REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1865, *June* 3.

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It is convenient on the present occasion to limit my Report to the period commencing 1864, May 20, and terminating 1865, May 10. The arrangement which I have maintained for many years is adopted without alteration.

I. Buildings and Grounds.—No alteration whatever has been made in the Buildings; unless I may include in that term the excavation of a hole in one of the walls, for the fixing of an iron safe. The whole of the external wood-work of the buildings was repaired and painted shortly after the last visitation of the Board.

The defect in the North Dome, to which I adverted in the last Report, has been made good. It was necessary to re-make the Dome-shutters entirely.

The two piers which are built in the Front Court, as well as a third pier built in the Magnetic Ground, having been used nearly in the way proposed for the observations connected with the Great Arc of Parallel (as will be hereafter mentioned), the portions of the piers which projected above the ground have been taken down; their capping-stones being left at the surface of the ground, with an inscription engraved on each for its identification.

Our telegraphic communications of every kind were again destroyed by a snow-storm and gale of wind which occurred on January 28, and which broke down nearly all the posts between the Royal Observatory and the Greenwich Railway Station. They were restored after a time, without alteration of plan, (except in the instance of the wire appropriated to the Electric and International Company, which, by request of that Company, and at their expense and under their superintendence, was placed underground,) but with general renovation.

In my last Report I described the steps which had been taken and the further arrangements which I proposed to make, for forming and adapting to use the subterranean room of the Magnetic Observatory, now called the "Magnetic Basement." Everything has been carried out as was then planned; and I believe with perfect success. Though it is still necessary sometimes to wipe a little moisture from the walls, yet the air of the room is usually very dry. The extreme difference of temperature between summer and winter is about 6°, the greatest variation in any one day about 2°; the temperature never differs much from 60°; (all in Fahrenheit's scale).

The only change of Buildings which I contemplate as at present required is the erection of a fire-proof Chronometer Room. The pecuniary value of Chronometers stored in the Observatory is sometimes perhaps as much as 8,000*l*. I do not see that this can be done in any other way than by retaining the present room (the room above the principal Computing Room), making fire-proof floor and ceiling, and stripping the old pannelling from the walls.

Several small repairs of buildings and fences, and some interior painting, lately sanctioned in the Navy Estimates, will shortly be put in hand.

Among the buildings of the Royal Observatory, I may now class the Time-Ball-Tower at Deal. On occasion of the sale of the Navy Yard at Deal, the Time-Ball-Tower, at my representation to the Admiralty, was specially reserved; and, as there is now no competent resident authority for its superintendence, it is placed generally under the care of the Astronomer Royal. Beyond this announcement I have no special remark to make.

The Visitors are acquainted with the proposal lately made for carrying a Railway through Greenwich Park. Such a proposal now assumes a character differing from what it ever had before. When in 1835 the scheme was first brought forward, it was supposed to be intended to only convey passengers from London Bridge to Gravesend. Now, in 1865, it would bring the whole personal and commercial traffic from every part of the North of England and from London to every part of Kent. It is also proper to remark that the shake of the Altazimuth felt in the earthquake of 1863, October 5, when no such shake was felt with instruments nearer to the ground,

(an experience which as I have heard on private authority, is supported by observation of artificial tremors), gives reason to fear that, at distances from a railway which would sufficiently defend the lower instruments, the loftier instruments (as the Altazimuth and the Equatoreals) would be sensibly affected.

II. Moveable Property.—An excellent copy Bust of one of the Members of the Board has been presented to the Observatory, and now adorns the room in which the Board usually meet. The East India 10-feet Standard of Length B, which for some years has been in the custody of the Astronomer Royal, is for a short time transferred to the Ordnance Survey Office at Southampton, for comparison by Captain A. R. Clarke, R. E., with a large number of Standards, Foreign as well as British, which have been employed in the principal geodetic operations. No other change has taken place in our standard property, except the occasional introduction of small apparatus subservient to the uses of the principal instruments.

Every article is catalogued as closely as is practicable.

Every part of the moveable property is maintained in good and serviceable order.

III. Manuscripts.—The ancient Manuscripts have always been carefully catalogued; and, about a year ago, a new and somewhat more systematic Catalogue was prepared, including all the bound Manuscripts to the present time. All are carefully preserved in fire-proof rooms or fire-proof presses, and are in good order.

The system which I introduced about 27 years ago, for temporary arrangement and connexion of current papers, is still found to work exceedingly well, and is still adopted in daily use. This system preserves the papers in a form ready at any time for binding; every paper is secure in its book (admitting, however, of change of place with little trouble), and every paper lies flat and easy for reading.

The copy of Bradley's Observations from 1743 to 1749, to which I alluded in the last Report to the Visitors, is still in the hands of Mr. Hugh Breen, for reduction of the Observations.

The copy of Bradley's and Bliss's Observations from 1750 to 1762 was delivered to Dr. Winnecke on occasion of his visit to the Royal Observatory in the summer of last year. I know not how the new reduction of the Observations has advanced. Dr. Winnecke, I grieve to say, has been struck with serious illness.

I have lately had a manuscript copy made (by tracing on thin paper), of every loose paper of Bradley's (a very large mass), and of the books in which he made his brief memoranda of the observations of stars whose names and elements of position had been set down in a systematic form for observation. The last-mentioned books were particularly desired by Professor Argelander and Dr. Winnecke, as giving great facilities for reference to all the days of observation of each star. The illness of Dr. Winnecke has prevented me from yet sending these manuscript copies to the Continent.

IV. Library.—The Catalogue of the Library has been completed by Mr. Carpenter, on the principle of moveable slips, as mentioned in the last Report. It is one advantage of this method that it allows the books to be grouped by similar sizes, and a great deal of shelf-room is thus gained. The division of the books under a few separate heads, both in the library-room and in the catalogues, is still retained.

The Library continues to increase, the additions being principally in works connected with Astronomy, Magnetism, and Meteorology, and the Mathematico-physical Sciences.

V. Astronomical Instruments:—

The Transit-Circle is in good order. In September of last year a series of experiments was made with very great care (no lamp-light being used) for the determination of the astronomical flexure of the telescope; and the coefficient $+0''\cdot76$, additive to zenith distances, was found; nearly agreeing with the mean of determinations antecedent to that of the summer of 1864 (noticed in the last Report). The circumstances of the summer observations of 1864 were not free from suspicion.

