THE

NATIONAL PHYSICAL LABORATORY.

REPORT FOR THE YEAR 1903.

LONDON:
HARRISON AND SONS, ST. MARTIN'S LANE,
Printers in Ordinary to His Majesty.

1904.

THE NATIONAL PHYSICAL LABORATORY.

MEMBERS OF THE GENERAL BOARD.

*Sir William Huggins, K.C.B., O.M., President R.S., *President.*
*The Right Honourable The Lord Rayleigh, O.M., F.R.S., *Chairman.*
*Mr. A. B. Kempe, Treasurer R.S.
*Professor J. Larmor, Secretary R.S.
Sir A. Geikie, Secretary R.S.
*Sir F. J. S. Hopwood, K.C.B., C.M.G., *Permanent Secretary, Board of Trade.*
Professor W. Grylls Adams, F.R.S.
*Sir J. Wolfe Barry, K.C.B., F.R.S., *Representative of the Institution of Civil Engineers.*
Mr. G. Beilby.
Mr. C. V. Boys, F.R.S.
*Professor Hugh L. Callendar, F.R.S.
*Sir Edward Carbutt, Bart., *Representative of the Institution of Mechanical Engineers.*
*Mr. R. F. Carpenter, *Representative of the Society of Chemical Industry.*
*Colonel Crompton, R.E.
Mr. H. F. Donaldson.
*Dr. F. Elgar, F.R.S., *Representative of the Institution of Naval Architects.*
Professor J. A. Ewing, F.R.S.
Professor J. A. Fleming, F.R.S.
*Principal G. Carey Foster, F.R.S.
Mr. R. Kaye Gray, *Representative of the Institution of Electrical Engineers.*
Professor A. Gray, F.R.S.
Mr. R. A. Hadfield, *Representative of the Iron and Steel Institute.*
Professor W. M. Hicks, F.R.S.
Capt. H. B. Jackson, R.N., F.R.S.
Professor J. Joly, F.R.S.
The Right Honourable The Lord Kelvin, G.C.V.O., O.M., F.R.S.
Mr. W. H. Maw, *Representative of the Institution of Mechanical Engineers.*
Dr. L. Mond, F.R.S.
*Sir Andrew Noble, Bart., K.C.B., F.R.S.
*Professor J. Perry, F.R.S.
Sir W. H. Preece, K.C.B., F.R.S., *Representative of the Institution of Civil Engineers.*
Mr. Walter F. Reid, *Representative of the Society of Chemical Industry.*
*Sir Arthur W. Rücker, F.R.S.
*The Right Honourable Sir Bernhard Samuelson, Bart., F.R.S., *Representative of the Iron and Steel Institute.*
Professor A. Schuster, F.R.S.
*Dr. W. N. Shaw, F.R.S.
*Mr. Alex. Siemens, *Representative of the Institution of Electrical Engineers.*
Mr. C. E. Stromeyer.
Mr. J. W. Swan, F.R.S.
Professor J. J. Thomson, F.R.S.
*Dr. T. E. Thorpe, C.B., F.R.S.
Professor W. C. Unwin, F.R.S.
Admiral Sir W. J. L. Wharton, K.C.B., F.R.S.
Mr. A. F. Yarrow, *Representative of the Institution of Naval Architects.*

* *Members of the Executive Committee.*

THE NATIONAL PHYSICAL LABORATORY.

REPORT FOR THE YEAR 1903.

Report of the Executive Committee.
Statement of Work for the year 1904.
Report of the Director, including—

(1) Report to the Director by the Superintendent of the Engineering Department.

(2) Report to the Director by the Superintendent of the Observatory Department.

(3) Appendices to the Report of the Superintendent of the Observatory Department.

REPORT OF THE EXECUTIVE COMMITTEE FROM JANUARY 1, 1903, TO DECEMBER 31, 1903, SUBMITTED TO THE GENERAL BOARD AT THEIR MEETING ON MARCH 18, 1904.

The Laboratory has been in full work during the year, and the progress in all Departments has been marked.

The staff at Bushy House at the beginning of the year consisted of 26 persons; it now numbers 34, while the total staff, including that in the Observatory Department, is 51.

In the nine months for 1902, during which the Engineering and Physics Departments were open, the total number of tests made was 269, and the sum received in fees for these was £69 2*s.* 8*d.*

In 1903 the number of tests increased to 1,330, and the fees received for these to £350 8*s.* 4*d.*

In addition to this, a sum of £536 10*s.* was received for researches undertaken in the Laboratory.

The following table shows the distribution of these tests :—

COMPARISON OF TESTS MADE DURING THE YEARS 1902 AND 1903.

PHYSICS DEPARTMENT.

			1903.	1902 (9 months)
Electricity and Magnetism.				
Resistance Coils	128			
Resistance Boxes	4			
Condensers	11			
Conductivity Tests	7			
Permeability and Hysteresis Tests	8			
Inductance Tests	3			
Permanent Magnets	10			
Supply Meters	10			
Miscellaneous	14			
	—	...	195	31
Thermometry.				
High Range Thermometers	59			
Melting Point of Alloys	13			
Freezing Point of Liquids	5			
Open Scale Thermometers	9			
Miscellaneous	7			
	—	...	93	39
Metrology.				
Micrometer	1			
Coefficients of Expansion	9			
Deflection Bars	4			
Inertia Bars	5			
Gauges	23			
Scales	1			
Density Determinations	28			
	—	...	71	12
Testing of Glass Vessels and Weights.				
Glass Vessels, Burettes, Flasks, &c.	665			
Chemical Weights	49			
	—	...	714	116
Metallography.				
Photomicrographs of Specimens of Metals	57			
Cooling Curves	14			
	—	...	71	16
Chemical Tests.				
Samples of Coke	3			
Insulating Fabric	4			
Water	5			
Steel and other Analyses	35			
	—	...	47	10

Microscopical Tests.

		1903.	1902 (9 months)
Samples of Paper	0 ...	0	5

Optics.

		1903.	1902 (9 months)
Incandescence Lamps	14		
Photographic Lenses	8		
Sunshine Spheres	3		
	— ...	25	0
		1,216	229

Engineering Department.

		1903.	1902 (9 months)
Gauges (Vacuum and Pressure)	19		
Calorific Value of Coke	3		
Strength of Materials	83		
Steam Pipe Lagging	4		
Anemometers	1		
Sets of Rubber Tests	4		
	— ...	114	40

In addition to the above, application has been made for a number of tests which it has been found impossible to carry out owing to the incomplete equipment of the Laboratory.

Among such applications the following may be noted :—

Mechanical tests on wire ropes, wires, &c. ; special tests on rubber; tests on tensile strength of metals after special hardening; tests on cement and stone; tests on certain bronze bars of large section; tests on water meters; and very high speed anemometers.

Electrical tests involving heavy currents; tests on alternate current instruments of all kinds. Extremely high voltage tests on insulators. Optical tests on a large astronomical object glass.

The Report of the Director shows that the equipment has been extended in many ways.

The Photometric Division is at work, and a number of important tests are in progress for the Admiralty and War Office, while the Optical Division is prepared to undertake observations on the refractivity of solids or liquids, or on the absorption of transparent materials.

The alternating set given by Messrs. Siemens Bros. has been delivered, and is at work; the transformers and most of the measuring apparatus required for alternate current tests remain to be installed.

In the Engineering Department the need of a powerful testing machine has been greatly felt; almost every engineer who visits or enquires about the Laboratory refers to the need for such a machine, and work is continually being declined which would be undertaken if the machine were installed. Thus, within the last few weeks there have been enquiries from the Eastern Telegraph Company for tests on wire ropes used for submarine cable work, and by the Board of Trade for tests on specimens cut from $1\frac{1}{2}$-inch plates and from steel bars 2 inches in diameter, while earlier in the year the need was pointed out by a deputation of railway engineers which visited the Laboratory.

Among the additions to the testing outfit of the Department should be mentioned the tank and apparatus for testing water gauges now in process of equipment, and the apparatus designed by Dr. Stanton for calibrating air meters.

The lathe house referred to in the last Report, which is to hold the special lathe for cutting standard leading screws, is complete, and it is hoped that the lathe may be delivered very shortly, after its approval by the War Office Committee, under whose direction it has been constructed. A description of the house is given in an Appendix.

The tide-predicting apparatus belonging to the Indian Government was, during the summer, cleaned and renewed by Messrs. Légé & Co., who originally constructed it, and has been working at the Laboratory since August last. Thus work of a special character is being done for two important Government Departments.

Towards the end of the year arrangements were made whereby much of the electrical apparatus which is to be sent to the St. Louis Exhibition will pass through the tests of the Laboratory, and, if approved, will receive certificates. The Committee hope in this way that their aid may prove of value to English exhibitors.

One large firm has arranged to issue all its standard resistances through the Laboratory.

Some of the researches outlined in the Statement of Work for 1903 have been carried to a satisfactory conclusion.

Dr. Stanton read a paper at the Meeting of the Institution of Civil Engineers on December 22 last, on the amount and distribution of pressure on plane surfaces exposed to a uniform current of air, which has been very favourably received. The chief result which appears to follow from the paper is that it is possible to infer from experiments on models of structures placed in a current of air what the resultant pressures will be on the structure itself when exposed to the wind. Arrangements are in progress for repeating the experiments in the open air on models on a large scale.

The machine for testing the effect for alternating stresses on materials has practically been completed, and the preliminary trials made with it have been successful.

Thanks to the assistance of the Manchester Steam Users' Association, who voted £150 to the funds of the Laboratory for the purpose, apparatus has been constructed for measuring the specific heat of super-heated steam up to a pressure of 200 pounds to the square inch, and the preliminary experiments made with it have shown that there is every reason to hope it will work satisfactorily. The method, due to Mr. Jakeman and Dr. Harker, consists in super-heating the steam by means of an electrical current, and determining the rise of temperature produced and the watts required. The present apparatus is capable of dealing with a flow at the rate of 600 grammes of steam per minute, or about 80 lbs. of steam per hour, but it is hoped to construct apparatus which will permit of higher temperatures and pressures being used.

Many of the tests asked for really involve small researches, such, for example, are a series of comparative tests on mica and other materials used for lagging steam pipes, an examination into the hardness of various specimens of type metal, the testing under pressures of a ton and a half to the square inch of some deep sea thermometers, the difficulty in this case was to eliminate the effects of thermodynamic heating of the oil in which the thermometer is immersed.

In the Metallurgical Division the scheme of work outlined in Section (1) of the proposals for 1902, is nearly complete.

Some thirty-three iron carbon alloys of great purity have been made, each specimen weighs from three to four pounds, and the carbon content is varied, by increments roughly of 0·1 per cent., from 0·02 up to about 4 per cent.

The temperatures of solidification and of the various critical points of these alloys have been determined.

The work is practically finished, and is to form a paper, by Dr. Carpenter and Mr. Keeling, at the forthcoming Meeting of the Iron and Steel Institute.

Some progress has been made with the second piece of work—the properties of certain nickel-steel alloys—outlined in the Report for 1902.

In this research Mr. Hadfield most kindly undertook to co-operate with the Laboratory in a joint investigation, and the Committee gladly welcomed his assistance. The series of alloys planned has been prepared, under his superintendence, at the Hecla Works, Sheffield, and delivered at the Laboratory, and a start has been made in the experiments on these.

In the Electrical Division Mr. Smith has completed his research on the mercury standards of resistance, and has constructed eleven mercury tubes. The results obtained from these tubes agree among themselves to some two or three parts in one hundred thousand, while the final result agrees with that obtained at the Reichsanstalt to one part in one hundred thousand.

A preliminary account of these experiments was communicated to the British Association at Southport, and a paper, dealing with the whole, is ready for presentation to the Royal Society. Incidentally, Mr. Smith has compared a large series of standard resistances, and has redetermined the coefficient of change of resistance with temperature of mercury. The whole of the work is marked by a very high degree of accuracy.

Another electrical research, undertaken at the request of the Engineering Standards Committee, is one on the effect of temperature on the insulating properties of materials used in dynamos, motors and transformers.

This has been carried through by Mr. Rayner, who volunteered for the work; the results have been communicated to the Committee and will be published in due time.

In the Thermometric Division, Dr. Harker's research on a comparison up to a temperature of 1,100° C. of the nitrogen thermometer, the platinum thermometer and certain thermo couples is complete, and has been communicated to the Royal Society. A satisfactory working scale of high temperatures has thus been established.

Further details as to these investigations will be found in the Director's Report.

During the year work has continued in the Observatory Department, and a number of interesting details will be found in the Report of the Superintendent.

The most important series of tests were those on the pendulums to be used for the geodetic survey of India now in progress. These were carefully standardised by Mr. Constable, and then employed by Major Burrard, R.E., and Major Lennox Cunningham, R.E., of the Indian Survey, assisted by Mr. Constable, in a comparison of the value of "g" at Kew and Greenwich. The results are not yet completely worked out.

Some progress has been made with the work of transferring the Magnetic Observations from Kew. A site has been selected and surveyed at Eskdale Muir, some

15 miles north of Langholm, in Dumfriesshire, and the Duke of Buccleuch has intimated his readiness to let it on a perpetual lease for the purposes of the Observatory. Plans and estimates have been prepared by the Office of Works and approved by the Committee and by the President and Council of the Royal Society, and the Secretary to the Treasury has officially intimated to the Society that it is the intention of the Government "to cause provision to be made in the Estimates for the year 1904–5 with a view to the commencement of the building of the new Magnetic Observatory, at Eskdale Muir, after the 1st April next."

The Committee trust that this site may remain free from magnetic disturbance for many years to come, and trust the work which has for so long been continued at the Kew Observatory may be shortly successfully transferred to it.

The income received from the Gassiot Trust has been expended in furtherance of the objects specified in the Gassiot Trust Deed of June 21, 1871.

The following table gives a comparative statement of the number of instruments verified in each of the last three years. It will be noticed that there is a fall of 3,500 in the number of clinical thermometers tested, and, in consequence, there is a drop in the total of 1,600.

COMPARISON OF NUMBERS OF INSTRUMENTS VERIFIED IN THE OBSERVATORY DEPARTMENT DURING THE YEARS 1901, 1902, 1903.

	1901.	1902.	1903.
Absolute Magnetic Instruments	31	26	13
Mercury Barometers	201	271	305
Aneroid Barometers	222	122	79
Hydrometers	120	410	363
Clinical Thermometers	20,389	22,856	19,393
Other Thermometers	3,506	3,086	3,240
Compasses	11	16	9
Sextants	938	769	901
Telescopes	2,029	1,678	3,180
Binoculars	669	924	1,048
Lenses	9	12	To Bushy
Watches	359	520	447
Chronometers	30	39	60
Milk Test	527	159	89
Miscellaneous	143	187	360
	29,184	31,075	29,477

But while the work of the Laboratory has prospered, the financial position is one which gives rise to grave anxiety. The receipts for the year amount to £10,200 4*s.* 3*d.* while the expenditure has been £10,306 14*s.* 6*d.*, thus leaving a deficit of £106 10*s.* 3*d.* Last year the corresponding figures were £9,314 19*s.* 3*d.*, and £9,235 9*s.* 8*d.*, giving a balance of £79 9*s.* 7*d.* In addition to this a sum of £1,036 6*s.* 11*d.* has been spent on equipment out of the accumulations of income transferred from the Kew Committee. The balance* is now £2,379 9*s.* 11*d.* as against £3,522 7*s.* 1*d.* at the beginning of the year.

The increase in income is due in part to the increase in the fees for test work, amounting to £550, in part to payments aggregating £536 10*s.* for work such as the Indian Tide predictions and other investigations. The increase in expenditure arises mainly from the additions to the staff and to the working expenses, and from the fact that the Laboratory was working fully for only nine months in 1902.

Thus the Laboratory is spending more than its income, and in the opinion of the Committee a further increase in expenditure will be necessary in the present year. To meet this a considerable increase in income is urgently required. By drawing on the balance it will be possible to continue for another year, but the time has come when the financial position must be reconsidered. This is the more necessary since the period for which the grant of £4,000 was originally made ends in September, 1904. In consequence of this the President and Council of the Royal Society have been in communication with the Treasury, and it has been arranged that the grant of £4,000 shall be continued to April, 1905—*i.e.*, for the financial year 1904–5—and that the Committee should prepare a scheme for the consideration of the Treasury. The Treasury have been asked when the scheme of the Executive Committee is received to carefully consider "the work and organization of the National Physical Laboratory, with a view to laying down the lines that ought to be followed in the future," and have stated in reply that they "will be prepared to give careful consideration to the statement and proposals with regard to the future."

It appears, from what has been already stated, that an increase of funds is required even to maintain the work of the Laboratory as at present, a further increase is necessary if it is to carry out all the work for which there is a demand. Again it is important for the sake of permanence that the positions of the senior members of the staff should be made more secure. The stipends now paid to the assistants—with one exception, £200 a year—are not commensurate with the work, and are insufficient to retain for long the services of men of the calibre required for that work, while the number of the staff is too small and should be increased.

Again in many branches the equipment is wholly inadequate.

For the Engineering Department a large testing machine should be supplied; to house this will require additional buildings, while considerable additions are needed to the tools. The divisions of Electrotechnics and Metrology must be extended, and more apparatus provided to meet the varied nature of the tests asked for, and the staff increased to carry out the work.

Since the Laboratory was started similar institutions have been founded in France and America. In Paris the new buildings of the Laboratoire d'Essais have cost £27,000, while £20,000 has been spent on equipment; the grant for the first year's income was £5,500. In Washington the buildings of the Standards Bureau are to cost £70,000 the equipment £45,000, and the annual grant is now £19,000.

In Berlin the grant to the Reichsanstalt alone is £16,000, while the total annual grant to the various institutions at Charlottenburg, which together cover the ground covered by the National Physical Laboratory, comes to about £40,000.

*This balance includes in addition to the cash at the bank the difference between the sums due to the Committee and the debts due from the Committee.

The Committee therefore, after careful consideration of the position, have come to the conclusions that :—

(1) To carry on the work already undertaken, even without providing for new developments, a further expenditure is needed: (*a*) for working expenses, (*b*) for equipment;

(2) In order to comply with requests for test work before the Committee, and to compare with similar institutions elsewhere, considerable increase in buildings and equipment is requisite, necessitating, in consequence, an increase in the staff;

(3) In order to obtain permanence for the work of the Laboratory, the position of the senior members of the staff should be improved and made more secure.

In accordance with the arrangement already arrived at it has been the duty of the Committee to prepare for the Treasury a detailed scheme for the future working of the Laboratory, and in this matter they hope to have the co-operation of the various institutions and societies represented on the General Board.

SUBSCRIPTIONS RECEIVED IN 1903 TOWARDS THE PROPOSED ANNUAL FUND OF £2,500.

Institution of Civil Engineers	£500	
Iron and Steel Institute	200	
Railway Companies' Association	200	
Society of Chemical Industry	100	
Eastern Telegraph Co.	50	
Sir E. H. Carbutt, Bart.	25	
Sir Bernhard Samuelson, Bart.	25	
Messrs. Hadfield's Steel Foundry Co.	10	10*s*
Messrs. Vickers, Sons, and Maxim	10	10*s*.
Messrs. J. J. Saville & Co.	3	3*s*.

STATEMENT OF WORK FOR THE YEAR 1904, SUBMITTED TO THE GENERAL BOARD AT THEIR MEETING ON MARCH 18, 1904.

ENGINEERING DEPARTMENT.

Wind Pressure Research.—Certain points connected with the measurements on small models remain to be cleared up. Among other things, a series of measurements will be made on the distribution of pressure in the rear of a rectangle of given breadth as the length is varied. The relation between the pressure on the curved surface of a cylinder and that on a plane through the axis of the cylinder bounded by the surface, is also being investigated.

For the purpose of extending the experiments to models of larger size, a tower 50 feet in height has been erected; at the top of this there will be a horizontal arm pivoted about a vertical axis, and from this arm pairs of similar plates will be supported. The experiments will consist in adjusting the distances of these plates from the common centre of rotation until the resultant thrusts on the two plates due to the wind balance. From this it will be possible to deduce the relation between the mean intensity of the pressure over a plate of given form and its area. Experiments on lattice work and on models of structures as large as can be fitted to the apparatus will then follow. It is hoped to make observations on areas amounting to 100 square feet.

Alloys Research.—The mechanical tests connected with the research on nickel-steel, undertaken jointly by Mr. Hadfield and the Laboratory, will go on in the Engineering Department. Further details of this work are given under Metallurgy.

A special feature of this investigation will be the series of experiments with the alternating stress-testing machine, described in the Annual Report for 1902, p. 12, and constructed in the Laboratory.

It is hoped by the aid of this machine, combined with the microscopical examination of the strained specimens, to investigate carefully the phenomena of elastic fatigue.

Steam Research.—The experience gained with the apparatus at present set up is sufficient to show that the method works and to give preliminary values for the specific heat of superheated steam. The next step will probably be to rebuild part of the apparatus on a larger scale so as to admit of larger flows and higher pressures. The present apparatus will stand over 200 lbs. pressure, and will condense about 80 lbs. of steam per hour; in any one of Regnault's experiments the maximum amount of steam condensed was 10 grammes. In an experiment of the present series, lasting for five minutes, 3 kilogrammes of steam are condensed.

When this work has been completed the same apparatus will be utilised to determine the latent heat of evaporation of water at high temperatures; and, finally, it is proposed to determine the relation between the pressure and temperature of superheated steam.

Special Screw-Cutting Lathe.—When this is delivered and erected a considerable amount of work will be required in the testing and calibrating of the screw of the lathe before it can be utilised for the manufacture of standard leading screws. This work will be undertaken conjointly with the Metrological Division.

General and Testing Equipment.—For the purposes of water-meter testing a 1,000-gallon tank has been procured, and the necessary pipe-fitting and erecting commenced.

A machine for the determination of the co-efficient of friction of bearing surfaces has been designed, and the construction will be proceeded with early in the year.

The work of the Workshop Staff will, it is expected, be mainly devoted to—

The construction of the apparatus for measuring wind-pressure, and for the research on superheated steam.

The running of the alternating stress-testing machine, and the preparation of the specimens.

The construction of apparatus for the new comparator in the Metrological Division.

The preparation of the specimens for the nickel steel researches.

