, II, III, IV, and those on the eastern pier, V, VI, VII, VIII. The readings of the former diminish, and those of the latter increase, as the telescope moves from the zenith toward the south. These microscopes magnify about forty-five diameters. Each revolution of their screws is equal to $30''$, and their micrometer-heads are divided to $0''.5$. Each microscope micrometer is furnished with two parallel threads about $12''$ apart, and the reading is made when

the image of the division on the limb of the circle is exactly midway between the threads. In addition to the microscopes already mentioned each pier carries another, which is employed as a pointer for setting the telescope by means of the course-graduation on circle A.

These microscopes magnify twenty-three diameters, and are placed at the extremities of horizontal radii to the circles, that on the western pier being to the north and that on the eastern pier being to the south of the axis. The setting-microscope in actual use is always the one at the clamp-end of the axis.

In the eye-piece of the telescope is a fixed reticule of fifteen vertical and two horizontal wires. The latter have a space of about 8'' between them, and are used principally to mark the center of the field of view. The notation and the approximate equatorial intervals between each vertical wire, and the mean of sets B and D, α , C_3 , and C_4 are as follows:

	s.		s.		s.
I	36.8	C_1	4.1	D_1	8.2
II	24.5	C_2	2.0	D_2	9.7
III = B_1	12.2	IV = C_3	0.0	V = D_3	12.2
B_2	9.7	C_4	2.0	VI	24.5
B_3	8.2	C_5	4.1	VII	36.8

The wires B_1 to B_3 are known as set B; C_1 to C_5 , set C; and D_1 to D_3 , set D. The wire on the western side of the field is always designated as wire I; consequently, when the instrument is reversed the notation of the wires is reversed.

In addition to the fixed reticule the eye-piece contains a right-ascension and a zenith-distance micrometer, in each of which the readings increase as the wire moves from the micrometer-head. The right-ascension micrometer is used in determining the collimation constant, and sometimes in obtaining the time of transit of close circumpolar stars when clouds prevent their being seen at the fixed wires. It is provided with a single vertical wire moved by a micrometer-screw, each revolution of which measures $1^{\circ}.024$. The zenith-distance micrometer carries four horizontal wires, the middle two of which are about 3'' apart, and the center of the space between them is regarded as the standard middle wire. One revolution of the zenith-distance micrometer = $15''.312$. The other two are placed at a distance of about ten revolutions of the screw on either side of the middle wires, that nearest the head of the micrometer being called wire A and the other wire B. In observing southern stars the micrometer-head is below the eye-piece if the clamp is west, and above it when the clamp is east. An increase of micrometer reading is subtractive from the reading of circle A and additive to that of circle B.

The illumination of the field of view is so arranged that the wires can be shown either dark on a bright field or bright on a dark field. In the case of bright field-illumination the color of the light can be varied from deep red, through light red, yellow, and light blue, to dark blue.

The instrument is provided with five positive eye-pieces, magnifying, respectively, 135, 158, 186, 279, and 395 diameters. That magnifying 186 diameters is generally used.

COLLIMATORS.

The Transit Circle is furnished with two collimators, having object-glasses of 35.2 inches focal length and 2.13 inches clear aperture. The eye-pieces have a power of 67. The collimators are mounted on sandstone piers, the one north and the other south of the Transit Circle, 14.8 feet from the center of the instrument. The field of view of collimator A contains a single vertical wire, crossed at its middle point by a horizontal wire. The field of view of collimator B contains a fixed wire and two intersecting wires, movable by means of a micrometer-screw. Each of these wires makes an angle of 12° with the vertical. Collimator A is usually mounted on the south pier. Two levels are provided by which the collimators may be placed horizontal.

Each side of the central cube of the Transit Circle telescope is pierced with a circular opening 2.3 inches in diameter, which is closed by screwing a cap into it. By removing the caps and setting the telescope vertical the wires of either collimator may be seen from the other.

THE STANDARD SIDEREAL CLOCK.

This clock is Kessels, No. 1324. In order to provide as far as possible against changes of temperature, the clock is inclosed in a vault of heavy masonry lined with tin, situated in the room which adjoins the observing-room on the eastern side, and to prevent the works of the clock from rusting the dryness of the air is maintained by keeping a fire in the clock-room throughout the year. The clock has a gridiron pendulum, and is connected with the galvanic system of the Observatory by means of a platinum point which projects from about the middle of the pendulum-rod, and at each vibration touches the surface of a small globule of mercury and closes the circuit. It is connected with the chronograph in the usual way. The rate of the clock is controlled by means of small weights which can be placed in a small cup on the pendulum-rod.

THE COUNTING-CLOCK.

This clock is attached to a brick pier near the eastern wall in the observing-room. It was made by Parkinson & Frodsham, of London, and has a mercurial pendulum. Its rate is controlled by means of small weights placed on the top of the jar containing the mercury, and it is kept within less than half a second of the Kessels clock.

This clock contains a delicate spring, furnished with a platinum point, resting upon a small plate of the same metal; the whole so arranged that at the beginning of each minute an arm attached to the arbor of the seconds-hand raises the spring and separates the point from the plate for one second. Wires are attached to this apparatus so that when desired it may be included in the same circuit with the Kessels clock, when, if the beats of the two clocks are nearly in coincidence, the mark for the sixtieth second of the Kessels clock is omitted on the chronograph.

THE STANDARD MEAN-TIME CLOCK.

This clock is attached to a stone pier in the chronometer-room, but the officer having charge of the Transit Circle is responsible for furnishing its errors and rates. It was made by Parkinson & Frodsham, of London, has a mercurial pendulum, and its rate is controlled by means of small weights placed on the jar containing the mercury.

It is usually compared with the standard sidereal clock by causing their beats to be recorded on the same chronograph, generally, until a coincidence is obtained, every day that a sufficient number of observations are obtained with the Transit Circle to determine the error of the sidereal clock. The accuracy of this clock is far superior to that of any other clock in the Observatory.

THE CHRONOGRAPH.

This apparatus is mounted on a small stand near the eastern wall of the observing-room. This instrument is a modified form of the Hipp chronograph, in which regularity of motion in the train is secured by a spring making 132 vibrations per second. The barrel of the chronograph is 6.37 inches in diameter, 13.5 inches long, and revolves once in a minute. A sheet of paper fastened on the chronograph-barrel by thin metallic springs is sufficient to contain the record of two hours' continuous work, and the train only requires winding when the paper is changed. The clock-signals and those of the observer are recorded by a single pen. The armature of the magnet which controls the pen is provided with repeating-points, for use in sending signals to distant stations when determining telegraphic differences of longitude.

The pen-carriage is moved forward by an endless screw, but may be lifted from its bearings and moved backward or forward so that the pen can be placed upon any desired part of the paper. The chronograph stops when the sheet is full. The record is made on paper of the quality of ordinary writing-paper, with an ink which does not freeze at 0° F. The ink is made in the following proportions:

Water	-	-	-	-	-	-	4 fluid ounces.
Alcohol	-	-	-	-	-	-	2 fluid ounces.
Concentrated Glycerine	-	-	-	-	-	-	1 fluid drachm.
Crystallized Aniline Blue	-	-	-	-	-	-	40 grains.

The ink should be thoroughly filtered before using.

The pen is of glass, and the lower part of the bulb is drawn out to a fine capillary tube, so that, when the bulb is filled with ink and the pen allowed to rest its whole weight on the paper, it produces a fine, sharp line as the barrel revolves.

THE BAROMETER AND THERMOMETER.

The Barometer is of the cistern form, and is suspended on the eastern wall of the observing-room, near its northeastern corner. This instrument reads by a vernier to the one-hundredth of an inch.

The Thermometer has a Fahrenheit scale, and is graduated from -36° to $+157^{\circ}$. It is suspended 1 foot outside the north front of the observing-room, 13.5 feet above the grass, and is protected from radiation by a shield formed of a double roof of boards, the outside one covered with tin painted white, and three sides of wooden, double louver-work.

THE OBSERVING-ROOM.

The interior of the observing-room, which has been occupied since February 2, 1870, measures 40 feet from north to south, and 28 feet 3 inches from east to west. Its height, from the floor to the under side of the shutters which cover the opening in the roof, is 23 feet 2 inches at the ridge, and 19 feet 6 inches at the eaves. The ridge of the roof extends east and west. The opening in the roof has a width of 3 feet 8 inches, and extends downward, in the north and south walls, to within 7 feet 4 inches of the floor. The portion in the roof is closed by means of four sliding shutters, while the portions in the north and south walls are each closed by double doors.