About the same time observations were made for testing the form of the pivots. Their error appears to be so small a fraction of a second that it seems idle to apply any correction for it. Still there is a certain degree of similarity in the results obtained in different years, which almost suggests that the apparent error is real.

The errors of Level and Azimuth have become rather large. Their magnitude sometimes introduces the necessity of correcting the observed places of the Moon for the difference between the position of the optical axis of the telescope and the true meridian.

It is matter for serious consideration, whether steps should be taken for placing our Transit-Circle on the same level of excellence as those which have been (under my superintendence) generally copied from it. The principal change required is the perforation of the central cube, so that a continual watch may be kept with ease on the coincidence of optical axes of the two collimators. It is curious that among the persons (all well acquainted with the use of astronomical instruments) who aided

in the preparation of the original plans, while all perceived the necessity of a clear view from collimator to collimator, no one remarked the facility of obtaining it by a perforation of the cube. Whether the change can be made in the existing instrument appears doubtful.

The Transit-Clock is in good order. Occasionally it has been stopped a few seconds through the retention of its wheel-teeth by the galvanic springs.

The Barrel-Clock of the Chronograph required, in the last winter, some repairs in the pivot-bearings, the round holes having been worn into an elongated and irregular form. Preparations have been made for altering the mechanism of water-resistance to the pendulum, so as to make it resemble that of the clock-movement of the South East Equatoreal; and the new apparatus has not been fixed, merely because the uninterrupted use of the barrel was required in connection with observations for the longitude of Glasgow Observatory.

The Reflex-Zenith-Tube is in good order. In the severe cold of last winter the micrometrical distances of the wires were measured, and were found to agree precisely with those formerly obtained in moderate weather.

The Microscopes of the Vertical Circle of the Altazimuth have been examined and put into general good order. Observations for the form of the pivots of the Vertical Circle were made in September last, but no sensible error was found. Some observations of magnetic instruments (to be noticed in the latter part of this Report) have made me think it probable that the sudden changes in the position of the Azimuthal Circle, which have been noticed as synchronous with large changes of atmospheric temperature, may arise from the circumstance, that the three principal radii of the circle, subjected to a thermal change of dimensions, but constrained by their bearing in the low iron Y's planted in the stone pier, retain their position for a time, and at last relieve themselves by a sudden start. I have, therefore, proposed to Mr. Simms that the radii of the Azimuthal Circle be raised from their Y's, and that the supporting and supported surfaces be polished as smooth as possible, in order to facilitate the gradual change of the bearing-position in the changes of temperature. At the same time, springs may be applied to alleviate the pressure on the Y's. It might be a question whether it would not be best to elevate the Y's upon pillars high enough to permit to each an independent spring-motion. By one or other of these courses I hope to destroy the sudden changes of Azimuthal Zero which have sometimes annoyed us.

The Motor Clock is in good order; and, since the abstraction of pendulum-contact-springs mentioned in the last Report, preserves a steadier rate than formerly. The

Visitors are aware that, for producing those very minute changes of rate for a small time which are required to correct the petty errors of indication that arise in the course of a day, there is fixed to the pendulum a small steel magnet, which swings over a galvanic coil, through which currents of either character can be sent, the coil then having the property of attracting or repelling the magnet, and thus accelerating or retarding the vibrations of the pendulum. We now avail ourselves of the presence of the same magnet to effect the larger adjustments of clock-rate without stopping the clock. A vertical piece of iron wire is fixed by friction in a piece of wood projecting from the back of the clock-case, so that the upper end of the magnet swings under the end of the wire; and by raising or lowering the wire, the clock-rate is less or more accelerated.

The apparatus for home-use and for distribution of galvanic currents at definite times is in good order.

The Shuckburgh Equatoreal is substantially in good order, and available for observation of phænomena; but at the present time requires, for efficiency as a place-determining instrument, to have its limbs cleaned, to have its internal reflector re-polished, and to have attention given to its microscopes. I trust that these repairs will be done, at least in part, before the meeting of the Visitors.

The Sheepshanks Equatoreal is in its usual good order.

The South-east Equatoreal is, generally speaking, in perfect order. The overtip-weight of the "Spade-Apparatus" in the clock-movement has been mounted by Mr. Simms, in conformity with my computations. Some wood teeth of one wheel of the train are broken, and thus the mechanism is (at the moment of my writing) disabled; but it will I hope soon be restored to efficiency. No alteration has been made in any subordinate optical apparatus. It has been necessary once to separate the lenses of the object glass for cleaning; a firm clammy matter had formed itself between them. No plans of the instrument are yet prepared.

The Barometers, Thermometers, and other subsidiary instruments, are in good order. A correction of $-0{\cdot}02$ inch is applied, in use, to the readings of the Transit-Circle Barometer, and $-0{\cdot}07$ to those of the Altazimuth Barometer.

I have received the sanction of the Government for procuring two instruments of the largest portable class, namely a Transit-instrument with diagonal reflector and eye-view in the axis, and an Altazimuth with similar reflector and eye-view. The former is ordered of Mr. Braun, artist of the Pulkowa Observatory; for the latter Mr. Simms has general instructions, but the details are not yet arranged. The examination of the

instruments embodying the principle of eye-view in the axis, which were brought here in the last summer by Colonel Forsch and Captain Zylinski, has removed some of my objections to that construction.

The Ancient Instruments are in good order, considered as instruments which are to be kept, not in efficiency for use, but in safe preservation. One of Dr. Winnecke's principal objects in his last year's visit was, to examine the minute parts and the divisions of Bird's Brass Quadrant. A small pin in the centre-work, usually covered by an external cap, appeared to be wanting; I conjecture that it must have been lost in Dr. Maskelyne's time, as there is no evidence that Mr. Pond ever unscrewed any part, and it had certainly not been touched since 1835. The graduations, as far as Dr. Winnecke could examine their relation in arcs of limited extent, were very satisfactory; but it was impossible, without great labour and long time, to examine the relation of distant divisions.

It has been found that the old Equatoreal, to which I referred in my last Report, was Bradley's.

