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A Comparison of the Records from British Magnetic Stations

Underground and Surface

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A COMPARISON OF THE RECORDS FROM BRITISH MAGNETIC STATIONS UNDERGROUND AND SURFACE

§ 1. Introduction.

From March, 1918, until the end of 1924, when the work was taken over by the Astronomer Royal, weekly tables of two-hourly values of D (magnetic declination), as obtained from the magnetographs of Kew Observatory, were issued to various representative individuals and to certain mining journals. Hours of exceptional magnetic disturbance were indicated by an asterisk, for the warning of engineers who might have been observing at the time. In June, 1918, a paper* on this and allied subjects by one of the authors was read before the Institution of Mining Engineers, and was discussed by a number of men with practical knowledge of surveying. Questions were put as to the difference between the magnetic variations in different parts of the country, and as to the possible differences between the surface and underground. Partly with a view to answering the questions thus raised, a comparison† was subsequently instituted between the movements regular and irregular shown by the magnetic curves of Kew, Eskdalemuir, Stonyhurst and Falmouth Observatories. None of these stations, however, is in a mining area, and none is underground.

So far as we are aware, the only investigation in which simultaneous records had been obtained from two near stations, one underground and one at the surface, had been carried out in 1906 near Dortmund, in Germany. A short account was published by Prof. Ad. Schmidt, of Potsdam, in *Terrestrial Magnetism*, Vol. XI, 1906, p. 181, and in the *Meteorologische Zeitschrift* for 1907, p. 130. The instruments in use at Dortmund in the underground and surface stations were identical, consisting of a vertical force instrument and a unifilar instrument, the latter functioning for part of the time as a D instrument, and for the rest of the time as an H (horizontal force) instrument. According to Dr. Schmidt, the apparent differences between the underground and surface records were trifling, and doubt was entertained as to their source, whether natural or artificial. Dr. Schmidt referred to a careful examination of instrumental constants and extensive reduction of the observations as being contemplated, but so far as we know no further discussion of the results has appeared.

Quite apart from Dr. Schmidt's conclusions we did not expect to find any large difference between magnetic changes underground and at the surface, under normal conditions ; because if any considerable difference existed normally, it could hardly have failed to disclose itself long ere this. But any differences that existed might be greater in Britain than in Germany, and further observations were obviously desirable especially during times of magnetic disturbance.

At this stage, in 1920, Mr. T. G. Bocking, M.I.Min.E., of Birmingham, entered into correspondence with us, and obtained the loan from the Director of the Meteorological Office of two eye-reading declinometers with which simultaneous observations might be taken underground and at the surface. The eye-reading instruments had, however, the disadvantage of requiring continuous readings over long periods of time by two observers, and experience showed that it was difficult to avoid interference with the routine work of the mine. This suggested the expediency of using magnetographs. There happened fortunately to be at Kew Observatory a variety of old pieces of apparatus, and, the approval of the Director of the Meteorological Office having been obtained, one of us (R. E. W.), out of the material available, put together two declination magnetographs. Mr. Bocking, with whom we were co-operating, undertook to secure facilities for the installation and running of the instruments in a suitable mine, and he obtained the co-operation of Mr. H. W. Hughes, General

* *Transactions of the Institution of Mining Engineers*, Vol. 55, p. 223.

† Meteorological Office, *Geophysical Memoirs* No. 17, 1921.

Manager of the Diamond Jubilee Pit at Sandwell Park Colliery, West Bromwich. The scheme obtained the approval of the Director of the Meteorological Office, who also gave permission for Mr. Watson to set up the instruments and pay occasional visits of inspection.

§ 2. Instruments.

The instruments available consisted of the two D magnetographs already mentioned, and of an H magnetograph designed by Mr. O. Krogness of Tromsö for use in high latitudes. This instrument was rather insensitive, but the insertion of additional mirrors, giving a longer optical path between the magnet mirror and the photographic paper, rendered it suitable for the object in view. The transformation of the two D instruments entailed the fitting of fixed mirrors for the base lines, and the suspension of suitable mirror magnets. The silk suspensions used were so fine that the scale values required no correction for torsion. Turning the torsion head through 90°, in fact, altered the reading by only some 2′. Unfortunately only one non-magnetic clock drum was available which rotated like the ordinary magnetograph drum about a horizontal axis. Thus for one of the instruments use had to be made of a vertical drum, a prism and mirror being employed to convert the horizontal motion of the magnet into vertical motion for the spot of light. The instrument thus fitted with a prism is referred to hereafter as No. I, the other being known as No. II. Initially No. I was at the surface, and No. II underground; but in view partly of their difference of type, they were interchanged half way through the investigation, so as to eliminate the effects of any possible instrumental peculiarities.

As facilities existed at the mine for charging accumulators, it was decided to use low voltage electric light for the magnetographs. After experimenting with several lamps, one pattern was found which answered admirably. This was a small 2-volt lamp with a straight filament about 0·75 cm. long. For full illumination it required only 0·1 ampère, thus the type of accumulator available, with a capacity of 24 ampère-hours, supplied the current necessary for a week's run, without risk of loss of trace. The lamp was covered with black paper, and a fine vertical razor-cut running parallel to the filament served in place of the usual illuminated slit.

It was expected that once the instruments were set up, expert professional attention would be required only occasionally for the determination of scale values and general supervision. But it was clearly essential that some one living in the neighbourhood should undertake the daily work which the running of magnetographs entails. This difficulty was overcome by the kind intervention of Mr. Bocking, who arranged with his partners, Messrs. J. H. Bailey and C. H. Bailey, that one of their assistant surveyors, Mr. S. W. Howarth, should take charge of this work. Mr. Howarth received the necessary instruction when the instruments were installed, and he performed his somewhat monotonous duties in a very satisfactory manner. The risk entailed by sending undeveloped photographs through the post was avoided through the kindness of Messrs. S. and J. Bailey, who allowed Mr. Howarth to develop the charts at their office. The sheets when developed were usually sent to Kew in weekly batches.

The three magnetographs were run on trial at Kew Observatory prior to their installation at the mine. In view of the considerable distance inevitable between underground and surface stations and other circumstances, it was obviously impossible to employ a time shutter actuated by a common clock. Also the driving clocks were entirely enclosed in the recording drums, and no method of time marking by the individual clocks appeared feasible. Accuracy of time thus depended on the accuracy of the time marks which were made on each sheet at the start and finish of each day's run, and on the uniformity in the rate of rotation of the clock drums. Careful observations on the latter point were made at Kew Observatory, and the results appeared satisfactory. Before the curves were measured, hour marks were put on each sheet, the interval between the beginning and ending time marks being carefully subdivided.

To face p. 4.

MAP SHOWING POSITION OF MAGNETOGRAPH STATIONS

Scale - 6" to 1 mile

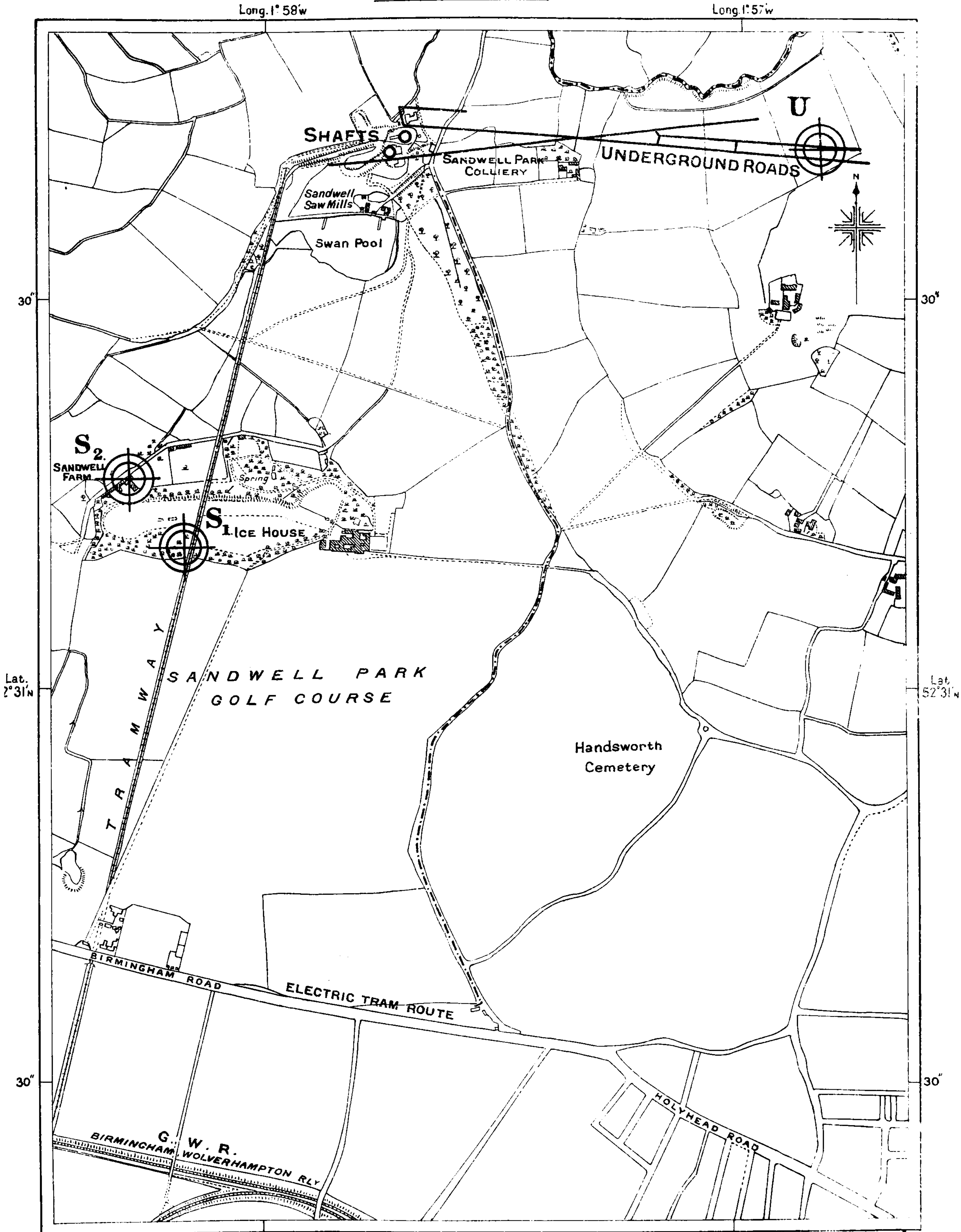


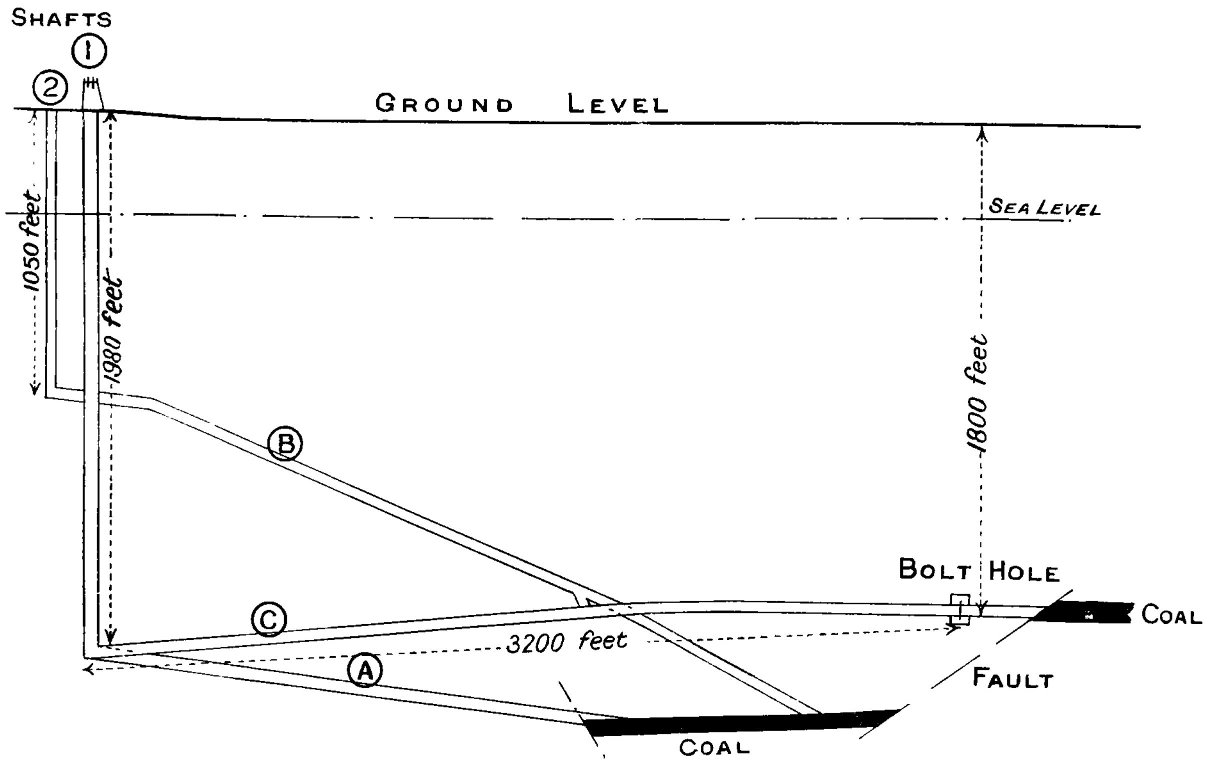
FIG. I

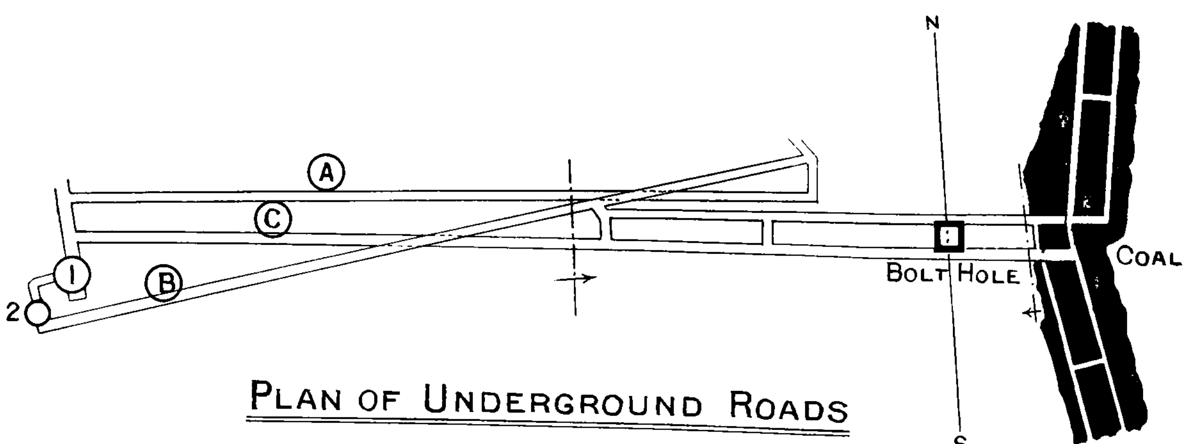
To face p. 5.

Sandwell Park Colliery.

Jubilee Pit.