The construction of the room is peculiar, the walls of the frame being covered with tin, and shaded from the direct rays of the sun on the east, south, and west sides by light wooden louver-work. This construction was adopted in order to secure identity of temperature between the internal and external air. The latitude of the Transit Circle is the same as that of the center of the central dome, but it is 77.8 feet $= 0^{\circ}.066$ west of that point.

VI.—THE XXVI-INCH EQUATORIAL.

[Prepared by Professor EDWARD S. HOLDEN, U. S. N.]

Section 18 of the "Naval Appropriation Bill," approved July 15, 1870, contained the following provision:

"That the Superintendent of the Naval Observatory be, and he is hereby, authorized to contract for the construction of a refracting telescope of the largest size, of American manufacture, at a cost not exceeding fifty thousand dollars."

Immediately upon the passage of this bill negotiations were entered into with the firm of ALVAN CLARK & SONS, of Cambridge, Massachusetts, resulting in the conclusion of a contract for the construction of the instrument, in the following terms:

"This indenture, made and concluded upon this thirteenth day of August, in the year one thousand eight hundred and seventy, between ALVAN CLARK, GEORGE B. CLARK, and ALVAN G. CLARK, all of Cambridge, Massachusetts, and doing business under the name and firm of ALVAN CLARK & SONS, as the party of the first part, and the UNITED STATES OF AMERICA, represented by Commodore B. F. SANDS, U. S. N., Superintendent of the Naval Observatory, by authority of the eighteenth section of the act making appropriations for the naval service for the year ending June 30, 1871, approved July 15, 1870, as the party of the second part, witnesseth:

"That, for the considerations hereinafter mentioned, the said party of the first part agrees to construct, finish, and mount in the United States Naval Observatory, Washington, free of all expense to the party of the second part, a refracting telescope of good definition, and of twenty-six inches clear aperture, mounted equatorially on the German plan, with all the usual and necessary counterpoises and other devices to secure its easy motion, its proper balance in all positions, and the safety of its object-glass; with divided circles, to be each read by two microscopes; the R. A. circle to seconds of time, and the Declination circle to tenths of a minute of arc; with a driving-clock sufficiently regular and powerful to secure an equable and steady motion in right ascension, for a period of at least three hours without stopping; with the usual number and description of eye-pieces and ring-micrometers; with a filar micrometer for measuring distance and angle of position; an AIRY'S double-image micrometer, and a divided glass or mica-scale micrometer. The said telescope shall also be furnished with such spectroscope, such devices to secure successful and easy manipulation, and such apparatus for illuminating the wires, the field, and the circle-divisions, as the party of the second part may prescribe, it being agreed, however, that no spectroscope shall be required by him of which the total necessary expense of construction shall exceed one thousand dollars, and that no new devices or apparatus thus prescribed shall be of an unusually expensive character.

"It is also agreed that the party of the second part shall build at his own expense a proper foundation of the instrument, to include all that part of the support which is commonly built of stone, and to be terminated on top by a horizontal surface, and that the contracting party shall furnish and put in complete working order everything which is to be borne by the said surface, and shall do everything necessary to secure the successful working and performance of the instrument, whether otherwise expressed in this contract or not.

"It is also agreed that the said instrument shall be completed and mounted within four years of the time of receiving the first payment.

“It is also agreed that all the designs of the instrument shall be submitted to the Superintendent of the Naval Observatory and be approved by him before being carried into execution, but such approval shall not be construed to diminish the responsibility of the contractors.

“In consideration of the foregoing, the party of the second part agrees to pay the party of the first part the sum of forty-six thousand (46,000) dollars in lawful money of the United States, in time and manner as follows, that is to say, a payment of ten thousand dollars when the glass shall have been tested and found of proper quality; an additional payment of five thousand dollars when the labor of figuring the glass shall be half performed; a payment of seven thousand five hundred dollars when the said labor shall have been completed and the glass proved in its cell; a payment of five thousand dollars when the instrument shall be ready for mounting; and the remainder of the price when the party of the first part shall have fully completed their contract. But it is agreed that if the party of the second part shall dispense with the spectroscope, a deduction of one thousand dollars shall be made from the above-mentioned price, and, furthermore, that if the United States shall remit the import-duty on the raw material, or any part of it, a deduction shall be made from the price equal to the currency-value of the duties thus remitted. The party of the second part also reserves the right, before making any payment, to require the contracting party to enter into a bond, with approved security, conditioned on the faithful performance of the contract, and to insure the work against injury by fire at their own expense.”

The glass disks were immediately ordered by the contractors from MESSRS. CHANCE BROTHERS & Co., of Birmingham, England, but such was the difficulty of casting disks of the required size that they did not arrive in this country until the end of December, 1871. The work of figuring them was immediately commenced and was completed in the autumn following. The mounting of the telescope was finished in the summer of 1873, and the whole was brought to Washington in October of that year. The work of mounting was completed during the month following, and on November 20 regular observations were commenced. The construction of the telescope and the building of the dome was under the immediate direction of Professor NEWCOMB. It is worthy of remark that the instrument was completed in less than half the time stipulated in the contract.

THE DOME.

The erection of the instrument upon the Observatory building would have required the removal of the old 10-inch equatorial, the remodeling of the interior of the building, and the erection upon it of a dome out of all proportion to the structure. It was therefore decided to extend the south wing of the Observatory, and to place the floor of the great dome upon the same level with the main floor of the rest of the building. The disadvantages of this course were believed to be far more than counterbalanced by its advantages. The only disadvantage to be taken into consideration is, that the telescope cannot sweep the horizon. In the north, the old dome rises to an altitude of about 16° , while in other directions the surrounding trees interfere with the view to an average height of perhaps 10° . This drawback is however entirely unimportant, for the reason that with so large an instrument astronomical observations can never be advantageously made so near the horizon. During the two years' use of the instrument no case has yet arisen in which the view of any object which it was desired to observe has been cut off by these obstructions. The advantages of the arrangement are cheapness and simplicity of construction, convenience of access from the adjoining computing-room, and partial protection from the wind.

The *foundation* of the dome is rubble-stone, 43 feet exterior diameter, and 2 feet

