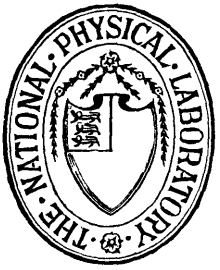


THE

# NATIONAL PHYSICAL LABORATORY.

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## REPORT FOR THE YEAR 1902.

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

1903.

# THE NATIONAL PHYSICAL LABORATORY.

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# THE NATIONAL PHYSICAL LABORATORY.

## REPORT FOR THE YEAR 1902.

Report of the Executive Committee.

List of Donations to the Equipment of the Laboratory and to the Library.

Work approved for 1903.

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, 1902, TO DECEMBER 31, 1902, SUBMITTED TO THE GENERAL BOARD AT THEIR MEETING ON MARCH 20, 1903.

The Laboratory was opened by their Royal Highnesses the Prince and Princess of Wales on March 19, 1902.

Their Royal Highnesses were received by the President of the Royal Society and Lady Huggins, the Chairman of the General Board and Lady Rayleigh, the members of the Executive Committee, and a number of distinguished visitors.

After inspecting the rooms in Bushy House they adjourned to the Engineering Building for the formal opening ceremony at which some 900 visitors were present.

Sir Wm. Huggins, President of the Royal Society, was in the chair.

After statements explaining the work of the Laboratory had been made by the Lord Rayleigh, Chairman of the General Board, and the Rt. Hon. G. W. Balfour, M.P.,

President of the Board of Trade, H.R.H. the Prince of Wales gave an address and declared the Laboratory open.

The thanks of the meeting were then, on the motion of the Lord Chancellor, supported by Lord Kelvin and the Lord Mayor, conveyed to their Royal Highnesses by the Chairman.

After the ceremony, the company adjourned to Bushy House for the inspection of the Laboratory.

Since the date of the opening, the Staff have been engaged in fitting up the apparatus and equipment, in carrying out a certain amount of test work and in commencing various researches.

Full details as to the equipment will be found in the Director's Report which accompanies this.

As regards the Test Work, the following table will show that a commencement has been made at Bushy House:—

## WORK DONE AT BUSHY HOUSE.

March 31—December 31, 1902.

### Engineering Department.

| | | |
|---|---|---|
| Deep Sea Thermometers (Strength) | 13 | |
| Gauges... | 2 | |
| Resistance Tests of Metals | 25 | |
| | | 40 |

### Physics Department.

*Electricity and Magnetism.*

| | | |
|---|---|---|
| Resistance Coils | 11 | |
| Resistance Boxes | 3 | |
| Condensers | 6 | |
| Permeability and Hysteresis Tests | 5 | |
| Conductivity Tests | 4 | |
| Inductance Tests | 1 | |
| Miscellaneous | 1 | |
| | — | 31 |

*Thermometry.*

| | | |
|---|---|---|
| High Range Thermometers | 10 | |
| Low Range Thermometers | 26 | |
| Platinum Thermometers | 2 | |
| Thermo-couples | 1 | |
| | — | 39 |

*Metrology.*

| | | |
|---|---|---|
| Micrometer | 1 | |
| Dial Measuring Machine | 1 | |
| Co-efficients of Expansion | 10 | |
| | — | 12 |

*Testing of Glass Vessels and of Weights.*

| | | |
|---|---|---|
| Glass Vessels, Burettes, Flasks, etc | 22 | |
| Chemical Weights | 94 | |
| | | — 116 |

*Metallography.*

| | |
|---|---|
| Photomicrographic Examination of Specimens of Metals | 16 |

*Chemical Tests.*

| | | |
|---|---|---|
| Aluminium Wires | 3 | |
| Samples of Paper | 5 | |
| Steel | 2 | |
| | — | 10 |

*Microscopical Tests.*

| | |
|---|---|
| Samples of Paper | 5 |
| Total | 229 |

Applications have been made for a number of other tests, which it has been impossible to carry out, mainly because of the incomplete equipment of the Laboratory. Among such applications may be noted the following:—

1. Testing of glow lamps. 2. Standards of light and photometry. 3. Testing of electric fans. 4. Testing of oil-flash point apparatus other than that certified by the Board of Trade. 5. Testing of ammeters up to 1,000 amperes. 6. Testing of alternate current meters of various kinds up to 2,000 Watts. 7. Testing of globe strain insulators for tramway work at high alternating potential. 8. General inquiries as to testing high voltage alternating instruments. 9. Standards for extremely low temperatures. 10. Specific heat and latent heat of petrol. 11. Specific heat of iron and nickel at high temperatures. 12. Testing of a number of three-phase measuring instruments and meters.

The equipment, however, is in various ways being extended, and it will be possible shortly to undertake a number of tests similar to those which have been declined.

This extension is due, in many cases, to the generosity of friends of the Laboratory. Thus, Messrs. Siemens Bros. and Co. are giving machinery for generating alternate current, while Sir Wm. Preece has most generously undertaken to provide a complete photometric outfit.

In connection with this, the thanks of the Committee are due to the Electric Power Storage Company for their gift of 150 cells for photometer work, and to Mr. A. P. Trotter for one of his photometers.

When these installations are complete, tests and experiments, involving the use of alternate two-phase or three-phase current, can be undertaken, provided funds are forthcoming for the necessary measuring apparatus.

The necessity for photometric work was emphasized by Professor Fleming's recent paper, read before the Institution of Electrical Engineers, and the discussions which have followed it. At the same time the inception of new work involves additional expendi-

ture; it will be difficult for the present staff to undertake the charge of a Photometric Laboratory, and though it appears probable that the fees will ultimately go far to cover the expenditure, this cannot be the case at once; still in view of the importance of the matter the Committee are of opinion that the work should be undertaken.

With regard to the research work, some progress has been made on each of the experiments mentioned in the Statement of Work presented a year ago to the General Board.

For the Alloys Research, the Metallurgical Laboratory has been equipped, and most of the apparatus is now working.

The Committee are indebted to Mr. George Beilby for the gift of a complete resistance pyrometer, as used by the late Sir Wm. Roberts-Austen and Dr. Stansfield at the Mint. Dr. Carpenter has gained useful experience in carrying out a short inquiry as to a new brand of tool steel, and in preparing and photographing sections of some of Mr. Hadfield's alloys for Professor Barrett.

A plan of work for the ensuing year will be found in the Statement of Work; it includes an investigation of certain Nickel Steel Alloys, and much of the material for this has been given by Mr. Hadfield's firm.

In connection with the same research, a machine, designed by Dr. Stanton, for testing the effect of repeated stress, is under construction in the Engineering Laboratory. Dr. Stanton has made some progress with his wind-pressure experiments. Funds for these last two experiments have been granted by the Government Grant Committee.

In the Thermometry Division, Dr. Harker has made a series of preliminary comparisons up to temperatures of about 1,000° C. between the constant volume nitrogen thermometer and some standard platinum thermometers. He has also constructed a set of six standard platinum thermometers for the British Association. A number of tests of both high- and low-range thermometers have been made, and one interesting inquiry related to the specific heat of iron at temperatures up to 900° C.

In the Electricity Division, Mr. Campbell and Mr. Melsom have been employed chiefly in setting up apparatus and in standardising the methods of testing. The standard air-condensers are now installed, and their capacities have been redetermined by Mr. Campbell.

Mr. Smith has made an inter-comparison of the resistance coils of the British Association and some standards certified by the Reichsanstalt; he has also made good progress with the construction of a number of mercury standards of resistance.

In the Metrology Division the various pieces of measuring apparatus have been calibrated and put into working order by Mr. Keeling, who has also determined a number of co-efficients of expansion.

During the year, work has been continued in the Observatory Department, and a number of details of interest will be found in the Report of the Superintendent to the Director. The following table gives a comparative statement of the various instruments tested during the past four years.

COMPARISON OF NUMBERS OF INSTRUMENTS VERIFIED TO THE END OF DECEMBER IN THE YEARS 1899, 1900, 1901, 1902.

| | 1899. | 1900. | 1901. | 1902. |
|---|---|---|---|---|
| Absolute Magnetic Instruments ..... | 14 | 22 | 31 | 26 |
| Mercury Barometers ..... | 194 | 219 | 201 | 271 |
| Aneroid Barometers ..... | 175 | 197 | 222 | 122 |
| Hydrometers ..... | 241 | 173 | 120 | 410 |
| Clinical Thermometers ..... | 16,020 | 20,476 | 20,389 | 22,856 |
| Other Thermometers ..... | 3,224 | 3,071 | 3,506 | 3,086 |
| Compasses ..... | 43 | 51 | 11 | 16 |
| Sextants ..... | 876 | 813 | 938 | 769 |
| Telescopes ..... | 561 | 1,345 | 2,029 | 1,678 |
| Binoculars ..... | 404 | 963 | 669 | 924 |
| Lenses ..... | 160 | 136 | 9 | 12 |
| Watches ..... | 431 | 421 | 359 | 520 |
| Chronometers ..... | 63 | 52 | 30 | 39 |
| Milk Test ..... | — | — | 527 | 159 |
| Miscellaneous ..... | 146 | 145 | 143 | 187 |
| | 22,552 | 28,084 | 29,184 | 31,075 |

The extension of electric traction in the neighbourhood of Kew has rendered the magnetic records which are still being taken there of very little value; the Committee regret that progress in obtaining a new site for a magnetic Observatory has been slow; they trust, however, to be able to report something definite before long, meanwhile the records required for co-operation with the Antarctic Expedition have been obtained at Bushy House. The tram lines are already laid in Teddington and the cars will be running very shortly.

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

Arrangements have been made for commencing two important new pieces of work at Bushy House very shortly. At the request of the Secretary of State for India in Council the tide-predicting machine, which for many years has been used under the charge of Mr. Roberts, of the Nautical Almanac Office, for predicting the Indian tides, is to be removed to Bushy House, and worked as part of the Laboratory equipment. In undertaking this work, the Committee are to have Mr. Roberts' assistance, the value of which they are glad to recognise.

A Committee, appointed by the Secretary of State for War, has for some time been considering the question of the production of standard leading screws for lathes for use in Government workshops and elsewhere. A machine for this purpose has been built by Messrs. Sir W. G. Armstrong, Whitworth & Co., to designs approved by this Committee, and is to be placed at Bushy House in charge of the Committee.

The Office of Works have now under consideration the plans of a special building for this machine. It will be the duty of the Committee to issue to the Government Workshops and to the Trade certified copies, made by this machine, of the standard screw

During the year a representative Committee under Sir John Wolfe Barry, as Chairman, has had under consideration the question of making known to manufacturers and others the opportunity afforded them by the Laboratory for tests of all kinds, and of securing support either by subscriptions or otherwise.

This Committee is still continuing its labours, the results have so far been gratifying. The Institute of Civil Engineers, the Iron and Steel Institute, the Society of Chemical Industry, and a number of private firms have promised subscriptions, in most cases for a term of years. A list of these is given with the Report, the aggregate sum amounts to about £1,000, and this the Funds Committee hope to raise very considerably.

The thanks of the Executive Committee are due both to the donors and to the gentlemen who have been instrumental in obtaining these funds. The accounts show that without this assistance the Laboratory would have been in a most serious condition. As a consequence of this help and in order to expedite progress with the various researches in hand it was thought right at the end of the year to increase somewhat the staff of the Laboratory.

The Committee are glad also to thank various donors for gifts of apparatus. In addition to those already mentioned, Sir Bernhard Samuelson has presented a blower for use in the smelting house, while Professor M'Leod has given a complete gas analysis apparatus, and the apparatus used in his standard determination of the pitch of a tuning-fork.

Apparatus has also been given by the Government Grant Committee of the Royal Society, and an arrangement has been made whereby physical apparatus belonging to that Committee which is not on loan is stored at the National Physical Laboratory, and may be utilised for researches or other work in progress there.

A list of apparatus given to the Laboratory since its establishment is appended.

During the year, the Library has been increased by various gifts. A letter was issued to a number of Societies and Institutions asking for an exchange of publications. To this a gratifying response was obtained, and, while the Library is still far from a large one, it contains now many important books of reference.

A list of private donors and of institutions with which an exchange has been arranged follows.

The financial position continues to be one of difficulty. As the Committee have already pointed out, the expenditure on internal maintenance, cleaning, heating, and lighting is necessarily very heavy, while the receipts from fees can grow but slowly.

The accounts show—omitting the extraordinary expenditure—a balance of £79 9*s.* 7*d.* on the year, but this is entirely due to the large sum received as subscriptions or donations. The Committee feel that it is desirable to increase the research work being done in the Laboratory. This, however, they consider it will be difficult to do unless they receive considerably more financial support.

During the year the Laboratory has lost by death two prominent supporters.

Sir William Roberts-Austen was a member of the original Treasury Committee on the establishment of the Laboratory. He took a warm interest in its work, and was of special assistance in organizing and developing the Metallurgical Division.

To the late Mr. Spring-Rice, of the Treasury, the Committee are indebted for much valuable advice and assistance. They feel that his early death is a real loss to science.

## DONATIONS TOWARDS THE EQUIPMENT FOR THE LABORATORY.

| | |
|---|---|
| Sir A. Noble, Bart., employed in purchasing, among other accurate instruments, a cathetometer, measuring machine, scales and gauges, a dividing engine, storage battery for thermometric work, materials for electric ovens, standard thermojunctions, a potentiometer, and other accessories for thermometric work | £1000 |
| Lady Galton, for a standard clock in memory of the late Sir Douglas Galton | 100 |
| The Drapers' Company, for a Lorenz apparatus in memory of the late Principal Viriamu Jones | 700 |
| George Beilby, Esq., for a recording pyrometer outfit | 100 |
| J. W. Gifford, Esq., for optical apparatus | 10 |

Dr. Isaac Roberts, a spectroscope and two induction coils.
Messrs. Willans and Robinson, gauge testing apparatus.
J. E. Stead, Esq., metal polishing apparatus.
Messrs. Siemens Bros. & Co., alternate current outfit.
Sir Bernhard Samuelson, Bart., pressure blower.
Messrs. Crompton & Co., potentiometer and accessories.
Dr. Common, an optically worked surface.
Dr. McLeod, gas analysis apparatus, electric clock and chronograph.
Messrs. Hadfield's Steel Foundry Co., materials for the Alloys Research.
Sir Wm. Preece, photometry outfit.
A. P. Trotter, Esq., a photometer.
Electric Power Storage Co., battery of 150 cells.