VI. Astronomical Observations.—As in preceding years, the first place has been given to regular observations of the principal fixed stars (for which, endeavours have been made on favourable days to observe the longest possible series extending through the greatest practicable number of hours); to observations for defining the position of the Ecliptic and the Sun's place in it; and especially to observations of the Moon, which body alone is followed with the Altazimuth as well as with the Transit-Circle (the latter instrument only being used for the other purposes just mentioned).

The stars observed on the meridian may principally be classified under the following Heads:—Stars for correcting the clock-error, to the number of 188; circumpolar stars for azimuthal determination; stars given in the Nautical Almanac as conculminating with the Moon, and stars occulted by the Moon; stars of the Seven-year Catalogue, insufficiently observed; those stars of Bradley's Catalogue which have not been observed at Greenwich since 1835 (the number in the entire list being about 1211, of which 425 have been observed); stars used in the British Survey by Colonel Sir Henry James; stars adopted by Captain Gilliss and Mr. Gould in the United States' Survey; low stars, both north and south, for check of the refraction-tables; stars believed to have large proper motion; Sirius and companion-stars (Sirius being no longer used as a clock-star); and γ Draconis with the reflex-zenith-tube.

The Moon is observed on the meridian on every day, without exception, when she is visible. The Sun and Planets are observed only on week days; the Sun and Inferior Planets every week day; the large Superior Planets when they pass before

14^h, or near the Moon in the morning; the Small Planets when they pass before 13^h, during the first half of every lunation, in conformity with the terms of the convention with M. Le Verrier described in the last Report.

The number of meridional observations with the Transit-Circle from 1864, May 20, to 1865, May 10, is as follows:—

Transits (two limbs being considered as two objects)	4,089
Pairs of observations of the Collimators by the Transit-Circle	288
Reflexion-observations of the transit-wires	286
Observations of Collimator by Collimator	52
Circle-observations of all kinds	4,038
Reflexion-observations of the zenith-distance-wire	282
Reflexion-observations of stars	199

(The "Circle-observations of all kinds" include the two classes last-mentioned).

With the Reflex-Zenith-Tube the following observations of γ Draconis have been made:—

Pairs of observations, with reversed instrument	51
Single observations	5

With the Altazimuth the following observations have been made:—

Azimuths of Moon and Stars	689
Azimuths of the Collimator	350
Zenith-distances of the Moon	374
Zenith-distances of the Collimator	350

The following are the numbers of complete observations of the Moon with the Altazimuth on the days when she is nearest to conjunction. The distance from the Sun is sufficiently described by the solar hour of transit:—

Between 21^h and 22^h	2
Between 22^h and 23^h	4
Between 23^h and 24^h	0
Between 0^h and 1^h	0
Between 1^h and 2^h	6
Between 2^h and 3^h	5

The whole number of days on which complete determinations of the Moon's place have been obtained, distinguishing the two instruments, is as follows:—

With the Altazimuth, 194, or 16·2 per lunation.
With the Transit-Circle, 107, or 8·9 per lunation.

No observations worth record have been made with the Equatoreals. The scrutiny of the Sun's surface, and the observations of star-spectra, have now been taken up so well by amateur observers, that it appeared to me just to leave those subjects in great measure to the private persons who have given to them such laudable attention.

Only 7 occultations of stars by the Moon, 4 disappearances and 3 reappearances, have been observed. The great southern declination of Jupiter has prevented us from observing more than 6 phænomena of his Satellites.

VII.—Reduction of Astronomical Observations :—

The successive steps in the reduction of transits are completed at the present time (1865, May 10) to the following dates respectively :—

Clock-time-transits over true meridian, after all corrections for instrumental errors, to . . .	1865, April 22
Clock errors and clock rates computed . .	„ April 21
Apparent right ascensions of centre of object . .	„ April 21
Stars' corrections computed	„ February 15
Stars' corrections applied	1864, December 31
Corrections for imperfect illumination of limbs of Moon and Planets	„ December 31
Mean Solar Times of observation of Sun, Moon, and Planets	„ December 31

The steps in the reduction of Circle Observations are completed to the following days :—

True zenith-distances, after correction for error of division, flexure of the instrument, instrumental zenith-point, refraction, and parallax . . .	1865, April 7
Stars' corrections computed	„ January 20
Stars' corrections applied	1864, December 31
Corrections for imperfect illumination . . .	„ December 31

The collection for each star, of all the results for mean place 1864, Jan. 1, is completed, in both elements, to the end of 1864, and the means are taken. Preparations are made for drawing up the Catalogue of Stars ; the number of stars is 885. The value of R—D is investigated for 1864 ; it scarcely differs from those found in the few years past. The colatitude differs only $0''{\cdot}04$ from that found last year.

The places of Sun, Moon, and Planets are thoroughly computed and discussed, as regards Right Ascension and North Polar Distance, to the end of 1864; but, as regards Longitude and Latitude, and Heliocentric Deductions, only to the end of 1863. The parallaxes of the Sun and Planets for 1865 are computed with Solar Horizontal Equatoreal Parallax at Mean Distance, 8″·94.

The observations with the Reflex-Zenith-Tube are reduced to the end of 1864.

The state of the Altazimuth reductions will be understood from the following Report:—

Observed Azimuths are corrected for all instrumental errors, and reduced to the indication of True Azimuth measured from the Astronomical Meridian, to . . .	1864, March 20
True Greenwich Zenith Distances computed to . .	„ April 16
Tabular Azimuths and Zenith Distances computed to .	„ March 20
Errors of Tabular R.A. and N.P.D. to . . .	„ March 20
Errors of Tabular Longitude and Ecliptic N.P.D. to .	„ March 20

The Occultations of Stars by the Moon are completely reduced to the end of 1864.

The following are some of the more obvious inferences from these reductions:—

The personal equations in transits are very little altered; the largest change is 0ˢ·04.

The azimuthal error of the Transit-Circle changes periodically, and that of the Altazimuth less regularly, nearly as before.

The obliquity of ecliptic, deduced from the southern solstice and generally the southern half of the ecliptic, in 1864, agrees closely with that deduced from the northern half; a very rare occurrence. I scarcely need to mention that this depends in part on several obscure points, of difficult determination; as the flexure, the magnitude and law of the quantity R—D, the colatitude, the refraction at small elevations, and the habit of the observer in placing the wire upon the atmospheric spectrum.