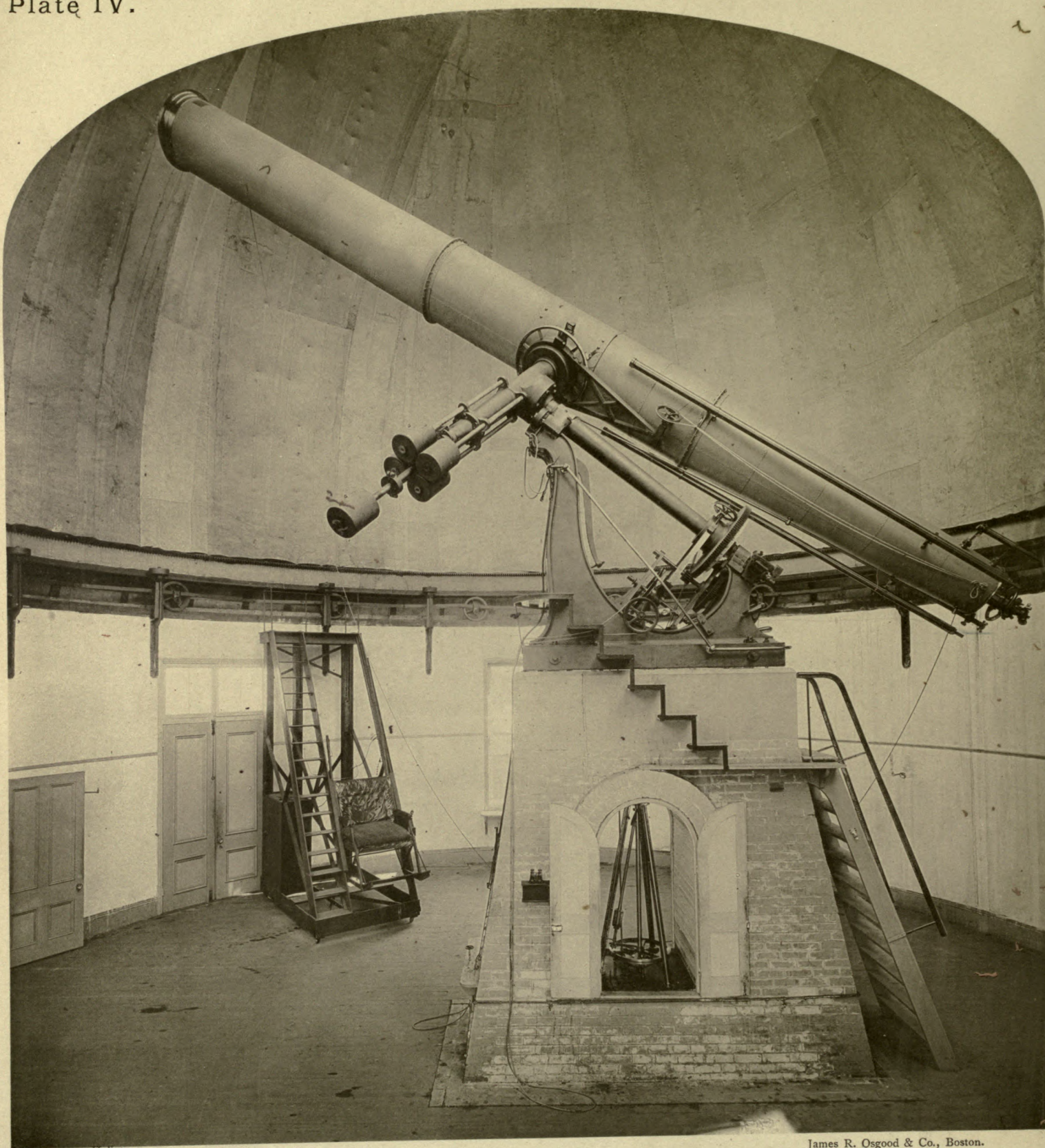
thickness of wall. It extends 17 feet below the main floor, and on the average, about 12 feet below the surface of the ground. This stone foundation extends only to the bottom of the joists which support the floor. On it rests a circular sill of oak timber in 8-foot sections, which is fastened down by iron anchors, each extending 3 feet into the stonework. On this sill rest vertical posts of oak timber, alternately 6 inches by 6 inches and 3 inches by 6 inches, which form the frame-work of the cylindrical portion of the dome. The interior diameter of this portion is 41 feet, and its height 14 feet. These joists are strengthened by six diagonal braces between each pair of posts, the alternate sets inclining in opposite directions. On top of the posts rests a circular plate of oak timber, 8 inches broad by 4 inches high. On this plate rests a plate of iron, cast in pieces about 6 feet long, with flanges 5 inches wide on the edges, which flanges fit snugly on the two vertical sides of the oak plate, so that the latter is inclosed by iron surfaces on three sides. The inner and outer edges of the iron plates are elevated so as to form a sort of railway, with convex surfaces, the rails being 6 inches to 7 inches apart from centers.

On these rails rest the rollers, sixteen in number, on which the dome turns. These are conical in form, the outer end being enlarged in the proportion of the distance it has to move, and each is supplied with a pair of flanges to prevent end motion. These rollers are connected by a linked coupling, like that employed by Mr. GRUBB in the dome of the Dublin observatory, which, at the same time, keeps the rollers at the proper distance apart, and maintains their axes in a line passing through the center of the dome. The principal deviation from Mr. GRUBB's system is, that his three narrow rollers are combined into a single wide one.

On the rollers rests another circular iron plate similar to the one upon which they rest, except that only the central part, about 3 inches broad, rests on the rollers, and that on the inside a horizontal flange, about 3 inches wide, is cast. Sixteen friction-rollers are supported at various points about the drum of the dome, which consist essentially of horizontal wheels, whose vertical rims are close to the vertical flanges of this circular plate, and which project slightly over its horizontal flange just described. Between the vertical flanges is set the 8-inch by 4-inch wooden sill on which the dome is built.

The dome is of the hemispherical pattern, the lower 3 feet, however, being as usual, cylindrical. The opening is 6.5 feet in width, and extends nearly 6 feet beyond the zenith. The sides are formed by two strong arches, into which all the smaller ribs are nailed. To prevent lateral springing of these arches, and to give solidity to the junction of the arches with the ribs, a 12-inch by 1-inch pine board is sprung on the frame-work under each arch, through the whole course of the latter, its outer edge being flush with the inner vertical surface of the arch. As the surface of this board is necessarily cylindrical, instead of spherical, the under edges of the ribs are notched away sufficiently to allow the board to fit into them, and the board is then nailed to each of them. That there has been no such lateral springing has been shown by careful measures of the width of the slit at various times. These arches have, necessarily, a powerful end thrust, tending to force the lowest circle of the moving portion of the dome into an elliptical form. This has been provided against by shrinking two

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Heliotype.

James R. Osgood & Co., Boston.

THE XXVI-INCH EQUATORIAL.

U. S. NAVAL OBSERVATORY, WASHINGTON. MOUNTED 1873.

OBJECT GLASS } Focal Length, 32 ft. 5.8 in.
 } Clear Aperture, 26 in.

bands of wrought iron, about 15 feet long, on the outside of the dome, so as to prevent such change of shape.

The frame-work of the dome is covered on the outside by sheets of galvanized iron and on the inside by canvas. The canvas on the inside of the cylindrical portion has been thoroughly soaked with several coats of *soluble glass*. Experiment has shown that it will not blaze when fire is applied to it, but only slowly smolder in such a way that some time would be required before the wooden frame-work could be ignited even if the canvas were to be accidentally set on fire. To provide against possible accidents of this kind, a hose is kept attached to a water-pipe supplied from the main reservoirs of the city, through which a powerful stream of water can be at once directed to any portion of the interior of the dome or of its adjacent office and bed-room. This hose is kept in working order in one of the closets opening directly into the dome.

Closets:—Three closets are provided, in one of which the Chronograph is placed, the other two serving as receptacles for the smaller apparatus, tools, etc.

The Chronograph-closet has within it the register of a hot-air furnace, which is opened whenever it becomes desirable (in the day-time, and not during observations) to prevent the *sweating* of the pier and instrument, which occasionally takes place by the deposition of dew from moist warm air upon the cold surfaces of the telescope, etc., which have not yet reached the temperature of the surrounding air.

The temperatures inside and outside of the dome are usually very nearly the same, owing to its peculiar construction; generally within 5° of Fahrenheit's scale. Ample provision has been made for securing this essential to the good performance of a large telescope, in the two windows and in the two wide doors of the dome, which are usually opened shortly after sunset on clear days.

The dome is lighted by eight gas-burners arranged at nearly equal distances around the drum or cylindric portion, about 6 feet above the floor. There is also a gas-pipe led around the pier, about 2 feet from the floor, in which are six stop-cocks, to which flexible-rubber tubes can be fitted, one on the north and south ends and two on the west and east sides. (See Plate IV.) From this pipe a branch goes up the north end of the pier and of the "harp-shaped piece" of the mounting, terminating in two burners near the north end of the polar axis. The photograph (Plate IV) shows the arrangement of these burners.¹

The dome is moved by means of a pinion of cast iron, 10 inches in diameter, which works into a rack, also of iron, cast in sections of about 4 feet in length, screwed firmly to the inner surface of the dome. This pinion is on the same horizontal axle as a cast-iron wheel, 3 feet in diameter, in whose grooved edge an endless manila rope, 1 inch in diameter, is laid. The rack, rollers, and friction-rollers are shown in Plate IV. This simple device has proved satisfactory, after two years' service. A pull of about fifty pounds is sufficient to start the dome to move, and less than this will preserve the motion.

SHUTTERS.

