# ADDRESS

OF

## THE ASTRONOMER ROYAL

TO THE

# INDIVIDUAL MEMBERS OF THE BOARD OF VISITORS

OF THE

## ROYAL OBSERVATORY, GREENWICH,

1855, OCTOBER 18:

AND

# REPORT

OF

## THE ASTRONOMER ROYAL

TO THE

# BOARD OF VISITORS,

READ AT THE ANNUAL VISITATION OF THE ROYAL OBSERVATORY,
GREENWICH, 1856, JUNE 7.

# ADDRESS

TO THE

# INDIVIDUAL MEMBERS OF THE BOARD OF VISITORS

OF THE

# ROYAL OBSERVATORY, GREENWICH,

BY

# THE ASTRONOMER ROYAL.

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The present time is peculiarly favourable for a decision of the Visitors on an important part of the instrumental equipment of the Royal Observatory; namely, on the kind of Equatoreal with which it ought to be furnished. The matter will, perhaps, be advantageously submitted to their notice, if I commence with an account of the Equatoreal establishment as it has existed for some years past, and of its condition at the present time.

In the year 1835 (when my official connexion with the Observatory commenced), and for several years before that time, the Equatoreal apparatus of the Observatory was contemptible. A small telescope, mounted on a rude polar axis, occupied the North-west Dome; and Shuckburgh's Equatoreal, carrying a telescope with a defective object-glass of 4-inch aperture, was in the North-east Dome (now called the North Dome), in the place which it still holds. The frame of this instrument is very weak, but it is furnished with very large graduated circles, both for hour-angle and for polar distance. The positions of these two instruments are so strangely misadapted to their purpose, that I am utterly at a loss to conceive under what circumstances their places were selected. The Octagon Room towers over them in such a manner that nearly the whole sky from south to east, to the height of 40° or more, is hidden from the North-west Dome; and nearly the whole sky from south to west, to the height of more than 50° in some parts, is hidden from the North-east Dome.

In the year 1837, my valued friend Mr. Sheepshanks presented the Observatory with an object-glass of $6\frac{3}{4}$ inches aperture. There was then vacant a small dome (now called the East Dome), with a view uninterrupted by any near buildings, whose dimensions were exactly adapted to receive this telescope, and in the center of which

there stood a pier on which a mounting, resembling generally the German mounting, might be placed. In this position, and with this form of mounting, the Sheepshanks telescope was accordingly placed. It has been a valuable addition to the instruments of the Observatory; but it is subject to two defects. First, the object-glass, though very good (especially for sidereal purposes) when used with care, is somewhat irrational, as well as veiny, and is not such as ought to be exhibited to a foreigner as the best telescope for general purposes in the National Observatory. Secondly, the mounting, which necessarily carries very small circles, makes it unfit for accurate determination of the place of a celestial body.

The determinations of place, rather than the observations requiring no graduated circles, must, I think, always be considered as the proper object for instruments in this Observatory. We are compelled, therefore, to rely on the Shuckburgh Equatoreal for what I consider to be, here, the normal applications of an Equatoreal.

Within the last two years the Shuckburgh Equatoreal has come to a condition that imperatively requires attention. The divisions of the hour-circle are illegible. Its construction renders it difficult to take to pieces for redivision, and I can hardly hope that it could be put together again with due firmness. New microscopes are required. The estimate for reinstating it is under 100*l.*; but I fear that this sum would be much exceeded before the instrument was replaced. And when this was done, we should have a small indifferent telescope, on a weak frame, in a position bad beyond anything that an astronomer ever imagined.

I think now that I may well submit to the consideration of the Visitors, whether it would not be preferable at once to seek a better telescope, and to endeavour to mount it upon a better frame in a better position.

It is known to the Visitors that I have uniformly objected to any luxury of extra-meridional apparatus, which would materially divert us from a steady adherence to the meridional system which both reason and tradition have engrafted on this Observatory; but I feel that our present instruments are insufficient even for my wishes; and I cannot overlook the consideration that due provision must be made for future interests, and that we are nearer by twenty years to the time when another judgment must decide on the direction which shall be given to the force of the Observatory.

I have endeavoured to obtain information on object-glasses free for sale at this time. With one exception, I cannot find any. The Munich Artists profess themselves willing to make one of any aperture from 6 to 13 or 14 French inches, but in not less than from one to two years. Mr. Merz, however, has one object-glass of 12 French inches

aperture, and 17¼ French feet in focal length, at the price of 13,300 florins (about 1,100*l.*), and this, perhaps, is still free for purchase. I am prepared to indicate a position (at the south-east angle of the new Record Room), where an Equatoreal of this size may be advantageously mounted.

