XVIII. *On a Self-recording Method of Measuring the Intensity of the Chemical Action of Total Daylight.* By Henry E. Roscoe, *F.R.S.*

Received November 27, 1873.—Read February 5, 1874.

Although the method of measuring the varying intensity of the chemically active rays, as affecting chloride-of-silver paper of constant sensitiveness described in the Bakerian Lecture for 1865, has been the means of pointing out many important facts * concerning the distribution of the sun's chemical activity through the atmosphere as well as in different situations on the earth's surface, it has not as yet been introduced as a regular portion of the work of meteorological observatories. Until this is done, and the measurements are regularly continued and made in many situations, we cannot hope to obtain any thing like a knowledge of the laws of distribution of these rays over the earth's surface, or any information as to the yearly variation of the solar chemical activity. This non-adoption of the method has to be explained, not in any want of reliance in the process or in the results, but in the fact that, in order to obtain a satisfactory curve of daily chemical intensity, at least hourly observations need to be made; this involves, however, the expenditure of so much time and labour that the permanent observatories, already too heavily weighted, have found it impossible to undertake the necessary work. In the present communication I have to describe a modification of the above-mentioned method, which, whilst preserving untouched the principles upon which it is based and the amount of exactitude of which it is susceptible, reduces the personal attention needed for carrying out the measurements to a minimum, and thus renders its adoption in observatories possible.

According to this plan, the constant sensitive paper is exposed to the action of total daylight at given intervals, say at every hour, during the day, by a self-acting arrangement, for accurately known times. The insolation-apparatus, stocked with sensitive paper, is placed in position either early in the morning of the day during which the measurements have to be made, or on the previous night; and by means of electric communication with a properly arranged clock, the sensitive paper is exposed every hour during the day, so that, in the evening, the observer has only to read off in the

* (1) Phil. Trans. 1867, p. 555, "On the Chemical Intensity of Total Daylight at Kew and Pará, 1865, 1866, 1867," by H. E. Roscoe, F.R.S.; (2) Phil. Trans. 1870, p. 309, "On the Relation between the Sun's Altitude and the Chemical Intensity of Total Daylight in a Cloudless Sky," by H. E. Roscoe, F.R.S., and T. E. Thorpe, Ph.D., F.R.S.E.; (3) Phil. Trans. 1871, p. 467, "On the Measurement of the Chemical Intensity of Total Daylight made at Catania during the Total Eclipse of December 22, 1870," by H. E. Roscoe, F.R.S., and T. E. Thorpe, F.R.S.E.

ordinary manner the hourly intensities which have been recorded on the paper during the day.

This self-recording arrangement, though at first sight simple enough, involves points which have rendered its successful completion a somewhat lengthy and difficult matter. Thanks, however, to the skill of Mr. CHARLES JORDAN, of Manchester, these mechanical difficulties have now been overcome, and the instrument perfectly answers the desired end.

Owing, in the first place, to the great variations which occur in the chemical intensity of total daylight in different places, at different times of the day, and in different periods of the year, and, secondly, owing to the fact that, in order to be able accurately to estimate chemical intensity, the coloration acquired by the paper must reach, but not much exceed, a given tint, it becomes necessary, on each occasion when an observation is needed, that the sensitive paper should be exposed mechanically, not once, but for several known but varying intervals of time, quickly succeeding each other; so that whatever may be the intensity of the total daylight (supposed during those intervals to remain constant), some one at least of the several exposed papers will possess the requisite shade. This is accomplished by a duplicate arrangement of a clock and insolation-apparatus. The clock has connected with its minute-wheel (Plate L. fig. 1, A) a train of three wheels (B, C, D, fig. 1), so arranged for speed that the last wheel (D) revolves once every two minutes. On the periphery of this metal wheel are fixed eleven stout platinum pins (marked 1 to 11, fig. 1), each projecting about 3 millims. from the face of the wheel. As this wheel revolves, each one of the pins is in turn brought for an instant into metallic contact with the platinum face of the elastic metallic arm (E, fig. 1). As the wheel passes on, metallic contact between the wheel and the arm is interrupted until the next pin comes into position. These platinum pins are so placed on the wheel that by its uniform rotation contact is instantly made, broken, and, after a given interval, again made and broken, in all eleven times in succession. The intervals during which contact is broken are of different lengths, dependent upon the positions of the pins. For use in this country the intervals are so arranged as to break the contact for times approximating to the following number of seconds:—

Interval ..	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.
Seconds ..	2	3	4	5	7	10	12	17	20	30

When the instrument is to be used in situations where the chemical intensity is much greater or much less than in our latitudes, different intervals must be adopted. Whilst the wheel is in metallic contact with the elastic arm (E), a current from four cells of a BUNSEN'S battery (or if a slow and constant current is required twelve to twenty cells of a LE CLENCH) passes by means of a second elastic arm (F) through wires connecting the clockwork with the insolation-apparatus; but this current ceases to pass as soon as the circuit at E is interrupted. The paper of constant sensitiveness, cut into long narrow strips like those used in MORSE'S telegraph, and of sufficient length (about 3 metres) to last for one day's observations, is wound on to a bobbin (B, fig. 2), from which it passes over the light metallic wheel (W, fig. 2) about 15 centims. in diameter, to the circumference of which one end of the strip is made fast. The escapement (E, fig. 2) is connected with the keeper (K) of a small electromagnet (M), round which the current from the battery passes whenever contact is made by the clock at E, fig. 1. The escapement-wheel (F, fig. 2), worked by a spring (S), is fixed on to the axis of the wheel (W) carrying the paper, so that when a current passes through the electromagnet the keeper (K) is attracted, the escapement (E) released, and the paper carried forward on the wheel to a distance regulated by the number of the teeth of the escapement-wheel (F). As soon as the current ceases, the keeper is brought back into the position shown in the drawing by means of the spiral spring at its extremity.

