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TRANSACTIONS**

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**PART I.**



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**MDCCCXLVII.**

X. *On Photographic Self-registering Meteorological and Magnetical Instruments.*By FRANCIS RONALDS, *Esq., F.R.S.*

Received November 18, 1846,—Read January 21, 1847.

THE Council of the Royal Society having, in April last, granted to me, out of the Donation Fund, fifty pounds “for the purchase of magnetical and meteorological instruments” necessary to the prosecution of experiments in which I was then (and had been long previously) engaged, I feel very anxious to express, now, my deep sense of obligation for its munificence, and to endeavour to show that successful and satisfactory results, in great measure due to the timely assistance thus kindly afforded, have been attained.

It would be superfluous to speak of those proposals of other gentlemen, or of my own, for self-registering, photographically, the variations of the declination magnet and the thermometer which were made previously to *the use of good achromatic lenses, for projecting, upon photographic paper, a sharp image, magnified to any required degree, of that part of the instrument whose motions are to be registered.*

This is the principal feature of the system which I have hitherto applied to procure the self-registration of the atmospheric electrometer, the thermometer, the barometer, and the declination magnetometer, and which I propose to apply to every other meteorological and terrestro-magnetical instrument. Although it had long occupied my thoughts, had received some approbation from the Astronomer Royal in April 1845, and had been the object in view in some experiments made in conjunction with Mr. H. COLLEN of Somerset Street, on photographic paper in the beginning of July 1845, yet my other contrivances and occupations at the Kew Observatory (elsewhere detailed) prevented the completion of any apparatus for actual registration until the end of that month.

*The photo-electrograph* as then constructed, and since improved, may be thus described.

A rectangular box, about 16 inches long and 3 inches square, constitutes the part usually called the “body” of a kind of lucernal microscope. A voltaic electrometer (properly insulated, and in communication with an atmospheric conductor) is suspended within this microscope, through an aperture in the upper side, and near to the *object* end. That end itself is closed by a plane of glass, when daylight is used, and by condensing lenses, when a common Argand lamp is employed. In either case an abundance of light is thrown into the microscope. Between the electrometer and the other, or *eye-end* of the microscope, fine achromatic lenses are placed, which have the double effect of condensing the light upon a small screen, situated at that eye-end, and of

projecting a strong image of the electrometer, in deep *oscuro*, upon it. Through the screen a very narrow slit, of proper curvature, is cut (the chord of the arc being in a horizontal position), and it is fitted into the back of a case, about two and a half feet long, which case is fixed to the eye-end of the microscope, at right angles with its axis, and vertically. Within this case is suspended a frame, provided with grooves, into which two plates of pure thin glass can be dropped, and brought into close contact by means of six little bolts and nuts. This frame can be removed at pleasure from a line, by which it is suspended, and the line after passing through a small aperture (stopped with grease) cut through the upper end of the long case, is attached to a pulley (about 4 inches in diameter) fixed, with capacity of adjustment, on the hour-arbor of a good clock. Lastly, counterpoises, rollers, springs, and a straight ruler are employed, for ensuring accurate rectilinear sliding of the frame when the clock is set in motion.

A piece of properly prepared photographic paper is now placed between the two plates of glass in the moveable frame; the frame is removed (in a box made purposely, for excluding light) and is suspended in the long case; this is closed so as to prevent the possibility of extraneous light entering it; the clock is started; and the time of starting is noted.

All that part of the paper which is made to pass over the slit in the screen, by the motion of the clock, becomes now therefore successively exposed to a strong light; and is consequently brought into a state which fits it to receive a dark colour on being again washed with the usual solutions, *excepting* those small portions upon which dark images of the lower parts of the pendulums of the electrometer are projected through the slit; these small portions of course retain the light colour of the paper; and form the long curved lines or bands, whose distances from each other at any given part of the photograph (*i. e.*), at any given time, indicate the electric tension of the atmosphere at that time.

Sometimes, when daylight was used, various appearances of the sky were noted during the process, by which it would seem, that, in serene weather, when the sun's light and heat varied, and the paper became consequently more or less darkened, the electric tension, as shown in the photograph, varied also; increasing with the increment of light, &c. This fact has not perhaps been before observed: and some attentive observations on the subject, made with the aid of a *good* actinometer, &c., are desirable.