Section through Ground showing Underground Workings, on East Side of Shafts.





Plan of Underground Roads

FIG. 2.

§ 3. Installation of the Apparatus.

The magnetographs were taken to Sandwell Park Colliery by Mr. Watson on March 26th, 1923. Two stations had been selected by Mr. Bocking, one S_1 at the surface, the other U underground. Their respective positions are shown in Fig. 1. As already mentioned, No. I declination instrument was originally set up at the surface station, while No. II and the *H* magnetograph were set up in the mine. The U station was the so-called " Bolt-hole," a cross cut running between the intake and return airways. Details of the relative positions of the instruments in the " Bolt-hole" are shown in Fig. 3. The two air ways were 100 feet apart, and the Bolt-hole was 1,800 feet below the surface, and 3,200 feet from the main shaft (see Fig. 2). The cables for supplying electric power to the pumps underground ran down the main shaft, but no disturbing effect due to them was detected. Two big wooden doors were fitted about 30 feet apart in the middle of the Bolt-hole. These excluded draughts, and being kept locked were a safeguard against unscientific curiosity. The in-take airway, running approximately east and west, was a main haulage road, down which were laid double tracks of narrow gauge iron rails, along which were drawn coal tubs to and from the coal seam by means of a continuous cable. These tubs, which were made of stout sheet iron, were generally in motion from 6 a.m. to 2 p.m. daily. A magnetic survey of the Bolt-hole, effected with a vibrating magnet whose time of vibration was observed, did not reveal any variation in the field arising either from fixed iron or the coal tubs. The geological structure of the mine itself would seem to have been non-magnetic, judging by the following description supplied by Mr. Bocking : " The underground station was in soft red sandstone and red shales of the coal measures, lying immediately above the ' thick coal ' of South Staffordshire. These coal measures are part of those lying below the Triassic rocks on the eastern side of the South Staffordshire coal field. Immediately below these is an unconformity, and the Cambrian rocks lie not far below the thick coal. So far as is known, there is no large mass of igneous rock within a lateral distance of 10 miles. The thick coal comes in at about the same level as the Bolt-hole, 100 yards to the north, and coal in the down throw side of the fault lies about 130 yards below."

As Fig. 3 shows, the *D* magnetograph No. II was to the north of the *H* magnetograph, and 15 feet from it. The recording drum was set up at an effective distance of 71·2 inches from the magnet mirror, due allowance being made for the optical system, giving a scale value of 0′·95 per mm. of ordinate. The *H* magnetograph was placed with its long axis, to which the magnetic needle when in adjustment was parallel, running magnetic east and west. The suspension of the magnet was a fine phosphor bronze wire, of diameter 0·0018 inch. The suspension which had been fitted at Kew was unfortunately broken through an accident in the dark, and a new suspension had to be fitted on the day of installation in the mine. Not unnaturally a slight drift ensued for a few days. The wire being rather fine, the torsion head had to be turned through about 450° to bring the magnet perpendicular to the magnetic meridian, and after registration had commenced it was found that the twist had been given in the direction which made *H* increase down the sheet, instead of up it as at Kew. It was decided to make no change, as it was immaterial so far as hourly measurements are concerned which was the direction of increasing force on the sheet. But the difference in the directions of increasing force on the Sandwell Park and Kew sheets made differences between the two traces less easy to recognize on superficial inspection.

The *D* and *H* underground instruments were each set up in a specially prepared non-magnetic concrete bed, and when finally adjusted were fixed in position by means of plaster of Paris. The accumulators were connected to the illuminating lamps by long leads, and placed in fixed positions so far from the magnetographs as to exert no sensible magnetic effect on the magnets. Special non-magnetic electric hand lamps were supplied by Mr. Bocking for use when visiting the instruments, so that no spurious effects were introduced at these times.

A thermograph with a weekly chart and a control mercury thermometer were installed on a shelf at the side of the Bolt-hole. But temperature was found to be practically constant, so that no temperature correction was required.

§ 4.—Surface Stations at Sandwell Park.

The country surrounding the colliery was quite open, mainly meadow and woodland, with a few farm houses scattered about. The nearest main road lay to the south about ¾ mile away, and along it ran electric trams. The first surface station, S_1 in Fig 1, was an ancient ice-house used by a former Earl of Dartmouth for preserving ice taken from a neighbouring pond. It consisted of an egg-shaped brick-lined cavity, the bottom being about 15 feet below, and the top about 8 feet above ground level. The greatest width was about 10 feet. The building was covered with earth and turf. The only entrance was through a hole 3 feet square, situated near the top of the ice-house, at the end of a short tunnel on its north side. The place was made light tight by doors at the two ends of the tunnel and a curtain over the entrance. The *D* magnetograph No. I was set up here fitted on a stout bench, running roughly east and west, which was supported about three feet above the floor by letting the ends into the brick walls of the house. The effective air distance between the magnet mirror and the drum was 71·2 inches, as in the case of No. II, so that the scale value was the same as for that instrument.

About 25 feet from the ice-house there ran in a north-south direction a double narrow gauge railway, along which the iron coal tubs were hauled in opposite directions by an endless cable. This went on usually from 7 a.m. to 2 p.m., but no disturbance consequent on the moving tubs was noticeable on the trace. The magnetograph had been installed for only about a week when, as a result of heavy rains, water being to collect in the ice-house, and as it continued to rise in spite of daily bailing, it was deemed prudent to search for another site for the magnetograph. At this stage Mr. Charles, the Chief Engineer of the Colliery, kindly placed at our disposal a dry cellar forming part of his own house. A magnetic survey of the cellar showed no variations in the field suggestive of disturbance due to local iron. The house, which formed part of the old Sandwell Park Farm House, was satisfactorily isolated. Its position, S_2, is shown in Fig. 1. It was about 300 yards north-west of the ice-house, and about the same distance from the coal haulage railway. The cellar was in the front of the house, past which ran a road leading from the colliery. This, however, was a quiet country lane, and was seldom used except by a few pedestrians. The cellar was quite dark and dry and around the sides was built a stone slab shelf about two feet wide and two feet high. To serve as a bench to accommodate the apparatus, two wooden deals 3 inches by 9 inches were set side by side across the cellar in an east-west direction, and fixed rigidly to the stone slab on which their ends rested, see Fig. 4. The magnetograph was installed at S_2 on April 19th. The effective distance between magnet-mirror and recording drum was now 75·2 inches, giving the slightly reduced scale value of 0′·90 per mm.

§ 5. Difficulties.

After registration had commenced it was found that both the surface and the underground traces were affected from about 5 a.m. to midnight by some artificial source of disturbance. A process of elimination identified this with the Handsworth electric trams, which ran within ⅔ of a mile of S_2 and within 1⅓ miles of U. The effect in the traces was comparatively small, and there was no difficulty in the measurement of mean hourly values. It was more troublesome when it came to measuring the amplitude of individual irregular movements. The hours when the disturbance was greatest were, however, also the hours when artificial disturbance was greatest at Kew. When comparing irregular movements it would have been necessary in any case to confine our attention mainly to the night hours, so this disadvantage was comparatively trifling.

Another source of trouble was the high relative humidity in the mine. Moisture condensed on all exposed glass surfaces. As condensation proceeded, the light passing from the lamp to the photographic paper became gradually reduced, and the trace tended to become too faint for measurement. This difficulty was largely overcome by lightly smearing the glass with soap, and then polishing with a dry cloth. The thin film of soap left prevented condensation.

To face p. 6.

PLAN OF "BOLT HOLE".

Scale 1/4" to 1'

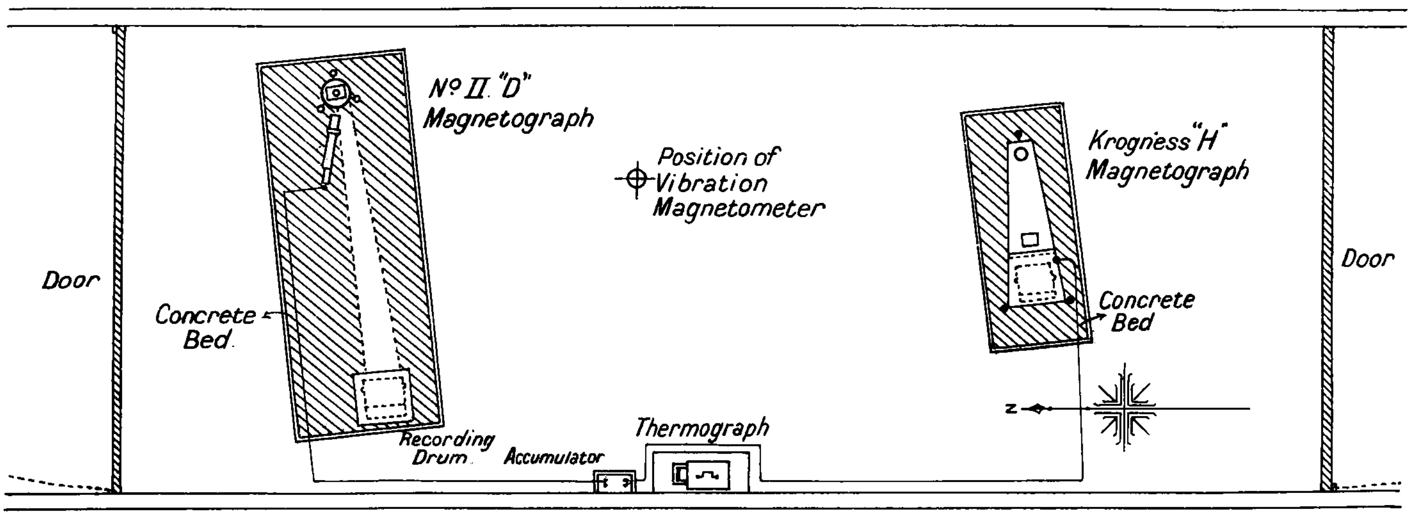


FIG. 3.

PLAN OF MR. CHARLES'S CELLAR.

Scale 1/2" to 1'.

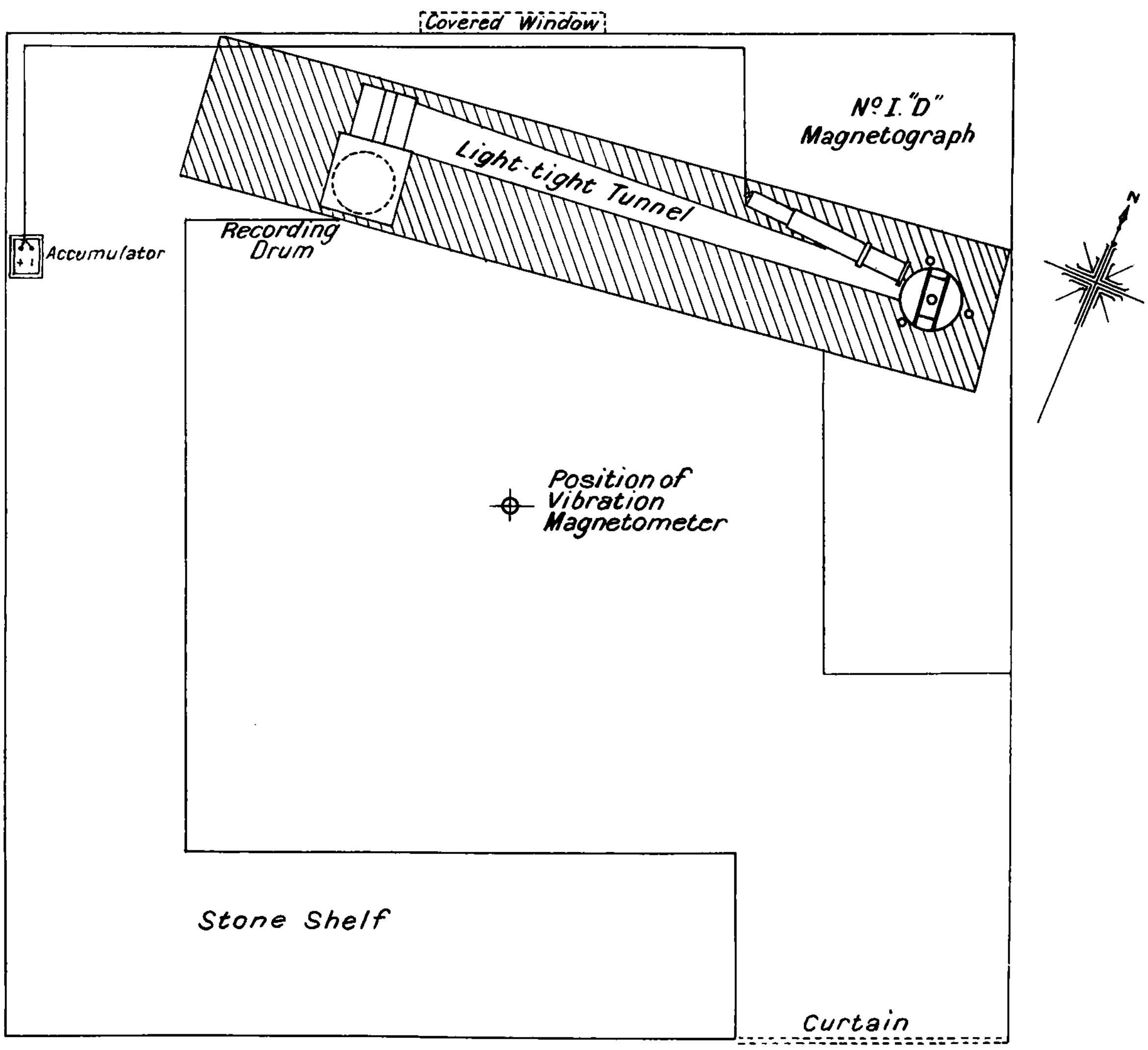


FIG. 4

Some trouble was experienced from interruptions of the underground traces which at first seemed somewhat mysterious. They were found to be due to insects of a species numerous in mines, which interrupted the light when crawling over the instruments. The surface traces, on the other hand, suffered a little from spiders, which spun their webs where they interfered with the light, but this trouble was surmounted by a liberal use of camphor.

One of the difficulties of the situation was that when any accident befell an instrument which required specialist knowledge to detect, or to put right, record was apt to be lost for several days. The first of the more serious accidents occurred on 11th June, when the underground *D* instrument was struck by stone falling from the roof of the Bolt-hole. The suspension was broken, and could not be replaced until Mr. Watson's visit on the 18th.

The time for which trace was lacking unfortunately included the 13th and 14th, the most disturbed days of the month. The plaster of Paris had prevented any change in the relative positions of the pieces of apparatus, so the scale value was unaffected. Repairs could not be made to the roof of the Bolt-hole without disturbing the apparatus, so protecting baulks of timber were set up temporarily in case of a further fall.

Another accident of a more subtle kind befell the surface declination instrument near the end of September. The cause was not discovered until Mr. Watson's visit on 7th October, when it was found that through a slight change in the level of the instrument there was grazing contact between the magnet clip and the suspension tube. During a quiet time obstruction of this kind manifests itself through approach in the trace to a straight line, but during a disturbed time it may not appeal to the eye. As it happened, the incident occurred at what was perhaps the most disturbed period of the year, including two really highly disturbed days, 27th and 28th September. It was only when the curves were measured that the diminished amplitude of the movements at S_2 in these days, as compared with the corresponding movements at the underground station and at Kew Observatory, put the existence of some obstruction beyond a doubt. Even with an expert on the spot immediate detection would have been unlikely, and under the circumstances it is fortunate that the time during which the trace was valueless was only about ten days.