When the minute-wheel (A, fig. 1) of the clock comes round to a given point, a fixed pin (p) on this wheel presses against the long end of a lever (L), and this pushes down the elastic arm (E) (which is insulated from the rest of the clockwork) on to the thick platinum pins fixed on to the metal wheel (D). By the passage of the pins in front of the end of the elastic arm contact is made, and then a current passes from the clock to the electromagnet on the insolation-apparatus. The paper on the wheel is then suddenly moved forward such a distance as is necessary in order to expose a fresh portion under the circular opening (O, fig. 3) on the upper side of the metal cover of the insolation-apparatus. This small disk of paper (4 millims. in diameter) remains exposed to the daylight until removed by the movement of the keeper caused by the contact of the second pin at E, fig. 1; a fresh disk of paper then instantly becomes visible, in its turn to be removed after having been exposed for a known length of time. This successive exposure of disks of sensitive paper for increasing periods of time up to 30 seconds goes on until the wheel carrying the platinum pins has completed one revolution. The fixed pin (p) on the minute-wheel has during that time passed so far round, that it has now ceased to press upon the curved and thickened end of the lever (L), and the tip of the elastic arm (E) is now drawn back by a small insulated spring (S); so that it remains in this position until an hour has elapsed, when it is again pressed on to the platinum pins by the point on the minute-wheel, and the exposure of another set of disks of sensitive paper occurs again. During the space of nearly an hour, during which the wheel (W, fig. 2) remains stationary, a very dark disk is obtained; and if one of these dark disks be marked during the day with the hour of exposure, the times of all the different exposed disks can be ascertained.

When in use the insolation-apparatus is covered with a light tight blackened metal cover (C, fig. 3), having a thin piece of metal at the top, which, when the instrument is placed in position, lies horizontally. In the centre of this plate a circular opening 4 millims. in diameter is bored, the edges of which are carefully bevelled off. A steel spring (A, B, fig. 2), over which the prepared paper passes, presses the strip against the lower surface of the horizontal metallic plate, so that the disk of paper is seen to lie close to the plate below the circular opening. In order to keep the paper and apparatus dry during rain, a glass shade is placed in wet weather over the insolation-apparatus, and the loss of light thus occasioned by reflection and absorption experimentally ascertained for each instrument.

On unrolling, at the end of the day, the strip of insolated paper from the wheel (W) in a room illuminated by the monochromatic light of a soda-flame, the black disks of the hours are seen, and between each of these are found ten circles variously tinted, from that (probably scarcely visible) which was exposed for 2 seconds, to that (perhaps too dark to read off) which was insolated for 30 seconds. Amongst these some one at least will be found to be of such a tint as to enable it to be read off on a graduated fixed strip, as described in my former communication*.

In order to be able to read off each hourly observation quickly, the half of each of the tinted disks which is of about the right shade is punched out of the paper by a solid semicircular punch, which is worked by the foot, whilst the long strip of paper is held in both hands. One end of the long paper band is then placed in one of the spring clamps of the reading-drum†, and the band brought through the other clamp, so that the remaining halves of the tinted disks are held against the graduated fixed strip which is placed on the drum. By moving the drum on its horizontal axis, the various shades of the fixed strip are made to pass and repass each of the semicircular holes on the band; and thus the point on the strip identical in tint with the remaining half of the disk can be easily ascertained, the reading being made in a darkened room by the light of a soda-flame. Each tint is thus read off ten times, and the mean taken as the result.

II. *On the Calibration of the fixed Strips and Standard Tints.*

The calibration of the fixed strips‡ can be advantageously effected, independently of the pendulum photometer, as follows:—The strip to be calibrated is gummed on to the reading-drum, and the points on this strip, of equal intensity to papers tinted by simultaneous exposure to zenith-light under vertical cylinders closed at the top with differently sized diaphragms, are ascertained. For a calibration thus made six cylinders were employed, each being 6 decims. long and 1 decim. in diameter, and blackened inside. On the top of each was fitted a metal plate perforated by a circular opening. These openings were of varying size, such that the relative intensities of the diffused zenith-light falling on the sensitive paper at the bottom of each cylinder were as follows:—

	Relative intensity.
Cylinder 1	1·00
„ 2	2·32
„ 3	4·00
„ 4	6·13
„ 5	8·72
„ 6	11·75

* Phil. Trans. 1865, vol. clv. p. 610. † Ibid. p. 615, fig. 6. ‡ Ibid. p. 610.

Standard sensitive papers thus exposed under the several cylinders were then taken into the dark room, and the points of identical tint on the fixed strip then read off. In this way a number of points are found upon the fixed strip, the relative intensities of which are known. The normal tint† (of which the intensity $=1$) is next read off on the strip; and if its reading corresponds to any one of the tints previously read off, the true value of that tint is known to be that of unity, and those of the other tints can readily be ascertained. Several experiments with the cylinders are made for each strip to be calibrated, and in one or more of these a tint is sure to be found equal to the normal tint. As an example I give the following data obtained in the calibration of a fixed strip marked C, on which the mean reading of the normal tint $I=1$ was found to lie at 132 millims.

Column I. contains the numbers of the cylinders under which the papers were exposed, column II. the mean reading of these tints on the fixed strip, column III. the corresponding relative intensities, and column IV. the true intensities when the tint of reading, 132 millims., is taken equal to the normal.

Experiment A.

I.	II.	III.	IV.
2.	170	2·32	0·27
3.	163	4·00	0·46
4.	151	6·13	0·70
5.	131*	8·72	1·00
6.	101	11·75	1·35

Experiment B.

2.	168	2·32	0·29
3.	158	4·00	0·52
4.	146*	6·13	0·79
6.	82	11·75	1·51

Experiment C.

1.	166	1·00	0·31
2.	150*	2·32	0·72
3.	106	4·00	1·24

Experiment D.

I.	II.	III.	IV.
1.	173	1·00	0·28
2.	157	2·32	0·65
3.	119*	4·00	1·12
4.	59	6·13	1·72
5.	21	8·72	2·44

Experiment E.

1.	161	1·00	0·44
2.	130*	2·32	1·02
3.	70	4·00	1·76
4.	15	6·13	2·69

Experiment F.

4.	147*	6·13	0·77
5.	123	8·72	1·09

The reading marked with an asterisk in each case is the one used to connect that experiment with the others. In cases in which no reading occurs identical with the one in previous experiments where the true intensities have been found, the true intensity of the nearest reading is obtained by interpolation from those of two previous observations. Thus the true intensity of the mean reading 146 millims. in Experiment B is found by interpolating from the true intensities of the mean readings 151 and 131 found in Experiment A.

