VII. *On the Automatic Registration of Magnetometers, and other Meteorological Instruments, by Photography.* *By* CHARLES BROOKE, *M.B., F.R.C.S.E.* *Communicated by* G. B. AIRY, *Esq., F.R.S., Astronomer Royal.*

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AN efficient method of continuously registering the variations of magnetometers having been generally admitted to be a desideratum in science at the Magnetic Conference held during the Meeting of the British Association at Cambridge, it became a matter of philosophical interest to supply the deficiency, and this, it is hoped, has by the following means been satisfactorily accomplished.

As the mechanical force which a suspended bar magnet is capable of exerting, during its variations of direction, is far too minute to actuate the most delicate mechanism without sensibly affecting its position, the desired object will probably be obtained by photography alone. In order to render any method of photographic registration practically useful, it is essential that the three following indications should be fulfilled.

First, to obtain an easily managed artificial light of sufficient intensity to affect photographic paper, especially at those periods when it is of most consequence to obtain a continuous register, namely, when the position of the magnet is undergoing great and rapid variations.

Secondly, to prepare by a ready process photographic paper sufficiently sensitive to receive the feeble impressions of artificial light, and at the same time sufficiently durable to retain those impressions during a period of at least twelve hours, as a more frequent attention to the apparatus would probably interfere with the ordinary arrangements of an observatory.

Thirdly, to magnify the movements of the magnet by some optical arrangement, so that the variations may be indicated with sufficient minuteness and accuracy.

The first point may be attained by a camphine lamp, the light of which is much whiter and more intense than that of any other known lamp; that which has been in use (see fig. 3, Plate V.) is of a square form, each side being $2\frac{1}{2}$ inches long and $1\frac{1}{2}$ high, and stands in a little wooden frame made exactly to fit it, that it may with certainty be replaced in exactly the same position, if removed for the purpose of being trimmed. Many registers prove this to have been the case, there not having been any visible displacement of the line at the recorded period of removal of the lamp. The wick is flat, and about 0·5 inch wide, and inserted near one corner of the lamp, that the reflected pencil may not be obstructed in its passage; and a feeder is inserted in the opposite corner, that the lamp may, if necessary, be supplied without removal; it will, however, contain more than enough for twelve hours' consumption. The plane of the wick is inclined at an angle of 4° or 5° to the axis of the pencil of light, which passes through a slit 0·25 inch long, and 0·01 inch wide in the side of a copper chimney: the chimney is supported on glass feet, to prevent the heating of the camphine by conduction, and for the same purpose the burner passes through a piece of wood. As the burner may occasionally require a vertical adjustment, it passes through a small collar with a set-screw; and as a minute quantity of resinous matter, resulting from the imperfect combustion of the camphine, will sometimes trickle down and interfere with the mobility of the collar, it is protected by a small concave rim attached to the burner. To prevent the escape of light from beneath the chimney, and also to protect the flame from the influence of slight currents of air, at the same time without excluding a due supply, a ring of metal is placed outside the glass supports, which rises about one-fourth of an inch above the bottom of the chimney. To render the combustion of the camphine more perfect, the draught in the chimney is confined by an obtuse conical diaphragm, having an aperture a little longer and wider than the burner, the exact size and position of which are represented in Plate V. figs. 4, 5, 6. The small obliquity of the wick is for the purpose of accumulating as much light as possible in a narrow pencil.

When the camphine is fresh, the lamp will burn for twelve hours without any deposition of carbon on the wick, or sensible diminution of the intensity of the light. The application of gas has not been attempted, as the apparatus would probably be applied in situations not accessible to the ordinary supplies of gas. For the purpose of actual observation, and especially wherever it may be proposed to obtain, not merely relative, but absolute determinations from the registers, it will be found desirable to detach the fine slit from the lamp, and to fix it by a suitable support to an immoveable stand on which the lamp is placed. It is also desirable that one edge of the slit should be adjustible by a fine screw, that the width of the aperture may be varied at pleasure*.

The second object has been attained by a paper prepared with the bromide of silver, which is well known to be affected by rays distributed over a larger portion of

* Since the paper was read the frequent use of the apparatus has suggested various modifications and improvements, both in its construction and practical application; these will be inserted in the form of notes for the sake of preserving the integrity of the original papers, and at the same time presenting all existing information on the subject.