In addition to these the following donations have been received:—

| | |
|---|---|
| Messrs. Sir W. G. Armstrong, Whitworth & Co. | £1000 |
| Anonymous | 1000 |
| Hon. C. A. Parsons | 100 |

While the following subscriptions, towards the proposed fund of £2500 per annum, have been promised, in most cases for five years.

| | |
|---|---|
| Institution of Civil Engineers | £500 |
| Iron and Steel Institute | 200 |
| Society of Chemical Industry | 100 |
| A. F. Yarrow, Esq. (if the whole be raised) | 100 |
| Eastern Telegraph Co. | 50 |
| Sir E. H. Carbutt, Bart. | 25 |
| The Mercers Company | 21 |
| Messrs. Hadfield's Steel Foundry Co. | 10 10*s.* |
| Messrs. Vickers, Sons, and Maxim | 10 10*s.* |
| Messrs. Boake, Roberts & Co. | 5 |

## LIBRARY.

Exchanges of publications have been arranged with the following Societies and Institutions. In many cases valuable donations of back numbers have been received.*

Royal Society—Transactions.
" —Proceedings.
" —Catalogue of Scientific Papers.
Institution of Civil Engineers—Minutes of Proceedings.
" Electrical Engineers—Journal.
" Mechanical Engineers—Report of Alloys Research Committee.
" " " —Transactions.
" Naval Architects—Transactions.
Iron and Steel Institute—Journal.
Society of Chemical Industry—Journal.
Australasian Association for the Advancement of Science—Report.
Berlin, Königl. Akademie der Wissenschaften—Sitzungsberichte.
British Association for the Advancement of Science—Report.
Comité International des Poids et Mèsures—Travaux et Mémoires.
" " " " —Procès Verbaux.
Institution of Mining and Metallurgy—Transactions.
Manchester Literary and Philosophical Society—Memoirs and Proceedings.
Physical Society of London—Proceedings.
Royal Dublin Society—Scientific Proceedings.
Royal Institution—Proceedings.
Royal Society of Edinburgh—Transactions.
" " " —Proceedings.
'Science Abstracts.'
Smithsonian Institution—Annual Report, &c.
Society of Arts—Journal.
Société d'Encouragement pour L'Industrie Nationale—Contributions.
Tokyo, College of Science, Imperial University—Journal.

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## STATEMENT OF WORK FOR THE YEAR 1903, SUBMITTED TO THE GENERAL BOARD AT THEIR MEETING ON MARCH 20, 1903.

### WORK AT BUSHY HOUSE.

The work planned for the year 1902 will in the main be continued. Up to the present much of the time of the staff has been occupied in setting up and adjusting apparatus.

It is now, however, possible to state in some detail the plan of the various investigations in progress.

With regard to the alloys research, the following scheme of work is proposed :—

* Donations to the Library of the Observatory Department are acknowledged separately, see p. 32.

## Metallurgy Division.

(1.) In his evidence before the Committee, held previous to the establishment of the National Physical Laboratory, Mr. Hadfield gave the first place in practical importance to a determination of the exact melting points of iron and iron-carbon alloys "commencing, say, with pure iron, then steel with 0·1 carbon, the latter element gradually increasing till white iron, containing $3\frac{1}{2}$—4 per cent. carbon, is arrived at."

These melting-point determinations could probably be done alongside of the nickel-iron research described in paragraph (2).

(2.) Mr. Hadfield, in his paper on Nickel Steel, writes :—"It is probable that the special advantage of the use of nickel is due not so much to the properties it confers upon iron in carbonless or nearly carbonless iron alloys, but to its modifying influence upon iron in the presence of carbon, when it probably forms a special carbide of nickel . . . . In the latter case it is hardly probable that high percentages of nickel will be required for ordinary uses to which steel is now applied."

Other authorities, notably M. Osmond, e a somewhat different view of the function of the nickel.

Using 0·15 carbon and varying nickel, Mr. Hadfield got maxima of tensile strength and elastic limit with a minimum of elongation for an alloy of 11·39 per cent. nickel.

It is proposed to make a complete determination of the mechanical and other properties of a series of (*a*) medium and (*b*) high carbon nickel iron alloys of the following composition :—

| Carbon. | | Nickel. | Manganese. | Silicon. | Iron. |
|---|---|---|---|---|---|
| Medium. | High. | Varying amounts | About | Small | |
| 0·45 | 0·9 | from 0·25 per cent. to 15·0 „ | 0·7 | amount. | |

It is also proposed to determine the electrical and magnetic properties of a few low carbon nickel iron alloys in order to investigate the cause of the sudden rise in Barrett's curves (figs. 2 and 9, 'Proceedings of Institution of Electrical Engineers,' 1902).

| Carbon. | Nickel. | Manganese. | Silicon. | Iron. |
|---|---|---|---|---|
| 0·15 | 10 | About 0·7 | Low and constant. | |
| 0·15 | 20 | „ | | |
| 0·15 | 30 | „ | | |

(3.) The iron aluminium and iron silicon alloys could be taken up in connection with their use for transformers. It seems desirable to repeat Barrett's work and extend the number of alloys experimented with—varying not only the aluminium and silicon contents (0—5 per cent.), but also the carbon content (0—0·9 per cent.).

The equipment of the Metallurgical Division is such that it ought to be possible to prepare these alloys at the Laboratory.

The furnaces installed should permit of ingots up to 30 lbs. or 40 lbs. being cast; outside assistance will be required in hammering and rolling the specimens; the tests can readily be conducted on the spot.

This work will be in charge of Dr. Carpenter and Mr. Keeling.

## ENGINEERING DEPARTMENT.

In close connection with the above will come the experiments on fatigue of metals to be conducted in the Engineering Department.

The breaking down in the strength properties of materials, due to repetition of stress, commonly called "fatigue," has been the subject of careful and laborious experiments by Wöhler, Bauschinger and others; but further inquiry seems to be necessary, as little is known about this effect on some of the special kinds of steel which are now becoming of common use in construction. One of the chief objections to the early methods employed is the time duration of the tests. Wöhler's work in this direction extending over many years, for the rapid carrying out of tests on samples of steel in a laboratory, a machine is obviously required which will produce alternations of stress of a very small period. Such a machine is described in a paper by Professor Osborne Reynolds and Mr. Smith (*Phil. Trans. Roy. Soc.*, vol. 199, p. 265). In this the repetition of stress is obtained from the inertia of a harmonically reciprocating mass attached to the specimen, the machine being capable of producing 2,000 alternations per minute.

In such an arrangement the conditions to be fulfilled to ensure the absence of any stresses due to periodic fluctuation of effort in the driving belt are (1) That the mechanism shall be completely balanced, and (2) That the kinetic energy of the moving parts of the mechanism shall be always constant. These conditions were approximately fulfilled in Reynolds's and Smith's machine, which was constructed for the testing of single specimens.

The arrangement adopted in the machine, now being constructed in the Engineering Department at the National Physical Laboratory is a horizontal, four-cranked steam-engine mechanism which enables a perfect balance to be secured, and the kinetic energy of the moving parts to be kept constant with the further advantage that four specimens can be tested simultaneously. The very considerable difficulties as regards the lubrication of the moving parts at the high speed required, 1,200 alternations per minute have necessitated very large bearing surfaces, and this has materially increased the cost of the machine. This increase, however, was felt to be justified on account of the almost insuperable lubrication troubles which Mr. Smith experienced in his research.

The cost of the material, castings, &c., for the machine, will be borne by a grant from the Government Grant fund.

Another research in progress is that on wind pressure.

It is proposed to make the experiments on flat plates and models, the linear dimensions of which will vary from 1 inch to 6 inches, placed in a current of air 24 inches diameter, which has a uniform velocity across its section, and the value of which can be varied between the limits of 5 feet per second, and 30 feet per second. These conditions have been obtained after some difficulty in the apparatus set up in the Engineering Laboratory during the past year.

The assumption on which the experimental work is based is that the wind pressure on actual structures can be calculated from experiments on models with the same degree of accuracy as is obtained in the calculation of the actual resistance of ships from experiments on models, the resistance of which is determined in a hydraulic tank; this is now generally recognised to be the most accurate method.

The first step will naturally be to determine the *distribution* of pressure on both sides of a flat plate, as well as the *resultant* pressure, in view of the marked differences between the observed resultant pressure on flat plates and that calculated from the theory of the pressure distribution on the windward side. Concurrently with this, it is proposed to study the effect of the form and linear dimensions of the plate on the resultant pressure.

The case of flat plates placed behind each other will then be taken, as there seems to be little agreement between the results of previous experiments on the screening effect of the windward plate. At the same time observations will be made on models of lattice girders of the usual type.

It is then proposed to investigate the effect of wind pressure on solids, beginning with cylinders and rectangular prisms, from which the pressure on chimneys may be determined.

The more difficult case of the pressure on inclined surfaces can then be treated—first by using a flat rectangular plate, and then, to approximate to the conditions of a roof, by screening one side. It is hoped that the experiments will throw further light on this very important problem.

Another piece of work to which it is possible some attention might usefully be given is connected with the shape of the cutting edges of tools. A paper on the subject was read recently at the Institution of Mechanical Engineers by Mr. H. F. Donaldson; both the paper and the discussion opened some important questions. Mr. Donaldson had measured the force on the cutting edge under various conditions, it would be of value to determine the work done. This has been done recently by Mr. Yarrow for drills; the extension of his metheds to cutting tools would be of interest.

At present the staff is fully occupied, but the Director hopes to carry the wind-pressure experiments to a conclusion before very long; in this event the problem of the work done by cutting tools might be attacked.

It has also been suggested to the Director that further experiments on the total heat of steam, both saturated and superheated, are required.

During the year, it is probable that the special screw-cutting lathe, referred to in the Committee's Report, will be installed.

## PHYSICS DEPARTMENT.

### Electricity Division.

In the Electrical Laboratory there is still much to be done before the testing of meters, &c., can be undertaken on a commercial scale. When the alternate current plant, kindly given by Messrs. Siemens and Co., has been delivered, it will be necessary to erect it and to instal the outfit of measuring instruments which will be required to utilise it.

The research work in this division will include some investigations into the conditions of hysteresis loss and the non-ageing properties of iron.

Colonel Crompton has recently urged on the Director the immediate necessity of temperature observations to ascertain a safe limit for temperature in insulations used in dynamos, motors, and transformers, and also the consideration of using alternating test voltages of different frequencies for testing the dielectric strength of insulators. These

investigations received the approval of the Electricity Sub-Committee, and the Director hopes to undertake them.

A reference to the test pamphlet will show that the variety of tests undertaken is considerable, and the demands are sufficient to keep Mr. Campbell and Mr. Melsom fully occupied.

Mr. Smith, who has charge of the experiments connected with the fundamental electrical units, hopes shortly to complete and test the mercury resistance standards now in hand. When this is done it may be desirable to set up additional similar tubes in order to utilise to the best advantage the experience already gained.

On completion of this work a revision of the standards of resistance will be possible.

Manganin resistance coils have been used freely in the Laboratory; the results of some investigations recently published by Professor Callendar seems to indicate a kind of hysteris effect under changing temperature. No definite results in the matter have yet been obtained, but it is desirable to investigate the question.

The intercomparison of various types of standard cells will be continued specially with a view to preparing a paste capable of reproduction at any time.

Arrangements have been made with Mr. Harrison, who was the late Professor Viriamu Jones's mechanical assistant during his work on the Ohm, and the Director hopes as a result to have shortly for consideration a set of drawings of a Lorenz apparatus, embodying Principal Jones's latest views. In discussing these he will have the valuable assistance of Professor Ayrton.

## Thermometry Division.

In this division Dr. Harker hopes to carry through his comparison between the platinum resistance thermometer and the gas thermometer up to 1,000 or 1,100° C., and to design platinum thermometers for a still higher temperature.

He will then endeavour to connect our gas scale directly with that at the Reichsanstalt by means of the thermo-couples studied for us through the kindness of President Kohlrausch, by Messrs. Holborn and Day.

Another task is the comparison of the Kew Scale of temperature with the hydrogen scale of the Bureau International through the intermediary of some standard Tonnelot thermometers.

A knowledge of the change of temperature with pressure for sulphur vapour near its boiling point is needed in platinum thermometry; the number now used is very uncertain and a redetermination would be a simple matter.

The construction of some high-range mercury standards going up to 550° C. to assist in the test work is also required and is now in hand, while Mr. Hugo is engaged in studying the properties of some thermometers suitable for high-range work, made out of a new glass manufactured by Messrs. Powell and Co. for the purpose.

Another problem for which as yet no provision has been made, but which calls for solution is the determination of the heat of combination, specific heat, and latent heat of new fuels such as petrol, gasoline, &c.

### Metrology Division.

In the Metrology Division the following pieces of work will be undertaken by Mr. Keeling :—

(1.) Installation of apparatus for the measurement of co-efficients of expansion at high temperatures, and determination of this expansion for various substances. For this purpose an electrically-heated oven, which is now being constructed, will be used.

(2.) The calibration of a yard measure for use in the standard screw-cutting lathe.

(3.) The determination of the co-efficient of dilatation for case-hardened nickel steel and for tool steel.

### Optics and Photometry Division.

The first work will be the establishment of the Photometric Laboratory, for which the equipment is being provided by Sir Wm. Preece.

In connection with the Optical Society, the Director hopes also to carry out some investigations into the optical properties and, in particular, the absorption of certain kinds of glass; while he would be glad, if funds permit, to modify the arrangements for the testing of photographic and other lenses.

## OBSERVATORY DEPARTMENT.

The testing of apparatus described in the Annual Report of this Department will be continued; together with the various meteorological and magnetic observations so far as electric trams permit.

The Superintendent, Dr. Chree, hopes to be able to reduce a number of the past magnetic observations, full details of which are kept. Various problems of interest might be elucidated if this were done.

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As to the testing work, particulars are contained in the test pamphlet for the Observatory Department, the Physics Department, and the Engineering Department respectively. The scope of this work will be increased as opportunity offers.

These pamphlets can be had on application.

## REPORT OF THE DIRECTOR FOR THE YEAR ENDING DECEMBER 31, 1902.

In presenting his first Report since the opening of the Laboratory, the Director has thought it best to give a somewhat full account of the equipment of each division.

The main part of the work for the year has been the installation and adjustment of the apparatus, and the Director welcomes the opportunity of thanking all members of the Staff for their co-operation and assistance.

Test pamphlets both of the Physics and the Engineering Departments have been issued, and it will be gathered from them and from the detailed Reports that follow, that the Laboratory is now ready to undertake a large variety of tests.

In the Engineering Department and in the divisions of Thermometry, Metallography, Chemistry (so far as it bears on Physical work) and Metrology of the Physics Department, the equipment is very satisfactory.

In the Electricity Division the arrangement for tests on capacity and inductance, standards, and for the ordinary measurement of current, resistance, and E.M.F. to a high degree of accuracy, are complete.

The testing of ordinary meters of all kinds for direct current up to 250 ampères and 250 volts can also be undertaken. The Director hopes shortly to extend the arrangements for this work very considerably, so as to admit of a large number of instruments being tested simultaneously on a commercial scale.

The machinery given by Messrs. Siemens Bros., and Co., when it is in position, will permit of such work being extended to alternate current and polyphase instruments, for which there is considerable demand already; to do this satisfactorily, further expenditure on measuring apparatus and equipment will be required.

Apparatus for the determination of permeability curves and for the measurement of hysteresis in iron is in position and is working well.

In the Optics Division very little has been done beyond the erection of the Kew photographic lens testing apparatus. An assistant to take charge of this Division is urgently needed. There have been numerous demands for photometric work, and Sir William Preece's gift announced at the end of the year will supply the apparatus required. The Optical Society have asked for assistance with regard to the optical properties of certain glasses, and have voted a contribution to the expenditure involved, while other friends also have come forward in support of the optical work.

The Director hopes it may be possible to start this division on a satisfactory footing early in the present year.

### PHYSICS DEPARTMENT.

#### I. ELECTRICITY. (*Mr. Campbell and Mr. Melsom.*)

##### A. *General Measurements.*

In the Electricity Division the work has consisted chiefly in the installation of apparatus some of which has been wholly or partly constructed in the Laboratory. In the earlier part of the year, numerous tests were made of the lighting and experi-

mental wiring, insulation resistance and voltage drop being observed. The running of additional leads (for the workshop and compressor motors and the arc lamp for photo-micrography) was arranged, and the work superintended.