From these numbers the following intensities are obtained for the undermentioned point on the strip in question:—

† Philosophical Transactions, 1863, vol. cliii. p. 157.

Millims.	I.	Millims.	I.	Millims.	I.	Millims.	I.
173	0·28	151	0·70	130	1·02	70	1·76
170	0·27	150	0·72	123	1·09	59	1·72
168	0·29	147	0·77	119	1·12	21	2·44
166	0·31	146	0·79	106	1·24	15	2·69
163	0·46	132	1·00	101	1·35		
158	0·52	131	1·01	82	1·51		

Hence the following Calibration Table is obtained for the same strip by graphical interpolation:—

I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
10	2·89	45	2·03	80	1·54	115	1·15	150	0·67
1	2·85	6	2·02	1	1·53	6	1·15	1	0·65
2	2·81	7	2·00	2	1·51	7	1·14	2	0·63
3	2·77	8	1·99	3	1·51	8	1·13	3	0·61
4	2·73	9	1·97	4	1·50	9	1·12	4	0·59
5	2·69	50	1·96	5	1·49	120	1·12	5	0·58
6	2·64	1	1·94	6	1·48	1	1·11	6	0·56
7	2·60	2	1·93	7	1·48	2	1·10	7	0·54
8	2·56	3	1·91	8	1·47	3	1·09	8	0·52
9	2·52	4	1·90	9	1·47	4	1·07	9	0·51
20	2·48	5	1·88	90	1·46	5	1·06	160	0·50
1	2·44	6	1·86	1	1·45	6	1·05	1	0·49
2	2·42	7	1·84	2	1·44	7	1·04	2	0·48
3	2·41	8	1·82	3	1·43	8	1·03	3	0·46
4	2·39	9	1·81	4	1·42	9	1·02	4	0·41
5	2·37	60	1·80	5	1·41	130	1·01	5	0·36
6	2·35	1	1·79	6	1·40	1	1·00	6	0·31
7	2·34	2	1·78	7	1·39	2	0·99	7	0·30
8	2·32	3	1·77	8	1·38	3	0·97	8	0·29
9	2·31	4	1·76	9	1·37	4	0·95	9	0·28
30	2·29	5	1·75	100	1·36	5	0·94	170	0·27
1	2·28	6	1·74	1	1·35	6	0·92	1	0·26
2	2·26	7	1·73	2	1·32	7	0·90	2	0·25
3	2·24	8	1·72	3	1·30	8	0·88	3	0·24
4	2·23	9	1·71	4	1·28	9	0·86	4	0·22
5	2·21	70	1·69	5	1·26	140	0·85	5	0·20
6	2·19	1	1·68	6	1·24	1	0·83	6	0·18
7	2·18	2	1·66	7	1·23	2	0·81	7	0·16
8	2·16	3	1·65	8	1·22	3	0·79	8	0·15
9	2·15	4	1·63	9	1·21	4	0·77	9	0·13
40	2·13	5	1·62	110	1·20	5	0·76	180	0·10
1	2·11	6	1·60	1	1·19	6	0·74		
2	2·09	7	1·59	2	1·18	7	0·72		
3	2·07	8	1·57	3	1·17	8	0·70		
4	2·05	9	1·56	4	1·16	9	0·68		

As a check upon this method of calibrating the fixed strip, a series of tints, obtained by exposure in quick succession in the hand-insolator * for known but varying times to the diffused light of a cloudless sky, were read off on the same strip. A Calibration Table was then constructed for the strip, and the values therein contained were found to coincide (within the limits of observational error) with those obtained by the former method.

* Philosophical Transactions, 1865, vol. clv. p. 612.

In order to avoid the necessity of making the foregoing experiments for the calibration of every new graduated strip, a series of standard tints * was prepared by reading off the points of identical tint on the graduated strip C. The following numbers were obtained:—

Standard tint.	Mean of ten readings.	Intensity.
No. I.	18 millims.	2·56
II.	54 "	1·90
III.	74 "	1·63
IV.	117 "	1·14
V.	132 "	1·00
VI.	146 "	0·74
VII.	157 "	0·54
VIII.	160 "	0·50
IX.	164 "	0·41

By means of these standard tints thus calibrated the intensities of any graduated strip can be read off.

III. *On the preparation of constant Sensitive Paper in long Strips.*

In the paper already referred to †, it has been shown that sheets of salted paper, each having an area of 0·3 square metre, can be silvered, so that each portion of the sheet, after drying, possesses exactly the same degree of sensitiveness. For the purposes of the present method the paper has to be used in the form of long thin strips; and if these strips can be silvered in lengths from 1 to 2 metres, and still retain a uniform degree of sensitiveness, much labour in cutting up the silvered sheets will be saved. That this uniformity can be obtained is seen from the following experiments.

Salted paper was silvered by laying it, in the form of sheets 2 decims. square, on to the surface of a 12 per cent. nitrate-of-silver solution. After lying on the bath for two minutes it was hung up to dry. Some of the same salted paper was next cut into long strips about 10 to 15 millims. in width, and these were silvered by floating on the silver solution contained in a narrow wooden trough 1·5 metre in length; the strips were then hung up to dry. Small pieces were next cut out of both the sheet and strip silvered paper, pasted on the back of the ordinary reading strips, and exposed to sunlight in two different hand-insolators at the same moment for identical periods of time. The tints obtained were read off on a calibrated strip, when it was found that the intensities obtained for the tints on the strip and sheet silvered paper were identical, as is shown by the following Tables:—

* Philosophical Transactions, 1865, vol. clv. p. 615, fig. 3.

† Ibid. 1863, cliii. p. 155.