The construction of the friction machine.

The fitting and erecting of the water tank.

The construction of certain parts of the ampère balance for the Electrical Division.

The delivery of the 7-inch lathe on order is expected early in the year, and will relieve the pressure on the existing machine tool equipment.

PHYSICS DEPARTMENT.

ELECTRICITY DIVISION.

Standard Cells.—The experiments made up to the present seem to show that differences remaining in the mercurous sulphate obtained from different makers, even when re-purified in the standard manner in the Laboratory, are the main cause in the differences observed between different standard cells. It is hoped that it may be possible to prescribe a standard method of preparing the sulphate, which will eliminate these differences. At present, the electrical test of purity is more sensitive than the chemical.

Ampère Balance.—At the request of the Electrical Standards Committee of the British Association, the Laboratory has undertaken the construction of a standard ampère balance, designed by the late Prof. Viriamu Jones and Prof. Ayrton. The coils of the balance consist of helices of bare copper wire wound on marble cylinders, and its working depends very greatly on the accuracy with which these coils are wound and measured; for this work the Laboratory is well equipped, and an experimental coil has been successfully wound and tested. The funds for this work are found by the British Association.

When this work is completed it will be possible to go on with the construction of the Lorenz machine, which is to be given by the Drapers' Company.

Electrical Tests for the Engineering Standards Committee.—The tests on insulating materials will be continued; the investigations now in progress relate to the distribution of temperature within the layers of the field coil of a dynamo or motor. Tests, as ordinarily made, give the mean temperature of the coils; it is desired to know by how much the maximum temperature may in practice differ from the mean.

These experiments are being conducted in co-operation with Messrs. Cromptons, Messrs. Johnson and Phillips, Messrs. Mather and Platt, Messrs. Siemens Bros., the British Westinghouse Co., and other firms.

General Testing Work.—Much requires to be done to complete the equipment.

Large currents are frequently needed for testing meters, &c., both direct and alternating. For this it will be necessary to supply some large storage cells and a set of step-down transformers for use with Messrs. Siemens Bros.' alternator.

The question of the automatic regulation of the current used for testing meters and similar apparatus is one of some difficulty, especially when the supply station is a small one and the load very variable. Considerable progress, however, has been made towards its solution, and it is hoped that the difficulty may shortly be overcome.

The testing of electrical instruments has increased greatly during the past year, and there seems every reason to anticipate a continued increase; the accommodation provided is already becoming too small.

Thermometry Division.

The work proposed includes:—

(1) The completion of the work on the specific heat of iron at high temperatures.

(2) Investigation of various methods of measuring temperatures between 1,400 C. and 1,800 C.

(3) Study of the thermo-electric force of junctions of platinum, platinum-rhodium and platinum, platinum-iridium, and of the effects of small impurities. For this research a good deal of material is in hand.

(4) An investigation into the effect of change of pressure on the boiling point of sulphur.

(5) In conjunction with the Engineering Department, an investigation into the properties of steam, involving determinations of—

(*a*) The specific heat of super-heated steam;

(*b*) The latent heat at various pressures;

(*c*) The variation of pressure with temperature.

(6) The continuation of the enquiry now in progress into the suitability of various glasses for high temperature thermometry.

Metrological Division.

The work in prospect includes the following:—

(1) The erection and standardization of the two comparators referred to in the Director's Report. One of these is for lengths up to ten feet, the other is arranged for the rapid inter-comparison of the divisions on a given bar.

(2) The completion of the standardization of the steel yard and nickel metre. The yard is primarily intended for the standard leading-screw lathe, which is being laid down for the Standard Leading Screw Committee of the War Office, and when this is installed the measurement of the screws cut upon it will be undertaken by the department.

(3) A comparison of an "end" yard and an "end" metre with the "line" standards and a calibration of the subdivisions of each. This work is urgently needed. A firm of engineers recently sent the same series of English-measure gauges to four different authorities for measurement, with the result that in the case of more than one gauge there were discrepancies amounting to as much as $\frac{1}{1000}$ of an inch.

(4) The standardization of a 4-metre and a 10-ft. standard, which it is hoped to acquire.

(5) The construction of an apparatus for measuring steel tapes and wires, also a machine for comparing " end " standards automatically.

(6) A determination of a number of co-efficients of expansion of nickel steels, in connection with the research mentioned under the head of Metallurgy.

(7) The inter-comparison of a series of weights from 1 lb. to 56 lbs., and from 1 kilogramme to 20 kilogrammes.

METALLURGICAL DIVISION.

Nickel Steel Investigation (jointly with Mr. Hadfield).

A series of eight medium carbon-nickel-iron alloys, having each about 0·45 per cent. of carbon and 0·8 per cent. of manganese, and varying in nickel content from 0 to 20 per cent., have been prepared by Mr. Hadfield.

Specimens of each of these are, as far as possible, to be subjected to the following series of tests :—

A.—*Mechanical (in Engineering Laboratory).*

(1.) Tension Tests :—
- (*a*) Yield point.
- (*b*) Breaking point.
- (*c*) Extension.
- (*d*) Contraction of area.

(2.) Young's Modulus.

(3.) Compression tests.
(4.) Bending tests.
(5.) Impact tests.
(6.) Repeated loads' tests.
(7.) Hardness tests.
(8.) Torsion tests.

B.—*Physical.*

(1.) Specific gravity.
(2.) Melting point.
(3.) Dilatation.
(4.) Electrical conductivity.
(5.) Permeability.

C.—*Chemical.*

(1.) Composition.
(2.) Corrosion.

D.—*Metallographical.*

(1.) Cooling curves and influence of heat treatment.

(2.) Microphotographs and influence of heat treatment; also in relation to cooling curves and to results of repeated load tests.

Iron Tungsten Alloys.—Mr. Hadfield has very kindly supplied the Laboratory with the ingot tops of a series of iron tungsten alloys recently prepared by him (Iron and Steel Institute, September, 1903). It is hoped that determinations may be made of the range of solidification of these alloys, and also of specimens of rare metals and of other rare alloys supplied by Mr. Hadfield for this purpose.

Crucible Steels.—Mr. Matthews, Metallurgist to the American Steel Crucible Company, has placed at the disposal of the Laboratory a series of bars forged from crucible steels of exceptional purity for cooling curve determinations.

Optical Division.

A.—*Photometry.*

Pentane Standard.—The first piece of research is an investigation into the conditions under which this lamp may be treated as standard. It is known that its intensity varies greatly with the quantity of aqueous vapour present, and also with the barometric pressure and with the carbonic acid. An examination into these causes of variation is now in progress, on its completion it will be possible to define the conditions under which the lamp may be used.

Primary Standard.—The pentane lamp can only be treated as a secondary standard; the next series of experiments will relate to the establishment of some primary standard, *e.g.*, the radiation from a square centimetre of glowing platinum at a definite temperature, or that from a perfectly black body at a definite temperature.

Testing Work.—A considerable amount of work and expenditure is required before the life-testing equipment can be considered as completely satisfactory, and various important questions connected with the life and most efficient working of lamps have been raised by the Electrical Adviser to the Admiralty and by others; some of these are now being attacked.

B.—*Optical Properties of Glass.*

Refractivity and Absorption.—A series of measurements on the refractivity and absorption of specimens of glass used by opticians has been undertaken.

OBSERVATORY DEPARTMENT.

In addition to the testing of apparatus as described in the Annual Report of the Superintendent, which will be continued, there are a number of investigations required connected with the magnetic instruments and the apparatus for recording the variations in atmospheric electricity, which will be necessary for the Observatory at Eskdale Muir.

These Dr. Chree hopes to carry out; he is also engaged on the reduction of the Kew magnetic records, and has already obtained from them results of great interest.

Particulars of the testing work are contained in the various test pamphlets, which may be had on application to the Director.

STAFF OF THE LABORATORY.

Director—R. T. GLAZEBROOK, D.Sc., F.R.S.

Observatory Department.

Superintendent—Charles Chree, LL.D., F.R.S.
Chief Assistant—T. W. Baker.
Senior Assistants—E. G. Constable, J. Foster, T. Gunter, W. J. Boxall.
Junior Assistants—E. Boxall, G. Badderly, A. C. Cooper, B. Francis, A. G. Williams.
Boy Clerks—P. H. Durham, H. A. Maudling, W. J. Stockwell, A. E. Gendle, A. F. Clayden.
Caretaker, &c.—R. Featherstone, with wife as housekeeper.

Physics Department.

Assistants—J. A. Harker, D.Sc.; A. Campbell, B.A.; H. C. H. Carpenter, M.A., Ph.D.; W. Hugo.; B. F. E. Keeling, B.A.; C. C. Paterson; F. J. Selby, M.A.; F. E. Smith, A.R.C.S.; W. A. Caspari, Ph.D.
Student—L. F. Richardson.
Computer—W. H. Brookes.
Instrument Maker—F. H. Murfitt.
Carpenter—W. Poulter.
Porter—R. Murrison, with wife as housekeeper.
Laboratory Boys—J. A. Gibb, C. H. Unsted, W. H. Eastland, E. G. Singleton.

Engineering Department.

Superintendent—T. E. Stanton, D.Sc.
Assistant—C. Jakeman.
Junior Assistant—S. W. Melsom.
Student—W. G. Duffield.
Mechanics—J. Taylerson, C. Hellary, W. Sidding.
Electrician—P. Rivers.
Engineer—H. Tunwell.
Laboratory Boys—W. Poulter, H. Price.

Office.

Clerk and Accountant—G. E. Bailey.
Boy Clerk—A. May.

Garden, etc.

J. W. Marshall, S. Hayes.

REPORT OF THE DIRECTOR FOR THE YEAR ENDING DECEMBER 31, 1903.

In presenting his Report for 1903 the Director wishes to call attention to the progress made in all Departments during the year. Attention has been drawn to the more important matters in the Report of the Committee; particulars of interest will be found in the detailed accounts of the various Departments which follow.

His thanks are due to the various members of the staff for the zeal and energy with which they have co-operated in promoting the work of the Laboratory.

PHYSICS DEPARTMENT.

I. ELECTRICITY.

A. *General Measurements.* (*Mr. Campbell and Mr. Melsom.*)

Tests.—A list of the tests carried out in the Electrical Division is given in the Report of the Committee.

In addition to those there mentioned, two series of investigations on the change of resistance of metallic films due to annealing have been completed.

Tests on Laboratory Instruments, etc.—The Standard B.A. Air Condensers were measured from time to time, their constancy being satisfactory within the limits of accuracy attained. An investigation was also made into the absorption in mica condensers by Muirhead and Carpentier.

In connection with an endeavour to obtain steady temperatures, four thermostats have been tested, and the distribution of temperature in a well-lagged oven investigated.

The electric clock, presented by Prof. McLeod, was partially rebuilt and set up. It has now been going for about a month, and is at present under observation.

In connection with the question of Matthiessen's Standard of copper conductivity a number of samples of copper were tested.

For purposes of comparison tests have been made upon seven samples of magnet steel of high-class make.

In connection with the 1-ampère balance in course of construction, a short research was carried out on the rise of temperature of thin strips carrying various currents.

In the same connection a number of samples of brass were tested for permeability.

The Standard Kelvin Voltmeter has had its scale drawn, and is being calibrated at intervals.

Some tests have been made on a sample Bastian Meter.

With a view to the testing of Ampère-Hour Meters on long runs, an investigation has been made upon sensitive relays, and an apparatus has been set up which automatically regulates current to 1 part in 1,000.

A series of tests was made on the Crompton Potentiometer belonging to the Laboratory, and a number of instruments and resistances were tested for the Photometric Department.

Apparatus Constructed or Installed. The following apparatus has been constructed or installed:—

Standard 0·001 ohm for 250 ampères.
„ 0·1 „ 15 „

Potential-dividing Box for 500 volts.
Regulating Box (4 dials and slide wire).
4 Shunts for Weston Voltmeter (1 to 25 ampères).
Set of Standard Coils to build up 10 ohms.
Ratio Box (0·1 to 10,000 ohms) for condenser tests.
Air Condenser for insulation tests.
Electro-Magnet to give H = 1,000, for watch testing.
Set of Coils (10 to 200 ohms).
Marble Mutual Inductance Standard (0·0001 to 1 henry).
Shunt Box and Special Key for insulation tests.
3 Electric Ovens for same.
2 Clamps for high voltage tests.
Shunt Box and Regulating Resistances for workshop test room.
Set of Regulating Resistances (to carry 100 ampères) for low resistance tests.

B.—*Fundamental Units.* (*Mr. Smith.*)

Experimental Work.—(a) *Mercury Standards.*—The work in connection with the Mercury Standards of Resistance has been carried to a successful conclusion during the past year, and a full report is now ready for publication. Of these mercury standards, eight are of Jena 16‴ glass, and three of Verre dur, the lengths of the eleven tubes varying from 60 to 120 cms. Fittings for each tube have been constructed, enabling the measured resistance to either include or omit the "end correction," the value of the latter having been determined for the special kind of connecting cups used.

The resistance measurements were made by means of the Kelvin Bridge, the Potentiometer, and the Carey Foster Bridge, the two former methods being adapted to either include or omit the end correction, and the last necessarily including it. The object of these different forms of measurement was to determine experimentally the best means of adapting the mercury standard as an easily reproducible standard for the Laboratory. The result of the observations on the whole eleven tubes shows that the difference between the International ohm, as defined by a uniform column of mercury 106·300 cms. long and 14·4521 gms. mass, at 0° C. is known to about ·001 per cent.

In order to render the experiments complete, the temperature co-efficient of mercury in Jena 16‴ glass, and also in Verre dur glass has been determined. The two values of the temperature co-efficient of a constant volume of mercury as deduced from these measurements are in very close agreement, and the probable error of the whole determination is exceedingly small.

It is proposed that these eleven mercury standards be compared with the manganin and platinum-silver standard of the Laboratory at least once in each year. In addition, some mercury standards of a more convenient form will be set up permanently in the coming year. The probability of changes occurring in these standards owing to the strained condition of the glass is discussed in the report, and but very small variations are anticipated. Moreover, such changes are capable of detection by repeating the processes employed in the construction. The Laboratory is, therefore, in a very firm position with respect to the reproduction of its unit.

(b) *Comparison of Units of Resistance.*—The unit of resistance employed at the Laboratory has been compared with that of the Board of Trade, and also with the

Reichsanstalt unit. The results of these comparisons were published in a paper read before the British Association at Southport. A comparison with the International ohm has, of course, been obtained by means of the mercury standards already referred to.

(c) *Wire Standards of Resistance.*—A complete report dealing with the past and present values of the platinum-silver and manganin standards of the British Association was presented at Southport. Marked changes were noted in certain of the coils. In addition, there are several new manganin standards—some purchased, and others made at the Laboratory These coils range from ·001 ohm to 10,000 ohms, the coils from 1 ohm upwards having been kept under very close observation. The lower coils are now being similarly observed, so that much information is accumulating respecting the reliability of wire standards for accurate work.

(d) *Standard Cells.*—The tests made on these have proved entirely satisfactory, but progress with new cells will not be made until next year. For these, Dr. Carpenter has prepared several samples of mercurous sulphate. The whole of the cells made in 1902 are in good condition, and the change in voltage of the faulty ones has been very much as anticipated. During the year several standard cells have been submitted for test, the results proving that the Clark cell cannot at present be regarded as reliable.

(e) *Ampère Balance.*—Experimental coils wound on marble have been constructed in the Engineering Department, and the necessary insulation tests, &c., made. Brass rods and castings intended for use in the construction of the balance have been tested for magnetic permeability with final satisfaction.

C.—Electrotechnics. (*Mr. Paterson.*)

This division is being organised for the purpose of undertaking tests on electrical instruments, such as ammeters, voltmeters, wattmeters, watt-hour-meters, &c., &c.

Equipment.—Arrangements are being made for dealing with heavy currents, both alternating and direct, as well as high voltages.

A 5-kilowatt motor alternator, presented by Messrs. Siemens Bros., has been put down and tested. Single-phase, two-phase, and three-phase currents can be obtained from this machine at frequencies varying from 20 to 120 alternations per second. Messrs. Siemens are also giving three high-tension transformers.

The following apparatus has been purchased and delivered:—

		Range.
1	Kelvin electrostatic voltmeter, with mirror attachment...	50 to 150 volts.
1	„ ampère balance	600 amps.
1	„ „ „	100 „
1	„ watt balance, with dividing resistance	10 amps. 1,000 volts.
1	Siemens wattmeter	100 amps. 1,500 volts.
1	„ „	10 amps. 1,500 volts.
1	Weston alternating current voltmeter	16 to 320 volts.

Three Addenbrooke electrostatic instruments (wattmeter, voltmeter and ammeter) are on order for use in alternating current testing. These will be used in conjunction with a slightly modified form of Mr. Addenbrooke's special switch box. Non-inductive series resistances and dividing resistances for high voltages will enable the apparatus to be used over a wide range.

A special low resistance potentiometer has been designed by Mr. Melsom, for use in direct current measurements, and will be put in hand early in the coming year.

II. Thermometry. (*Dr. Harker and Mr. Hugo.*)

Tests.—During the year tests have been made and certificates granted to the instruments indicated on the list in the Report of the Executive Committee.

Melting-point determinations have been made on thirteen samples of metals, at temperatures up to 1,100°, and on five Seger cones, the highest of which melted at 1,450° C.

The freezing points and behaviour at low temperatures of two samples of oil have also been determined.

To meet the demand for the verification of the very long high range thermometers used in various industries, special apparatus was constructed, in which the reading of the instrument could be taken with any definite immersion in a vapour of known boiling point—diphenylamine and naphthaline being two of the most useful substances.

New Apparatus constructed :—

(*a*) Three new high temperature electric furnaces, with nickel heating coils.

(*b*) Three annealing ovens for mercury thermometers, for 100°, 250°, and 450°, heated in series from the 100-volt lighting circuit, with heating coils of eureka wire.

(*c*) New steam bath for mercury thermometers.

(*d*) Five thermo-junctions for high temperature work.

(*e*) Baths for high temperature fixed points of long stem thermometers. Boiling points of naphthaline and diphenylamine.

(*f*) New ice baths for Tonnelot thermometers and for thermo-junctions.

Research Work.—(a.) *High Temperature Comparisons of Standards.*—The research work of the Department for the year has consisted mainly of a continuation of the investigation mentioned in last year's Report on the various high temperature standards. In addition to the comparisons of gas and platinum thermometers investigations have been made on the behaviour of thermo-junctions for high temperature measurement, and in particular the junctions of platinum and platinum-rhodium obtained from the Reichsanstalt, where they had been standardized at a number of fixed points by Dr. Holborn.

During the present year the inter-comparison of the gas thermometer with porcelain bulb, one of the platinum-platinum-rhodium junctions alluded to, and two different platinum thermometers has been continued, and after all corrections are applied the discrepancies between the different instruments are found to be very small. Between the two types of instruments least affected by temperature lag, namely, the platinum thermometers and the junctions, the difference in one set of experiments, extending from 500° to 1,000° C. never attains 1° C., and the several series of independent measurements with different fillings of the gas thermometer concord as closely as could be expected.

The results of these experiments have been communicated to the Royal Society.

(b.) *Specific Heat of Iron Experiments.*—The experiments on the specific heat of iron mentioned in the last Report have been continued, and the numbers previously obtained, which differed materially from the most generally accepted value for this constant, have been, on the whole, confirmed, but between 800° and 900° C., the part of the curve where for pure iron free from carbon a discontinuity was noticed previously, the later experiments seem to point to some influence on the specific heat of the temperature to which the iron has previously been subjected. This point needs further investigation.

(c.) *Constants of Steam.*—Conjointly with the Engineering Department work has been commenced on a redetermination of the constants of steam: the first of these undertaken being the specific heat of superheated steam. An apparatus has been constructed and erected in the main Engineering Laboratory, which promises to give satisfactory results. A heating coil of "resista," a nickel steel of very high resistivity, has been built of thin strip, insulated with mica, by which a current of steam from the experimental boiler can be superheated up to about 300° C., the temperature of the steam being taken by thermometers in steel tubes at the points where it enters and leaves the superheater. For this small preliminary apparatus the maximum flow given by the boiler is 40 lbs. of steam per hour with an atmospheric gas burner, but provision has been made to considerably increase this by addition of an air blast, when required. In the larger apparatus shortly to be constructed provision is being made to take all the temperatures electrically, thus obviating the many difficulties peculiar to high temperature mercury thermometry.

(d.) The tests on the constancy and general characteristic properties of the different thermometric glasses supplied by Messrs. Powell & Sons, alluded to in the last Report, have been continued. A number of special thermometers, constructed by different makers, of various kinds of representative thermometer glasses, have also been studied. The effect of prolonged annealing at various temperatures on the depression of the freezing point has been the subject of a long series of tests, which promise interesting results, and to throw light on some of the difficulties associated with high-range mercury thermometry.

III. Metrology. (*Mr. Keeling.*)

Tests.—These have comprised coefficients of expansion, tests of "line" and "end" measures of length, specific gravities (chiefly of rail steels for the Engineering Standards Committee), &c.

Work done.—There have been added to the equipment of the Department—

The British Association machine for measuring small screws.

A balance for testing weights up to 20 kilogrammes.

A comparator has been designed and will be installed early in January for the calibration of the sub-divisions of standards of length.

Drawings have been prepared and considerable progress made in the construction of a water-bath comparator for the standardization of measures up to four metres in length, and for the measurement of tapes which are intended to be used flat.

The principal room of the Department has been fitted with an automatically regulated gas stove.

The Department was engaged during part of the year in measuring the mean cross-section of the tubes used by Mr. Smith in his determination of the specific resistance of mercury.

Progress has been made with the standardization and inter-comparison of the Laboratory standards. A steel H-form bar, divided on a platinum-iridium strip over

40 inches into $\frac{1}{10}$ths, has been delivered. A 36-inch length of this bar has been compared with a cast-iron yard placed at the disposal of the Laboratory by the Board of Trade Standards Department, and also with the Laboratory metre.

Using the latest determination of the relation between the yard and metre (1 metre = 39·37011 ins.) and taking 16·67° C. on the hydrogen scale as the standard temperature for the yard, the two values thus obtained agreed to about one part in one million.

Progress has been made with the calibration of the sub-divisions which, it is hoped, will be completed early in the coming year.