The correction to the Moon's Tabular Semidiameter, to make it applicable to the observations with the Altazimuth, has lately been investigated from all the observations bearing on that element, and the two values 0″·49 and 1″·01, additive to the semidiameter now adopted in the Nautical Almanac, are found for azimuth and for zenith distance. It was to be expected that the larger value would be found for zenith distance, as the vertical diameter is increased by atmospheric dispersion; and possibly, for the very small elevations, a still larger quantity ought to be used,

The matter is not unimportant for the inference of correct results from the Altazimuth ; inasmuch as, in all cases when the Moon is near the Sun, and in a great number of other cases, it is necessarily the lower limb of the Moon which is observed, and a fault in the numerical value of semidiameter introduces a constant as well as a variable error of results.

VIII.—Printing and Distribution of Astronomical Observations :—

In my last Report, I stated my intention of issuing the Volume for 1862 in two parts. But, upon remarking that the aggregate of sheets would really not exceed that to which some preceding volumes have extended, I thought it best to abandon this proposal, and to collect all in one volume, as usual.

The Astronomical part of the Volume for 1863 is completely printed, excepting only the Index and Errata.

More than three-fourths of the manuscript for the Volume for 1864, preceding the Star-Catalogue, is sent to the Printer. The printing has advanced as follows : Transits to 1864 March 19, Circle Observations to March 15, Azimuths with the Altazimuth to March 19, Zenith Distances with the Altazimuth to April 19, Tabular Azimuths and Zenith Distances for comparison with the Altazimuth results to April 13.

In printing the Results of Observations of the Small Planets, the observations made at the Observatory of Paris, under the direction of M. Le Verrier, have been incorporated with those made at Greenwich, in conformity with the plan described in the last Report.

The number of copies annually printed is 350. The number now on hand, from 1836 to 1840, varies between 3 and 14 ; from 1841 to 1862, between 58 and 93. Of the Astronomical Results, including that part of the Astronomical portion of the Volume which begins with the Catalogue of Stars, 150 additional copies are printed ; of these, in one year, only 12 remain.

IX.—Magnetical and Meteorological Instruments :—

The form of the Magnetic Basement, the location in it of the three Magnetometers, the location of the Free Declination Magnet (for absolute determinations) vertically above the Photographic Declination Magnet, the nature of the supporting piers, and the location of the Theodolite for observing circumpolar stars as well as the Collimator

of the free magnet, were described in the last Report. No alteration has been made in these, except in the suspension-wires, to which I shall allude shortly.

I have already adverted to the uniformity of temperature which has been obtained. I shall now remark on the separate instruments.

The Upper Declination Magnet was suspended on 1864, May 27, and the Lower Photographic Declination Magnetometer was made available for photographs on June 25. Both were suspended on steel wires of no greater strength than was necessary for safety. Under the pressure of business, the determination of various constants of adjustment was deferred to the end of the year. The immediate results of observation, however, began to excite suspicion; and after a time it was found that, in spite of the length of the suspending wire (about 8 feet) the torsion-coefficient was not much less than $\frac{1}{6}$. The wires were promptly dismounted, and silk skeins substituted for them. With these, the torsion-coefficient is about $\frac{1}{210}$. The two magnets have now been in use, suspended by the silk skeins, since 1865, January 20 and 30.

The Horizontal Force Magnetometer was carried by a loop wire of about half the strength of that for the Declination Magnetometer; its photographs commenced also on June 25. The experience of the wires for the Declination Magnets was sufficient to demand the immediate removal of that of the Horizontal Force Magnet. A silk skein was applied, and has been in use since 1865, February 3. In this year, as in former years, the observations for adjustment were so planned, as to make it certain that the Magnet's mean position is transverse to the Magnetic Meridian.

The new Vertical Force Magnetometer was mounted in the summer of 1864, nearly at the same time as the others; but various troubles arose in the use of it. Its magnetic power (as stated by me in the last Report) was too small, but it was found that the steel was imperfectly magnetized; a proper dose of magnetism was given by Mr. Simms, on June 15. Various irregularities followed, and the knife-edge was changed, unnecessarily as I believe, for a stronger bar. I at length discovered the cause of these troubles in the accidental contact of a small spring which presses the mirror used for eye-observations. After the instrument had been got into satisfactory action, it was found that one of the adjusting weights was a little unsteady, the effect of a small inequality in the diameter of the screw-stalk. This was remedied, and the instrument is now in a very fine state. Its scale of indications is large, small disturbances are shewn in great perfection, and the dislocations in the photographic curves have entirely ceased.

I have repeatedly stated in late years my conjecture that the dislocations arose from starts in the connexions of an instrument, composed partly of steel and partly of brass, and subjected to changes of temperature; and under this impression I

constructed the new instrument entirely of steel and iron. I also made the two knife-edges and their connecting bar in one piece instead of five, as in their former construction, a very slight power of adjustment being given by straining-screws. The cessation of dislocations gives great plausibility to my conjecture. Assuming it to be correct, the present immunity from dislocations is perhaps to be attributed in part to the uniform temperature of the Magnetic Basement.

For many years past I have been perfectly satisfied that, notwithstanding the dislocations, the instrumental zero has undergone no change; and that, with little attention, the small portion of the curve affected by the unfair strain may be corrected with almost ultimate accuracy; and this process was in fact used in measuring the hourly ordinates for the investigation of the diurnal inequalities ending with 1857; (in the accompanying reduction of magnetic storms there was no instance of dislocation). I am confirmed in this opinion by comparison of some of our photographs, in which the dislocations were very sensible, with some of the Kew observations, in which the dislocations are very small. As depends on this cause alone, the photographs with the old instrument may be made nearly as good as those with the new one; although inferior as regards the magnitude of the scale and the requirement of correction for the temperature.

The temperature-coefficient of the Vertical Force Magnet has not been determined by use of hot water or by other experiment since a determination was made by means of heated air. The values then obtained, both for the Horizontal Force and for the Vertical Force Magnets, were so large that I hesitate to receive them; though I can see nothing in the process which can explain error. It has occurred to me that possibly magnetism may have been developed in the stove and magnet-box, both made of copper, by the heat; if this should prove correct, it would throw doubts on the results obtained with water in a copper vessel. I absolutely reject any process depending on the comparison of the results on warm days and on cold days, as assuming a knowledge of the absence of connexion between magnetical and meteorological phænomena on which we have no right to presume. I regard this matter as still involved in difficulty. As relating to the correction of our own results, now obtained in almost uniform temperature, it is of little importance; but as a physical problem, affecting other magnetical determinations, it is important, and appears well to deserve the attention of experimental institutions.