§ 6. Interlude and Interchange of Declination Instruments.

With the approach of the holiday season, it was decided to suspend operations during July and August. As it was undesirable to leave the instruments unattended in the damp atmosphere of the mine, they were brought to the surface and stored in a dry room. The opportunity was taken of having the clocks in the recording drums cleaned and oiled by a clockmaker. The removal of the magnetographs also enabled the roof of the Bolt-hole to receive attention.

As already stated, when work was resumed in September the opportunity was taken of interchanging the two *D* instruments, so that during the remainder of the time No. I was underground, and No. II in Mr. Charles's cellar (see Fig. 4). In the resetting of the instruments the effective air distances between the magnet mirrors and recording drums were slightly altered, the new scale values being 0′·92 per mm. for No. I and 0′·95 per mm. for No. II.

The Krogness *H* magnetograph was replaced in its former position in the south concrete bed in the Bolt-hole. The magnetographs ceased to operate on 13th November, when they were packed and brought back to Kew Observatory. They were re-erected there in the "Experimental House," and were run for a time to test their behaviour.

§ 7. Scale Values.

During the progress of the work a good many determinations were made of the scale values of the *H* magnetograph, some by Mr. Watson and some by Mr. Howarth. A selection of the results is given in Table I, mainly with a view to showing the considerable difference in the sensitiveness during the first and second periods. When the instrument was finally set up at Kew a further decline in sensitiveness was found to have occurred, scale value determinations made in December giving 1 mm. = 8·0γ.

The reality of these somewhat large changes is borne out by the changes that were observed in the vibration time of the magnet. This was 23·0 sec. on 27th March, 17·4 sec. on 13th November, 1923, and 15·4 sec. on 11th January, 1924. The scale value should vary roughly as the inverse square of the time of vibration, and this will be found to hold true in the present case. The cause of the change was a fall in the moment of the magnet, which was presumably not a very stable one, and which must have received some mechanical or magnetic shock between the two periods of its use in the mine and during transport to Kew. The weaker a magnet becomes the smaller is the angle of torsion required to bring it perpendicular to the magnetic meridian, and consequently the larger the fraction of local H, which answers to a given change in the torsion angle.

TABLE I.—SCALE VALUE DETERMINATIONS OF (KROGNESS) H MAGNETOGRAPH.

Series A.—1 mm. in D = 0′·95 ≡ 4·97γ (assuming H = 0·180 C.G.S.).

DATE, 1923.	DOUBLE DEFLECTION IN MILLIMETRES.								Scale Value per mm.
	H Instrument.				*D* Instrument.				
	Magnet on				Magnet on				
	South Arm.		North Arm.		East Arm.		West Arm.		
	80 cm.	90 cm.	80 cm.	90 cm.	80 cm.	90 cm.	80 cm.	90 cm.	γ
May 16	81·2	54·3	79·0	54·7	63·6	44·0	60·8	43·0	3·91
June 7	78·9	54·6	76·8	51·8	61·2	44·2	61·0	43·2	3·99
Mean	—	—	—	—	—	—	—	—	3·95
Series B.—1 mm. in D = 0′·92 ≡ 4·82γ (assuming H = 0·180 C.G.S.).									
Oct. 29	51·9	33·4	48·6	33·8	65·3	45·3	65·3	43·9	6·33
November 7	51·0	32·9	48·4	34·8	64·9	46·1	62·3	43·9	6·31
November 12* ..	52·0	—	48·0	—	64·9	—	64·1	—	6·22
Mean	—	—	—	—	—	—	—	—	6·30

* Allowed only half weight.

The times of vibration were also taken on several occasions of the magnets in both D magnetographs. In their case, of course, a fall of moment would have led to an increase in the time of vibration at a fixed temperature. As a matter of fact, however, no certain change of the period was detected in either instrument.

No attempt was made to find the absolute value of D at either the surface or the underground station. In the mine, of course, observations on sun or stars to determine the geographical meridian accurately were impossible, and that being so exact evaluation of D at the surface station seemed uncalled for.

As regards H, *comparative* values at the two stations and at Kew Observatory were obtained on several occasions by taking the time of swing of a Kew collimator magnet (marked N E) in the magnet box of Unifilar Jones 102, which was attached rigidly to a fixed tripod stand. In the observations in the mine the scale carried in the magnet had to be artificially illuminated, but the magnet was shielded from any sensible heating effect. The usual procedure was to observe with a Kew certificated chronometer watch the time of three sets each of 25 vibrations. The watch gave fifths of seconds, and its satisfactory going was checked against the standard clock at Kew before and after each visit to Sandwell Park. The temperature co-efficient of the magnet had been determined, and due allowance was made for the difference of temperature on the several occasions. The results were as consistent as could reasonably be expected under the circumstances. Accepting for Kew 0·1839 C.G.S., the mean of the curve values on the occasions of observation, the values obtained for the surface and underground stations were as follows :—

Station.	*H*.
S_1	0·1792
S_2	0·1798
U	0·1808

The difference between the results for S_1 and S_2 might well be due to observational uncertainties. The resulting mean 0·1795 may be taken as a fair approximation to the surface value of H at the station. This derives some support from the results of the surveys by Rücker & Thorpe* and by G. W. Walker.†

These give the following results :—

	Epoch 1891.	Epoch 1915.
Kew Observatory	0·1820	0·1848
Birmingham‡‡ (52° 25′·5 N, 1° 52′·2 W)	0·1777	0·1799
Excess of Kew	·0043	·0049

Birmingham was included in Walker's district vi, and Kew in his district viii. The secular changes deduced by Walker for these two districts for the 29 years, 1st January, 1886, to 1st January, 1915, were respectively $+389\gamma$ and $+392\gamma$, and so were practically equal. Thus the difference between the two values given above for the excess of H at Kew over H at Birmingham remains unaccounted for, and all we can say is that the value obtained for the excess of H at Kew over H at Sandwell Park, viz., 0·0044, is intermediate between the two.

The apparent excess of H at the underground stations over H at the surface is small, but a larger value was obtained at the underground station on each occasion, so there probably was a small difference in the direction indicated. A difference of the order of 1 part in 200 in H would be of practical significance only in the event of the employment of magnetographs of a very superior kind. To have arrived at a full assurance of its existence and of its amount would have required the taking of several complete observations of H with a unifilar magnetometer and ordinary chronometer. This, no doubt, could have been done, in spite of illumination difficulties, and it is perhaps regrettable that it was not done. But it would have been difficult to fit in owing to the other claims on our time.

§ 8. Observatory Records used.

As Sandwell Park is situated so far to the north of Kew Observatory, it was obviously desirable to compare results with at least one other observatory situated to the north, and Eskdalemuir (55° 19′ N, 3° 12′ W) naturally suggested itself. An obstacle existed, however, to as intimate a comparison as was desirable in the fact that the magnetographs at Eskdalemuir did not record D and H directly, but only N (north component) and W (west component). It is possible, of course, to calculate values of D and H from the corresponding values of N and W, and this is, in fact, quite easy so far as mean hourly values are concerned. But even in that case greater accuracy is possible when the elements compared are the same, and unless the elements are the same intercomparison of irregular movements is practically impossible. Accordingly a third declination magnetograph was put together at Kew Observatory, and was brought into action at Eskdalemuir on 28th May, 1923. All the comparisons of irregular D movements at Eskdalemuir depend on its records, and they also supplied in general the mean hourly values of D. But some hourly values for D, and all the hourly values given for H, were calculated from the hourly values of N and W in the tables prepared by the Eskdalemuir staff.

While the reductions were in progress, the D and H curves from the magnetographs brought into operation at Lerwick (60° 9′ N) in 1923 were sent to Kew Observatory to be reported on. Inspection showed that in general there was no difficulty in identifying the Lerwick D movements corresponding with those at

* *Phil. Trans. R. Soc.* Vol. 188, A, 1896. † *Phil. Trans. R. Soc.* Vol. 219, A, 1919.

‡‡ These are the co-ordinates of Walker's Station. The station occupied by Rücker & Thorpe was slightly different in position (52°27′·6 N, 1°53′·7 W).

Sandwell Park. Thus an extension of the comparison to Lerwick was clearly possible. The facts that the Scottish coal fields extend considerably to the north of Eskdalemuir, and that *H* curves were available for Lerwick and not for Eskdalemuir, pointed to the desirability of the extension, and the necessary work was accordingly undertaken. Mean hourly values of *D* and *H* had been already got out in Scotland, so the additional work called for was comparatively light.

§ 9. Presentation of Results.

The mode of presenting the results was partly determined by the losses of trace in the *D* instruments at Sandwell Park. As it happened, the losses in the two instruments were not usually simultaneous, and the number of days when there was satisfactory registration with both instruments was restricted. The best course seemed to be to select from the days available two groups, one representative of quiet, the other of disturbed conditions.

Table II gives the days thus selected. Such of them as were international quiet or disturbed days are distinguished by heavy type.

There were unfortunately no April days, and only two May days of a quiet character for which *D* data were available for both Sandwell Park stations. The disturbed days available in June were restricted to three, owing to the accident to the underground *D* instrument already mentioned.

Table II.—Selected Quiet and Disturbed Days.

Element.	Month.	Quiet Days.					Disturbed Days.				
D	April	—	—	—	—	—	**12**	**13**	**21**	**22**	24
	May	—	—	—	**22**	**24**	**18**	19	20	**29**	**30**
	June	—	**24**	25	26	29	—	—	**21**	27	**30**
	September ..	**21**	**22**	23	24	25	**26**	**27**	**28**	29	30
	October ..	13	**23**	**24**	28	**30**	**15**	**16**	20	27	31
	November ..	4	**5**	8	**10**	11	7	**12**	—	—	—
H	April	**2**	**5**	**17**	**26**	**27**	**12**	**13**	**21**	**22**	24
	May	**1**	**12**	**13**	**22**	**24**	**3**	**17**	**18**	**29**	**30**
	June	**9**	**10**	**17**	**18**	**24**	**4**	**13**	**14**	**21**	**30**
	September ..	**21**	**22**	23	24	25	—	**27**	**28**	29	30
	October ..	13	**23**	**24**	28	**30**	—	**15**	**16**	27	31
	November ..	4	8	**10**	11	—	7	**12**	—	—	—

The running of the instruments was suspended in July and August, so no data were available for those months. The running was not resumed until the middle of September, so that the choice of both quiet and disturbed days was restricted to the later part of the month. Also, as already explained, the surface *D* traces were unsatisfactory during the 26th and subsequent days. It was thus possible to get disturbed day *D* results only from the underground instrument. The suspension of operations on 13th November gave a possible choice of only two disturbed days for that month.

The possible choice of days was considerably greater in the case of *H*, at least during the earlier months. It was thus possible to employ a larger proportion of the international days. By restricting the quiet and disturbed day groups to not more than five a month, and employing the international days on which the observatory records had to be tabulated in any case, there was a great economy of labour.

Table III gives the mean of the international magnetic character figures—the daily values being taken to 0·1—for the groups of days specified in Table II. The quiet day mean in September is notably higher, and the disturbed day mean in November notably lower than in the case of the true international days, but, with these exceptions, the selected days were better representatives of their class than the limited choice of days would have led one to expect.

TABLE III.—MEAN INTERNATIONAL CHARACTER FIGURES ON SELECTED DAYS.

Month.	*D*		*H*	
	Quiet Days.	Disturbed Days.	Quiet Days.	Disturbed Days.
April	—	1·04	0·08	1·04
May	0·10	1·04	0·10	1·24
June	0·12	0·97	0·08	1·22
September	0·22	1·28	0·22	1·18
October	0·06	1·24	0·06	1·40
November	0·10	0·75	0·10	0·75

§ 10. DIURNAL INEQUALITIES, RANGES, &c., FOR DECLINATION.

Diurnal inequalities were calculated for the quiet and disturbed days of each month separately, but are not reproduced here. So far as the individual months are concerned, we confine ourselves to the ranges and A.D.s given in Tables IV and V The A.D., or average departure, is the arithmetic mean of the 24-hourly differences from the mean of the day which constitute the diurnal inequality. The A.D. is less influenced than the range by the accident of whether the real maximum or minimum falls near an exact hour G.M.T. It gives a better idea than does the range of the general activity of the diurnal inequality forces, especially when the inequality is derived from a few disturbed days and exhibits prominent peaks.

TABLE IV.—DECLINATION, DIURNAL INEQUALITY, RANGES.

Month or Season.	Kew.		S.U.		S.S.		Eskdalemuir.		Lerwick.	
	q	*d*	*q*	*d*	*q*	*d*	*q*	*d*	*q*	*d*
	′	′	′	′	′	′	′	′	′	′
April	—	10·66	—	10·83	—	11·60	—	11·91	—	13·28
May	7·43	10·58	7·82	10·43	7·25	10·73	7·71	11·04	8·49	10·59
June	8·57	11·85	8·29	12·04	8·89	11·91	8·54	12·35	9·53	13·14
September	7·14	11·93	7·28	12·90	7·68	—	7·65	14·56	7·22	18·83
October	5·95	12·17	5·66	12·70	5·98	13·00	6·03	13·94	5·07	16·14
November	4·13	10·00	4·11	10·79	4·38	10·81	4·35	13·34	3·73	17·27
May & June	7·99	10·99	8·04	10·71	8·07	10·90	8·12	11·14	8·75	10·29
September to November.	5·73	10·27	5·56	10·92	5·94	—	5·96	11·97	5·20	13·62

TABLE V.—DECLINATION, DIURNAL INEQUALITY, AVERAGE DEPARTURE.

Month or Season.	Kew.		S.U.		S.S.		Eskdalemuir.		Lerwick.	
	q	*d*	*q*	*d*	*q*	*d*	*q*	*d*	*q*	*d*
	′	′	′	′	′	′	′	′	′	′
April	—	2·57	—	2·60	—	2·81	—	2·80	—	3·15
May	1·86	2·60	1·99	2·69	1·86	2·60	2·11	2·84	2·33	2·99
June	1·87	3·03	1·98	3·17	2·26	3·12	2·03	3·28	2·52	3·13
September	1·69	2·77	1·71	2·94	1·77	—	1·89	3·36	1·95	4·13
October	1·29	2·59	1·18	2·54	1·28	2·64	1·29	3·09	1·23	3·65
November	0·93	1·93	0·82	2·05	0·93	1·96	1·00	2·37	0·96	2·78
May & June	1·77	2·81	1·93	2·93	2·05	2·88	2·00	3·06	2·40	3·01
September to November.	1·29	2·20	1·21	2·27	1·31	—	1·37	2·62	1·36	3·15

Tables IV and V give the range and the A.D. for each month separately, and for two groups of months, the first including May and June, the second September, October and November. April was omitted from the first group, as quiet days were not available in that month. The object of combining the months was to secure more elimination of accidental features, especially for the disturbed days. The combination of November with September and October is not ideal, but the November days were all from the first half of the month. In the headings S.U. and S.S. denote respectively Sandwell Park Underground and Surface, *q* and *d* denote quiet and disturbed days.