In addition to the above, a nickel H-form metre has been acquired, and its error at 0° C. and its coefficient of expansion have been determined.

Attention has been paid te the Laboratory's end-standards. The sub-divisions of the foot have been compared amongst themselves with a resulting change in the relative errors attributed to each.

IV. Chemistry. (*Dr. Carpenter and Dr. Caspari.*)

Investigations of a somewhat extensive character have been made on :—

(*a*) A material used for electrical insulation purposes.

(*b*) An oil for the Marine Department of the Board of Trade.

(*c*) Specimens of sound and faulty bronze castings.

The analytical work includes complete analyses of nickel-steel forgings, phosphor-bronze rings, mild steel rivets, steel rails, standard copper, water, coke, and caoutchouc.

In addition, analyses of some 30 iron-carbon alloys, made in the Metallurgical Department, have been carried out.

Further experiments on the preparation of pure mercurous sulphate for standard cells have been made.

Testings of Glass Measuring Vessels.—Some 665 of such vessels have been tested.

V. Metallurgy. (*Dr. Carpenter and Mr. Keeling.*)

Apparatus.—Various additions to the furnace equipment have been made. Through the kindness of Messrs. Chance Bros., Birmingham, two specially-constructed concentric jet crucible furnaces have been supplied. Electrically-heated tube furnaces, suitable for cooling curve work, are now installed.

A potentiometer has been specially constructed for use with the thermo-junctions employed in the measurement of temperatures up to 1,500–1,600° C.

Tests.—Photo-micrographs have been taken of mild steels, tool-steels, cast-irons, bronzes, phosphor-bronzes, and caoutchouc. Cooling curves have been taken of various steels.

Research.—The scheme of work outlined in Section (1) [Report for the year 1902] is nearly completed.

Some 33 iron-carbon alloys of great purity have been made by melting in a crucible furnace suitable mixtures of a low-carbon and high-carbon alloys. These latter were kindly supplied by Mr. Hadfield. Each alloy weighs between 3 and 4 lbs. The carbon content varies from 0·12 to 3·87 per cent., broadly speaking, by increments of 0·1 per cent. as aimed at.

The range of temperature through which the solidification of each alloy extends has been determined. In addition, the various critical changes which take place before the alloy has cooled to the ordinary temperature have been investigated by differential coolings against platinum; the results have shown the necessity of further micrographic investigation, as the alloys cool from 600–500° C. This is in progress.

The authors (Dr. Carpenter and Mr. Keeling) hope to present this work at the forthcoming meeting of the Iron and Steel Institute.

The series of medium-carbon nickel-iron alloys, referred to in Section (2) [Report for the year 1902], have been prepared at the Hecla Works, Sheffield. Eight alloys, whose compositions vary as follows, have been cast:—

	Carbon.	Nickel.	Manganese.
1798 A	0·47	Nil	0·95
B	0·50	1·27	0·89
C	0·46	2·19	0·83
D	0·40	4·18	0·75
E	0·43	7·97	0·79
F	0·41	12·19	0·82
G	0·45	15·94	0·83
H	0·41	19·81	0·96

Part of each ingot has been forged to a bar $1\frac{1}{4}$-inch diameter. The remainder has been cut into test pieces.

Unannealed, as well as annealed, test pieces of A, B, C and D have been prepared.

Alloys E, F, G and H were so hard that they could only be machined after annealing at a particular temperature, which was different for each alloy. The forging, machining, and annealing have been done at Sheffield.

The electrical conductivities of the forged bars have been determined at Bushy House.

VI. Optics.

A.—*Photometry.* (*Mr. Paterson.*)

Equipment.—The organisation of this department was begun in the early summer of the present year.

The 300-volt battery kindly presented by the Electrical Power Storage Company has been installed, together with a regulating switchboard, and three separate circuits to the photometer room; these, in addition to alternating current leads and two circuits from the experimental battery, will fully meet all requirements for photometric work of incandescence lamps.

The equipment of the photometer room has been carried out with a view both to rapid and accurate repetition work and convenience in experimental research.

Messrs. Robertson & Co., Hammersmith, have kindly undertaken to make, and present to the Labaratory, a set of large bulb secondary standards, with voltages ranging from 100 to 250, and candle powers from 8 to 100. Messrs. Robertson are paying special attention to the manufacture of these lamps, which will form a very complete set of standards. Four have already been delivered.

The equipment for life tests is not yet complete.

Apparatus.—The following are the principal pieces of apparatus :—

1 Photometer bench (Reichsanstalt pattern) by Messrs. Schmidt & Heensch, presented by Sir William Preece.

1 Crompton potentiometer, presented by Messrs. Crompton & Co.

1 Harcourt 10-candle-power Pentane lamp, presented by Sir William Preece.

1 Trotter bar photometer, presented by A. P. Trotter, Esq.

3 Fleming type large bulb secondary standards, presented by Dr. Fleming.

1 Kelvin electrostatic voltmeter with mirror attachment and scale at two meters radius reading to $\frac{1}{100}$ volt.

1 Ayrton & Mather reflecting galvanometer shunting a set of series resistances, used as ammeter.

1 Ayrton & Mather reflecting galvanometer with dividing resistances, used as voltmeter.

An apparatus has been made for automatically regulating the voltage of lamps on life test. This is giving satisfactory results, and a larger piece of apparatus is now under construction for the same purpose.

Tests.—The chief work undertaken up to the present has been the thorough investigation of a 10-candle-power Harcourt Pentane lamp, with a view to determine the variation of its light strength with barometric pressure, as well as humidity and carbon dioxide in the air. In connection with these experiments, the Chemical Department has fitted up an apparatus for measuring the carbon dioxide in the air by titration method. These investigations will be carried on during 1904, but they are now sufficiently far advanced to enable lamp testing on a large scale to be undertaken.

B.—*Experiments on Optical Glass.* (*Mr. Selby.*)

The following apparatus has been provided :—

(*a.*) A Pulfrich refractometer for the measurement of refractive indices and of dispersion : with a heating apparatus for use in determining the refractive indices of liquids at temperatures ranging to about 75° C.

(*b.*) A König-Martens spectrophotometer, for absorption measurements.

The refractometer has been standardized, and the Department is now prepared to undertake the determination of the optical constants of glass and other substances. A good spectrometer, with circle divided to 5′, is also available for this purpose when greater accuracy is desired.

For the absorption measurements, which are undertaken at the request of the Committee of the Optical Society, Messrs. Chance Bros. have promised to furnish specimens of glass, and it is hoped that a series of observations may be carried out on the absorptive qualities of glasses of different composition.

Experiments are also in progress relative to the use of mercury lamps for optical purposes, especially in connection with the specification of glass for the information of optical instrument makers.

VII. Tide Prediction. (*Mr. Selby and Mr. Brookes.*)

The tide-predicting machine, designed by Lord Kelvin and Mr. Edward Roberts, of the Nautical Almanac Office, which has been used for some twenty years for the prediction of the Indian tides, has now been transferred to the care of the National

Physical Laboratory. The machine, which is the property of the Indian Government, underwent thorough repair during the early part of the year, and in August was erected in the Laboratory. An assistant has been appointed to superintend the work, with a computer to carry out the calculations and measure the curves.

The preparation of the tide tables for 1905 is now in progress. Thirty curves have been run off on the machine, and the work of measuring these to obtain the heights and times of high and low water is proceeding. A start has also been made on the work for the riverain ports, in connection with which the machine can only be used to give the corrections for the diurnal tides.

VIII. Library. (*Mr. Selby.*)

A Librarian has now been appointed; arrangements have been made for a Card Catalogue, and the work of cataloguing the books at present in the Library has been carried out.

In addition to those previously mentioned, the following Societies and Institutions have agreed to an exchange of publications:—

The Chemical Society.
The Faraday Society.
The Society of Public Analysts.
Chambre Centrale des Poids et Mesures de l'Empire de Russie.
University of Upsala.
The Institution of Gas Engineers.
Königliche mechanisch-technische Versuchsanstalt, Charlottenburg.
Koninklijke Akademie, Amsterdam.
The American Philosophical Society.
The London Mathematical Society.

To some of these the Library is also indebted for donations of books or of back numbers of "Proceedings."

The following have been added to the periodicals purchased for the Library:—

The Philosophical Magazine.
Comptes Rendus.
L'Eclairage Électrique.
Elektrotechnische Zeitschrift.
Stahl und Eisen.
Recueil des Travaux Chimiques du Pays-Bas.
International Catalogue of Scientific Literature.

The Library has to thank the Royal Society for a valuable gift of back volumes of the "Philosophical Transactions."

D

REPORT ON THE ENGINEERING DEPARTMENT FOR THE YEAR ENDING DECEMBER 31, 1903, MADE BY THE SUPERINTENDENT TO THE DIRECTOR.

Commercial Testing.—A statement as to tests carried out for the public is given in the Report of the Committee.

Apparatus for the determination of the efficiency of steam-pipe coverings was designed and made in the Department. For the purpose of temperature tests on materials, a high-pressure digester has been made and fitted to the experimental boiler.

A large steam drum has been fitted to the experimental boiler, completing the equipment necessary for the testing of indicator springs under steam pressure. The apparatus used for the research work on the pressure of air on surfaces has been modified, to enable tests to be made on air meters in currents moving at 3,000 feet a minute—several inquiries for these high-velocity tests having been received. A new cylinder, for the purpose of testing deep-sea thermometers up to a pressure of 1,000 fathoms of water, has been constructed and attached to the high-pressure gauge testing apparatus.

Research Work.—(1) The effect of wind pressure on structures. The first part of this research, which included the determination of the nature and distribution of the pressure on surfaces placed in a uniform current of air, has been completed, and the results embodied in a Paper, communicated to the Institution of Civil Engineers, which was read and discussed on December 22nd. The construction of the apparatus required for the second part, which will be devoted to observations of the effect of wind pressure on models of structures of considerable size, is well in hand—a tower, 50 feet high, having been erected, and the design of the balancing arrangements completed.

(2) The apparatus required for the research on the specific heat of super-heated steam has been constructed and set up, and the experiments are proceeding.

Work done by Workshop Staff.—The chief part of this has been devoted to the construction of apparatus required for the air-resistance research, and to the fitting and erecting of the alternating stress testing machine, which is now practically completed. Other work which has been carried out includes :—

Making resistance frame and fixing and fitting switch-board for new battery in Physical Laboratory.
Fitting up forge and smelting house.
Erecting tide-calculating machine.
Fitting magnalium dome for seconds pendulum.
Construction and winding of marble cylinders for ampère balance.
Preparation of specimens for metallurgical research.
Erecting sundry machines.
Construction of apparatus for super-heated steam research.

Lighting and Heating Department.—The earthenware pipes leading from the turbine condenser supply tank to the cooling pond have been replaced by stronger ones of cast iron, and the leakage of the pond stopped.

All the batteries have continued in good working order throughout the year. The increased demand for power during the year has put a severe strain on the present arrangements for charging the batteries separately, and the addition to the plant of another booster set, for charging the batteries in parallel, is becoming necessary.

T. E. STANTON,

Superintendent of the Engineering Department.

APPENDIX TO THE REPORT OF THE SUPERINTENDENT OF THE ENGINEERING DEPARTMENT.

New Lathe House for the Whitworth Standard Screw-cutting Lathe Erected at the National Physical Laboratory.

A house has been built on a site selected for the purpose in the grounds of Bushy House to contain the new Whitworth screw-cutting lathe.

As will be seen from the plans,* the lathe room is completely surrounded by an outer shell, the spaces between the walls being utilised for the driving and heating plant; an arrangement adopted to secure uniformity of temperature in the lathe room. The system of ventilation is by induced draught from a Davidson Sirocco Fan placed at the outlet. The air is drawn into the space between the inner and outer walls, where it is heated by passing over hot-water pipes. It is then admitted into the lathe room, at a distance of two feet from the floor, and finally passes out at the top into a trunk running along the outside of the inner wall to the outlet. The lathe room is provided with a glazed roof, and a glazed partition at one side through which observations can be made from the outside of the room, and is air-tight, with the exception of the ventilation inlets and outlets. The foundation of the lathe consists of twenty tons of concrete covered with six inches of York stone. The power is supplied by a 5-h.p. motor, which drives the lathe through two countershafts. Arrangements are also made for driving the lathe mandrel direct from the outside of the room. Professor Hele-Shaw has kindly presented one of his patent friction clutches for starting and stopping the lathe, and which is placed on the last countershaft.

The heating, on the low-pressure hot-water system, is by means of a segmental boiler, situated in a separate stokehold, and admits of considerable temperature regulation.

The house was built by Messrs. Dorey & Co., of Brentford, the electrical equipment being carried out by Messsrs. F. A. Glover & Co., and the heating apparatus by Messrs. Rosser & Russell.

---

* See plate at end of Report.

REPORT ON THE OBSERVATORY DEPARTMENT FOR THE YEAR ENDING DECEMBER 31, 1903, MADE BY THE SUPERINTENDENT TO THE DIRECTOR.

The work at the Kew Observatory in the Old Deer Park at Richmond, now forming the Observatory Department of the National Physical Laboratory, has been continued during the year 1903 as in the past.

This work may be considered under the following heads:—

I. Magnetic observations.
II. Meteorological observations.
III. Seismological observations.
IV. Experiments and Researches in connection with any of the departments.
V. Verification of instruments.
VI. Rating of Watches and Chronometers.
VII. Miscellaneous.

I. Magnetic Observations.

The magnetographs have been in constant operation throughout the year, and the usual scale value determinations were made in January.

The ordinates of the various photographic curves representing Declination, Horizontal Force, and Vertical Force were then found to be as follows:—

Declinometer: 1 cm. = 0° 8′·7.

Bifilar, January, 1903, for 1 cm. δH = 0·00051 C.G.S. unit.
Balance, January, 1903, for 1 cm. δV = 0·00049 C.G.S. unit.

On May 5, it was found necessary to re-adjust the position of the dots of light of the Horizontal Force Curves, as their position had become too wide apart for safe registration. On July 22, the Vertical Force instrument was also re-adjusted.

During the earlier part of the year the curves were generally quiet, but since June they have become more disturbed. The principal movements that were recorded took place on the following days:—

April 6; June 1, 2, 30; July 25–28; August 11, 22, 26; September 19, 20, 23; October, 12, 13, 31; December 13, 31.

The magnetic storm of October 31 is much the largest recorded at Kew since February 14, 1892. The curves for the 30th showed some disturbance of an ordinary type after 8 p.m.; but the first distinct precursor of the storm was a sudden movement at about 6.3 a.m. on the 31st, most conspicuous in the declination and horizontal force traces. Larger movements followed at about 6.45 a.m., and the disturbance remained prominent until 7 or 8 p.m., and continued very appreciable, especially in declination, until 4 a.m. next morning. During the storm there was an altogether exceptional number of large sudden movements, mostly of an oscillatory character. These were largest between 1.30 p.m. and 7 p.m., but more numerous between 10 a.m. and 1 p.m. The following were amongst the largest movements in declination: 70′ in three minutes at 2.5 p.m.; 66′ in three minutes at 2.12 p.m.; 80′ in six minutes at 3.45 p.m.

Between 6.50 p.m. and 7.12 p.m. there was a movement of 77′ to the west and return movement of 82′ to the east. The extreme range of the declination needle during the storm was about $2\frac{1}{4}°$. The value of the horizontal force at 1.26 p.m. exceeded that at 1.2 p.m by 685γ ($1\gamma \equiv 1 \times 10^{-5}$ C.G.S.), a rise of 525γ having occurred in six minutes. Between 3.16 p.m. and 3.36 p.m. there was a rise of 500γ, and between 3.45 p.m. and 3.53 p.m. a fall of 450γ.

There were also large rapid changes in vertical force. In the case of both the horizontal and vertical components the trace went repeatedly off the photographic sheet, so that the full extent of the disturbance was not determined; the difference between the extreme values certainly exceeded 870γ in horizontal force and 500γ in vertical force. A brief account of the storm was communicated to "Nature" and the "Electrician," copies of some of the disturbed curves appearing in the former journal.

The hourly means and diurnal inequalities of the Declination and Horizontal Force for 1903 for the quiet days selected by the Astronomer Royal have been tabulated as usual, and the results will be found in Appendix I, together with the monthly means of the Inclination as derived from the absolute observations. Owing, however, to the disturbance of the vertical force produced by electric trams, it has been found impossible to tabulate the curves for this element satisfactorily. This has led to the omission of the tables of diurnal inequalities of vertical force and inclination published previous to 1902.

A correction has been applied to the horizontal force curves for the diurnal variation of temperature, use being made of the records from a Richard thermograph as well as of the eye observations of a thermometer.

The mean values at the noons preceding and succeeding the selected quiet days are also given, but these of course are not employed in calculating the daily means or inequalities.

The following are the mean results for the entire year :—

From curves	Mean Westerly Declination...........	16° 40′·5 W.
	Mean Horizontal Force	0·18488 C.G.S. unit.
From absolute observations, corrected	Mean Inclination	67° 6′·5 N.
	Mean Vertical Force	0·43784 C.G.S. unit.

The absolute observations have been reduced to the mean value for the day by applying corrections based on the diurnal variation observed in previous years.

Observations of absolute declination, horizontal intensity, and inclination have been made weekly as a rule.

A table of recent values of the magnetic elements at the Observatories whose publications are received at Kew will be found in Appendix IA to the present Report.

Between May 11 and 16, the Superintendent and the Chief Assistant proceeded to Eskdale Muir, the intended site of the new magnetic observatory, and took a number of magnetic observations. The weather was, unfortunately, wet and stormy, and somewhat unfavourable to field work. The observations did not disclose any source of appreciable local disturbance, and the mean values obtained, viz.—

Declination	19° 6′·2 W.,
Inclination	69° 41′·5 N.,
Horizontal Force ...	0·16818 C.G.S.,

seem consistent with the results obtained in that neighbourhood in Rücker & Thorpe's "Magnetic Survey of the British Isles," when allowance is made for the secular change.

In connection with the International Antarctic Observations, quick runs were taken with the magnetographs on the 1st and 15th of the first seven months of the year.

At the request of Professor Birkeland, of the University, Christiania, copies of certain magnetograph curves of the years 1902 and 1903, for use in connection with the researches of the Norwegian Polar stations, have been made and forwarded to Christiania.

Copies of the great magnetic disturbance of October 31 have also been sent to M. Rykatchew, Director of the Central Physical Observatory, St. Petersburg, and to Dr. A. Schmidt, Meteorological and Magnetical Observatory, Potsdam, together with particulars of the extent of the variations recorded.

At the request of the Under-Secretary of State for India, Lieutenants A. Bingham and W. C. Taylor, of the Royal Indian Marine, visited the Observatory in July, and went through a course of instruction in the taking of magnetic observations.

In September and October, by request of the Chief of the U.S. Weather Bureau, facilities for taking magnetic observations were afforded to Mr. L. G. Schultz, who is about to take charge of a magnetic observatory in South America.

In September, Mr. Baker visited Falmouth and Valencia Observatories, and took check observations with the absolute magnetic instruments at both stations. In December, Mr. Kitto sent the Falmouth vertical force curves for the previous part of the year to Kew. Their comparison with the corresponding Kew curves, at hours undisturbed by electric trams, enabled the Superintendent to deduce a temperature co-efficient for the Falmouth curves.

A set of self-recording magnetographs (Watson pattern) have been verified for the Government Observatory, Bombay; a similar set for the Indian Government, intended for Rangoon, are now under examination.

II. Meteorological Observations.

The several self-recording instruments for the continuous registration of Atmospheric Pressure, Temperature of Air and Wet-bulb, Wind (direction, pressure and velocity), Bright Sunshine, and Rain have been maintained in regular operation throughout the year, and the standard eye observations for the control of the automatic records have been duly registered.

The tabulations of the meteorological traces have been regularly made, and these, as well as copies of the eye observations, with notes of weather, cloud, and sunshine, have been transmitted, as usual, to the Meteorological Office.

With the sanction of the Meteorological Council, data have been supplied to the Council of the Royal Meteorological Society, the Institute of Mining Engineers, and the editor of "Symons' Monthly Meteorological Magazine." On the initiative of the Meteorological Office, special cloud observations have been made with the Fineman and Strachey nephoscopes in connection with the International scheme of balloon ascents. Some observations have also been made of "upper clouds," in connection with the Norwegian Polar investigations, being carried out by Professor Birkeland.

Bright Sunshine.—As explained in the Annual Report for 1901, Table III, Appendix II, in the present Report, gives the monthly and annual percentages according to both the "old" and the "new" points of view, and it is intended to publish both results for some years.

This year, as in 1901 and 1902, the new method gives for the annual mean percentage a value greater than that given by the old, in the proportion roughly of 11 to 10, mainly due to the fact that the new method allows less weight than the old to the winter months.

Rainfall.—The fall for the year, 38·175 inches, is the largest recorded at Kew since exact observations began. It is fully double the fall in 1901, and about 80 per cent. in excess of the average fall during the last ten years.

Earth Thermometers.—At the request of the Meteorological Council two Symons' earth-thermometers were placed in position on the lawn, one at a depth of 1 foot and the other at a depth of 4 feet, the tubes being 12 feet apart and at a distance of 60 feet from the radiation thermometers.

They have been read at 10 a.m., 4 p.m., and 10 p.m. daily since May 1st, and the 10 a.m. readings have been forwarded weekly to the Meteorological Office, together with the corresponding readings of the Solar Radiation and Terrestrial Radiation thermometers.

Electrograph.—This instrument worked generally in a satisfactory manner during the year.

The E.M.F. of the battery fell off considerably during the early part of February; accordingly on February 10–12 the spare set of 20 chloride of silver cells were charged up and used in place of the more faulty set of 20, while the remaining 20 cells were cleaned and re-charged.

Opportunity was taken of this interruption to entirely dismount, overhaul, and clean all parts of the instrument. This was the only serious stoppage during the year. Determinations of scale-value were made on February 13, February 19, July 13, and November 20.

A series of curves—ten a month—have been selected as representative of the variations of potential on electrically "quiet" days, defined as days when irregular fluctuations of potential are fewer than usual. These curves have been tabulated and the results appear, with the permission of the Meteorological Office, in Appendix II, Tables IV and V. Owing presumably in large measure to the fewness of the selected days, the values deduced from the actual curve measurements show in some months a considerable non-cyclic element. This element has been eliminated from the diurnal inequality in the way customary in dealing with meteorological data.