The lamps now in use have been constructed by WATKINS and HILL, having a detached slit with a fine adjustment (see fig. 7, Plate V.): much nicety is requisite in their arrangement, to enable the camphine to burn without smoking, at a point nearly approaching the maximum of illumination.

If the lamp and slit by which the base-line is described be similarly fixed in position, and the angular value of the distance between the base-line and the register at any given time determined, the declinations may be read off from the registers, with a limit of error depending on the length of scale and the definition of the line. —May 1847.

the spectrum than any of the other argentine salts, and is on that account preferable for the influence of artificial light. The sensibility of paper prepared with this salt has been found to be greatly augmented by the addition of a small quantity of iodide of silver (figs. 1 and 2, Plate V.). In fig. 1, the development of the impression has been arrested when distinctly visible on the iodized portions, but invisible on the remainder of the paper: in fig. 2, the difference in the clearness and darkness of the several portions of the line is very well marked. A little isinglass is also added, partly because the presence of a small quantity of organic matter appears to assist the catalytic action that ensues on the development of the impression, and partly for the purpose of retaining the salts dissolved with it on the surface of the paper.

The mode of preparation is thus: to a filtered solution of four grains of isinglass in one fluid ounce of boiling distilled water, add ten grains of bromide of potassium, and two grains of iodide of potassium*: when cold, the solution is evenly laid with a camel's hair brush on highly glazed paper in sufficient quantity to thoroughly wet the surface, but not to run off; the paper is then quickly dried by the fire, to prevent the solution being absorbed by the paper. Paper thus prepared may be kept for a considerable time in a dry place; but it is recommended not to prepare at one time more than enough for a week's consumption.

When about to be used, a piece of the above paper is evenly washed over by a camel's hair brush with a solution of fifty grains of crystallized nitrate of silver in one fluid-ounce of distilled water, by the aid of red or yellow light only, and placed damp in the apparatus, as the sensibility of the paper is much diminished by permitting it to become dry. When removed from the apparatus, the latent impression is developed by washing the paper with a saturated solution of gallic acid in distilled water, to which a very small quantity of strong acetic acid is added, when used; the addition of the acetic acid is found to diminish the darkening of the paper. The piece of paper used for each of these registers is half a sheet of folio post paper, torn lengthwise into two strips: to the quantity of gallic acid necessary to wet the surface of one of these pieces, which is about a teaspoonful, the addition of three drops of acetic acid is found to be sufficient. As soon as the impression is sufficiently developed, all soluble matter is removed by washing the paper two or three times in water; and lastly, the image is fixed by washing with a solution of twelve grains of hyposulphite of soda in one fluid-ounce of distilled water. A little practice in the manipulation is necessary for the success of this or any other photographic process. It may here be usefully remarked, that in all photographic processes, the strictest attention to cleanliness, as regards all instruments employed, is indispensably necessary: separate cloths, brushes and glasses should be used, and each retained for its respective purpose, as the smallest undue admixture of the materials will entirely frustrate the object to be attained.

The paper prepared as above described, is placed round the outside of a cylindrical

* See note, p. 67.

French shade, about 10 inches high and $14\frac{1}{2}$ in circumference (figs. 1 and 5, Plate VI.), the corners being held together by a little gum dissolved in acetic acid. The shade, after having been blacked in the inside, is cemented into a cap 1 inch deep in the rim, and having a brass pin about $1\frac{1}{2}$ inch long and a quarter of an inch thick fixed perpendicularly in its centre. A second shade, a little larger than the former, is then placed over it, leaving an annular space about one-eighth of an inch wide; the two cylinders are retained in a concentric position, by placing a sufficient number of turns of tape or ribbon round the rim of the cap of the inner cylinder, to fill up the intervening space. As the sensibility of the paper has been found to be materially diminished by allowing it to become dry, the tape or ribbon is saturated with water, previously to the outer cylinder being placed over it, and a piece of moist lint is placed between the round ends of the cylinders: the paper is thus kept perfectly damp until its removal, after having been in action twelve hours. The pin in the cap of the inner cylinder rests on a pair of friction rollers, and the cap rests against a horizontal roller, Plate V. fig. 8; the rounded end of the outer cylinder also rests upon a pair of rollers, which are adjustible in the direction of the common axis of the cylinders, Plate VI. fig. 1; the axis may thus be always rendered horizontal. By these means, the cylinders revolve so easily that they have been carried round by the hour-hand of a common watch; as however stoppages occasionally took place, from a deficiency of motive power, a stronger movement, such as now in use, is recommended*. A small collar with a set-screw fits on the pin of the cylinder, into which is inserted a bent wire that engages with a fork at the end of the hour-hand of the time-piece (Plate VI. fig. 3), the hour-hand being a little longer than the minute-hand. The cylinder is thus carried round its axis once in twelve hours, and at the commencement of the observation the carrier is so adjusted that the point of light may fall at the top of the paper. From the preceding description, it will be readily understood that by a combination of the vertical movement of the paper with the horizontal movement of the luminous point, the magnetic curve is traced out. The time-scale, which is measured lengthwise in the photographs, is evidently $\frac{1}{12}$th of the circumference of the inner cylinder to one hour, and the dimensions above mentioned, which allow 0·1 inch very nearly to five minutes, have been considered to define the period of any