In order that the state of the electrometer itself may be known at any period of the process, a small microscope is fitted to an aperture in the door of the long case, opposite to the slit in the screen, and arrangements are made whereby the eye may be applied to it, and to view the images through the semitransparent photographic paper, without damage by the admission of extraneous light.

The adjustment of the lenses in the body of the lucernal microscope, for procuring the best possible *chemical* focus, can only be obtained by a short series of experiments; but having been once found, future adjustments are not necessary.

In pursuance of a hint or suggestion of the Astronomer Royal, a very useful addition to the electrometer has been made, by which *the kind* in addition to the *tension* of the electrical charge is registered. It depends upon the same principle as that of the "*Dry Pile* distinguishing apparatus," and will be clearly understood by reference to the diagram.

The above-described instrument, with its various improvements, made during the progress of the experiments, was used in connection with an atmospheric conductor situated much lower, and otherwise much less advantageously than our ordinary Kew-conductor\*.

In order to adapt the greater part of the apparatus to the purposes of a *thermograph*, a thermometer of the horizontal kind, and having a flat bore, is employed. Its tube is introduced through a side of the microscope in lieu of the electrometer; a diaphragm is fixed upon it of narrower dimensions than the breadth of the mercury; and the slit in the screen at the eye-end of the microscope is (of course) straight and horizontal; the manipulation and all else remaining as before.

*The photo-barometrograph* requires a somewhat different arrangement of the same microscope, &c.

The long case in which the frame carrying the photographic paper slides, is now placed in a horizontal position. The clock with its pulley, &c. is fixed near to one end of that case: the usual line, attached to the pulley on the clock-arbor, enters the case, as before, and is hooked to the sliding frame, and provision is made of the same kind as before, &c. for ensuring its steady and regular motion.

The lower leg of a siphon barometer is introduced through the *now* lower side of the microscope (in lieu of the thermometric tube), and a very light blackened pith-ball rests upon the surface of the mercury. In order to procure a clean and correct boundary-line in the photograph, a kind of contracting and expanding diaphragm on the barometer tube became very useful in this case, for when daylight was used, very minute adjustments of the aperture were required. The slit in the screen is (of course) vertical. The curves seen in the photographs represent the actual variations nearly of this *siphon* barometer, but it is my intention to try to fill a barometer of the *cistern* kind, in the late Professor DANIELL's manner, with a pith-ball on the surface of the mercury still, and then to use a magnified range of the image.

The curve or right line which forms the right-hand boundary of the dark band, seen in the photographs of the thermometer and barometer, represents the variations of the mercury as accurately as the usual scale readings of ordinary instruments.

The applicability of this system of self-registration to a *magnetograph* was sufficiently obvious; but a much more solid kind and disposition of apparatus is necessary.

The two-feet magnet, now used for this purpose at the Kew Observatory, was kindly lent to me by the Astronomer Royal (in February 1846), and is suspended by

\* The photographs executed between July 24, 1845, and August 29, 1846, by means of this and my various other instruments, were produced at the meeting of the Royal Society, at which this communication was read.

a silken skein of the same kind as that used for suspending the Greenwich declination magnet. The damper surrounding the magnet is of mahogany coated (by means of the electrotype process) with pure copper, and the mode of suspension is *essentially* similar to that of COULOMB. The length of the skein from the magnet to the point of suspension is nine feet, and the detorsion plate is supported by braced frame-work, fixed firmly by brass bolts upon the two pillars which formerly carried the Kew transit instrument. The interior and exterior cases containing the magnet are coated entirely with gold paper, as are those of the Greenwich magnets.

A light conical brass tube projecting about six inches beyond the north end of the magnet, is affixed to the lower side of the stirrup which carries the magnet. Into this end slides (for adjustments) a small cylindrical tube, and from the extremity of the latter descends, vertically, a very small blackened wire (called the index) which passing through slits (long enough for its free motion always) cut through the bottoms of the cases, takes the place of the above-described electrometer, &c. in a lucernal microscope below.