After trial and experiments upon various systems of shutters for closing the observing-slit, which is 6.5 feet wide and 39.5 feet long, the following very simple device

¹ It is to be noted that Plates IV and V are *reversed* north and south. Plate VI, however, is not inverted.

was chosen, which after a year's trial has shown itself to be satisfactory and convenient. A piece of canvas, 43 feet long and 9 feet 4 inches wide, is used for the covering; to make it water-tight it is treated with two or three coats of linseed-oil. One end of the canvas is lashed through eyelets to ring-bolts at the lower extremity of the slit, and the other end is fastened to a cross-bar of 1-inch round iron, which has a grooved wheel, 4 inches in diameter, at each end. These grooved wheels rest upon brass railway-tracks, laid on the outside of each of the main arches which limit the slit, and travel up and down upon these tracks as the cross-bar is raised or lowered. In the longer sides of the canvas, galvanized-iron rings are inserted every 3 or 4 feet, and these rings embrace two arches composed of stiff galvanized-iron pipes, 2 inches in diameter, which are bent to a circle of a radius 3 or 4 inches greater than the outside radius of the sphere of the dome. The ends of these pipes are secured by passing them through oak blocks bolted firmly to the outside of the dome. To the iron cross-bar, at the upper end of the canvas, two wire ropes are attached, each of which runs from its end of the cross-bar through a series of nicely-fitted brass guide-blocks or *fair-lead*ers, eight in number, fastened to the faces of the main arches, up to the outside of the dome and to a cast-iron wheel, 1 foot in diameter; returning, the rope passes round this wheel and through a second series of guide-blocks, immediately below the first, and round a second iron wheel, of the same size as that at the top of the slit, at the end of a horizontal axle placed at the bottom of the slit and inside of the dome, and from thence back to the other side of the cross-bar to the point where it is first fastened. It is thus, practically, an endless rope.

Motion can be given to the horizontal axle, at the bottom of the slit, by a simple mechanical arrangement. This motion is at once communicated to the iron bar at the upper end of the canvas through the wire ropes, and the slit is opened or closed with ease. The office of the 2-inch galvanized-iron arches on the outside of the dome is to confine the sides of the canvas by means of the rings which slip upon them, so as to prevent flapping of the canvas in case of high winds, and to keep its edge so close to the dome that rain may not beat in under it. The railway-tracks direct the motion and lessen friction. Simple mechanical arrangements are provided for lengthening or shortening the wire ropes, and for causing the direction of the pull of these ropes to be exerted upon the iron cross-bar in the most advantageous way. This shutter can be opened or closed in two minutes by one man, and it is perfectly water-tight, the canvas requiring renewal about once a year. In a more northern latitude snow might seriously interfere with its efficiency. During the winter of 1874-'75 at Washington, however, no trouble was experienced from this cause.

OBSERVING-CHAIRS.

The large observing-chair and step-ladder, shown in Plate IV, is of the simplest and lightest construction, and may be understood by an examination of the photograph. It is not placed upon a track, as it serves as a step-ladder as well as a chair, and moves upon the solid floor of the dome on ordinary casters. The chair itself is over-counterpoised, and will move upward by the application of a slight force and downward when the observer is seated in it. To adjust it to any position of the telescope, it is moved

slightly above the proper place, the observer enters it, and as it moves slowly downward he fixes it in position by the motion of a lever which interposes a stop in a toothed rack. The lower portion of the frame-work carries a closet in which are placed a Ruhmkorff coil and a battery.

This chair is not available for observations near the zenith. For these an ordinary "invalid-chair" is provided, which serves for all observations from the zenith southward to 75° of north polar distance, at which point the larger chair becomes available.

THE PIER.

At its foundation the pier which supports the telescope is divided into four parts, each 5 feet by 3 feet, the longer sides being north and south. These are set so as to leave an opening 14 feet long from north to south and 3 feet 10 inches wide from east to west. The opening in the shorter direction is arched over at a height of 8 feet above the floor of the cellar, and the longer opening, running north and south, at a height of 12 feet. The latter arch is built of brick, as is also the pier above it. At the level of the floor of the dome the brick pier is nearly 11 feet long from north to south, and 4 feet from east to west. It tapers slightly on each side to the top. It is surmounted by a stone cap 2 feet by 2 feet by 8 feet, on which rests the cast-iron support ("harp-shaped piece") of the telescope. Above the floor of the dome and within the brick pier is a closet, whose floor is covered by an iron base (for the support of the driving-clock) about 3 feet square, the inside height of the closet being about 5.5 feet. This closet (shown in Plate IV) is closed by two doors on its east and west sides, and the driving-clock is thus thoroughly protected from dust, etc. The cap-stone is secured to the brick pier by four solid iron rods which pass completely through the base of the harp-shaped piece and through the cap-stone, and are secured by nuts inside the brick pier and above the base of the casting. In Plate IV the position of the southeast rod may be traced from the nut at the top of the base of the casting downward to the hole in the brick pier, in which the under nut is secured. This hole is printed quite dark in the photograph. These four rods make the brick pier, the cap-stone, and the harp-shaped piece one connected system.

THE MOUNTING.

The harp-shaped piece, while it is strongly connected with the cap-stone and pier, is yet capable of three motions: one in azimuth; one a rocking motion in zenith-distance, about a north and south line; and one a rocking motion in zenith-distance, about an east and west line. Before the harp-shaped piece was mounted, two pieces of cast iron were firmly bolted to the top of the cap-stone 5 feet 5 inches apart. These serve simply for four horizontal screws to abut against, by whose motion the whole instrument is slewed in azimuth. Plate IV shows two of these screws, the head of the southeast screw being just below the handle of the crank for rapid motion in right-ascension, and the head of the northeast screw being vertically under the upper bearing of the polar axis. Immediately above these screw-heads are the heads of two vertical

screws which, with two other similar screws on the west side of the pier, serve to give to the mounting the two motions in zenith-distance just described. It has been found that the stability of this mounting leaves little to be desired.

THE AXES AND CIRCLES.

The polar axis is 7 inches in diameter at its thickest part, tapering slightly toward its lower end. The north end of this axis is 19 feet above the floor of the dome. The declination-axis is of the same size, and is pierced through its length by a cylindrical opening, about 2 inches in diameter. A steel flexure-bar passes through this opening, one end of it being firmly fastened to a frame-work inside the tube of the telescope, as near to the cone of rays as it was judged safe to place it. This bar attains its greatest diameter about a foot outside the telescope-tube, where it accurately fills the bore of the declination-axis. It then tapers gradually toward the outer end, the amount of the taper being so calculated that the weight which the bar carries at this end shall be somewhat less than is necessary to make the rod touch the side of the bore.

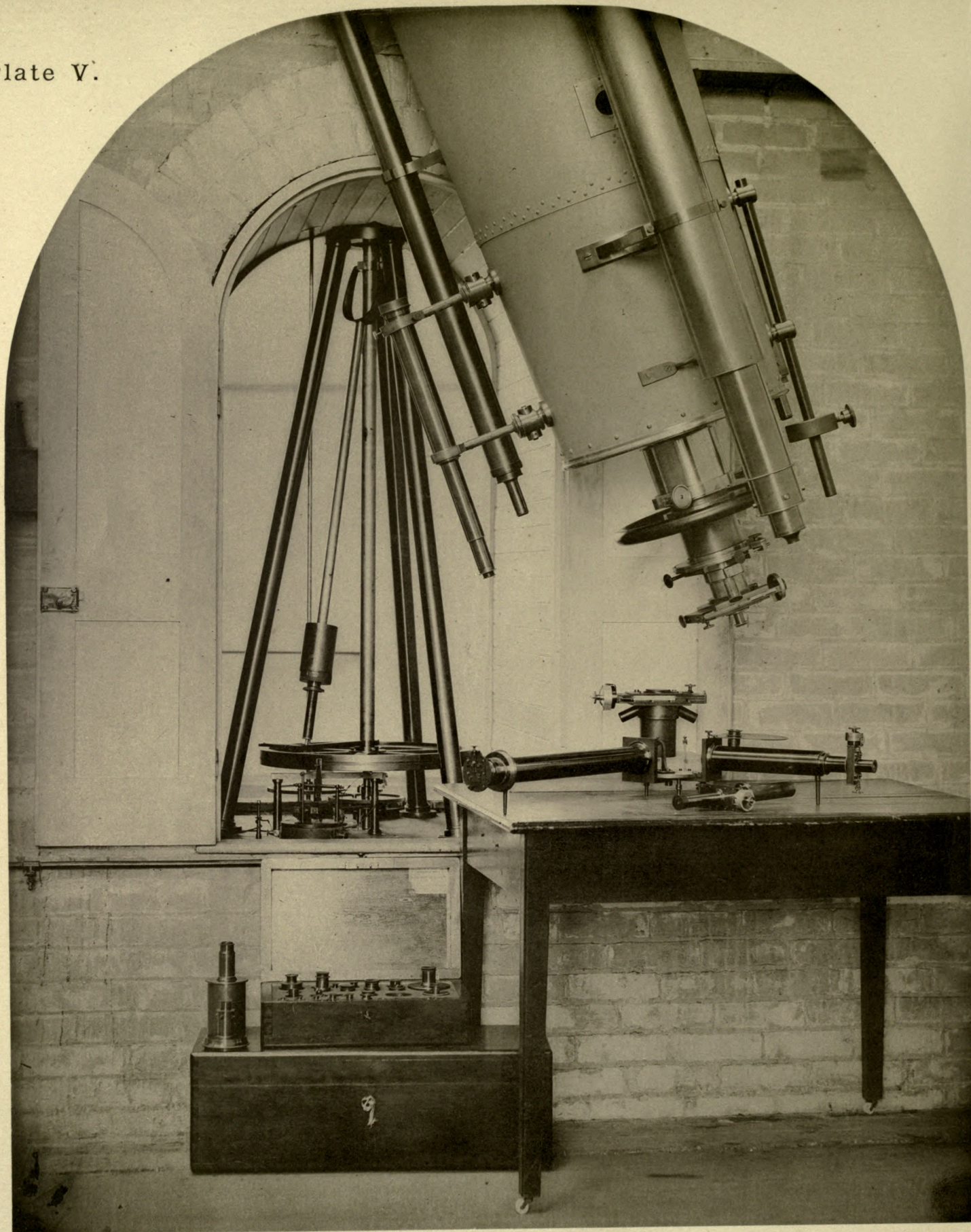
Friction-Rollers and Counterpoises.—The north end of the polar axis rolls in a brass box and is supported by two friction-rollers of steel, about 7 inches in diameter. The weight of the axis is taken from the box by means of a strong steel spring, several feet in length, which is shown in Plate IV, just under the polar axis and to the south of the harp-shaped piece. The lower end of this is perforated, and traversed by a bolt, whose north end is fixed to the casting and whose south end has a screw-thread cut upon it. A nut on the screw-thread confines this spring in any required position. For the declination-axis there are no friction-rollers. The counterpoises, composed of four heavy iron cylinders, are so disposed that the center of gravity may fall within the upper box of the polar axis.