* The size of the time-pieces in use is that of an ordinary ship chronometer, and in the construction of these a great improvement has recently suggested itself. The motion of the hour-hand is usually reduced from that of the arbor carrying the minute-hand by two wheels and pinions, the play of which, although necessary for their free action, allows a degree of mobility in the hour-hand rarely less than equivalent to five minutes in time, and consequently, without due caution, an error to this amount may be introduced in the register; moreover, the hour-hand is supported by too short an axis to enable it to overcome a considerable resistance applied to its extremity, without acting as a drag upon the whole train. To obviate these inconveniences, the hour-hand is placed on the arbor of the centre or second wheel, which is driven directly by the barrel, and drives the rest of the train. With this and other necessary modifications of the train, the variation of rate, whether the hour-hand moves freely, or is engaged in carrying the cylinder, will be scarcely sensible. In carrying out these views, the author is bound to acknowledge his obligation to the skill and intelligence of Mr. Eiffe.—May 1847.

given variation with sufficient accuracy. As it is extremely improbable that two or more cylinders should be obtained of precisely similar circumference, it is desirable that a correct time-scale should be constructed for each cylinder employed, which may be readily effected in the following manner. Let a piece of paper, made as damp as the photographic paper usually is when placed on the cylinder, be cut so as to exactly meet round it; when dry, let this be divided into twelve equal parts, each of which will represent 1^h; these again into twelve parts, each of which will correspond to 5^m. By this arrangement an allowance is made for the shrinking of the paper*. The angular deviation is measured from a line on the paper drawn in the direction of its motion, such, for example, as would be described by the point of a fixed pencil resting constantly against it; and at the scale of 0·05 inch to one minute (which may perhaps be taken as the best working scale with the existing apparatus), the edge of the line when the various adjustments have been carefully attended to, is sufficiently well defined (as may be observed by a reference to many of the photographs) to determine its place to half or less than half a division of a scale of $\frac{1}{60}$th of an inch, that is, the position of the magnet may be read to within ten seconds. The plan adopted for determining the position of the base-line on the photographs, has been that of drawing pencil marks across the line at which one end of the paper overlaps the other, previously to its removal from the cylinder. When the register is dried, a line drawn through the two corresponding marks at the two ends has been taken to be the base-line. As however it can never be expected to obtain glass cylinders that have either perfectly cylindrical surfaces or perfect surfaces of revolution, the line of intersection of a plane perpendicular to the axis of the cylinder with the paper, would not probably be a perfectly straight line when the paper is opened out; and if the paper should from any cause contract unequally in drying, this line of intersection, which is the true base-line, would be liable to some further distortion. A comparison of many photographs with the Greenwich observations has led to the belief, that a small portion of error has occasionally arisen from these causes; there is, however, no reason for supposing that it has ever exceeded one minute. The means of obviating these sources of error by a photographic base-line are under consideration, but have not yet been perfected†.