In considering the significance of the apparent differences in Tables IV and V between the several stations, various things have to be borne in mind. Accuracy to nearer than 1 per cent. can hardly be claimed for the scale values. The mean hourly curve ordinates were estimated to the nearest 0·1 mm., say, to 0'·1 at Kew, Sandwell Park and Eskdalemuir, and 0'·2 at Lerwick. But an accuracy of 0·1 mm. is not attainable in mean hourly values, except on quiet days and with very good traces. On disturbed days, when there are large oscillations, independent estimates may well differ by 1 mm. or more. In general an error in a D scale value affects all data alike, and so cannot produce any irregularity as between successive monthly values. At Sandwell Park, however, the interchange of the underground and surface instruments in September has to be borne in mind.

The point of greatest interest in Tables IV and V is whether there is a difference between S.S. (Sandwell Park Surface) and S.U. (Sandwell Park Underground). If we take the quiet days, we find that the S.S. range in Table IV is the greater in every case except the month of May, and the same is true of the A.D. in Table V. On disturbed days the S.S. range is the greater in Table IV in every case except the month of June, but in Table V S.U. supplies the larger value of the A.D. in three months out of five. There are *a priori* grounds for expecting the S.U. amplitude to be the smaller, because the cause of the diurnal changes is presumably an electrical current, and the displacement due to an electric current varies inversely as the value of H. Now the comparisons instituted between the values of H at the underground and surface stations made the former the larger. The difference obtained, however, was only some 0·5 per cent. of the value of H at the surface, and if we increased the underground figures in Tables IV and V by 0·5 per cent. it would not in general alter the sign of the difference between the S.S. and S.U. ranges and A.D.s.

The most prominent feature in Tables IV and V is the large increase of amplitude produced by disturbance. This can be best studied by considering Table VI, which gives the ratio borne by the disturbed day range or A.D. to the corresponding quiet day range or A.D. Here and in subsequent tables E, K, L in the headings stand for Eskdalemuir, Kew and Lerwick. The ratio is of course largely dependent on the accident of how disturbed and how quiet the selected disturbed and quiet days respectively were. But the days employed were the same for all the stations, and the ratio would be unaffected by any error in the accepted scale value at any station. In deriving the four-month mean September was omitted. In May and June there is no apparent tendency in the ratio to increase with latitude. In fact, Lerwick supplies the smallest value of the ratio for both the range and the A.D. in May and for the A.D. in June. But in the later months the ratio is invariably least at Kew and greatest at Lerwick, there being a marked step up from Sandwell

TABLE VI.—DECLINATION. RATIO OF DISTURBED TO QUIET DAY RANGE OR A.D.

Month.	Range.					Average Departure.				
	K	S.U.	S.S.	E	L	K	S.U.	S.S.	E	L
May ..	1·42	1·33	1·48	1·43	1·25	1·40	1·35	1·40	1·35	1·28
June ..	1·38	1·45	1·34	1·45	1·38	1·62	1·60	1·38	1·62	1·24
September..	1·67	1·77	—	1·90	2·61	1·64	1·72	—	1·78	2·12
October ..	2·05	2·24	2·17	2·31	3·18	2·01	2·15	2·06	2·40	2·97
November ..	2·42	2·62	2·47	3·07	4·63	2·08	2·50	2·11	2·37	2·90
4-month mean.	1·82	1·91	1·87	2·06	2·61	1·78	1·90	1·74	1·94	2·10

Park to Eskdalemuir, and a still larger step up from Eskdalemuir to Lerwick. This tendency to an enhancement of the ratio with increase of latitude is, it may be added, conspicuous in the case of the Eskdalemuir and Lerwick diurnal inequalities from the international selected days of 1923 in all except the summer months, May to August.

A feature of Table VI, implied by what has been already mentioned in the discussion of Tables IV and V, is that the ratio of the disturbed to the quiet day range or A.D. is, except in May, when there were only two quiet days, larger for S.U. than for S.S. The evidence in favour of a greater relative increase with disturbance in the amplitude of the regular diurnal variation underground is hardly sufficient to justify the final acceptance of the phenomenon as a general fact. But at all events we may take it that the evidence, so far as it goes, is opposed to the reduction underground in the influence of disturbance in increasing the regular diurnal variation.

The variation with latitude in the amplitude of the regular diurnal inequality is most easily studied in Table VII which gives the ratio of the range or A.D. at each station to the corresponding range or A.D. at the most southern station, Kew. In the case of disturbed days the tendency is clearly for the ratio to increase with increasing latitude. This is especially conspicuous in the three final months. Omitting S.U., as possibly not comparable with the other stations, the tendency even on quiet days is for a small increase in amplitude as we go north, but the Lerwick range is the smallest in October and November, and the Lerwick A.D. is the smallest in October. This might be supposed an accident of the days selected, but it will be found if we take the international quiet day inequalities of 1923 that the range was smaller at Lerwick than at Eskdalemuir in January, February, October, November and December. The minimum at midwinter in the amplitude of the regular diurnal variation on quiet days seems more pronounced at Lerwick than further south.

TABLE VII.—RATIO OF *D*. RANGES AND A.D.'S AT OTHER STATIONS TO THOSE AT KEW.

Month or Season.	Range.								Average Departure.							
	Quiet Days.				Disturbed Days.				Quiet Days.				Disturbed Days.			
	S.U.	S.S.	E	L	S.U.	S.S.	E	L	S.U.	S.S.	E	L	S.U.	S.S.	E	L
April ..	—	—	—	—	1·02	1·09	1·12	1·25	—	—	—	—	1·01	1·09	1·09	1·23
May ..	1·05	0·98	1·04	1·14	0·99	1·01	1·04	1·00	1·07	1·02	1·13	1·25	1·03	1·02	1·09	1·15
June ..	0·97	1·04	1·00	1·11	1·02	1·01	1·04	1·11	1·06	1·21	1·09	1·35	1·05	1·03	1·08	1·03
September	1·02	1·08	1·07	1·01	1·08	—	1·22	1·58	1·01	1·05	1·12	1·15	1·06	—	1·21	1·49
October ..	0·95	1·01	1·01	0·85	1·04	1·07	1·15	1·33	0·91	0·99	1·00	0·95	0·98	1·02	1·19	1·41
November	1·00	1·06	1·05	0·90	1·08	1·08	1·33	1·73	0·88	1·00	1·08	1·03	1·06	1·01	1·23	1·44
5 or 6 months' mean	1·00	1·03	1·03	1·00	1·04	1·05	1·15	1·33	0·99	1·05	1·08	1·15	1·03	1·03	1·15	1·29
May and June.	1·01	1·01	1·02	1·10	0·97	0·99	1·01	0·94	1·09	1·16	1·13	1·36	1·04	1·03	1·09	1·07
Sept. to Nov.	0·97	1·04	1·04	0·91	1·06	—	1·17	1·33	0·94	1·02	1·06	1·05	1·03	—	1·19	1·44

From a practical point of view the most important result is that on quiet days there is in general only a comparatively small variation in the amplitude of the regular diurnal inequality throughout Britain.

§ 11.—DIURNAL INEQUALITIES, RANGES, ETC., FOR DECLINATION—*contd.*

The extent to which parallelism exists between different stations is most easily grasped by considering the inequalities in Table VIII and their graphical representation in Figs. 5 to 8. Principal maxima and minima in Table VIII are in heavy

TABLE VIII.—DECLINATION.

Hour G.M.T.	1	2	3	4	5	6	7	8	9	10	11	Noon
STATION.												MAY AND JUNE.
Kew	−0·13	−0·61	−1·07	−1·76	−2·80	−3·48	**−3·90**	−3·69	−2·70	−0·78	+1·50	+3·17
Sandwell Pk., Underground	−0·41	−0·92	−1·41	−2·09	−2·98	−3·83	**−3·98**	−3·60	−2·67	−0·93	+1·45	+3·29
Sandwell Park, Surface ..	−0·34	−0·82	−1·51	−1·95	−3·12	−4·03	**−4·23**	−4·02	−3·04	−1·45	+0·65	+2·68
Eskdalemuir	−0·38	−1·00	−1·48	−2·17	−3·21	−3·80	**−4·06**	−3·81	−2·78	−1·15	+1·10	+3·20
Lerwick	−0·20	−1·26	−2·34	−3·31	−4·25	**−4·92**	4·85	−4·16	−2·93	−0·51	+1·91	+3·61
												MAY AND JUNE.
Kew	−1·25	−1·52	−1·87	−2·40	−3·52	−3·60	**−4·05**	−3·80	−2·83	−0·77	+1·56	+4·34
Sandwell Pk., Underground	−1·53	−1·81	−2·10	−2·94	−3·81	−3·79	**−3·88**	−3·77	−2·94	−1·16	+1·68	+4·30
Sandwell Park, Surface ..	−1·40	−1·81	−2·02	−2·74	−3·54	−3·74	**−3·91**	−3·88	−3·29	−1·84	+0·85	+3·84
Eskdalemuir	−1·57	−2·03	−2·36	−3·06	−3·93	−3·34	**−4·04**	−3·86	−2·86	−1·42	+1·42	+4·34
Lerwick	−1·60	−2·13	−2·93	−3·52	**−4·35**	−3·76	−3·65	−3·49	−2·44	−0·87	+2·57	+4·96
												SEPTEMBER, OCTOBER AND NOVEMBER.
Kew	−0·88	−0·78	−0·63	−0·62	−0·71	−1·09	−1·54	**−2·18**	−1·94	−0·39	+1·98	+3·35
Sandwell Pk., Underground	−0·83	−0·76	−0·69	−0·66	−0·82	−1·06	−1·46	**−2·02**	−1·93	−0·62	+1·64	+3·21
Sandwell Park, Surface ..	−1·06	−0·95	−0·84	−0·85	−0·98	−1·20	−1·55	**−2·12**	−1·90	−0·22	+2·07	+3·50
Eskdalemuir	−0·97	−0·90	−0·81	−0·76	−0·93	−1·21	−1·56	**−2·16**	−1·95	−0·34	+1·96	+3·52
Lerwick	−1·13	−1·00	−1·00	−1·09	−1·11	−1·32	−1·53	**−1·73**	−1·42	+0·28	+2·23	+3·37
												SEPTEMBER, OCTOBER AND NOVEMBER.
Kew	−2·36	−1·33	−0·81	−0·32	+0·12	+0·74	−0·34	−1·16	−0·71	+0·80	+2·58	+4·24
Sandwell Pk., Underground	−2·35	−1·69	−0·81	−0·51	+0·04	+0·73	−0·37	−0·83	−0·42	+0·77	+2·69	+4·24
Eskdalemuir	−3·14	−1·90	−1·16	−0·52	+0·23	+1·02	−0·18	−0·66	−0·17	+1·25	+2·79	+4·67
Lerwick	−5·10	−2·73	−2·01	−0·57	+0·29	+1·78	+0·39	+0·16	+0·73	+2·31	+3·61	+4·93

type. In calculating the inequalities equal weight was allowed to the months included. Thus May, with only two quiet days, counted equally with June, which had four.

Considering the small number of days available, the quiet day May-June curves in Fig 5. are remarkably smooth. Close inspection shows, however, some apparently accidental features, notably an enhancement of the value at 19^h or depression at 20^h, which becomes increasingly prominent as we travel from Kew to Lerwick. The similarity of the five curves appeals at once to the eye. Similar remarks apply to the quiet day curves for September to November in Fig. 7. In view of the fact that these depend on three months each with five quiet days, the smoothness of these curves is less surprising. There is, however, even in this case an apparently accidental depression at 21^h, which increases in prominence as we go north.

At first sight the two sets of quiet day curves are of the same type, both showing a prominent minimum (easterly extreme) about 7^h or 8^h, and a prominent maximum at 13^h or 14^h. But closer inspection shows a decided difference. The May-June curves, even that for Lerwick, show only a slight retardation near midnight in the easterly movement in progress from 14^h to the forenoon minimum, but in the September to November curves a secondary minimum near midnight is decidedly in evidence, its prominence increasing as we go north. This tendency to a secondary minimum near midnight is apparent in the disturbed day May-June curves in Fig. 6, while in the disturbed day September to November curves in Fig. 8 the minimum near midnight has become the principal minimum. The forenoon minimum appears only as a temporary reversal in the rise to the maximum at 13^h The relative unimportance of the forenoon minimum increases as we go north.

The assumption that the quiet day inequality applies to all days, including the

DIURNAL INEQUALITY.

13	14	15	16	17	18	19	20	21	22	23	24	Hour G.M.T.
QUIET DAYS.												STATION.
+**4·09**	+4·05	+3·39	+2·07	+1·17	+0·90	+0·67	+0·14	+0·07	−0·02	−0·11	−0·17	Kew
+**4·06**	+3·99	+3·32	+2·13	+1·50	+1·24	+1·06	+0·44	+0·38	+0·28	−0·03	−0·32	Sandwell Pk., Underground
+3·75	+**3·84**	+3·32	+2·38	+1·84	+1·70	+1·64	+0·86	+0·72	+0·70	+0·53	0·00	Sandwell Park, Surface
+**4·06**	+4·04	+3·33	+2·28	+1·90	+1·59	+1·37	+0·45	+0·45	+0·16	+0·07	−0·19	Eskdalemuir
+**3·83**	+3·62	+3·29	+2·62	+2·14	+2·07	+2·24	+1·19	+0·82	+0·62	+0·60	+0·20	Lerwick
DISTURBED DAYS.												
+6·17	+**6·94**	+6·23	+4·31	+3·09	+1·02	−0·65	−0·99	−1·42	−1·57	−1·57	−1·88	Kew
+6·26	+**6·83**	+6·26	+4·74	+3·51	+1·54	−0·24	−0·80	−1·30	−1·33	−1·43	−2·31	Sandwell Pk., Underground
+5·81	+**6·99**	+6·17	+5·09	+4·16	+1·66	−0·17	−0·58	−1·07	−1·19	−1·31	−2·07	Sandwell Park, Surface
+6·21	+**7·10**	+6·56	+5·16	+4·18	+1·70	−0·29	−0·79	−1·43	−1·77	−1·54	−2·42	Eskdalemuir
+4·73	+5·06	+**5·94**	+4·70	+5·26	+2·69	+0·26	−0·13	−1·11	−1·85	−1·60	−2·74	Lerwick
QUIET DAYS.												
+**3·55**	+2·95	+1·76	+0·99	+0·52	+0·30	+0·04	−0·33	−0·91	−0·92	−1·26	−1·24	Kew
+**3·54**	+2·83	+1·69	+0·85	+0·45	+0·25	+0·09	−0·15	−0·70	−0·79	−1·04	−1·00	Sandwell Pk., Underground
+**3·82**	+2·97	+1·66	+0·85	+0·38	+0·32	+0·12	−0·26	−0·84	−0·83	−1·03	−1·11	Sandwell Park, Surface
+**3·80**	+3·14	+1·91	+1·05	+0·58	+0·31	+0·14	−0·22	−1·02	−1·07	−1·30	−1·24	Eskdalemuir
+**3·47**	+2·76	+1·64	+1·01	+0·74	+0·47	+0·39	−0·02	−1·08	−1·07	−1·38	−1·40	Lerwick
DISTURBED DAYS.												
+**5·07**	+4·32	+3·69	+2·74	+1·37	+0·75	−1·17	−2·47	−3·25	−**5·20**	−4·37	−2·94	Kew
+**5·28**	+4·58	+4·01	+2·88	+1·43	+0·62	−1·08	−2·60	−3·71	−**5·64**	−4·55	−2·75	Sandwell Pk., Underground
+**5·69**	+4·80	+4·52	+3·44	+1·94	+1·13	−1·23	−2·98	−4·11	−**6·28**	−5·75	−3·38	Eskdalemuir
+**5·58**	+4·71	+4·96	+3·92	+2·48	+2·05	−0·64	−3·50	−4·47	−**8·04**	−7·16	−3·75	Lerwick

disturbed days of the month, would obviously lead to somewhat erroneous results near midnight even in summer, while in equinox and winter it would be badly at fault throughout most of the day.