It is necessary, in even suggesting the possibility of procuring such an instrument, to enter into some details as to the form of mounting. Viewing (as I do) the determination of celestial places as being, in this Observatory, paramount to all others, I at once give up the German form of mounting as insufficient. I confine my attention to the English form, with double polar cheeks; and I think that the question lies principally between a braced frame of wood (such as that of the Northumberland Equatoreal at Cambridge), and a frame of metal plates (as that of the Liverpool Equatoreal). I prefer the frame of the Northumberland Equatoreal, slightly modified, as equally firm, and cheaper and more convenient.

But, in any case, the expense must be considerable. I could scarcely hope that the building and mounting could be provided for 2,000*l.* in addition to the price of the object-glass.

It appears to me that the question is now in a state in which it would be wrong in me to take any further step, or to express any further opinion, without consulting the Visitors. And having laid before them all the ideas that occur to me as bearing in an important degree on this matter, I solicit the early expression of their opinion, so as to enable me (if such should be the direction of their decision) to act promptly, both with our own Government and with the artists who would furnish the lenses and mountings.

*Royal Observatory, Greenwich,*
1855, *October* 18.

G. B. AIRY.

# REPORT OF THE ASTRONOMER ROYAL

TO THE

# BOARD OF VISITORS

OF THE

## ROYAL OBSERVATORY, GREENWICH.

*Read at the Annual Visitation of the Royal Observatory*, 1856, *June* 7.

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THE Report which I now present to the Visitors applies to the state of the Observatory, on 1856, May 19. The interval between the date of the last Report, 1855, May 15, and that of the present Report, embraces a period of twelve and a half lunations, which is convenient for the exposition of several points in the astronomical history of the Observatory.

I. Grounds and Buildings.—The new building for the Reflex Zenith Tube, to which I alluded in the last Report, is erected. A well is sunk beneath it, to the depth of ten feet. I shall explain, in speaking of the instrument, the purpose and the effect of this well.

In order to obtain more room and more convenient accommodation for our galvanic batteries, it has been necessary to occupy the small cellar at the foot of the Octagon Room staircase; and, to bring this into connexion with the rest of the battery basement, a subterranean passage has been made between the basement of the Octagon Room staircase and the basement of the North Dome staircase.

In the Address dated 1855, October 18, which I submitted to the individual Members of the Board of Visitors, I stated that I was prepared to indicate a position for the proposed new Equatoreal. I beg leave to point out to them a locality on the map, at the south-eastern corner of the eastern buildings, but not actually in contact with the buildings, which I think possesses all desirable advantages. The Equatoreal must be on the third story. As the old carpenter's shop would interfere inconveniently with this erection, I have already built a new carpenter's shop, and made other arrangements which will enable me to clear the ground at a moment's notice.

II. Moveable Property.—No change has been made which is worth mention, beyond the incessant petty alterations of furniture, &c., incidental to a busy office. There are now lodged in the Observatory; the Cape Altitude and Azimuth Instrument, the copies of American Standards of Weight and Measure belonging to the Treasury, the East India Standard of Length, the Cape Standard, Ramsden's Standard, Roy's Standard, and several of the copies of the New British Standard constructed by Mr. Sheepshanks; as well as some ancient Standard Pounds. There are lent from the Observatory; a journeyman clock to the South Eastern Railway Station, for occasionally keeping up the motion of the large galvanic clock there (the property of the Royal Observatory); a journeyman clock and bar magnet to the Observatory of Kew; and a copy of Piazzi's Catalogue to the Observatory of Durham. The Micrometer which was lent to Colonel Lloyd has not been recovered. Some small apparatus is in preparation for Professor C. Piazzi Smyth's expedition to Teneriffe.

The visitors are aware that one of the four official sets of copies of the National Standards of Length and Weight is lodged in the Observatory. Some time before the last meeting of the Board, these standards had been placed in an oak box, so arranged that when the top and front of the box were removed, the standards were seen under cover of glass; and the box was planted upon two stone piers in the new Record Room. A short time since, upon examining into the state of the standards, I found that the free acid of the oak wood was acting prejudicially on them. Its operation appeared rather capricious: in some places (but not in all) it had acted powerfully upon the brass, especially that of the plugs in the division-wells, which was covered with a thick layer of sap-green colour; it had very slightly touched the bronze of the standard-bar; while the iron was untouched, and in many places shining brilliantly. I have now taken away the oak box, and have substituted a box of mahogany.