Owing to the pressure of other work, but few observations on the loss of positive and negative electrical charges have been made with the "dissipation apparatus" of Elster and Geitel's pattern.

Inspections.—In compliance with the request of the Meteorological Council, the following Observatories and Anemograph Stations have been visited and inspected:—Stonyhurst, Armagh, Dublin, Kingstown, Valencia, Scilly Isles, and Falmouth, by Mr. Baker; Radcliffe Observatory (Oxford), Aberdeen, Deerness (Orkney), North Shields, Alnwick Castle, Glasgow, and Fort William, by Mr. Constable.

III. Seismological Observations.

Professor Milne's "unfelt tremor" pattern of seismograph has been maintained in regular operation throughout the year; particulars of the time of occurrence and the amplitude in millimetres of the largest movements are given in Table I, Appendix III.

The largest disturbances recorded took place on January 14, when the maximum amplitude exceeded 17 mm., and on February 1, when the maximum was 4·5 mm.

A detailed list of the movements recorded from January 1 to December 31, 1903, was made and sent to Professor Milne, and will be found in the 'Report' of the British Association for 1903, "Seismological Investigations Committee's Report."

IV. Experimental Work.

Fog and Mist.—The observations of a series of distant objects, referred to in previous Reports, have been continued. A note is taken of the most distant of the selected objects which is visible at each observation hour.

Atmospheric Electricity.—The comparisons of the potential, at the point where the jet from the water-dropper breaks up, and at a fixed station on the Observatory lawn, referred to in previous Reports, have been continued, and the observations have been taken every day when possible, excluding Sundays and wet days. The ratios of the "curve" and the "fixed station" readings have been computed for each observation, and these have thrown considerable light upon the action of the self-recording electrometer, especially with reference to the insulation problem.

Sunshine Recorder.—The experiments referred to in last year's Report were continued throughout the year.

Inertia Bars.—A number of observations have been made with the bars referred to in last year's Report.

Gravity Observations in connection with the Trigonometrical Survey of India.

In March, a set of four half-second pendulums and apparatus for the relative determination of gravity were received from the India Office, and the Laboratory was asked to undertake the determination of—

(*a*) The time of oscilliation of the four pendulums at Kew, and

(*b*) The correction constants for temperature and pressure.

It was also requested that the two officers, who would be in charge of the apparatus in India, Major Burrard, R.E., and Major Lenox-Conyngham, R.E., should take sets of observations with the Kew observer, to ensure that the same procedure should be adopted in England and India.

The apparatus consists principally of four half-second pendulums of the Von Sterneck type, with agate knife edges, an agate suspension plate on a tripod bracket-stand, the latter being screwed down to a massive granite slab or base, a flash-box, and observing telescope by Schneider, of Vienna, a heavy auxiliary pendulum (used to determine the rigidity or flexure correction of the stand), and a gun-metal "gallows" on which to hang the pendulums when not in actual use, by Toepfer & Sohn, Potsdam.

The sidereal half-second clock, to give the current serving to work the coils and lever in the flash-box, was supplied by Strasse & Rohde, Glashütte, the contacts being made by a lifting pallet on the Invar pendulum rod.

The pendulums were set up in the room originally built for platinum thermometry, as the space now available in the old pendulum room was insufficient.

The new station is 100 feet west of, and $6\frac{1}{2}$ feet higher than the site where the American half-second pendulums were swung by Mr. Putnam in 1900, and the Antarctic set in 1901.

The room is well suited for the purpose, having thick walls and a substantial concrete floor, and the range of temperature under ordinary circumstances is but small.

An air-tight chamber and manometer for the "pressure" experiments was designed at the Laboratory and made by P. Adie, London, the metal employed being magnalium.

The corrections C_t and C_p necessary to reduce the time of oscillation of each pendulum at temperature $t°$ C., and pressure p mm. of mercury, to what it would have been at temperature 0° C., and in vacuo, are assumed to be given by $C_t = -Ct$,

$$C_p = \frac{-C'(B+b)\left(1-\frac{3}{8}\frac{e}{B}\right)}{760+2{\cdot}79t},$$

where B is the barometric pressure, B + b the pressure under which the pendulums are swinging, e the pressure of aqueous vapour in the air (all pressures being measured in mm. of mercury at 0° C.), t the temperature of the chamber, and C and C′ are constant for any one pendulum.

The values of C were found from observations at temperatures approximately 7°, 20°, and 35° C., and the values of C′ were deduced from swings at pressures of about 395, 585 and 775 mm. of mercury.

The results obtained were as follows :—

Pendulum No.	$C \times 10^7$	$C' \times 10^7$
137	48·9	605
138	50·8	591
139	48·2	621
140	49·6	597
Means	49·4	603

Besides the observations necessary for the above deductions, several complete sets were taken by Mr. Constable to determine the time of oscillation of each pendulum at Kew, which gave the following mean results (reduced to 0° C. and to vacuo) :—

Pendulum No.	Time of Oscillation.
137	·5067039 second.
138	·5069564 ,,
139	·5066116 ,,
140	·5065376 ,,

These observations were all made with the Laboratory Standard Sidereal Clock, Morrison 8702.

In addition to the above, a number of observations were taken at Kew by Major Burrard, Major Lenox-Conyngham, and Mr. Constable in June and July. With the courteous permission of the Astronomer Royal, full sets of swings were also made by the same three observers at Greenwich, where every facility and help were afforded. During these comparative observations, use was made of the Strasse and Rohde clock received with the pendulum apparatus. Some features of its behaviour not seeming quite satisfactory, the clock was sent to the makers for improvement. On its return in October, fresh observations were taken at Kew and Greenwich by Major Lenox-Conyngham and Mr. Constable, Major Burrard having meantime sailed for India. The comparative observations made at Kew and Greenwich are now being worked up by the Indian observers, and it is hoped they will materially help to settle the disputed question as to the true difference between gravity at Greenwich and at Kew.

V. VERIFICATION OF INSTRUMENTS, EXCLUSIVE OF WATCHES AND CHRONOMETERS.

The subjoined is a list of the instruments—exclusive of watches and chronometers—examined in the year 1903, compared with a corresponding return for 1902 :—

	Number tested in the year ending December 31.	
	1902.	1903.
Air-meters	10	24
Anemometers	8	14
Aneroids	128	86
Artificial horizons	17	21
Barometers, Marine	134	103
,, Standard	109	112
,, Station	36	83
Binoculars	924	1,048
Compasses	16	9
Declinometers	1	—
Deflectors	4	—
Hydrometers	403	353
Hypsometers	1	—
Inclinometers	11	8
*Photographic Lenses	6	—
Levels	8	16
Magnets	8	15
Milk-test apparatus	159	89
Rain Gauges	19	67
Rain-measuring Glasses	34	131
Sextants	769	901
Sunshine Recorders	12	6
Telescopes	1,678	3,180
Theodolites	24	23
Thermometers, Clinical	22,912	19,393
,, Deep sea	44	56
,, High Range	81	42
,, Hypsometric	10	45
,, Low Range	124	51
,, Meteorological	2,733	2,851
,, Beckmann	—	1
,, Solar radiation	57	67
,, Standard	101	127
Unifilars	14	5
Miscellaneous	—	35
Total	30,595	28,962

Duplicate copies of corrections have been supplied in 114 cases.

* The testing apparatus has been transferred to Bushy House.

The number of instruments rejected in 1902 and 1903 on account of excessive error, or for other reasons, was as follows:—

	1902.	1903.
Thermometers, clinical	109	79
„ ordinary meteorological	55	80
Sextants	106	102
Telescopes	144	172
Binoculars	9	11
Various	185	79

There were at the end of the year in the Observatory, undergoing verification, 15 Barometers, 646 Thermometers, 6 Hydrometers, 25 Sextants, 185 Telescopes, 14 Binoculars, 1 Unifilar Magnetometer, 1 set of Magnetographs, 5 Various.

VI. Rating of Watches and Chronometers.

The number of watches sent for trial this year is 458, as compared with 530 in 1902, and 363 in 1901.

The "especially good" class A certificate was obtained by 129 movements. The high degree of excellence to which attention was called in last year's Report has been fully maintained, and there have been some exceptionally fine performances.

The following figures show the percentage number of watches obtaining the distinction "especially good," as compared to the total number obtaining class A certificates:—

Year	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.
Percentage "especially good"	16·6	30·5	28·0	22·1	26·6	35·4	35·5	31·6	42·4

The 458 watches received were entered for trial as below:—

For class A, 390; class B, 45; and for the subsidiary trial, 23. Of these, 304 were awarded class A certificates, 36 obtained class B certificates, 18 passed the subsidiary test, and 100 failed from various causes to gain any certificate.

In Appendix IV will be found a table giving the results of trial of the 50 watches which gained the highest number of marks during the year. The first place was taken by the keyless going-barrel, tourbillon chronometer watch No. 16639 (fitted with the "Guillaume" Invar balance), made by Paul Ditisheim, of Chaux-de-Fonds, and deposited by J. H. Agar-Baugh, London.

This watch obtained the extremely high value of 94·9 marks out of a maximum of 100, the highest number of marks yet obtained here.

The first place for English lever watches was taken by A. E. Fridlander, Coventry, with the keyless going-barrel karrusel watch No. 25646, which obtained 91·2 marks. Five watches in all succeeded in passing the 90 marks limit.

Marine Chronometers.—During the year, 48 chronometers were entered for the Kew A trials; of these, 39 gained certificates, and 9 failed.

Two "electric" clocks, by David Perret, of Neuchâtel—in which power is transmitted by a weak spring (taking the place of the usual barrel), which is extended every minute, and acts directly upon the minute wheel—have been rated and tested in the clock-room at temperatures varying from 55° to 95° F.

The sidereal clock, Morrison 8702, presented by Lady Galton and destined for Bushy House, was set up and rated for a considerable time, whilst several improvements were suggested, which were carried out by the makers.

VII. Miscellaneous.

Commissions.—The following instruments have been procured, examined, and forwarded to the Observatories on whose behalf they were purchased:—

For Mauritius.—A "Marvin" nephoscope (U.S.A. Weather Bureau pattern), a recording hygro-graph, a special "non-magnetic" lamp, a Babinet sling thermometer, and four other thermometers.

For Melbourne.—A maximum non-oscillating pressure-plate anemometer. This was constructed by Mr. P. Adie, several improvements being introduced during the trial.

Paper.—Prepared photographic paper has been supplied to the Observatories at Hong Kong, Mauritius, Lisbon, Oxford (Radcliffe); and through the Meteorological Office to Aberdeen, Fort William, and Valencia.

Photographic paper has also been sent in quarterly instalments to the India Office for use at Colaba (Bombay), Calcutta, Madras, and Kodaikanal.

Anemograph and Sunshine Sheets have been sent to Hong Kong and Mauritius; and Seismograph rolls to Mauritius.

Visit of Mr. G. T. Walker.—In January, Mr. Walker—who has been appointed to succeed Sir J. Eliot in the Indian Meteorological service—spent ten days at the Observatory to study the magnetic and meteorological observations.

Discussion of Kew Magnetic Data.—The analysis of *quiet* day data for the 11-year period (1890 to 1900) referred to in last year's Report, was communicated in May to the Royal Society, and has been published in the "Philosophical Transactions."

Bending of Magnetometer Deflection Bars.—A discussion of the results hitherto obtained, and of a simple method of arriving at the necessary data, was read before the Physical Society in October, and will appear in the "Philosophical Magazine" for January, 1904.

Library.—During the year the Library has received publications from:—

18 Scientific Societies and Institutions of Great Britain and Ireland,
102 Foreign and Colonial Scientific Establishments,

as well as from several private individuals.

The card catalogue has been proceeded with.

CHARLES CHREE,
Superintendent.

List of Instruments, Apparatus, &c., the Property of the National Physical Laboratory Committee, at the present date out of the custody of the Director, on Loan.

To whom lent.	Articles.	Date of loan.
The Science and Art Department, South Kensington.	Articles specified in the list in the Annual Report for 1893	1876
Professor W. Grylls Adams, F.R.S.	Unifilar Magnetometer, by Jones, No. 101, complete	1883
	Pair 9-inch Dip Needles with Bar Magnets	1887
Lord Rayleigh, F.R.S.	Standard Barometer (Adie, No. 655)	1885
New Zealand Government.	Unifilar Magnetometer, by Jones, marked N.A.B.C., complete	1899
	Dip Circle, by Barrow, with one pair of Needles and Bar Magnets	1899
	Tripod Stand	1899
Scottish Antarctic Expedition.	Dip Circle, by Barrow, No. 24, with two pairs of Needles, Bar Magnets, and a Tripod Stand	1902

APPENDIX I TO REPORT OF SUPERINTENDENT OF OBSERVATORY DEPARTMENT.

MAGNETIC OBSERVATIONS, 1903, KEW OBSERVATORY.

Latitude 51° 28′ 6″ N., and Longitude $0^h\ 1^m\ 15^s{\cdot}1$ W.

The results in the following Tables I to IV are deduced from the magnetograph curves, which have been standardised by observations of Declination and Horizontal Force. The observations were made with the Collimator Magnet K.C.I. and the Declinometer Magnet K.O., 90 in the 9-inch Unifilar Magnetometer, by Jones.

Inclination observations were also taken with the Inclinometer, No. 33, by Barrow, with needles 3½ inches in length. Table V gives the monthly means of these observations as actually taken, and also as corrected to the mean of the day from previous years' results. It also gives monthly values of the Vertical Force, calculated from the corrected values of the Inclination and the mean monthly values of the Horizontal Force.

The values of Inclination and Vertical Force are a little influenced by electric tram currents, which produce apparently a slightly enhanced value of Vertical Force throughout the day. The Declination and Horizontal Force inequalities are not absolutely above suspicion in this respect, but any uncertainty that may exist in their case is undoubtedly small.

The Declination and Horizontal Force values given in Tables I to IV are prepared in accordance with the suggestions made in the fifth report of the Committee of the British Association on comparing and reducing Magnetic Observations.

The following is a list of the days during the year 1903 which were selected by the Astronomer Royal, as suitable for the determination of the magnetic diurnal inequalities, and which have been employed in the preparation of the magnetic tables :—

January	7, 9, 15, 17, 25.
February	2, 4, 14, 24, 27.
March	3, 15, 17, 18, 26.
April	11, 13, 14, 20, 24.
May	10, 11, 12, 18, 26.
June	8, 9, 12, 13, 27.
July	3, 7, 9, 22, 24.
August	3, 7, 17, 19, 29.
September	3, 15, 16, 17, 26.
October	9, 10, 16, 21, 24.
November	6, 9, 14, 15, 25.
December	11, 12, 18, 24, 25.

Table I.—Hourly Means of Declination at Kew Observatory, as determined

Hours	Preceding noon.	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
		(16° + West.)					Winter.						
1903. Months.	′	′	′	′	′	′	′	′	′	′	′	′	′
Jan. ..	44·7	42·0	42·5	42·9	42·9	43·2	42·7	42·3	42·1	41·8	41·6	43·0	43·9
Feb. ..	43·5	40·9	41·2	41·6	41·9	41·8	41·6	41·1	40·7	40·2	39·9	40·9	42·4
March.	45·0	40·8	40·9	41·2	41·4	41·4	41·0	40·7	40·1	39·1	38·7	40·3	42·6
Oct. ..	44·5	38·0	38·4	38·7	38·9	39·2	39·4	39·1	38·6	37·1	36·7	38·4	41·4
Nov. ..	42·6	38·4	38·9	39·0	39·0	39·2	39·1	38·6	38·4	37·8	37·2	38·3	40·6
Dec. ..	40·8	37·8	38·2	38·2	38·5	38·6	38·6	38·2	38·1	37·8	37·6	38·6	39·8
Means	43·5	39·6	40·0	40·2	40·5	40·6	40·4	40·0	39·7	39·0	38·6	39·9	41·8
							Summer.						
	′	′	′	′	′	′	′	′	′	′	′	′	′
April ..	44·8	40·2	40·2	40·3	40·5	40·1	40·1	39·4	38·4	37·1	36·9	38·8	41·5
May ..	45·8	40·1	40·1	39·9	39·5	38·9	37·9	36·8	35·7	35·5	37·0	40·3	43·0
June ..	46·0	40·0	39·5	39·7	39·5	38·8	37·0	35·4	34·9	35·4	37·1	40·9	44·6
July ..	44·1	39·5	39·3	39·3	39·1	38·4	36·9	36·0	36·3	36·7	37·5	39·9	42·7
Aug. ..	45·1	39·0	38·6	38·6	38·0	37·8	36·9	36·3	36·0	35·6	36·7	39·0	41·0
Sept ...	45·7	39·7	39·3	38·8	38·5	38·5	38·5	38·0	37·3	37·3	38·4	41·0	43·5
Means	45·3	39·7	39·5	39·4	39·2	38·8	37·9	37·0	36·4	36·3	37·3	40·0	42·7

Table II.—Diurnal Inequality of the

Hours	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
						Summer Means.						
	′ −0·6	′ −0·8	′ −0·9	′ −1·1	′ −1·5	′ −2·4	′ −3·3	′ −3·9	′ −4·0	′ −3·0	′ −0·3	′ +2·4
						Winter Means.						
	′ −1·1	′ −0·8	′ −0·5	′ −0·3	′ −0·2	′ −0·4	′ −0·7	′ −1·1	′ −1·8	′ −2·2	′ −0·8	′ +1·0
						Annual Means.						
	′ −0·8	′ −0·8	′ −0·7	′ −0·7	′ −0·9	′ −1·4	′ −2·0	′ −2·5	′ −2·9	′ −2·6	′ −0·6	′ +1·7

NOTE.—When the sign is + the magnet
" " − "

from the selected Quiet Days in 1903. (Mean for the Year = 16° 40′·5. West.)

Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.	Succeeding noon.
						Winter.							
′	′	′	′	′	′	′	′	′	′	′	′	′	′
44·9	45·3	45·1	44·2	43·3	42·9	42·8	42·5	42·3	42·1	42·1	41·9	42·1	44·7
43·7	44·8	44·8	43·8	42·4	42·1	41·7	41·4	41·2	40·9	40·6	40·7	41·1	44·3
45·0	46·0	45·6	44·2	42·6	41·8	41·2	41·2	41·2	41·2	41·0	40·9	41·1	45·0
43·7	44·6	44·1	42·4	41·4	40·5	39·9	39·5	39·4	39·3	39·4	39·1	38·9	44·0
42·5	43·2	42·6	41·6	41·0	40·3	39·7	39·5	39·2	38·8	38·2	38·2	38·1	43·2
40·3	40·4	40·1	39·9	39·8	39·4	38·9	38·6	38·4	38·3	38·2	38·1	38·1	40·6
43·3	44·1	43·7	42·7	41·8	41·2	40·7	40·5	40·3	40·1	39·9	39·8	39·9	43·6
						Summer.							
′	′	′	′	′	′	′	′	′	′	′	′	′	′
44·3	46·4	46·4	45·1	43·9	42·5	41·4	41·0	40·7	40·6	40·4	40·3	40·2	44·5
45·1	45·3	44·6	43·3	42·1	40·8	40·2	40·3	40·1	40·3	40·3	39·9	39·8	45·0
47·2	47·7	46·9	45·4	43·5	41·9	41·1	40·6	40·7	40·7	40·8	40·6	40·5	45·6
45·0	45·1	44·7	43·9	42·4	40·8	40·2	40·2	40·1	39·9	40·1	40·1	40·2	45·1
42·7	43·1	42·6	41·1	39·6	38·8	38·8	39·3	39·3	39·1	39·0	39·1	39·2	46·0
45·0	45·4	44·3	42·8	41·2	40·4	40·4	40·5	40·3	40·3	40·2	39·9	40·0	44·5
44·9	45·5	44·9	43·6	42·1	40·9	40·4	40·3	40·2	40·2	40·1	40·0	40·0	45·1

Kew Declination as derived from Table I.

Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
						Summer Means.						
′	′	′	′	′	′	′	′	′	′	′	′	′
+4·6	+5·2	+4·6	+3·3	+1·8	+0·6	+0·1	0·0	−0·1	−0·1	−0·2	−0·3	−0·3
						Winter Means.						
′	′	′	′	′	′	′	′	′	′	′	′	′
+2·6	+3·3	+2·9	+1·9	+1·0	+0·4	−0·1	−0·3	−0·5	−0·7	−0·8	−0·9	−0·9
						Annual Means.						
′	′	′	′	′	′	′	′	′	′	′	′	′
+3·6	+4·2	+3·8	+2·6	+1·4	+0·5	0·0	−0·2	−0·3	−0·4	−0·5	−0·6	−0·6

points to the west of its mean position.
" east " "

F

TABLE III.—Hourly Means of the Horizontal Force at Kew Observatory in C.G.S.
(The Mean for the

Hours	Preceding noon.	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
0·18000 +						Winter.							
1903. Months.													
Jan. ...	476	483	483	483	484	484	487	487	488	486	482	478	475
Feb. ...	467	485	484	485	487	487	487	488	489	489	483	476	474
March..	480	498	498	498	498	498	497	497	493	495	487	484	484
Oct. ...	472	487	485	484	484	486	487	489	488	484	475	470	468
Nov. ...	451	472	470	469	471	471	473	477	475	469	461	454	451
Dec. ...	473	484	484	483	485	485	488	489	489	486	481	478	478
Means..	470	485	484	484	485	485	487	488	488	485	478	473	472
						Summer.							
April...	471	488	486	486	485	485	486	487	486	484	477	466	461
May ...	484	495	495	492	491	489	487	484	479	474	470	470	476
June ...	485	500	499	499	497	495	496	491	485	478	473	475	478
July ...	486	501	499	497	497	494	494	489	482	479	475	473	478
Aug. ...	488	499	497	495	494	492	492	487	482	477	472	475	479
Sept. ...	479	499	498	494	493	491	492	491	484	479	472	471	475
Means..	482	497	496	494	493	491	491	488	483	479	473	472	474

Table IV.—Diurnal Inequality of the

Hours	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
						Summer Means.						
	+ ·00006	+ ·00004	+ ·00002	+ ·00002	·00000	·00000	− ·00003	− ·00008	− ·00012	− ·00018	− ·00020	− ·00017
						Winter Means.						
	+ ·00001	·00000	·00000	+ ·00001	+ ·00001	+ ·00003	+ ·00004	+ ·00004	+ ·00001	− ·00006	− ·00011	− ·00012
						Annual Means.						
	+ ·00003	+ ·00002	+ ·00001	+ ·00001	+ ·00001	+ ·00001	+ ·00001	− ·00002	− ·00006	− ·00012	− ·00015	− ·00014

NOTE.—When the sign is + the

units (corrected for Temperature) as determined from the selected Quiet Days in 1903.
Year = 0·18488.)

Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.	Succeeding noon.
Winter.													
477	480	486	487	488	487	487	486	486	486	484	482	483	479
475	478	483	485	485	486	487	488	488	488	487	486	487	472
487	487	494	497	497	497	498	500	501	501	500	501	501	488
473	480	483	484	485	488	490	491	491	493	493	494	492	477
454	461	464	466	467	468	471	472	474	474	474	473	473	458
480	483	484	485	486	488	490	490	492	490	490	490	490	488
474	478	482	484	485	486	487	488	489	489	488	488	488	477
Summer.													
463	468	477	485	488	490	490	492	491	490	490	491	491	462
481	484	485	492	496	498	502	503	501	501	500	499	497	482
483	490	497	500	504	506	506	508	508	508	507	506	503	485
484	493	497	503	503	506	506	507	508	506	504	504	506	488
488	492	495	498	498	497	501	506	506	506	505	504	504	496
485	492	492	494	492	494	498	502	502	502	501	500	499	489
481	487	491	495	497	499	500	503	503	502	501	501	500	484

Kew Horizontal Force as deduced from Table III.

Noon	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
Summer Means.												
− ·00011	− ·00005	− ·00001	+ ·00004	+ ·00006	+ ·00007	+ ·00009	+ ·00012	+ ·00011	+ ·00011	+ ·00010	+ ·00009	+ ·00009
Winter Means.												
− ·00010	− ·00006	− ·00001	·00000	+ ·00001	+ ·00002	+ ·00003	+ ·00004	+ ·00005	+ ·00005	+ ·00004	+ ·00004	+ ·00004
Annual Means.												
− ·00010	− ·00005	− ·00001	+ ·00002	+ ·00003	+ ·00005	+ ·00006	+ ·00008	+ ·00008	+ ·00008	+ ·00007	+ ·00007	+ ·00006

reading is above the mean.

Table V.—Mean Monthly Values of Inclination and Vertical Force at Kew Observatory during the year 1903.

1903.	Mean time of Observation.	Inclination observed.	Inclination reduced to the mean value for the day.	Vertical force (mean value for the day), C.G.S. Units.
	h. m.	° ′	° ′	
January	3 0	67 7·0	67 6·8	0·43786
February	3 11	67 7·5	67 7·4	0·43811
March.........	3 46	67 6·4	67 6·4	0·43798
April..........	3 50	67 6·2	67 6·3	0·43761
May	3 52	67 6·2	67 6·4	0·43786
June	3 11	67 5·6	67 5·9	0·43781
July	3 23	67 5·9	67 6·2	0·43792
August	3 35	67 6·4	67 6·6	0·43801
September	3 42	67 5·7	67 5·8	0·43767
October........	3 33	67 6·1	67 6·0	0·43761
November......	2 49	67 7·9	67 7·7	0·43780
December......	2 50	67 6·6	67 6·4	0·43776
Mean for year	..	..	67 6·5	0·43784

APPENDIX IA.

Mean Values, for the years specified, of the Magnetic Elements at Observatories whose Publications are received at the National Physical Laboratory.

Place.	Latitude.	Longitude.	Year.	Declination.	Inclination.	Horizontal Force, C.G.S. Units.	Vertical Force, C.G.S. Units.
Pawlowsk	59° 41′ N.	30° 29′ E.	1901	0° 41′·9 E.	70° 36′·3 N.	·16558	·47031
Katharinenburg	56 49 N.	60 38 E.	1901	10 8·6 E.	70 40·8 N.	·17778	·50708
Kasan	55 47 N.	49 8 E.	1897	7 54·8 E.	68 34·8 N.	·18616	·47454
Copenhagen ...	55 41 N.	12 34 E.	1900	10 12·2 W.	68 39·0 N.	·17513	·44803
Flensburg	54 47 N.	9 26 E.	1902	11 32·5 W.	68 15·0 N.	—	—
Barth	54 22 N.	12 45 E.	1902	9 58·6 W.	67 39·9 N.	·18221	·44350
Stonyhurst	53 51 N.	2 28 W.	1902	18 4·3 W.	68 46·2 N.	·17356	·44678
Hamburg......	53 33 N.	9 59 E.	1902	11 16·6 W.	—	—	—
Wilhelmshaven	53 32 N.	8 9 E	1902	12 21·2 W.	67 41·8 N.	·18134	·44208
Potsdam	52 23 N.	13 4 E.	1900	9 56·3 W.	66 33·7 N.	·18844	·43466
Irkutsk........	52 16 N.	104 16 E.	1901	2 0·8 E.	70 16·7 N.	·20116	·56114
de Bilt (Utrecht)	52 5 N.	5 11 E.	1901	13 46·2 W.	—	·18524	—
*Valencia (Ireland)......	51 56 N.	10 15 W.	1902	21 24·2 W.	68 23·9 N.	·17833	·45035
			1903	21 18·7 W.	68 22·4 N.	·17833	·44977
Kew..........	51 28 N.	0 19 W.	1903	16 40·5 W.	67 6·5 N.	·18488	·43784
Greenwich.....	51 28 N.	0 0	1902	16 22·8 W.	67 3·4 N.	·18505	·43715
Uccle (Brussels)	50 48 N.	4 21 E.	1901	14 8·3 W.	66 7·8 N.	·18956	·42838
Falmouth	50 9 N.	5 5 W.	1902	18 21·5 W.	66 40·4 N.	·18737	·43451
			1903	18 18·3 W.	66 38·5 N.	·18759	·43436
Prague	50 5 N.	14 25 E.	1902	8 57·6 W.	—	·19903	—
St. Helier (Jersey).........	49 12 N.	2 5 W.	1903	16 50·4 W.	65 39·2 N.	—	—
Parc St. Maur (Paris)	48 49 N.	2 29 E.	1899	14 49·5 W.	64 55·7 N.	·19704	·42119

* *See* remarks on p. 73.

APPENDIX IA—*continued.*

Place.	Latitude.	Longitude.	Year.	Declination.	Inclination.	Horizontal Force, C.G.S. Units.	Vertical Force, C.G.S. Units.
	° ′	° ′		° ′	° ′		
Vienna........	48 15 N.	16 21 E.	1898	8 24·1 W.	—	—	—
Munich	48 9 N.	11 37 E.	1899	10 33·7 W.	63 21·5 N.	·20583	·41029
			1900	10 27·9 W.	63 18·5 N.	·20610	·40993
O'Gyalla (Pesth)	47 53 N.	18 12 E.	1903	7 14·0 W.	62 27·3 N.	·21178	·40605
Odessa........	46 26 N.	30 46 E.	1899	4 36·7 W.	62 18·2 N.	·21869	·41660
Pola..........	44 52 N.	15 51 E.	1902	9 15·1 W.	60 10·6 N.	·22234	·38784
Agincourt (Toronto).......	43 47 N.	79 16 W.	1900	5 28·8 W.	74 32·5 N.	·16512	·59709
Nice	43 43 N.	7 16 E.	1899	12 4·0 W.	60 11·7 N.	·22390	·39087
Perpignan	42 42 N.	2 53 E.	1900	13 37·3 W.	59 58·4 N.	·22441	·38828
Tiflis	41 43 N.	44 48 E.	1898	2 5·5 E.	55 50·6 N.	·25635	·37784
Capodimonte (Naples)	40 52 N.	14 15 E.	1901	9 5·7 W.	56 20·8 N.	·24150	·36276
Madrid	40 25 N.	3 40 W.	1899	15 48·4 W.	—	—	—
Coimbra.......	40 12 N.	8 25 W.	1902	17 12·6 W.	59 15·4 N.	·22841	·38403
			1903	17 9·3 W.	59 11·9 N.	·22859	·38345
Lisbon	38 43 N.	9 9 W.	1900	17 18·0 W.	57 54·8 N.	·23516	·37484
San Fernando..	36 28 N.	6 12 W.	1900	15 59·3 W.	55 9·2 N.	·24631	·35378
			1901	15 55·8 W.	55 8·3 N.	·24664	·35405
Tokio.........	34 41 N.	139 45 E.	1897	4 29·9 W.	49 2·8 N.	·29816	·34356
*Zi-ka-wei	31 12 N.	121 26 E.	1901	2 24·7 W.	45 41·6 N.	·32891	·33697
Havana	23 8 N.	82 25 W.	1902	3 7·4 E.	—	—	—
Hong Kong....	22 18 N.	114 10 E.	1902	0 15·0 E.	31 16·3 N.	·36834	·22372
†Colaba (Bombay)	18 54 N.	72 49 E.	1900	0 24·5 E.	21 22·4 N.	·37438	·14652
			1901	0 21·9 E.	21 30·5 N.	·37434	·14752
			1902	0 19·5 E.	21 37·3 N.	·37422	·14833
Manila........	14 35 N.	120 59 E.	1901	0 52·2 E.	16 11·1 N.	·38099	·11058
Batavia	6 11 S.	106 49 E.	1898	1 14·9 E.	29 47·4 S.	·36752	·21040
Dar-es-salaam ..	6 49 S.	39 18 E.	1898	8 18·1 W.	36 56·8 S.	·28966	·21785
Mauritius	20 6 S.	57 33 E.	1900	9 29·0 W.	54 11·0 S.	·23826	·33015
Rio de Janeiro .	22 55 S.	43 11 W.	1901	8 10·0 W.	13 23·3 S.	·24983	·05942
			1902	8 17·2 W.	13 22·9 S.	·24869	·05912
Melbourne.....	37 50 S.	144 58 E.	1901	8 26·7 E.	67 25·0 S.	·23305	·56024

* These values relate to new Observatory buildings. Observations at the old and new sites show apparently *small* differences in Declination and Horizontal Force (Zi-ka-Wei Bulletin, Vol. XXVII., p. 7).

† These data differ from those in previous years' Tables in being reduced to the mean value for the day.

APPENDIX II.—Table I.

Mean Monthly Results of Temperature and Pressure for Kew Observatory.
1903.

Months.	Thermometer.									Barometer.*						Mean vapour tension.
	Mean.	Means of—			Absolute Extremes.					Mean.	Absolute Extremes.					
		Max.	Min.	Max. and Min.	Max.	Date.	Min.	Date.			Max.	Date.	Min.	Date.		
	°	°	°	°	°		°			ins.	ins.		ins.			in.
January …	41·1	44·6	36·9	40·8	53·6	5th 2 P.M.	25·0	16th 8 A.M.		29·995	30·595	14th 9 A.M.	29·299	7th 4 A.M.		·220
February ..	45·2	50·2	39·7	45·0	57·3	20th 3 ,,	25·4	18th 5 ,,		30·139	30·677	17th 10 ,,	29·255	1st 4 ,,		·249
March …..	46·0	52·6	39·0	45·8	65·3	25th 7 ,,	28·2	11th 7 ,,		29·856	30·394	8th 9 P.M.	28·792	2nd 10 P.M.		·244
April …..	44·7	51·7	37·8	44·8	59·8	29th 4 ,,	30·0	16th 5 ,, / 19th 6 ,, / 20th 6 ,,		29·893	30·426	18th 9 A.M.	29·276	29th 5 A.M.		·214
May ……	53·8	61·9	45·9	53·9	75·6	30th Noon	34·9	13th 4 ,,		29·885	30·446	23rd 11 P.M.	29·210	4th 6 P.M.		·308
June ……	56·1	63·3	48·2	55·8	80·8	27th 5 P.M.	39·6	13th 4 ,,		30·030	30·419	6th 8 A.M.	29·565	19th 1 ,,		·332
July ……	61·7	69·4	53·8	61·6	83·3	11th 3 ,,	46·3	8th 4 ,,		29·937	30·353	1st 0 ,,	29·541	28th 7 ,,		·399
August ….	59·6	67·3	52·5	59·9	76·3	8th 3 ,,	45·0	23rd 6 ,,		29·871	30·261	26th 9 ,, / 11 ,,	29·225	15th 4 A.M.		·387
September..	57·4	64·7	50·0	57·4	79·0	1st 3 ,,	37·0	17th 6 ,,		30·024	30·508	15th 7 ,,	28·884	11th 0 ,,		·379
October …	52·9	57·9	47·5	52·7	65·1	1st 2 ,,	37·9	24th 4 ,, / 6 ,,		29·663	30·131	18th 7 P.M.	28·967	12th 8 P.M.		·338
November..	45·0	50·0	39·0	44·5	55·4	1st 2 ,,	29·0	20th 3 ,,		30·059	30·627	5th 9 A.M.	29·064	27th 10 ,,		·253
December..	39·2	42·5	35·5	39·0	52·3	9th 1 ,,	25·9	5th 9 ,,		29·760	30·318	21st 11 ,,	29·086	10th 4 ,,		·207
Means	50·2	56·3	43·8	50·1	..	..	..	..		29·926	..	..	..	..		·294

* Reduced to 32° at M.S.L.

This table has been compiled at the Meteorological Office from values intended for publication in the volume of "Hourly Means" for 1903.

Appendix II. Table IA.

Mean Monthly Results of Temperature and Pressure for Kew Observatory for the Thirty years 1871 to 1900.

Month.	Thermometer. Mean.	Means of Max.	Means of Min.	Means of Max. and min.	Absolute extremes. Max.	Date.	Min.	Date.	Barometer.* Mean.	Absolute extremes. Max.	Date.	Min.	Date.
	°	°	°	°	°		°		ins.	ins.		ins.	
January ..	38·7	42·7	34·2	38·5	56	19th, 1877	9	17th, 1881	30·011	30·983	18th, 10 A.M., 1882	28·346	24th, 5 A.M., 1872
February..	39·9	44·7	35·1	39·9	62	10th, 1899	11	7th, 1895	29·998	30·860	23rd, 9, 10 and 11 A.M., 1883	28·526	19th, 11 P.M., 1900
March	42·0	48·8	35·8	42·3	67	24th 1896	18	4th, 1890	29·944	30·753	6th, 8 and 9 P.M., 1874	28·467	12th, noon, 1876
April	47·0	55·0	39·7	47·4	80	20th, 1893	27	1st, 1891	29·910	30·737	17th, 7 A.M., 1887	28·885	14th, 1 A.M., 1899
May	52·4	60·9	44·1	52·5	84	30th, 1895	30	5th, 1877	29·985	30·680	10th, 11 P.M., 1881	29·101	13th, 9 A.M., 1886
June......	59·0	67·8	50·7	59·3	87	11th, 1900	37	5th, 1880	29·993	30·559	15th, 7 and 8 A.M., 1874	29·183	30th, 7 P.M., 1890
July......	62·3	71·0	54·2	62·6	90	5th, 1881	43	1st, 1882	29·963	30·484	27th, 7 A.M., 1882	29·116	15th, 2 A.M., 1877
August ...	61·4	69·9	53·7	61·8	92	13th, 1876	41	31st, 1890	29·953	30·499	21st, 10 P.M., 1874	29·125	31st, 2 P.M., 1876
September.	56·8	64·8	49·4	57·1	88	8th, 1898	33	29th, 1887	29·985	30·555	22nd, 10 A.M., 1873	28·739	25th, 10 A.M., 1896
October...	49·0	55·4	42·6	49·0	77	4th, 1886	25	28th, 1895	29·917	30·684	31st, midnight, 1891	28·643	16th, 9 A.M., 1886
November.	43·9	48·7	38·5	43·6	63	14th, 1876	20	19th, 1871	29·934	30·748	21st, 11 A.M., 1897	28·466	11th, 11 A.M., 1891
December .	39·5	43·6	34·7	39·2	57	5th, 1888	11	22nd, 1890	29·960	30·822	23rd, 3 A.M., 1879	28·312	9th, 5 A.M., 1886
Mean.	49·3	56·1	42·7	49·4	..	..	..	..	29·963	—	—	—	—

* Reduced to 32° at M.S.L.

Compiled at the Meteorological Office.

Meteorological Observations.—Table II.

Kew Observatory.

Months.	Mean amount of cloud (0=clear, 10=overcast).	Rainfall.* Total.	Rainfall.* Maximum.	Rainfall.* Date.	Weather. Number of days on which were registered: Rain. ‡	Snow.	Hail.	Thunderstorms.	Clear sky.	Overcast sky.	Gales.§	Wind.† Number of days on which it was: N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.‖
1903.		ins.	ins.																	
January	6·9	2·260	0·750	4	15	1	1	1	4	19	2	2	2	5	3	3	10	5	1	4
February	7·4	0·925	0·310	27	11	1	3	0	2	17	3	1	1	1	..	2	13	7	3	1
March	7·2	2·350	0·295	6	19	0	1	0	1	15	6	..	..	..	1	7	14	7	2	1
April	7·4	1·820	0·430	25	11	3	0	0	0	15	0	9	2	1	1	3	5	4	5	2
May	6·5	3·285	1·155	30	16	0	2	5	5	13	0	3	4	6	1	3	8	4	2	3
June	7·3	7·205	1·790	13	11	0	1	2	1	16	0	4	12	3	1	4	2	3	1	5
July	7·4	4·270	1·285	23	14	0	0	2	1	16	0	3	1	1	..	3	9	8	6	2
August	7·1	3·930	0·795	24	17	0	0	0	2	17	0	1	..	..	..	3	13	9	5	4
September	6·3	3·240	1·555	4	11	0	0	1	2	10	1	3	1	6	2	4	7	4	3	3
October	7·9	5·550	1·085	11	26	0	0	0	0	17	1	..	..	1	1	8	12	7	2	3
November	6·6	1·725	0·790	27	12	1	0	0	4	12	0	7	3	1	1	2	2	10	4	3
December	7·9	1·615	0·405	10	10	0	0	0	3	21	0	3	4	8	3	6	4	2	1	3
Totals and means...	7·2	38·175	..	..	173	6	8	11	25	188	13	36	30	33	14	48	99	70	35	34

* Measured at 10 A.M. daily by gauge 1·75 feet above ground. † As registered by the Robinson anemograph.
‡ The number of rainy days are those on which 0·01 inch rain or melted snow was recorded.
§ In a "gale" the mean wind velocity has exceeded 35 miles an hour in at least one hour of the twenty-four.
‖ In a "calm" the mean wind velocity for the twenty-four hours has not exceeded 5 miles an hour.

Meteorological Observations.—Table III.

Kew Observatory.

Months.	Bright Sunshine (by Campbell-Stokes Recorder).					Maximum temperature in sun's rays. (Black bulb *in vacuo*.)			Minimum temperature on the ground.			Horizontal movement of the air.* Miles per hour.		
	Total number of hours recorded.	Mean percentage of possible sunshine.		Greatest daily record.	Date.	Mean.	Highest.	Date. †	Mean.	Lowest.	Date. ‡	Average hourly velocity.	Greatest hourly velocity.	Date.
		Old method.	New method.											
1903.	h. m.			h. m.		°	°		°	°				
January	53 18	21	21	6 54	23	65	91	30	30	13	16	14·9	38	14
February	75 30	27	27	7 54	25	80	103	25	33	13	18	15·2	44	27
March	127 18	35	35	8 42	8	97	115	22	32	19	9	15·8	41	28
April	136 0	33	33	10 18	17	102	120	27	27	12	18	11·9	28	7
May	165 42	34	34	14 0	25	113	128	22	38	24	13	11·0	33	27
June	184 0	37	37	14 6	29	113	138	23	42	28	13	10·0	30	8
July	190 0	38	38	14 0	1	124	136	11	47	32	8	8·7	25	6
August	194 6	43	43	13 18	7	123	135	8	47	35	23	11·1	31	15
September	161 12	42	42	11 18	1	114	131	1	42	28	17	10·2	38	10
October	83 42	25	25	6 48	13	95	118	3	41	27	31	12·5	38	6
November	47 24	18	18	6 6	25	73	97	1	32	18	20	9·6	33	23
December	17 54	7	7	5 12	2	56	80	9	29	12	3	12·3	34	3 & 7
Totals and Means	1,436 6	30	32	..	..	..	..	..	..	..	..	11·9	..	..

* As indicated by a Robinson anemograph, 70 feet above the general surface of the ground, the original factor 3 being used.
† Read at 10 A.M., and entered to previous day. ‡ Read at 10 A.M., and entered to same day.