The simplest way of presenting the facts is probably as follows : In the diurnal inequality for the year as a whole there is throughout Britain a principal maximum at 13^h or 14^h, and a principal minimum about 8^h. There are, however, two tendencies working to promote a minimum near midnight. These are, disturbance at any season of the year, and shortening of the daylight hours. Both influences tend to increase as we go north. If we take, for example, the inequalities from the international days of 1923 and from all days we find that, so far as the seasons are concerned, the occasions when the principal minimum appeared near midnight were as follows :—

	Quiet Days.	All Days.	Disturbed Days.
At Eskdalemuir ..	No season ..	Winter	Winter, Equinox, Year.
At Lerwick ..	Winter ..	Winter, Equinox	Winter, Equinox, Year.

§ 12. DIURNAL INEQUALITIES, RANGES, &C., FOR HORIZONTAL FORCE.

Tables IX to XII refer to H. The Kew curves were corrected for temperature in the usual way. At the other stations no temperature correction was considered necessary owing to the small diurnal variation of temperature. It was practically certain *a priori* that the temperature changes experienced by the H instrument at Sandwell Park would be extremely slow, and records from a thermograph confirmed this anticipation. At Eskdalemuir there was unfortunately no H magnetograph, and all H data had to be derived from X (north component) and W (west component) records. In the case of diurnal inequalities based on five quiet days or on all days of the month, H inequalities derived from X and W curves should be little if at all inferior in accuracy to those derived from H curves. But this cannot be claimed for results derived from single days or from a few disturbed days. A numerical result which represents a difference between two much larger numerical results, each with a sensible probable error, has an undesirably large uncertainty. Another regrettable fact was that no H instrument was available for the surface station at Sandwell Park.

TABLE IX.—HORIZONTAL FORCE. DIURNAL INEQUALITY. RANGE.

Month or Season.	Kew.		Sandwell Park.		Eskdalemuir.		Lerwick.	
	q	*d*	*q*	*d*	*q*	*d*	*q*	*d*
	γ	γ	γ	γ	γ	γ	γ	γ
April	30·7	46·6	36·8	53·4	41·7	52·2	44·1	64·5
May	28·3	43·5	33·2	47·6	41·0	68·8	45·9	109·8
June	31·6	44·5	33·9	51·3	41·0	64·8	43·4	109·0
September	25·7	33·2	33·0	38·6	33·7	36·7	34·3	130·6
October	25·4	36·2	26·3	40·2	25·1	36·4	22·9	148·5
November	21·8	—	25·4	—	18·2	—	15·3	—
April to June	30·2	39·8	34·7	45·2	41·2	58·5	44·2	87·5
September and October ..	25·2	30·3	29·7	32·8	29·4	31·1	27·3	119·8

TABLE X.—H. DIURNAL INEQUALITY. AVERAGE DEPARTURE.

Month or Season.	Kew.		Sandwell Park.		Eskdalemuir.		Lerwick.	
	q	*d*	*q*	*d*	*q*	*d*	*q*	*d*
	γ	γ	γ	γ	γ	γ	γ	γ
April	6·83	9·81	8·30	11·73	9·70	11·72	10·64	14·59
May	6·72	9·45	7·37	10·97	9·01	15·14	9·96	23·05
June	8·09	10·70	9·06	13·00	10·77	15·09	10·47	23·76
September	5·31	6·59	7·02	7·99	7·73	8·13	8·28	25·52
October	5·02	9·13	6·54	11·28	6·31	8·73	4·97	28·26
November	4·76	—	5·83	—	4·04	—	3·70	—
April to June	6·86	9·30	8·17	11·56	9·80	13·00	10·31	20·00
September and October ..	5·09	7·02	6·74	9·11	6·98	7·08	6·63	23·51

In the months of April, May, June and September, the quiet day ranges and *A.D.'s* at Sandwell Park given in Tables IX and X occupy an intermediate position between those at Kew and Eskdalemuir, as we should expect at an intermediate surface station. In these months, as is most easily seen in Table XII, there is in general a steady and very considerable increase in the quiet day range and *A.D.* as we pass from Kew to Lerwick, the increase with latitude being considerably greater than it was in the case of D. But in October and November the quiet day range and *A.D.* at Sandwell Park exceed those at both Kew and Eskdalemuir. Whether this is in any way due to the station being underground, it is impossible to say. In October and November there is a decline in both range and *A.D.* as we pass from Eskdalemuir to Lerwick, which is consistent with the amplitude attaining a maximum at some spot south of Eskdalemuir. If it did, the phenomenon would seem to have been an accident of the days selected, because if we take the international quiet day inequalities at Eskdalemuir and Lerwick, January and February were the only months in which the Lerwick range was the smaller, and January and December the only months in which the Lerwick *A.D.* was the smaller.

To face p. 16.

MAY & JUNE. QUIET DAYS.

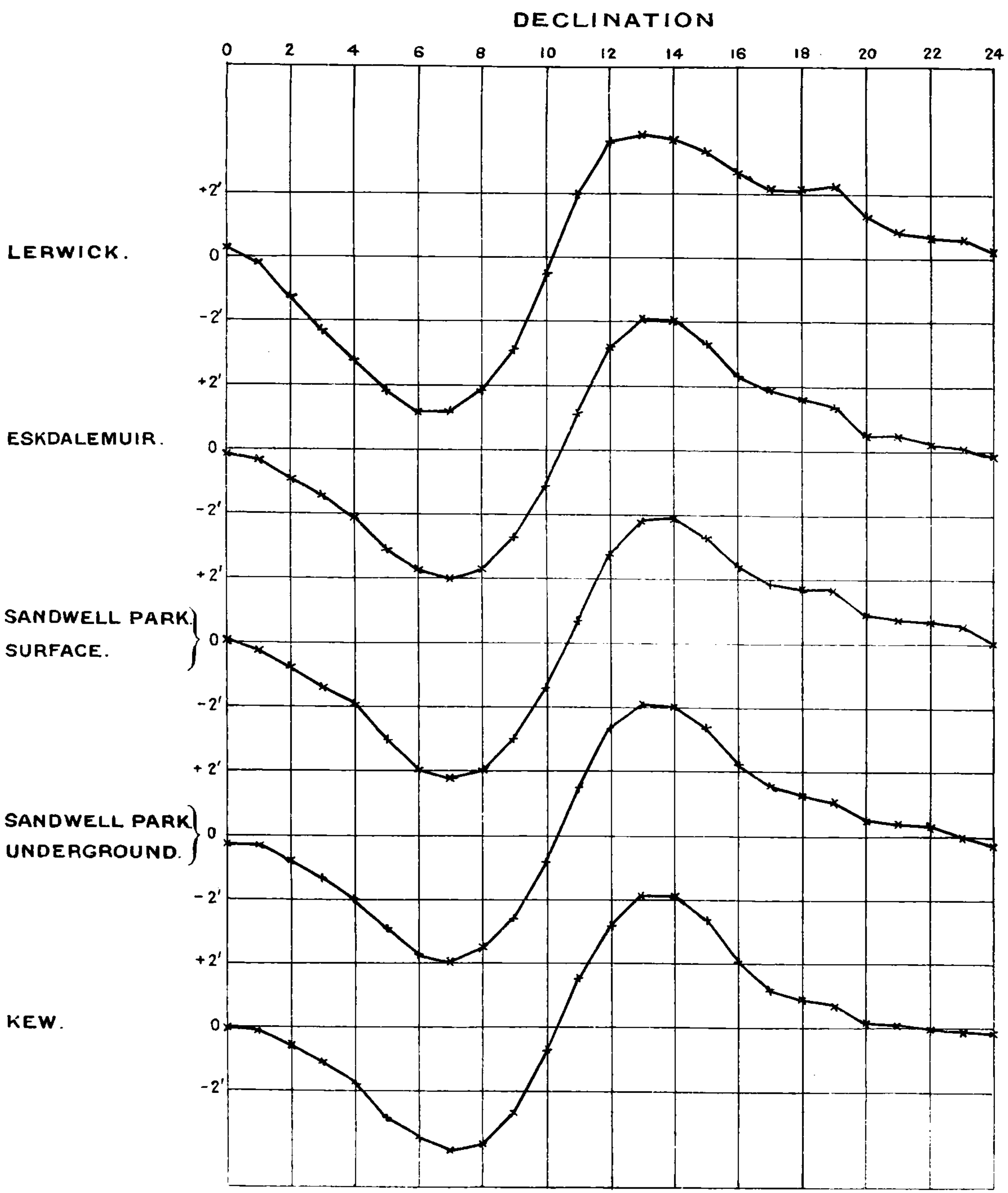


FIG. 5.

MAY & JUNE. DISTURBED DAYS.

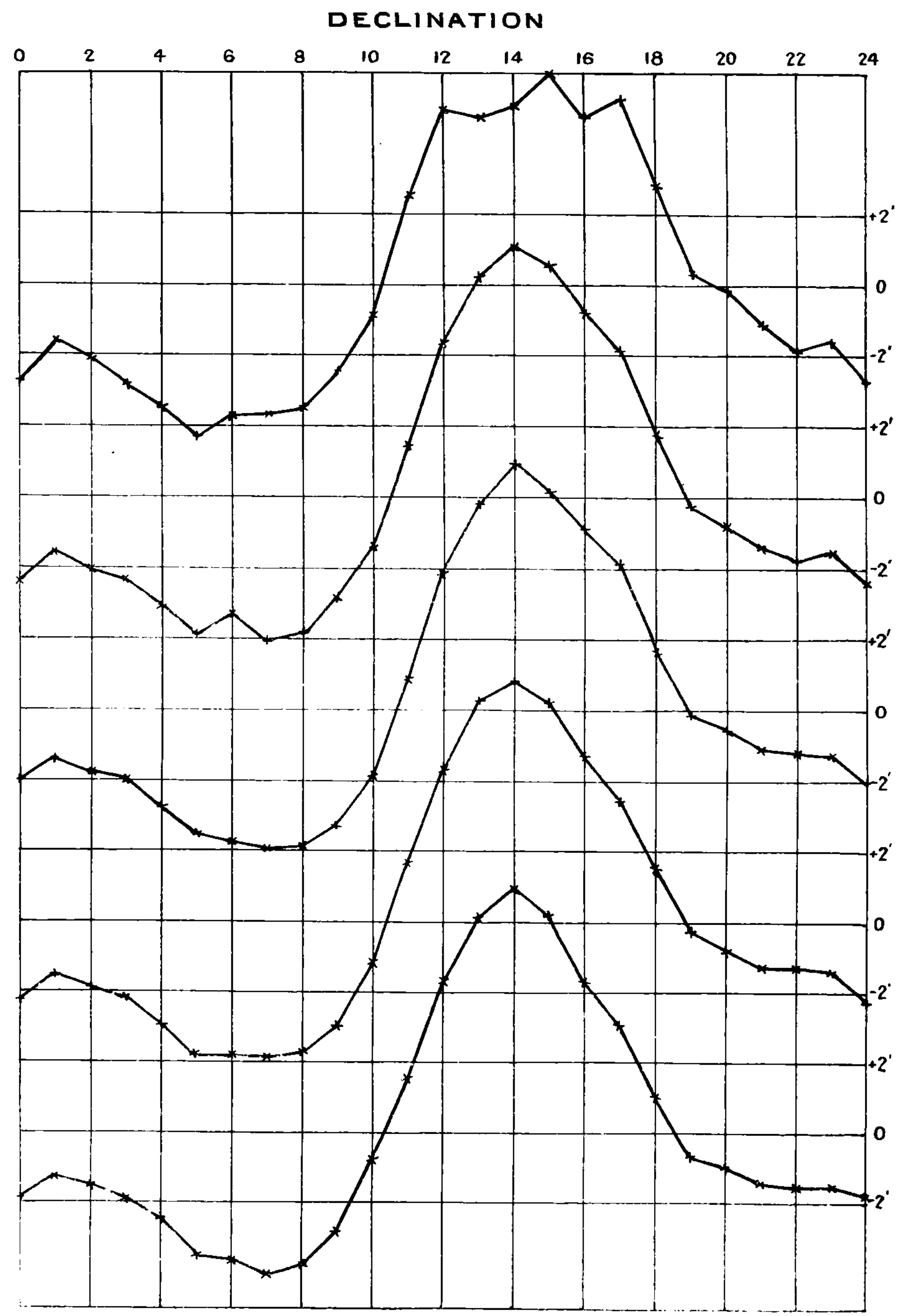


FIG. 6.

To face p. 17.

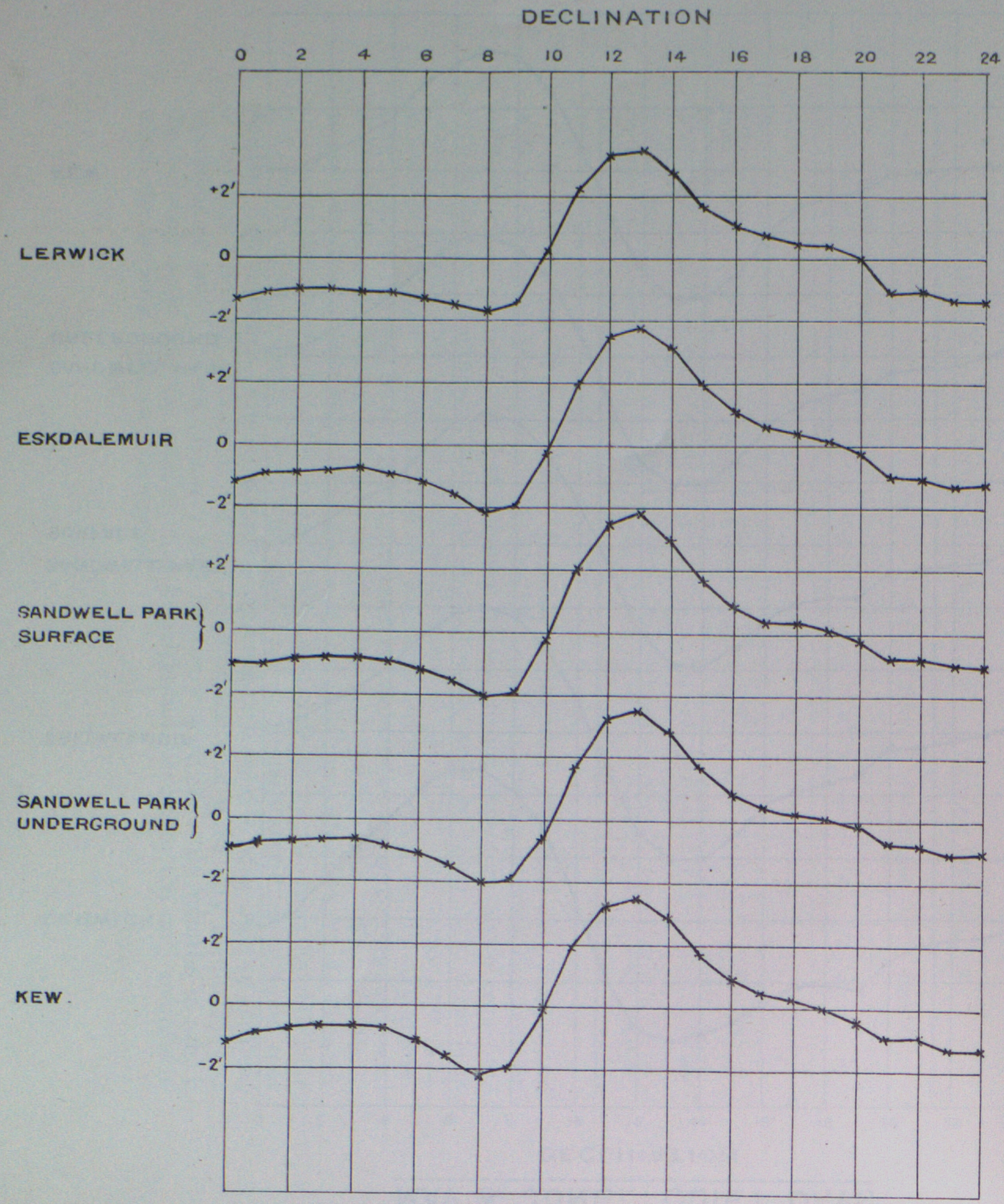


FIG. 7.