III. Manuscripts.—The usual care is taken of our Papers, and a few Volumes are at present in the binder's hands.

None of our Manuscripts are lent out; and no Manuscripts are borrowed by the Observatory, excepting a Volume containing the Minutes of the earlier meetings of the Board of Visitors, borrowed from the Royal Society.

IV. Library.—No important addition has been made to the Library, except in the continuation of serial works. The books are in good order.

V. Astronomical Instruments:—

The Transit-Circle is in good order, and fully maintains its character.

The Reflex Zenith Tube has been shifted from its original position near the entrance gate, to the new building erected for it in the Middle Garden, in the angle between the passage behind the Astronomer Royal's Room and the south projection of the Transit-Circle Room. The intention of this shift was to avoid the tremors of quicksilver, to which the first-mentioned locality was peculiarly liable. The quicksilver was now supported on a box of dry sand, resting upon the ground. On planting a Collimator vertically above the Instrument as a mark for observation, the tremor was found to be insufferably great, and never ceasing. A well was dug below to various depths, finally to the depth of ten feet below the surface, or seven feet below the deepest foundation; and stages were erected from time to time for support of the quicksilver trough, always resting on the bottom of the well without touching the sides. The tremor was not in the smallest degree diminished. Besides the great disturbances, causing the wire-comb of the Collimator to disappear, when a door was shut in any part of the Observatory, or when a person walked within many yards, there was a constant tremor which usually made the wire invisible. The experience of this investigation justifies me in believing that no practicable depth of trench prevents the propagation of tremor when the soil is like that of Greenwich Hill, a gravel, in all places very hard, and in some, cemented to the consistency of rock. I then filled the well with incoherent rubbish, and placed a stage upon it; the tremor was now sensibly diminished. Then (acting on a plan which was in some measure tried at the Paris Observatory, and which was again urged by Sir John Herschel), from the stage No. 1 I suspended, by straps of vulcanized caoutchouc, a stage No. 2, and from this in like manner I suspended a stage No. 3, and on this the trough of quicksilver was placed. The habitual tremor was now destroyed, and minute roughnesses of the Collimator-comb and wire were seen; but the image slowly floated or oscillated. I then connected the trough horizontally in two directions by shreds of vulcanized caoutchouc with stage No. 1, and this nearly destroyed the floating, leaving the image practically almost perfect. The small oscillation which remained, though visible to the eye, was less in amplitude than the breadth of the wire. I think, therefore, that there is a fair prospect of overcoming all difficulties in the use of this instrument.

In the Altazimuth a change is made, by substituting under each pivot of the horizontal axis a pair of antifriction wheels (carried by one frame) instead of a single wheel. The tendency of the counterpoise-pressure to disturb the horizontal axis in azimuth must now be extremely small.

The Barrel Apparatus, for chronographic registration of transits in the American manner, is in good order. To make this theoretically perfect, means are wanted for making the time of rotation practically equal in large arcs and in small arcs (the rotation in large arcs being at present made in the shorter time). I have not yet succeeded in arranging a mechanical contrivance for this purpose.

The Galvanic Apparatus for clock movements remains in the same state as in last year. That for communication of signals has received the following alterations. The clock is employed solely to pull a detent (the same which drops the Time Signal Ball if the Ball is raised); it makes this pull at every hour. The motion of this detent acts in the way of relay to complete circuits of independent batteries to the South Eastern Railway (for Deal at 1 o'clock, and for other lines of the South Eastern Railway at other hours), and to Lothbury (for extensive distribution on railways, and for regulating the Post-office clocks, dropping the Strand ball, &c. Probably in no long time other circuits will be completed by the same detent-motion. The entanglement of wires and of the relations of circuits is materially diminished by this alteration. The Motor Clock has been transferred from the Galvanic Register Room to the Ball Lobby.

The North Equatoreal is still in the imperfect state which was described in last year's Report.

The East Equatoreal (Sheepshanks') is in its usual state. The Double Image Micrometer, which is frequently attached to it, is in its usual condition, and gives great satisfaction.

The proposal for a new Equatoreal may now perhaps merit the special attention of the Board. I will recapitulate the proceedings relating to it, as far as they have yet advanced.