Table IV.—Hourly Means of Atmospheric Electric Potential (in volts) from the on selected "Quiet" Days

19

Month.	Mid.	1 h.	2 h.	3 h.	4 h.	5 h.	6 h.	7 h.	8 h.	9 h.	10 h.	11 h.
January ...	107	105	92	96	95	103	114	148	161	158	154	167
February ..	194	187	168	132	120	135	146	173	220	245	237	205
March	207	204	196	188	186	203	220	234	267	263	227	164
April......	209	199	188	177	179	194	221	259	277	259	226	190
May	200	179	171	162	156	176	195	212	229	232	215	172
June	191	170	151	140	140	141	147	163	169	180	195	209
July	122	105	96	92	85	97	115	145	147	136	119	102
August	175	158	140	128	126	134	157	190	205	208	179	156
September .	141	123	121	121	119	120	121	131	138	139	129	120
October....	124	111	110	104	106	111	130	160	183	195	192	169
November..	161	157	155	159	155	156	154	163	175	186	203	197
December ..	201	181	169	166	166	167	167	177	188	199	216	227

Table V.—Diurnal Inequality of Atmospheric Electric Potential Gradient

19

Month, &c.	1 h.	2 h.	3 h.	4 h.	5 h.	6 h.	7 h.	8 h.	9 h.	10 h.	11 h.	Noon.	1 h.
January ...	−19	−36	−35	**−38**	−32	−32	+11	+23	+16	+10	+21	+16	+13
February ..	− 9	−25	−58	**−69**	−54	−42	−16	+29	**+54**	+47	+18	− 9	−15
March.....	+ 2	− 6	−13	−15	+ 1	+18	+31	**+63**	+59	+25	−35	−54	−62
April......	−15	−23	−31	−29	−17	+ 5	+34	**+49**	+35	+10	−17	−25	−30
May	− 8	−16	−23	−29	−12	+ 4	+19	+33	+36	+21	−17	−22	−36
June	−11	−27	−36	**−37**	−36	−31	−19	−13	− 4	+ 8	+19	+ 8	− 8
July	−12	−19	−23	−28	−17	− 1	+27	+29	+19	+ 4	−11	−17	−19
August	− 9	−23	−32	−33	−25	− 6	+23	+36	+39	+16	− 2	−16	−26
September .	−14	−16	−16	−17	−16	−13	− 3	+ 5	+ 6	− 3	−12	**−21**	− 9
October....	−41	−41	**−46**	−42	−36	−15	+16	+42	**+56**	+54	+32	+ 8	− 9
November..	−24	**−25**	−21	−24	−23	−24	−15	− 3	+ 9	+26	+21	+ 8	+ 2
December ..	−28	−46	−50	−51	**−52**	−51	−46	−26	−14	+ 6	+18	+17	+22
Winter	−20	−33	−41	**−45**	−40	−37	−16	+ 6	+16	+22	+19	+ 8	+ 6
Equinox ...	−17	−21	−27	−26	−17	− 2	+20	**+40**	+39	+21	− 8	−23	−28
Summer ...	−10	−21	−29	**−32**	−22	− 8	+12	+21	+23	+12	− 3	−12	−22
Year	−16	−25	−32	**−34**	−27	−16	+ 5	+22	+26	+19	+ 3	− 9	−15

* Principal maxima and

Self-recording Kelvin Water-dropping Electrograph at Kew Observatory, (10 each Month).

03.

Noon.	1 h.	2 h.	3 h.	4 h.	5 h.	6 h.	7 h.	8 h.	9 h.	10 h.	11 h.	Mid.
165	164	159	157	176	196	189	190	173	167	181	171	166
175	168	165	178	170	181	209	218	221	215	199	188	170
144	136	132	135	145	165	191	231	247	254	252	233	205
180	173	169	176	180	184	228	248	248	261	254	217	196
167	151	142	143	153	174	204	231	237	237	235	227	208
195	177	164	168	177	188	214	238	257	249	229	207	198
96	93	85	82	87	98	108	130	153	159	146	130	115
138	124	118.	110	125	141	155	175	202	203	176	160	149
111	121	122	127	129	138	149	159	151	140	133	136	129
145	128	120	122	136	155	151	140	136	136	125	107	93
184	178	172	175	189	201	199	194	192	190	173	159	151
228	231	235	245	251	248	246	244	244	236	231	225	211

at Kew Observatory near the Ground in volts per metre of height.*

03.

2 h.	3 h.	4 h.	5 h.	6 h.	7 h.	8 h.	9 h.	10 h.	11 h.	Mid.	Range of inequality.	Monthly and seasonal mean absolute values.
+ 4	+ 1	+17	**+37**	+26	+25	+ 3	− 5	+ 6	− 6	−14	75	162
−17	− 4	−10	+ 1	+28	+38	+41	+37	+23	+13	− 3	123	174
−65	−62	−52	−34	− 9	+29	+45	+51	+49	+31	+ 5	128	191
−33	**−34**	−23	−20	+15	+31	+31	+42	+37	+ 9	− 8	83	165
−44	−43	−35	−17	+ 9	+32	**+37**	**+37**	+35	+27	+10	81	167
−19	−16	− 8	0	+22	+42	**+58**	+50	+34	+15	+ 7	95	156
−26	**−29**	−24	−13	− 4	+17	+38	**+44**	+32	+17	+ 5	73	105
−30	**−36**	−23	− 9	+ 4	+21	+44	**+46**	+25	+12	+ 4	82	129
− 8	− 2	0	+10	+22	**+33**	+25	+15	+ 7	+12	+ 4	54	135
−14	−11	+ 4	+26	+23	+12	+ 9	+11	+ 1	−16	−29	102	141
− 3	0	+15	**+27**	+25	+21	+19	+18	+ 1	−12	−20	52	172
+26	+38	**+44**	+40	+38	+34	+34	+24	+18	+ 9	− 7	96	250
+ 3	+ 9	+16	+26	**+29**	**+29**	+24	+18	+12	+ 1	−11	..	190
−30	−27	−18	− 5	+12	+26	+27	+30	+24	+ 9	− 7	..	158
−30	−31	−22	−10	+ 8	+28	**+44**	**+44**	+31	+18	+ 6	..	139
−19	−16	− 8	+ 4	+16	+28	**+32**	+31	+22	+ 9	− 4	..	162

minima are in heavy type.

APPENDIX III.—Table I.

Register of principal Seismograph Disturbances at Kew Observatory. 1903.

No. in Kew register.	Date.	Commencement.	Time of Max.	Max. Amplitude.	Duration.	Remarks.
		h. m.	h. m.	mm.	h. m.	
422	Jan. 14	1 59·3	2 37·0	>17·0	3 4	Traces overlap.
424	„ 24	6 10·8	6 18·5	1·0	0 35	
426	Feb. 1	10 1·2	10 17·0	4·5	1 4	
428	„ 5	19 15·0	19 45·7	1·8	1 28	Commencement of "Preliminary tremors" ill-defined.
434	„ 27	1 8·6	1 52·2	3·5	2 34	
435	„ 28	10 18·0	10 27·7	1·6	0 38	
437	March 15	14 45·3	14 54·3	1·4	0 30	
439	„ 25	22 37·8	22 46·5	0·8	0 30	
448	Apr. 28-29	23 51·8	0 3·2	1·5	1 5	
449	„ 29	5 33·5	5 48·5	1·5	0 56	
450	May 13	6 58·0	7 46·0	1·6	2 2	Movements very small after 8 hours.
454	„ 29	9 44·0	9 48·0	1·0	0 18	
455	June 2	13 33·5	13 46·7	2·0	1 17	
457	„ 7	9 29·5	9 59·7	1·0	0 40	Time of "Preliminary tremors" commencement is uncertain.
477	Aug. 11	4 37·8	4 51·5	1·7	0 42	
492	Oct. 21	10 23·5	11 0·0	0·8	0 48	Completion of "swings" interrupted.
499	Nov. 16	9 46·2	—	1·0	1 34	"Seismic" character somewhat doubtful.
504	„ 26	12 12·7	12 26·0	1·1	0 38	
507	Dec. 6	23 43 5	23 47·5	0·8	0 20	
509	„ 7	15 30·0	15 47·5	1·1	0 46	Time of "Preliminary tremors" commencement somewhat uncertain.
510	„ 11	17 18·0	17 41·5	1·4	1 4	
514	„ 28	3 37·0	4 7·5	1·1	1 0	

The times recorded are G.M.T., midnight = 0 or 24 hours.

The figures given above are obtained from the photographic records of a Milne Horizontal Pendulum; they represent E—W displacements.

The scale value throughout the year has been 1 mm. = 0″·53.

APPENDIX IV.—Table I.

RESULTS OF WATCH TRIALS. Performance of the 50 Watches which obtained the highest number of marks during the year.

Watch deposited by	Number of watch.	Escapement, balance spring, &c.	Mean daily rate. Pendant up.	Pendant right.	Pendant left.	Dial up.	Dial down.	Mean variation of daily rate. ±	Mean change of rate for 1° F.	Difference between extreme gaining and losing rates.	Marks awarded for Daily variation of rate. 0—40	Change of rate with change of position. 0—40	Temperature compensation. 0—20	Total Marks. 0—100.
			secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.				
P. Ditisheim, Chaux-de-Fonds	16639	G.b., d.o., "Tourbillon" chronometer, Guillaume balance	+3·1	+2·2	+2·8	+3·2	+2·6	0·18	0·004	2·0	36·4	38·8	19·7	94·9
A. E. Fridlander, Coventry	25646	S.r., g.b., s.o., "Karrusel"	+0·5	+0·6	+0·1	−0·8	+0·5	0·25	0·03	4·2	35·0	38·3	17·9	91·2
C. J. H. Marlow, Coventry	22125	S.r., g.b., s.o., "Karrusel"	+0·3	+0·4	+0·6	+0·8	+1·1	0·3	0·03	2·5	34·3	39·0	17·7	91·0
R. Milne, Manchester	1353	S.r., g.b., s.o., "Karrusel"	+1·7	+2·0	+2·0	+2·9	+2·5	0·25	0·04	2·5	35·2	38·5	17·1	90·8
A. and N. C. S., Ltd., London	8872	S.r., g.b., s.o., "Karrusel"	−0·0	−1·2	−0·6	+0·2	+0·9	0·2	0·05	3·0	36·0	37·6	16·7	90·3
C. Frodsham & Co., London	08964	S.r., g.b., d.o., "Tourbillon lever"	−0·9	−0·8	−0·4	+0·1	−0·6	0·35	0·03	3·0	32·9	38·8	18·1	89·8
A. E. Fridlander, Coventry	25636	S.r., g.b., s.o., "Karrusel"	+1·2	+0·7	+1·2	+1·7	−0·4	0·3	0·04	2·8	34·3	37·6	17·5	89·4
Newsome & Co., Coventry	148831	S.r., g.b., s.o., "Karrusel"	−0·0	+0·6	+0·2	−0·0	+1·5	0·4	0·03	4·5	32·6	38·1	17·7	88·4
B. Bonniksen, Coventry	57169	S.r., g.b., s.o., "Karrusel"	−2·9	−2·7	−2·3	−1·5	−2·0	0·3	0·05	3·5	33·5	38·4	16·4	88·3
Baume & Co., London	12583	D.r., g.b., d.o., chronograph	+1·9	+1·2	−1·0	+0·7	−0·1	0·35	0·02	4·2	32·8	36·5	18·8	88·1
S. Yeomans, Coventry	85226	S.r., g.b., s.o., "Karrusel"	−0·2	−0·2	+0·3	+1·6	+1·3	0·3	0·05	3·8	34·1	37·2	16·7	88·0
Evan Roberts, London	22077	S.r., g.b., s.o., "Karrusel"	+0·5	−0·3	+0·2	−0·5	+0·5	0·4	0·04	4·0	32·2	38·5	17·1	87·8
Newsome & Co., Coventry	147828	S.r., g.b., s.o., "Karrusel"	−0·6	+0·1	+0·6	+0·4	+1·0	0·4	0·05	4·5	32·5	38·3	16·8	87·6
W. Gabriel, London	556/1000	S.r., g.b., s.o., "Karrusel"	+1·2	+1·0	+2·2	+3·2	+1·3	0·3	0·05	3·5	33·6	36·9	17·0	87·5
B. Bonniksen, Coventry	56909	S.r., g.b., s.o., "Karrusel"	−1·4	−0·5	−0·3	−2·2	+0·7	0·35	0·03	5·5	32·9	36·6	18·0	87·5
" "	55177	S.r., g.b., s.o., non-magnetic "Karrusel"	+4·2	+2·8	+3·6	+1·3	+3·6	0·45	0·01	6·2	31·4	36·6	19·3	87·3
Usher & Cole, London	39724	S.r., fusee, s.o., "Karrusel"	+4·3	+3·5	+3·9	+3·0	+2·4	0·3	0·08	7·2	34·5	37·8	14·8	87·1
R. Milne, Manchester	1383	S.r., g.b., s.o., "Karrusel"	+0·2	+0·4	+0·2	+1·0	+2·6	0·35	0·04	4·5	32·9	37·0	17·1	87·0
Williamson, Ltd., London	86783	S.r., g.b., s.o., "Karrusel"	+0·5	+1·5	+1·4	+4·4	+2·6	0·25	0·05	4·7	34·7	35·4	16·6	86·7
Montandon-Robert, Geneva	1170	D.r., g.b., s.o., min. repeater,	−1·4	−0·3	−0·6	+0·5	−2·2	0·35	0·05	3·2	33·0	36·8	16·9	86·7
B. Bonniksen, Coventry	56898	S.r., g.b., s.o., "Karrusel"	−0·4	+0·6	+1·2	+0·8	+2·7	0·3	0·06	5·0	33·5	36·9	16·1	86·5
H. Golay, London	1582	S.r., g.b., s.o., "Karrusel"	−1·0	−1·3	−1·5	−0·1	−3·1	0·3	0·07	4·0	34·2	37·1	15·1	86·4
A. and N. C. S., Ltd., London	8809	S.r., g.b., s.o., "Karrusel"	−2·0	−1·1	−0·8	+1·0	−0·8	0·35	0·06	5·3	33·1	37·2	15·9	86·2
S. Smith & Son, London	239–4	G.b., d.o., "Karrusel chronometer"	+0·1	+0·2	+0·3	+0·2	+1·0	0·5	0·05	4·5	30·3	39·0	16·9	86·2
B. Bonniksen, Coventry	56916	S.r., g.b., s.o., "Karrusel"	+2·2	+1·8	+1·1	+0·4	+1·7	0·5	0·04	7·2	30·6	37·8	17·6	86·0
Newsome & Co., Coventry	143411	S.r., g.b., s.o.	+1·7	+1·4	−1·9	−0·3	+1·8	0·3	0·05	5·2	34·3	34·7	16·9	85·9
S. Yeomans, Coventry	85223	S.r., g.b., s.o., "Karrusel"	+0·8	+0·1	+0·3	+3·6	+2·3	0·3	0·05	4·2	34·3	35·1	16·5	85·9
B. Bonniksen, Coventry	57112	S.r., g.b., s.o., "Karrusel"	−3·3	−2·5	−2·7	+1·3	−0·6	0·3	0·04	6·0	34·4	34·0	17·5	85·9
R. Milne, Manchester	1322	S.r., g.b., s.o., "Karrusel"	+4·1	+3·5	+4·2	+2·6	+5·1	0·4	0·04	5·2	31·2	37·2	17·5	85·9

Table I—*continued.*

Watch deposited by	Number of watch.	Escapement, balance spring, &c.	Mean daily rate. Pendant up.	Pendant right.	Pendant left.	Dial up.	Dial down.	Mean variation of daily rate. ±	Mean change of rate for 1° F.	Difference between extreme gaining and losing rates.	Marks awarded for Daily variation of rate.	Change of rate with change of position.	Temperature compensation.	Total Marks.
											0—40	0—40	0—20	0—100.
			secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.				
Stauffer, Son & Co., London	187904	D.r., g.b., s.o., chronograph	+1·3	+0·9	+2·0	+0·5	+2·2	0·5	0·03	4·7	30·0	37·7	18·1	85·8
Waltham Watch Co., U.S.A.	10552661	D.r., g.b., s.o.	+2·2	−0·7	+2·2	+1·4	+2·0	0·45	0·03	5·5	31·3	36·6	17·7	85·7
C. J. H. Marlow, Coventry	22124	S.r., g.b., s.o., "Karrusel"	−1·2	+0·1	−0·5	+0·6	+2·9	0·3	0·07	5·8	34·6	35·6	15·3	85·5
Williamson, Ltd., London	56897	S.r., g.b., s.o., "Karrusel"	−5·0	−4·3	−4·2	−0·5	−3·6	0·3	0·05	5·7	33·7	35·2	16·5	85·4
R. Milne, Manchester	1365	S.r., g.b., s.o., "Karrusel"	+1·1	+1·3	+1·5	+2·4	+3·3	0·4	0·04	3·8	31·3	37·0	17·1	85·4
Waltham Watch Co., U.S.A.	10070393	D.r., g.b., s.o.	−1·8	+0·8	−0·9	−2·5	−2·4	0·4	0·04	6·5	32·5	35·6	17·1	85·2
Newsome & Co., Coventry	144776	S.r., g.b., s.o.	+0·4	−0·6	+1·3	+0·9	+1·4	0·5	0·04	3·8	30·5	37·5	17·1	85·1
Evan Roberts, London	22171	S.r., g.b., s.o., "Karrusel"	−4·2	−2·4	−3·6	−2·2	+0·6	0·4	0·04	7·0	32·5	35·0	17·5	85·0
Stauffer Son & Co., London	187905	D.r., g.b., s.o., chronograph	+2·3	+1·3	+2·8	+0·9	+3·2	0·4	0·05	4·5	31·5	36·8	16·7	85·0
T. Russell & Son, Liverpool	51965	D.r., g.b., s.o.	+1·0	+0·8	+1·3	−0·0	−1·2	0·4	0·06	5·7	31·7	36·8	16·3	84·8
Usher & Cole, London	30769	S.r., g.b., s.o., "Karrusel"	+0·1	−0·5	−1·2	+2·0	−0·1	0·3	0·08	4·5	33·5	36·8	14·4	84·7
A. E. Fridlander, Coventry	25641	S.r., g.b., s.o., "Karrusel"	−2·9	−3·8	−4·2	−1·4	−0·8	0·25	0·08	4·7	35·0	35·2	14·4	84·6
G. J. Hollis, Coventry	62985	S.r., g.b., s.o., "Karrusel"	−7·7	−8·0	−7·9	−5·9	−7·7	0·4	0·08	5·2	32·5	37·5	14·5	84·5
J. Hewitt, Coventry	58137	D.r., g.b., s.o.	+1·3	+3·2	−0·1	+0·8	+1·3	0·35	0·08	7·5	32·9	36·9	14·4	84·2
W. Matthews, Coventry	101098	S.r., g.b., s.o., "Karrusel"	−1·7	−1·2	−1·4	+1·5	+2·7	0·4	0·03	6·0	32·9	33·2	18·1	84·2
B. Bonniksen, Coventry	56888	S.r., g.b., s.o., "Karrusel"	−2·9	−2·1	−1·7	+1·4	−0·7	0·4	0·05	6·0	32·7	35·0	16·5	84·2
Usher & Cole, London	30768	S.r., g.b., s.o., "Karrusel"	+2·8	+2·8	+3·9	+3·6	+5·4	0·4	0·09	6·2	32·6	37·0	14·6	84·2
S. Smith & Son, London	192–451/25655	S.r., g.b., s.o., "Karrusel"	+2·8	+1·8	+2·0	+3·6	+6·9	0·3	0·06	7·0	33·7	34·1	16·3	84·1
B Bonniksen, Coventry	57001	S.r., g.b., s.o., "Karrusel"	−2·6	−1·8	−1·2	−0·1	+1·4	0·4	0·06	6·5	32·6	35·2	16·3	84·1
,, ,,	57111	S.r., g.b., s.o., "Karrusel"	−4·0	−3·0	−3·1	−1·3	−5·4	0·4	0·06	5·0	32·6	35·6	15·9	84·1
,, ,,	57006	S.r., g.b., s.o., "Karrusel"	+1·6	+1·1	+1·6	+2·3	+3·9	0·4	0·07	6·7	31·8	36·8	15·5	84·1

s.r. = single roller; d.r. = double roller.
s.o. = ,, overcoil; d.o. = ,, overcoil.

Table II.

Highest Marks obtained by Complicated Watches during the year.

Description of watch.	Number.	Deposited by	Marks awarded for: Variation.	Position.	Temperature.	Total marks.
			0—40	0—40	0—20	0—100.
Minute and split seconds chronograph, repeater, and perpetual calendar, with phases of the moon .... Tourbillon	148–2	S. Smith and Son, London....	28·8	35·6	13·8	78·2
Minute and split seconds chronograph	12583	Baume and Co., London......	32·8	36·5	18·8	88·1
" " "	187904	Stauffer, Son and Co., London	30·0	37·7	18·1	85·8
" " "	187905	" " "	31·5	36·8	16·7	85·0
" " "	187903	" " "	32·4	33·4	17·3	83·1
Minute and seconds chronograph	51990	E. Dent and Co., London	30·9	34·6	17·7	83·2
" " " .... (non-magnetic)	3322	H. Golay, London...........	30·4	29·8	18·6	78·8
Minute repeater	1170	Montandon-Robert, Geneva ..	33·0	36·8	16·9	86·7
Quarter "	53106	E. Dent & Co., London	29·4	37·6	14·3	81·3
"Non-magnetic"	55177	Bonniksen, Coventry	31·4	36·6	19·3	87·3
"	191–236	S. Smith and Son, London....	32·9	33·7	14·5	81·1
"	229–428 / 15238	" " "	27·3	34·6	15·9	77·8

APPENDIX IV.

Report on the Magnetic Instruments at the Valencia and Falmouth Observatories September–October, 1903, by T. W. Baker.

Valencia.—The magnetic instruments at this Observatory were generally examined and found in good order.

I made a complete set of observations of Horizontal Force, Declination and Inclination, which on reduction were found to be in close agreement with the observations last taken by Mr. Cullum.

I found that more suspension threads were used in the magnetometer than was absolutely necessary, and suggested that a fewer number be employed so as to reduce the torsional effect as much as possible.

I re-determined the azimuth reading of the Dip Circle corresponding to the magnetic meridian, and found the value practically the same as the one Mr. Cullum was using. The determination of the meridian reading is made at the beginning of each year.

Falmouth.—The magnetographs have been in constant operation during the year. The Horizontal Force and Declination Curves are good, excepting that in a few instances the light has been faint, but there is practically no loss of trace.

Since the Vertical Force Magnet was altered and re-mounted in November, 1902, the traces show a decided improvement. There are, however, still numerous small dislocations, and at times it is difficult to locate the recovery of them.

On October 15, I made deflections of the Vertical Force, and brought the sensibility up to the Standard Scale 1 cm. = ·00050 C.G.S. units.

From the general trend of the curves the temperature correction would appear to be rather large.

The absolute instruments were all found to be in good order.

On October 12, I made a complete set of observations of the three elements, whilst Mr. Kitto observed on the 2nd and 16th. The results appeared in satisfactory agreement.

I re-determined the meridian reading of the Dip Circle, the result obtained being practically the same as the value used for the preceding year.

November 23, 1903.

APPENDIX V.

MAGNETIC OBSERVATIONS, 1902, FALMOUTH OBSERVATORY.

Latitude 50° 9′ 0″ N., and Longitude 5° 4′ 35″ W., Height, 167 feet above mean sea level.

Photographic curves of magnetic Declination and of Horizontal Force variations have been regularly taken during the year.