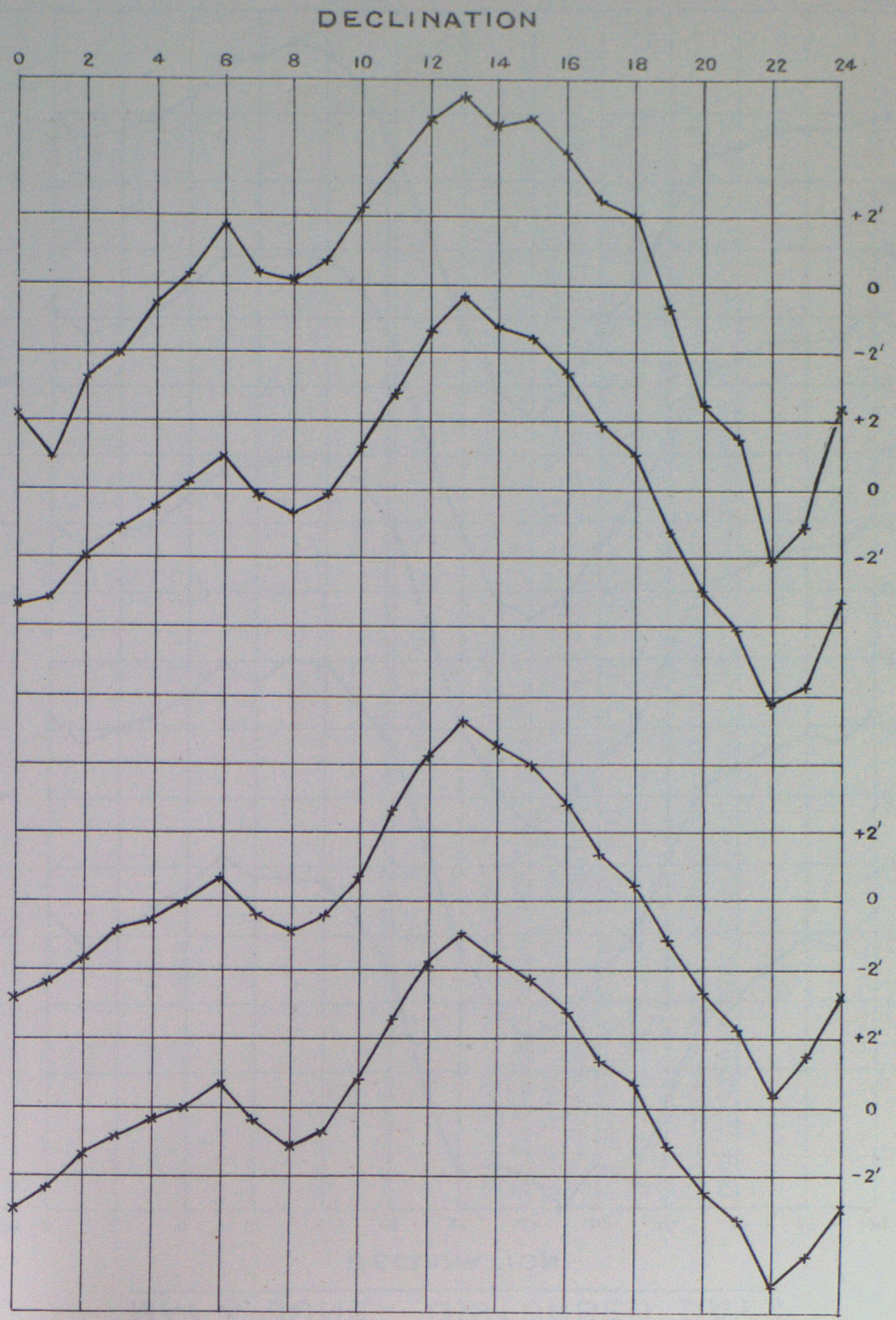


FIG. 8.

To face p. 16.

APRIL . MAY . JUNE. QUIET DAYS.

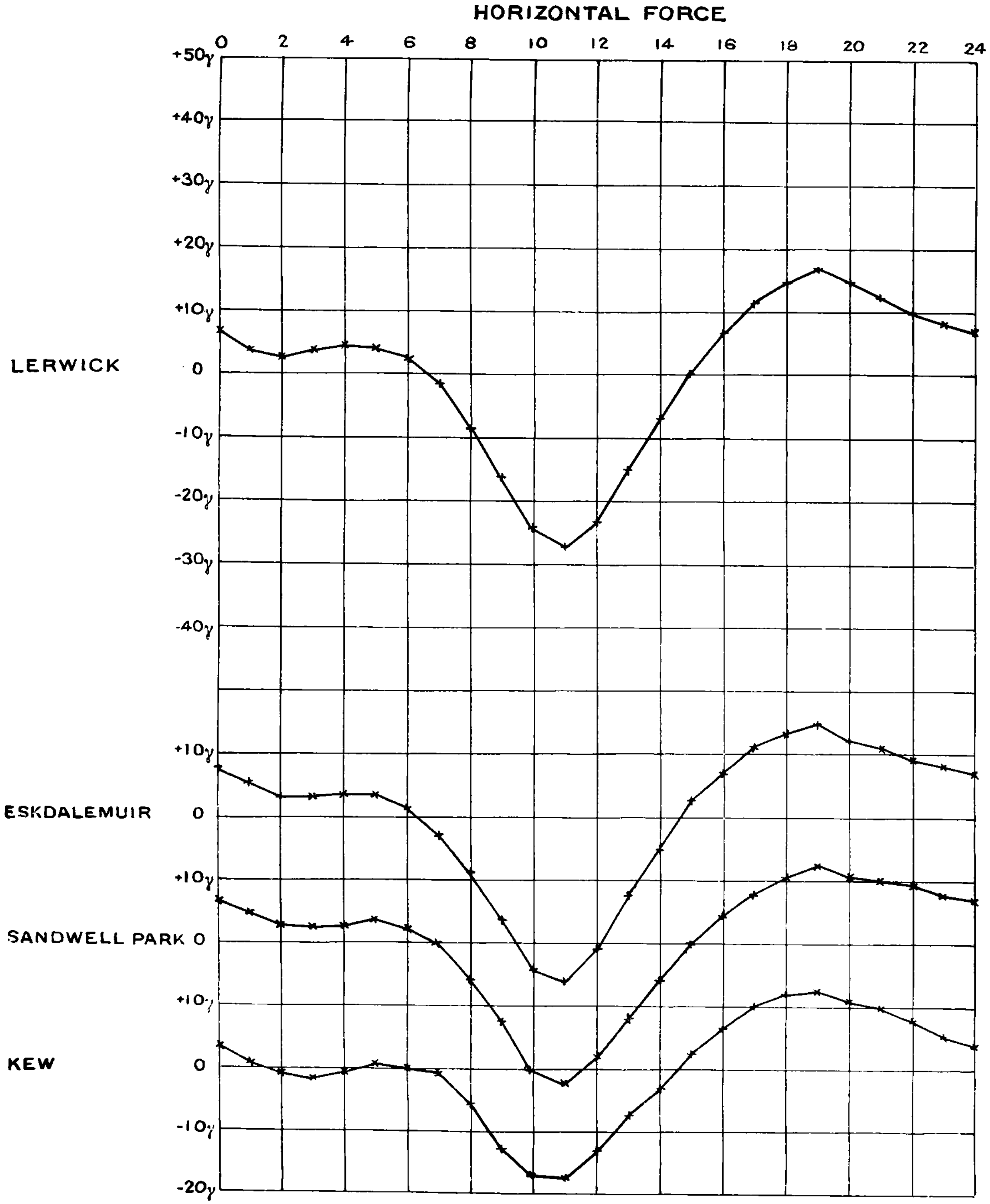


FIG. 9.

APRIL. MAY. JUNE. DISTURBED DAYS.

FIG. 10.

To face p. 17.

SEPT. & OCT. QUIET DAYS.

HORIZONTAL FORCE.

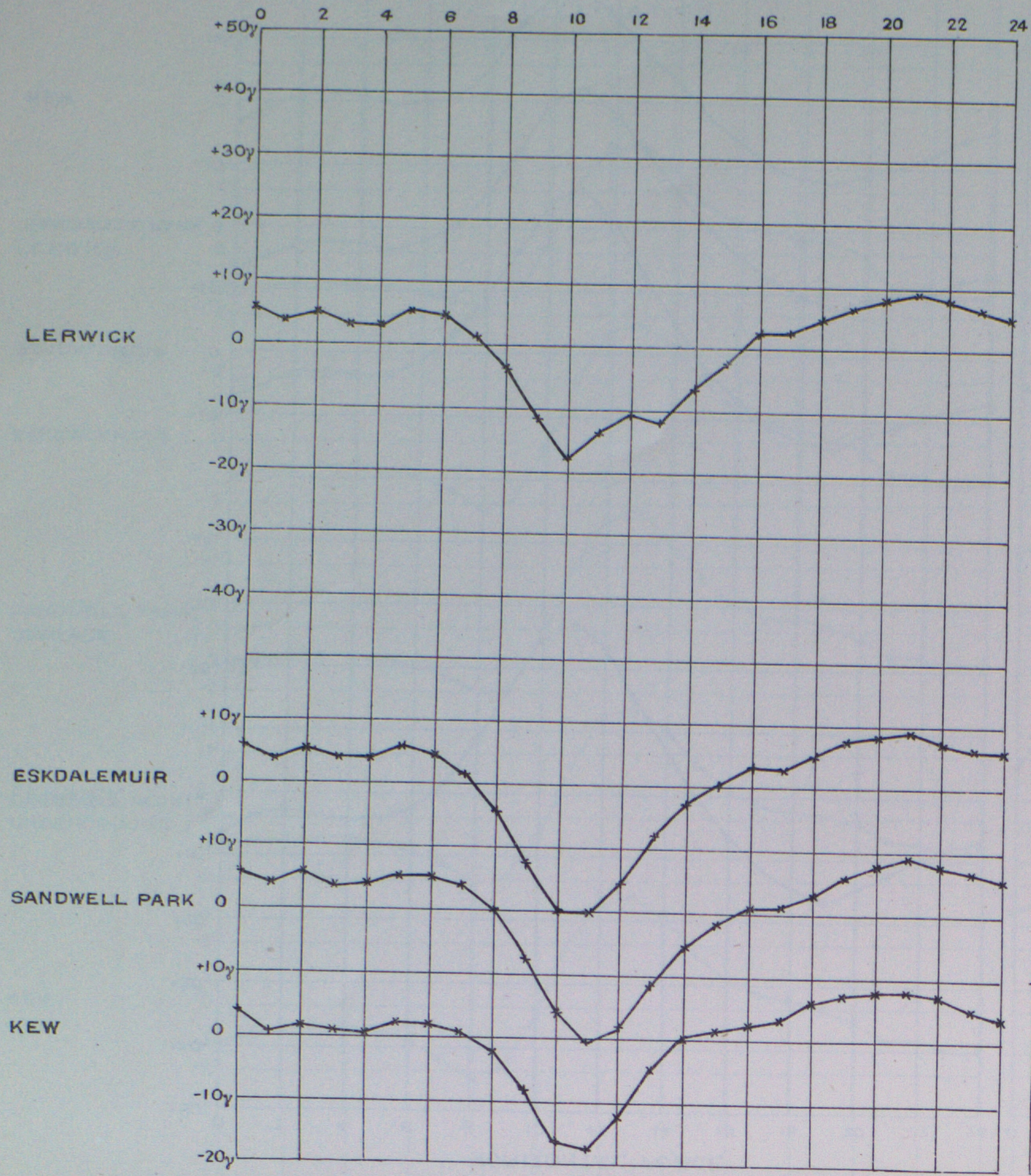


FIG. 11.

SEPT. & OCT. DISTURBED DAYS.

HORIZONTAL FORCE.