* It is questionable whether the inequalities in length of the different registers, arising from different degrees of moisture and corresponding expansion of the paper, and from other causes, may not be too great to admit of the use of any fixed scale; in this case it will be necessary to divide each base-line into twelve parts by a suitable pair of proportional compasses, or some other contrivance. The errors arising from unequal expansion of different parts of the same piece of paper would, it is believed, be too minute to be recognised. In order, however, to guard against these sources of error, and generally for the purpose of marking any given epoch on the paper, the pencil of light by which the base-line is described is shut off by a sliding piece attached to the cover. After remaining so for a few minutes, it is readmitted for a period of ten seconds, and again shut off for a few minutes more, the time of its readmission being recorded. A small dot in the midst of an interrupted portion of the base-line will serve to determine the given epoch on the register, for an example of which see fig. 8, Plate IX.—May 1847.

† In the combined register of the declinometer and bifilar magnetometer, the base-line is now described by a

The following arrangements have been adopted to fulfil the third indication, that of magnifying sufficiently the movements of the magnet. A concave mirror of ten inches focus, and three inches aperture, is attached to a brass stem intervening between the frame which supports the magnet and the suspension chord. In order to reduce as much as possible the influence of torsion on the position of the magnet, the suspension skein consists of six equal bundles of untwisted silk fibres about six feet long, being portions of the same skein of flos silk; these, after being boiled in a solution of bichloride of mercury to render them less hygrometric, were stretched by six equal weights, the sum of which was very nearly that which the whole would subsequently have to support, and after having been left for three or four days to find their position of rest, were firmly bound together: by these means the probable equality of tension and freedom from torsion in the entire chord will, it is believed, be considerably augmented. The mirror may be moved round with the stem through any angle of azimuth, that the reflected pencil of light may proceed in a convenient direction; and the lamp must be placed at such a distance from the mirror that the conjugate focus may be at any required distance: and on this distance depends the amplitude of the scale, on which the variations of the magnet are represented. If the image of the slit is formed at a distance of 7 feet 2 inches from the line of suspension, each minute of angular motion of the magnet will be represented by a change of position of the line on the paper, amounting to $\frac{1}{20}$th of an inch; if formed at 9 feet $6\frac{1}{2}$ inches, 1′ will be equivalent to $\frac{1}{15}$th of an inch; if at 11 feet $11\frac{1}{4}$ inches, to $\frac{1}{12}$th of an inch; and if at 14 feet 4 inches, $\frac{1}{10}$th of an inch will represent 1′. The support of the lamp by which its adjustments are effected will be readily understood by an inspection of Plate I. fig. 1*.

The pencil of light forming the image of the slit is intercepted by a cylindrical lens, the axis of which is horizontal, and perpendicular to the vertical plane passing through the image and the centre of the mirror; the lens being placed at its focal distance from the image. By this arrangement, that portion of the pencil which passes through the lens is condensed vertically into a narrow space, without at all interfering with its horizontal movement. The most suitable focal length of the cylindrical lens depends upon the length of range: at the shortest distance above-mentioned, a focal length of 1·5 inch will be found to answer very well; at the next, two inches; and at the longest, three inches.

As the amount of spherical aberration increases considerably as the eccentricity of the reflected pencil is increased, it is desirable that this eccentricity should be the least possible; with this view, the lamp must be so adjusted in the horizontal

separate lamp placed about 9 or 10 inches from the cylinder; a small pencil, the axis of which is perpendicular to the axis of the cylinder, is received by a lens placed at less than its focal distance from the paper, a small portion of the pencil thus condensed is transmitted through a narrow vertical fixed slit, and marks the paper (see fig. 8, Plate IX.). In the combined register of the balanced magnetometer and the barometer, the base-line is described by the barometer lamp, as mentioned in the Supplement.—May 1847.

* The lamp now stands on a fixed pillar to which the fine slit is attached.—May 1847.

plane, that the reflected pencil may pass close by the side of the chimney. It is obvious that the angle contained between the incident and reflected pencils may be diminished to any required extent by increasing the focal length of the mirror, as the lamp will then be placed at a greater distance from it, and by the same means the portion of light incident on the mirror is diminished, but the illumination of the image remains constant, its area alone being altered by varying the focal length of the mirror. Mirrors of 5, 6, 8½, 10, 12, and 15 inches focal length have been tried; and in conjunction with the cylindrical lenses which have been used, the mirrors of 8½ and 10 inches focal length and 3 inches aperture, appear to have produced the best effects. It may be here remarked, that the lenses used have been either cylinders, or portions of cylinders cemented together, filled with water; but with solid glass lenses, and more particularly with achromatic combinations, could such be obtained, it is probable that a better effect would be produced with mirrors of from 12 to 16 inches focus, and 3½ or 4 inches aperture*.