*Apparatus.*—(1.) The two air condensers of the British Association have been set up, together with the apparatus for measuring capacities in terms of resistance and time, including motor-driven commutator, stroboscopic disc and tuning fork, galvanometer and scale, and resistances.

In connection with the air condensers, highly-insulated leads have also been run, and a special key has been constructed for comparisons of capacity by the method of mixtures.

(2.) For the measurement of magnetic flux and allied quantities, particularly in relation to iron and steel, a highly sensitive moving-coil ballistic galvanometer by the Cambridge Scientific Instrument Company has been set up, its calibration being obtained by means of a mutual inductance standard, tested by Carey Foster's method against the air condensers.

For measuring magnetising currents (and H) a dead-beat galvanometer has been set up, and a set of resistances have been constructed as shunts with ranges from 0·1 up to 20 ampères.

Rheostats and switches have also been mounted to give the suitable variation of current requisite for carrying iron through the usual magnetic cycles. A double marble bobbin is being wound as a secondary standard of mutual inductance.

(3.) A Wheatstone Bridge Resistance Box by Wolff has been set up with galvanometer lamp and scale.

(4.) A Kelvin Current Balance (to 100 ampères) has been installed with suitable switch, leads, and terminals.

(5.) A special Kelvin Electrostatic Voltmeter (reading up to 160 volts) has been mounted with a long and open scale.

For use with this, a large potential dividing box has been constructed with a total resistance of 100,000 ohms. This serves two purposes (*a*) calibration of the voltmeter scale by aid of a standard cell, (*b*) extension of the range to 1,000 volts.

(6.) For the measurement of low resistances a Differential Galvanometer, as employed by Mr. Crawley, has been arranged in a double-walled and lagged box, and the necessary added resistances and terminals for it have been made.

In addition to these the following pieces of apparatus are in position:

(7.) Wolff Thomson Double Bridge.

(8.) Wolff Potentiometer.

(9.) Siemens and Halske Millivoltmeter, with shunts and added resistances to vary the range.

(10.) Weston Millivoltmeter, with shunts and added resistances.

(11.) Ewing Permeability Bridge, with apparatus for testing the standard bars.

(12.) Large 6-dial Resistance Bridge.

(13.) Standard low resistances, constructed in the Laboratory, including one of 0·01 ohm to carry 100 ampères.

(14.) Carpentier 1 m.f.d. Condenser of Silvered Mica.

(15.) A special form of Bridge with galvanometer shunts, &c., for use in adjusting resistances.

(16.) Evershed Testing Set.

*Tests.*—Magnetic ageing tests have been made on several samples of sheet iron by heating them for several weeks to moderate temperatures (60° or 100° C.). In one specimen treated thus the hysteresis loss was only slightly increased, whilst in others very large increase was observed.

Magnetic tests, made with a view to finding the influence of previous history upon magnetic properties, showed the necessity of thorough demagnetization before every test.

A set of oil-cooled low resistances (0·1, 0·01, and 0·001 ohm) were tested by several methods (Potentiometer, Thomson Bridge, &c.), and very satisfactory agreement was obtained between these measurements and others made at the German Reichsanstalt.

In addition to regular tests on the Standard Air Condensers, numerous tests have also been made on mica condensers, and interesting results have been obtained with regard to absorption and variation of frequency of charge and discharge.

In carrying out some of these tests an important point was noticed, viz., that, when an ordinary galvanometer is used in a null method with intermittent current, it is very important that the needles in their zero position should be in a plane perpendicular to the axis of the deflecting coils. If this condition is not attended to considerable errors may arise owing to magnetism induced in the needles by the current.

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

(*a.*) Apparatus.

The coils of the British Association, together with the British Association Bridge and accessories, were installed at Bushy House during the early part of the year. Certain portions of the bridge have since been re-made, and oil-baths obtained to facilitate the measurement of temperature co-efficients. The room which the coils occupy has been fitted with a silver ammonium-chloride thermostat, the regulation is very good, so that a constant temperature is assured.

For the comparison of resistances lower in value than the unit and greater than 10 units, a new bridge has been constructed. The arrangements in this are such as to enable resistances varying in value from 0·0001 to 10·000 ohms to be tested.

For test work on standard cells, a Wolff Potentiometer has been set up. Between 40 and 50 cells of various types have been constructed, the majority of these being utilised in Research work. For general use in the Laboratory a number of Weston cells have been prepared.

The Watson magnetographs were erected in February, and have been utilised on the term days of the Antarctic Expedition.

(*b.*) Important Tests and Research Work.

*The B.A. Standards.*—Inter-comparisons of the platinum-silver coils of the British Association have been extensively made during the year. In connection with this work, a very full report on the whole of the unit coils has been prepared. The report deals with the past and present values of the coils, and their temperature co-efficients over a moderate range.

Tests between Wolff standards—certificated by the Reichsanstalt—and the British Association coils have enabled the difference to be estimated between the Laboratory standards and the International ohm. Three of these Wolff coils have recently been

despatched to the Reichsanstalt for further comparison, so that on their return, the difference may be estimated with greater precision. Comparisons are also being made between the Board of Trade standards and those of the Laboratory.

The manganin coils of the Association, from 1 to 1000 ohms, have been determined in terms of the unit coil.

*Mercury Standards of Resistance.*—These were delayed in the early part of the year owing to the non-standardisation of the Laboratory weights. This difficulty is now removed, and at the present time 6 tubes—3 of Jena glass 16′′′, and 3 of "Verre dur" glass are in a near state of completion.

*Standard Cells.*—There are many points of interest in connection with these, even though the cells are not sufficiently aged, nor the tests complete, for the data to be published. Originally, the intention was to make up a number of Clark cells with two different samples of mercurous sulphate. The difference in E.M.F., however, was so great that an investigation was essential. The plan adopted was to isolate possible disturbing factors in turn, and so determine their contributions to the difference observed. The tests proved decisively that one of the samples of mercurous sulphate was greatly at fault. The behaviour of the faulty cells is still under observation. A third sample of the sulphate, prepared in the Laboratory by Dr. Carpenter, is also being tested, and promises well. The chemical treatment of all the samples being similar, rather indicates that something more than a chemical test should be applied to the sulphate used for standard cells. It is hoped eventually to specify the mode of manufacture of the substance to be used.

An investigation of the mercury, zinc, and zinc sulphate employed has also been conducted. For these special tests, different types of cell were made up, with satisfactory results. Measurements of the difference—if any—between the H and tube form of cells, are in progress.

The Weston cells constructed are, so far, similar in every respect, and are very consistent.

*Magnetographs.*—The instruments designed by Mr. Watson have been used only on the term days of the Antarctic Expedition.

A special instrument of Mr. Watson's design has been under examination during the latter part of the year. The magnet system is suspended by a horizontal quartz fibre, and swings in a plane at right angles to the meridian. Variations in the vertical force are measured. The compensation for temperature effects is very similar to that of Mr. Watson's first instrument, except that the varying rigidity of the quartz now plays a part. The tests showed the instrument to be very sensitive, the photographic records indicating the electric traction effects well. Originally it had a considerable temperature co-efficient, but this was reduced to a negligible amount, the instrument in its final condition behaving very well.

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

(*a.*) *Apparatus.*—The chief work of the department has been the installation and study of the different standards of temperature, and the apparatus required for the comparison with those of the various kinds of instruments sent for test. In the following list will be found the principal pieces of apparatus constructed in the Laboratory during the year 1902:—

Two large electric furnaces for the gas thermometer reading up to 1200° C.
One large electric furnace for thermo-junction comparisons.
Three smaller electric furnaces for miscellaneous work.
One large thermometer comparison bath for nitrates of potash and soda, with fittings for inter-comparison of mercury thermometers and for gas-platinum comparisons, between 220° and 650°.
One oil bath for range 50° to 220°.
One electrically-heated comparison bath for observations in water.
Several smaller baths for fixed points and apparatus for special ranges.
Pressure-co-efficient apparatus with heating arrangement.
Ten platinum thermometers.
Three thermo-junctions platinum-platinum-iridium and platinum-platinum-rhodium.
One direct-reading potentiometer for thermo-junction comparisons to 20,000 microvolts.
One very sensitive low-resistance galvanometer for thermal work.

The gas thermometer presented by Sir Andrew Noble, with all its accessories, which had been used at Kew for comparisons to 200° C., has been re-erected in the position made for it, and comparisons have been made up to nearly 1000° C. in an electric furnace with a standard platinum thermometer. These experiments are still in progress.

Six new platinum thermometers of various patterns have been constructed of the wire purchased by the British Association Committee. The investigation of these is still in progress.

A potentiometer of original design has been specially constructed and calibrated for work of a high accuracy with thermo-junctions, and by means of this, a few comparisons have been made in the electric furnace between one of the platinum-rhodium junctions, standardised by Dr. Holborn at the Reichsanstalt, and some other specimens of platinum-iridium and platinum-rhodium wire, which will serve as working thermometers.

The liquid-air plant—Hampson liquefier and Brotherhood compressor—has been set up and used during the year.

The original gas-analysis apparatus, presented by Professor McLeod, has been repaired and erected in a room, which has been specially fitted for it, near the Chemical Laboratory, where also a large Sprengel pump and accessory water-pump have been installed in permanent form.

(*b.*) *Tests and Researches.*—The attention of the Laboratory having been called to the discrepancies between the values obtained by different observers for the specific heat of iron at high temperatures, some experiments have been made on this question at temperatures up to 1000° C. Two specially pure specimens of known composition were used, the heating was done in a small closed electric furnace, and the temperature, when steady, measured by a platinum thermometer. The results differed materially from the numbers most generally accepted—those of Pionchon.

It was found, however, that if Pionchon's temperature-scale, which depended on the Violle calorimetric method, were revised so as to bring the melting-point of silver as obtained by him—907° C.—into accordance with more modern measurements—962° C.—the two sets of results came into as close agreement as could be expected from specimens from different sources. The results of this work will shortly be published.

A number of tests have been made on a series of thermometers of special glass, manufactured by Messrs. Powell and Sons. These show, after proper treatment, a very slight secular rise of zero and a remarkably small temporary depression on heating. The experiments on the subject are still in progress, and a number of thermometers, made to a special design for the purposes of the test, have been received lately from Mr. J. J. Hicks, whose assistance has been of great value.

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

In the Metrological Division, the following pieces of apparatus have been installed:—

(1.) A comparator, for comparing line measures, constructed by the Société Genevoise pour la construction d'Instruments de Physique.
(2.) A measuring machine for end measures, with a capacity of about 48 inches or 1200 mm., constructed by the Pratt and Whitney Co.
(3.) Two measuring machines, by Sir W. G. Armstrong, Whitworth & Co., Limited.
(4.) A dividing engine, with a capacity of 1 metre, by the Société Genevoise.

The screw of this machine has been calibrated against the Laboratory standard metre.

*Tests.*—The co-efficients of expansion of a number of specimens of steel and brass have been measured in the comparator. Amongst these have been a number of nickel-steel rods with a low co-efficient—in some cases about one-tenth that of ordinary steels.

Apparatus has also been installed for the testing and calibration of measuring vessels used in chemical laboratories and also of weights.

## IV. Chemistry. (*Dr. Carpenter.*)

*Apparatus.*—The large Chemical Laboratory is equipped for all ordinary qualitative and quantitative work. A stirring apparatus, capable of holding six vessels, which can be heated, if desired, has been constructed in the Engineering Laboratory and set up here. It is driven by a $\frac{1}{20}$-H.P. Lundell motor.

The Gas Analysis Room contains—

(*a.*) The original gas analysis apparatus of Professor McLeod, and presented by him.
(*b.*) A Cossor 3-fall Sprengel pump, fitted with McLeod gauge.
(*c.*) Apparatus for the purification and distillation of mercury.

The room, in which the testing of glass-measuring vessels is carried on, is fitted with the necessary balances. A sand-blast apparatus for marking those vessels that have passed the Laboratory test, with the Laboratory stamp, has been installed near this room.

*Tests.*—A series of 20 pipettes with 50 stem divisions above the bulb, of sizes varying between 1 and 5 c.c., have been tested; and experiments were undertaken with a view to finding out the most suitable form of pipette for delivering a 75 per cent. solution of glycerin in physiological saline solution.

A complete series of microscopical and chemical tests of five first-class printing

papers have been carried out, while the necessary analysis of the tool steel, the tests on which are described in the next section were made in the Laboratory.

Experiments have also been conducted on the preparation of pure mercurous sulphate for the Clark cells.

## V. Metallography. (*Dr. Carpenter.*)

*Apparatus.*—In the large laboratory is fitted a Crompton 1½-H.P. motor which drives

(i.) A hack saw for cutting sections of metals.
(ii.) A Crowell rotary air-blower used for various concentric jet gas-furnaces.
(iii.) A vertical drill.

The laboratory contains—

Two wind furnaces (with coke as fuel).

A large closed gas muffle furnace (size of muffle 18″ by 14″ by 8″) fitted with a gas-governor.

Two concentric jet crucible furnaces, capable of holding 6 and 12 lbs. of metal respectively.

One small compressed oxygen injector furnace.

A large petroleum spray crucible furnace, capable of making a 60-lb. metal ingot, has been placed in a special outhouse, designed for the purpose with arrangements for handling the crucible and teeming the metal.

In the large Laboratory has been placed a thermo-electric pyrometer, suitable for research work, constructed according to the designs of Roberts-Austen and Stansfield. This piece of apparatus was presented by Mr. G. Beilby.

The outfit for the microscopic examination of metals is complete. It contains, in addition to the above—

(*a.*) A polishing apparatus, in which three pieces of metal can be polished simultaneously, designed for and presented to the Laboratory by Mr. J. E. Stead.

(*b.*) A complete Zeiss photomicrographic outfit for metals. The source of light used is a 30 ampère, 45-volt arc lamp, and magnified images of metal surfaces up to 10,000 diameters, can be obtained.

*Tests.*—A photomicrographic examination of a tool steel—

(*a*) Cast, (*b*) hammered, (*c*) rolled, and (*d*) hardened.

A photomicrographic comparison of six steel rods, drawn from one bar, as bearing on their magnetic qualities and temperature co-efficients.

A photomicrographic investigation of two alloys, aluminium-iron, and silicon iron, made by Hadfield and examined by Barrett, and stated by him to have a higher permeability than pure Swedish charcoal iron.

## VI. Optics.

This division of the Physics Department remains to be organised.

The Director trusts he may be in a position to take it in hand at once.

## VII. Instrument Shops.

The main shop has been fitted with the necessary lathes and other tools—including a small milling machine—for the construction and repair of apparatus, the whole being driven by a Crompton Motor, and has proved most valuable. Work can be rapidly and efficiently carried out on the spot by F. H. Murfitt, the instrument maker in charge.

In addition, small workshops have been attached to the Electricity and Thermometry Divisions, which the Assistants find of great service.

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## REPORT ON THE ENGINEERING DEPARTMENT FOR THE YEAR ENDING DECEMBER 31, 1902, MADE BY THE SUPERINTENDENT TO THE DIRECTOR.

