REPORT

OF THE

THIRTY-NINTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

EXETER IN AUGUST 1869.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1870.

reports which are not ready for the press immediately after the close of this present Meeting of the Association.

The Council have been informed that Invitations for 1870 will be presented to the General Committee by Deputations from Liverpool, Edinburgh, Brighton, and Bradford.

Report of the Kew Committee of the British Association for the Advancement of Science for 1868–69.

The Committee of the Kew Observatory submit to the Council of the British Association the following statement of their proceedings during the past year:—

The nature and amount of assistance to be rendered by this Committee to the Meteorological Committee of the Royal Society have now been clearly defined, and the duties undertaken at Kew Observatory may, as in the last Report, for clearness' sake be again considered under the two following heads:—

(A) The work done under the direction of the British Association.
(B) That done at Kew as the Central Observatory of the Meteorological Committee.

This system of division will be adopted in this Report, and it has been thought desirable, for the information of the Association, in the financial statement hereto appended, to include the sums received from the Meteorological Committee as well as those received from the British Association. It will thus be clearly seen that the work done at Kew for the Meteorological Committee has been paid for from funds supplied by that Committee, and not in any way from money subscribed by the British Association.

(A) Work done by Kew Observatory under the direction of the British Association.

1. *Magnetic work.*—The Self-recording Magnetographs ordered by the Mauritius Government for Mr. Meldrum, after having been verified at Kew, have been forwarded to their destination.

A Unifilar and Dip-circle for Mr. Meldrum have likewise been verified.

A Unifilar and Dip-circle have been repaired and verified for the Rev. M. Colombel, who has gone to Nankin, where he intends making magnetical observations.

M. Colombel as well as M. Berg, of the Wilna Observatory, have received magnetical instruction at Kew.

A Dip-circle is in the course of being verified for Lieut. Elagin, of the Russian Navy.

The usual monthly absolute determinations of the magnetic elements continue to be made by Mr. Whipple, Magnetic Assistant. During the last year it has been found necessary to replace the wooden pillars of the magnetic house with pillars of Portland stone, which had been previously ascertained to be non-magnetic. It has also been found necessary slightly to repair the Unifilar and Dip-circle hitherto used in these monthly determinations.

The Self-recording Magnetographs are in constant operation as heretofore, also under the charge of Mr. Whipple, and the photographic department connected with these instruments remains under the charge of Mr. Page.

The task of tabulating and reducing the magnetic curves produced at Kew

subsequent to January 1865 is in progress under the direction of Mr. Stewart. Considerable advance has been made in these reductions during the present year, and it is hoped that during the next session of the Royal Society a paper may be communicated to that body by Mr. Stewart, giving certain results of these reductions, as well as results of the absolute magnetic observations made every month.

Lieut. Elagin has communicated through Mr. Stewart to the Royal Society an account of observations made at the various European observatories, by means of a Dip-circle which had been lent to him from the Kew Observatory.

Mr. Stewart has likewise communicated to the Royal Society a short paper by Senhor Capello "On the reappearance of certain periods of Declination-disturbance during two, three, or several days;" also a joint paper by the Rev. W. Sidgreaves and himself, embodying the results of a preliminary comparison of the Kew and Stonyhurst declination-curves; also a paper embodying the magnetical results obtained by Lieut. Rokeby at the island of Ascension, reduced by Mr. Whipple, Magnetical Assistant at Kew. Finally, Mr. Stewart has communicated to the Royal Society a paper containing a preliminary discussion of the peaks and hollows of the Kew magnetic curves for the first two years during which the Magnetographs were in operation.

2. *Meteorological work.*—The meteorological work of the Observatory continues in the charge of Mr. Baker.

Since the Norwich Meeting, 157 Barometers have been verified, and 27 have been rejected; 1153 thermometers have been verified, and 24 have been rejected. Two Standard Thermometers have been constructed for the Standards' Commission*, one for Stonyhurst College, and nine for Professor Tait. 38 Hydrometers have likewise been verified.

The progressive nature of this department of the Kew work will be seen by the following statement of the numbers of Barometers and Thermometers verified during the last few years:—

	Barometers.	Thermometers.
1863–64	97	389
1864–65	88	420
1865–66	126	395
1866–67	89	608
1867–68	78	1139
1868–69	157	1153

The self-recording meteorological instruments now at work at Kew will be again mentioned in the second division of this Report. These are in the charge of Mr. Baker, the photography being superintended by Mr. Page.

A Self-recording Barograph verified at Kew for Messrs. R. & J. Beck has been disposed of by these opticians to Mr. Meldrum, of the Mauritius Observatory. A Barograph and Thermograph have been verified at Kew and dispatched to Mr. Ellery, at Melbourne, and a Barograph has recently been verified for Mr. Smalley, of Sydney.

At the request of Mr. G. J. Symons, the old Kew Thermometer frame has been lent to him for certain experiments, which are being carried on by him in conjunction with the Rev. C. H. Griffith, at Strathfield Turgis.

The attention of meteorologists is directed towards an instrument devised by Mr. Beckley, mechanical assistant at Kew, for the purpose of registering

* While this Report was being printed, an application was received from the Warden of the Standards, through Lieut.-Gen. Sir Edward Sabine, for an Air Thermometer.

the rainfall automatically. A description of this instrument will be submitted to the Association at Exeter.

Attention is likewise directed to a paper to be communicated by Mr. Balfour Stewart to the Association at the Exeter Meeting, entitled "Remarks on Meteorological Reductions, with especial reference to the Element of Vapour;" separate copies of which will be at the disposal of Members.

The following revised fees are charged for the verification of meteorological instruments at Kew:—

	s.	*d.*
Barometers (requiring index- and capacity-corrections) ..	10	0
Ditto (not requiring capacity-correction—inches measured)	5	0
Thermometers (ordinary)	1	0
Boiling-point Thermometers	2	6
Hydrometers	1	0

3. *Photoheliograph.*—The Kew Heliograph, in charge of Mr. De La Rue, continues to be worked in a satisfactory manner. During the past year 274 negatives have been taken on 168 days: 40 pictures of the Pagoda in Kew Gardens, as a fixed terrestrial object at a known distance, have likewise been taken, with the object of determining, by measurements of these pictures, which are taken in different parts of the field of the telescope, both the optical distortion of the sun-pictures and the angular diameter of the Sun.

A paper communicated to the Royal Society by Messrs. Warren De La Rue, Stewart, and Loewy, entitled "Researches on Solar Physics.—Heliographical Positions and Areas of Sun-spots observed with the Kew Photoheliograph during the years 1862 and 1863," is the first of the series of reductions of the photographic solar records; it is in the course of publication in the 'Transactions' and will shortly be distributed.

It is hoped that, during next winter, a paper containing the heliographical positions and areas of the spots observed at Kew during the years 1864, 1865, and 1866 may be communicated to the Royal Society, as well as a paper representing, both numerically and graphically, the spotted area of the sun during three complete solar periods, the results being partly derived from Schwabe's and partly from Carrington's observations, in addition to those made with the Kew photoheliograph.

Another paper by the above authors, entitled "Account of some Recent Observations on Sun-spots made at the Kew Observatory," has likewise been ordered to be published in the 'Philosophical Transactions.'

M. Berg, of the Wilna Observatory, has during the past year received instruction at Kew in the method of taking Solar Photographs and in that of measuring the positions and areas of sun-spots, the Director of the Observatory with which he is connected being desirous of working along with Kew, and of following out the same methods of observation as well as the same researches.

The number of sun-spots recorded after the manner of Hofrath Schwabe, together with a Table exhibiting the monthly groups observed at Dessau and at Kew for the year 1868, have been communicated to the Astronomical Society, and published in their 'Monthly Notices.'

We regret to mention that Hofrath Schwabe, owing to his great age, has found it necessary to discontinue his observations; but the Committee have satisfaction in stating that arrangements have been made for continuing, at Kew, the grouping of sun-observations which has been carried on for some

time according to Hofrath Schwabe's plan, and for publishing the results annually.

A minute comparison of the records of Hofrath Schwabe with the simultaneous photographic records at Kew has revealed the great trustworthiness of his drawings, which are at present in the possession of Kew Observatory. The proposed communication already alluded to as representing the spotted area of the sun during three complete solar periods is thus rendered possible; and while it is imagined that by this means a valuable record of the past will be obtained, it is hoped that the interest now displayed in solar research will secure the uninterrupted continuance of such a record for the future.

4. *Miscellaneous work.*—The Superintendent has recently received a grant of £60 from the Government-Grant Committee of the Royal Society for the purpose of continuing certain experiments by Prof. Tait and himself on the rotation of a disk *in vacuo*; and means are in progress for obtaining a nearly perfect vacuum, Mr. Beckley, Mechanical Assistant at Kew, having devised an apparatus for this purpose.

An account of preliminary observations made with Kater's pendulum by the Superintendent, in conjunction with Mr. B. Loewy, has been communicated to the Royal Society.

The instrument devised by Mr. Broun for the purpose of estimating the magnetic dip by means of soft iron, constructed at the expense of the British Association, remains at present at the Observatory awaiting Mr. Broun's return to England.