Towards the close of 1855 I circulated among the Visitors a printed address, dated 1855, October 18, explaining that our present Equatoreal establishment is not of the highest order; that Messrs. Merz & Son, of Munich, were prepared to furnish an object-glass of 12 French inches aperture; and that a proper site might be found; and requesting the opinions of the Visitors. I believe that it was not convenient for the Board then to meet, and in consequence of this nearly all the individual members of the Board wrote to me fully on the subject. I laid extracts of their letters before the First Lord of the Admiralty, and I very soon received his assurance that the necessary sum should be placed on the Estimates to be submitted to Parliament. The sum has since been voted by Parliament. As soon as I had received Sir Charles Wood's assent, I authorized Messrs. Merz to send the object-glass for trial, and I prepared a large equatoreal stand upon the Magnetic Ground for mounting the object-glass for trial when it should arrive. Messrs. Merz, however, have written to me that they are very anxious to supply the Royal Observatory at Greenwich with the best possible object-glass, and that they desire to try another which they have in hand before deciding which they shall send here. And so rests the matter as regards the supply of the object-glass.

In the meantime the method of mounting the Telescope has occasionally occupied my thoughts. The objections to clamping or moving a telescope by a hold of small radius, and the mechanical objections to what engineers call a "gooseneck" mounting, are in my opinion serious; and as these peculiarities are necessarily connected with

the German form, I am unwilling to adopt it. Supposing the English form adopted, I think that there is nothing firmer than a braced frame, provided that proper means are prepared for straining those braces and struts, which, though not immediately opposed to each other, are practically antagonistic. In respect to the general form, I think that, for the sake of observations at and near the Pole, the following suggestion may deserve consideration. In the German construction, the Telescope is excentric laterally; that is, if it is employed in viewing an object on the meridian, the Telescope is east or west of the Polar Axis. Now I think that in the English form (if the bars, &c. of the polar frame can be conveniently arranged), the Declination-Axis may very well be placed excentrically towards the meridian; that is, that the Declination-Axis shall not be in the same plane with the imaginary Polar-Axis, but shall be so placed that, when the Telescope is viewing an object on the meridian, the Declination-Axis shall be distant from the imaginary Polar-Axis by 12 or 14 inches measured towards the culminating point of the Celestial Equator. With this arrangement, the Telescope would command every point of the sky from the very Pole, without the interruption of any bar whatever. In regard to the support of the Polar-Axis, the elevated locality of our instrument (which, as I have said, must be on the third story) presents at first some difficulties. Supposing one solid pier provided to support the South Pole, and two piers through two stories to carry lighter work for supporting the North Pole, I cannot hope to give that lighter work the firmness *per se* which is desirable for such an Instrument. I propose, therefore, to consider that lighter work or upper northern frame as being, in fact, one of the supportable portions of the Instrument; to furnish the upper polar pivot with a mushroom head, and to let it hang upon the upper northern frame, and prevent that northern frame from slipping away; and thus to make the northern frame support the Polar-Axis, and the Polar-Axis support the northern frame. I conceive that all requisite firmness would thus be given, without any inaccuracy of position. In regard to the Hour-Circle for receiving the action of clock-work, there is no plan comparable to that which I introduced at Cambridge and Liverpool; namely, that of keeping a complete circle in movement, without any reference to the movement of the polar frame, and attaching the polar frame to it at pleasure. In regard to the clock-work itself, I propose, as at Liverpool, to use the power of water-pressure, acting by means of a reaction-machine (a form of Barker's mill), and regulated by Sieman's Chronometric Governor; this instrument is simple in construction and perfectly efficient, and gives very little trouble. For covering the instrument, I can probably arrange a drum-dome, with hinged shutters flapping quite back. As I am yet in uncertainty as to the exact dimensions of the future Telescope, I have been unable to take any important steps in preparing these different parts; I have, however, requested Messrs. Ransomes and Sims to draw plans for the water-power clock-work.

The old Instruments of the Observatory are in their usual state.

VI. Astronomical Observations.—No alteration has been made in our long-established Meridional System; and no observations, made upon the accidental requirements of other persons, have tended to disturb the system. The Stars of an extensive standard list are observed, if possible, twenty times in three years; some Stars are observed for refraction, or because they have been observed as conculminating with the Moon, or for some reasons, of equal weight; the Moon is observed at every opportunity without exception; the Sun and Planets every day except Sunday, omitting only the small Planets after $15^h$, and the large Planets after $15^h$ when there is no Moon to be observed.