The Circles.—The *hour-circle* is divided on its southern *face* to one minute of time, and is read by two microscopes marked E. and W. (east and west) to one second of time. These microscopes are reached by means of wooden steps, permanently attached to the south end of the pier. There is also a coarse division on the *edge* of the circle in black and white paint, which can be read from the floor by the unassisted eye to one minute of time, and by means of this latter division the telescope can be set for any object which can be recognized in the finder. The *declination-circle* is close to the telescope-tube, and can be read by two opposite verniers to 0.2 of one minute of arc. These verniers are read from the eye-end of the telescope through two long microscopes, (marked A and B,) into which the images of the divisions of the circle and of the vernier are reflected by means of two right-angled prisms of glass fixed to the tube. The declination-circle is also divided coarsely on its *edge* to one degree of polar distance, and can be set by means of an opera-glass to one-half of one degree. For many purposes these coarse divisions of the two circles are the only ones which are needed.

Plate IV shows the east microscope of the hour-circle and both microscopes of the declination-circle, as well as one prism and the index for the coarse divisions. Both the fine and coarse divisions of each circle can be read in the day-time with ease. At

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Plate V.



Heliotype.

James R. Osgood & Co., Boston.

DETAILS OF CLOCK-WORK, ETC., OF XXVI-INCH EQUATORIAL.

night the coarse divisions of both circles can be made visible by lighting one or two of the gas-burners of the dome. To read the fine divisions of the hour-circle oil hand-lamps must be placed on stands fitted for this purpose. For illuminating the fine divisions of the declination-circle it was originally intended to use Geissler tubes, driven by a Ruhmkorff coil, and this method was given a thorough trial. It was found that while enough light could be thrown on the circle, the management of the coil and battery was far too annoying, and the very simple device was resorted to of running a gas-pipe up the north end of the harp-shaped piece, at the end of which two stop-cocks were fitted, to which were attached flexible-rubber tubes terminating in gas-lamps convenient to hold in the hand. A set of steps was put on the east side of the casting, and a small platform which does not in any way interfere with the moving of the instrument nor with its stability, was fixed to its north end. To set the circle the instrument is brought into the meridian and set by means of the coarse divisions to within less than one degree of north polar distance of the required position, an assistant mounts upon the platform and holds the gas-lamp near the vernier, and the fine setting is accomplished by the observer seated in the observing-chair, the declination-clamp and slow-motion screw being convenient to his hand.

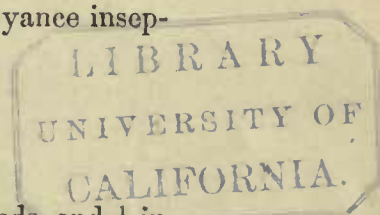
This method is perfectly satisfactory, and does away with all the annoyance inseparable from complicated devices.

THE TELESCOPE.

Tube.—The tube is of steel, $\frac{1}{16}$ of an inch in thickness near the ends and $\frac{1}{8}$ in the middle, and is made in three sections. It is about 32 feet in length, the middle one-third being about 31 inches in diameter. From this middle one-third the tube gradually tapers to about 28 inches at the object-end and 21 inches at the eye-end. This latter is closed by a brass plate, into which the sliding-tubes for holding the position-circle, eye-pieces, &c., fit. The photograph (Plate V) gives the best notion of the arrangement of the eye-end. At the object-end of the tube are two iron doors, about 4 inches square, which can be removed for ventilating the tube. Such experiments as have been made indicate that the difference of temperature of the air outside and inside the tube is usually not greater than 1° Fahrenheit. One of the ventilators is shown in Plate IV close to the cell of the object-glass.

Object-glass.—The object-glass is composed of an equi-convex front lens of crown-glass and a nearly plano-concave flint lens, the clear aperture being 26 English inches, and the principal focal distance of the combination being 390 inches, nearly. The radii of the three curved surfaces are each about 161 inches. The thickness of the objective at the center is about 2.87 inches. It is confined in a gun-metal cell which has adjusting-screws for collimation, etc. The objective cannot be rotated in its cell.

The glasses are free from all hurtful rings and striæ, and are of nearly perfect figure. To test their figure, the telescope, with the full aperture of 26 inches, was pointed upon *Uranus* March 10, 1874, and the eye-piece, magnifying 600 diameters, was carefully focused on the two satellites *Oberon* and *Titania*. The central



bisections of the satellite with the micrometer-wire were made, any error peculiar to the bisecting of the satellite with the *movable wire* would remain. In practice, however, the micrometer-wire is moved to the other side of wire A and set at the proper distance, approximately. Wire A is now brought by the motion of screw A accurately upon the *satellite*, and the movable wire is brought to bisect the planet's disk. The whole process of repeated trial and rectification is now gone through until a satisfactory bisection is attained, and the reading of the scale and micrometer-head now obtained, joined with that first read, gives a measure of *double* distance. It will be observed that in both positions of the micrometer-wire relative to wire A, the eye is occupied with but one question at a time and has simply to decide whether a single object is accurately bisected by a certain wire or not. It is not required that the eye should decide this while the hand is employed in altering the distance, but, the wires *remaining* at a given distance apart, the eye has simply to decide whether the given distance is the one required, and the final process is identically the same for both positions of the micrometer-wire. It is conceived that in this way the likelihood of constant errors is lessened. It should be noted that the final movement of the screw M is always made so that this screw acts against the springs of the micrometer.

The value of one revolution of the screw of this micrometer has been carefully determined, from 804 transits of equatorial and zenith stars on eleven different nights, to be

$$9''.9480 \pm 0''.0015.$$

Owing to the difficulty of getting a convenient bright field-illumination at the time these measures were made all the transits were observed over bright wires in a dark field, and the coincidences of the fixed and movable wires were observed in the same way. This accounts for the large probable error which, from so many transits, observed with a telescope of so great focal length with the advantage of the greater precision of black wires in a bright field, would be smaller. Professor NEWCOMB has shown (Washington Astronomical Observations, 1873, p. civ) that the value of one revolution of this screw is sensibly uniform throughout, and that the periodic inequalities are inappreciable. This micrometer has been used from the mounting of the instrument, in November, 1873, to the present time. The illumination of the wires has been generally accomplished by the aid of a hand-lamp held by an assistant, and this method has been found to be very convenient and satisfactory for the class of work hitherto done. Although means have been provided to illuminate the field of view, all observations have hitherto been made in a dark field with illuminated wires. From measures by Professor HALL, the thickness of the unilluminated wires projected against the bright disk of *Jupiter* has been found to be $0''.251$.