*Machinery and Apparatus.*—The chief work upon which the Staff of the Department has been engaged during the year has been the equipment of the Engineering Workshop and Laboratory.

The machines which have been put down and are now in use are:—

An 8-inch Muir lathe.
A 6-inch Whitworth lathe.
A 7-inch lathe from A. Herbert.
A wood lathe.
A Guest universal grinder.
A shaping machine.
A drilling machine.
A metal saw and emery wheels.
A Roots blower for the forge and furnaces.

The erection of these machines, with their counter shafts and striking gear, together with the work entailed in the erection of the 10-ton testing machine, and the 2-ton traveller for the workshop has been carried out by the workshop staff.

For the Physical Laboratory the work done by the workshop staff has included:—

The erection of the motor and compressor for the liquid air apparatus and the sand blast machine.

The equipment of the Metallurgical Laboratory with countershafting for motor and the erecting of the blower, drilling machine and saw.

Alterations to a 5-inch lathe.

The plant for the supply of light and power has worked satisfactorily throughout the year, all necessary repairs having been carried out in the department. The total electrical output for the year has been about 10,000 kilowatt hours.

*Tests and Researches.*—The standard low-pressure gauges have been compared with the mercury column and tables of corrections made.

A new form of dead weight pressure gauge for high pressures has been designed and made in the workshop, and is now available for the calibration of high-pressure

gauges up to a maximum reading of 8 tons per square inch. This gauge is fully described in *Engineering*, January 2nd, 1902.*

The arrangement for making experiments on the distribution of wind pressure on surfaces has been set up in the Laboratory and is found to work satisfactorily. In this apparatus a 30-inch motor-driven Blackman fan is made to produce a down draught in a channel 24 inches diameter. There are special features for producing a uniform velocity of flow across the section, and the speed can be varied from 5 feet to 30 feet a second. Preliminary experiments have been made on the distribution of pressure on flat plates and consistent results obtained, so that the research is in a fairly advanced state. As considerable difficulty has been encountered in procuring an air-meter which could be used as a means of determining the absolute velocity of the air, it has been found necessary to attempt to design, and make one which it is hoped will enable the velocity of the wind to be measured with sufficient accuracy.

The testing machine for producing reversals of stress in iron and steel specimens, which is being made in the workshop, is approaching completion owing to the addition of another fitter to the Staff of the Department which has enabled work on the machine to be resumed, and it is hoped that it will be completed early in the coming year.

The experimental boiler for experiments with steam pressure up to 400 lbs. per square inch has been erected and tested.

The chief tests, which have been carried out in the department, have been a series of tests on the properties of a new steel submitted by Mr. F. B. Behr.

Specimens were prepared from a sample ingot supplied, and tensiles and hardness tests made on the material of the ingot, and also on a bar forged from the ingot. Cutting tools were also prepared and tried in the lathe at varying rates of cutting.

A series of pressure tests have also been made on deep-sea thermometers for which special cylinder has been made and attached to the high-pressure gauge testing machine.

T. E. STANTON,
*Superintendent.*

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* Fuller details of this are given in the Statement of Work for 1903.

## REPORT ON THE OBSERVATORY DEPARTMENT FOR THE YEAR ENDING DECEMBER 31, 1902, 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 1902 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 connexion with any of the departments.
V. Verification of instruments.
VI. Rating of Watches and Chronometers.
VII. Miscellaneous.

### I. Magnetic Observations.

In January from the 23rd to the 29th the magnetograph clock was dismounted and sent to Mr. P. Adie to have an extra wheel and pinion fitted, in order to obtain quick running curves on the days selected during the period of antarctic research in terrestrial magnetism. With this exception the instruments have been in constant operation throughout the year.

The usual determination of the scale values 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, 1902, for 1 cm. $\delta H$ = 0·00051 C.G.S. unit.
Balance, January, 1902, for 1 cm. $\delta V$ = 0·00050 C.G.S. unit.

On June 2 and again on November 21, the dots of light of the Vertical Force trace had become too wide apart for safe registration, and in consequence their position was readjusted.

The curves during the past year have been quite free from any large magnetic changes; the principal movements that were recorded took place on the following days:—

January 15–16; March 24–25; April 11; May 9; July 24; August 21, and November 24.

The hourly means and diurnal inequalities of the Declination and Horizontal Force for 1902 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 increased disturbance of the Vertical Force produced by the extension of electric trams during the latter part of the year, 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 in previous Reports.

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° 44′·8. |
| | Mean Horizontal Force ..... | 0·18475 C.G.S. unit. |
| From absolute observations, corrected | Mean Inclination ..... | 67° 8′·0. |
| | Mean Vertical Force ..... | 0·43809 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.

Mr. R. C. Mossman, of the Scottish Antarctic Expedition visited the Observatory from July 15 to 31, and went through a course of instruction in the taking of magnetic observations.

A Dip Circle by Barrow No. 24, with four needles and weights for total force observations, together with a pair of bar magnets and a tripod stand, were lent to Mr. Bruce, the leader of the Scottish Antarctic Expedition.

In April the Falmouth Vertical Force Magnet with its fittings and slate slab were sent to the observatory by Mr. Kitto, in order that experiments might be carried out with a view to remedying one or two important defects, the chief one being the largeness of the temperature coefficient, and the erratic behaviour of the magnet during changes of temperature.

It was eventually found that through want of symmetry in its supports the mirror attached to the magnet twisted with change of temperature, the movement thereby caused in the spot of light being much larger than that due to the direct temperature effect on the magnet. This defect was removed and various structural changes made by Mr. Adie, in hopes of improving the general action. The magnet was taken back to Falmouth and restarted there by Mr. Baker when inspecting the Observatory.

## 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, some special cloud observations have been made in connection with the International scheme of balloon ascents. Extra observations have also been made, when possible, of "upper clouds," in connection with the Norwegian Polar investigations, being carried out by Professor Birkeland.

*Bright Sunshine.*—As explained in last year's annual Report, 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 1900, 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.

*Electrograph.*—This instrument worked generally in a satisfactory manner during the year. In July, all parts of the instrument were thoroughly cleaned, and in December the "Mascart" insulators were dismounted, cleaned, fresh acid added, and the ebonite supports coated with paraffin wax. Small alterations have been made to the down pipe, to improve the insulation.

Scale value determinations were made on April 7, July 18, and December 12; and the potential of the chloride of silver battery, has been tested fortnightly. Forty cells have been employed, giving about 30 volts.

A series of curves—usually 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.

*Inspections.*—In compliance with the request of the Meteorological Council, the following Observatories and Anemograph Stations have been visited and inspected:—Glasgow, Aberdeen, Deerness (Orkney), Fort William, and Falmouth, by Mr. Baker; and Radcliffe Observatory (Oxford), Stonyhurst, Armagh, Dublin, Kingstown, Valencia, and Yarmouth, 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 on the trace are given in Table I, Appendix III.

The largest disturbances recorded took place on September 23, when the maximum amplitude exceeded 17 mm., on September 22, when the maximum was 8·5 mm., and on April 19, when the maximum amplitude was 7 mm.

Early in May, a request was received from Professor Milne, that the adjustments should be so altered, that a 4° turn of the test screw should cause a movement of 14 mm. of the outer end of the boom. This was done with a view to making the Seismographs at Shide, Bidston, Edinburgh, and Kew equal in sensibility to tilting.

This change was made on May 12 and 13, since which date the period of the pendulum has varied between 18 and 19 seconds, and the scale can be taken as 1 mm. amplitude = a tilt of 0″·54 of arc.

Before the change on May 12 the scale value was 1 mm. = 0″·8 of arc. Owing to overlapping of the trace it is very difficult to accurately measure swings exceeding 17 mm.

A detailed list of the movements recorded from January 1 to December 31, 1902, has been made, 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.

At the request of the Meteorological Council, extra observations of surface fog and darkness have been made in connection with the investigation of London fogs, undertaken by the Office and the London County Council.

*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, have been continued, and the observations have been taken on 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. These throw considerable light upon the action of the self-recording electrometer, and have been made use of in constructing Table V, Appendix II.

Since January 1, a new fixed stand has been used, instead of the older station.

The new stand consists of a stout brass tube, down which a brass rod slides. The rod carries a small table just large enough to take the portable electrometer, furnished with guard pins to prevent the instrument being accidentally knocked over. The rod can be clamped at any point, so that even in case of heavy snow, the distance between the electrometer and the surface beneath, could be kept constant.

A series of observations were made on the new and on the old stone stand to establish a connection between the results obtained at the two stations. The new stand has also been used for observing the potential at three different heights, viz., 125 cm., 150 cm., and 175 cm. above the ground.

Observations on the loss of positive and negative electrical charges have been made with a "dissipation apparatus" of Elster and Geitel's pattern. Usually the loss of charge has been very slow, and the apparent differences in the state of insulation of the apparatus before and after the proper dissipation experiment have introduced an undesirably large element of uncertainty.

The results are meantime withheld pending further experience.

*Magnets.*—Some experiments have been made with magnet systems devised by

Dr. Watson for his type of magnetograph. Attention has principally been given to the question of the temperature coefficient.

*Inertia Bars.*—A series of inertia bars have been obtained from the chief English makers of magnetometers. After careful measurement, these have been swung with the collimator magnet of the Kew standard magnetometer, with a view to determining its true moment of inertia, and arriving at an estimate of the probable error in determinations of this kind. Experiments are still in progress.

*Sunshine Recorder.*—It having been observed that the card in the present standard-pattern of the Campbell-Stokes sunshine recorder is situated well inside the focus of the spherical lens, experiments have been made as to whether this is the best arrangement. Messrs. Chance Brothers, on being applied to, constructed and lent for experiment a sphere of the standard glass, of less than the normal dimensions, and a series of observations have been taken with this, employing a bowl of normal dimensions, kindly lent by the Meteorological Office. Further experiments are being made.

## V. Verification of Instruments, exclusive of Watches and Chronometers.

The number of instruments rejected in 1901 and 1902 on account of excessive error, or for other reasons, was as follows:—

| | 1901. | 1902. |
|---|---|---|
| Thermometers, clinical | 163 | 109 |
| „ ordinary meteorological | 114 | 55 |
| Sextants | 155 | 106 |
| Telescopes | 139 | 144 |
| Binoculars | 18 | 9 |
| Various | 78 | 185 |

There were at the end of the year in the Observatory, undergoing verification, 12 Barometers, 1105 Thermometers, 50 Hydrometers, 11 Sextants, 29 Telescopes, 30 Binoculars, 1 Inclinometer, 1 Unifilar Magnetometer, Various 18.

The subjoined is a list of the instruments examined in the year 1902, compared with a corresponding return for 1901 :—

| | Number tested in the year ending December 31. | |
|---|---|---|
| | 1901. | 1902. |
| Air-meters | 13 | 10 |
| Anemometers | 14 | 8 |
| Aneroids | 222 | 128 |
| Artificial horizons | 10 | 17 |
| Barometers, Marine | 111 | 134 |
| „ Standard | 65 | 109 |
| „ Station | 29 | 36 |
| Binoculars | 669 | 924 |
| Compasses | 11 | 16 |
| Declinometers | — | 1 |
| Deflectors | 29 | 4 |
| Hydrometers | 120 | 403 |
| Hypsometers | 2 | 1 |
| Inclinometers | 15 | 11 |
| *Photographic Lenses | 9 | 6 |
| Levels | 2 | 8 |
| Magnets | 3 | 8 |
| Milk-test apparatus | 527 | 159 |
| Rain Gauges | 19 | 19 |
| Rain-measuring Glasses | 33 | 34 |
| Sextants | 938 | 769 |
| Sunshine Recorders | — | 12 |
| Telescopes | 2,029 | 1,678 |
| Theodolites | 11 | 24 |
| Thermometers, Avitreous or Immisch's | 6 | — |
| „ Clinical | 20,389 | 22,912 |
| „ Deep sea | 112 | 44 |
| „ High Range | 62 | 81 |
| „ Hypsometric | 54 | 10 |
| „ Low Range | 72 | 124 |
| „ Meteorological | 3,077 | 2,733 |
| „ *Electrical Resistance | 3 | — |
| „ Solar radiation | 12 | 57 |
| „ Standard | 111 | 101 |
| Unifilars | 15 | 14 |
| Total | 28,794 | 30,595 |

Duplicate copies of corrections have been supplied in 87 cases.

* The testing apparatus has been transferred to Bushy House in the course of the year.

## VI. Rating of Watches and Chronometers.

The number of watches sent for trial this year shows a considerable increase over the number sent in 1901, the total entries being 530, as compared with 363 in the preceding year.

The "especially good" class A certificate was obtained by 119 movements. There have been two or three exceptionally fine performances, and the average standard, though somewhat below that of last year, is still highly satisfactory.

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. |
|---|---|---|---|---|---|---|---|---|
| Percentage "especially good" | 16·6 | 30·5 | 28·0 | 22·1 | 26·6 | 35·4 | 36·5 | 31·6 |

The 530 watches received were entered for trial as below :—

For class A, 474; class B, 28; for the subsidiary trial, 28. Of these, 377 were awarded class A certificates, 21 obtained class B certificates, 24 passed the subsidiary test, and 108 failed from various causes to gain any certificate.

In Appendix IV will be found a table giving the results of trial of the 52 watches which gained the highest number of marks during the year. The highest place was taken by H. Golay, Clerkenwell, London, with the keyless going-barrel annular tourbillon resilient lever watch, No. 7,556, which obtained 92·7 marks out of a maximum of 100.

This is the highest number of marks yet obtained here by any watch, English or foreign.

*Marine Chronometers.*—During the year, 32 chronometers have been entered for the Kew A trial and 1 for the B trial. Of these, 23 gained A certificates, 1 gained a B certificate, and 9 failed.

The demand for the B certificate has been very small indeed for some years past, and the question of the retention of the class B trial requires consideration.

A minute clock, with lever escapement, to be used in the photometric testing of coal gas was examined for Messrs. Alex. Wright and Co., at temperatures of 55°, 60°, and 65° F.

## VII. Miscellaneous.

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

For St. Petersburg, two Robinson cup anemographs.

For Christchurch, New Zealand, two Kelvin portable electrometers and fuses, a tank and insulators for electrograph, an Exner electrometer, a "dissipation" apparatus, and a tripod stand.

For Mauritius, a Dines pressure tube anemograph, a Mason's hygrometer, ordinary maximum and minimum thermometers.

For Melbourne, a Dines pressure tube anemograph, a tide gauge, a siphon barometer, a hypsometer, two dip needles and five thermometers.

*Paper.*—Prepared photographic paper has been supplied to the Observatories at Hong Kong, Mauritius, Lisbon, Stonyhurst, 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, Mauritius, and St. Petersburg; and Seismograph rolls to Mauritius.

*Photographic Room.*—In the autumn it was found that part of the woodwork in the photographic room had been attacked by dry rot. H. M. Office of Works on having their attention called to the fact, had the whole room cleared out and the walls distempered.

*Magnetograph Quick Runs.*—In accordance with the scheme agreed on with the British and German Antarctic Expeditions quick runs were taken with the magnetographs on the 1st and 15th of each month in the early part of the year. In the latter part of the year the electric tram disturbances rendered Kew unsuitable for work of this kind, and the observations were taken instead at Bushy House, with magnetographs kindly lent by Dr. W. Watson.