The Observatory was honoured on June 25th by a visit from the eminent French chemist, M. Dumas, permanent Secretary of the Imperial Academy of Sciences, Paris, accompanied by M. Hervé-Mangon.

(B) Work done at Kew as the Central Observatory of the Meteorological Committee.

The relation between the two Committees, the Kew and the Meteorological, has during the last year been definitely settled.

The Kew Committee have undertaken to maintain the self-recording instruments belonging to the Meteorological Committee in regular operation at Kew, to tabulate from the traces, and to forward the traces and tabulations once a month to the central office of the Meteorological Committee in London, where they will be finally reduced, under the supervision of the Director of that office. They have also sanctioned the employment of such assistance by Mr. Stewart as may be necessary to enable him to examine the records which arrive from the various outlying observatories of the Meteorological Committee in accordance with a plan which has been approved by that body. Once a week, therefore, documents from these various observatories arrive at Kew, and about the middle of each month the documents for all the observatories (including Kew) for the previous month, after having been well examined, are forwarded to the Meteorological Office with a few remarks, which are printed in the Minutes of the Meteorological Committee.

Besides these duties which they have undertaken, the Kew Committee are glad to render the Meteorological Committee any occasional assistance which it may be in their power to bestow.

1. *Work done at Kew as one of the Observatories of the Meteorological Committee.*—This consists in keeping in constant operation the Barograph, Thermograph, and Anemograph furnished by the Meteorological Committee. Mr. Baker is in charge of these instruments. From the first two of these instru-

ments traces in duplicate are obtained, one set being sent to the Meteorological Office and one retained at Kew; as regards the Anemograph, the original records are sent, while a copy by hand of these on tracing-paper is retained. The tabulations from the curves of the Kew instruments are made by Messrs. Baker, Page, and Foster.

2. *Verification of Records.*—In order to maintain uniformity in the system of observation at the various meteorological observatories, it is arranged by the Meteorological Committee that Mr. Stewart shall personally visit all the observatories once every year, in addition to which, when necessary, some one of the Kew assistants will occasionally visit particular stations with a specific object in view. At the request of the Meteorological Committee, a system of checks has been devised by the Kew Committee for testing the accuracy of the observations made at the different Observatories. This system, with slight modifications, is now in operation*. As this revision takes place at Kew, it has been found necessary to engage an additional assistant for the purpose of undertaking it. Mr. Rigby has been engaged for this duty—Mr. Baker, Meteorological Assistant, having the general superintendence of this department.

3. *Occasional Assistance.*—In addition to devising the system of checks mentioned above, the Kew Committee have also, at the request of the Meteorological Committee, examined the subject of instrumental verifications, and it has been found that, owing to improved construction, a higher standard of excellence in meteorological instruments may be insisted upon without rejecting more than a very small percentage of those furnished by good makers.

It has therefore been resolved by the Meteorological Committee that in future the following limits of error shall be allowed in the construction of their instruments:—

Marine Barometers of the pattern adopted by the Meteorological Office.—Reject all for which the index-error at the ordinary pressure is greater than ·015 inch, or the capacity-error greater than ·004 inch, or for which the mercury does not fall from $1\frac{1}{2}$ inch to $\frac{1}{2}$ inch above the present pressure in a time between 3 and 6 minutes. But for *barometers purporting to be standards*, reject all for which the index-error at the ordinary pressure is greater than ·010 inch.

Thermometers (graduated on the stem) of the pattern adopted by the Meteorological Office.—Reject all in which the largest error at any point is greater than 0°·3, or in which any space of 10° is more than 0°·3 wrong.

Hydrometers of the pattern adopted by the Meteorological Office.—Reject all in which the largest error at any point is greater than 1 division of the scale (equal to ·001 sp. gr.), or in which any space of 10 divisions is more than 0·6 division wrong.

Models of Pantagraphic Apparatus, designed by Mr. Galton, have been made and experimentally used at Kew, at the desire of the Meteorological Committee, to reduce the tracings of the self-registering instruments in any desired proportions, either in length or in breadth, with a view to the ultimate publication by that Committee of all the tracings supplied by the seven Observatories in a compact volume.

It may also be mentioned, under the head of Occasional Assistance, that at the request of the Meteorological Committee, Mr. Beckley, Mechanical

* This scheme, having been extracted, with permission, from the Report of the Meteorological Committee, will be found in the Appendix to this Report.

Accounts of the Kew Committee of the British Association from August 19, 1868, to August 18, 1869.

RECEIPT

	£	s.	d.
Balance from Central Observatory account	4	1	10
Received from the General Treasurer	600	0	0
„ for the verification of Meteorological Instruments from the Meteorological Office 34 5 0			
„ „ from Opticians 61 16 6	96	1	6
„ for the verification of Magnetical Instruments	35	0	0
„ for the verification of self-recording Meteorological Instruments	25	0	0
„ for the construction of a Standard Thermometer	1	0	0
„ from the Meteorological Office:—			
Allowance as one of the Observatories of the Meteorological Committee, from 1st October 1868 to 30th September 1869	250	0	0
Extra allowance from Meteorological Committee to Kew as Central Observatory:—			
From 1st October 1868 to 1st January 1869, at £120 per annum 30 0 0			
From 1st January to 30th September 1869, at £200 per annum 150 0 0			
For subsidiary Barograph tabulations 25 0 0			
For lamp-glasses sent to various Observatories 1 11 4			
For services of assistants 7 10 0	214	1	4
	£1225	4	8

PAYMENTS.

	£	s.	d.
Balance from last account	0	0	5
Salaries, &c.:—			
To B. Stewart, four quarters, ending 30th September, 1869 ..... 200 0 0			
Ditto, allowed for petty travelling expenses ... 10 0 0			
G. Whipple, salary to quarter ending 30th September, 1869 ..... 128 6 0			
T. Baker 100 0 0			
F. Page 70 0 0			
J. Rigby, from 4th Feb. to 30th Sept., 1869 ... 39 3 0			
R. Beckley, to 16th August, 1869 ..... 127 0 0			
J. Foster, salary from 4th July, 1868, to 5th June, 1869, 48 weeks at 12s. per week... 28 16 0			
A. Hill, salary from 7th Nov., 1868, to 5th June, 1869, 30 weeks at 8s. per week ... 12 0 0	715	5	0
Apparatus, Materials, Tools, &c.	62	8	7
Ironmonger, Carpenter, Mason	30	19	6
Printing, Stationery, Books, Postage	40	1	9
Coals and Gas	68	2	3
House Expenses, Chandlery, &c.	67	18	10
Porterage and petty expenses	61	12	0
Meteorological work done at extra hours	70	17	6
Magnetical work done at extra hours	39	12	6
Rent of Land attached to Observatory	11	0	0
Tuition of assistants	10	10	0
Balance	46	16	4
	£1225	4	8

Examined with the vouchers and found correct.

3rd *August*, 1869.

A. STRANGE, Lt.-Col.

Assistant, was sent to Armagh to examine the Barograph there, and to Sandwick-manse, Orkney, to superintend the erection of an anemometer. The expenses have, on both these occasions, been repaid by the Meteorological Committee.

In conclusion, the Kew Committee desire to bring under the notice of the British Association, that the system of automatic records established and in actual work at the Kew Observatory, comprehends magnetic, barometric, and thermometric observations, as well as those of the direction and velocity of the wind, to which an electric self-recording instrument will soon be added. They think that it would be very advantageous to magnetical and meteorological science if a fully illustrated work were published descriptive of these instruments, and of the method of working them, together with the method of reductions actually employed.

J. P. GASSIOT, *Chairman.*

Kew Observatory,
15th July, 1869.

APPENDIX.

A Description of the Means adopted by the Meteorological Committee for ensuring Accuracy in the Numerical Values obtained from their Self-recording Instruments.

(Extracted, with permission, from the Report of the Meteorological Committee.)

In the first Report of this Committee the principles of construction of their self-recording instruments were fully described, and enough was said to render it probable that good results would be obtained; but the final method of tabulating from the traces of these instruments was not then decided on, nor had any scheme been devised for ensuring accuracy in the tabulated numerical values.

The labours of the Committee in this department have been materially aided by suggestions from the superintending Committee of the Central (Kew) Observatory, and also from the Directors of the various outlying observatories, and as a result the Committee are now satisfied that the process of examination to which the tabulated values are subjected before reaching the central office is such as to afford a satisfactory guarantee of accuracy.

It may be a fitting sequel to the description of these instruments (already given), to give here an account of the method adopted for ensuring accuracy in the results which they afford.

In the first place, the nature of the various instrumental errors and the best method of avoiding these may with propriety be described, and in the next place it may be desirable to give in detail the code of regulations adopted by the Committee for the guidance of their various observatories.

Barograph.

The values of atmospheric pressure derived from this instrument are liable to have their accuracy affected by three causes:—

(1) By an imperfect temperature compensation.
(2) By a sluggish action of the mercury in the Barograph tube.
(3) By imperfection in the system of recording and tabulating.

Temperature compensation.—The method by which the Barographs are compensated for temperature has been described in the Report of the Meteorological Committee for the year 1867. The precise position of the fulcrum of the glass rod was determined by means of some preliminary expe-

riments made at Kew upon the first Barograph. These experiments consisted in subjecting the instrument to a very considerable range of temperature artificially produced, while frequent comparisons of its indications with those of a Standard Barometer gave the means of determining approximately what ought to be the position of the fulcrum. It may be presumed that the determination thus arrived at cannot be wrong more than one-tenth of the whole, and assuming this to be the case, the next point is to find what is the actual daily temperature range at the various observatories.