As affecting the Declination and Horizontal Force Magnetometers, which are furnished with copper dampers, I have to communicate some singular observations. I will premise that these dampers were made by Messrs. Vivian & Sons of Swansea, of copper fresh from the smelting; and I was assured by them that, as far as the manufacturer's art could secure it, they contained no iron; and, upon experimenting on them at the Royal Observatory, we could not discover any magnetic effect.

Dr. Lamont lately called my attention to a theory published by himself (of which I have been unable to procure a copy), on the effect of dampers in limiting the magnitude of diurnal and other small inequalities. We have accordingly made experiments with the damper surrounding the Declination Magnetometer; first, by vibrations with and without the damper, which led to no very certain result; secondly, by slewing the damper, and the effect of this is very curious. When the damper is in the position in which it has been many years, every slew of the damper is accompanied by a drag of the magnet in the same direction, to an angular extent equal to about $\frac{1}{120}$ of the angle of slew of the damper. When the damper is reversed (S. to N.), a slew of the damper produces no discoverable effect. It seems from this that the damper acts by two magnetic powers of equal magnitude, exactly analogous to those which in iron ships we call "subpermanent magnetism" and "transient induced magnetism," and that their two forces, in one position of the damper (namely that in which it has always been used) combine their effects, and in the opposite position neutralize each other. The point appears worthy the attention of experimental institutions. It would seem that our exhibited inequalities are too small by $\frac{1}{120}$ part, a matter of little importance in itself. But it is not easy for us to say, whether this power has grown up gradually or suddenly; and it is a delicate practical question, whether the damper should or should not be now retained in the same position.

We have ascertained that the damper of the Horizontal-Force-Magnetometer, (which has been for many years in a magnetic E. and W. position), when placed to encircle the Declination-Magnet, possesses no power of checking its vibrations.

I propose shortly to ascertain the effect of slewing the damper of the Horizontal-Force-Magnetometer.

We have lately revised with care the chemical process of our Photographic Operations, comparing our sheets with some produced by a different process; and the result is that I am satisfied that the process employed here by Mr. Glaisher (and which is described in detail in late Introductions to our printed "Magnetical Results") is the best in use. No other, I believe, is competent to register very sudden changes in the instrumental indications. A small change has been made in our naphthalizing apparatus.

In consequence of the uniformity of temperature (at no time differing much from 60° Fahrenheit), of the Magnetic Basement, in which the photo-chemical operations are conducted, the photographs are much neater than formerly; and we hope that we shall be enabled in great measure to dispense with the darkening by sepia, for the preparation of secondary photograms.

The Kew Deflexion-Instrument is in the same state as at the last Report.

The history of the Dip-Instrument during the year just elapsed is important.

In discussing all the observations made since the introduction of the new Instrument, I found it totally impossible to infer from them the value of the zenith-point (or reading of the circle when the dipping-needle is vertical). The instrument is adapted to needles of three different lengths (3, 6, 9, inches) and the difficulty was felt equally with all. It then appeared to me that we had been proceeding in a course philosophically wrong, in attempting to infer the value of a purely geometrical element from observations so foreign in their nature and so defective in their accuracy as magnetical dips, when an independent and accurate determination might with ease be obtained. I therefore directed Mr. Simms to construct a Zenith-Point-Needle of brass; with pivots similar to those of the dip-needles; and with three pairs of points corresponding to the three lengths of needles used; loaded at one end so as to take a position perfectly definite with respect to the direction of gravity; to be observed with the microscopes, and to be reversed, exactly as the dip-needles. I consider this small apparatus to be a valuable adjunct to the Dip Instrument, as giving the means of deducing independently a separate result from every one of the observations made in the several positions of the needle.

The Visitors will remember that, in many successive years, I have adverted with great anxiety to the difficulties which I have experienced in the determination of Magnetical Dips, and that in my last Report I expressed my inability to receive as certain the reputed accordance of dip-determinations obtained in other places. To this I was led partly by the irregularities of our dip-results, of which after the severest examination I could find no direct explanation; and by the difficulties which, as I knew, had troubled other observers: but mainly by finding that needles of different forms produced systematic differences in the magnitude of the discordances which were produced by simply raising and lowering the needles. In the course of the last autumn, the Committee of the Kew Observatory courteously acceded to my request that two of their dip-instruments should be placed for a time at the Royal Observatory, in order that Mr. Glaisher, in concert with Mr. Balfour Stewart (Directors of the Kew Observatory), might make observations with them. The dips were found to be accordant to a degree which I never witnessed before. Without having yet strictly brought the results to numerical comparison, I have now no doubt that they do bear a consistency equal to or comparable to that which is claimed for them; and I recognize that I was misled by the reasons, strong as I still consider them to be, which I adduced in my last Report to the Visitors. It happened that Mr. Simms, by whom our instruments now in use were prepared, and who had personally witnessed our former difficulties, was present during some of these experiments. Our own instrument being placed in his hands (November 10 to 19) for another purpose, he spontaneously re-polished the apparently faultless agate-bearings. To my great astonishment, the inconsistencies of every kind have

nearly or entirely vanished. On raising and lowering the needles, they return to the same readings, and the dips with the same needle appear generally consistent.

No care had been spared to make our agate-edges perfect. Those of the old instrument were prepared by Mr. Robinson and were revised by Mr. Barrow. Those of the new instrument were made by Mr. Simms. In using the services of the three confessedly best artists of Britain, I thought myself secure as to the character of the workmanship which I should obtain; and indeed I know not what else could have been done.

As the greatest enemy to success in instrumental constructions is secrecy on the manipulation adopted, I will here give all the information that has reached me on the methods actually employed. On a very close examination of Robinson's agates, Mr. Simms sees concavities, (which, as I believe, I also see myself) suggesting to him the idea that, after being shaped (perhaps by some inefficient process) with coarse emery, the surfaces were immediately polished with tin-oxide or other polishing powder carried by a cloth. Mr. Simms' first agate-edges, after being roughly shaped, were brought to form with coarse emery, then ground with fine emery, and then polished with rotten-stone-powder, all carried by the same leaden tool; the form of the tool admitted of cross-stroke, and it is believed that the only fault in the process was that the cross-stroke was used too freely. The same agate-edges were brought to their present state by the use successively of fine emery and tin-oxide, carried by a brass tool which nearly fitted the agates, and which scarcely permitted cross-strokes; and the strokes were almost entirely longitudinal.