Experiment A.									
Paper in sheet.					Paper in strip.				
No.	n.	Mean readi g.	I.	$\frac{I}{n}$.	No.	n.	Mean reading.	I.	$\frac{I}{n}$.
1.	20''	76	0·99	0·049	1.	20''	73	1·03	0·051
2.	15	117	0·76	0·051	2.	15	115	0·83	0·055
3.	20	72	1·04	0·052	3.	20	56	1·25	0·062
4.	15	78	0·98	0·065	4.	15	78	0·98	0·065
5.	10	79	0·97	0·097	5.	10	74	1·01	0·101
6.	10	131	0·66	0·066	6.	10	115	0·77	0·077
7.	15	76	0·99	0·066	7.	15	61	1·20	0·080
8.	10	114	0·78	0·078	8.	10	113	0·78	0·078
			Mean	0·066				Mean	0·071
Experiment B.									
1.	10	128	0·69	0·069	1.	10	126	0·70	0·070
2.	10	120	0·75	0·075	2.	10	122	0·73	0·073
3.	15	97	0·87	0·058	3.	15	114	0·78	0·052
4.	5	153	0·47	0·094	4.	5	154	0·45	0·090
5.	5	117	0·76	0·152	5.	5	131	0·66	0·132
6.	10	123	0·73	0·073	6.	10	125	0·71	0·071
7.	5	140	0·60	0·120	7.	5	139	0·61	0·122
8.	5	135	0·63	0·126	8.	5	140	0·60	0·120
9.	5	141	0·59	0·118	9.	5	142	0·58	0·116
			Mean	0·098				Mean	0·094

The mean intensity obtained by insolation of paper in sheet from the two experiments is therefore $\frac{0·066+0·098}{2}=0·082$; that obtained by the insolation of paper cut into strips and silvered is $\frac{0·071+0·094}{2}=0·082$. Hence we may conclude that the method of silvering the paper in strips can be relied upon.

IV. *Determination of the Times of Exposure of the constant Sensitive Paper in the Insolator.*

The time during which each one of the disks of sensitive paper is exposed to the total daylight depends upon the length which elapses between the contact of the elastic arm (E, fig. 1) with the two consecutive platinum pins on the wheel D. A certain time, however, elapses after the passage of the current before the escapement-wheel (F, fig. 2) on the insolator is brought into motion and the paper thus moved. It therefore becomes necessary to ascertain the times of exposure for each particular insolator, by observing the moment at which the paper is released, and noting the space of time which elapses until the paper disk disappears. The estimation of these intervals, some of them of only short duration, was made with a chronograph kindly lent by Mr. J. B. Dancer, by which intervals of time could be accurately measured to within one fifth of a second. A large number of observations were made with this instrument, and the mean reading of the interval taken as the duration of exposure for each one (see Table *infra*). In order to check these times, the duration of the longer intervals was also ascertained by counting with a watch whose seconds' hand indicated quarter seconds; and these coincided with the times observed with the chronograph.

Interval..	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.
	2″·2	2″·8	3″·8	5″·2	6″·7	9″·5	10″·8	17″·3	20″·2	31″·4
	2·0	3·0	2·8	5·3	7·0	8·7	10·3	16·2	20·6	32·0
	1·7	3·8	3·0	6·0	7·0	9·3	11·0	17·8	19·7	32·4
	2·9	3·1	4·3	5·3	6·8	9·9	10·0	16·9	19·4	31·1
	1·7	2·0	3·1	4·8	6·7	9·7	9·7	17·2	20·4	30·7
	2·7	2·6	3·9	5·2	6·7	9·0	10·2	18·1	20·5	31·7
	2·9	1·9	3·6	6·1	6·8	9·5	10·0	16·6	20·2	31·4
		3·0	4·0	5·2	7·0	9·2	10·3	17·0	20·5	31·1
			4·1	5·2	6·3	10·0	9·9	16·7	20·2	31·6
				4·5	6·9	9·2	10·1	17·9	20·5	32·0
				5·3	7·1	9·7	10·6	16·6	19·7	32·6
				5·3	7·0	9·4	10·1	17·0	20·1	32·4
					6·9	9·4	10·3	16·9		
					6·9	10·1	10·0			
					7·0	10·4	10·1			
					7·0	10·1	10·1			
					6·9	9·7	10·3			
						10·2				
Mean....	2·3	2·8	3·6	5·3	6·9	9·6	10·2	17·1	20·2	31·7

V. *Determination of the Coefficient for the Reflection and Absorption due to glass cover.*

In order to keep the disk of sensitive paper dry and to preserve the insolation-apparatus from damage by rain, it is covered during wet weather with a glass shade, chosen of such dimensions that the exposed disk of paper lies as nearly as possible in the centre of the hemisperical top of the shade. For the purpose of determining the value of the coefficient representing the loss of light caused by this glass covering, simultaneous observations of the intensity of total daylight were made with the hand-insolator and with the self-registering instrument covered by the glass shade. From the equation $I_h = I_c \times \text{const}$ (where I_h signifies the intensity obtained by the hand-instrument, and I_c that obtained by the self-recording instrument covered with the shade) the value of the coefficient can be ascertained. The following experiments give the value of the coefficient for the glass shade used in the determinations which follow. A similar series of observations must be made for every shade employed.

	Self-registering instrument.					Hand instrument.				
Experiment.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.
I.	h m 11 0 A.M.	″ 5·3 10·2 17·1	169 154 144	0·26 0·45 0·56	0·049 0·044 0·033	h m 11 0 A.M.	″ 5 10	154 133	0·45 0·65	0·090 0·065
				Mean	0·042				Mean	0·078
II.	2 0 P.M.	9·6 10·2 17·1	145 138 60	0·55 0·61 1·21	0·057 0·059 0·070	2 0 P.M.	10	57	1·24	0·124
				Mean	0·062				Mean	0·124
III.	2 30 P.M.	5·3 6·9 9·6	155 150 143	0·44 0·50 0·57	0·083 0·072 0·059	2 30 P.M.	5 5	140 137	0·60 0·62	0·120 0·124
				Mean	0·071				Mean	0·122
IV.	3 0 P.M.	3·6 5·3 6·9	168 162 150	0·28 0·36 0·50	0·077 0·068 0·072	3 0 P.M.	5 5	137 120	0·62 0·75	0·124 0·150
				Mean	0·072				Mean	0·137
V.	3 30 P.M.	5·3 6·9 9·6	160 139 121	0·39 0·61 0·74	0·073 0·088 0·077	3 30 P.M.	5 5	109 122	0·81 0·73	0·162 0·146
				Mean	0·079				Mean	0·154
VI.	4 0 P.M.	9·6 10·2 17·1 20·2	166 161 145 130	0·31 0·38 0·55 0·67	0·032 0·037 0·032 0·033	4 0 P.M.	10 15 15	131 117 65	0·66 0·76 1·14	0·066 0·051 0·076
				Mean	0·034				Mean	0·064
VII.	4 30 P.M.	20·2 31·7	116 68	0·77 1·10	0·038 0·035	4 30 P.M.	15	59	1·22	0·081
				Mean	0·037				Mean	0·081
VIII.	5 0 P.M.	17·1 20·2	137 133	0·62 0·65	0·036 0·032	5 0 P.M.	15	76	0·99	0·066
				Mean	0·034				Mean	0·066