The following Table exhibits both the mean and the maximum daily range for each month for each of the seven observatories up to the end of 1868. In all these, with the exception of Stonyhurst, a night observation is made of the temperature of the Barograph at 10 o'clock, but the result will show that in Stonyhurst such an observation is unnecessary. It ought here to be borne in mind that from the system adopted in these instruments, namely, constant reference each day to a standard, it is only the daily range of temperature that we have to consider.

Daily range of temperature, in degrees Fahrenheit, as given by the observation hours.

1868.	Aberdeen.		Armagh.		Falmouth.		Glasgow.		Kew.		Stonyhurst.		Valencia.	
	Mean.	Maximum.	Mean.	Maximum.	Mean.	Maximum.	Mean.	Maximum.	Mean.	Maximum.	Mean.	Maximum.	Mean.	Maximum.
January	...	...	...	...	...	...	1·9	4·9	...	...	0·2	0·8	...	...
February ...	...	...	...	...	...	...	1·4	3·0	0·9	1·7	0·2	0·6	...	...
March	...	...	...	...	...	...	1·7	4·3	0·9	1·7	0·2	1·6	...	...
April	2·1	3·7	...	...	...	...	1·6	3·4	1·1	3·1	0·1	0·6	...	...
May	1·9	5·0	...	...	1·4	3·0	1·4	3·0	1·4	3·3	0·2	0·6	...	...
June	2·1	3·7	...	...	1·7	6·7	1·9	4·1	1·5	3·7	0·4	1·8	...	...
July	3·0	4·8	...	...	1·9	3·6	2·1	4·4	2·0	5·6	0·8	3·0	...	...
August	1·9	3·2	1·7	3·9	1·7	2·8	1·9	4·8	2·7	7·0	0·5	1·3	1·4	2·5
September ...	2·3	4·6	1·8	3·8	1·8	6·3	2·2	7·3	2·4	8·7	0·5	1·2	1·2	2·6
October	1·5	2·5	1·9	3·6	1·4	3·0	2·0	6·0	0·8	1·8	0·6	2·7	1·2	2·7
November ...	2·1	3·7	1·9	3·6	1·4	2·8	1·3	3·1	1·0	1·9	0·7	1·3	1·2	2·4
December ...	2·0	6·3	1·4	2·2	1·1	2·3	1·3	4·9	0·9	2·5	0·7	2·4	1·0	4·3

From the results of this Table it would appear that, assuming the temperature adjustment to be one-tenth wrong, the greatest error introduced from this cause into any of the observations during the year 1868 would be about 0·0024 in., while the mean monthly error would be inappreciable in all cases.

We may therefore with confidence presume that in these Barographs the method of tabulation exemplified in the Report for 1867 and now practised is sufficiently accurate to obviate all effects of changes of temperature, and that it is unnecessary to resort to that more complicated but perfect system of reduction alluded to in the same Report, by which the influence of temperature may be completely eliminated. The near correspondence between the simultaneous Standard and Barograph readings, as exhibited in page lvii of this Report, is another proof that the temperature correction is practically perfect.

Sluggishness of Mercury.—As the Barograph tube is always in perfect

repose, and the adhesion of the mercury to the glass is not counteracted by tapping or moving the tube, it is desirable to test the results obtained in order to see if the influence of adhesion causes a perceptible sluggishness of the mercury. The Standard Barometers, to which in all cases the Barographs are referred, are, on the other hand, subject to motion, and are probably sufficiently moved in the operation of reading to counteract any sluggishness of the mercury.

Now, four or five times each day, while the light is cut off from the recording cylinder of the Barograph by the clock arrangment, the Standard Barometer is read. We can thus compare these standard readings with the simultaneous measurements of the Barograms, these latter being of course properly tabulated, converted into true inches, and the residual correction applied as described in the Report of the Meteorological Committee for 1867.

Should there be any sluggishness in the mercury of the Barograph we might expect to discover it by means of this comparison, for in such a case the Barograph would lag behind, and thus read too low with a rising and too high with a falling barometer.

If therefore we presume that the Standard Barometer is free from sluggishness, and denote its readings by S, and those of the Barograph by B, then S—B ought in the case of sluggishness of the Barograph to be *positive* for a *rising* and *negative* for a *falling* barometer.

Several months' observations have been discussed in this manner for each of the observatories, and the result is exhibited in the following Table :—

Name of Observatory.	Months used.	S—B (Barometer rising).	S—B (Barometer falling).
		in.	in.
Aberdeen	July to December	+0·00033	−0·00028
Armagh	September to December ...	+0·00045	−0·00032
Falmouth	August to December	+0·00006	−0·00020
Glasgow	July to December	+0·00027	−0·00025
Kew	January to June	+0·00027	−0·00019
Stonyhurst.....	January to June	−0·00042	+0·00058
Valencia	August to November	+0·00005	+0·00015

From this Table we see how inappreciable in all the observatories is the retardation of the Barograph Barometer as compared with the Standard, while in Stonyhurst the Standard even appears to be a trifle more retarded than the Barograph Barometer.

Errors of recording and tabulating.—Under this head we may include (A) errors of adjustment and attachment of paper, (B) errors of time and date, (C) errors in tabulating from the traces. To begin with the first of these :—

(A) *Errors of adjustment and attachment of paper.*

Want of definition arising from an improper adjustment of the lens ought to be noticed, but it is believed that the definition is good in the case of all the observatories. As the instrumental constants for all the various Barographs have now been determined, it would hardly seem expedient to alter the position of the lens, which would alter these constants, for the purpose of procuring greater perfection in definition.

The photographic sheet which is attached to the cylinder of the Barograph

ought to be evenly put on without any *bagging* or *bulging*; as, if it bulged, besides giving a bad result, it might come into contact with the end of the temperature adjustment bar.

Care ought to be taken that there is no *want of light*, especially in the case of a low barometer; and finally, great precaution should be taken to avoid *finger-marks* and every species of *bad photography*.

(B) *Errors of Time and Date.*

Suppose that the sheet has been placed in an unexceptionable manner upon the Barograph cylinder, the next point is for the operator to set the instrumental clock before starting to correct Greenwich mean time, as given by his chronometer. Now the instrumental clock has an arrangement for cutting off the light for four minutes every two hours, beginning to do so two minutes before an even hour and ending two minutes after it, and the practice is for the observer to read the Standard Barometer about five times every day at periods two minutes after even hours, as ascertained by his chronometer, or when the light should be about to be restored after having been cut off by the clock-stop. If therefore the instrumental clock keeps good time and its stop acts, and if the observer reads the Standard Barometer correctly and at the proper moment as ascertained by his chronometer, and if he finally reduces his curves properly, the near coincidence between the corresponding curve and Standard readings will be a good practical test, not only that all these operations have been properly performed, but also that throughout the curve the instrumental clock keeps good time with the chronometer. A further check with regard to time is afforded by the comparison made between the chronometer and the instrumental clock at the moment when the curve is taken off the cylinder, the results of which are recorded on the curve.

The clock may sometimes possibly stop, or the clock-stop may go wrong. Without discussing minutely these possibilities, it may be sufficient to state that when any such misadventure occurs the curve ought to be inspected by the Director of the Central Observatory.

There still remains the question of *date*. The security that a curve is rightly dated depends ultimately on the strong improbability that an observer at any of the observatories should make a mistake with regard to the first day of the week. When therefore he returns the Barograph journal filled up, we may be quite certain that the observations entered on the line with Sunday were really made on that day, although he may possibly put the wrong day of the month on the form beside it.

Again, the photographic operator when he takes off a curve, should mark on the back in pencil the day of the week and month when the curve was taken off, and should also, after drying, write upon its face the hour and day of putting on and taking off as recorded by the journal. If, therefore, the accuracy of the observer in assigning the proper day of the month to Sunday be checked at Kew as each week's journals are transmitted to that establishment, and if it also be seen that the date written in pencil on the back of the curve corresponds to that written on its face, and if the times of starting and ending of the curve as described in front are found to agree with the curve itself as measured by a simple time-scale, there can hardly be any doubt that the curve has been properly dated; if there still remain any doubt it will be dispelled when the tabulations from that curve are examined and it is found that the tabulated readings agree well with the simultaneous readings of the Standard Barometer.

(C) *Errors in tabulating from the traces.*

It will, in the first place, be necessary to discuss some arrangement for ensuring the entry under the *proper date* into the tabulation forms of the measurements from each curve; for even supposing that by the method now described we can ensure the proper dating of the curve, yet the tabulations from this curve may be entered under the wrong date in the tabulation form.

The appropriate check would seem to be the independent entry from the journal of the Standard readings reduced. For if either of these two independent entries be wrongly made, this will be seen by a non-coincidence of the reduced readings when compared with the simultaneous Standard readings. Our security becomes, therefore, the security which we have that these two independent readings cannot both be erroneously entered, and this may be converted into a certainty if the assistant at the Central Observatory sees that the journal readings are entered under their proper dates into the Barograph tabulation forms.