The second position-filar-micrometer has for its primary object the measures of differences of right ascension and north polar distance. For this purpose the reticle is arranged with three fixed wires for determination of differences of right ascension, and the micrometer-screw carries a system of five wires for measures of differences of north polar distance. The inconvenience of reading the whole revolutions from a small scale on the edge of the micrometer-box is obviated by causing the micrometer-

screw M to carry two divided heads whose planes are parallel to each other and close together. On one of these heads the decimals of a revolution are counted, and on the adjacent one whole revolutions are registered. Both heads are read by the same index or pointer, which is placed between the two. Plate V shows this micrometer detached from the telescope, and also the spectroscope and double-image micrometers, which have the same device.

A thermometer has been imbedded in the micrometer-box itself, so as to be in metallic contact with the micrometer-screw. From this thermometer the true thermal condition of the whole micrometer-box can be ascertained, and as the illumination of the wires is intended to be done by means of Geissler tubes driven by a Ruhmkorff coil, thus avoiding the heat from oil or gas lamps, it is hoped that an accurate determination of the value of the temperature co-efficient of this screw can be obtained. The micrometer-screws of both the filar micrometers were cut on the same tool; the first (Micrometer I) has 53.265 turns to the inch, the second (Micrometer II) has 53.318.

A new double-image micrometer, also by CLARK & SONS, has been furnished, which has the advantage of a larger field of view than the ordinary instruments of this construction.

Eye-pieces.—There are four negative eye-pieces, of the AIRY pattern, which fit into the slipping tube of the telescope when the micrometer is removed. Their magnifying powers and fields of view are as below.

NEGATIVE EYE-PIECES.

Designation.	Magnifying power.	Field of view.	Makers.
A_I	<i>Diameters.</i> 155*	25.2	Clark & Sons.
A_{II}	439*	10.5	Do.
A_{III}	863*	3.5	Do.
A_{IIII}	1,360*	2.5	Do.

* Approximate.

A BRADLEY rhomboidal micrometer and several ruled-glass scales of various patterns have been ruled for use with the telescope by Mr. WILLIAM A. ROGERS, assistant in the Harvard College observatory.

The micrometer eye-pieces (which fit either of the two filar-micrometers) are as below:—

POSITIVE EYE-PIECES:

Designation.	Magnifying power.	Field of view.	Makers.	Remarks.
	<i>Diameters.</i>			
1	173	13.2	Clark & Sons	
2	284	8.1	Kahler	
3	392	9.9	Clark & Sons	
3 A	400*	6.6	Kahler	Achromatic.
4	636	3.5	Clark & Sons	
5 A	606	4.2	Kahler	Achromatic.
6 A	888	2.3	Steinheil	Do.
7 C	761	3.2	Kahler	Crown-glass.
8 F	875	3.2	...do.....	Flint-glass.
9	1,103	2.6	...do.....	
10	1,282	2.1	...do.....	
11	1,802	1.6	...do.....	
I	390	4.9	...do.....	Single lens.
II	585	3.2	...do.....	Do.
III	780	2.6	...do.....	Do.
IV	1,560	1.8	...do.....	Do.

* Approximate.

Finders.—There are two finders, one, by CLARK & SONS, 5 inches in aperture, 72.5 inches focal length, with two eye-pieces. The one usually used has a field of view of $1^{\circ} 18'$, and a magnifying power of about 30 diameters. The other has a magnifying power of about 75 diameters. The second finder, by KAHLER, is situated 90° in position-angle from the first, and has an aperture of $2\frac{1}{8}$ inches, a focal length of 21 inches, and carries an eye-piece magnifying about 12 diameters, and having a field of view of over 3° . This finder is quite convenient for use when the larger one is either too high or too low for ready access. Both these instruments are very carefully made. Plate IV shows the small finder above the tube, the 5-inch finder being on the west side, and not shown. Plate V shows the eye end of the 5-inch finder and the whole of the small finder.

Spectroscope.—The instrument is provided with a star spectroscope of two 60° prisms, made, after designs by Professor NEWCOMB, by CLARK & SONS. This is shown in Plate V. It has three eye-pieces.

Dynameter.—A Ramsden dynameter has been made for use with the telescope by Mr. EDWARD KAHLER.

Clock.—A sidereal clock is mounted on the east side of the dome, and connected electrically with the chronograph.

MOTIONS OF THE TELESCOPE.

The telescope being mounted on the German plan, has motion about two axes perpendicular to each other. Arrangements are provided for securing—

- (a) A slow motion in North Polar Distance.
- (b) A rapid motion in Right Ascension.
- (c) A slow motion in Right Ascension.

(a.) The clamping in north polar distance is done by means of a long, stiff brass

rod, (shown just below the telescope-tube in Plate IV, but hidden in Plate V.) The slow motion in north polar distance is given by means of an endless rope passing round the head of a large wheel at the end of the slow-motion screw. The whole of this rope is shown in Plate IV, extending from near the eye-piece to the wheel.

(b.) The device for securing rapid motion of the telescope in right ascension is not completely shown in Plate IV, but most of the important portions can be seen. It consists essentially in a large cast-iron toothed wheel, having 96 teeth, (one tooth to each fifteen minutes of right ascension,) which is clamped firmly to the polar axis just above the hour-circle. Immediately below this wheel Plate IV shows a small iron pinion which turns on an axis parallel to the polar axis of the instrument. By the motion of a lever on the west side of the pier, (not shown in the photograph,) this pinion may be raised or lowered so as to be *in* or *out of gear* with the first-described wheel. This pinion is connected by a small train to a horizontal axle running east and west, which is fastened to the south end of the harp-shaped piece. The east end of this axle carries a crank, (shown in Plate IV,) and the west end carries a wheel, round whose rim an endless rope passes, which reaches nearly to the floor on the west side of the pier. If the observer wishes to set the hour-circle while he is at the microscopes of this circle, (*i. e.*, standing on the steps at the south end of the pier,) he first depresses the lever which puts the pinion in gear, and then by turning the crank shown in the photograph he causes the telescope to move in hour-angle at the rate of 15 minutes of time for each revolution of the crank. After this setting is completed the lever must be raised and the pinion thrown out of gear, in order that the driving-clock may act. More usually the rapid motion in right ascension is required in setting the telescope from the floor of the dome on the west side of the pier. The observer can depress or raise the lever for throwing the pinion in or out of gear from the floor by means of two ropes, and the motion in right ascension is effected by a pull upon the rope encircling the rim of the small wheel-which is at the west end of the same axis which carries the crank.

This whole apparatus is simple and, at the same time, effective; by means of it this telescope can be reversed nearly as quickly as the 10-inch Munich telescope of the Observatory. It should be noticed that to each end of the telescope-tube a stout cotton braided line is attached, (which is shown in the photograph, Plate IV,) for the purpose of aiding in manœuvering the telescope. Some portion of this is always within reach from the floor of the dome.

(c.) The clamping in right ascension is done by means of a rope on the northwest corner of the pier, which passes round the head of a wheel, shown in Plate IV, between the polar axis and the telescope and close to the large wheel for rapid motion in right ascension. The slow motion in right ascension is secured by turning a wheel, shown in the photograph directly in the middle of the harp-shaped piece, and on its east side. The endless rope for giving this motion is shown at the northeast corner of the pier.

THE DRIVING-CLOCK.

The form of driving-clock adopted is the invention of Professor NEWCOMB, and was devised by him with special reference to the xxvi-inch equatorial.