The following Table shows that the values of the coefficient obtained at the undermentioned varying hours of the day are sensibly constant. The mean value 1·94 is therefore taken as representing the coefficient for the shade used in the determinations which follow:—

Time.	Coefficient for glass shade.	Deviation from mean.
h m		
11 0 A.M.	1·857	−0·080
2 0 P.M.	2·000	+0·063
2 30 ,,	1·950	+0·013
3 0 ,,	1·902	−0·035
3 30 ,,	1·718	−0·219
4 0 ,,	1·939	+0·002
4 30 ,,	2·189	+0·252
5 0 ,,	1·941	+0·004
Mean	1·937	0·083

VI. *Comparison of Curves of Daily Chemical Intensity obtained* (1) *with the Hand-insolator and* (2) *with the Self-recording Instrument.*

During the months of May, June, and July 1873 simultaneous hourly determinations of the chemical intensity of total daylight were made in Victoria Park, Manchester, with the hand-insolator and the self-recording arrangement described above on twelve separate days, whilst on ten other days the intensity was ascertained by the automatic apparatus alone. Of these I deem it unnecessary to give the details of more than six full days' observations with both instruments for the purpose of showing that the chemical intensities, as measured by the two methods, closely agree, and that therefore the self-recording instrument gives reliable and accurate results.

The daily observations selected for this purpose were made on May 17th and 19th, June 9th, 17th, and 18th, and on July 1st. The following Tables and accompanying curves (fig. 4, Plate L.) show the close correspondence of both sets of observations. The Curves marked in thicker lines give the results of the hand-insolator measurements, those in thinner lines the results of the measurements recorded by clockwork.

The integrals of total chemical intensity* for six of the days on which simultaneous observations were made with the two instruments agree as closely as can be expected from the nature of the case.

Daily Integrals of Chemical Intensity determined

	(1) By clock instrument.	(2) By hand instrument.
May 17th	82·8	81·6
,, 19th	49·5	47·2
June 9th	87·1	96·7
,, 17th	51·0	52·2
,, 18th	52·2	47·4
July 1st	111·2	117·3

I have to thank Mr. THOMAS CARNELLEY, B.Sc., for the able assistance which he has given me in carrying out the above determinations.

* Philosophical Transactions, "Bakerian Lecture," 1865, vol. clv. p. 621.

May 17th, 1873.

Clock.					Hand.				
Time.	n.	Mean reading.	I.	$\frac{I}{n}$.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.
h m 11 15 A.M.	″ 9·6	41	1·87	0·195	h m 11 15 A.M.	″ 10	56	1·74	0·174
	6·9	90	1·43	0·207		5	120	1·06	0·212
	5·3	148	0·84	0·154				Mean	0·193
			Mean	0·187				Diff.	—0·006
12 15 P.M.	9·6	47	1·82	0·190	12 15 P.M.	10	56	1·74	0·174
	6·9	75	1·57	0·227		5	119	1·10	0·220
	5·3	136	0·86	0·162		10	55	1·75	0·175
			Mean	0·193				Mean	0·190
								Diff.	+0·003
1 15 „	10·2	63	1·68	0·163	1 15 „	5	130	0·92	0·184
	6·9	97	1·37	0·198		10	56	1·74	0·174
						5	122	1·00	0·200
			Mean	0·182				Mean	0·186
								Diff.	– 0·004
2 15 „	3·6	144	0·78	0·216	2 15 „	5	127	0·95	0·190
	5·3	140	0·82	0·155		10	57	1·73	0·173
						5	126	0·96	0·192
			Mean	0·185				Mean	0·185
								Diff.	0·000
3 15 „	5·3	145	0·77	0·145	3 15 „	10	78	1·54	0·154
	6·9	92	1·42	0·205		5	139	0·83	0·166
	10·2	58	1·72	0·170		10	85	1·48	0·148
			Mean	0·173				Mean	0·156
								Diff.	+0·017
4 15 „	6·9	143	0·79	0·114	4 15 „	15	97	1·37	0·091
	17·1	71	1·60	0·094		10	122	1·00	0·100
	9·6	135	0·87	0·091		15	99	1·35	0·090
			Mean	0·099				Mean	0·094
								Diff.	+0·005
5 15 „	10·2	150	0·70	0·068	5 15 „	20	125	0·97	0·049
	17·1	124	0·98	0·057		15	128	0·94	0·062
	20·2	114	1·22	0·060		15	129	0·93	0·062
						15	135	0·87	0·058
			Mean	0·062				Mean	0·056
								Diff.	+0·006
6 15 „	20·2	154	0·64	0·032	6 15 „	20	158	0·58	0·029
	31·7	152	1·00	0·032		25	148	0·74	0·030
			Mean	0·032				Mean	0·029
								Diff.	+0·003

May 19th, 1873.