Having thus ascertained the entry into the tabulation forms under their proper dates of the tabulations and of the reduced standard readings, we come next to inquire what check there is for *accuracy of tabulations*; and here we may consider separately the cases of large and small errors.

But before proceeding to this part of the subject it may be desirable to say a few words regarding the system of Barograph tabulation.

The progress made in tabulating the Barograms up to the date of publication of the last Report of the Committee has been described in that Report. The first operation is to measure by the aid of a simple tabulating instrument, carrying a scale with a vernier attached to it, and capable of being read to the thousandth of an inch, the whole depth of the Barogram for every hour.

This system is nevertheless laborious, implying two measurements and one subtraction for each hour, besides the application of tables of conversion, and the consequence is the liability to make an occasional mistake. But although at first it is absolutely necessary to have in the case of the Barograph a tabulating instrument measuring inches, in order by its means to determine the constants of each instrument, yet when once these instrumental constants have been accurately determined, it has been found serviceable to replace the tabulating instrument by another which gives the true pressure in one measurement, instead of requiring two measurements, one subtraction and one conversion. Instruments of this nature have been obtained by this Committee for their various observatories, by which the labour of tabulation has been greatly reduced and accuracy of result much increased.

Nevertheless there is still the liability to make an occasional blunder, and as this may take the shape of a large error, it is necessary to devise some means for detecting and obviating all such mistakes.

The best remedy appears to be the use of a simple kind of subsidiary tabulating instrument, consisting of an ivory scale having a breadth equal to one hour of the time-scale, by means of which the hourly depth of the Barogram may be read to the hundredth of an inch. If these readings be compared with the readings taken independently by the tabulating instrument, any error in the latter will be at once discovered; for the errors to which the tabulated measurements are liable are such as *five hundredths of an inch*, or *one-tenth of an inch*,—errors of a large size, which may easily be detected by the system of sudsidiary measurement.

The following is an example of a day's comparison after this method, exhibiting an error which has thus been brought to light:—

August 29th.	Tabulated reading from weekly tabulation sheet to the nearest hundredth. A.	Subsidiary tabulation with ivory scale. B.	A—B in hundredths of an inch.
1 A.M.	30·22	30·21	+1
2 „	·22	·22	0
3 „	·21	·21	0
4 „	·22	·23	−1
5 „	·22	·22	0
6 „	·23	·22	+1
7 „	·24	·24	0
8 „	·25	·25	0
9 „	·25	·25	0
10 „	·26	·26	0
11 „	·26	·27	−1
Noon	·26	·27	−1
1P.M.	·25	·25	0
2 „	·25	·25	0
3 „	·26	·27	−1
4 „	·25	·26	−1
5 „	·25	·25	0
6 „	·24	·34	−10 Error.
7 „	·24	·24	0
8 „	·24	·25	−1
9 „	·25	·26	−1
10 „	·24	·24	0
11 „	·24	·24	0
Midnight	30·24	30·25	−1

It ought to be remarked as necessary to the completeness of the check, that the observer should first of all by means of his subsidiary ivory scale fill in column B, and then (meanwhile concealing B from his view) fill in column A from the ordinary tabulation sheets. The correctness of the column A—B should be tested at the Central Observatory.

Having by this means obtained correct tabulations, the next point is to check the accuracy with which the *residual correction* has been obtained and applied (see Report for 1867, page 46). And first, with regard to the method by which it is obtained, the latest practice has been to calculate it for each day separately, making the day begin at 11 A.M. The advantage of this arrangement is that each fresh paper, which is always put on between 10 and 11 A.M., will have its own residual correction*. The accuracy of calculation of this correction ought to be checked, and such a check may be devised out of the practice pursued at Kew, of taking the mean monthly difference between simultaneous readings of the Standard and Barograph readings corrected. If these differences are taken for each day apart, beginning the day at 11 A.M. and giving each difference its appropriate sign, then the residual correction may be presumed to be accurate, when for that day there are as many *minus* as *plus* differences. Also, when any such difference exceeds, say, ·005 of an inch, the accuracy with which the

* A special arrangement regarding the residual correction has been made for Sundays and those days on which there are few observations of the Standard Barometer.

Standard readings have been reduced to 32° ought in this case to be examined. When a Standard reading is evidently wrong it ought to be noted as such on the curve, and should not be made use of either in calculating the residual correction or the monthly mean difference between the Standard and Barograph readings. By applying both the above tests any error in the calculation of the residual correction will be detected, and ought to be remedied at once. Having by this means obtained an accurately calculated residual correction, the accuracy with which this is applied to the various hours ought to be tested by the Kew assistant, who, obscuring from his view the column which embodies the values after the residual correction has been applied, should independently apply it on a separate piece of paper, thus producing a new column of corrected pressure, which ought to be compared with the old one; any error discovered by this comparison should be corrected at once. Before leaving this subject, it ought to be stated that the tabulating instrument as well as the subsidiary ivory scale are so arranged as always to ensure reading the proper point of the curve for every odd hour.

Should any portion of the curve be too *faint* for measurement with the ordinary tabulating instrument, but not too faint for measurement with the ivory scale, it ought to be measured with this scale, applying to the measurements so obtained their own appropriate residual correction. Such readings ought to be specially noted in the tabulation forms.

Should any part of the curve be *deficient from want of light or any other cause*, it ought not to be inked in. If the deficiency be in the border of the temperature curve, it will be possible to correct it, but if it be in the barometric curve, this cannot be done.

All curves in which the *clock has stopped or the clock-stop has been out of action*, should be personally inspected by the Director of the Central Observatory, in order that he may ascertain if the tabulations have been properly made.

Finally, it is right to state that the accuracy of the method of checking the tabulated values now described, has been practically confirmed by the month of October at Kew being independently measured by two observers. The results of the two sets, when compared together, are found to differ very slightly from one another, the greatest difference being ·008 in., which may be supposed to denote a difference in each of ·004 on either side of the truth. This extreme difference only occurs three times in the course of the month, that is to say, in 744 observations.

The method of subsidiary tabulations now described is thus proved to be effective in discovering the larger errors that the observer is liable to make when he measures the curve. But to ensure an efficient standard of correctness, it is not only necessary that the larger errors should be altogether eliminated, but *smaller errors* should be reduced to a minimum. Thus an observer might be sufficiently cautious in reading his scale to make no large error, yet sufficiently incautious to read erroneously when he came to the third figure of decimals. For rough results such an observer might be reckoned a good one, but for the more delicate class of investigations his figures would be of less value.

The only way of perfectly eliminating this class of errors is for two independent observers to make separate measurements, each with a tabulating instrument, a course involving much additional labour and expense. But it is obvious that the Standard Barometer affords a ready approximate means of estimating the correctness of an observer's results. For should he be an incautious observer, the mean difference between the simultaneous readings

of the Standard and the Barograph Barometer will be comparatively great, but if he both observe his Standard and measure his curves well, the mean difference will be small.

The following Table exhibits the results of monthly comparisons between simultaneous Barograph and Standard readings for the year 1868 for all the observatories.

Mean Differences between Barograph and Standard Readings.

	Aberdeen.	Armagh.	Falmouth.	Glasgow.	Kew.	Stonyhurst	Valencia.
1868.	in.	in.	in.	in.	in.	in.	in.
January	.....	.....	.....	0·0067	0·0027	0·0032	.....
February	.....	.....	.....	0·0045	0·0027	0·0032	.....
March	.....	.....	.....	0·0039	0·0028	0·0025	.....
April	0·0035	.....	.....	0·0035	0·0027	0·0017	.....
May	0·0032	.....	0·0042	0·0036	0·0025	0·0031	.....
June	0·0029	0·0049	0·0029	0·0036	0·0021	0·0021	.....
July	0·0032	0·0045	.....	0·0026	0·0027	0·0032	.....
August	0·0031	0·0033	0·0032	0·0038	0·0025	0·0023	0·0033
September	0·0023	0·0031	0·0041	0·0031	0·0025	0·0025	0·0027
October	0·0028	0·0029	0·0024	0·0030	0·0017	0·0028	0·0031
November	0·0019	0·0024	0·0017	0·0029	0·0015	0·0019	0·0038
December	0·0022	0·0022	0·0022	0·0028	0·0018	0·0030	0·0033

It is imagined that the mean differences shown by this Table have for all the observatories by the end of the year reached a minimum value not much larger than would be obtained by two observers reading the same Standard, or by the same observer reading it twice.

But while the simultaneous readings of the Standard and Barograph Barometer afford us one means of testing the correctness of the observation measurements, they do not yet do quite enough; for, in the first place, these simultaneous differences may be caused in part by an instrumental error or by some local peculiarity, such as rapid heaving of the barometer, and in the next place, an observer may unconsciously bestow a greater amount of pains upon these measurements, which are simultaneous with Standard readings, than he does upon his other measurements, and the above differences may not therefore be a true representative of his general correctness. A certain number of remeasurements of the curves of each observatory should therefore be made at the Central Observatory, and the monthly mean difference between these and the corresponding measurements by the local observer be recorded*.