The scale values of the instruments were determined on 13th November, 1902. The following values of the ordinates of the photographic curves were then found:—

Declination, 1 cm. = 0° 11′·7.
Bifilar, 1 cm. δ H. = 0·00052 C.G.S. unit.
Balance, 1 cm. δ V. = 0·00050 C.G.S. unit.

The Magnetic Curves during the past year have shown very few large fluctuations; the principal variations recorded took place on the following dates:—January 15, 16; February 7; March 24; April 11, 20; May 9; August 21, 22; October 11, 31; November 24.

Observations with the Absolute Instruments have been made about four times a month, of which the following is a summary:—

Determination of	Horizontal Intensity,	48.
,,	Inclination,	48 sets of four.
,,	Declination,	48.

The results of the Magnetic Elements for the year 1902, are as follows:—

Mean Horizontal Force, 0·18737 C.G.S. units; Mean Westerly Declination 18° 21′·5, both deduced from the Photographic Curves; and Mean Inclination 66° 40′·4 derived from the Absolute Observations.

The Declination and the Horizontal Force are deduced from hourly readings of the photographic curves, and so are corrected for the diurnal variation.

The results in the following tables, Nos. I, II, III, IV, are deduced from the magnetograph curves, which have been standardised by observations of declination and of deflection and vibration. These were made with the Collimator Magnet, marked 66A, and the Declinometer Magnet, marked 66C, in the Unifilar Magnetometer No. 66, by Elliott Brothers, of London. The temperature correction (which is probably very small) has not been applied.

In Table V, H is the mean of the absolute values observed during the month (generally four in number), uncorrected for diurnal variation and for any disturbance. V is the product of H and of the tangent of the Observed Dip (uncorrected likewise for diurnal variation).

In Table VI, the Inclination is the mean of the absolute observations, the mean time of which is 3 p.m. The Inclination was observed with the Inclinometer No. 86, by Dover, of Charlton, Kent, and needles 1 and 2, which are 3½ inches in length.

The Declination and the Horizontal Force values given in Tables I to IV are prepared in accordance with the suggestions made in the fifth report of the Committee of the British Association on comparing and reducing magnetic observations, and the time given is Greenwich Mean Time, which is 20 minutes 18 seconds earlier than local time.

The following is a list of the days during the year 1902 which were selected by the Astronomer Royal as suitable for the determination of the magnetic diurnal variations, and which have been employed in the preparation of the magnetic tables:—

January	5, 11, 12, 22, 30.
February	1, 4, 18, 22, 27.
March	3, 4, 14, 28, 31.
April	7, 14, 15, 25, 26.
May	3, 11, 12, 16, 23.
June	2, 13, 17, 19, 27.
July	6, 13, 14, 20, 30.
August	6, 12, 14, 29, 30.
September	7, 8, 14, 16, 24.
October	3, 7, 10, 17, 26.
November	5, 9, 16, 27, 29.
December	4, 8, 14, 18, 20.

EDWARD KITTO,
Superintendent.

TABLE I.—Hourly Means of Declination at Falmouth
Five selected Quiet Days in each Month

	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon
(18° + West.)				Winter.									
1902.	′	′	′	′	′	′	′	′	′	′	′	′	′
January	22·0	22·4	22·8	23·0	22·9	22·7	22·3	21·9	21·5	21·0	21·8	22·9	24·2
February	22·2	22·6	22·8	22·8	22·5	22·5	22·4	22·2	22·0	21·8	22·6	23·6	24·7
March	22·6	22·9	22·9	22·9	22·8	22·7	22·4	22·1	21·1	20·3	21·3	23·5	26·1
October......	21·0	21·0	21·0	21·1	20·9	21·0	20·7	20·2	19·1	18·5	19·9	22·5	24·8
November....	19·1	19·4	19·6	19·7	19·6	19·6	19·3	19·0	18·7	18·3	18·7	20·0	21·4
December....	19·4	19·6	19·8	20·2	20·2	20·2	19·9	19·8	19·7	19·6	20·2	20·9	21·7
Means	21·1	21·3	21·5	21·6	21·5	21·5	21·2	20·9	20·4	19·9	20·8	22·2	23·8
					Summer.								
1902.	′	′	′	′	′	′	′	′	′	′	′	′	′
April........	21·3	21·4	21·3	21·3	21·3	20·6	20·5	19·8	18·6	18·0	19·3	21·3	24·3
May	21·5	21·4	21·3	21·3	21·1	20·5	19·7	18·9	18·2	18·4	19·7	21·0	23·4
June	19·5	19·5	19·1	18·9	18·4	17·4	16·2	15·8	15·9	16·0	17·7	19·5	21·6
July	21·5	21·5	21·2	21·0	20·9	20·1	18·6	18·2	17·4	18·1	19·6	21·4	24·4
August	20·7	20·6	20·4	20·1	19·9	19·2	18·4	17·9	18·0	18·5	20·1	22·6	24·8
September ..	20·5	20·2	20·3	20·4	20·1	20·1	19·8	19·3	18·7	19·4	20·7	22·2	24·3
Means	20·8	20·8	20·6	20·5	20·3	19·7	18·9	18·3	17·8	18·1	19·5	21·3	23·8

TABLE II.—Diurnal Inequality of the Falmouth

Hours	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon
					Summer Means.								
	′ −0·4	′ −0·4	′ −0·6	′ −0·7	′ −0·9	′ −1·5	′ −2·3	′ −2·9	′ −3·4	′ −3·1	′ −1·7	′ +0·1	′ +2·6
					Winter Means.								
	′ −0·6	′ −0·4	′ −0·2	′ −0·1	′ −0·2	′ −0·2	′ −0·5	′ −0·8	′ −1·3	′ −1·8	′ −0·9	′ +0·5	′ +2·1
					Annual Means.								
	′ −0·5	′ −0·4	′ −0·4	′ −0·4	′ −0·6	′ −0·9	′ −1·4	′ −1·9	′ −2·4	′ −2·5	′ −1·3	′ +0·3	′ +2·4

NOTE.—When the sign is + the magnet

Observatory, determined from the Magnetograph Curves on during 1902. (Mean for the year = 18° 21′·5 W.)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
					Winter.						
′	′	′	′	′	′	′	′	′	′	′	′
25·1	25·0	23·9	23·2	22·9	22·6	22·1	22·0	21·9	21·9	21·9	22·1
24·9	24·7	24·1	23·4	23·1	22·9	22·5	22·3	22·1	22·1	22·2	22·2
27·3	27·3	25·9	24·2	23·1	23·1	22·9	22·9	22·8	22·8	22·7	22·6
25·7	25·4	24·2	22·6	21·5	21·5	21·2	21·1	20·7	20·8	20·6	20·6
21·8	21·6	20·5	19·8	19·6	19·4	19·2	19·0	18·9	18·9	18·7	18·7
21·9	21·8	21·1	21·0	20·5	20·3	19·8	19·9	19·7	19·5	19·6	19·9
24·5	24·3	23·3	22·4	21·8	21·6	21·3	21·2	21·0	21·0	21·0	21·0
					Summer.						
′	′	′	′	′	′	′	′	′	′	′	′
26·3	26·2	24·5	23·4	22·6	21·7	21·2	21·4	21·4	21·4	21·4	21·5
24·7	25·2	24·3	23·2	22·7	22·1	21·4	21·4	21·1	21·3	21·2	21·2
22·6	23·2	22·7	21·5	20·0	19·7	19·7	19·8	19·7	19·9	19·6	19·7
26·6	26·9	26·2	24·3	22·8	22·0	21·8	22·0	21·9	22·0	21·9	21·7
26·8	26·5	24·6	22·5	20·9	20·1	20·2	20·6	20·6	20·7	20·6	20·3
24·9	24·7	23·7	22·5	21·6	21·4	21·1	21·1	20·8	21·0	21·0	21·2
25·3	25·5	24·3	22·9	21·8	21·2	20·9	21·1	20·9	21·1	21·0	20·9

Declination as deduced from Table I.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
					Summer Means.						
′ +4·1	′ +4·3	′ +3·1	′ +1·7	′ +0·6	′ 0·0	′ −0·3	′ −0·1	′ −0·3	′ −0·1	′ −0·2	′ −0·3
					Winter Means.						
′ +2·8	′ +2·6	′ +1·6	′ +0·7	′ +0·1	′ −0·1	′ −0·4	′ −0·5	′ −0·7	′ −0·7	′ −0·7	′ −0·7
					Annual Means.						
′ +3·5	′ +3·5	′ +2·4	′ +1·2	′ +0·4	′ −0·1	′ −0·4	′ −0·3	′ −0·5	′ −0·4	′ −0·5	′ −0·5

points to the West of its mean position.

TABLE III.—Hourly Means of the Horizontal Force at Falmouth
Five selected Quiet Days in each Month

Hours ..	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon
0·18000 + (C.G.S. units). Winter.													
1902.													
January	721	721	721	723	724	723	726	727	724	718	713	713	713
February	730	728	729	729	730	732	734	735	734	729	726	724	724
March	738	737	737	738	738	739	739	739	735	729	725	721	722
October	749	749	749	749	750	750	750	748	743	734	727	725	728
November ...	742	741	742	743	743	744	745	744	744	738	732	732	733
December	741	741	742	743	744	745	746	745	743	741	739	740	739
Means	737	736	737	738	738	739	740	740	737	732	727	726	727
Summer.													
1902.													
April	735	734	732	732	731	731	732	732	730	722	714	711	717
May	743	742	741	740	739	739	739	737	734	731	729	727	727
June	740	738	738	737	736	736	733	728	724	718	715	715	721
July	747	746	745	744	745	745	742	737	733	726	720	721	729
August	739	738	738	737	736	735	732	729	724	717	715	719	726
September ...	750	750	748	749	749	748	747	742	736	728	725	729	735
Means	742	741	740	740	739	739	738	734	730	724	720	720	726

TABLE IV.—Diurnal Inequality of the Falmouth

Hours	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon.
Summer Means.													
	+ ·00005	+ ·00004	+ ·00003	+ ·00003	+ ·00002	+ ·00002	+ ·00001	− ·00003	− ·00007	− ·00013	− ·00017	− ·00017	− ·00011
Winter Means.													
	+ ·00001	·00000	+ ·00001	+ ·00002	+ ·00002	+ ·00003	+ ·00004	+ ·00004	+ ·00001	− ·00004	− ·00009	− ·00010	− ·00009
Annual Means.													
	+ ·00003	+ ·00002	+ ·00002	+ ·00003	+ ·00002	+ ·00003	+ ·00003	+ ·00001	− ·00003	− ·00009	− ·00013	− ·00014	− ·00010

NOTE.—When the sign is + the

Observatory, determined from the Magnetograph Curves on during 1902. (Mean for the year = 0·18737.)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10	11.	Mid.
					Winter.						
717	721	723	723	726	726	726	726	725	724	723	722
726	728	729	728	729	731	733	735	734	733	732	733
726	732	735	738	737	739	741	741	741	741	741	740
733	738	741	744	745	748	748	749	750	750	751	751
737	742	742	743	743	745	746	746	745	745	744	743
741	745	745	744	745	746	747	747	745	744	743	743
730	734	735	737	738	739	740	741	740	739	739	739
					Summer.						
724	728	731	734	737	738	738	738	738	738	738	738
729	734	738	742	747	748	745	746	746	745	744	743
723	729	734	733	734	739	744	745	744	743	741	740
738	743	747	747	747	748	752	753	752	753	751	749
735	738	738	739	737	738	741	743	742	742	741	740
742	745	745	746	746	747	749	751	750	750	750	751
732	736	739	740	741	743	745	746	745	745	744	744

Horizontal Force as deduced from Table III.

1.	2.	3.	4.	5.	6.	.	8.	9.	10.	11.	Mid.
					Summer Means.						
− ·00005	− ·00001	+ ·00002	+ ·00003	+ ·00004	+ ·00006	+ ·00008	+ ·00009	+ ·00008	+ ·00008	+ ·00007	+ ·00007
					Winter Means.						
− ·00006	− ·00002	− ·00001	+ ·00001	+ ·00002	+ ·00003	+ ·00004	+ ·00005	+ ·00004	+ ·00003	+ ·00003	+ ·00003
					Annual Means.						
− ·00006	− ·00002	+ ·00001	+ ·00002	+ ·00003	+ ·00005	+ ·00006	+ ·00007	+ ·00006	+ ·00006	+ ·00005	+ ·00005

reading is above the mean.

Table V.—Magnetic Intensity. Absolute Observations.
Falmouth Observatory, 1902.

1902.	C. G. S. Measure. H or Horizontal Force.	C. G. S. Measure. V or Vertical Force.
January	0·18708	0·43429
February	0·18720	0·43450
March	0·18728	0·43444
April	0·18723	0·43447
May	0·18737	0·43437
June	0·18726	0·43436
July	0·18733	0·43414
August	0·18730	0·43404
September	0·18740	0·43430
October	0·18723	0·43429
November	0·18743	0·43441
December	0·18739	0·43418
Means	0·18729	0·43432

Table VI.—Observations of Magnetic Inclination.
Falmouth Observatory, 1902.

Month.		Mean. °	Mean. ′	Month.		Mean. °	Mean. ′
January	2 ..	66	41·2	July	2 ..	66	40·1
	14 ..	66	41·2		14 ..	66	38·7
	16 ..	66	42·8		16 ..	66	39·8
	31 ..	66	41·6		31 ..	66	39·8
		66	41·7			66	39·6
February	3 ..	66	41·9	August	2 ..	66	39·2
	14 ..	66	41·1		14 ..	66	39·5
	15 ..	66	41·8		16 ..	66	39·6
	28 ..	66	41·2		31 ..	66	39·8
		66	41·5			66	39·5
March	1 ..	66	39·7	September	2 ..	66	40·4
	14 ..	66	40·8		14 ..	66	38·9
	15 ..	66	42·1		16 ..	66	39·4
	31 ..	66	40·7				
		66	40·8			66	39·6
April	2 ..	66	40·8	October	9 ..	66	39·5
	14 ..	66	41·9		14 ..	66	40·2
	16 ..	66	41·4		16 ..	66	40·7
	30 ..	66	40·5		31 ..	66	42·3
		66	41·2			66	40·7
May	2 ..	66	40·4	November	2 ..	66	41·3
	14 ..	66	39·4		14 ..	66	39·7
	17 ..	66	39·3		16 ..	66	39·3
	31 ..	66	40·9		17 ..	66	38·3
					30 ..	66	39·7
		66	40·0			66	39·7
June	2 ..	66	39·9	December	2 ..	66	39·4
	14 ..	66	42·0		14 ..	66	39·2
	16 ..	66	40·7		16 ..	66	39·1
	30 ..	66	40·1		31 ..	66	39·3
		66	40·7			66	39·3

APPENDIX VI.

MAGNETIC OBSERVATIONS, 1903, FALMOUTH OBSERVATORY.

Photographic curves of magnetic Declination and of Horizontal Force variations have been regularly taken during the year.

The scale values of the instruments were determined on 29th June, 1903. The following values of the ordinates of the photographic curves were then found:—

Declination, 1 cm. $= 0° \; 11'{\cdot}7$.
Bifilar, 1 cm. δ H. $= 0{\cdot}00053$ C.G.S. unit.
Balance, 1 cm. δ V. $= 0{\cdot}00053$ C.G.S. unit.

The Magnetic Curves during the past year have shown very few large fluctuations; the principal variations recorded took place on the following dates:—April 6; June 29; August 22; September 19; October 12, 13, 31; November 1; and December 31.

That of October 31 was of exceptional magnitude, as may be seen from the accompanying reduced copies of the curves.*

Each of the three magnetic elements is recorded in reality on a separate sheet, two days' curves being taken on the same sheet with separate base or time lines, the upper curve and time line referring to the earlier of the two days. The sheets are changed every second day, shortly after 10 a.m. In the reproductions shown here, the changes in the elements appear on one sheet, a common time line being given for all three. In the reproduced curves the scale of ordinates has been reduced to about one-half the originals, so that 1 cm. represents approximately 20′ in Declination, and ·00100 C.G.S. in Vertical and Horizontal Force. It will be noticed that the curves—especially those for Declination and Horizontal Force—show appreciable disturbance in the late evening of October 30 and early morning of October 31, but that in the case of each element there is a sudden movement very shortly after 6 a.m. on the 31st, which may fairly be regarded as ushering in the storm.

Observations with the Absolute Instruments have been made about four times a month, of which the following is a summary:—

Determination of	Horizontal Intensity,	46.
,,	Inclination,	46 sets of four.
,,	Declination,	46.

The results of the Magnetic Elements for the year 1903, are as follows:—

Mean Horizontal Force, 0·18759 C.G.S. units, Mean Westerly Declination $18° \; 18'{\cdot}3$, both deduced from the Photographic Curves; and Mean Inclination $66° \; 38'{\cdot}5$ derived from the Absolute Observations.

The Declination and the Horizontal Force are deduced from hourly readings of the photographic curves, and so are corrected for the diurnal variation.

The results in the following tables, Nos. I, II, III, IV, are deduced from the magnetograph curves, which have been standardised by observations of declination and of deflection and vibration. These were made with the Collimator Magnet marked 66A,

* See plate at end of Report.

and the Declinometer Magnet, marked 66C, in the Unifilar Magnetometer No. 66, by Elliott Brothers, of London. The temperature correction (which is very small) has not been applied.

In Table V, H is the mean of the absolute values observed during the month (generally four in number), uncorrected for diurnal variation and for any disturbance. V is the the product of H and of the tangent of the Observed Dip (uncorrected likewise for diurnal variation).

In Table VI the inclination is the mean of the absolute observations, the mean time of which is 3 p.m. The inclination was observed with the Inclinometer No. 86, by Dover, of Charlton, Kent, and needles 1 and 2, which are 3½ inches in length.

The Declination and the Horizontal Force values given in Tables I to IV, are prepared in accordance with the suggestions made in the fifth report of the Committee of the British Association on comparing and reducing magnetic observations, and the time given is Greenwich Mean Time, which is 20 minutes 18 seconds earlier than local time.

The following is a list of the days during the year 1903 which were selected by the Astronomer Royal as suitable for the determination of the magnetic diurnal variations, and which have been employed in the preparation of the magnetic tables :—

January	7, 9, 15, 17, 25.
February	2, 4, 14, 24, 27.
March	3, 15, 17, 18, 26.
April	11, 13, 14, 20, 24.
May	10, 11, 12, 18, 26.
June	8, 9, 12, 13, 27.
July	3, 7, 9, 22, 24.
August	3, 7, 17, 19, 29.
September	3, 15, 16, 17, 26.
October	9, 10, 16, 21, 24.
November	6, 9, 14, 15, 25.
December	11, 12, 18, 24, 25.

EDWARD KITTO,
Superintendent.

TABLE I.—Hourly Means of Declination at Falmouth
Five selected Quiet Days in each Month

	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon.
	(18° + West.)				Winter.								
1903.	′	′	′	′	′	′	′	′	′	′	′	′	′
January	18·8	19·1	19·1	19·4	19·6	19·4	19·0	18·8	18·6	18·5	18·4	20·3	21·3
February	18·4	18·9	19·2	19·5	19·4	19·5	19·0	18·8	18·3	17·6	18·2	19·3	20·8
March	17·9	18·0	18·2	18·5	18·3	18·2	18·1	17·7	16·6	16·2	17·0	19·1	21·6
October......	16·1	16·9	17·4	17·6	17·6	17·8	17·5	17·1	15·9	15·2	16·4	18·9	21·5
November....	15·5	16·1	16·2	16·4	16·4	16·4	15·6	15·6	15·2	14·4	15·0	16·8	19·1
December....	13·7	14·2	14·5	14·6	14·6	14·6	14·4	14·3	14·1	13·8	14·5	15·4	16·4
Means	16·7	17·2	17·4	17·7	17·7	17·7	17·3	17·1	16·5	16·0	16·6	18·3	20·1
					Summer.								
1903.	′	′	′	′	′	′	′	′	′	′	′	′	′
April........	17·5	17·8	17·7	17·9	17·5	17·7	17·2	16·6	14·9	14·2	15·5	17·6	20·3
May	18·4	18·5	18·2	17·9	17·4	16·6	15·7	14·3	14·0	14·9	17·2	20·2	22·4
June	18·2	17·9	18·1	17·8	17·2	15·8	14·1	13·2	13·2	14·6	17·7	21·3	24·0
July	17·5	17·3	17·3	17·1	16·9	15·6	14·1	14·2	14·4	14·8	16·7	19·0	21·8
August	17·8	17·7	17·6	17·2	16·8	16·2	15·5	15·2	14·5	15·0	17·0	19·2	21·5
September....	19·5	19·3	19·0	18·9	18·9	18·7	18·3	17·5	17·1	17·9	20·4	22·5	22·5
Means	18·2	18·1	18·0	17·8	17·5	16·8	15·8	15·2	14·7	15·2	17·4	20·0	22·1

TABLE II.—Diurnal Inequality of the Falmouth

Hours.	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon.
					Summer Means.								
	′ −0·5	′ −0·6	′ −0·7	′ −0·9	′ −1·2	′ −1·9	′ −2·9	′ −3·5	′ −4·0	′ −3·5	′ −1·3	′ +1·3	′ +3·4
					Winter Means.								
	′ −1·2	′ −0·7	′ −0·5	′ −0·2	′ −0·2	′ −0·2	′ −0·6	′ −0·8	′ −1·4	′ −1·9	′ −1·3	′ +0·4	′ +2·2
					Annual Means.								
	′ −0·8	′ −0·7	′ −0·6	′ −0·6	′ −0·7	′ −1·1	′ −1·8	′ −2·2	′ −2·7	′ −2·7	′ −1·3	′ +0·9	′ +2·8

NOTE.—When the sign is + the magnet

Observatory, determined from the Magnetograph Curves on during 1903. (Mean for the Year, 18° 18′·3 W.)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
Winter.											
′	′	′	′	′	′	′	′	′	′	′	′
21·8	22·1	21·1	20·2	19·4	19·2	18·8	18·7	18·3	18·3	18·2	18·4
22·2	22·9	21·9	20·4	19·8	19·6	18·9	18·7	18·4	18·1	18·2	18·6
23·1	23·3	22·3	20·9	19·5	18·9	19·0	18·9	18·8	18·7	18·4	18·5
22·8	22·8	21·3	20·0	19·0	18·3	17·9	17·6	17·4	17·7	17·4	17·7
20·2	19·8	19·0	18·3	17·6	17·0	16·5	16·3	15·8	15·6	15·4	15·4
16·5	16·6	16·1	16·1	15·6	15·0	14·6	14·5	14·3	14·3	14·3	14·4
21·1	21·3	20·3	19·3	18·5	18·0	17·6	17·5	17·2	17·1	17·0	17·2
Summer.											
′	′	′	′	′	′	′	′	′	′	′	′
22·3	23·3	22·6	21·3	20·1	18·9	18·1	17·9	17·8	17·7	17·7	17·8
23·1	23·0	22·0	20·8	19·6	19·0	18·7	18·8	18·7	18·8	18·4	18·4
25·1	24·6	23·3	21·7	19·9	19·0	18·5	18·5	18·4	18·5	18·4	18·4
22·3	22·7	21·8	20·5	18·7	18·1	17·8	18·0	17·5	17·8	17·8	17·8
22·4	22·8	21·1	19·7	18·5	17·9	17·8	18·0	18·3	18·5	18·3	18·7
25·2	24·5	23·1	21·3	20·4	20·2	20·8	20·3	20·3	20·3	20·0	20·1
23·4	23·5	22·3	20·9	19·5	18·9	18·6	18·6	18·5	18·6	18·4	18·5

Declination as deduced from Table I.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
Summer Means.											
′	′	′	′	′	′	′	′	′	′	′	′
+4·7	+4·8	+3·6	+2·2	+0·8	+0·2	−0·1	−0·1	−0·2	−0·1	−0·3	−0·2
Winter Means.											
′	′	′	′	′	′	′	′	′	′	′	′
+3·2	+3·4	+2·4	+1·4	+0·6	+0·1	−0·3	−0·4	−0·7	−0·8	−0·9	−0·9
Annual Means.											
′	′	′	′	′	′	′	′	′	′	′	′
+4·0	+4·1	+3·0	+1·8	+0·7	+0·2	−0·2	−0·3	−0·5	−0·5	−0·6	−0·5

points to the West of its mean position.