The observations of Transits, both with the Transit-Circle and with the Altazimuth, have been made, in general rule, by the American or galvanic chronographic method; observations being made by eye and ear, only when from accidental causes the galvanic apparatus has failed. The galvanic method is found in practice so much easier, especially for young observers, than that by eye and ear, that the greatest difficulty which we experience in training beginners is that of inducing them to give sufficient attention to the eye-and-ear operation to become expert and accurate with that method.

The whole number of Meridional Observations from 1855, May 15, to 1856, May 19, is as follows:—In the Department of Transits: Observations of Transits (reckoning two limbs, or two methods of Observation by ear and by touch, as two Observations), 4620; Observations of Collimator, by the Telescope of the Transit-Circle, 312 pairs; Observations of Transit-wires by Reflexion, 310; Observations of one Collimator by the other, 53. In the Department of Zenith Distances (reckoning two limbs, or Direct and Reflexional Observations, as two Observations): Circle Observations of all kinds, 4660.

The general system of adjustment is unaltered.

No special observations have been made for errors of graduation, or similar fundamental determinations.

The number of Observations of $\gamma$ Draconis with the Reflex Zenith Tube is 73.

With the Altazimuth, the number of days of complete Observations of the Moon is 204, or 16·3 per lunation, while with the Transit-Circle the number is 109, or 8·7 per lunation. Of the Altazimuth Observations, 0 are on days when the Moon's meridian passage occurred between $0^h$ and $1^h$ solar time, 2 when between $1^h$ and $2^h$, 5 when between $2^h$ and $3^h$, 5 when between $21^h$ and $22^h$, 3 when between $22^h$ and $23^h$, 0 when

between $23^h$ and $24^h$. There are no corresponding meridional observations. The whole number of separate observations of the Moon and Stars is 1019, and the whole number of observations with the Collimator 704.

With the Equatoreals, no observations have been made.

With the Double-Image Micrometer, measures of $\gamma$ Virginis have been made on three evenings; measures of the rings of Saturn on thirteen evenings; and measures of the diameters of Mars on four evenings.

VII. Reduction of Astronomical Observations.—In one department, it will be seen, the reductions have slightly fallen in arrear. They will, however, under favourable circumstances, soon be brought up.

In the department of Transits, the Clock Times of True Transits are formed to May 11; the Apparent Right Ascensions from Observation to May 1; the Star Corrections in R.A. are computed and examined to May 14, but are not yet applied for the present year. In the department of Zenith Distances, the Concluded Circle Readings are formed to May 16; the True Zenith Distances and North Polar Distances are computed to April 5, but none have yet been examined for the present year; the Star Corections in N.P.D. are computed to March 11, but not examined for the present year. The retardation in these reductions has been produced principally by the long and serious illness of the Senior Assistant, to whom this department is specially intrusted; and the occupation of other trustworthy Assistants in the large Catalogue (to which I shall further allude) has prevented me, for the present, from making adequate arrangements for supplying his place.

The Ledger of Stars' Mean R.A. from Observation is complete to the end of 1855, and the means are taken for each star. That for Mean N.P.D. is complete only to 1855, August 29.

The usual comparison of Observed and Tabular Places and Diameters of Sun, Moon, and Planets, with the deductions from the comparisons, have not yet been made for 1855.

With the Reflex Zenith Tube, the Sums of Equivalents for the Micrometer Readings are formed to the end of 1855, but the further reductions (a very trifling work) are not completed.

With the Altazimuth, the Zenith Distances are completely reduced to April 28, and the Azimuths to March 31; various steps in the calculations being completed nearly

to the present time. The Tabular Computations of Zenith Distance and Azimuth are complete to March 31. The conversion of Errors of Azimuth and Zenith Distance into Errors of R.A. and N.P.D. is complete to February 26.

The Occultations are reduced (except the formation of the final equation) to the end of 1855.

The observations with the Double Image Micrometer are reduced to the present time. Those made on the Rings of Saturn will be found, I trust, to possess considerable value.

In the nature of comment on these observations, I shall offer only the following remarks :—

The Personal Equations of Transits in the chronographic method of registration, as deduced from the observations of 1855, are (as before) very small. One amounts to $0^s{\cdot}14$, and one to $0^s{\cdot}11$ ; the largest of the remainder is $0^s{\cdot}05$.