Clock.					Hand.				
Time.	n.	Mean reading.	I.	$\frac{I}{n}$.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.
h m 10 30 A.M.	6·9″	160	0·54	0·078	h m 10 30 A.M.	25″	73	1·59	0·064
	9·6	151	0·69	0·072		15	61	1·69	0·113
	17·1	100	1·34	0·078		10	149	0·72	0·072
	20·2	84	1·49	0·074		15	106	1·29	0·086
			Mean	0·076				Mean	0·084
								Diff.	−0·008
11 30 „	5·3	127	0·95	0·177	11 30 „	5	148	0·74	0·148
	6·9	52	1·78	0·257		10	34	1·94	0·194
	9·6	48	1·81	0·188		10	41	1·87	0·187
			Mean	0·207				Mean	0·176
								Diff.	+0·031
12 30 P.M.	20·2	138	0·84	0·042	12 30 P.M.	20	142	0·80	0·040
	17·1	155	0·62	0·036		15	151	0·69	0·046
	9·6	168	0·37	0·039					
			Mean	0·039				Mean	0·043
								Diff.	−0·004
1 30 „	17·1	98	1·36	0·079	1 30 „	10	141	0·81	0·081
	10·2	145	0·77	0·075		10	145	0·77	0·077
	9·6	152	0·67	0·070		7	146	0·76	0·108
			Mean	0·075				Mean	0·089
								Diff.	−0·014
2 30 „	No observations.				2 30 „	No observations.			
3 30 „	17·1	92	1·42	0·083	3 30 „	10	135	0·87	0·087
	10·2	145	0·77	0·075		15	126	0·96	0·064
	9·6	135	0·87	0·090		10	150	0·70	0·070
	6·9	152	0·67	0·097					
			Mean	0·083				Mean	0·074
								Diff.	+0·009
4 30 „	9·6	162	0·49	0·051	4 30 „	15	156	0·61	0·041
	17·1	152	0·67	0·039		20	146	0·76	0·038
	20·2	140	0·82	0·040		25	128	0·94	0·038
			Mean	0·043				Mean	0·039
								Diff.	+0·004
5 30 „	31·7	126	0·96	0·030	5 30 „	30	146	0·76	0·025
	20·2	155	0·62	0·030		20	159	0·56	0·028
						30	131	0·91	0·030
			Mean	0·030				Mean	0·028
								Diff.	+0·002

June 9th, 1873.

Clock.					Hand.				
Time.	n.	Mean reading.	I.	$\frac{I}{n}$.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.
h m 7 30 A.M.	17″·1	132	0·66	0·039	h m 7 30 A.M.	15″	136	0·63	0·042
	20·2	120	0·75	0·037		20	115	0·77	0·039
	31·7	56	1·25	0·039		30	56	1·25	0·042
			Mean	0·039				Mean	0·041
								Diff.	−0·002
8 0 „	6·9	114	0·78	0·113	8 0 „	10	84	0·95	0·095
	9·6	85	0·94	0·098		15	17	1·61	0·107
	10·2	55	1·26	0·124		10	50	1·31	0·131
			Mean	0·112				Mean	0·111
								Diff.	+0·001
9 0 „	5·3	139	0·61	0·115	9 0 „	No obse	rvations.		
	6·9	77	0·99	0·143					
	9·6	47	1·34	0·140					
			Mean	0·133					
10 0 „	10·2	140	0·60	0·059	10 0 „	10	137	0·62	0·062
	17·1	110	0·80	0·047		15	116	0·77	0·051
	20·2	70	1·07	0·053		20	62	1·19	0·060
			Mean	0·053				Mean	0·058
								Diff.	−0·005
11 0 „	5·3	138	0·61	0·115	11 0 „	10	30	1·49	0·149
	9·6	20	1·58	0·165		10	18	1·60	0·160
	10·2	17	1·61	0·158		15			
			Mean	0·146				Mean	0·154
								Diff.	−0·008
12 0	9·6	117	0·76	0·079	12 0 „	10	70	1·07	0·107
	10·2	105	0·83	0·081		10	73	1·03	0·103
	17·1	11	1·67	0·098		15	17	1·61	0·107
			Mean	0·086				Mean	0·106
								Diff.	−0·020
1 0 P.M.	3·6	132	0·66	0·183	1 0 P.M.	No obse	rvations.		
	5·3	121	0·74	0·140					
	6·9	25	1·54	0·223					
			Mean	0·182					
2 0 „	5·3	114	0·78	0·147	2 0 „	5	113	0·78	0·156
	6·9	112	0·79	0·114		10	18	1·60	0·160
	9·6	72	1·04	0·108		10	15	1·63	0·163
			Mean	0·123				Mean	0·160
								Diff.	−0·037

June 9th, 1873 (continued).

Clock.					Hand.				
Time.	n.	Mean reading.	I.	$\frac{I}{n}$.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.
h m 3 0 P.M.	″ 9·6	113	0·78	0·081	h m 3 0 P.M.	″ 10	67	1·11	0·111
	10·2	108	0·81	0·080		10	56	1·25	0·125
	17·1	20	1·58	0·092		15	15	1·63	0·109
			Mean	0·084				Mean	0·115
								Diff.	−0·031
4 0 ,,	9·6	132	0·66	0·069	4 0 ,,	10	83	0·95	0·095
	10·2	129	0·68	0·067		15	57	1·24	0·083
	17·1	55	1·26	0·074					
			Mean	0·070				Mean	0·089
								Diff.	−0·019
5 0 ,,	9·6	163	0·35	0·036	5 0 ,,	10	140	0·60	0·060
	10·2	161	0·38	0·037		10	140	0·60	0·060
	17·1	137	0·62	0·036		15	124	0·71	0·047
			Mean	0·036				Mean	0·056
								Diff.	−0·020
6 0 ,,	10·2	159	0·40	0·039	6 0 ,,	10	152	0·48	0·048
	17·1	143	0·57	0·033		15	131	0·66	0·044
	20·2	123	0·72	0·036		20	109	0·81	0·041
			Mean	0·036				Mean	0·044
								Diff.	−0·008

June 17th, 1873.

Clock.					Hand.				
Time.	n.	Mean reading.	I.	$\frac{I}{n}$.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.
h m 5 20 A.M.	″ 20·2	149	0·51	0·025	No observations.				
	31·7	117	0·76	0·024					
			Mean	0·025					
6 20 ,,	17·1	116	0·77	0·045					
	20·2	76	0·99	0·049					
			Mean	0·047					
7 20 ,,	5·3	161	0·38	0·072					
	6·9	147	0·53	0·077					
			Mean	0·075					
8 20 ,,	5·3	153	0·47	0·089					
	6·9	139	0·61	0·089					
			Mean	0·089					

June 17th, 1873 (continued).