The lucernal microscope is in this instance much longer than before, in order that the motion of the index may be considerably magnified in its image, without sensible error of aberration, &c. The long case (now vertical) with its sliding frame, &c., have the usual form and dimensions; and the clock, with brass pendulum, weight, &c., is placed at a proper distance from the magnet.

I have taken great pains to prevent internal and external currents of air, but the magnet is far from being as steady as the Greenwich magnets, particularly during strong westerly and north-westerly winds. If it were as little subject to mechanical disturbances as the Greenwich magnets, I feel quite sure that the photographs would present as sharp outlines as those of the barometer, electrometer, &c.

Concerning the impressions which have been submitted to the Astronomer Royal's inspection, and compared with the readings of the Greenwich declinometer, I am permitted kindly by Mr. AIRY to say, that the agreement of those results with such readings is highly satisfactory.

*Postscript.—January 7, 1847.*

Since writing the above I have felt strongly impressed with the great advantage which would result in these kind of registrations of the barometer, if that instrument could be rendered *accurately* self-corrective for temperature; and I have been much occupied with a project of this kind (promising very fairly). It consists in applying a solid metallic thermometer in such manner as to cause the whole barometer to descend exactly as much as increments of temperature cause the mercury to ascend.



Fig. 1.

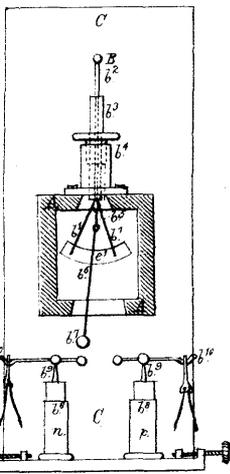
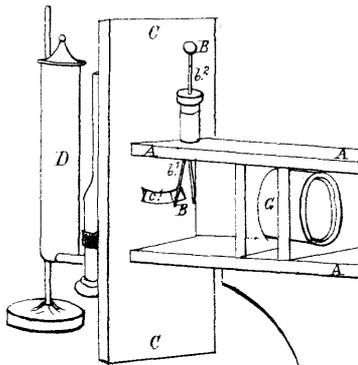


Fig. 6.

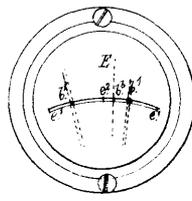
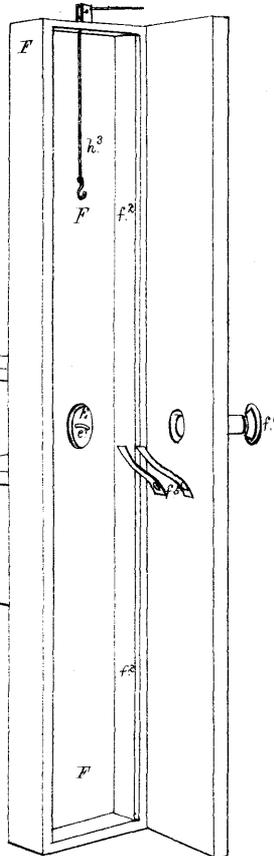


Fig. 7.

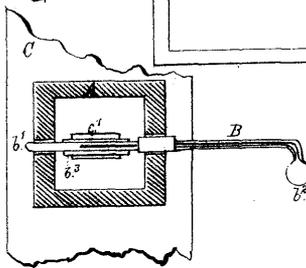


Fig. 3.

Fig. 2.