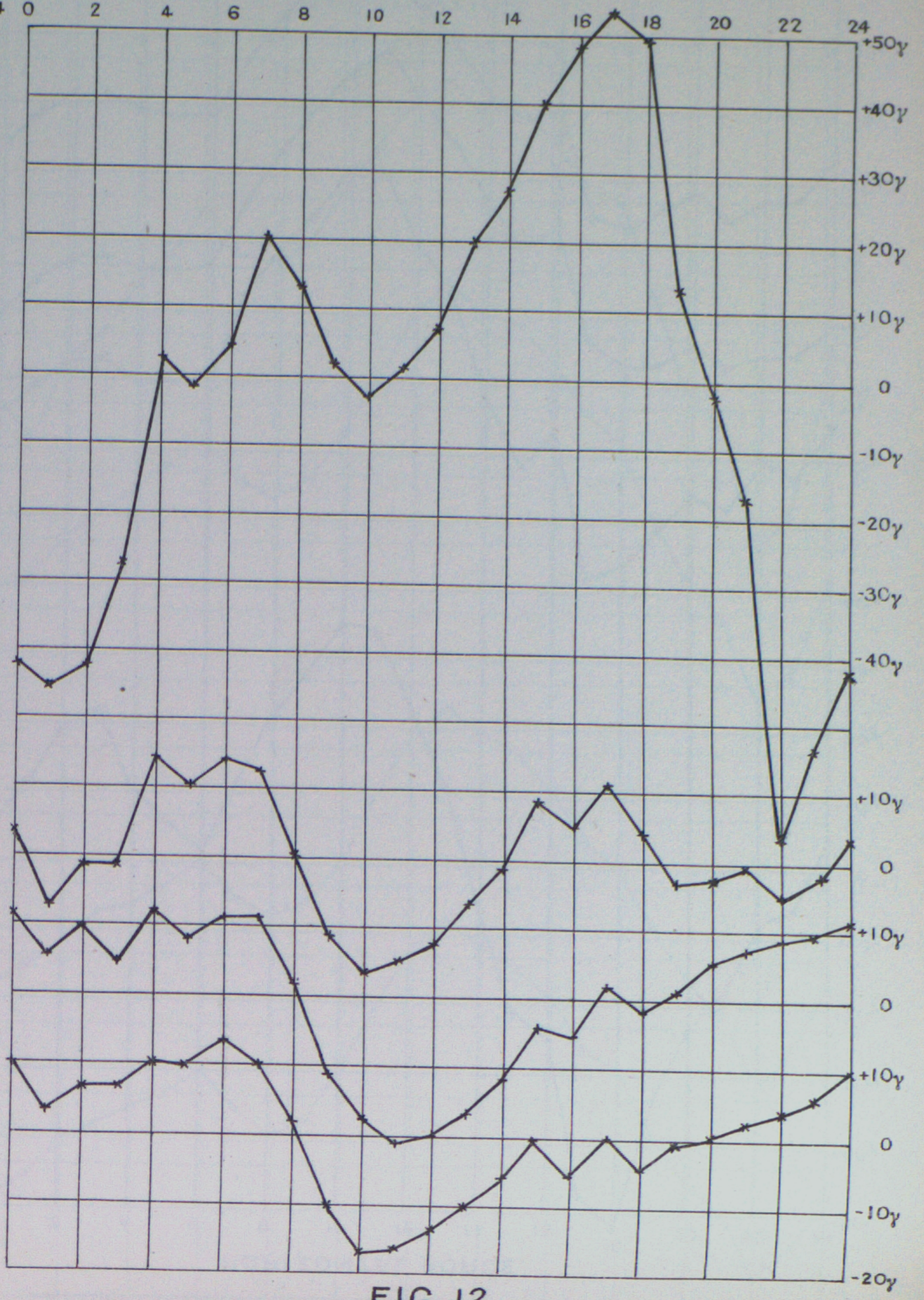


FIG 12.

H.M.S.O. Press, Kingsway, W.C.2.

Ps. 35827/1414. Wt.18947A. D.14536/1273. 685.4/27.

TABLE XI.—RATIO OF DISTURBED TO QUIET DAY RANGE OR A.D. (*H*).

Month.	Range.				Average Departure.			
	K	S.U.	E	L	K	S.U.	E	L
April	1·52	1·45	1·25	1·46	1·44	1·41	1·21	1·37
May	1·54	1·43	1·68	2·39	1·41	1·49	1·68	2·31
June	1·41	1·51	1·58	2·51	1·32	1·43	1·40	2·27
September	1·29	1·17	1·09	3·81	1·24	1·14	1·05	3·08
October	1·43	1·53	1·45	6·49	1·82	1·73	1·38	5·69
Mean	1·44	1·42	1·41	3·33	1·45	1·44	1·34	2·94

TABLE XII.—RATIOS OF *H* RANGES AND A.D.'S AT OTHER STATIONS TO THOSE AT KEW.

Month or Season.	Range.						Average Departure.					
	Quiet Days.			Disturbed Days.			Quiet Days.			Disturbed Days.		
	S.U.	E.	L	S.U.	E	L	S.U.	E	L	S.U.	E	L
April..	1·20	1·36	1·44	1·15	1·12	1·38	1·22	1·42	1·56	1·20	1·19	1·49
May	1·17	1·45	1·62	1·09	1·58	2·52	1·10	1·34	1·48	1·16	1·60	2·44
June	1·07	1·30	1·37	1·15	1·46	2·45	1·12	1·33	1·29	1·21	1·41	2·22
September	1·28	1·31	1·33	1·16	1·11	3·93	1·32	1·46	1·56	1·21	1·23	3·87
October	1·04	0·99	0·90	1·11	1·01	4·24	1·30	1·26	0·99	1·24	0·96	3·10
November	1·17	0·83	0·70	—	—	—	1·22	0·85	0·78	—	—	—
6 months' mean	1·15	1·21	1·23	—	—	—	1·21	1·28	1·28	—	—	—
5 months' mean	1·15	1·28	1·33	1·13	1·26	2·90	1·21	1·36	1·38	1·20	1·28	2·62
April to June	1·15	1·36	1·46	1·14	1·47	2·20	1·19	1·43	1·50	1·24	1·40	2·15
September and October	1·18	1·17	1·08	1·08	1·03	3·95	1·32	1·37	1·30	1·30	1·01	3·58

The disturbed day *H* ranges and *A.D.s*, as Table XI shows, are in all cases much larger than the corresponding quiet day ranges and *A.D.s*. But the phenomenon does not follow the same course as in the case of *D*. Table VI for *D* shows on the average a rise in the ratio borne by the disturbed to the quiet day range or *A.D.* as we travel north, and the increase as we pass from Eskdalemuir to Lerwick is not out of keeping with the increase from Kew to Eskdalemuir. But Table XI for *H* shows on the average no decided increase in the ratio, but rather a fall, as we pass from Kew to Eskdalemuir, while the ratio is more than doubled as we pass from Eskdalemuir to Lerwick. The rise in the ratio as we pass from Eskdalemuir to Lerwick is especially pronounced in October, and the phenomena presented by the 15th and 16th, the two most disturbed days of that month, will be separately considered later.

§ 13. DIURNAL INEQUALITIES, RANGES, &c., FOR HORIZONTAL FORCE.

Table XIII gives the quiet and disturbed day *H* inequalities for two selected groups of months, the principal maximum and minimum being in heavy type. The results are shown graphically in Figs. 9 to 12. The grouping adopted in the case of *D* was not followed, because *H* data were available for April and not for November.

The quiet day April to June *H* curves in Fig. 9 depend on three months, each with five quiet days, and so naturally are very smooth. Their close similarity of type appeals to the eye, but the increase in the amplitude as we go north is easily recognisable. The September-October quiet day curves in Fig. 11 are decidedly less smooth. Apparently accidental irregularities from 1^h to 3^h and at 16^h or 17^h are seen at all the stations. But there is a special irregularity at Lerwick, between 10^h and 13^h, which is not represented at the more southern stations. Both sets of quiet day curves have as their most prominent feature a minimum about 11^h. There are indications of a secondary minimum in the early morning, but it is in all cases merely a trace. The April to June disturbed day curves, Fig. 10, at the three more southern stations, do not differ much in type from the quiet day curves. But at Lerwick there is a

TABLE XIII.—HORIZONTAL FORCE.

Hour G.M.T.	1	2	3	4	5	6	7	8	9	10	11	Noon
STATION.								APRIL, MAY AND JUNE.				
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	+ 0·6	− 1·0	− 1·7	− 0·9	+ 0·5	+ 0·1	− 0·8	− 5·8	−12·9	−17·0	**−17·7**	−13·7
Sandwell Park	+ 4·7	+ 2·9	+ 2·5	+ 2·6	+ 3·6	+ 2·6	− 0·1	− 5·7	−12·5	−20·7	**−22·4**	−18·6
Eskdalemuir	+ 5·2	+ 3·1	+ 3·0	+ 3·3	+ 3·4	+ 1·5	− 2·5	− 8·9	−16·5	−24·6	**−26·3**	−21·2
Lerwick	+ 3·7	+ 2·8	+ 3·8	+ 4·3	+ 4·1	+ 2·6	− 1·5	− 8·7	−16·4	−24·1	**−27·2**	−23·5
STATION.								APRIL, MAY AND JUNE.				
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	+ 1·4	− 1·0	− 1·0	+ 0·7	+ 1·6	+ 1·9	− 6·8	−12·9	−18·7	−22·2	**−23·1**	−14·7
Sandwell Park	+ 5·6	+ 2·3	+ 2·2	+ 3·9	+ 4·2	+ 3·1	− 6·7	−13·7	−20·0	−25·1	**−28·3**	−21·1
Eskdalemuir	+ 0·5	− 2·6	− 3·0	+ 0·2	+ 0·1	0·0	−12·7	−19·4	24·1	**−31·0**	−30·4	−20·0
Lerwick	−11·6	−19·3	−22·2	−10·7	− 6·0	− 1·5	−12·0	−21·0	−27·9	**−35·3**	−34·2	−21·9
STATION.								SEPTEMBER AND OCTOBER.				
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	+ 0·7	+ 1·7	+ 1·0	+ 0·4	+ 2·1	+ 1·9	+ 1·0	− 1·8	− 8·2	−16·4	**−17·4**	−12·6
Sandwell Park	+ 4·0	+ 5·6	+ 4·0	+ 4·0	+ 5·4	+ 5·5	+ 4·2	+ 0·2	− 7·4	−16·0	**−20·5**	−18·2
Eskdalemuir	+ 3·9	+ 5·3	+ 4·0	+ 3·9	+ 5·9	+ 4·4	+ 1·6	− 4·2	−12·8	−20·2	**−20·3**	−15·6
Lerwick	+ 3·7	+ 4·8	+ 3·1	+ 3·0	+ 5·3	+ 4·5	+ 1·7	− 3·6	−11·6	**−18·3**	−13·8	−11·0
STATION.								SEPTEMBER AND OCTOBER.				
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	+ 3·0	+ 7·0	+ 6·6	+10·2	+ 9·8	**+13·3**	+10·2	+ 2·3	− 9·8	**−17·0**	−16·2	−13·7
Sandwell Park	+ 5·6	+ 9·5	+ 4·8	**+12·0**	+ 8·0	+11·0	+11·2	+ 2·0	−11·0	−17·8	**−20·8**	−19·7
Eskdalemuir	− 7·4	− 1·3	− 1·4	**+14·4**	+10·3	+14·1	+12·6	+ 0·3	−11·3	**−16·7**	−14·8	−12·6
Lerwick	−45·7	−42·7	−27·6	+ 2·8	− 1·7	+ 4·3	+20·5	+13·3	+ 2·0	− 2·8	+ 1·1	+ 7·0

markedly increased development of the secondary minimum near 3^h, and the prominence of the afternoon maximum is also enhanced. When we come to the September-October disturbed day curves, Fig. 12, the difference between Lerwick and the other stations is conspicuous. At Kew and Sandwell Park the type is on the whole similar to that of the quiet day curves ; exactly how similar it is difficult to say, owing to the irregularities before 7^h and after 15^h. At Eskdalemuir influences tending to oppose the evening rise after 17^h and to produce a minimum at night make their presence felt. But the minimum near noon remains the most prominent feature. At Lerwick, however, the fall after 17^h and the development of a minimum near midnight are much the most prominent features, and the minimum at 10^h is comparatively inconspicuous.

This unexpected difference between Lerwick and the more southern stations appeared so interesting that an examination was made of the international disturbed day inequalities for the whole year 1923 at Eskdalemuir and Lerwick. This showed that the phenomena exhibited by the September-October disturbed curves in Fig. 12 are fairly representative of disturbance in the equinoctial and winter seasons. Even one summer month, June, which contained some really highly disturbed days, had the principal minimum at Lerwick at 3^h. Also the principal minimum for the year as a whole at Lerwick was at 2^h. On the other hand, Eskdalemuir disturbed day inequalities showed a principal minimum at 10^h or 11^h in all three seasons, and October was the only month which gave a minimum within six hours of midnight.

The general inference from the *H* inequalities is that for England and Southern Scotland the assumption that the regular diurnal variation derived from quiet days is also applicable to disturbed days is less erroneous than in the case of *D*, but for Northern Scotland, if we may judge by Lerwick, the reverse is the case, the type of the diurnal variation undergoing a complete change on days of large disturbance.

DIURNAL INEQUALITY.

13	14	15	16	17	18	19	20	21	22	23	24	Hour G.M.T.
QUIET DAYS.												STATION.
γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
− 7·6	− 3·5	+ 2·5	+ 6·8	+ 9·9	+11·8	**+12·5**	+10·7	+ 9·9	+ 7·8	+ 5·2	+ 3·7	Kew
−12·1	− 6·0	0·0	+ 4·4	+ 7·8	+10·6	**+12·3**	+10·7	+ 9·9	+ 9·3	+ 7·5	+ 6·7	Sandwell Park
−12·5	− 5·1	+ 2·8	+ 7·1	+11·2	+13·6	**+14·9**	+12·0	+11·1	+ 9·3	+ 8·3	+ 7·7	Eskdalemuir
−15·2	− 7·2	+ 0·4	+ 6·5	+11·5	+14·9	**+17·0**	+14·8	+12·4	+ 9·7	+ 8·2	+ 7·0	Lerwick
DISTURBED DAYS.												STATION.
γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
− 9·0	− 1·8	+ 1·5	− 0·3	+15·3	**+16·7**	+14·1	+11·3	+15·6	+12·6	+12·6	+ 6·3	Kew
−14·9	− 5·9	0·0	− 2·9	+13·3	**+16·9**	+16·7	+13·7	+16·8	+15·0	+14·7	+10·5	Sandwell Park
−13·1	+ 1·1	+11·8	+ 6·2	**+27·5**	+25·9	+20·6	+15·7	+17·6	+10·6	+12·9	+ 5·0	Eskdalemuir
−11·4	+ 6·4	+21·6	+25·1	+47·3	**+52·2**	+33·1	+23·3	+18·1	+ 7·2	+ 5·7	− 5·0	Lerwick
QUIET DAYS.												STATION.
γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
− 4·7	+ 0·4	+ 1·6	+ 2·6	+ 3·0	+ 6·0	+ 7·2	+ **7·8**	+ **7·8**	+ 7·1	+ 5·1	+ 3·7	Kew
−11·4	− 5·7	− 1·7	+ 0·8	+ 1·1	+ 2·9	+ 6·0	+ 7·5	+ **9·2**	+ 7·9	+ 7·0	+ 5·6	Sandwell Park
− 7·8	− 2·9	+ 0·2	+ 3·1	+ 2·8	+ 5·2	+ 7·4	+ 8·1	+ **9·1**	+ 7·1	+ 6·1	+ 5·7	Eskdalemuir
−12·0	− 6·7	− 2·6	+ 2·3	+ 2·7	+ 4·8	+ 6·6	+ 8·1	+ **9·0**	+ 8·1	+ 6·4	+ 5·5	Lerwick
DISTURBED DAYS.												STATION.
γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
−10·1	− 6·3	− 0·4	− 5·2	+ 0·3	− 4·6	− 0·9	+ 0·1	+ 2·0	+ 3·6	+ 5·8	+10·0	Kew
−16·8	−11·7	− 4·4	− 5·3	+ 2·1	− 1·8	+ 1·0	+ 5·3	+ 7·2	+ 8·5	+ 9·5	+11·6	Sandwell Park
− 6·3	− 1·2	+ 8·8	+ 5·1	+11·2	+ 4·6	− 3·0	− 2·4	− 0·7	− 4·5	− 1·2	+ 3·7	Eskdalemuir
+19·9	+27·2	+40·3	+48·1	**+53·4**	+49·2	+12·8	− 1·0	−17·5	**−66·4**	−53·6	−41·9	Lerwick

Even in England the assumption that the amplitude of the diurnal inequality is everywhere the same is not justified.