Clock.					Hand.				
Time.	n.	Mean reading.	I.	$\frac{I}{n}$.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.
h m 9 20 A.M.	″ 5·3	145	0·55	0·104	h m 9 20 A.M.	″ No observations.			
	6·9	138	0·61	0·088					
			Mean	0·096					
10 20 „	6·9	60	1·21	0·175	10 20 „	5	119	0·75	0·150
	9·6	10	1·68	0·175		5	118	0·76	0·152
						10	20	1·58	0·158
			Mean	0·175				Mean	0·153
								Diff.	+0·022
11 20 „	5·3	153	0·47	0·088	11 20 „	5	150	0·50	0·100
	6·9	145	0·55	0·080		5	153	0·47	0·094
	9·6	129	0·68	0·071		10	117	0·76	0·076
			Mean	0·080				Mean	0·087
								Diff.	−0·007
12 20 P.M.	10·2	154	0·45	0·044	12 20 P.M.	10	156	0·43	0·043
	17·1	125	0·71	0·042		15	137	0·62	0·041
			Mean	0·043				Mean	0·042
								Diff.	+0·001
1 20 „	5·3	124	0·71	0·134	1 20 „	No observations.			
	6·9	95	0·89	0·129					
			Mean	0·132					
2 20 „	2·8	151	0·49	0·175	2 20 „	3	145	0·55	0·183
	3·6	131	0·66	0·183		5	123	0·72	0·144
	5·3	113	0·78	0·147		5	132	0·66	0·132
			Mean	0·168				Mean	0·153
								Diff.	+0·015
3 20 „	10·2	155	0·44	0·043	3 20 „	10	153	0·47	0·047
	17·1	142	0·58	0·034		15	146	0·54	0·036
			Mean	0·039				Mean	0·041
								Diff.	−0·002
4 20 „	10·2	134	0·64	0·063	4 20 „	10	138	0·61	0·061
	17·1	90	0·91	0·053		15	127	0·69	0·046
	20·2	63	1·17	0·058		20	69	1·09	0·055
			Mean	0·058				Mean	0·054
								Diff.	+0·004
5 20 „	10·2	158	0·41	0·040	5 20 „	10	158	0·41	0·041
	17·1	146	0·54	0·032		15	153	0·47	0·031
	20·2	123	0·72	0·036		20	120	0·75	0·035
	31·7	65	1·14	0·036		30	73	1·03	0·034
			Mean	0·036				Mean	0·035
								Diff.	+0·001

June 18th, 1873. (Protector for first four hours.)

Clock.					Hand.				
Time.	n.	Mean reading.	I.	$\frac{I}{n}$.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.
h m	"				h m	"			
4 30 A.M.	31·7	168	0·28	0·017	No observations.				
5 30 „	20·2	151	0·49	0·024					
	31·7	118	0·76	0·024					
			1·94 × mean	= 0·046					
6 30 „	10·2	146	0·54	0·053					
	17·1	117	0·76	0·044					
			1·94 × mean	= 0·093					
7 30 „	6·9	152	0·48	0·070					
	17·1	61	1·20	0·070					
			1·94 × mean	= 0·136					
8 30 „	3·6	147	0·53	0·147					
	5·3	122	0·73	0·138					
			1·94 × mean	= 0·123					
9 30 „	3·6	111	0·80	0·222					
	5·3	57	1·24	0·234					
			Mean	0·228					
10 30 „	2·3	133	0·65	0·282	10 30 A.M.	3	116	0·77	0·257
	2·8	118	0·76	0·271		5	22	1·57	0·314
	6·9	10	1·68	0·243		5	42	1·39	0·278
			Mean	0·265				Mean	0·283
								Diff.	−0·018
11 30 „	3·6	139	0·61	0·169	11 30 „	5	144	0·56	0·112
	6·9	107	0·82	0·111		5	143	0·57	0·114
	9·6	83	0·95	0·099		10	68	1·10	0·110
			Mean	0·129				Mean	0·112
								Diff.	+0·017
12 30 P.M.	3·6	119	0·75	0·208	12 30 P.M.	5	71	1·06	0·212
	5·3	62	1·19	0·225		5	71	1·06	0·212
	6·9	30	1·49	0·216		7	25	1·54	0·220
			Mean	0·216				Mean	0·215
								Diff.	+0·001
1 30 „	10·2	133	0·65	0·064	1 30 „	No observations			
	17·1	73	1·03	0·060					
			Mean	0·062					
2 30 „	17·1	147	0·53	0·031	2 30 „	10	166	0·31	0·031
						15	157	0·42	0·028
								Mean	0·030
								Diff.	+0·001

June 18th, 1873 (continued).

Clock.					Hand.				
Time.	n.	Mean reading.	I.	$\frac{I}{n}$.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.
h m	"				h m	"			
3 30 P.M.		No obser	vations.		3 30 P.M.		No obser	vations.	
4 30 „	31·7	167	0·30	0·010	4 30 „				
5 30 „	17·1	149	0·51	0·030	5 30 „	15	121	0·74	0·049
	20·2	112	0·79	0·039		20	71	1·06	0·053
	31·7					30	10	1·68	0·056
			Mean	0·035				Mean	0·053
								Diff.	—0·018

July 1st, 1873. (Protector for first two hours.)

Clock.					Hand.				
Time.	n.	Mean reading.	I.	$\frac{I}{n}$.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.
h m	"				h m	"			
5 0 A.M.	20·2	160	0·39	0·027	5 0 A.M.		No obser	vations.	
6 0 „	17·1	143	0·57	0·064	6 0 „				
(Henceforward fixed strip A used.)									
7 0 „	9·6	157	0·59	0·061	7 0 A.M.	10	152	0·67	0·067
	10·2	155	0·62	0·062		10	148	0·74	0·074
	17·1	118	1·14	0·067		15	128	0·94	0·063
			Mean	0·063				Mean	0·068
								Diff.	—0·005
8 0 „	10·2	172	0·31	0·030	8 0 „	10	169	0·36	0·036
	17·1	165	0·43	0·025		15	167	0·39	0·026
	20·2	165	0·43	0·023		20	158	0·58	0·029
			Mean	0·026				Mean	0·030
								Diff.	—0·004
9 0 „	17·1	160	0·54	0·032	9 0 „	10	155	0·62	0·062
	20·2	146	0·76	0·038		15	143	0·79	0·053
						20	124	0·98	0·049
			Mean	0·035				Mean	0·055
								Diff.	—0·020
10 0 „	5·3	162	0·49	0·092	10 0 „	5	154	0·64	0·128
	9·6	103	1·32	0·138		10	90	1·43	0·143
	17·1	10	2·18	0·127		15	29	1·98	0·132
			Mean	0·119				Mean	0·134
								Diff.	—0·015

July 1st, 1873 (continued).