*Discussion of Kew Magnetic Data.*—The Superintendent has been engaged in a discussion of the magnetic records obtained on the selected *quiet* days of the 11-year period 1890 to 1900. This is still unfinished, but a preliminary note dealing with some prominent features of the relationship between sun spot frequency and the amplitudes of the duirnal inequalities of the several magnetic elements was communicated to the Royal Society in December.

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

20 Scientific Societies and Institutions of Great Britain and Ireland,
112 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 |
| Mr. P. Baracchi (Melbourne University). | 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 |

## 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.*—M. Baker, 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.
*Junior Assistants*—B. F. E. Keeling, B.A.; F. E. Smith, A.R.C.S.; F. W. Skirrow, M.Sc.
*Instrument Maker*—F. H. Murfitt.
*Carpenter*—W. Poulter.
*Porter*—R. Murrison, with wife as housekeeper.
*Laboratory Boys*—J. A. Gibb, W. Powell, C. H. Unsted.

*Engineering Department.*

*Superintendent*—T. E. Stanton, D.Sc.
*Junior Assistants*—C. Jakeman, S. W. Melsom.
*Mechanics*—J. Taylerson, C. Hellary.
*Electrician*—P. Rivers.
*Engineer*—H. Tunwell.
*Laboratory Boy*—W. Poulter.

*Office.*

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

*Garden, etc.*

J. W. Marshall, S. Hayes, and a boy.

R. T. GLAZEBROOK,
*Director.*

# APPENDIX I TO REPORT OF SUPERINTENDENT OF OBSERVATORY DEPARTMENT.

## MAGNETICAL OBSERVATIONS, 1902.

## Made at the Kew Observatory, Old Deer Park, Richmond, Lat. 51° 28′ 6″ N. and Long. $0^h\ 1^m\ 15^s{\cdot}1$ 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 $3\frac{1}{2}$ 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 1902 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 | 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. |

Table I.—Hourly Means of Declination, as determined from the

| Hours | Preceding noon. | Mid. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (16° +) West | | | | | | Winter. | | | | | | |
| 1902. Months. | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ |
| Jan. .. | 47·9 | 48·0 | 48·5 | 47·1 | 47·2 | 47 0 | 46·6 | 46·3 | 46·0 | 45·3 | 45·1 | 45·1 | 47·2 |
| Feb. .. | 48·3 | 45·5 | 46·1 | 46·6 | 46·2 | 46·3 | 46·0 | 45·7 | 45·4 | 44·8 | 44·8 | 45·9 | 47·1 |
| March. | 49·5 | 45·7 | 46·0 | 46·0 | 45·9 | 45·8 | 45·7 | 45·3 | 44·7 | 43·5 | 43·4 | 44·8 | 47·2 |
| Oct. .. | 47·4 | 43·2 | 43·3 | 43·5 | 43·6 | 43·4 | 43·3 | 42·9 | 42·1 | 40·7 | 40·7 | 42·7 | 45·3 |
| Nov. .. | 45·3 | 42·6 | 43·0 | 43·4 | 43·3 | 43·3 | 43·2 | 42·9 | 42·7 | 42·2 | 41·9 | 43·0 | 44·3 |
| Dec. .. | 44·6 | 42·3 | 42·7 | 43·0 | 43·2 | 43·4 | 43·0 | 42·7 | 42·5 | 42·5 | 42·4 | 43·5 | 44·0 |
| Means | 47·2 | 44·2 | 44·6 | 44·9 | 44·9 | 44·9 | 44·6 | 44·3 | 43·9 | 43·2 | 43·1 | 44·2 | 45·9 |
| | | | | | | Summer. | | | | | | | |
| | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ |
| April.. | 49·4 | 45·5 | 45·8 | 45·8 | 45·6 | 45·6 | 45·0 | 44·7 | 43·5 | 42·3 | 42·2 | 43·9 | 46·3 |
| May .. | 48·3 | 44·7 | 44·9 | 44·7 | 44·7 | 44·5 | 43·5 | 42·8 | 41·9 | 41·4 | 41·9 | 43·4 | 45·1 |
| June .. | 49·4 | 44·7 | 44·7 | 44·6 | 44·2 | 43·6 | 42·3 | 41·5 | 41·2 | 41·4 | 41·9 | 43·9 | 46·1 |
| July .. | 48·2 | 44·2 | 44·1 | 44·1 | 43·8 | 43·4 | 42·3 | 41·0 | 40·7 | 40·5 | 41·6 | 43·2 | 45·2 |
| Aug. .. | 48·8 | 44·2 | 44·2 | 44·3 | 43·9 | 43·6 | 42·7 | 41·9 | 41·6 | 42·2 | 42·5 | 44·3 | 47·0 |
| Sept... | 48·2 | 43·1 | 43·0 | 43·2 | 43·2 | 42·9 | 42·9 | 42·5 | 41·8 | 41·5 | 42·3 | 43·9 | 45·8 |
| Means | 48·7 | 44·4 | 44·5 | 44·4 | 44·2 | 43·9 | 43·1 | 42·4 | 41·8 | 41·6 | 42·1 | 43·8 | 45·9 |

Table II.—Diurnal Inequality of the

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

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

selected quiet Days in 1902. (Mean for the Year = 16° 44′·8. West.)

| Noon | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | Mid. | Succeeding noon. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter. | | | | | | | | | | | | | |
| ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ |
| 48·3 | 49·0 | 48·3 | 47·4 | 46·8 | 46·7 | 46·4 | 46·2 | 45·9 | 45·7 | 45·8 | 46·1 | 46·1 | 47·8 |
| 48·0 | 48·0 | 47·7 | 47·0 | 46·4 | 46·3 | 46·0 | 45·8 | 45·7 | 45·5 | 45·5 | 45·9 | 45·8 | 47·9 |
| 49·1 | 50·3 | 49 6 | 48·1 | 46·4 | 45·9 | 46·0 | 45·9 | 45·8 | 45·7 | 45·5 | 45·6 | 45·7 | 50·3 |
| 47·0 | 47·6 | 47·1 | 45·5 | 44·0 | 43·5 | 43·3 | 43·3 | 43·2 | 43·0 | 42·8 | 42·9 | 43·1 | 47·9 |
| 45·5 | 45·6 | 44·9 | 43·8 | 43·6 | 43·4 | 43·1 | 42·9 | 42·7 | 42·7 | 42·6 | 42·7 | 42·6 | 45·8 |
| 44·4 | 44·3 | 44·0 | 43·3 | 43·3 | 42·8 | 42·7 | 42·4 | 42·4 | 42·2 | 42·3 | 42·2 | 42·3 | 44·9 |
| 47·1 | 47·5 | 46·9 | 45·8 | 45·1 | 44·8 | 44·6 | 44·4 | 44·3 | 44·1 | 44·1 | 44·2 | 44·3 | 47·4 |
| Summer. | | | | | | | | | | | | | |
| ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ |
| 49·5 | 50·7 | 49·9 | 48·2 | 47·1 | 46·4 | 45·5 | 45·4 | 45·5 | 45·5 | 45·5 | 45·6 | 45·7 | 49·4 |
| 47·1 | 47·9 | 47·8 | 47·3 | 46·2 | 45·5 | 44·8 | 44·5 | 44·5 | 44·4 | 44·5 | 44·6 | 44·6 | 46·2 |
| 48·0 | 48·6 | 48·8 | 48·0 | 46·5 | 45·2 | 44·8 | 44·9 | 44·9 | 45·0 | 45·0 | 44·9 | 44·9 | 49·7 |
| 48·3 | 50·2 | 49·9 | 48·6 | 46·7 | 45·2 | 44·6 | 44·7 | 44·9 | 44·7 | 44·8 | 44·5 | 44·4 | 49·0 |
| 49·3 | 50·7 | 49·5 | 47·7 | 45·6 | 43·9 | 43·6 | 43·9 | 44·2 | 44·3 | 44·4 | 44·3 | 44·1 | 49·5 |
| 47·2 | 47·6 | 46·8 | 45·7 | 44·6 | 44 0 | 43·7 | 43·8 | 43·6 | 43·2 | 43·2 | 43·3 | 43·7 | 48·5 |
| 48·2 | 49·3 | 48·8 | 47·6 | 46·1 | 45·0 | 44·5 | 44·5 | 44·6 | 44·5 | 44·6 | 44·5 | 44·6 | 48·7 |

Kew Declination as derived from Table I.

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

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

TABLE III.—Hourly Means of the Horizontal Force in C.G.S. units (corrected
(The Mean for the

| Hours | Preceding noon. | Mid. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 ·18000 + | | | | | | Winter. | | | | | | | |
| 1902. Months. | | | | | | | | | | | | | |
| Jan. ... | 459 | 466 | 466 | 466 | 467 | 468 | 469 | 469 | 469 | 467 | 460 | 458 | 458 |
| Feb. ... | 456 | 463 | 463 | 460 | 462 | 462 | 466 | 467 | 469 | 469 | 464 | 461 | 458 |
| March .. | 452 | 469 | 467 | 466 | 467 | 467 | 468 | 469 | 469 | 464 | 457 | 455 | 453 |
| Oct. ... | 468 | 486 | 485 | 485 | 486 | 486 | 487 | 487 | 484 | 478 | 469 | 464 | 466 |
| Nov. ... | 477 | 482 | 482 | 482 | 484 | 484 | 484 | 485 | 484 | 481 | 478 | 473 | 474 |
| Dec. ... | 481 | 479 | 480 | 481 | 483 | 483 | 483 | 484 | 484 | 481 | 480 | 479 | 479 |
| Means.. | 465 | 474 | 474 | 473 | 475 | 475 | 476 | 477 | 476 | 473 | 468 | 465 | 465 |
| | | | | | | Summer. | | | | | | | |
| April... | 462 | 475 | 471 | 470 | 471 | 470 | 470 | 472 | 474 | 473 | 464 | 456 | 457 |
| May ... | 467 | 480 | 476 | 475 | 476 | 474 | 474 | 474 | 472 | 469 | 466 | 465 | 465 |
| June ... | 472 | 482 | 479 | 479 | 480 | 479 | 479 | 475 | 470 | 467 | 461 | 458 | 459 |
| July ... | 467 | 486 | 483 | 482 | 483 | 484 | 483 | 479 | 474 | 469 | 462 | 458 | 463 |
| Aug. ... | 465 | 475 | 474 | 472 | 474 | 472 | 470 | 467 | 465 | 459 | 455 | 451 | 456 |
| Sept. ... | 469 | 482 | 481 | 480 | 483 | 483 | 482 | 479 | 473 | 467 | 449 | 457 | 463 |
| Means.. | 467 | 480 | 477 | 476 | 478 | 477 | 476 | 474 | 471 | 467 | 459 | 457 | 461 |

Table IV.—Diurnal Inequality of the

| Hours | Mid. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Summer Means. | | | | | | | |
| | + ·00005 | + ·00002 | + ·00001 | + ·00002 | + ·00002 | + ·00001 | − ·00001 | − ·00004 | − ·00008 | − ·00016 | − ·00018 | − ·00015 |
| | | | | | Winter Means. | | | | | | | |
| | ·00000 | ·00000 | − ·00001 | + ·00001 | + ·00001 | + ·00002 | + ·00003 | + ·00002 | − ·00001 | − ·00006 | − ·00009 | − ·00009 |
| | | | | | Annual Means. | | | | | | | |
| | + ·00002 | + ·00001 | ·00000 | + ·00001 | + ·00001 | + ·00001 | + ·00001 | − ·00001 | − ·00005 | − ·00011 | − ·00014 | − ·00012 |

NOTE.—When the sign is + the

for Temperature) as determined from the selected quiet Days in 1902. Year = 0·18475.)

| Noon | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | Mid. | Succeeding noon. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Winter.** | | | | | | | | | | | | | |
| 459 | 466 | 469 | 470 | 470 | 471 | 472 | 471 | 471 | 471 | 469 | 468 | 468 | 457 |
| 462 | 463 | 463 | 465 | 464 | 464 | 467 | 468 | 468 | 468 | 467 | 466 | 466 | 463 |
| 456 | 460 | 467 | 469 | 471 | 470 | 472 | 474 | 473 | 473 | 472 | 471 | 471 | 457 |
| 469 | 473 | 478 | 480 | 481 | 483 | 485 | 486 | 489 | 488 | 489 | 488 | 488 | 471 |
| 476 | 480 | 483 | 485 | 484 | 485 | 487 | 487 | 487 | 488 | 487 | 486 | 486 | 475 |
| 480 | 484 | 485 | 483 | 484 | 485 | 485 | 484 | 485 | 483 | 482 | 482 | 482 | 482 |
| 467 | 471 | 474 | 475 | 476 | 477 | 478 | 478 | 479 | 478 | 477 | 477 | 477 | 468 |
| **Summer.** | | | | | | | | | | | | | |
| 463 | 469 | 473 | 475 | 478 | 480 | 480 | 479 | 479 | 480 | 480 | 480 | 479 | 470 |
| 465 | 467 | 471 | 476 | 479 | 485 | 485 | 482 | 483 | 483 | 481 | 480 | 480 | 470 |
| 466 | 469 | 475 | 478 | 478 | 481 | 486 | 490 | 490 | 489 | 486 | 485 | 484 | 474 |
| 470 | 479 | 484 | 483 | 488 | 487 | 488 | 492 | 493 | 492 | 491 | 489 | 488 | 478 |
| 465 | 473 | 475 | 476 | 475 | 474 | 474 | 480 | 480 | 479 | 478 | 478 | 478 | 468 |
| 471 | 477 | 479 | 481 | 481 | 481 | 482 | 483 | 484 | 484 | 483 | 483 | 483 | 471 |
| 467 | 472 | 476 | 479 | 480 | 481 | 483 | 484 | 485 | 484 | 483 | 482 | 482 | 472 |

Kew Horizontal Force as deduced from Table III.

| Noon | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | Mid. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Summer Means.** | | | | | | | | | | | | |
| – ·00009 | – ·00003 | + ·00001 | + ·00003 | + ·00004 | + ·00006 | + ·00007 | + ·00009 | + ·00009 | + ·00009 | + ·00008 | + ·00007 | + ·00007 |
| **Winter Means.** | | | | | | | | | | | | |
| – ·00007 | – ·00004 | ·00000 | + ·00001 | + ·00001 | + ·00002 | + ·00004 | + ·00004 | + ·00005 | + ·00004 | + ·00003 | + ·00003 | + ·00003 |
| **Annual Means.** | | | | | | | | | | | | |
| – ·00008 | – ·00003 | ·00000 | + ·00002 | + ·00003 | + ·00004 | + ·00005 | + ·00006 | + ·00007 | + ·00006 | + ·00005 | + ·00005 | + ·00005 |

reading is above the mean.