* It was not until the various observatories had been supplied with their improved tabulating instrument that the final method of making these measurements was decided on. Since the beginning of 1869 the plan has been to make for each month for each observatory forty remeasurements of the curve at Kew, obtaining also independently the residual correction. These final values are then compared with the corresponding values obtained at the outlying observatories, and the result of this comparison for the first three months of 1869 has been as follows:—

Mean Difference between 1st and 2nd Measurements.

	Aberdeen.	Armagh.	Falmouth.	Glasgow.	Kew.	Stonyhurst.	Valencia.
1869.	in.	in.	in.	in.	in.	in.	in.
January	0·0020	0·0017	0·0026	0·0022	0·0012	0·0029	0·0017
February	0·0030	0·0025	0·0023	0·0022	0·0023	0·0031	0·0026
March	0·0024	0·0021	0·0025	0·0026	0·0018	0·0030	0·0025

THERMOGRAPH.

The accuracy of the Thermograph results is liable to be deranged by three causes:—

(1) By a cause depending on the situation and exposure of the instrument.
(2) By instrumental deficiencies, and especially the arrangements connected with the wet bulb.
(3) By a deficient system of tabulation.

Situation of Instruments.

The situation of their various Thermographs was a point carefully considered by the Meteorological Committee, and there is no reason to think that the effect of local peculiarity is considerable in the case of any of their instruments.

In the Report for 1867 this subject was alluded to, and the result of simultaneous comparisons made at Kew between the readings of two sets of dry and wet bulbs was given for the month of February, one of these sets being placed in a frame detached from the main building of the observatory, and the thermometers having very small bulbs, the other set being the wet- and dry-bulb Standard Thermometers of the Thermograph frame.

The result seemed to indicate that the local peculiarity of either frame was comparatively small; indeed, taking the average of the month, there was no residual difference between the dry bulbs, while, on the whole, the Thermograph wet bulb stood 0°·12 higher than the other.

A similar comparison made for the month of July gave no residual difference either for the dry or wet bulbs.

Dr. Robinson, of Armagh, has likewise made a similar comparison between his Thermograph dry bulb and another Thermometer placed at a higher elevation, and has obtained as the result of 150 observations made during the months of April and May, a mean difference indicating that the Thermograph Thermometer read on the whole 0°·27 less than the other. While this difference is not large, Dr. Robinson is of opinion that the upper thermometer is more liable to be affected by the sun, and that the Thermograph Thermometer is in consequence the most correct. No other observations have been made on the subject.

Instrumental Deficiencies.

The *wet-bulb arrangements* are peculiarly liable to go wrong, and the following course of action is suggested in order to reduce this source of error to a minimum.

The Standard Thermometers should be read at least five times a day at those moments when the light is cut off by the clock arrangement. The light remains cut off by this arrangement for four minutes, and it is necessary to read the Standard Thermometers *at the beginning* of this interval; the exact points in the curves corresponding to certain known readings of the Standards may thus be determined. When the Standards are read, the observer ought to notice if both wet bulbs are acting properly. If both are right, the sign $\surd$ should be made after the recorded temperature of the wet Standard. If the Thermograph wet bulb is wrong, the sign *t* should be made, and if the Standard wet bulb is wrong, the sign *s*. Either wet bulb, if found wrong, ought to be put right at once. Should it happen that the wet bulbs are frozen at the moment of observation, the present temperature

being also below 32°, cold water should be poured over the wet bulbs and the connecting strings. In a few minutes the wet bulbs will by this means be covered with a fresh coating of ice; this should be repeated if necessary. If this operation is performed two or three times a day during very cold weather, there is reason to believe that the wet bulb will always be covered with a sufficient coating of ice. But if the wet bulb and the water of the water-vessel be frozen from previous cold, the present temperature being above 32°, the ice of the water-vessel may be thawed by warm water, using no more than is necessary for the purpose.

If these regulations be followed during the cold months of the year, it is believed that there are comparatively few instances where we may not know the temperature of evaporation during frost.

During dry weather the wet-bulb arrangement is again liable to go wrong, although from a different cause. The thread, which in the arrangement adopted lies along a copper groove, gets dry in its passage from the water-vessel to the bulb, the capillary action ceasing. Sometimes it apparently rights itself without aid, but sometimes it continues wrong until it is put right at the next observation hour. The commencement and termination of such a wrong state of the wet bulb are generally so clearly indicated by the curve itself, that there appears to be little or no uncertainty in ascertaining what observations ought to be rejected. This action would best appear to be prevented by the use of an india-rubber tube lying along the metallic groove, and having one end dipping into the water of the water-vessel; and through this tube the thread ought to be carried in its passage from the water-vessel to the thermometer. Evaporation is thus avoided, and the arrangement will probably answer in winter. When the supply of water is too rapid, it may be easily and safely altered by turning up the tube.

Even when the action of the wet bulb is unexceptionable, water must frequently be added to the water-vessel. It is usual for this water to have the temperature of the air; but in cases of a great difference between the two bulbs, this will be much above the temperature of evaporation; the consequence is found to be, that in such cases there is a rise in the wet-bulb curve which, in extreme cases, may not completely right itself until a quarter of an hour has elapsed. This can only be remedied by each observatory doing all in its power to ensure that under such circumstances the water supplied to the water-vessel shall represent as nearly as possible the temperature of the wet bulb at that moment, and also that the supply of water from the water-vessel to the wet bulb shall be no greater than is necessary to keep the bulb thoroughly damp without dripping.

With regard to other deficiencies, it will only be necessary to remark here such as are peculiar to the Thermograph, since all those common to this instrument and the Barograph have already been stated under the head of the latter.

In the first place, it should be noticed that there is sufficient *light* to illuminate the whole range of the curve in a proper manner. In order to ensure this, and at the same time procure the best possible definition, the heights of the thermometers may, as occasion requires, and without detriment to the instrument, be altered so as to bring the mean temperature of the time into a central position with respect to the lens and light. This change ought, however, to be made as seldom as possible (perhaps twice or thrice in a year), and when made great care ought to be taken that there is no strain upon the wet-bulb Thermometer through tightness of the thread, whether arising from frost or any other cause.

Errors in Trace and Tabulation.

The arrangement proposed for ensuring the entry under the *proper date* into the tabulation forms of the measurements of the Thermograph curves, and of the Standard readings corrected, is almost precisely the same as that stated in the case of the Barograph.

Having ascertained the entry into the tabulation forms under their proper dates of the tabulations, and of the Standard readings corrected, we come in the next place to consider the check upon *accuracy of tabulation*, and here, as in the case of the Barograph, it will be necessary to consider separately large and small errors.

In the first place, with respect to *large errors*, in order to prevent entirely their occurrence, it is necessary to resort to the system of subsidiary tabulations. An instrument for this purpose has been devised at Kew. It is unnecessary here to state its principle of construction; suffice it to say, that the results furnished by it are used in the same manner as in the case of the Barograph ivory scale already mentioned. By this means correct columns of tabulated readings may be obtained. Again, with regard to the *Standard readings*, all that appears to be necessary is to examine both the accuracy of entry of the Standard reading corrected, and the accuracy of tabulation for all those cases in which the recorded Thermograph temperature is more than half a degree different from the corresponding Standard reading, and to make any correction that may be found to be necessary. When a Standard reading is evidently wrong, it ought to be noted as such on the curve, and should not be made use of in calculating the monthly mean difference between Standard and Thermograph readings. Before leaving this subject, it ought to be stated that the tabulating instrument as well as the subsidiary scale, are both so arranged as to ensure reading the proper point of the curve for every odd hour.

It ought to be noted that, in tabulating from the Thermograph curves, the tabulating instrument should be set from those observation hours where there is little thermometric fluctuation.

All the dry-bulb readings ought to be compared with the corresponding wet-bulb ones, and should the latter ever appear higher than the former, the case ought to be marked.

The *maximum* and *minimum* temperatures furnished by the outlying observatories ought to be checked.

All *large errors* may, it is hoped, be completely obviated by the means now described.

With regard to *small errors*, the plan adopted is the same as that for the Barograph, viz.:—

(1) To record the monthly mean difference between the simultaneous Standard and Thermograph readings.
(2) To make forty remeasurements from each month's curves at Kew.