Clock.					Hand.				
Time.	n.	Mean reading.	I.	$\frac{I}{n}$.	Time.	n.	Mean reading.	I.	$\frac{I}{n}$.
h m	"				h m	"			
11 0 A.M.	5·3	127	0·95	0·179	11 0 A.M.	5	165	0·43	0·086
	6·9	157	0·59	0·085		5	164	0·45	0·090
	9·6	152	0·67	0·070		10	142	0·80	0·080
			Mean	0·111				Mean	0·085
								Diff.	+0·026
12 0	2·8	148	0·74	0·264	12 0	3	150	0·70	0·233
	3·6	127	0·95	0·264		3	145	0·77	0·257
	5·3	119	1·10	0·207		5	119	1·10	0·220
			Mean	0·245				Mean	0·234
								Diff.	+0·011
1 0 P.M.	2·8	147	0·75	0·268	1 0 P.M.	3	145	0·77	0·257
	3·6	140	0·82	0·228		3	144	0·78	0·260
	5·3	122	1·00	0·190		5	86	1·47	0·294
			Mean	0·230				Mean	0·270
								Diff.	−0·040
2 0 „	3·6	122	1·00	0·278	2 0 „	No	observa	tions.	
3 0 „	2·8	163	0·47	0·168	3 0 „	3	159	0·56	0·187
	3·6	156	0·61	0·170		3	162	0·49	0·163
			Mean	0·169				Mean	0·175
								Diff.	−0·006
4 0 „	9·6	165	0·43	0·045	4 0 „	10	149	0·72	0·072
	17·1	127	0·95	0·056		15	143	0·79	0·053
			Mean	0·051				Mean	0·062
								Diff.	−0·011
5 0 „	6·9	162	0·49	0·071	5 0 „	15	120	1·06	0·071
	9·6	159	0·56	0·058		10	147	0·75	0·075
			Mean	0·065				Mean	0·073
								Diff.	−0·008

Fig. 1.

Fig. 2.

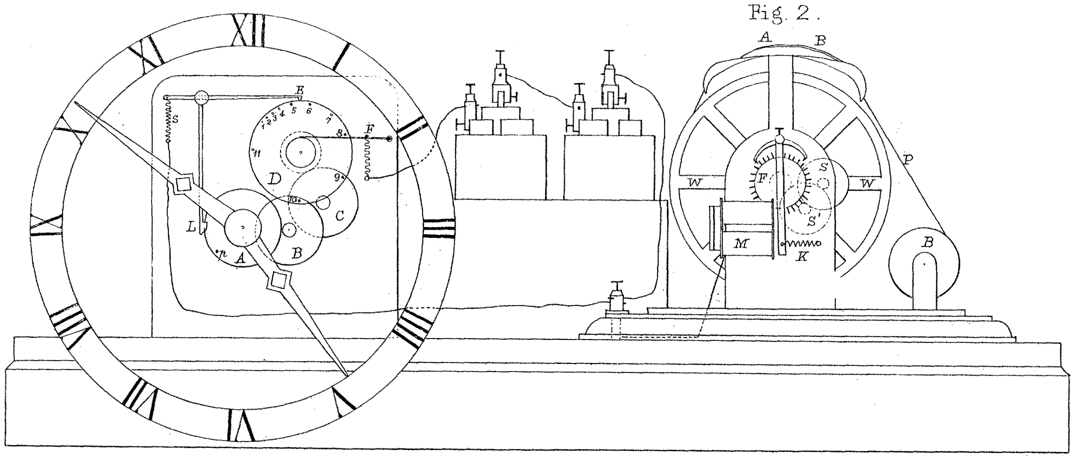

Fig. 3.

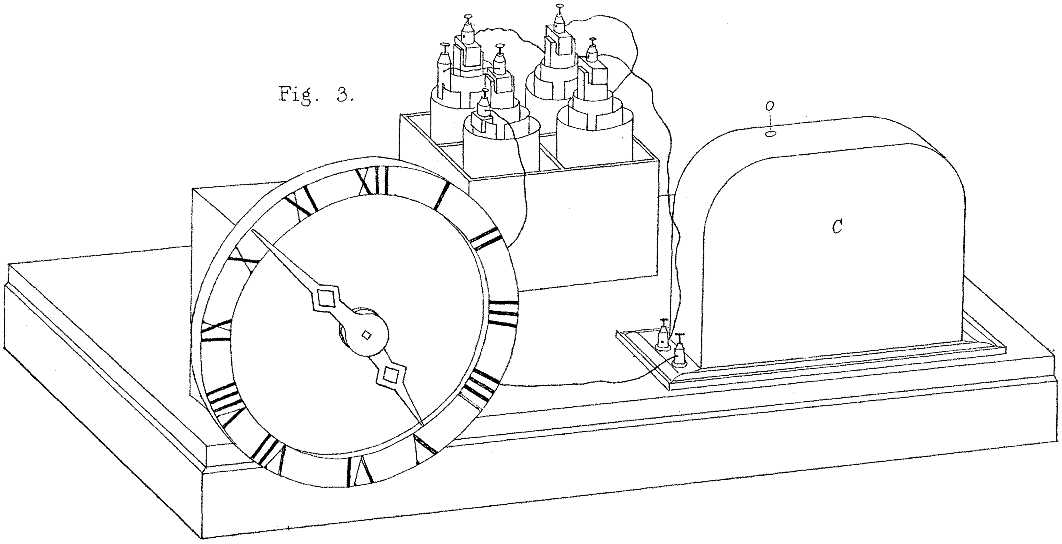

Fig. 4.