Table V.—Inclination Observations made during the year 1902, with Barrow Circle 33.

| 1902. | Mean time. | Inclination uncorrected. | Inclination reduced to the mean value for the day. | Vertical force (mean value for the day). |
|---|---|---|---|---|
| | h. m. | ° ′ | ° ′ | |
| January ..... | 3 0 | 67 9·0 | 67 8·9 | 0·43822 |
| February ..... | 3 22 | 67 8·4 | 67 8·3 | 0·43796 |
| March..... | 3 24 | 67 8·2 | 67 8·1 | 0·43793 |
| April..... | 3 36 | 67 8·4 | 67 8·6 | 0·43820 |
| May ..... | 3 38 | 67 8·2 | 67 8·4 | 0·43821 |
| June ..... | 3 32 | 67 8·1 | 67 8·3 | 0·43822 |
| July ..... | 3 31 | 67 8·4 | 67 8·6 | 0·43843 |
| August..... | 3 47 | 67 7·5 | 67 7·7 | 0·43786 |
| September ..... | 3 47 | 67 7·2 | 67 7·4 | 0·43791 |
| October..... | 3 18 | 67 7·4 | 67 7·3 | 0·43797 |
| November..... | 2 58 | 67 7·7 | 67 7·6 | 0·43813 |
| December..... | 2 39 | 67 7·5 | 67 7·4 | 0·43803 |
| Mean for year | .. | .. | 67 8·0 | 0·43809 |

## 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. | 1900 | 0 37·6 E. | 70 37·4 N. | ·16548 | ·47050 |
| Katharinenburg | 56 49 N. | 60 38 E. | 1900 | 10 4·0 E. | 70 40·3 N. | ·17789 | ·50718 |
| 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 | ·4480 |
| Stonyhurst .... | 53 51 N. | 2 28 W. | 1901 | 18 9·7 W. | 68 45·7 N. | ·17348 | ·44638 |
| Hamburg..... | 53 34 N. | 10 3 E. | 1901 | 11 16·0 W. | — | — | — |
| Wilhelmshaven | 53 32 N. | 8 9 E. | 1901 | 12 24·2 W. | 67 39·4 N. | ·18121 | ·44058 |
| Potsdam ..... | 52 23 N. | 13 4 E. | 1900 | 9 56·3 W. | 66 33·7 N. | ·18644 | ·43466 |
| Irkutsk..... | 52 16 N. | 104 16 E. | 1900 | 2 1·3 E. | 70 14·8 N. | ·20129 | ·56053 |
| de Bilt(Utrecht) | 52 5 N. | 5 11 E. | 1899 | 13 54·7 W. | — | ·18502 | — |
| | | | 1900 | 13 50·5 W. | — | ·18508 | — |
| | | | 1901 | 13 46·2 W. | — | ·18524 | — |
| Valencia (Ireland)..... | 51 56 N. | 10 15 W. | 1901 | 21 27·7 W. | 68 26·3 N. | ·17801 | ·45048 |
| Kew..... | 51 28 N. | 0 19 W. | 1902 | 16 44·8 W. | 67 8·0 N. | ·18475 | ·43809 |
| Greenwich..... | 51 28 N. | 0 0 | 1901 | 16 26·0 W. | 67 6·1 N. | ·18481 | ·43754 |
| Uccle (Brussels) | 50 48 N. | 4 21 E. | 1900 | 14 13·6 W. | 66 9·8 N. | ·18952 | ·43896 |
| Falmouth ..... | 50 9 N. | 5 5 W. | 1901 | 18 25·5 W. | 66 42·8 N. | ·18720 | ·43495 |
| Prague ..... | 50 5 N. | 14 25 E. | 1901 | 9 1·7 W. | — | ·19965 | — |
| St. Helier (Jersey)..... | 49 12 N. | 2 5 W. | 1902 | 16 54·1 W. | 65 40·3 N. | — | — |
| Parc St. Maur (Paris) ..... | 48 49 N. | 2 29 E. | 1899 | 14 49·5 W. | 64 55·7 N. | ·19704 | ·42119 |

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. | — | ·20797 | — |
| O'Gyalla(Pesth) | 47 53 N. | 18 12 E. | 1902 | 7 18·5 W. | — | ·21170 | — |
| *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. | 1901 | 9 20·1 W. | 60 13·2 N. | ·22230 | ·38848 |
| Nice ..... | 43 43 N. | 7 16 E. | 1899 | 12 4·0 W. | 60 11·7 N. | ·22390 | ·39087 |
| Agincourt (Toronto)..... | 43 47 N. | 79 18W. | 1900 | 5 28·8 W. | 74 32·5 N. | ·16512 | ·59709 |
| Perpignan..... | 42 42 N. | 2 53 E. | 1899 | 13 42·5 W. | 60 0·0 N. | ·22418 | ·38829 |
| | | | 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. | 1900 | 9 10·2 W. | — | — | — |
| Madrid ..... | 40 25 N. | 3 40W. | 1899 | 15 48·4 W. | — | — | — |
| Coimbra..... | 40 12 N. | 8 25W. | 1901 | 17 16·1 W. | 59 19·6 N. | ·22805 | ·38449 |
| Lisbon..... | 38 43 N. | 9 9W. | 1900 | 17 18·0 W. | 57 54·8 N. | ·23516 | ·37484 |
| Tokio..... | 35 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. | 1900 | 2 22·2 W. | 45 45·5 N. | ·32859 | ·33741 |
| Havana..... | 23 8 N. | 82 25W. | 1900 | 3 7·8 E. | 52 36·0 N. | ·30948 | ·40479 |
| Hong Kong.... | 22 18 N. | 114 10 E. | 1901 | 0 16·4 E. | 31 20·8 N. | ·36783 | ·22406 |
| Colaba(Bombay) | 18 54 N. | 72 49 E. | 1899 | 0 25·4 E. | 21 13·9 N. | ·37448 | ·14549 |
| 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-salem .. | 6 49 S. | 39 18 E. | 1898 | 8 18·1 W. | 36 56·8 S. | ·28966 | ·21785 |
| Mauritius ..... | 20 6 S. | 57 33 E. | 1899 | 9 32·9 W. | 54 16·8 S. | ·23854 | ·33171 |
| Rio de Janeiro . | 22 55 S. | 43 11 W. | 1900 | 7 55·7 W. | 13 17·0 S. | ·2504 | ·0592 |
| Melbourne..... | 37 50 S. | 144 58 E. | 1901 | 8 26·7 E. | 67 25·0 S. | ·23305 | ·56024 |

* There is a discontinuity between the values for 1898 and 1899.

## APPENDIX II.—Table I.

Mean Monthly Results of Temperature and Pressure for Kew Observatory.
1902.

| Months. | Thermometer. | | | | | | | | | | Barometer.* | | | | | | | Mean vapour-tension. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Means of— | | | Absolute Extremes. | | | | | | | Absolute Extremes. | | | | | | |
| | Mean. | Max. | Min. | Max. and Min. | Max. | Date. | Hour. | Min. | Date. | Hour. | Mean. | Max. | Date. | Hour. | Min. | Date. | Hour. | |
| | ° | ° | ° | ° | ° | | | ° | | | ins. | ins. | | | ins. | | | in. |
| January ... | 42·0 | 45·9 | 37·6 | 41·8 | 52·8 | 10 | 3 P.M. | 24·1 | 15 | 8 A.M. | 30·168 | 30·896 | 15 | 9 A.M. | 29·150 | 25 | 5 A.M. | ·223 |
| February .. | 35·8 | 40·3 | 31·6 | 36·0 | 52·6 | 28 | 4 ,, | 17·7 | 16 | 8 A.M. | 29·873 | 30·682 | 1 | 1 ,, | 29·254 | 27 | 3 ,, | ·179 |
| March ..... | 44·8 | 51·9 | 38·3 | 45·1 | 60·0 | 31 | 3 ,, | 30·0 | 7 | 2 & 5 ,, | 29·858 | 30·260 | 17 | 11 ,, | 29·108 | 24 | 11 P.M. | ·239 |
| April ..... | 47·3 | 54·9 | 39·8 | 47·4 | 65·6 | 19 | 1 ,, | 32·1 | 7 | 6 ,, | 29·953 | 30·360 | 7 | Noon | 29·547 | 22 | 11 A.M. | ·236 |
| May ..... | 49·2 | 57·0 | 42·2 | 49·6 | 70·2 | 31 | 4 & 5 ,, | 32·3 | 14 | 4 ,, | 29·972 | 30·479 | 25 | 8 A.M. | 29·287 | 18 | 1 ,, | ·261 |
| June ..... | 58·2 | 66·2 | 51·0 | 58·6 | 80·5 | 30 | 3 ,, | 40·1 | 10 | 4 ,, | 29·917 | 30·284 | 24 | 8 ,, | 29·358 | 13 | 3 ,, | ·357 |
| July ..... | 60·8 | 69·6 | 52·6 | 61·1 | 83·0 | 14 | 6 ,, | 45·6 | 12 | 4 ,, | 30·030 | 30·326 | 2 | 11 P.M. & Midt. | 29·472 | 26 | 8 P.M. | ·373 |
| August .... | 59·6 | 67·6 | 52·8 | 60·2 | 76·5 | 16, 29 | 2 ,, | 44·4 | 11 | 5 ,, | 29·931 | 30·236 | 22 | 10 A.M. | 29·627 | 30 | 3 A.M. | ·403 |
| September.. | 56·0 | 64·2 | 48·7 | 56·5 | 73·7 | 22 | 2 ,, | 37·0 | 19 | 6 ,, | 30·070 | 30·499 | 26 | 9 ,, | 29·537 | 3 | 7 A.M. | ·353 |
| October ... | 50·0 | 55·5 | 44·1 | 49·8 | 64·3 | 10 | 2 ,, | 34·9 | 19 | 7 ,, | 29·988 | 30·586 | 24 | 9 ,, | 29·427 | 10 | 3 ,, | ·298 |
| November.. | 45·0 | 49·6 | 40·2 | 44·9 | 58·2 | 7 | 4 A.M. | 29·9 | 20, 21 | 10 P.M. 1 A.M. | 29·891 | 30·401 | 14 | 9 P.M. | 29·190 | 25 | 3 P.M. | ·260 |
| December .. | 41·8 | 45·3 | 37·8 | 41·6 | 57·1 | 17 | Noon | 25·7 | 6, 7 | Midt. 0·5 A.M. | 30·061 | 30·622 | 23 | 10 A.M. | 28·945 | 30 | 1 A.M. | ·223 |
| Means | 49·2 | 55·7 | 43·1 | 49·4 | .. | .. | .. | .. | .. | .. | 29·976 | .. | .. | .. | .. | .. | .. | +·284 |

* Reduced to 32° at M.S.L.

† The mean vapour tension obtained from the mean temperature for the year, and the mean depression of the wet-bulb = ·276 in.

This table has been compiled at the Meteorological Office from values intended for publication in the volume of "Hourly Means" for 1902.

## Appendix II. Table IA.

### Mean Monthly Results of Temperature and Pressure 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. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | °F. | °F. | °F. | °F. | °F. | | °F. | | 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.* | | | Weather. Number of days on which were registered | | | | | | | Wind.† Number of days on which it was | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total. | Maximum. | Date. | Rain.‡ | Snow. | Hail. | Thunderstorms. | Clear sky. | Overcast sky. | Gales.§ | N. | N.E. | E. | S.E. | S. | S.W. | W. | N.W. | Calm.‖ |
| 1902. | | ins. | ins. | | | | | | | | | | | | | | | | | |
| January | 7·1 | 0·715 | 0·225 | 1 | 8 | 2 | 1 | 0 | 3 | 19 | 1 | 2 | 4 | 1 | .. | 1 | 11 | 10 | 2 | 3 |
| February | 7·4 | 0·855 | 0·305 | 24 | 11 | 4 | 0 | 0 | 4 | 17 | 2 | 4 | 6 | 6 | 3 | 3 | 3 | 2 | 1 | 2 |
| March | 7·3 | 1·750 | 0·490 | 14 | 12 | 0 | 4 | 1 | 2 | 13 | 0 | 1 | 1 | 2 | .. | 3 | 11 | 9 | 4 | 6 |
| April | 7·1 | 0·560 | 0·085 | 3 | 11 | 0 | 0 | 0 | 2 | 17 | 3 | 2 | 8 | 2 | 1 | 4 | 5 | 5 | 3 | 6 |
| May | 7·6 | 2·400 | 0·485 | 17 | 22 | 0 | 6 | 2 | 0 | 18 | 0 | 10 | 1 | 1 | 1 | 1 | 5 | 5 | 7 | 2 |
| June | 6·7 | 3·705 | 0·960 | 13 | 19 | 0 | 0 | 2 | 5 | 14 | 0 | 4 | 1 | 6 | 4 | 3 | 7 | 4 | 1 | 4 |
| July | 6·7 | 1·135 | 0·415 | 1 | 8 | 0 | 1 | 2 | 2 | 13 | 0 | 5 | 2 | 1 | .. | 3 | 8 | 8 | 4 | 3 |
| August | 7·4 | 3·470 | 0·870 | 18 | 23 | 0 | 0 | 0 | 1 | 13 | 0 | 4 | 1 | 3 | 1 | 3 | 11 | 6 | 2 | 7 |
| September | 5·8 | 2·495 | 1·385 | 10 | 7 | 0 | 0 | 1 | 3 | 10 | 0 | 4 | 5 | 4 | 2 | 4 | 5 | 4 | 2 | 9 |
| October | 7·9 | 1·390 | 0·325 | 15 | 17 | 0 | 0 | 0 | 1 | 21 | 0 | 6 | 5 | 1 | .. | 4 | 4 | 7 | 4 | 9 |
| November | 7·4 | 1·580 | 0·260 | 24 & 29 | 15 | 0 | 0 | 0 | 1 | 18 | 1 | 1 | 3 | 9 | 4 | 6 | 5 | 1 | 1 | 5 |
| December | 7·8 | 1·370 | 0·490 | 17 | 9 | 1 | 0 | 0 | 2 | 21 | 1 | 2 | 7 | 2 | .. | 1 | 8 | 8 | 3 | 2 |
| Totals and means... | 7·2 | 21·425 | .. | .. | 162 | 7 | 12 | 8 | 26 | 194 | 8 | 45 | 44 | 38 | 16 | 36 | 83 | 69 | 34 | 58 |

* Measured at 10 A.M. daily by gauge 1·75 feet above ground.