The following Table exhibits the results of the method employed for testing the accuracy of the Thermograph tabulations as regards small errors:—

	Aberdeen.					Armagh.					Falmouth.					Glasgow.					Kew.					Stonyhurst.					Valencia.				
	Mean Difference between Thermograph and Standard readings.		No. of remeasurements made.	Mean Difference between first and second measurements.		Mean Difference between Thermograph and Standard readings.		No. of remeasurements made.	Mean Difference between first and second measurements.		Mean Difference between Thermograph and Standard readings.		No. of remeasurements made.	Mean Difference between first and second measurements.		Mean Difference between Thermograph and Standard readings.		No. of remeasurements made.	Mean Difference between first and second measurements.		Mean Difference between Thermograph and Standard readings.		No. of remeasurements made.	Mean Difference between first and second measurements.		Mean Difference between Thermograph and Standard readings.		No. of remeasurements made.	Mean Difference between first and second measurements.		Mean Difference between Thermograph and Standard readings.		No. of remeasurements made.	Mean Difference between first and second measurements.	
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1868.	dry.	wet.		dry.	wet.	dry.	wet.		dry.	wet.	dry.	wet.		dry.	wet.	dry.	wet.		dry.	wet.	dry.	wet.		dry.	wet.	dry.	wet.		dry.	wet.	dry.	wet.		dry.	wet.
January...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	·14	·16	...	...	...	...	...	12	·06	·05	·06	·11	12	·08	·12	...	...	...	...	...
February .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	·13	·13	12	·06	·05	·10	·10	12	·05	·06	·11	·20	12	·08	·07	...	...	...	...	...
March ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	·13	·14	12	·04	·05	·08	·07	12	·04	·03	·18	·35	12	·09	·30	...	...	...	...	...
April	·17	·16	12	·15	·15	...	...	...	...	...	...	...	...	...	...	·12	·15	12	·09	·15	·08	·08	12	·04	·05	·12	·15	12	·10	·12	...	...	...	...	...
May	·18	·18	12	·16	·12	·10	·12	12	·12	·10	·13	·12	12	·10	·12	·11	·11	12	·08	·12	·07	·08	12	·04	·07	·10	·16	12	·10	·05	...	...	...	...	...
June	·18	·17	12	·11	·12	·13	·13	12	·09	·14	·13	·09	12	·13	·07	·15	·12	12	·05	·10	·06	·07	12	·06	·08	·10	·15	12	·09	·08	...	...	...	...	...
July	·15	·26	48	·16	·13	·15	·16	48	·10	·10	·12	·15	48	·14	·10	·11	·12	48	·11	·07	·06	·09	48	·15	·08	·13	·13	48	·15	·16	...	...	...	...	...
August ...	·14	·15	48	·16	·10	·11	·16	48	·10	·09	·08	·14	48	·07	·10	·12	·10	48	·08	·08	·05	·07	48	·04	·06	·08	·10	48	·07	·07	·09	·08	48	·18	·20
September.	·11	·12	48	·08	·12	·13	·14	48	·06	·09	·09	·09	48	·13	·14	·08	·09	48	·08	·07	·08	·07	48	·04	·06	·08	·09	48	·06	·10	·09	·12	48	·12	·10
October ...	·10	·13	48	·10	·13	·17	·19	48	·07	·07	·09	·09	48	·07	·06	·09	·09	48	·11	·11	·06	·06	48	·06	·05	·08	·08	48	·09	·09	·09	·12	48	·08	·08
November.	·18	·14	48	·09	·12	·12	·14	48	·11	·09	·08	·07	48	·10	·07	·08	·10	48	·10	·13	·06	·06	48	·06	·04	·05	·08	48	·10	·10	·09	·10	48	·08	·08
December .	·10	·11	48	·17	·11	·10	·13	48	·06	·09	·08	·07	48	·07	·10	·10	·09	48	·12	·09	·06	·06	48	·06	·05	·07	·09	48	·08	·07	·10	·11	48	·04	·05

It is believed that the results of this Table afford satisfactory evidence not only of the accuracy with which the Standard Thermometers are read, but also of the accuracy of tabulation from the traces. A tendency in the monthly mean differences to decrease from their first values at starting will be noticed in the case of all the observatories.

Anemograph.

The accuracy of the Anemograph is, like that of the Thermograph, liable to be deranged by three causes:—

(1) By a cause depending on the situation and exposure of the instrument.
(2) By instrumental deficiency, such as friction.
(3) By deficient traces and tabulations.

Situation of Instruments.

These instruments are placed on the highest points of the various observatories, and as far as possible out of the reach of local influences. The exposure may therefore be considered good in the case of all the observatories.

Instrumental Deficiencies.

Friction is the most important of these, and may be supposed to affect to a small extent both the records of direction and velocity. The axle of the direction-vane moves in a wooden bearing, which is saturated with oil. It is believed that when the instrument is regularly attended to, the friction consequent upon this arrangement can be kept very small.

As regards the influence of friction upon the velocity-records, this has been determined in the case of the Kew instrument, and also by Dr. Robinson for his Anemograph, which has been for many years in operation. The following friction coefficient has been adopted, with the concurrence of Dr. Robinson, as applicable to the records of all the Anemographs belonging to the Meteorological Committee:—

Observed.	miles.	miles.
For velocities from	0·0 to 0·5	add 1·5
"	1·0 to 3·0	add 1·0
"	4·0 to 10·0	add 0·5

Errors of Trace and Tabulation.

It ought to be noticed that *both the direction- and the velocity-pencils* are working well and freely on the paper.

It is also to be noticed that, for all the observatories except Falmouth, the *needle on the cylinder* goes through the centre of the crosses marked on the metallic paper.

In Falmouth the velocity-pencil is slightly out in position, and in consequence that observatory has been directed to set to a point which is not quite in the centre of the crosses. The Falmouth instrument has also been oriented for this position of setting. A note of the proper position of setting for Falmouth is preserved at Kew, and the assistant there ought to inspect each Falmouth Anemogram to see that it has been properly set.

With regard to *date*, each curve when taken off the cylinder should have both the day of the week and of the month written upon it, and when it reaches Kew it ought to be inspected by the assistant there in order to see that the observer has attached the proper day of the month alongside the day of the week.

He should also see that the week's curves sent are dated consecutively.

With regard to *time*, a prick made in the small time-scale of the metallic sheet denotes in terms of the hour-lines ruled on this sheet, the moment of starting, and a similar prick that of taking off. These pricks ought to denote the true chronometer times of starting and taking off very nearly, if the instrumental clock has been properly regulated. All *stoppages* of the instrumental *clock* ought to be marked.

It ought also to be noticed that the *cylinder is well clamped*, otherwise the friction of the pencil upon the cylinder may occasionally overcome that of the clamp, in which case the cylinder will slip.

With regard to *errors of tabulation*, the assistant at Kew ought in the first place to ascertain that the curve is tabulated under its *proper date*. Probably an intelligent inspection of the direction- and velocity-records in connexion with the tabulated results will be sufficient to determine this point.

A simple system of *subsidiary tabulations* has been adopted in order to check the direction-results. The observer at the outlying observatory is requested to write down on a separate sheet in numbers the direction of the wind at each hour as read from the curve by his eye, and compare it, as in the case of the Barograph and Thermograph, with the tabulated results. The differences between the two columns or A — B ought to be inspected at Kew, and when they are greater than *two points* the case ought to be examined, and any error detected ought to be corrected at once. With respect to direction, fractional parts of a point ought not to be recorded.

With regard to *velocity-traces*, the action of the instrument is such as to give by a glance at a curve the whole space travelled over by the wind for that day. Perhaps, therefore, it will be a sufficient check upon the velocity-records if, in addition to an intelligent comparison of the traces and tabulations, each day's results are added up and the sum total compared with that derived by glancing at the curve. When the difference between these two daily sum totals is greater than *one-twentieth of the whole*, the tabulated velocities for that day ought to be gone over again, and if any error is detected it ought to be put right at once.

It is probably unnecessary to check the recorded oscillations, as these are of inferior scientific value, and additional labour bestowed upon them would appear to be superfluous.

Finally, in order to keep a check upon *small errors*, the system of making at Kew forty remeasurements for each month, both for direction and velocity, has been adopted.

The following Table exhibits the results of the method employed for testing the accuracy of the Anemograph tabulations as regards small errors.

It will be seen from this Table that the standard of accuracy as represented by the smallness of the mean monthly differences has gradually increased up to the end of the year.

	Aberdeen.			Armagh.*			Falmouth.			Glasgow.			Kew.			Stonyhurst.			Valencia.		
	No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.		No. of re-measurements made.	Mean Difference.	
		Direction.	Velocity.		Direction.	Velocity.		Direction.	Velocity.		Direction.	Velocity.		Direction.	Velocity.		Direction.	Velocity.		Direction.	Velocity
1868,	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
January	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
February	...	...	...	...	...	...	...	...	...	12	0·8	0·5	12	0·2	0·7	12	0·4	1·0	...	...	...
March	...	...	...	...	...	...	12	0·5	0·5	12	1·0	0·4	12	0·0	1·0	12	0·0	0·7	...	...	...
April	10	0·5	1·0	...	...	...	12	0·2	0·9	12	0·2	1·0	12	0·3	0·8	12	0·1	0·6	...	...	...
May.	12	0·4	0·8	...	...	...	10	0·3	1·1	12	0·2	0·7	12	0·1	1·0	12	0·7	0·5	...	...	...
June	12	0·5	0·9	...	...	...	12	0·2	1·1	12	0·7	0·3	12	0·5	0·9	10	0·5	0·3	...	...	...
July	48	0·1	0·5	...	...	...	48	0·3	0·6	48	0·3	0·9	48	0·1	0·9	48	0·2	0·5	...	...	...
August	48	0·2	0·5	...	...	...	48	0·3	1·0	48	0·2	0·6	48	0·1	0·5	48	0·4	0·5	48	0·2	0·9
September	48	0·2	0·6	...	...	...	48	0·1	0·9	48	0·2	0·8	48	0·1	0·5	48	0·4	0·5	48	0·2	1·0
October	48	0·3	0·7	...	...	...	48	0·3	0·6	48	0·4	0·5	48	0·3	0·4	48	0·5	0·5	48	0·4	1·0
November	48	0·4	0·6	...	...	...	48	0·2	0·8	48	0·4	0·7	48	0·3	0·3	48	0·3	0·5	48	0·3	1·2
December	48	0·3	0·8	...	...	...	48	0·2	0·8	48	0·3	0·7	48	0·2	0·5	48	0·3	0·6	24	0·3	1·2

* The Anemograph of Dr. Robinson is somewhat different from the others, and it is only since the beginning of 1869 that the method of checking his results has been finally decided on.