There are still fluctuations, sometimes sudden ones, in the Zero of Azimuth of the Altazimuth Horizontal Circle. But the improvement in the Instrument (which I believe to be real), from the change of the antifriction wheels, and the attention given to the fluctuations by Mr. Dunkin, have seemed to throw some light upon this obscure matter. In every instance, I believe, where the change is sudden and considerable, there is a notable change of atmospheric temperature. But through these changes the reading of the Collimator is very little affected. Remarking that the Collimator-mark is about 30 feet from the Altazimuth pier, and in a separate building, I cannot very well reconcile these observations, except by supposing that in sudden atmospheric changes the gravel rock of Greenwich Hill does suddenly change its position.

The computations which I have reported are those applying to the ordinary annual work. I stated, however, in the last Report, that a new Six-Year Catalogue of Stars was commenced, referred to the epoch 1850, and including all the results obtained from 1848 to 1853. This Catalogue has been completed, and great pains have been taken to insure its accuracy. The Catalogue is accompanied with the Constants e, f, g, h, l, e′, f′, g′, h′, l′, for every Star, intended to facilitate the computation of star-corrections in conformity with the system which I have introduced. In order to verify those Constants, the following step has been taken. For a certain day, the Corrections in R.A. and in N.P.D. of every Star of the Catalogue have been computed by two methods ; namely, by the old method of Aa + Bb + Cc + Dd; Aa′ + Bb′ + Cc′ + Dd′, and by the new method of Ee+ Ff + Gg + Hh + L +l − 300, Ee′ +

$Ff' + Gg' + Hh' + L + l' - 300$; and the resulting corrections have been compared. This verification has required the computation of six thousand corrections; but it will enable me to give the numbers to the world with far greater reliance on their accuracy than could have been obtained in any other way.

VIII. Printing of Astronomical Observations.—The Volume for 1854, including a Description (with Plates) of the Reflex Zenith Tube, has been printed some time ago, but the Catalogue for 1850 is not yet completely worked off (it has reached $14^h$ of R.A.), and I have deferred the binding of the annual Volume until the Catalogue can be bound with it.

For 1855: The Transits are printed to May 22, the Meridian Zenith Distances to April 24, the Altazimuth Azimuths to the end of the year, and the Altazimuth Zenith Distances to February 1: other sheets having been read. The greater part of the remaining MS. for printing is in the hands of the printers.

IX. Magnetical and Meteorological Instruments.—No alteration whatever has been made in these. The same free magnet, two feet in length, is used both for absolute measure of Declination (carrying a Collimator, which is viewed by the telescope of a 2-feet theodolite that can also be employed to observe the stars near the pole), and for constant registration of the small changes of Declination (carrying the concave mirror by which the light of naphthalized gas is thrown upon a revolving cylinder of photographic paper). The bifilar magnet, and the horizontal magnet oscillating on knife edges, are also two-feet magnets, carrying concave mirrors. The dipping-needle is one of Barrow's $9\frac{1}{2}$-inch needles. The standard barometer is Newman's, the zero-reference being made by bringing an ivory point to touch the surface of the mercury in the cistern. In some of the maximum thermometers Negretti's construction is used (in which the quicksilver that has passed a strangulation of the tube does not descend when the temperature falls). The indications of atmospheric electricity are taken from a wire about 400 feet long, extended from the top of the 80-feet mast near the Magnetic Observatory to the north-west turret of the Octagon Room. Other instruments require no particular description. All are in generally good working condition.

X. Magnetical and Meteorological Observations.—The photographic system is applied to the three magnetic elements, and to the barometric and thermometric (dry and wet bulb) indications; eye observations being used to give zeros. Magnetic dip is observed about once a week, and Deflexions about once a month. The wind and rain are recorded by Whewell's and Osler's self-registering instruments. Captain Sanders,

R.N., of the Dreadnought Hospital Ship, communicates to me the maximum and minimum readings of thermometers in the Thames.

XI. Reduction of Magnetical and Meteorological Observations.—The equivalents for the readings (in eye-observations) of the Declination Magnetometer are formed to the present time, and the Western Declinations are deduced to the end of 1855. The equivalents for readings of the Bifilar or Horizontal Force Magnetometer are formed to the present time, and those for the Vertical Force Magnetometer to the end of 1855. The Dip reductions are examined to the end of 1855, and the Deflexions to the end of 1854; but the reductions of the Dips are nearly completed to the present time, and those of the Deflexions to the end of 1855. The daily meteorological observations are reduced to this day.

The Photographic Sheets are in every respect furnished with zeros and scales, both of time and of measure, to the end of 1855; and considerable advance is made in portions of the work for 1856. The indications of the prominent points of the Photographic curves are translated into numbers to the end of 1855.