† As registered by the 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. | | | | | Maximum temperature in sun's rays. (Black bulb *in vacuo*.) | | | Minimum temperature on the ground. | | | Horizontal movement of the air.* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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. | | | | | | | | | | | |
| 1902. | h. m. | | | h. m. | | ° | ° | | ° | ° | | miles. | miles. | |
| January | 48 12 | 18 | 19 | 7 24 | 29 | 66 | 83 | 24 | 32 | 14 | 15 | 11·7 | 38 | 31 |
| February | 49 24 | 18 | 18 | 7 30 | 9 | 63 | 94 | 28 | 25 | 4 | 16 | 9·5 | 43 | 1 |
| March | 96 42 | 26 | 26 | 9 30 | 16 | 93 | 114 | 31 | 30 | 19 | 26 | 9·9 | 34 | 24 |
| April | 138 6 | 33 | 33 | 13 0 | 28 | 105 | 125 | 23 | 31 | 16 | 7 | 12·8 | 41 | 27 |
| May | 174 36 | 36 | 36 | 13 30 | 26 | 114 | 131 | 26 | 34 | 21 | 2 | 9·5 | 25 | 18, 19 |
| June | 184 12 | 37 | 37 | 15 0 | 26, 27 | 119 | 138 | 29, 30 | 44 | 29 | 10 | 9·2 | 34 | 26 |
| July | 206 0 | 41 | 41 | 14 36 | 7 | 125 | 139 | 5 | 45 | 32 | 12 | 8·2 | 34 | 26 |
| August | 127 48 | 28 | 28 | 11 6 | 22 | 118 | 138 | 5 | 44 | 33 | 2 | 7·0 | 20 | 7 |
| September | 161 42 | 43 | 43 | 11 42 | 4 | 110 | 127 | 4 | 40 | 30 | 20 | 8·3 | 27 | 3 |
| October | 62 18 | 19 | 19 | 8 54 | 21 | 89 | 116 | 10 | 37 | 25 | 31 | 9·8 | 34 | 15 |
| November | 40 48 | 15 | 15 | 5 42 | 9, 23 | 71 | 99 | 1 | 32 | 19 | 18 | 10·3 | 37 | 8 |
| December | 33 30 | 14 | 14 | 4 42 | 30 | 60 | 82 | 20 | 31 | 15 | 5 | 14·0 | 35 | 10 |
| Totals and Means | 1323 18 | 27 | 30 | .. | .. | .. | .. | .. | .. | .. | .. | 10·0 | .. | .. |

* 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 Self-recording

19

| | Mid. | 1 h. | 2 h. | 3 h. | 4 h. | 5 h. | 6 h. | 7 h. | 8 h. | 9 h. | 10 h. | 11 h. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January ... | 113 | 119 | 116 | 121 | 117 | 114 | 119 | 134 | 159 | 183 | 196 | 215 |
| February .. | 231 | 229 | 214 | 209 | 198 | 204 | 203 | 255 | 285 | 314 | 362 | 363 |
| March ... | 159 | 150 | 145 | 156 | 151 | 161 | 156 | 160 | 170 | 185 | 189 | 174 |
| April..... | 144 | 144 | 130 | 127 | 124 | 128 | 144 | 165 | 175 | 175 | 163 | 149 |
| May ..... | 130 | 120 | 113 | 111 | 114 | 121 | 126 | 121 | 118 | 107 | 90 | 80 |
| June ..... | 119 | 110 | 104 | 102 | 104 | 120 | 120 | 141 | 152 | 159 | 133 | 107 |
| July ..... | 99 | 81 | 79 | 79 | 77 | 92 | 97 | 116 | 118 | 121 | 108 | 91 |
| August .... | 142 | 116 | 99 | 80 | 75 | 77 | 95 | 102 | 112 | 119 | 108 | 102 |
| September * | 86 | 76 | 73 | 69 | 63 | 65 | 79 | 88 | 91 | 102 | 106 | 91 |
| October.... | 65 | 66 | 72 | 67 | 62 | 60 | 68 | 78 | 91 | 103 | 103 | 101 |
| November.. | 152 | 148 | 133 | 127 | 123 | 125 | 144 | 156 | 159 | 163 | 178 | 173 |
| December.. | 226 | 196 | 185 | 180 | 167 | 171 | 188 | 211 | 249 | 276 | 282 | 260 |

Table V.—Diurnal Inequality of Atmospheric Electric Potential

19

| | 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 ... | −35 | −39 | −35 | −38 | **−44** | −40 | −26 | − 2 | +20 | +32 | +49 | +62 | **+71** |
| February .. | −39 | −51 | −55 | **−65** | −60 | −60 | −17 | + 8 | +32 | +72 | +73 | **+87** | +22 |
| March..... | 0 | − 7 | + 1 | − 6 | 0 | − 6 | − 5 | + 2 | +12 | +13 | − 2 | −21 | −22 |
| April..... | − 3 | −17 | −20 | −24 | −20 | − 6 | +14 | +23 | +22 | +10 | − 4 | −24 | **−44** |
| May ..... | +15 | + 8 | + 6 | +10 | +16 | +21 | +16 | +14 | + 4 | −11 | −20 | −26 | −29 |
| June ..... | − 4 | −10 | −13 | −12 | + 2 | + 1 | +19 | +29 | +34 | + 9 | −16 | −29 | −38 |
| July ..... | −13 | −15 | −15 | −16 | − 3 | + 2 | +19 | +21 | +24 | +12 | − 4 | −15 | −19 |
| August .... | 0 | −17 | −36 | **−40** | −38 | −18 | −10 | 0 | + 8 | − 2 | − 8 | −10 | −16 |
| September . | −25 | −27 | −31 | **−37** | −35 | −19 | − 8 | − 4 | + 9 | +13 | − 2 | + 3 | − 1 |
| October.... | −26 | −19 | −26 | −34 | **−37** | −28 | −17 | − 1 | +14 | +13 | + 9 | − 4 | −15 |
| November.. | −14 | −31 | −37 | **−43** | −41 | −20 | − 9 | − 5 | − 2 | +14 | + 7 | +18 | +18 |
| December .. | −39 | −50 | −55 | **−69** | −65 | −48 | −25 | +13 | +40 | +45 | +23 | + 7 | + 1 |
| Winter .... | −32 | −43 | −46 | **−54** | −52 | −42 | −19 | + 4 | +22 | +41 | +38 | **+44** | +28 |
| Equinox ... | −13 | −18 | −19 | **−25** | −23 | −15 | − 4 | + 5 | +14 | +12 | 0 | −11 | −21 |
| Summer ... | 0 | − 8 | −14 | −15 | − 6 | + 1 | +11 | +16 | +17 | + 2 | −12 | −20 | −26 |
| Year ..... | −15 | −23 | −26 | **−31** | −27 | −19 | − 4 | + 8 | +18 | +18 | + 9 | + 4 | − 6 |

* Maxima and minima

Kelvin Water-dropping Electrograph, on certain selected Quiet Days (usually 10 each Month.)

02.

| Noon. | 1 h. | 2 h. | 3 h. | 4 h. | 5 h. | 6 h. | 7 h. | 8 h. | 9 h. | 10 h. | 11 h. | Mid. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 229 | 239 | 202 | 179 | 176 | 183 | 184 | 189 | 175 | 179 | 179 | 156 | 139 |
| 380 | 302 | 294 | 293 | 299 | 301 | 288 | 291 | 296 | 279 | 280 | 254 | 234 |
| 154 | 156 | 152 | 152 | 156 | 171 | 201 | 218 | 227 | 240 | 248 | 223 | 222 |
| 129 | 110 | 124 | 134 | 155 | 163 | 175 | 180 | 186 | 192 | 195 | 174 | 159 |
| 73 | 70 | 68 | 70 | 77 | 81 | 89 | 88 | 103 | 123 | 132 | 130 | 126 |
| 94 | 85 | 86 | 87 | 108 | 126 | 137 | 149 | 167 | 168 | 168 | 145 | 143 |
| 78 | 74 | 72 | 69 | 73 | 74 | 87 | 112 | 123 | 132 | 125 | 110 | 98 |
| 99 | 92 | 88 | 83 | 91 | 103 | 116 | 130 | 138 | 146 | 158 | 152 | 126 |
| 96 | 92 | 89 | 96 | 101 | 113 | 123 | 121 | 109 | 106 | 103 | 89 | 76 |
| 92 | 84 | 88 | 94 | 108 | 126 | 138 | 137 | 131 | 124 | 115 | 99 | 85 |
| 183 | 183 | 172 | 173 | 180 | 181 | 183 | 188 | 190 | 191 | 186 | 181 | 162 |
| 244 | 238 | 238 | 250 | 271 | 285 | 286 | 276 | 269 | 261 | 248 | 242 | 230 |

Gradient near the Ground in volts per metre of height.*

02.

| 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. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| +34 | +10 | + 5 | +11 | +11 | +15 | 0 | + 3 | + 2 | −21 | −40 | 115 | 164 |
| +15 | +14 | +18 | +20 | + 9 | +12 | +16 | + 2 | + 3 | −19 | −36 | 152 | 232 |
| −27 | **−30** | −29 | −18 | + 5 | +18 | +23 | +31 | **+37** | +13 | +10 | 67 | 152 |
| −30 | −21 | − 1 | + 6 | +16 | +20 | +26 | +31 | **+34** | +13 | − 3 | 78 | 149 |
| **−31** | −28 | −22 | −18 | −11 | −12 | + 2 | +21 | **+29** | +27 | +24 | 60 | 93 |
| **−38** | −38 | −19 | − 4 | + 6 | +16 | +31 | **+31** | +30 | + 8 | + 5 | 69 | 115 |
| −21 | **−24** | −20 | −19 | − 7 | +15 | +25 | **+34** | +27 | +14 | + 3 | 58 | 86 |
| −20 | −24 | −15 | − 3 | +11 | +27 | +35 | +44 | **+57** | +51 | +25 | 97 | 111 |
| − 3 | + 4 | +11 | +25 | **+37** | +35 | +21 | +19 | +16 | + 1 | −13 | 74 | 104 |
| −12 | − 5 | +13 | +35 | **+49** | +46 | +37 | +27 | −15 | − 6 | −26 | 86 | 123 |
| + 5 | + 6 | +13 | +14 | +15 | +20 | **+23** | +22 | +17 | +11 | −10 | 66 | 178 |
| + 1 | +12 | +33 | +47 | **+48** | +38 | +31 | +22 | + 9 | + 3 | − 9 | 117 | 237 |
| +14 | +11 | +17 | +23 | +21 | +21 | +17 | +12 | + 8 | − 7 | −24 | .. | 203 |
| −18 | −13 | − 1 | +12 | +27 | **+30** | +27 | +27 | +18 | + 5 | − 8 | .. | 132 |
| −27 | **−29** | −19 | −11 | 0 | +11 | +23 | +32 | **+36** | +25 | +14 | .. | 101 |
| −11 | −10 | − 1 | + 8 | +16 | +21 | +23 | **+24** | +20 | + 8 | − 6 | .. | 145 |

are in heavy type.

## APPENDIX III.—Table I

### Register of principal Seismograph Disturbances. 1902.

| No. in Kew register. | Date. | P.T.* Commence. | L.W.* Commence | Max. | Max. Amplitude. | Duration. |
|---|---|---|---|---|---|---|
| | | h. m. | h. m. | h. m. | m.m. | h. m. |
| 347 | Jan. 1 | 5 41·8 | 6 8·2 | 6 21·4 | 1·0 | 1 45 |
| 358 | ,, 30 | 14 23·0 | 14 48·8 | 14 55·0 | 1·0 | 1 12 |
| 361 | Feb. 13 | 9 51·0 | — | 10 10·0 | 1·0 | 0 40 |
| 362 | ,, 17 | 0 49 5 | 1 8·0 | 1 18·2 | 0·8 | 1 10 |
| 371 | ,, 28 | 15 3·2 | 15 6·0 | 15 58·8 | 0·7 | 1 30 |
| 374 | Apr. 19 | 2 36·2 | 2 45·8 | 3 10·1 | 7·0 | 2 55 |
| 375 | May 2 | 11 58·5 | — | 12 32·0 | 0·7 | 0 26 |
| 378 | June 11 | 6 41·6 | 6 50·8 | 6 54·9 | 1·0 | 0 34 |
| 381 | July 5 | 15 0·5 | 15 7·0 | 15 7·8 | 1·9 | 0 34 |
| 384 | ,, 6 | 14 26·5 | 14 34·3 | 14 46·0 | 1·0 | 2 20 |
| 386 | ,, 9 | 4 6·5 | — | 4 8·4 | 0·8 | 0 27 |
| 394 | Aug. 30 | 22 5·0 | 22 18 4 | 22 22·7 | 6·3 | 1 17 |
| 397 | Sept. 22 | 2 5 3 | 2 11·5 | 2 48·6 | 8·5 | 2 54 |
| 398 | ,, 23 | 20 31·2 | 20 55·7 | 23 10·0 | >17·0 | 3 26 |
| 414 | Nov. 21 | 7 28·2 | 7 53·7 | 7 59·4 | 1·8 | 1 20 |
| 415 | Dec. 12 | 23 40·0 | 23 49·2 | 23 57·3 | 2·5 | 1 3 |
| 416 | ,, 13 | 17 38·3 | 17 46·2 | 17 47·8 | 1·0 | 0 25 |
| 417 | ,, 16 | 5 25·8 | 5 34·0 | 5 35·2 | 1·5 | 0 59 |
| 418 | ,, 28 | 2 5·8 | 2 13·7 | 2 15·3 | 0·8 | 0 30 |

On May 12, at the request of Professor Milne, the scale value was altered so as to make 1° on test screw = 3·5 mm. displacement of end of boom. After this change 1 mm. amplitude = 0″·55 of arc, previous to this 1 mm. amplitude = 0″·8 of arc.

* P.T. = Preliminary Tremors. L.W. = Large Waves. 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 times of commencement of the Large Waves of Earthquakes Nos. 361, 375, and 386 could not be definitely assigned.

## APPENDIX IV.—Table I.

RESULTS OF WATCH TRIALS. Performance of the 52 Watches which obtained the highest number of marks during the year.