Code of Regulations adopted by the Meteorological Committee for ensuring Accuracy in the Results derived from their Self-recording Instruments.

In the first place a set of rules have been framed for the guidance of the various observatories, including the Central Observatory at Kew. Secondly, a set of forms have been constructed on which to register the deficiencies and mistakes in the returns from the various observatories, copies of which when filled up are forwarded to the Directors of these observatories on the one hand, and to the Meteorological Office on the other. Thirdly, a diary of operations has been constructed, from which each observatory may know the times at which the various documents ought to be sent to Kew. Fourthly, each month's results are laid before the Meteorological Committee, accompanied with the remarks of the Director of the Central Observatory, which are then printed in the minutes of that body*.

Regulations for Barograph.

Outlying Observatory.

(1.) The curves, journals, and tabulation forms to be written upon according to the pattern furnished.

(2.) Always begin a new month with new forms. The curves and forms are to be numbered consecutively from the beginning of the year, as will be seen from the diary.

(3.) Clock to be set to Greenwich mean time at starting, and its error not to exceed two minutes in two days.

(4.) The Barograph Thermometer and the Standard Barometer, and its attached Thermometer, ought to be read five times a day if possible while the light is cut off by the clock-arrangement. The light remains cut off by this arrangement for four minutes, and it is necessary to read the Standard Barometer *at the end* of this interval—the exact points in the curve corresponding to certain known readings of the Standard may thus be determined. It ought to be noticed when the Standard is heaving or oscillating.

(5.) The instrument should always be started between 10 and 11 A.M. Greenwich mean time on those days mentioned in the diary.

(6.) Every change made in the instrument, every stoppage of clock, &c., and all peculiarities in the curve, noticed by the observer, should be inserted in the journal under the head of "Remarks," with the exact time attached thereto. Should the height of the Barometer-cistern be altered, or any change made which will affect the curve, this ought, as already mentioned, to be noticed; it is, however, considered that all such changes ought to be avoided.

(7.) The previous week's curves, journals, and tabulations should be sent to Kew every Thursday, as mentioned in the diary.

* In these remarks there is recorded, amongst other things, each blank in the traces during the month. The following were the blanks for February 1869:—

Anemograph (direction)	10	hourly	records	lost out of	4704.
Ditto (velocity)	20	"	"	"	4704.
Barograph	13	"	"	"	4704.
Thermograph (dry bulb)	2	"	"	"	4704.
Ditto (wet bulb)	12	"	"	"	4704.

Central Observatory (Assistant).

(8.) The assistant at Kew shall examine each curve in order to see if there is any want of light or appearance of bagging, or of finger-marks, or of bad photography, and he shall occasionally see that the temperature bar is in proper action.

(9.) He shall see that the clock and clock-stop have been in good action for the time of the curve.

(10.) That the instrumental clock does not differ more than two minutes from the chronometer as recorded on the curve.

(11.) That the date written on the back of the curve agrees with that on the face.

(12.) That the curve is properly written upon after the pattern.

(13.) That in the Barograph Journal the proper day of the month is placed alongside of Sunday, and that the others follow consecutively.

(14.) That the times of starting and stopping the curve as recorded in the journal have been properly recorded on the face of the curve.

(15.) Finally, he shall ascertain, by means of a simple inspection of the curve, that the beginning and ending, as shown by the curve itself, are the same as those described on the face of the curve.

(16.) He shall see that the journal readings of the Standard Barometer are entered under their proper dates into the Barograph tabulation sheets.

(17.) Then examine in a general manner the accordance of the Barograph and Standard readings for each day. If these two tests be satisfactory, he may conclude that the tabulations and Standard readings have both been entered under their proper dates.

(18.) Check the accuracy of the subtractions made in the tables of subsidiary measurements furnished by the outlying observatory.

(19.) Investigate all cases where A — B is greater than ·02 in.; if an error be revealed in the tabulations, this error ought to be corrected at once. These corrections ought to be made before the next step in the process is commenced.

(20.) Then ascertain the accuracy with which the residual correction has been found according to the method described, and whenever it has been found necessary to alter the residual correction, a correction should also be made in the last column of the tabulation papers.

(21.) Then check after the manner described the accuracy with which the residual correction has been applied, producing a new column of corrected pressure, which he shall compare with the old one, and any error discovered by this comparison shall be corrected at once.

(22.) Portions of the curve too faint for the ordinary instrument, but capable of being measured by the ivory scale, shall be measured, corrected, and marked as specified.

Central Observatory (Director).

23. The assistant at Kew shall bring all curves and tabulations which exhibit deficiencies personally before the Director of the Central Observatory, and the latter shall make the necessary remarks on the curves and tabulations, or cause them to be made, and shall communicate all cases of failure to the Meteorological Committee on the one hand and to the Director of the observatory where the

failure occurred on the other, making any remark that may tend in his estimation to obviate in future the cause of failure.

(24.) He shall also communicate as above the monthly mean differences between the Barograph readings reduced, and the simultaneous Standard readings.

(25.) He shall also communicate as above the result of forty remeasurements for each observatory for each month, to be made at Kew, noting (1) the greatest difference, (2) the mean difference irrespective of sign, (3) the residual difference (if any), taking signs into account.

Regulations for Thermograph.

Outlying Observatory.

(1.) The curves, journals, and tabulation forms to be written upon according to the pattern furnished.

(2.) Always begin a new month with new forms. The curves and forms are to be numbered consecutively from the beginning of the year, as will be seen from the diary.

(3.) Clock to be set to Greenwich mean time at starting, and its error not to exceed two minutes in two days.

(4.) The Standard Thermometers should be read at least five times a day at those moments when the light is cut off by the clock-arangement. The mode of dealing with the wet bulb has been already described, p. lviii.

(5.) The instrument should always be started between 10 and 11 A.M. Greenwich mean time, on those days mentioned in the diary.

(6.) Every change made in the instrument, every stoppage of clock, &c., and all peculiarities in the curve noticed by the observer, should be inserted in the journal under the head of "Remarks," with the exact time attached thereto.

(7.) The muslin and connecting threads ought to be taken off the bulbs, washed and replaced as often as they become soiled.

(8.) The previous week's curves, journals, and tabulations should be sent to Kew every Thursday, as mentioned in the diary.

Central Observatory (Assistant).

(9.) The assistant shall examine each curve in order to see if there is any want of light, bagging, finger-marks, bad photography, or defective action of wet bulb, during however short a space of time.

(10.) He shall see that the clock and clock-stop have been in good action for the time of the curve.

(11.) That the instrumental clock does not differ more than two minutes from the chronometer as recorded on the curve.

(12.) That the date written on the back of the curve agrees with that in front.

(13.) That the curve is properly written upon after the pattern adopted.

(14.) That in the Thermograph Journal the proper day of the month is placed alongside of Sunday, and that the others follow consecutively.

(15.) That the times of starting and stopping the curve as recorded in the journal have been properly recorded on the face of the curve.

(16.) He shall ascertain, by means of a simple inspection, that the beginning and ending, as shown by the curve itself, are the same as those described in front of the curve.

(17.) That the journal readings of the Standard Thermometer are entered under their proper dates into the Thermograph tabulation sheets.

(18.) He shall examine in a general manner the accordance of the Thermograph and Standard readings for each day. If these two tests be satisfactory, he may conclude that the tabulations and Standard readings have both been entered under their proper dates.

(19.) Check the accuracy of the subtractions made in the tables of the subsidiary measurements.

(20.) Investigate all cases in which A — B is greater than 0°·5 Fahr.; and if an error is revealed, it ought to be corrected at once.

(21.) Examine both the corrected Standard reading and the corresponding tabulated one for all those cases in which there is a difference greater than 0°·5 between the two.

(22.) Compare the dry-bulb readings with the corresponding wet ones, marking and examining all those cases in which the latter appear higher than the former.

(23.) Check the accuracy of the maximum and minimum temperatures furnished by the outlying observatories.

(24.) Record the monthly mean differences between the simultaneous Standard and Thermograph readings.

(25.) Make forty remeasurements as specified.

Central Observatory (Director).

(26.) The assistant at Kew shall bring before the Director of the Central Observatory all curves, with their corresponding tabulations, that are deficient from any cause, and the Director shall make the necessary remarks on the curves and tabulations, or cause them to be made, and shall communicate all cases of failure to the Meteorological Committee on the one hand, and to the Director of the observatory where the failure occurred on the other, making any remarks that may tend in his estimation to obviate in future the causes of failure.

(27.) The Director of the Central Observatory shall also communicate as above the monthly mean differences between the simultaneous Thermograph and Standard readings, as well as the result of the forty remeasurements made at Kew.

REGULATIONS FOR ANEMOGRAPH.

Outlying Observatory.

(1.) The curves and tabulation forms to be written upon according to the patterns furnished.