I am still unable to see how this change of treatment can account for the removal of the discordances formerly observed, and I regard these discordances as authentic facts of observation, the study of which may not improbably lead to important conclusions on the nature of magnetization, and the nature of pivot-bearing.

After numerous delays, the apparatus for the Self-Registration of Spontaneous Earth-Currents was brought into a working state in the month of March. Two wires are led to the Royal Observatory, one from Croydon and one from Dartford; they communicate with earth at both extremities, but in every other part they are carefully insulated. The apparatus upon which they act is in the Magnetic Basement. Each of them, by means of coils of the usual form, deflects a suspended Magnet. The currents are found to be so unexpectedly strong that it has been necessary in each; first to place the two magnetized needles with poles in the same direction (instead of in opposing directions), secondly to diminish materially the number of wires in the coil. The light from one lamp falls upon both sets of apparatus; in each case it first falls upon a cylindrical lens with axis vertical, then upon a plane mirror carried by the magnet, then upon a more powerful system of cylindrical lenses with axis horizontal or parallel to the axis of the revolving barrel. The barrel is of ebonite covered with

photographic paper; it revolves once in 24 hours. The ebonite discoloured the first three or four sheets of photographic paper, but its power of acting chemically seems to have been rapidly exhausted, and the sheets are now perfectly clean.

The Meteorological apparatus is in an efficient state. The instruments which I proceed to mention are adapted to constant use. Of the class of instruments read by eye, and showing the indications at the moment, we have barometer, dry and wet thermometers, anemometer, and electrometers. Of those which record maximum and minimum, and those which record accumulations without definition of time, and require daily reading, there are Robinson's anemometer, pluviometers (five to be read once or twice in a day, and one to be read once in a month,) maximum and minimum thermometers in the air, maximum and minimum thermometers for radiation from the sun or to the sky (all read twice a day), and thermometers of the same class in the Thames (read once a day). The following instruments record their indications continually, with definition of time: The barometer (registered photographically on the same vertical cylinder as the Vertical Force Magnetometer), the dry and wet thermometers (registered photographically on opposite sides of a vertical cylinder revolving in 48 hours), and Osler's anemometer and pluviometer (registering, by pencil marks, the direction and force of the wind, and the fall of the rain, upon a flat sheet made to travel by a clock). All are in good order.

The Actinometer is in a serviceable condition.

A self-registering Electrometer for the electricity of tranquil weather has lately been introduced to public notice, constructed on principles explained by Professor William Thomson. It may be matter for consideration whether an instrument of this class should not be attached to our establishment.

The public Barometer of which I spoke in the last Report has been mounted, and is a subject of great interest, and gives valuable information, not only to the public but even to ourselves. It constantly exhibits the present state of the barometer, and the last maximum and last minimum since 9^{h} P.M. of the preceding evening.

X. Magnetical and Meteorological Observations.

Photographic registers were obtained from the three Magnetometers during nearly the latter half of 1864, but the instrumental difficulties which I have described make it doubtful whether great value can be attached to them. Since the month of January of 1865 the records are irreproachable, and the series is perfect. All necessary eye-observations are properly kept up.

The first effective register of Earth-Currents, with the needles and coils of the recording instrument in the form now adopted for use, took place on April 6. More

lately, a natural base-line has been introduced, by simply interrupting the continuity of the wire, when the needle soon settles to rest, and the trace becomes a straight line.

Dips have been observed about twice each week, except when the instrument was in the hands of Mr. Simms; deflexions for absolute measure of vertical force about twice a month; circumpolar stars, for the astronomical meridian to which the declination observations are referred, about once a month.

The various Meteorological instruments, mentioned under the last head as adapted to constant use, have been continually employed, I believe without interruption.

The Actinometer has been used on 45 days, and 60 observations have been obtained.

Special observations are taken every morning for publication in the Bulletin circulated by M. Le Verrier; and the London District Telegraph Company and the Submarine Telegraph Company give gratuitously the services of their establishments for immediate transmission of the results to M. Le Verrier. I have long experienced the liberality of commercial bodies in lending the aid of their powerful organisations to scientific enterprise, but I think that in no instance is it more remarkable than in the continued devotion of personal service and instrumental equipment which has been contributed by these two companies.

XI. Reduction of Magnetical and Meteorological Observations.

The equivalents for scale-divisions read in the eye-observations of the three Magnetometers, and the temperature-corrections for the Horizontal Force and Vertical Force instruments (computed with the same co-efficients which have been in use for many years past), as well as the readings for Astronomical Meridian, are applied as far as 1864, December 31. The Theodolite observations of circumpolar stars are however reduced to 1865, May 5. The time scales are all graduated as far as 1864, December 31, but no new or second base-lines for zero of ordinate-measure are laid down for 1864. The deflexion-observations are reduced to 1864, December 31, and the dip-observations to the present time.

The mean Magnetic declination for 1864 is about 20°·38′, and the mean dip about 68°·4′, but, for reasons which have been explained, both these numbers are a little uncertain. The dip at the present time is very near to 68°·0′.

I do not propose to undertake a complete reduction of the Magnetometer photograms for the second half of 1864. In freedom from constant error they are not comparable to those of 1863 and 1865; and in the representation of diurnal and other inequalities, their indications are too small. They may however be available on some disputed points, and they will be kept in a fit state for reference.

I propose to take further steps in reducing the Magnetometer Results from 1858 to 1863, similar to those taken for the Results from 1841 to 1857. The first process is the determination of the Mean Monthly Diurnal Inequalities, and sheets of paper are already prepared for the entry of numbers to be read off the photograms. I am not able to say when active steps will be taken on the computations.

It will be necessary shortly to decide on a plan for the reduction of the Earth Current observations. Supposing the disturbances from the Croydon wire and from the Dartford wire to be exhibited on the same scale, it is easily seen that the westerly currents and the northerly currents which produce them will be inferred by the addition, in each case, of a certain multiple of the Croydon disturbance to another certain multiple of the Dartford disturbance. I propose to effect this graphically by the use of proportional compasses. I may state here that, on some disturbed days, the disturbances from the Croydon wire have greatly resembled those of the Declination Magnet. The disturbances on the Dartford wire are much smaller than those of the Croydon wire.