It will be convenient to describe first that portion which is for the purpose of giving the requisite motion to the train, and second the portion whose office it is to

regulate the motion and to make it sensibly uniform. The driving part is mainly situated in the cellar beneath the dome. It consists, first, of a small reaction water-wheel, (the "BARKER'S Mill,") which is moved by water from the city water-pipes. This water may be turned on from the dome by means of a vertical rod at the north end of the pier. (See Plate IV.) When the water is so turned on the reaction-wheel begins to revolve, and causes a weight in the cellar to ascend. When this weight has reached a certain point the water-supply is automatically shut off, and the reaction-wheel wholly or partially ceases to turn, while the weight falls. While the first weight is falling a weight of about one-fourth or one-fifth the weight of the first is forced to ascend, and just before the first weight reaches its lowest point the water-supply is again automatically turned on and the first weight is again raised. The connection between these weights, by which one is made to rise when the other falls, and by which both weights are connected with the driving-clock and the vertical axis of the water-wheel, is that of the well-known HUYGHENS' loop.¹ The cord which forms this loop is endless and passes around *four* wheels, two horizontal and two vertical, small guide-pulleys being introduced to change direction. It first passes round a horizontal wheel on the vertical shaft of the water-wheel, from thence round a vertical wheel above and attached to the heavier driving-weight, thence round a horizontal wheel which is fixed to the vertical shaft of the driving-clock, (in the closet of the pier above the floor of the dome,) and from thence to the vertical wheel of the lighter weight, and finally back to the point of beginning.² By close inspection a portion of this rope may be seen in Plate V passing round the bottom of the vertical shaft of the clock just below the first toothed wheel of the train. In this way the driving-weight gives approximately uniform motion to the first wheel of the train, and from this first wheel the motion is transmitted through the wheels of the train to a vertical rod on the west side of the pier, at the top of which is the beveled wheel through which the motion is transmitted to the sector, etc. This rod is shown in Plate V inside the closet of the driving-clock.

The first wheel of the train is on the vertical axis of the conical pendulum, by means of which the regulation of the motion is obtained. On this same vertical axis is the horizontal wheel round which a portion of the HUYGHENS' loop is wound, and also a heavy horizontal fly-wheel. The fly-wheel, the vertical shaft of the pendulum, the three inclined supports of this shaft, and the pendulum itself are well shown in Plate V. The pendulum is of the conical description and makes one revolution in two seconds of time. To insure isochronism, the horizontal axis of the fork which supports the upper end of the pendulum does not pass through the center of the vertical shaft, but beyond it, at such a distance that the average inclination of the pendulum-rod corresponds to the minimum velocity of the axis. The pendulum is constrained to move nearly in a circle, but it has a slight play in a direction radial to the horizontal fly-wheel, and this play takes place in a small narrow slot, about three-quarters of an inch in length, inside of which the narrow lower end of the pendulum moves. The pendulum in moving outward in this slot pushes before it an insulated strip of platinum to which a

¹ HUYGHENS' *Horologium oscillatorium, etc.*, Paris, 1673.

² About 95 foot-pounds per minute is required to drive the clock in its present form, but by far the largest part of this is expended in overcoming friction in the apparatus beneath the floor of the dome.

copper wire is attached, which is connected with one pole of an electro-magnet. The wire from the other pole of this magnet is connected, through contact springs, etc., with the pendulum itself, so that so long as the pendulum touches the platinum strip, *i. e.*, so long as the clock is running too fast, the electro-magnet is in action, and attracts its armature to itself. To the armature is attached a small brake or friction-pad which plays against the rim of the fly-wheel, and so long as the electro-magnet is in action the friction-pad is pressed against the rim of the fly-wheel, thus retarding the motion. The moment the pendulum drops within its proper limit the brake is released from action. The brake is set in action several times for each revolution when the clock is running well. By constant care this form of clock-work may be made to perform extremely well, but neglect of oiling for a few days causes irregularity of going. This constant care is given to it and it has usually given good satisfaction.

The Sector.—The general method of transmitting the motion of the clock-work to the polar axis through the sector is similar to that usually employed by the CLARKS. The sector will run for more than two hours continuously, and a means is provided for quickly setting it back to its first position.

CHRONOGRAPH.

The Chronograph is peculiar only in the method of regulation, which is a simple modification of the system adopted in the driving-clock. Its conical pendulum makes one revolution in one second, and it is suspended on its vertical axis just as the conical pendulum of the driving-clock of the Equatorial. To insure accurate circularity in its path, the following simple device is used: on the vertical axis of the pendulum, and below this, is placed a ring with three arms. This ring slips around on the axis, a very slight force serving to move it. The three arms are horizontal, and at an angular distance of 120° apart. The outer end of each of these light arms is bent upward, so that, seen sidewise, the arm looks somewhat like an ordinary fish-hook, with the point turned in toward the pendulum-axis. The length of these arms is so regulated that when the pendulum is moving in its proper circular orbit the lower end of it just swings inside of the points of the arms. If, from any cause, the pendulum begins to move in an ellipse, (and hence not uniformly,) it cannot move more than 120° (that is, not longer than one-third of a second) without touching one of the three arms as it swings outward. This arm will now be carried round in front of the pendulum (carrying the ring and other arms with it) until the pendulum drops inside the arm, and the whole process is repeated. For a fixed Observatory this form of Chronograph is perhaps as convenient as any other, and the regularity of the motion of the barrel leaves nothing to be desired.

OBSERVATIONS MADE WITH THE XXVI-INCH TELESCOPE.

It may not be out of place to summarize the principal work done with the xxvi-inch Telescope since its mounting in November, 1873. The instrument was in charge of Professor S. NEWCOMB, with Professor HOLDEN as assistant, from November, 1873, till June 16, 1875, when Professor HALL relieved Professor NEWCOMB.

NEPTUNE.

On November 20, 1873, the first measure of the satellite of Neptune was made, and these measures have been continued until the present time, April 20, 1876, whenever Neptune was suitably situated for observation.

In 1873	measures were made on	-	-	12	nights.
1874	do.	-	-	51	do.
1875	do.	-	-	42	do.
1876	do.	-	-	9	do.
				<hr/>	
In all	-	-	-	114	nights.

These observations may be found in the annual volumes of the United States Naval Observatory, and also in *Monthly Notices Royal Astronomical Society*, volume xxxv, page 49, from November 20, 1873, to February 10, 1874; and in *Astronomische Nachrichten*, No. 2061, Band 86, col. 321, from January 4 to February 17, 1875.

URANUS.

From January 8, 1874, all four satellites of Uranus have been observed whenever practicable.

<i>Oberon</i> was observed in	1874 on	-	-	27	nights.
	1875 on	-	-	34	do.
	1876 on	-	-	19	do.
				<hr/>	
In all	-	-	-	80	nights.
<i>Titania</i> was observed in	1874 on	-	-	28	nights.
	1875 on	-	-	32	do.
	1876 on	-	-	22	do.
				<hr/>	
In all	-	-	-	82	nights.
<i>Umbriel</i> was observed in	1874 on	-	-	9	nights.
	1875 on	-	-	3	do.
	1876 on	-	-	8	do.
				<hr/>	
In all	-	-	-	20	nights.
<i>Ariel</i> was observed in	1874 on	-	-	5	nights.
	1875 on	-	-	4	do.
	1876 on	-	-	11	do.
				<hr/>	
In all	-	-	-	20	nights.

These observations are to be found in the annual volumes of the Naval Observatory, as well as in *Monthly Notices Royal Astronomical Society*, volume xxxv, page 49, from January 8, 1874, to May 26, 1874; and in *Astronomische Nachrichten*, No. 2061, Band 86, col. 321, from January 5 to May 28, 1875.

All of the preceding observations of the satellites of both *Uranus* and *Neptune*, which were made by Professor NEWCOMB, have been discussed by him in Appendix I to the Washington Astronomical Observations for 1873.

SATURN.

The satellites of *Saturn* have been the subject of observation since August 29, 1874.

<i>Mimas</i> was observed in	1874 on	-	-	3 nights.
<i>Enceladus</i> was observed in	1874 on	-	-	13 nights.
	1875 on	-	-	17 do.
In all	-	-	-	30 nights.
<i>Tethys</i> was observed in	1874 on	-	-	18 nights.
	1875 on	-	-	29 do.
In all	-	-	-	47 nights.
<i>Dione</i> was observed in	1874 on	-	-	18 nights.
	1875 on	-	-	31 do.
In all	-	-	-	49 nights.
<i>Rhea</i> was observed in	1874 on	-	-	19 nights.
	1875 on	-	-	31 do.
In all	-	-	-	50 nights.
<i>Titan</i> was observed in	1874 on	-	-	21 nights.
	1875 on	-	-	42 do.
In all	-	-	-	63 nights.
<i>Hyperion</i> was observed in	1874 on	-	-	3 nights.
	1875 on	-	-	41 do.
In all	-	-	-	44 nights.
<i>Japetus</i> was observed in	1874 on	-	-	11 nights.
	1875 on	-	-	69 do.
In all	-	-	-	80 nights.