(2.) Always begin a new month with new tabulation forms. The curves and forms are to be numbered consecutively from the beginning of the year, as will be seen from the diary.

(3.) The pricks on the curve, when compared with the Greenwich mean times of commencement and taking off, ought to agree with the latter within five minutes at each end.

(4.) The curve should be taken off at $10^h\ 30^m$ A.M., and a new one replaced if possible at $10^h\ 32^m$, Greenwich mean time.

(5.) Every change made in the instrument, every stoppage of clock, &c., and all peculiarities in the curve noticed by the observer, should be recorded on the blank part of the sheet of metallic paper, with the exact time attached thereto. The orientation should be tested once a month.

(6.) The previous week's curves and tabulations should be sent to Kew every Thursday, as recorded in the diary.

Central Observatory (Assistant).

(7.) The assistant at Kew shall examine each curve in order to see if both pencils work well and freely, and if the paper has been accurately attached to the cylinder, and if the cylinder has not slipped.

(8.) He shall see that the clock has been in good order during the time of the curve.

(9.) That the curve is properly written upon after the pattern adopted.

(10.) That in the writing upon the curve the proper day of the month is placed alongside the day of the week.

(11.) That the times of putting on and taking off as recorded by the pricker do not differ more than five minutes from the chronometer time.

(12.) He shall inspect the direction- and velocity-curves in connexion with the tabulated results, in order to ascertain that each curve is tabulated under its proper date.

(13.) Check the accuracy of the subtractions made in the tables of the subsidiary direction measurements.

(14.) Examine all cases in which A — B is greater than *two points*, and if an error is revealed it ought to be corrected at once.

(15.) Check the accuracy of the velocity tabulations, according to the method herein indicated.

(16.) Make forty remeasurements for each month, both for direction and velocity, as in the case of the other instruments.

Central Observatory (Director).

(17.) The assistant at Kew shall bring before the Director of the Central Observatory all curves, with their corresponding tabulations, that are deficient from any cause, and the Director shall make the necessary remarks on the curves and tabulations, or cause them to be made, and shall communicate all cases of failure to the Meteorological Committee on the one hand, and to the Director of the observatory where the failure occurred on the other, making any remarks that may tend in his estimation to obviate in future the causes of failure.

(18.) The Director of the Central Observatory shall also communicate as above the result of the forty remeasurements made at Kew.

I.—WEEKLY FORM FOR REGISTERING DEFICIENCIES.

_____ BAROGRAMS, &c.

(*Received at Kew,* _____.)

Tabulation No. and corresponding Documents.

Points noticed at Kew.	Results and Remarks.
1. Deficiency in number of documents sent . . .	
2. Errors in numbering and writing upon them .	
(A.) Want of light in curves	
(B.) Bagging in do.	
(C.) Finger-marks, &c., in do.	
3. Action of clock	
4. Regulation of do.	
(D.) Action of clock-stop	
5. Errors in dating curves	
(E.) Do. in entry or date of entry of journal readings of standard into tabulation sheets	
6. Do. in date of entry of tabulated readings into tabulation sheets	
7. Do. of subtraction in subsidiary tables . . .	
8. Do. of tabulation discovered by subsidiary tables	
(*c.*) Do. in calculating residual correction	
(*d.*) Do. in applying residual correction	
9. Ten remeasurements	
(1.) *Greatest difference*	
(2.) *Mean difference irrespective of sign* . . .	
(3.) *Residual difference*	

II.—WEEKLY FORM FOR REGISTERING DEFICIENCIES.

THERMOGRAMS, &c.

(*Received at Kew,* _____.) Tabulation No. and corresponding Documents.

Points noticed at Kew.	Results and Remarks.
1. Deficiency in number of documents sent . . .	
2. Errors in numbering and writing upon them .	
(A.) Want of light in curves	
(B.) Bagging in do.	
(C.) Finger-marks, &c., in do.	
(*a*.) Defective action of wet bulb	
3. Action of clock	
4. Regulation of do.	
(D.) Action of clock-stop	
5. Errors in dating curves	
(E.) Do. in entry or date of entry of journal readings of standard into tabulation sheets	
6. Do. in date of entry of tabulated readings into tabulation sheets	
7. Do. of subtraction in subsidiary tables . . .	
8. Do. of tabulation discovered by subsidiary tables	
(*b*.) Do. in maxima and minima	
9. Ten remeasurements	
(1.) *Greatest difference*	
(2.) *Mean difference irrespective of sign* . . .	
(3.) *Residual difference*	

III.—WEEKLY FORM FOR REGISTERING DEFICIENCIES.

_____ ANEMOGRAMS, &c.

(*Received at Kew*, _____.) Tabulation No. and corresponding Documents.

Points noticed at Kew.	Results and Remarks.
1. Deficiency in number of documents sent . . .	
2. Errors in numbering and writing upon them .	
(*e.*) Action of pencils	
(*f.*) Errors of attachment of paper	
(*g.*) Slipping of cylinder	
3. Action of clock	
4. Regulation of do.	
5. Errors in dating curves	
6. Do. in date of entry of tabulated readings into tabulation sheets	
7. Do. of subtraction in subsidiary tables . . .	
8. Do. in direction discovered by subsidiary tables .	
(*h.*) Do. in velocity discovered by subsidiary arrangement	
9 (*a.*) Ten remeasurements (*direction*)	
(1.) *Greatest difference*	
(2.) *Mean difference irrespective of sign* . .	
(3.) *Residual difference*	
9 (*b.*) Ten remeasurements (*velocity*)	
(1.) *Greatest difference*	
(2.) *Mean difference irrespective of sign* . .	
(3.) *Residual difference*	

Specimen of Diary of Operations for 1869. **JANUARY.**

Day of Month.	Day of Week.	No. of Bar. and Ther. sheets taken off this day.	No. of Anem. sheet taken off this day.	No. of Journals and Tabulations ending this day.	Send to Kew.				Remarks.
					Bar. and Ther. Curves, Nos. inclusive.	Anem. Curves, Nos. inclusive.	Journals and Tabulations, Nos.	Weather Report for	
1.	Friday ...	1	1						
2.	Saturday...	.....	2	1					
3.	**Sunday**...	2–3	3						
4.	Monday ...	.....	4						
5.	Tuesday ...	4–5	5						
6.	Wednesday	.....	6						
7.	Thursday..	6–7	7	...	1 to 3	1 to 3	1		
8.	Friday ...	.....	8						
9.	Saturday...	8–9	9	2					
10.	**Sunday**...	.....	10						
11.	Monday ...	10–11	11						
12.	Tuesday ...	.....	12						
13.	Wednesday	12–13	13						
14.	Thursday..	.....	14	...	4 to 11	4 to 10	2		
15.	Friday ...	14–15	15						
16.	Saturday...	.....	16	3					Kew to send in documents for December 1868 to the central office.
17.	**Sunday**...	16–17	17						
18.	Monday ...	.....	18						
19.	Tuesday ...	18–19	19						
20.	Wednesday	.....	20						
21.	Thursday..	20–21	21	...	12 to 17	11 to 17	3		
22.	Friday ...	.....	22						
23.	Saturday...	22–23	23	4					
24.	**Sunday**...	.....	24						
25.	Monday ...	24–25	25						
26.	Tuesday ...	.....	26						
27.	Wednesday	26–27	27						
28.	Thursday..	.....	28	...	18 to 25	18 to 24	4		
29.	Friday ...	28–29	29						
30.	Saturday...	.....	30	5					
31.	**Sunday**...	30–31	31	6					

FEBRUARY.

Day of Month.	Day of Week.	No. of Bar. and Ther. sheets taken off this day.	No. of Anem. sheet taken off this day.	No. of Journals and Tabulations ending this day.	Send to Kew.				Remarks.
					Bar. and Ther. Curves, Nos. inclusive.	Anem. Curves, Nos. inclusive.	Journals and Tabulations, Nos.	Weather Report for	
1.	Monday ...	.....	32						
2.	Tuesday ...	32–33	33						
3.	Wednesday	.....	34						
4.	Thursday..	34–35	35	...	26 to 31	25 to 31	5		
5.	Friday ...	.....	36						
6.	Saturday..	36–37	37	7					
7.	**Sunday**...	.....	38						
8.	Monday ...	38–39	39						
9.	Tuesday ...	.....	40						
10.	Wednesday	40–41	41						
11.	Thursday..	.....	42	...	32 to 39	32 to 38	6 and 7	January	
12.	Friday ...	42–43	43						
13.	Saturday..	.....	44	8					
14.	**Sunday**...	44–45	45						
15.	Monday ...	.....	46						
16.	Tuesday ...	46–47	47						
17.	Wednesday	.....	48						
18.	Thursday..	48–49	49	...	40 to 45	39 to 45	8		
19.	Friday ...	.....	50						
20.	Saturday..	50–51	51	9					
21.	**Sunday**...	.....	52						Kew to send in January documents to the central office.
22.	Monday ...	52–53	53						
23.	Tuesday ...	.....	54						
24.	Wednesday	54–55	55						
25.	Thursday..	.....	56	...	46 to 53	46 to 52	9		
26.	Friday ...	56–57	57						
27.	Saturday..	.....	58	10					
28.	**Sunday**...	58–59	59	11					