On the Barometer-Photographs and the Thermometer-Photographs, the time-scales are completed to the end of 1864, but no other step of reduction is made.

The number of complete revolutions in the direction N., E., S., W., made by the vane of Osler's anemometer in the year 1864, was $+17 \cdot 2$.

XII. Printing of Magnetical and Meteorological Observations.

I have thought it desirable to prefix to the Magnetical and Meteorological Observations of 1863, an Introduction of nearly the same length and in nearly the same terms as that for the Observations of 1862. The manuscript has, some time ago, been transmitted to the Printer, but the printing is not yet begun.

The Indications of Magnetometers are printed, in the same form as for many years past, to the end of September 1863. Two sheets of the Meteorological Abstracts for 1863 are printed. The entire manuscript is in the Printer's hands.

The number of copies printed, as for many years past, is 600. Of these, 350 are bound in the "Greenwich Observations," which work includes the Observatory's annual publications of every kind; 250 are circulated, as separate copies, among institutions and persons more particularly interested in Magnetism and Meteorology.

The number of separate copies of Magnetical and Meteorological Results for different years now on hand varies from 20 to 66.

For 1864, the Abstracts of Dip observations and Deflexion observations are prepared;

and this probably is the whole of the Magnetical work to be printed. In the Meteorological section, the left hand pages of the Monthly Abstracts, and several tables of abstracts which follow, are generally ready for printing.

Two copies of each of the photographic sheets are taken. Those for Declination and Horizontal Force are finished to 1862, December 31, and those for Vertical Force (including also the Barometric Curves) to 1863 April 30. We hope that the improvement in our original photograms, consequent on the gain in uniformity of temperature, will render the application of sepia less frequently necessary, and that our copying operations will thus be accelerated.

XIII.—Chronometers, Communications of Time, Longitudes, &c.

A short time since the number of Chronometers on hand exceeded 200. On May 10, the number is 175, thus distinguished:—Chronometers the property of Government, 110; Chronometers the property of chronometer-makers, on the annual competitive trial, 47; Chronometers on trial for purchase by the Government, the property of makers (to be taken in exchange for dilapidated Chronometers, or to be tried as deck-watches), or the property of Officers of the Royal Navy, 11; Chronometers on trial for the India Store Department, 7. There are also 2 clocks on trial, for the India Store Department, All Chronometers on trial are rated every day, by comparision with one of the clocks sympathetic with the Motor Clock; a portion of the Government Chronometers, far more than sufficient for probable wants of the service, are also so compared; the remainder are compared every week. Every Chronometer, whether on trial, or returned from a chronometer-maker as repaired, is tried at least once in the heat of the Chronometer-Oven, the temperature being usually limited to 90° Fahrenheit; and, guided by the results of very long experience, we have established it as a rule, that every trial in heat be continued through three weeks.

The decision on the merits of Chronometers, tried for purchase or for classification in merit, rests with me: it is a troublesome and responsible work, but the principal part occurs only once a year. The repairs of Government Chronometers are managed entirely under the superintendence of the Observatory, and are a source of continual correspondence and trouble of various kinds.

The system of sympathetic clocks of Mr. Shepherd's construction includes seven, of which the most worthy of attention are, the Motor Clock, the large Public Clock, the Clock for Chronometer-comparisons, and a small clock no bigger than a chronometer fixed in the computing-room. The same galvanic current gives motion to the train of wheels in each of these clocks; and as the contacts completing the galvanic circuit are

made by one pendulum (below the Motor Clock), it is only necessary, for their regulation, to regulate that pendulum. This is effected in the computing-room, by means of a commutator affecting the current of a subsidiary battery, by which a current of either kind is sent through a coil, which is fixed to the case of the Motor Clock in such a position that a steel magnet carried by the pendulum swings just over it.

There is another small sized clock in the computing room of a different construction, sympathetic with the Transit-Clock; and the comparison of the Transit-Clock with the Motor Mean Time Clock, for determination of the errors of the Motor Clock, is in fact effected by the comparison of their sympathetic representatives in the computing-room, where also is the commutator by which the corrective action above mentioned is applied to the pendulum of the Motor Clock, accelerating or retarding it as long as may be necessary to correct its error of indication.

The same current from the Transit-Clock regulates a clock in the S.E. Equatoreal room (on Mr. R. L. Jones' principle), and drives a chronometer on the eye end of the S. E. Equatoreal telescope.

The whole of this system is in good order, excepting the telescope-chronometer, which is not perfectly efficient. I am trying a new construction of regulating (not driving) a chronometer by galvanic current.

A galvanic circuit passes through the face of the Motor Clock by a wire which is interrupted at two places, where junction is made at every 60 minutes and at every 60 seconds respectively. Thus an accurate current is sent every hour, discharging the detent of the Time-Signal-Ball (which however is used only at 1^h. P.M.) and working a relay which sends hourly currents to the South Eastern Railway Station, London Bridge, the Electric and International Telegraph Company's Office, and the Office of the London District Telegraph. At the S. E. R. Station is a clock, the property of the Royal Observatory, and governed by a current at every second from the Royal Observatory; by the mechanism of this clock, the course of the hourly current is determined. At 1^h. P.M. it is sent to Deal to drop the Time-Signal-Ball there; the establishment connected with that Time-Signal-Ball is now entirely subordinate to the Royal Observatory, and for that public Signal, but for no other, the Astronomer Royal is responsible. At other hours the current goes to different stations on the S. E. Railway, at the discretion of their Telegraph Superintendent, Charles V. Walker, Esq. F.R.S. The seconds current is made useful to private Offices in London. At the Office of the Electric and International Telegraph Company, the Superintendent, Cromwell F. Varley, Esq., has mounted very beautiful apparatus for distributing the signal over various lines of railway reaching almost to the extremities of Britain, and for firing signal guns at Newcastle and Shields. The currents sent at every hour to the Office of the London District Telegraph are made available to chronometer-makers.

Signals of a less public character are sent to the Clocks of the Post Office and to the Clock on the Westminster Palace, and for these the Astronomer Royal is responsible.