In the adjustment of the lamp, it is necessary that the plane of incidence and reflexion should be perpendicular to a vertical plane passing through the slit and the centre of the mirror. This adjustment may be most conveniently effected by placing a piece of wire horizontally across the slit and the reflected pencil, and having fixed the lamp at such an azimuth that the brightest portion of the pencil may be incident on the centre of the mirror, by moving the lamp vertically until the wire appears to coincide with its image at the centre of the mirror. By this adjustment, the image of the slit, being a portion of a caustic surface, is condensed in the direction of a tangent plane, and the confusion of the rays forming the luminous point is a minimum: the effect may be observed by comparing the line, fig. 3, Plate VII., in which this adjustment was intentionally disregarded, with fig 4, in which it was attended to, all other circumstances remaining precisely the same. It may be here observed, that the line being formed by a portion of a caustic surface condensed, the distinctness of its edge is independent of the distance at which the image is formed, and consequently of the

* The register, fig. 8, Plate IX., has been obtained by means of a mirror of 5 inches aperture, and 20 inches focal length; the reflected pencil being refracted through a combination of two plano-convex cylindrical lenses, one of which has a radius of 2 inches, and the other of 1 inch, the aperture of each being about 60 degrees, the interval between them about 1½ inch, and the more convex nearer to the paper. These lenses have been very beautifully executed by M. Lerebours. The mirror has been by successive trials carefully rendered elliptical, the conjugate foci being at the distances of about 2 feet, and 12 feet 4 inches from its surface. The latter distance was selected as suiting the locality of the Royal Observatory for which the apparatus was constructed. It may not be irrelevant to mention here the means by which the elliptical figure of the mirror was obtained. After being brought nearly to the proper figure, a screen was placed in front of it consisting of narrow concentric annuli of card, moveable on a wire, so that either of them could be placed perpendicular to the surface of the mirror, while the rest remained parallel to it, the lamp being placed at the distance of the nearer focus. By means of this screen the incident pencil might be received upon any annular portion of the mirror separately, and after many successive trials, the figure of the mirror was altered until an image was found to be formed by each annulus at the required distance. It is obvious that on the perfection of the figure of the mirror, the sharpness of the edge of the line will in a great measure depend.—May 1847.

amplitude of the scale. This may be observed by a comparison of figs. 1 to 20, Plate VII., in which the scale is 0·05 inch to 1′, with fig. 5, in which it is 0·1 inch to 1′: the only difference is in the darkness of the line, depending on the intensity of the point of light by which it is described.

In order to prevent the paper being darkened by the influence of stray light, a rectangular cover is placed over the cylinders, with a slit in the side, in the same horizontal plane as the axis of the cylinders, the slit being just wide enough to allow the point of light to pass through it: the paper is thus protected from the rays dispersed by the water lens. The time-piece, cylinders and lens, are placed on a tripod stand with the usual vertical adjustment (see fig. 1, Plate VI.), by which the whole apparatus may be so placed that the lens may receive the brightest part of the image. The surface of the stand, and all parts of the apparatus from which light could be reflected on to the paper are blackened over, and the whole is covered by a second case; in the side of which, towards the reflected pencil, is an aperture guarded by a tube about one foot long, and sufficiently large to admit the reflected pencil in any position that it may assume. The box in which the magnet is inclosed, to protect it from being disturbed by currents of air, and all other objects visible through the tube by an eye placed at the paper, except the mirror, are also rendered black; and so complete is this protection, that not the slightest difference can be perceived in the paper, whether bright daylight is freely admitted through three large windows, or wholly excluded. This apparatus has hitherto been applied to register the variations of the declination magnet only, but it may be considered equally applicable, with appropriate modifications, to record the variations of the horizontal and vertical elements of magnetic force.