| Watch deposited by | Number of watch. | Escapement, balance spring, &c. | Mean daily rate. | | | | | Mean variation of daily rate. ± | Mean change of rate for 1° F. | Difference between extreme gaining and losing rates. | Marks awarded for | | | Total Marks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pendant up. | Pendant right. | Pendant left. | Dial up. | Dial down. | | | | Daily variation of rate. | Change of rate with change of position. | Temperature compensation. | |
| | | | | | | | | | | | 0—40 | 0—40 | 0—20 | 0—100. |
| | | | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | | | | |
| H. Golay, London | 7556 | D.r., g.b., s.o., "Annular Tourbillon" resilient lever | −0·7 | −0·4 | +0·1 | +0·7 | −0·4 | 0·2 | 0·02 | 2·0 | 36·0 | 38·2 | 18·5 | 92·7 |
| ,, ,, | 7557 | D.r., g.b., s.o., "Annular Tourbillon" resilient lever | +0·6 | +1·8 | −1·0 | −0·4 | +0·8 | 0·2 | 0·01 | 3·5 | 35·7 | 36·6 | 19·4 | 91·7 |
| Montandon-Robert, Geneva | 1069 | D.r., g.b., s.o., bar-lever | +0·8 | +1·1 | +1·2 | +1·2 | +1·1 | 0·3 | 0·04 | 3·2 | 34·2 | 39·4 | 17·3 | 90·9 |
| J. R. Harris, London | 11050 | D.r., g.b., s.o. | +1·6 | +0·6 | +1·0 | +1·5 | +0·8 | 0·4 | 0·03 | 3·2 | 32·9 | 38·5 | 18·1 | 89·5 |
| Carley & Co., London | 50956 | D.r., g.b., d.o., palladium | +3·8 | +1·4 | +1·4 | +0·8 | +0·1 | 0·3 | 0·01 | 6·0 | 33·3 | 36·4 | 19·5 | 89·2 |
| S. Smith & Son, London | 1901–26 | S.r., g.b., s.o., "Karrusel" | +0·3 | +1·4 | +0·9 | −0·3 | +1·9 | 0·25 | 0·05 | 5·5 | 35·2 | 37·3 | 16·6 | 89·1 |
| A. E. Fridlander, Coventry | 25635 | S.r., g.b., s.o., "Karrusel" | +0·8 | +1·2 | +1·5 | +2·2 | +1·3 | 0·3 | 0·07 | 3·7 | 34·9 | 38·5 | 15·3 | 88·7 |
| Baume & Co., London | 103031 | G.b., s.o., "Tourbillon" chronometer | −0·0 | −0·4 | +0·5 | +0·7 | −1·3 | 0·3 | 0·05 | 4·3 | 34·5 | 37·6 | 16·6 | 88·7 |
| W. Ehrhardt, Ltd., Birmingham | 190305 | S.r., g.b., s.o., "Karrusel" | +1·6 | +0·5 | +0·5 | +1·7 | +2·9 | 0·3 | 0·02 | 4·8 | 33·2 | 36·9 | 18·4 | 88·5 |
| A. E. Fridlander, Coventry | 25637 | S.r., g.b., s.o., "Karrusel" | +0·4 | −0·1 | +0·4 | +1·2 | −0·1 | 0·3 | 0·06 | 3·5 | 33·3 | 38·6 | 16·3 | 88·2 |
| ,, ,, | 25634 | S.r., g.b., s.o., "Karrusel" | −0·1 | +1·0 | +1·1 | +3·6 | +2·0 | 0·25 | 0·04 | 5·7 | 35·0 | 36·0 | 17·1 | 88·1 |
| H. Golay, London | 2494 | S.r., g.b., d.o., chronograph, "Karrusel" | +1·7 | +2·0 | +2·7 | +4·5 | +4·4 | 0·3 | 0·03 | 4·5 | 34·4 | 35·6 | 18·1 | 88·1 |
| Montandon-Robert, Geneva | 1208 | D.r., g.b., s.o., repeater, clock | −2·0 | −3·2 | +1·1 | −0·3 | −2·8 | 0·3 | 0·01 | 5·7 | 34·0 | 34·1 | 19·1 | 87·2 |
| A. and N. C. S., Ltd., London | 8770 | S.r., g.b., d.o., "Karrusel" | −0·6 | −0·1 | −0·3 | +0·1 | +0·5 | 0·3 | 0·07 | 5·5 | 33·2 | 38·8 | 15·2 | 87·2 |
| Barraud & Lund, London | 3<br>4681 | D.r., fusee, d.o. | +1·6 | +1·0 | +3·0 | +1·5 | +2·5 | 0·4 | 0·03 | 4·2 | 31·8 | 37·3 | 17·7 | 86·8 |
| H. Golay, London | 1580 | S.r., g.b., s.o., "Karrusel" | −1·3 | −0·3 | +0·1 | −1·8 | −2·8 | 0·3 | 0·06 | 5·5 | 34·0 | 36·3 | 16·3 | 86·6 |
| T. Russell & Sons, Liverpool | 101096 | S.r., g.b., s.o., "Karrusel" | +2·8 | +4·0 | +3·9 | +0·0 | +3·8 | 0·3 | 0·04 | 6·7 | 34·0 | 35·2 | 17·3 | 86·5 |
| R. Milne, Sale | 1299 | S.r., g.b., s.o., "Karrusel" | +2·0 | +2·2 | +2·1 | +2·7 | +1·3 | 0·5 | 0·05 | 3·5 | 30·7 | 38·7 | 17·0 | 86·4 |
| A. M. Jacobs & Co., London | 12161 | S.r., g.b., s.o., "Karrusel" | −2·1 | −0·8 | +0·6 | −0·7 | −1·0 | 0·4 | 0·06 | 5·5 | 32·2 | 37·5 | 16·3 | 86·0 |
| W. Matthews, Coventry | 101089 | S.r., g.b., s.o., "Karrusel" | +1·1 | −0·1 | +1·0 | +0·2 | +3·5 | 0·5 | 0·01 | 5·5 | 30·6 | 36·3 | 19·1 | 86·0 |
| A. E. Fridlander, Coventry | 25624 | S.r., g.b., s.o., "Karrusel" | +3·9 | +4·5 | +4·5 | +3·0 | +3·5 | 0·3 | 0·09 | 6·2 | 33·9 | 38·0 | 14·0 | 85·9 |
| ,, ,, | 25620 | S.r., g.b., s.o., "Karrusel" | −1·8 | −0·8 | −1·0 | −0·0 | −2·5 | 0·4 | 0·05 | 4·5 | 32·5 | 36·9 | 16·5 | 85·9 |
| C. J. Marlow, Coventry | 21957 | S.r., g.b., s.o., "Karrusel" | −1·1 | −0·7 | −0·7 | −1·7 | −2·9 | 0·4 | 0·03 | 3·7 | 31·0 | 37·1 | 17·8 | 85·9 |
| R. Milne, Sale | 1352 | S.r., g.b., s.o., "Karrusel" | −2·8 | −2·8 | −2·7 | −2·1 | +0·5 | 0·3 | 0·06 | 5·7 | 33·5 | 36·0 | 16·3 | 85·8 |
| W. Ehrhardt, Ltd., Birmingham | 494567 | S.r., g.b., s.o. | −1·5 | −1·0 | −2·1 | +0·5 | −0·5 | 0·4 | 0·03 | 7·0 | 32·0 | 35·8 | 18·0 | 85·8 |
| Chas. Frodsham & Co., London | 08868 | D.r., g.b., s.o., "Tourbillon" lever | +2·2 | +1·8 | +2·3 | +0·3 | +1·7 | 0·4 | 0·06 | 5·7 | 31·7 | 37·9 | 16·2 | 85·8 |
| J. Hewitt, Coventry | 57896 | D.r., g.b., s.o. | −1·8 | −1·8 | −0·8 | −2·6 | −0·5 | 0·4 | 0·04 | 4·7 | 31·1 | 37·2 | 17·5 | 85·8 |
| H Golay, London | 1572 | S.r., g.b., s.o., "Karrusel" | +4·5 | +4·1 | +4·9 | +5·1 | +7·0 | 0·4 | 0·05 | 5·7 | 31·7 | 37·0 | 17·0 | 85·7 |

Table I—*continued.*

| Watch deposited by | Number of watch. | Escapement, balance spring, &c. | Mean daily rate. | | | | | Mean variation of daily rate. ± | Mean change of rate for 1° F. | Difference between extreme gaining and losing rates. | Marks awarded for | | | Total Marks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pendant up. | Pendant right. | Pendant left. | Dial up. | Dial down. | | | | Daily variation of rate. | Change of rate with change of position. | Temperature compensation. | |
| | | | | | | | | | | | 0—40 | 0—40 | 0—20 | 0—100. |
| | | | secs. | secs. | secs. | secs. | secs. | secs. | secs. | secs. | | | | |
| H. Williamson, Ltd., London | 56788 | S.r., g.b., s.o., "Karrusel" | −1·6 | +0·2 | +0·5 | +2·9 | +2·4 | 0·3 | 0·05 | 6·0 | 34·5 | 34·6 | 16·5 | 85·6 |
| S. Smith & Son, London | 240–1 | D.r., fusee, d.o., "Tourbillon" lever | +0·8 | −0·7 | −0·9 | +1·0 | +3·2 | 0·3 | 0·05 | 5·2 | 34·0 | 35·2 | 16·4 | 85·6 |
| W. Hurcomb, London | 56324 | S.r., g.b., s.o., "Karrusel" | −0·9 | −0·9 | +0·4 | +0·8 | +0·8 | 0·4 | 0·04 | 3·5 | 31·4 | 36·8 | 17·4 | 85·6 |
| A. E. Fridlander, Coventry | 25640 | S.r., g.b., s.o., "Karrusel" | −2·1 | −2·6 | −4·0 | −0·7 | −1·4 | 0·4 | 0·05 | 5·0 | 32·8 | 36·3 | 16·4 | 85·5 |
| Usher & Cole, London | 30723 | S.r., fusee, s.o., "Karrusel" | +1·9 | +1·3 | +1·8 | +2·4 | +3·3 | 0·5 | 0·04 | 4·7 | 30·8 | 37·7 | 17·0 | 85·5 |
| A. E. Fridlander, Coventry | 25618 | S.r., g.b., s.o., "Karrusel" | −0·8 | −1·0 | −1·9 | −2·3 | −1·7 | 0·3 | 0·09 | 6·7 | 33·4 | 38·0 | 14·0 | 85·4 |
| H. Williamson, Ltd., London | 56786 | S.r., g.b., s.o., "Karrusel" | −0·1 | −0·2 | −0·2 | +2·6 | +1·1 | 0·3 | 0·06 | 4·5 | 33·3 | 36·1 | 15·9 | 85·3 |
| H. Golay, London | 1566 | S.r., g.b., s.o., "Karrusel" | +0·1 | +1·0 | +0·8 | +2·5 | −1·4 | 0·4 | 0·05 | 5·5 | 32·6 | 36·1 | 16·6 | 85·3 |
| S. Yeomans, Coventry | 85224 | S.r., g.b., s.o., "Karrusel" | −0·3 | +0·2 | +0·4 | +1·2 | +0·5 | 0·3 | 0·10 | 6·5 | 33·0 | 38·6 | 13·5 | 85·1 |
| H. Williamson, Ltd., London | 56784 | S.r., g.b., s.o., "Karrusel" | +0·1 | +1·1 | +0·1 | +3·0 | +4·0 | 0·3 | 0·05 | 5·3 | 34·2 | 34·1 | 16·7 | 85·0 |
| Wales & McCulloch, London | 3483 | S.r., g.b., s.o., chronograph, "Karrusel" | −4·1 | −3·5 | −4·4 | −1·8 | −3·5 | 0·3 | 0·09 | 5·5 | 33·3 | 37·3 | 14·2 | 84·8 |
| A. E. Fridlander, Coventry | 25631 | S.r., g.b., s.o., "Karrusel" | −1·4 | −0·3 | +1·1 | +0·8 | +0·3 | 0·4 | 0·06 | 4·5 | 31·9 | 37·0 | 15·9 | 84·8 |
| W. Matthews, Coventry | 101037 | S.r., g.b., s.o., "Karrusel" | −0·0 | −1·1 | +0·4 | −1·7 | +0·2 | 0·3 | 0·09 | 7·2 | 33·6 | 36·9 | 14·2 | 84·7 |
| A. E. Fridlander, Coventry | 25638 | S.r., g.b., s.o., "Karrusel" | −1·8 | −2·2 | −2·2 | +1·5 | +0·4 | 0·3 | 0·05 | 5·0 | 33·5 | 34·2 | 16·9 | 84·6 |
| ,, ,, | 25604 | S.r., g.b., s.o., "Karrusel" | +1·1 | +0·7 | +0·1 | +2·0 | +0·7 | 0·3 | 0·10 | 5·5 | 33·3 | 38·0 | 13·3 | 84·6 |
| S. Yeomans, Coventry | 76644 | S.r., g.b., s.o., "Karrusel" | +1·0 | +0·4 | +0·1 | +3·6 | +1·4 | 0·3 | 0·07 | 4·7 | 33·1 | 36·2 | 15·2 | 84·5 |
| Russells, Ltd., Liverpool | 88053 | S.r., g.b., s.o. | −2·9 | −2·6 | −1·8 | −0·8 | −1·2 | 0·4 | 0·07 | 4·3 | 31·7 | 37·2 | 15·6 | 84·5 |
| S. Yeomans, Coventry | 85222 | S.r., g.b., s.o., "Karrusel" | −1·5 | −1·4 | −1·2 | +0·2 | −0·4 | 0·5 | 0·05 | 4·0 | 30·4 | 37·6 | 16·5 | 84·5 |
| Thos. Kinder, Coventry | 57653 | S.r., g.b., s.o., "Karrusel" | −3·2 | −2·4 | −2·9 | −1·9 | −4·6 | 0·6 | 0·02 | 5·0 | 28·4 | 37·1 | 18·9 | 84·4 |
| Barraud & Lund, London | 3/4686 | D.r., fusee, d.o. | +3·6 | +6·6 | +3·7 | +1·9 | +5·7 | 0·4 | 0·04 | 9·0 | 32·9 | 34·1 | 17·2 | 84·2 |
| Williamson, Ltd., London | 56829 | S.r., g.b., s.o., "Karrusel" | −4·4 | −2·2 | −2·6 | −0·4 | −1·2 | 0·4 | 0·04 | 5·5 | 31·5 | 35·6 | 17·1 | 84·2 |
| Usher & Cole, London | 30713 | S.r., g.b., s.o. | +4·5 | +3·4 | +0·7 | +2·6 | +2·8 | 0·5 | 0·04 | 6·2 | 30·4 | 36·3 | 17·5 | 84·2 |
| Jos. White & Son, Coventry | 37271 | D.r., g.b., s.o. | −1·5 | −3·2 | −2·9 | −1·0 | −1·8 | 0·5 | 0·04 | 4·8 | 29·9 | 36·9 | 17·4 | 84·2 |
| C. J. H. Marlow, Coventry | 21161 | S.r., g.b., s.o. | −3·1 | −2·2 | −2·6 | −4·2 | −5·4 | 0·5 | 0·02 | 5·5 | 29·5 | 35·8 | 18·9 | 84·2 |

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 | | | Total marks. |
|---|---|---|---|---|---|---|
| | | | Variation. | Position. | Temperature. | |
| | | | 0—40 | 0—40 | 0—20 | 0—100. |
| Minute and split seconds chronograph, repeater, and perpetual calendar, with phases of the moon ..... Tourbillon | 1901–24 | S. Smith and Son, London .... | 34·0 | 36·5 | 13·3 | 83·8 |
| Minute and split seconds chronograph, and minute repeater Tourbillon | 1901–17 | S. Smith and Son, London .... | 29·7 | 37·7 | 15·3 | 82·7 |
| ,, ,, ,, ,, Tourbillon | 08867 | Chas. Frodsham, London .... | 29·7 | 30·0 | 18·7 | 78·4 |
| ,, ,, ,, ,, ..... | 196170 | Stauffer, Son and Co., London | 24·8 | 34·2 | 16·1 | 75·1 |
| Minute and split seconds chronograph ..... Karrusel | 2494 | Golay, London ..... | 34·4 | 35·6 | 18·1 | 88·1 |
| ,, ,, ,, ..... Karrusel | 3483 | Wales and McCulloch, London | 33·3 | 37·3 | 14·2 | 84·8 |
| ,, ,, ,, ..... Tourbillon | 1901–20 | S. Smith and Son, London.... | 28·6 | 34·0 | 15·4 | 78·0 |
| Minute and seconds chronograph ..... | 260538 | Baume and Co., London ..... | 31·2 | 32·6 | 19·4 | 83·2 |
| ,, ,, ,, ..... Karrusel | 133133 | Newsome and Co., Coventry .. | 27·9 | 36·5 | 16·3 | 80·7 |
| ,, ,, ,, ..... | 50750 | E. Dent and Co., London .... | 29·2 | 33·5 | 14·5 | 77·2 |
| ,, ,, ,, ..... | 260528 | Baume and Co., London..... | 30·4 | 27·3 | 18·5 | 76·2 |
| Minute repeater and clock ..... | 1208 | Montandon-Robert, Geneva .. | 34·0 | 34·1 | 19·1 | 87·2 |
| ,, ,, ,, ..... | 11365 | Nicole Nielsen and Co., London | 27·0 | 32·2 | 11·3 | 70·5 |
| Non-magnetic ..... | 25628 | Fridlander, Coventry ..... | 34·4 | 31·5 | 15·7 | 81·6 |
| ,, ..... | 170–411 25622 | S. Smith and Son, London .... | 31·8 | 32·4 | 17·4 | 81·6 |
| ,, ..... | 28236 | Player and Son, Ltd , Coventry | 27·4 | 34·5 | 14·9 | 76·8 |
| ,, ..... | 57743 | John Hewitt, Coventry ..... | 29·5 | 28·2 | 17·7 | 75·4 |