These observations may be found in detail in the Observatory volumes, and in *Monthly Notices Royal Astronomical Society*, volume xxxv, page 327, for 1874, and in *Astronomische Nachrichten*, Band 87, col. 177, for 1875.

A few measures of the ball and rings have been made, but the circumstances have not been favorable. A drawing of *Saturn*, as it appeared in September, 1875, has been made by M. L. TROUVELOT, and a reduced heliotype of the original pastel is given in Plate VI, Fig. 1. Of this and the succeeding figures it may, in general, be said that nothing is laid down which was not seen by more than one observer. The exception to this is in the case of the notches, represented on the inside of the outer ring of Saturn, which were seen by M. TROUVELOT with the 15-inch telescope of Harvard College observatory, and again in Washington, and of whose existence he has no doubt.¹

JUPITER.

A few eclipses of the first satellite have been observed as follows :

In 1874	-	-	4 disappearances ;	4 reappearances.
1875	-	-	4 do.	5 do.
In all	-	-	8 disappearances ;	9 reappearances.

Eleven crayon drawings, in color, of the appearance of the markings of *Jupiter's* disk, have been made on the following dates : June 9, 10, 16, 18, 21, 23, 24, July 8, 13, 14, 16. These are described in *Monthly Notices Royal Astronomical Society*, volume xxxvi, page 13, November, 1875.

MARS.

Five crayon drawings of *Mars* have been made, on June 14, 16, 21, 23, and August 5. These are described in the paper last cited.

DOUBLE STARS.

The principal use to which the telescope has been applied has been in the study of the satellite systems of the outer planets, but on many occasions close double stars have been observed. The only system which has been continuously followed is that of *Sirius*.

Measures were made of the companion of *Sirius*—

In 1873 on	-	-	-	-	-	-	1 night.
1874 on	-	-	-	-	-	-	12 nights.
1875 on	-	-	-	-	-	-	10 do.
1876 on	-	-	-	-	-	-	14 do.
In all	-	-	-	-	-	-	37 nights.

¹ See *Proceedings American Academy of Arts and Sciences*, 1875, page 174.

The observations of the companion of *Sirius*, during 1873, 1874, and 1875, may be found in *Astronomische Nachrichten*, No. 2061, Band 86, col. 321, and in the annual volumes of the Observatory.

NEBULÆ.

A study has been made of the Omega Nebula, (HERSCHEL'S General Catalogue, No. 4403,) and a pastel drawing of this on a large scale has been completed by M. L. TROUVELOT. A reduced heliotype of this is given in Plate VI, Fig. 3. This drawing is described in *American Journal of Science* for May, 1876, page 341. The Annular Nebula in *Lyra* (G. C., 4447) has also been studied, and a pastel drawing of this is reproduced in Plate VI, Fig. 2. The observations upon which this depends are given in *Monthly Notices Royal Astronomical Society*, volume xxxvi, page 61, December, 1875. Preliminary studies have also been made in 1874, 1875, and 1876 of the nebula of *Orion*, (G. C., 1179,) and an uncompleted sketch of its central portion by M. TROUVELOT is given in Plate VI, Fig. 4. TEMPEL'S nebula in the *Pleiades* (G. C., 768) has also been viewed occasionally, as well as a few others, notably the Trifid nebula, (G. C., 4355,) of which several sketches have been begun.

None of the figures in Plate VI are satisfactory representations of the drawings from which they were copied.

S.

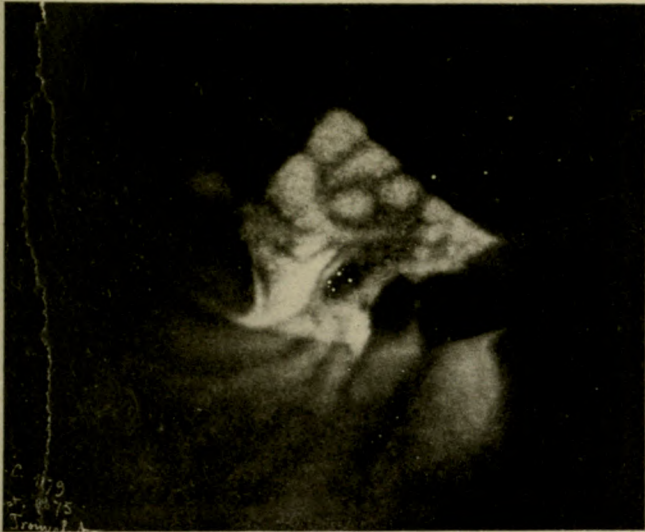


Fig. 4. ORION NEBULA.

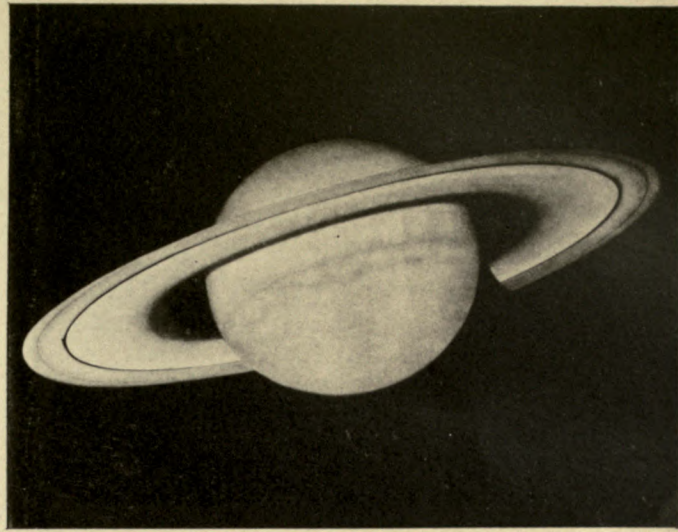
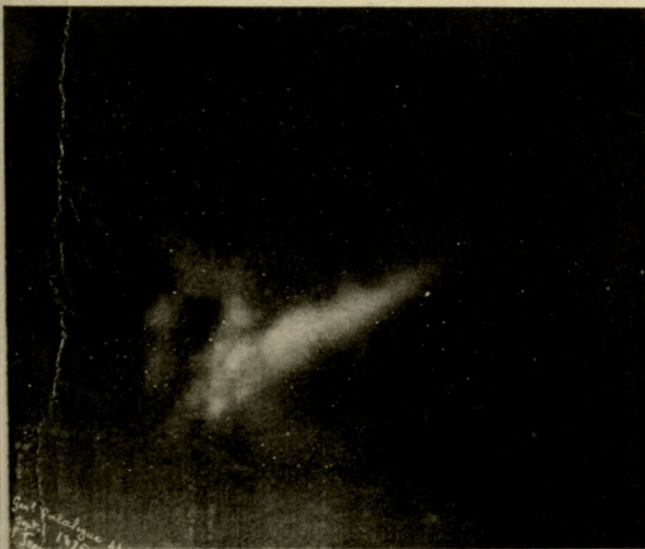


Fig. 1. SATURN.

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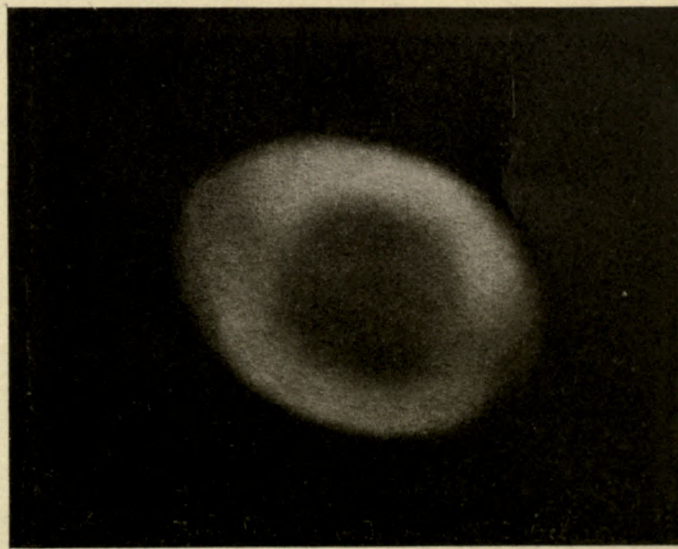
E.



Heliotype.

Fig. 3. OMEGA NEBULA.

N.



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Fig. 2. ANNULAR NEBULA.

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