No further step is made in the treatment of the results.

XII. Printing of the Magnetical and Meteorological Observations.—No part of the manuscript for 1855 is yet placed in the printer's hands, but the whole is very nearly ready. It is arranged in the same form as in past years; giving the time and reading of every salient point on the photographic curves, giving the dips and deflexions for absolute measure in sufficient detail, and giving the Meteorological Observations partly in the state of daily maxima and minima, and partly in the state of daily means.

In regard to the contemplated photographic multiplication of copies of the photographic sheets, our experience had become so far settled, that it appeared proper to examine into the probable expense of that process. Mr. Glaisher, at my request, entered minutely into an estimate of all the various charges for paper, chemical materials, and personal labour, and concluded that the work could not be done in the Royal Observatory for less than sixpence or sevenpence for each individual sheet. I applied then to the two professional firms, in which, on the ground of their experience and skill, I have the greatest confidence, namely, Messrs. Negretti and Zambra, and Messrs. Horne and Thornthwaite, and their estimates amounted to almost precisely the same sum. Another person thought that the expense might be reduced to two-thirds, but I did not in this instance feel the same security in the experience of the manipulator. A

year's set of the three daily sheets of photographs would thus cost about 27*l*. This expense seems to be an insuperable impediment to the multiplication of copies. But it may perhaps be prudent for us to take one or two secondaries for our own use, inasmuch as these will serve for any graphical or other operations in ulterior reductions as well as the original curves themselves.

Two secondaries have been taken from each photographic sheet, to the end of 1854.

XIII. Chronometers, Communications of Time, and Operations for Longitude.—The number of Chronometers of all kinds now on hand is sixty-five. They are compared with a mean solar clock, daily or weekly, as appears to be necessary. The Chronometers on trial for purchase are sometimes exposed to extreme temperatures. The valuations, repairs, receipts, and issues of Chronometers purchased for or belonging to the Government, are generally managed in the Observatory.

On 1855, December 6, the Time Signal Ball was blown down. An examination of the broken mast revealed the cause of its decay; the ball has now been reinstated in a way which it is hoped will not again expose it to similar accidents.

The Galvanic System of Clocks is in the same state in which it was last year.

The Time Signal Ball at Deal is dropped regularly every day, by the action of the galvanic current from the Royal Observatory, without any material interruption. Where the circumstances of communication are so extremely complicated (for the Deal line is perhaps the most difficult that could have been selected in the kingdom) there will be occasional failures; and without the active assistance of C. V. Walker, Esq., (Superintendent of Telegraphs of the South Eastern Railway,) they might have been numerous. As it is, the number of failures is very small.

As it appears probable that the system of Time Signal Balls may receive some extension, it is intended (at the first opportunity) to make an alteration in the galvanic communication with the Submarine Company's lines, which will facilitate our connexion with the principal Dockyards.

One of the Galvanic Clocks in the Post Office Department, Lombard Street, is already placed in connexion with the Royal Observatory, and is regulated at noon every day, sending also a signal at a certain minute before noon, to inform me how far it is then wrong, and sending another signal at a certain minute after noon, to assure me of the efficiency of the correction. Other clocks at the General Post Office are

nearly prepared for the same regulation, and I expect that the complete system will soon be in action. The difficulties attending a new enterprise of this kind cause to all parties (except the actual workmen) an amount of trouble which cannot be adequately represented by money, and I can only express my thanks to Latimer Clark, Esq., Engineer of the Electric Telegraph Company, for the aid which he has given in a very annoying series of trials and adjustments.

No operations have been undertaken for difference of longitude.

XIV. Personal Establishment.—The number and names of the Assistants are the same as at the last Report. The list is as follows:—First Assistant, Rev. R. Main; Astronomical Assistants, Mr. Henry, Mr. Dunkin, Mr. Breen, Mr. Ellis, Mr. Criswick; Magnetical and Meteorological Assistants, Mr. Glaisher, Mr. Downs.

Mr. Henry, in the last year, has taken special charge of the Zenith Distances with the Transit Circle, and of Chronometers; Mr. Dunkin superintends the Altazimuth; Mr. Breen is general inspector of computations and printing, and of the work of the supernumerary computers; Mr. Ellis and Mr. Criswick take charge of the Transits made with the Transit Circle, and of the Galvanic Work.

At present five supernumeraries are employed in the Astronomical department, and three in the Magnetical and Meteorological department.