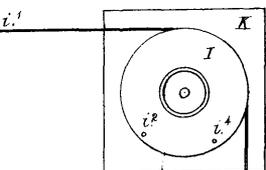
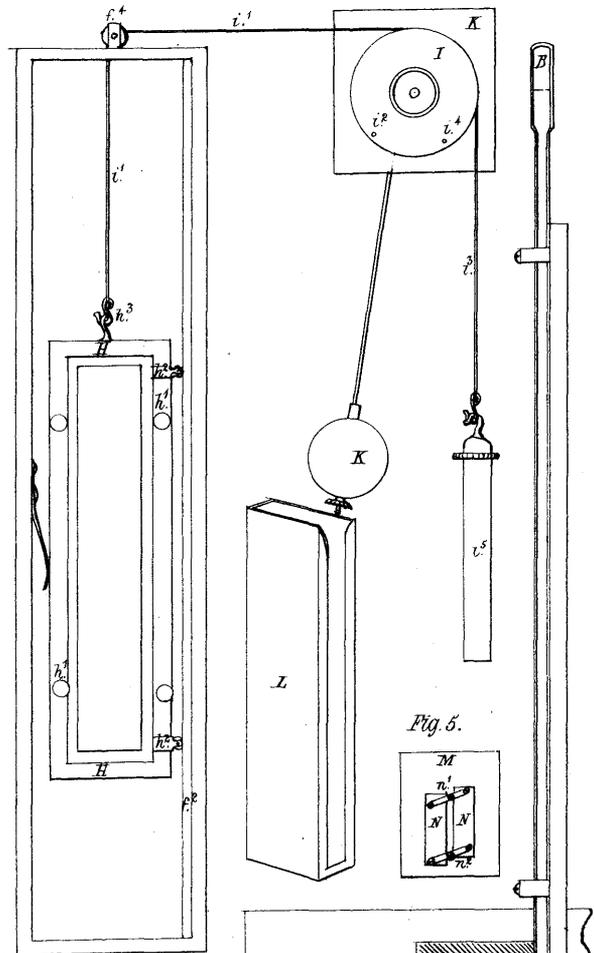


Fig. 5.

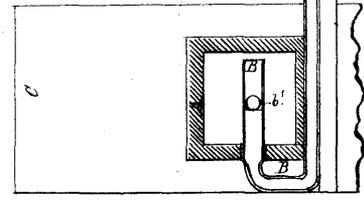
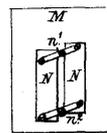


Fig. 4.

## EXPLANATION OF THE PLATES.

## PLATE X.

Fig. 1. *Electrograph.*

- A. The body of the lucernal microscope ; its nearest side removed.
- B. The voltaic electrometer ; the pendulums  $b^1$  suspended by hooks from an insulated piece  $b^2$ .
- C. A board fitted to the end of A, and having a curved diaphragm ( $c^1$ ) cut through it. The condensing lens is placed beyond this diaphragm (and not visible).
- D. The Argand fountain lamp, or a camphine lamp.
- E. The screen, with its slit ( $e^1$ ).
- F. The case which receives the sliding-frame.  $f^5$ . Springs pressing the glass of the frame (H. fig. 2) against E when the door is closed.
- G. The tube containing the achromatic lenses.

Fig. 2.

- H. The sliding frame suspended in F.  $h^1, h^1, \&c.$  Bolts and nuts for pressing the photographic paper between the two plates of glass.  $h^2, h^2$ . Friction-rollers.  $f^3$ . Spring for pressing H against  $f^2$ , the ruler.  $h^3$ . Hooks.
- I. The pulley on the hour-arbor of the clock.  $i^1$ . The line (of gut) suspending H ;  $i^5$ . the counterpoise (to H) suspended by  $i^3$ ;  $i^2$ , and  $i^4$ , terminations of  $i^1$  and  $i^3$ .
- K. The time-piece.
- L. The transfer-box.

Fig. 3. *Thermometrograph.*

- A. Section of the lucernal microscope.
- B. Thermometer ;  $b^1$ , its tube ;  $b^2$ , its bulb.  $b^3$ . Diaphragm fixed upon  $b^1$ .

Fig. 4. *Barometrograph.*

- A. Section of the microscope.
- B. Siphon barometer.  $b^1$ . Black pith-ball resting on the mercury.

Fig. 5. *Contracting Diaphragm.*

- M. Plate having a slit cut through its central part.
- N. Small parallel ruler (of the common kind).  $n^1$  and  $n^2$ . Screws which pass through the centres of its cross-bars (with friction) and screw firmly into M in the line of the centre of the slit.

Fig. 6. *Distinguishing Electrograph.*

- A. Section of the microscope.
- B. The voltaic electrometer.  $b^1$ . The pendulums suspended from the piece  $b^2$ .  $b^5$ . A little plate attached to the lower end of  $b^2$  between the pendulums.  $b^6$ . A longer pendulum suspended by a hook from  $b^5$ , and

passing through a large aperture in the bottom of A.  $b^7$ . A pith-ball fixed on  $b^5$ .  $b^8, b^8$ . Two small Leyden jars, of *very* thin glass, fitted upon sliders, which can be made to approach or recede from each other by means of adjusting screws.  $b^9, b^9$ . Wires connected with their interior coatings, and capable of adjustment for height.  $b^{10}, b^{10}$ . Cross wires, each carrying at one end a brass ball, and at the other a small electroscope, of straws.