The experiments have been conducted under the unfavourable influence of that constant tremor which exists in a London thoroughfare: this has been as far as possible counteracted by attaching to the magnet, about half-way between the point of suspension and its extremity, a piece of copper wire, the end of which dips into a glass vessel of oil; this does not appear to have interfered with the movements of the magnet*. The effect of the damper, in arresting the influence of local causes on the vibrations of the magnet, may be best appreciated by a reference to fig. 19, Plate VII., a register taken during a *maximum* local disturbance, namely, a quadrille party in the next house, from the party-wall of which the magnet has been suspended. The unsteady movement of the magnet during the period of the dance (the termination of which is very well-marked) is strikingly contrasted with those periodically augmented and diminished vibrations of the magnet about its mean place, the existence

* The use of oil as a damper is liable to the objection that it may congeal at low temperatures, and thus impede the movement of the magnet; and on this account a slip of wood attached to the magnet, and dipping into a glass vessel of mercury, has been substituted. The use of mercury seems moreover desirable on account of its gravity when so large a concave surface as that of a mirror of 5 inches aperture is exposed to the influence of currents of air, which would in all probability produce more or less vibration in the magnet.—May 1847.

of which has frequently been noticed, and which are very conspicuous in fig. 20, a portion of a register purposely taken during the most quiescent period of the week.

Notwithstanding the local sources of error above alluded to, it is very satisfactory to observe the close agreement between the photographs and several hundreds of the observations made at the Royal Observatory, which have been very carefully laid down upon them. These automatic registers include the two last term-days, and several periods of unusual disturbance, during which extraordinary observations have been made at Greenwich at intervals of one, two, or three minutes, and throughout the whole series the number of discrepancies is very small. An almost continuous registration has been maintained during the present year; and it is due to the praiseworthy vigilance of the observers engaged at the Royal Observatory to state, that very few extraordinary disturbances have escaped their notice.

Of those which have been compared with the Greenwich observations, fig. 20, Plate VII., the register of April 6th, 1846, and fig. 1, Plate VIII., that of April 16th, exhibit the greatest disturbance; in both instances it may be remarked that the greatest variation has occurred between 7^h and 11^h. It may here be conveniently remarked, that in accordance with the practice of the Royal Observatory, the time adopted is Göttingen mean astronomical time, which is 39^m 46^s in advance of Greenwich mean time.

Fig. 17, Plate VII., the register of April 15th, exhibits a brief disturbance, occurring between 8^h and 9^h, in which the photograph differs more essentially from the Greenwich observations than in any other instance: a sharp cusp in the latter, corresponding at two points to a mere bend in the former, would lead to the inference, that the disturbing cause must have been so near to Greenwich as to have exerted a materially greater influence on the magnet there under observation.

A singular fact is established by some of these photographs, namely, that after a certain space of time the actinic influence spontaneously decays; for in some instances the paper has been suffered to remain on the cylinder more than twelve hours; and consequently a second impression is made upon the paper within a very small distance of that which had been made twelve hours previously, and while the latter impression is distinctly developed, the former is very faint: fig. 6, Plate VII. is a good illustration of this fact. The succeeding portions however of the first impression become more and more distinct, thus showing that the decay is gradual. It appears to commence after a period of from ten to fourteen or fifteen hours; but the conditions on which this variation of time depends have not been ascertained*.

* Subsequent observation has led to the opinion that this decay of the impression depends on the paper having been originally prepared with too weak a solution of bromide of potassium. The solution now used contains 4 grains of isinglass, 16 grains of bromide of potassium, and 4 grains of iodide of potassium in one fluid-ounce of distilled water. The paper prepared with this solution appears to retain the actinic impression unimpaired for a period of more than 24 hours. Consequently two registers, each of 12 hours' variation, may be obtained on the same paper by allowing the cylinder to go twice round. An example of this may be seen in Plate IX. fig. 8, in which it may be observed that the occasional crossing of the lines does not at all interfere with their

The most violent shock that has been recorded, fig. 10, Plate VII., occurred between 5^h and 6^h on the 1st of April. On this occasion, the magnet, after suffering two small shocks, was at 5^h 20^m suddenly displaced as by a blow, and thrown into a wide oscillation, from which it did not return to a state of rest for 25^m; it then sustained a considerable shock in the opposite direction, from which it again returned to a state of rest, in nearly its original position, about 6^h.

It is confidently anticipated that a continuance of these observations during the approaching period of the year, when disturbances are usually most frequent and considerable, may lead to some interesting results.

distinctness. By this means half the trouble of changing the papers and developing the impressions is saved, and the relative positions at intervals of 12 hours may be determined with a much greater degree of certainty, the only source of error being in reading the position of the edge of the lines on a scale.—May 1847.

29 *Keppel Street*,
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