In the instances of the Deal Signal Ball, the Post Office Clocks, and the Westminster Clock, the instruments automatically report their own state, which thus becomes immediately known to us.

I am informed that the value of these public signals is rising very much in general estimation.

The whole system is in a perfectly efficient state.

This extensive arrangement is founded entirely on amicable agreements made by me with the different commercial companies, on the basis of mutual assistance; nominal payments being made, as royalties, for the use of the poles on which the wires are stretched, and for small repairs. The establishment of the wires for earth-currents is on a similar footing.

I can hardly doubt that there will soon be movements in London, as in other great cities of our Empire, for more perfect regulation of Public Clocks, and for other exhibitions of Time Signals. The business of the Royal Observatory, in reference to such proposals, will consist mainly in the transmission of currents accurately at every hour, or every minute, or every second, to definite offices in London; and to this I shall be prepared to give all the attention which it can require.

In conformity with arrangements made by Professor Argelander and Mr. Otto Struve for measures of differences of longitude on various parts of the Great European Arc of Parallel, observations were made in the summer and autumn of last year for determining our differences of longitude with Bonn, with Nieuport, and with Haverford-West. In carrying out these operations, I had the pleasure of seeing Colonel Forsch and Captain Zylinski (of the Russian service), and Dr. Thiele (attached to the Observatory of Bonn). Every assistance was given by the Telegraph Companies whose systems of telegraph connected the various points with London. The plan of operations which was adopted, though beautiful in theory, was better adapted to a steady climate, uniform over a large district, than to a climate so unsteady as that of the British Islands; and in consequence the determinations became very laborious. Every part, I believe, was finally carried out to the perfect satisfaction of the observers, with only this insignificant anomaly, that their final longitude was referred to a point in the Magnetic Ground, marked as "Forsch's Transit," and their final latitude to a point in the Front Court, marked as "Zylinski's Vertical Circle." I am not yet in possession of the numerical results.

Operations have been going on, and will probably have been finished at the time of the Visitation, for determining the longitude of the Observatory of Glasgow. Professor Grant has adopted the method of observation of the same catalogue of stars at both stations, and of chronographic registration of all the transits (whatever might be the place of observation), at both stations.

XIV.—Personal Establishment.

The office of First or Confidential Assistant is held by Mr. Edward James Stone, M.A., Fellow of Queens' College, Cambridge; the Second Assistant is Mr. James Glaisher, F.R.S., who superintends the Magnetical and Meteorological Department. Other Assistants in the order of seniority are: Mr. Dunkin, who is charged with the general care of observations and calculations connected with the Altazimuth, and who superintends the fundamental adjustments of the Transit Circle, &c.; Mr. Ellis, who, acting as astronomical observer, has the special care of Chronometers, Galvanism, and Time-work generally, and also of Money Accounts; Mr. Criswick, who, also observing generally, sometimes assists Mr. Ellis, and sometimes takes part in astronomical reductions; Mr. Lynn, B.A., London University, who observes less frequently, but, as controlling the supernumerary computers, has the charge of the greater part of routine computations; Mr. Carpenter, who observes generally, and especially with the Equatoreal, and who has the entire care of Library, Manuscripts, and Distribution of Observations; Mr. Nash, who, under a separate appointment, is specially attached to the Magnetical and Meteorological Department, in subordination to Mr. Glaisher. The number of supernumerary computers is frequently varying; there are usually about four attached to the Astronomical Department, under the direction of Mr. Lynn, and about three attached to the Magnetical and Meteorological Department, under the direction of Mr. Glaisher.

The necessities of the Observatory compel me to have workmen perpetually at command. In spite of every endeavour to keep down the demands for labour, I can seldom dispense with the employment of three workmen.

The responsibility of each Assistant or Supernumerary is generally to the officer under whom he acts, but, in all cases not specially restricted, to myself.

I alone am ultimately responsible to the Government, the Board of Visitors, and the Public, for every transaction at the Royal Observatory.

XV. Extraneous Work.

The only employment extraneous to the Observatory which has occupied any time within the last year is the giving three Lectures on the Magnetism of Iron Ships (at the request of the Lords of the Committee of Council on Education) in the Theatre of the South Kensington Museum. The preparations, however, for these lectures, to be given in a room ill-adapted to them, occupied a great deal of my own time, and of the time of an Assistant of the Observatory.

I alluded in the last Report, among other things, to works by Mr. H. Breen, requiring ultimately my revision; namely the Moon's Diameter from Occultations

(finished); and the reduction of the Greenwich Observations 1743 to 1749 (in progress); to which I may add the extension of reduction of the Greenwich Planetary Observations 1831 to 1835 (finished). Some obscurities in the first of these works have impeded my examination so much that, with a great expenditure of time, I have really made little progress in my part of the work.

It will readily be understood by the Visitors that the longitude-operations, to which I have alluded, have interfered much with the regular business of the Observatory, but, beyond that reference, I have no further remark to make.

XVI. General Remarks.

The Reductions have rather fallen back in the last year; owing probably to the circumstance, that, under the anticipation of considerable interruption in the Magnetic Observations, I solicited a smaller grant than usual for the payment of supernumerary computers. I have however learnt from very long experience that what is lost in calculation in one year can easily be made up in another year, and I attach no importance to this apparent falling back. The class of work which cannot be made up in the next year is the Observations; and I trust it has sufficiently appeared that, while several reasons combine to urge restriction on any thing inessential, yet in no instance has any essential observation been lost when it could have been secured.

On various occasions I have remarked that the observations taken at Greenwich have been found useful to the world; and I may here state that lately, application has been made to me by a foreign government for communication of observations tending to fix the longitudes of points in their most important colony.

Referring to a matter extraneous to the Observatory, but in which the interests of Astronomy are deeply concerned, I think it right to report to the Visitors my late representation to the Government, to the effect that, in reference to possible observation of the Transit of Venus in 1882, it will be necessary in no long time to examine the coasts of the Great Southern Continent. In the ordinary course of things, this representation would have been deferred for two or three years; but under the circumstance of other plans for naval expeditions having been publicly urged, I have deemed it my duty to take care that a proposal relating to a determination of great specific value, and which must either be carried out in a few years or must be abandoned for ever, should not at a critical time escape notice.

G. B. AIRY.

Royal Observatory, Greenwich,
1865, *May* 20.