When this distinguishing electrometer is in use, the jars are charged artificially, one negatively, the other positively: consequently, if B receives a positive charge from the atmospheric conductor,  $b^7$  is attracted toward the negative ball, and  $b^6$  inclines in that direction, and *vice versâ*.

It is evident, therefore, that in the resulting photograph a line must appear between the two lines, produced by the images of the short straws  $b^1, b^1$ , but nearer to one than to the other. In order to ascertain with certainty, in low intensities, to which ball it inclines, a very small bar ( $e^2$ , fig. 7) is placed across the exact centre of the slit in the screen; the *shadow* of which bar ( $e^2$ ) of course creates a central line in the photograph.

These jars retain a *sufficient low* charge for twenty-four hours even in a humid state of the air (for they are somewhat similarly circumstanced to an electrophorus, which will frequently retain a low charge for one or *two* months).

Fig. 7. The screen E (*vide* fig. 1) with its slit  $e^1$ , the visible parts of the images of the short straws  $b^1, b^1$ , that of the long straw  $b^6$ , and the bisecting little cross-bar  $e^2$ .

## PLATE XI.

Fig. 8. *The Declination Magnetograph.*

AV. A box divided into two compartments.

W. An interior box.

A. The lucernal microscope.

B. The declination magnet.  $b^2$ . Its stirrup, from which it may be removed at pleasure, and the usual brass bar substituted after relaxing two milled-headed screws and turning downward the nearest sides of the stirrup.  $b^3$ . The pair of light tubes connected with the stirrup by means of a short tube, which permits a horizontal adjustment of  $b^3$ . The counterbalance on the nearer end of  $b^3$  is also adjustable.

$b^1$ . The index.  $b^4$ . The damper, the central parts of which, above and below, are expanded and form rings.





- C. The condensing lens (or a glass plane), beyond which a brass lamp (*vide* fig. 1), or when daylight is used, a mirror is placed.
- G. The tube containing the achromatic lenses.
- O. A diaphragm.
- E. The screen.  $e^1$ . The slit cut through it.
- F. The case for reception of the sliding frame (*vide* H, fig. 2).
- IK. The pulley, clock, &c. (*vide* fig. 2.)
- PP. The two pillars of the late transit instrument at Kew.
- QQQ. Parts of the frame-work and braces fixed upon PP.
- XX. Bearers clamped firmly upon PP by means of cross-bars,  $x^1$ ,  $x^1$ , and wedges,  $x^2$ , &c.

A plumb-line, not visible in the sketch, is suspended from the summit of the frame-work and descends to X for the purpose of ascertaining whether any appreciable movement of the point of suspension has occurred. I have not yet discovered any such movement.

Fig. 9.

- R. One of the two bearers which unite the upper opposite ends of QQ (fig. 8).
- S. Section of the detorsion-plate, &c.  $s^1$ . A rectangular plate which can be slid between grooved pieces fixed upon the bearers (R) and accurately adjusted by means of the screws  $s^2$ ,  $s^2$  passing through the pieces  $s^3$ ,  $s^3$ .  $s^4$ . The graduated circular plate with its central neck descending through a socket in  $s^1$ \*. On  $s^4$  a pulley is supported, which is provided with milled-headed nuts on its prolonged axis, serving to secure it from revolution at pleasure.  $s^5$ . The silken skein attached to the pulley and descending through a small aperture in the neck of  $s^4$ .
- T. The upper part of a narrow box inclosing the skein. The lower part is seen at T, fig. 8.

\* I propose to avail myself of Sir JOHN HERSCHEL'S obliging suggestion of turning, with *extreme* slowness and equability, this detorsion-plate on its centre by means of a tangent screw, moved by simple apparatus worked *below*, and whilst the effect on the brass bar may be watched by the operator, even when the boxes are closed.