A labourer, a gate-porter, and a night-watchman are attached as part of the establishment; a carpenter is practically kept in constant employ.

XV. Extraneous Works.—In the pendulum experiments at the Harton Colliery, to which I alluded in my last Report, the temperatures of the upper and lower stations differed about seven degrees. I thought it undesirable to adopt the received tables of correction for this range without further examination; and therefore in the last winter Mr. Dunkin and Mr. Ellis made a series of experiments at the Observatory with the same pendulums which had been used at Harton. They seem to show that Colonel Sabine's correction requires a very small increase, perhaps one twenty-eighth part.

For more than a year I have been prevented from proceeding with the proposed Extension of Lunar Reductions by the want of a competent Superintendent. In the winter, however, I was able to secure the services of Mr. Lucas, formerly Assistant at the Oxford Observatory; and nine young computers are now employed under him on that work.

At my request, Mr. Main has undertaken a discussion of all our Observations of low Stars from 1836, with the view of testing Bessel's Refraction Tables. The results show (so far as I can judge) that no sensible correction is required to the temperature-coefficient or to the theoretical table of refractions; but the supplementary table, founded on observations only, appears to be open to amendment.

The sudden decease of my valued friend, Mr. Sheepshanks, left the affairs of Standards (on which he had been engaged to the very evening preceding that on which he was struck down by his mortal illness) in some confusion. Although, in the course of my continued communication with Mr. Sheepshanks on the subject of Standards through so many years, a large portion of the documents relating to it had come into my hands, and had been in some measure arranged, yet there was found a considerable mass of papers in great confusion. It was my duty, in official connexion and private friendship, to take up the subject as it was left, and to carry it on, in spirit rather than in form, as my late friend would have carried it on. After placing the papers in order, I was able to finish the reductions yet left incomplete, and to distribute with proper indications the authentic Standards which the British Government proposed to present to other countries. I then turned my attention to the formation of End-Standards from Line-Standards (a matter which had given great annoyance to Mr. Sheepshanks, and which really is a far more troublesome work than would be at first imagined), and, under the active practical management of Mr. Simms, three End-Standards of bronze have been constructed and compared, and four of iron are nearly finished. I have made some progress in the first part of a Memoir on the construction of the Standards of Length.

As the recognition by Baron Plana of Mr. Adams' correction of the Lunar Secular Acceleration renders a re-calculation of the Ancient Eclipses indispensable, I have committed that work to Mr. Breen, who ably conducted the calculations on the former elements.

XVI. General Remarks.—The immediate assent of the Board of Admiralty and of the Legislative Bodies to the appropriation of the large sum required for the proposed new Equatoreal is but an instance of the unvarying liberality with which applications on reasonable grounds, in favour of this establishment, have, to the best of my knowledge, been always received. The habitual assurance of support from the body which supplies the funds, necessarily throws a more distinct responsibility upon the officers who direct the expenditure; and, under this impression, it is well to consider the general spirit of the present administration of the Observatory.

The Visitors may be assured that the course of daily proceedings in the Observatory has been decided upon consideration of what appears to be best for the interests of its science, and especially for those interests which will be involved, when in some distant century an appeal to the Observations of this time may be required for settling grave questions of future science. And I will indicate in a few words the course to which these considerations have led. No Observatory possesses, in an equal degree with this, the power which is given by tradition and organization for keeping up standard Meridional Observations and Lunar Observations; these also are most likely to possess the greatest permanent interest: and these, therefore, must in any case be maintained in vigour and in accuracy. The Fundamental Determinations of Magnetism and Meteorology have claims of a somewhat similar nature. The various classes of extra-meridional and scrutinizing Observations of Astronomy receive at present so much attention from other observers, that it is scarcely necessary to give a thought to them here; still, in viewing the uncertain duration of that attention, it is well that this Observatory should be prepared in instruments, and in habits, for taking up them also. Lastly, there are employments which connect the scientific observatory with the practical world; the distribution of accurate Time, the improvement of marine Time-keepers, the observations and communications which tend to the advantage of Geography and Navigation, and the study, in a practical sense, of the modifications of Magnetism; a careful attention to these is likely to prove useful to the world, and conducive to the material prosperity of the observatory: and these ought not to be banished from our system.

Regarding the Board of Visitors as the body to whom the regulation of the course of the Observatory on the broad scale rightly attaches, I submit to their judgment this general outline of what I conceive to be the proper policy of the Royal Observatory.

G. B. AIRY.

1856, *May* 23.