TABLE III.—Hourly Means of the Horizontal Force at Falmouth
Five selected Quiet Days in each Month

Hours ..	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon
0·18000 + (C.G.S. units).						Winter.							
1903.													
January......	758	758	758	758	758	760	762	762	760	756	750	747	747
February	761	761	762	762	763	764	766	766	766	759	753	749	749
March	766	765	766	766	767	767	768	768	766	757	751	750	749
October	754	752	752	754	754	754	757	756	753	744	737	732	735
November ...	746	746	745	746	747	748	752	749	746	738	730	725	727
December	753	752	753	754	754	756	756	757	756	750	745	744	747
Means	756	756-	756	757	757	758	760	760	758	751	744	741	742
						Summer.							
1903.													
April	768	765	766	765	766	767	768	768	763	755	744	737	737
May	765	764	764	763	762	760	758	752	747	741	741	743	747
June	773	773	773	772	771	771	766	760	752	748	749	751	755
July	775	773	773	773	770	771	765	758	753	749	747	750	755
August	771	768	768	767	766	765	761	756	749	744	744	746	755
September....	764	762	759	758	758	758	756	751	744	738	735	738	747
Means	769	768	767	766	766	765	762	758	751	746	743	744	749

TABLE IV.—Diurnal Inequality of the Falmouth

Hours	Mid.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Noon
							Summer Means.						
	+ ·00006	+ ·00005	+ ·00004	+ ·00003	+ ·00003	+ ·00002	− ·00001	− ·00005	− ·00012	− ·00017	− ·00020	− ·00019	− ·00014
							Winter Means.						
	+ ·00001	+ ·00001	+ ·00001	+ ·00002	+ ·00002	+ ·00003	+ ·00005	+ ·00005	+ ·00003	− ·00004	− ·00011	− ·00014	− ·00013
							Annual Means.						
	+ ·00004	+ ·00003	+ ·00003	+ ·00003	+ ·00003	+ ·00003	+ ·00002	·00000	− ·00005	− ·00011	− ·00016	− ·00017	− ·00014

NOTE.—When the sign is + the

Observatory, determined from the Magnetograph Curves on during 1903. (Mean for the year ·18759.)

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
					Winter.						
753	758	760	762	763	763	761	761	761	759	758	758
751	758	760	761	762	764	766	766	766	764	763	764
754	758	763	764	765	766	768	770	770	771	770	769
741	747	748	749	752	755	756	756	759	758	760	757
734	737	740	742	744	746	748	749	749	750	751	750
748	752	751	753	755	757	757	758	756	756	756	756
747	752	754	755	757	759	759	760	760	760	760	759
					Summer.						
743	752	761	764	768	770	770	769	769	769	770	770
752	755	762	766	768	772	773	773	772	771	768	767
761	767	772	778	779	781	782	782	782	781	780	777
765	770	776	777	779	780	781	782	779	778	778	780
760	765	766	768	768	771	775	777	777	775	774	774
753	755	756	756	759	763	766	765	765	764	764	764
756	761	766	768	770	773	775	775	774	773	772	772

Horizontal Force as deduced from Table III.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Mid.
					Summer Means.						
− ·00007	− ·00002	+ ·00003	+ ·00005	+ ·00007	+ ·00010	+ ·00012	+ ·00012	+ ·00011	+ ·00010	+ ·00009	+ ·00009
					Winter Means.						
− ·00008	− ·00003	− ·00001	·00000	+ ·00002	+ ·00004	+ ·00004	+ ·00005	+ ·00005	+ ·00005	+ ·00005	+ ·00004
					Annual Means.						
− ·00008	− ·00003	+ ·00001	+ ·00003	+ ·90005	+ ·00007	+ ·00008	+ ·00009	+ ·00008	+ ·00008	+ ·00007	+ ·00007

reading is above the mean.

Table V.—Magnetic Intensity. Absolute Observations.
Falmouth Observatory, 1903.

1903.	C.G.S. Measure.	
	H or Horizontal Force.	V or Vertical Force.
January	0·18749	0·43451
February	0·18749	0·43410
March	0·18752	0·43437
April	0·18750	0·43388
May	0·18759	0·43391
June	0·18745	0·43380
July	0·18765	0·43415
August	0·18757	0·43397
September	0·18742	0·43383
October	0·18731	0·43375
November	0·18722	0·43423
December	0·18724	0·43421
Means	0·18745	0·43406

Table VI.—Observations of Magnetic Inclination.
Falmouth Observatory, 1903.

Month.	Mean.	Month.	Mean.
	° ′		° ′
January 2 ..	66 38·7	July 2 ..	66 38·6
14 ..	66 39·6	14 ..	66 37·8
16 ..	66 39·0	16 ..	66 35·5
31	66 41·0	31 ..	66 38·0
	66 39·6		66 37·5
February 2 ..	66 38·7	August 2 ..	66 36·9
14 ..	66 38·5	14 ..	66 37·8
16 ..	66 38·1	16 ..	66 37·7
28 ..	66 31·3	31 ..	66 37·6
	66 38·4		66 37·5
March 2 ..	66 38·7	September 2 ..	66 37·4
14 ..	66 38·6	25 ..	66 38·5
16 ..	66 38·7	30 ..	66 38·4
31 ..	66 40·2		
	66 39·0		66 38·1
April 2 ..	66 37·8	October 2 ..	66 38·5
14 ..	66 38·4	12 ..	66 38·8
16 ..	66 39·0	16 ..	66 38·5
29 ..	66 35·4		
	66 37·7		66 38·6
May 2 ..	66 37·1	November 2 ..	66 42·5
14 ..	66 37·3	14 ..	66 39·9
16 ..	66 37·5	16 ..	66 40·4
30 ..	66 36·8	30 ..	66 39·5
	66 37·2		66 40·6
June 2 ..	66 38·3	December 2 ..	66 40·2
16 ..	66 37·1	14 ..	66 40·7
17 ..	66 37·6	16 ..	66 39·9
30 ..	66 38·2	31 ..	66 40·6
	66 37·8		66 40·4

APPENDIX VII.

MAGNETIC OBSERVATIONS, 1903, VALENCIA OBSERVATORY, CAHIRCIVEEN.

Latitude, 51° 56′ N. Longitude, 10° 15′ W.

The monthly observation of Magnetic Declination, Inclination and Horizontal Force, has been continuously made during the year with Unifilar 139, and Dip Circle 118, both by Dover. The values for Vertical Force and Total Force have been calculated from the formulæ V.F. = H.F. tan dip, and T.F. = H.F. sec dip.

Until May duplicate determinations of the three elements were made in the middle of each month, but from June, at the suggestion of Dr. Glazebrook, they were made on the 1st and 15th of each month, the individual observations and mean for the month being given.

In the earlier part of the year the mean times of the two monthly H.F. observations were, as in previous years, about 11 a.m. and 3 p.m. G.M.T. respectively; from June onwards the mean time for both was noon. This change of hour tends slightly to reduce the mean value for 1903 as compared to previous years, the reduction being approximately ·00004 C.G.S. The consequent reductions in V.F. and T.F. are each approximately ·00010 C.G.S.

On September 27, Mr. T. W. Baker inspected the Observatory, and at my request kindly made a complete set of observations, which on reduction were in close accord with my own, and are included in the mean for September.

The magnetic storm on October 31 had but partially subsided the next morning when the observations were made, and, although they are entered, they are not included in the means, another determination being made on November 3.

J. E. CULLUM,
Observer and Superintendent.

TABLE I.—Magnetic Observations at the Valencia Observatory, Cahirciveen, during 1903.

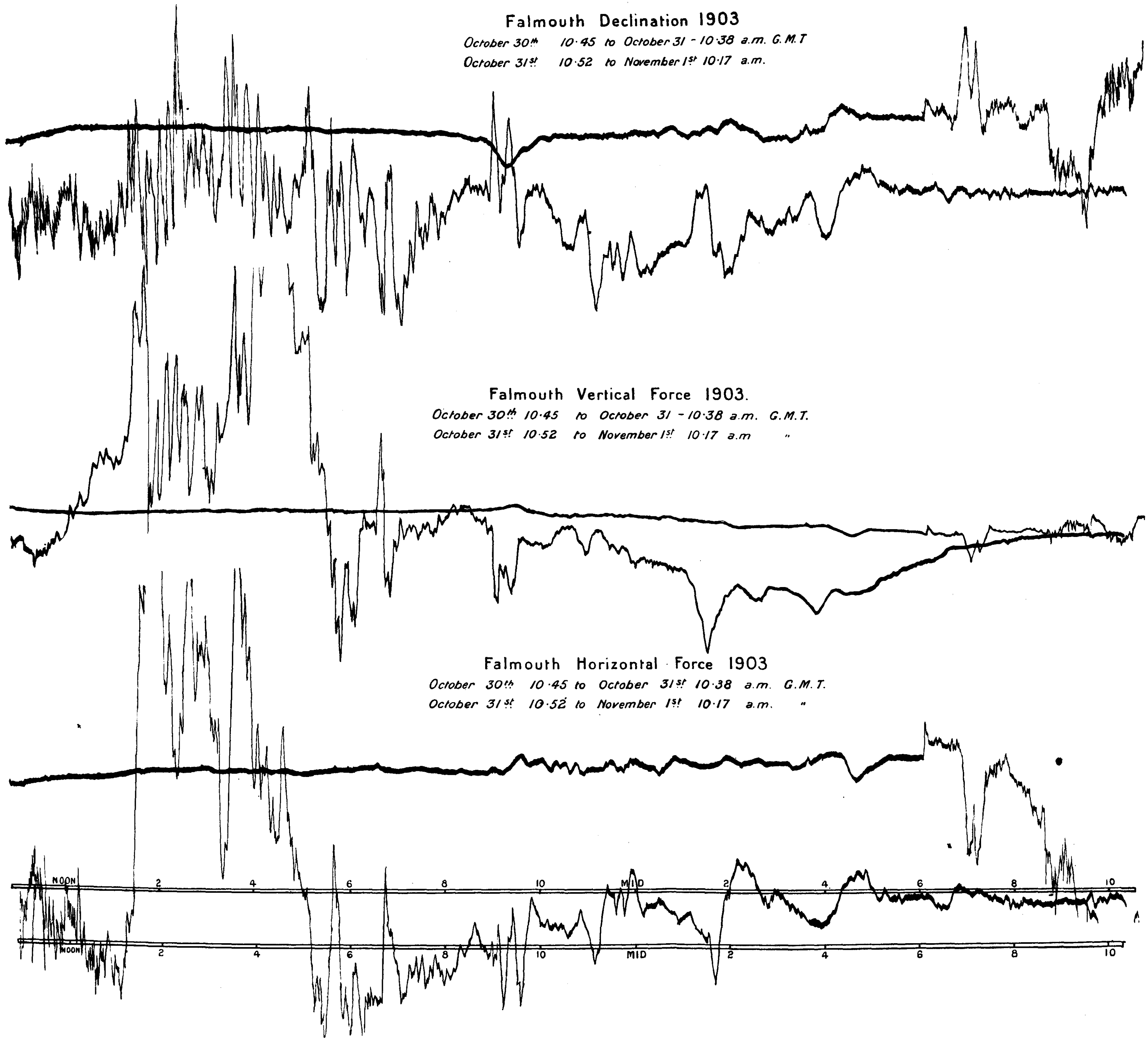
Date.	Declination.	Monthly Mean.	Remarks.
	° ′	° ′	
January 19 ..	21 22·2	—	
„ 20 ..	21 21·1	21 21·7	
February 13 ..	21 19·8	—	Too much disturbed to observe on the 14th.
„ 16 ..	21 19·3	21 19·6	
March 16 ..	21 19·2	—	
„ 17 ..	21 19·7	21 19·5	
April 13 ..	21 15·3	—	
„ 14 ..	21 14·5	21 14·9	
May 14 ..	21 15·4	—	
„ 15 ..	21 19·8	21 17·6	
June 1 ..	21 22·1	—	Commenced to observe every fortnight.
„ 15 ..	21 16·5	21 19·3	
July 4 ..	21 19·8	—	
„ 5 ..	21 16·5	—	
„ 17 ..	21 18·6	21 18·3	
August 1 ..	21 17·3	—	
„ 15 ..	21 19·6	21 18·5	
September 1 ..	21 23·7	—	
„ 15 ..	21 17·4	—	
„ 27 ..	21 21·3	21 20·8	Inspection observation.
October 1 ..	21 17·1	—	
„ 15 ..	21 18·1	21 17·6	
November 1 ..	21 21·3	—	Magnetic storm not included in mean.
„ 3 ..	21 17·3	—	
„ 15 ..	21 16·8	21 17·1	
December 1 ..	21 19·6	—	
„ 15 ..	21 19·0	21 19·3	
Mean ..	at 10 a.m., G.M.T.	21 18·7	

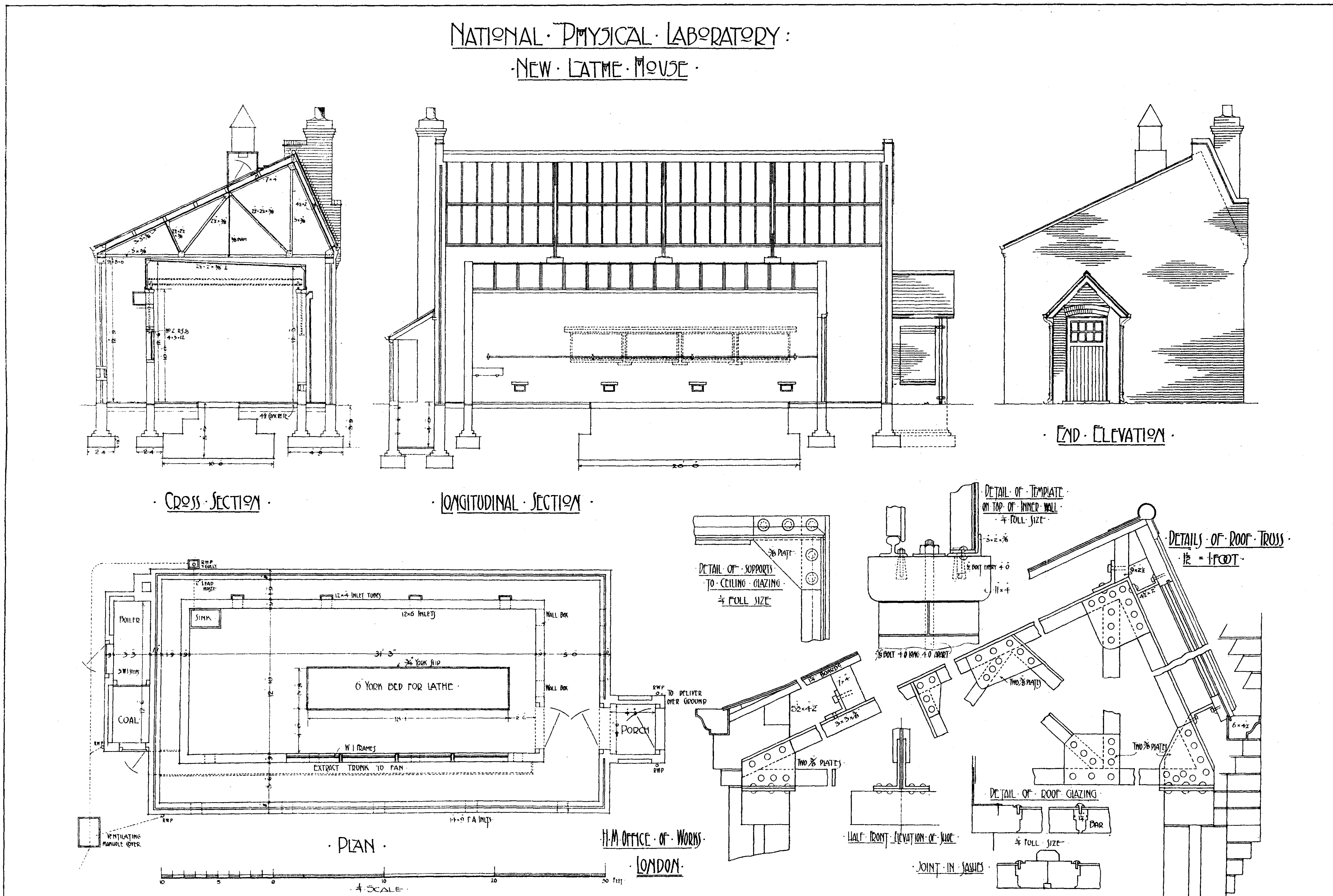
TABLE II.—Inclination, at Valencia Observatory, 1903. Dover Circle 118.

Date.	H.F.	Mean.	V.F. (H.F. Tan Dip).	T.F. (H.F. Sec Dip).
January 19	0·17832	—	—	—
„ 19	0·17848	0·17840	0·44994	0·48401
February 13	0·17816	—	—	—
„ 13	0·17842	0·17829	0·44893	0·48288
March 16	0·17814	—	—	—
„ 16	0·17869	0·17842	0·44991	0·48399
April 13	0·17819	—	—	—
„ 13	0·17832	0·17826	0·45022	0·48424
May 14	0·17832	—	—	—
„ 14	0·17853	0·17843	0·44983	0·48392
June 1	0·17831	—	—	—
„ 15	0·17833	0·17832	0·44955	0·48361
July 5	0·17822	—	—	—
„ 17	0·17823	0·17823	0·44924	0·48330
August 1	0·17830	—	—	—
„ 15	0·17823	0·17827	0·44943	0·48348
September 1	0·17822	—	—	—
„ 15	0·17825	—	—	—
„ 27	0·17828	0·17825	0·44907	0·48315
October 1	0·17831	—	—	—
„ 15	0·17821	0·17826	0·44978	0·48382
November 1	0·17760	—	—	—
„ 3	0·17815	—	—	—
„ 15	0·17839	0·17827	0·45064	0·48462
December 1	0·17854	—	—	—
„ 15	0·17853	0·17854	0·45070	0·48479
Means	at Noon, G.M.T.	0·17833	0·44977	0·48382

TABLE II.—Magnetic Force (C.G.S.), at Valencia Observatory, 1903.
Dover Unifilar 139.

Date.		Mean of two needles.	Monthly mean.	Remarks.
		° ′	° ′	
January	19 ..	68 21·7	—	
„	20 ..	68 22·9	68 22·3	
February	13 ..	68 23·5	—	
„	16 ..	68 22·6	68 23·1	
March	16 ..	68 21·7	—	
„	17 ..	68 22·4	68 22·1	
April	13 ..	68 23·6	—	
„	14 ..	68 24·3	68 24·0	
May	14 ..	68 21·0	—	
„	15 ..	68 22·6	68 21·8	
June	1 ..	68 23·6	—	
„	15 ..	68 20·0	68 21·8	
July	5 ..	68 21·8	—	
„	17 ..	68 21·4	68 21·6	
August	1 ..	68 21·6	—	
„	15 ..	68 22·0	68 21·8	
September	1 ..	68 21·0	—	
„	15 ..	68 21·4	—	
„	27 ..	68 20·5	68 21·0	
October	1 ..	68 21·8	—	
„	15 ..	68 23·8	68 22·8	
November	1 ..	68 26·5	—	
„	..	68 26·2	—	
„	[illegible] ..	68 23·8	68 25·0	
December	1 ..	68 22·3	—	
„	15 ..	68 24·5	68 23·4	
Mean	..	at 1 p.m., G.M.T.	68 22·6	


Falmouth Declination 1903
October 30th 10·45 to October 31 - 10·38 a.m. G.M.T
October 31st 10·52 to November 1st 10·17 a.m.
Falmouth Vertical Force 1903.
October 30th 10·45 to October 31 - 10·38 a.m. G.M.T.
October 31st 10·52 to November 1st 10·17 a.m "
Falmouth Horizontal Force 1903
October 30th 10·45 to October 31st 10·38 a.m. G.M.T.
October 31st 10·52 to November 1st 10·17 a.m. "
NOON 2 4 6 8 10 MID 2 4 6 8 10
NOON 2 4 6 8 10 MID 2 4 6 8 10



Harrison & Sons Lith. St Martins Lane W.C.