§ 14. FOURIER COEFFICIENTS.

With a view to further investigation of the differences between different stations and different types of days, Fourier coefficients were calculated from the D and H inequalities in Tables VIII and XIII. The results appear in Tables XIV to XIX. The inequalities were analysed in the two alternative series :—

$$a_1 \sin 15^\circ t + b_1 \cos 15^\circ t + a_2 \sin 30^\circ t + b_2 \cos 30^\circ t + \ldots .$$

$$c_1 \sin (15^\circ t + \alpha_1) + c_2 \sin (30^\circ t + \alpha_2) + \ldots\ldots,$$

t being the time in hours counted from Greenwich midnight. The a, b coefficients were calculated by the usual formulae and the c, α constants were then derived from the formulæ :—

$$\alpha_n = \tan^{-1} (a_n/b_n),\ c_n = a_n/\sin \alpha_n \text{ or } b_n/\cos \alpha_n.$$

Factors 1·0029, 1·0115, 1·026 and 1·047 were then applied to c_1, c_2, c_3 and c_4 respectively, to allow for the fact that mean not instantaneous hourly values were used. If Greenwich time were replaced by local time, the addition made to the values of α_1 would be 19′ at Kew, 1° 57′ at Sandwell Park, 3° 12′ at Eskdalemuir and 1° 11′ at Lerwick. The additions to α_2, α_3 and α_4 would be respectively twice, thrice and four times as great. This implies that if the diurnal inequality followed local time, and was of invariable type throughout the country, we should expect the value of α_1 at Kew, when Greenwich time is used, as has been done here, to exceed that at the other stations, the excess being 1° 38′ for Sandwell Park, 2° 53′ for Eskdalemuir and 0° 52′ for Lerwick. The differences for α_2, α_3 and α_4 are of course correspondingly larger, but differences larger than any of these might well arise from errors in the curve measurements when only a few days' traces are utilized.

TABLE XIV.—*D*. DIURNAL INEQUALITY. FOURIER COEFFICIENTS. AMPLITUDES.

Season.	Amplitude.	Quiet Days.					Disturbed Days.				
		K.	S.U.	S.S.	E.	L.	K.	S.U.	S.S.	E.	L.
May and June.	c_1	2·58′	2·81′	3·00′	2·95′	3·53′	3·91′	4·17′	4·12′	4·36′	4·42′
	c_2	1·88	1·72	1·62	1·69	1·74	2·59	2·43	2·45	2·47	1·81
	c_3	0·60	0·61	0·56	0·55	0·52	0·54	0·53	0·60	0·53	0·12
	c_4	0·15	0·16	0·15	0·24	0·30	0·14	0·14	0·12	0·15	0·33
September to November.	c_1	1·67	1·58	1·75	1·82	1·89	3·26	3·45	—	4·00	4·88
	c_2	1·20	1·13	1·17	1·22	0·97	1·87	1·93	—	2·10	2·07
	c_3	0·86	0·83	0·87	0·85	0·74	0·57	0·44	—	0·45	0·48
	c_4	0·49	0·43	0·45	0·44	0·39	0·54	0·59	—	0·58	0·66

According to Table XIV the difference in the amplitudes of the *D* diurnal inequality at the several stations depends mainly if not entirely on the increase with latitude of the 24-hour Fourier wave. In the case of May and June there is a depression of c_2 and c_3 at Lerwick on disturbed days, and there is a considerable enhancement of c_4 on quiet days at Eskdalemuir, and on both quiet and disturbed days at Lerwick. But these may be accidental features, as they do not appear in September to November. The agreement between the values of c_2, c_3 and c_4 at the two Sandwell Park stations is remarkably close.

Table XV gives the ratios borne by the amplitudes of the 12-hour, 8-hour and 6-hour Fourier waves in *D* to the corresponding 24-hour wave. The decline in the relative importance of the shorter period waves with increase of disturbance, and except in the case of c_4 with increase of latitude is conspicuous. It is clear that in anything like a complete discussion of terrestrial phenomena it would be necessary to employ data from a very large number of stations, and also for a diversity of conditions as regards disturbance.

The differences between quiet day phase angles at the different stations in Table XVI are surprising small. In May-June a_1, a_2, a_3 are larger for S.U. than for S.S.,

TABLE XV.—DIURNAL INEQUALITY. RELATIVE AMPLITUDES OF FOURIER WAVES.

Season.	Ratio.	Quiet Days.					Disturbed Days.				
		K.	S.U.	S.S.	E.	L.	K.	S.U.	S.S.	E.	L.
May and June.	c_2/c_1	0·73	0·61	0·54	0·57	0·49	0·66	0·58	0·59	0·57	0·41
	c_3/c_1	0·23	0·22	0·19	0·19	0·15	0·14	0·13	0·15	0·12	0·03
	c_4/c_1	0·06	0·06	0·05	0·08	0·09	0·04	0·03	0·03	0·03	0·07
September to November.	c_2/c_1	0·72	0·72	0·67	0·67	0·51	0·57	0·56	—	0·53	0·42
	c_3/c_1	0·51	0·53	0·50	0·47	0·39	0·17	0·13	—	0·11	0·10
	c_4/c_1	0·29	0·27	0·26	0·24	0·21	0·17	0·17	—	0·15	0·14

TABLE XVI.—*D*. DIURNAL INEQUALITY. FOURIER COEFFICIENTS. PHASE ANGLES.

Season.	Phase Angle.	Quiet Days.					Disturbed Days.				
		K.	S.U.	S.S.	E.	L.	K.	S.U.	S.S.	E.	L.
		°	°	°	°	°	°	°	°	°	°
May and June.	a_1	205·7	204·0	194·8	201·6	198·3	223·1	221·1	216·8	221·2	220·2
	a_2	51·0	54·0	50·4	50·9	67·8	33·0	31·5	25·2	26·8	28·7
	a_3	254	254	249	256	289	206	201	188	188	320
	a_4	48	52	57	58	81	343	351	5	32	117
September to November.	a_1	235·2	231·8	234·6	234·9	237·0	265·2	265·8	—	266·3	268·1
	a_2	38·3	40·4	46·3	39·5	46·3	1·3	1·5	—	354·0	337·6
	a_3	252	247	250	251	265	261	261	—	270	300
	a_4	79	67	75	69	72	66	60	—	64	77

but the reverse is true of September to November, so the difference may be accidental.

The differences between the S.U. and S.S. phase angles for the May-June disturbed days are in the same direction as on the quiet days. It is unfortunate that there are no September to November disturbed day data for S.S.; but at S.U. the phase angles are in remarkable agreement with those at Kew, and have presumably no exceptional features.

Perhaps the only unmistakable features in Table XVI are the excesses at all the stations of the disturbed day over the quiet day values of α_1, and the excesses of the quiet day over the disturbed day values of α_2. In the latter case it will be noticed that when compared with the quiet day angles 39°·5 and 46°·3, the disturbed day angles 354·0° and 337·6° must be interpreted as −6·0° and −22·4° respectively.

§ 15.—Fourier Coefficients—*contd.*

The phenomena presented by the amplitudes of Fourier waves appear less simple in H than in D. In Table XVII in April to June there is a decided increase of both c_1 and c_2 with increase of latitude all the way from Kew to Lerwick. But in September-October this increase stops short of Lerwick in both c_1 and c_2 for the quiet days, and short of Eskdalemuir for the disturbed days in c_1. In this latter case c_1 seems abnormally depressed at Eskdalemuir.

Table XVII.—*H*. Diurnal Inequality. Fourier Coefficients. Amplitudes.

Season.	Amplitude.	Quiet Days.				Disturbed Days.			
		K.	S.U.	E.	L.	K.	S.U.	E.	L.
		γ	γ	γ	γ	γ	γ	γ	γ
April to June.	c_1	10·53	12·34	14·58	15·31	14·88	17·83	20·15	27·93
	c_2	5·99	6·74	8·10	9·17	6·02	7·03	10·28	17·71
	c_3	2·41	2·73	3·00	2·43	3·38	3·12	3·38	4·77
	c_4	0·99	1·14	1·15	1·06	1·98	1·67	1·88	4·61
September and October.	c_1	7·87	9·99	10·23	9·62	9·61	12·92	3·29	35·04
	c_2	4·44	5·42	5·72	4·80	5·27	5·84	9·95	27·87
	c_3	3·37	3·49	3·51	2·34	4·68	4·44	5·52	3·75
	c_4	1·97	1·91	1·74	0·83	1·38	0·92	1·85	3·57

Table XVIII tells us that in the case of H on quiet days c_2/c_1 varies little with latitude, while c_3/c_1 and c_4/c_1 fall as latitude increases. So far as Kew and Sandwell Park are concerned, the phenomena on disturbed days are fairly similar to those on quiet days. But at Eskdalemuir the disturbed day ratios are entirely different for the two seasons. This appears mainly due to the abnormally low value of c_1 for September-October.

Table XVIII.—*H*. Relative Amplitudes of Fourier Waves.

Season.	Ratio.	Quiet Days.				Disturbed Days.			
		K.	S.U.	E.	L.	K.	S.U.	E.	L.
April to June.	c_2/c_1	0·57	0·55	0·56	0·60	0·40	0·39	0·51	0·64
	c_3/c_1	0·23	0·22	0·21	0·16	0·23	0·18	0·17	0·17
	c_4/c_1	0·09	0·09	0·08	0·07	0·13	0·09	0·09	0·17
September and October.	c_2/c_1	0·56	0·54	0·56	0·50	0·55	0·45	3·03	0·80
	c_3/c_1	0·43	0·35	0·34	0·24	0·49	0·34	1·68	0·11
	c_4/c_1	0·25	0·19	0·17	0·09	0·14	0·07	0·56	0·10

The phase angles in Table XIX seem to throw light on this phenomenon. It will be noticed that on disturbed September-October days α_1 at Lerwick differs nearly 180° from α_1 at the other three stations. This implies a practically complete reversal of phase. The value of α_1 at Eskdalemuir is similar to those at Kew and

Sandwell Park. Considering the small size of c_1 at Eskdalemuir, the explanation which suggests itself is that in the disturbed September-October days the 24-hour wave began to diminish somewhere north of Sandwell Park, and passed through a zero value not far north of Eskdalemuir; then, reversing its phase, it increased rapidly with latitude. The phenomenon might mean that two sets of forces producing 24-hour waves of opposite phase were in action, the one being the more dominant in the South of England, the other in the North of Scotland.

TABLE XIX.—*H*. DIURNAL INEQUALITY. FOURIER COEFFICIENTS. PHASE ANGLES.

Season.	Phase Angle.	Quiet Days.				Disturbed Days.			
		K.	S.U.	E.	L.	K.	S.U.	E.	L.
		°	°	°	°	°	°	°	°
April to June.	α_1	134·7	117·3	122·8	120·8	131·5	120·9	142·2	167·3
	α_2	278·7	282·5	291·7	282·9	284·2	282·3	295·6	282·6
	α_3	148	141	141	143	168	173	161	133
	α_4	37	14	17	12	94	84	104	101
September and October.	α_1	120·9	97·6	108·8	105·7	67·7	79·0	76·0	247·9
	α_2	283·8	275·5	295·3	281·1	299·3	262·7	301·4	293·3
	α_3	159	145	165	168	155	143	152	46
	α_4	345	325	357	51	40	326	121	60

The phase angles at Kew, Sandwell Park and Eskdalemuir differ more amongst themselves than was the case in *D*. In three cases out of four the Sandwell Park values of α_1 and α_2 are the least, but this may be accidental.

§ 16. IRREGULAR DECLINATION MOVEMENTS.

Table XX gives the results of measurements of irregular *D* movements similar to those described in the Meteorological Office's *Geophysical Memoirs*, No. 17, pp. 187 *et seq*. The movements were almost entirely from the night hours, because sharply defined irregular movements are most common at night, and artificial disturbance is then least. What was measured was the difference in ordinate between turning points separated by comparatively short intervals of time. A short time interval is desirable to minimize the effects of the regular diurnal variation. As the uncertainty in the

TABLE XX.—DECLINATION. IRREGULAR MOVEMENTS.

DATE.		NUMBER OF MOVEMENTS.	K.	S.U.	S.S.	E.	L.	INTERNATIONAL CHARACTERS.	
			′	′	′	′	′		
March	26–27	8	34·3	40·5	—	—	66·2	1·4	1·1
	27–28	6	22·7	25·8	—	—	50·8	1·1	0·8
	28–29	7	23·5	29·1	31·1	—	57·7	0·8	0·6
	29–20	4	10·5	13·1	16·5	—	28·2	0·6	0·3
	30–31	2	6·9	8·2	10·2	—	18·5	0·3	0·4
April	7– 8	4	7·7	—	11·9	—	19·7	0·3	0·6
	8– 9	5	16·6	—	17·9	—	33·6	0·6	0·6
	9–10	6	29·2	—	33·5	—	49·6	0·6	0·9
	10–11	7	30·4	—	33·1	—	56·4	0·9	0·8
	11–12	5	28·3	31·3	32·8	—	56·4	0·8	0·9
	12–13	1	11·9	12·2	12·1	—	—	0·9	1·1
	13–14	9	63·7	69·0	74·4	—	126·2	1·1	0·8
	14–15	3	10·3	10·5	—	—	17·8	0·8	0·3
	20–21	10	61·5	63·6	65·9	—	109·4	0·9	1·2
	21–22	12	58·6	64·7	68·2	—	100·4	1·2	1·2
	22–23	17	93·0	99·8	111·2	—	—	1·2	1·0
	22–23	11	53·8	56·9	63·3	—	113·3		
	23–24	8	35–0	36·1	38·6	—	66·8	1·0	0·8
	24–25	5	23·6	26·5	28·7	—	55·4	0·8	0·2

TABLE XX.—DECLINATION. IRREGULAR MOVEMENTS—*continued.*

Date.		Number of Movements.	K.	S.U.	S.S.	E.	L.	International Characters.	
			′	′	′	′	′		
May	7– 8	11	26·3	29·4	—	—	57·7	0·4	0·8
	7– 8	5	11·9	12·8	15·0	—	—		
	8– 9	5	8·6	9·9	—	—	18·1	0·8	0·3
	8– 9	3	5·0	6·0	7·2	—	11·2		
	14–15	5	7·6	8·2	7·5	—	12·5	0·4	0·3
	16–17	4	19·4	20·6	—	—	37·8	0·2	1·6
	17–18	12	120·0	134·5	—	—	242·4	1·6	1·3
	18–19	8	23·6	24·0	20·5	—	38·2	1·3	0·9
	19–20	3	12·1	13·5	13·8	—	25·1	0·9	0·7
	20–21	4	13·2	15·1	15·0	—	25·9	0·7	0·5
	29–30	7	32·1	36·6	37·5	49·6	89·0	1·2	1·1
	30–31	4	14·6	16·5	17·3	—	35·1	1·1	0·3
June	4– 5	8	19·8	—	23·6	—	41·9	1·0	0·9
	4– 5	4	9·9	9·9	11·2	—	21·8		
	6– 7	7	24·1	27·1	26·4	37·2	44·0	0·7	0·2
	8– 9	1	2·2	2·3	2·3	—	—	0·1	0·1
	12–13	8	90·2	—	105·2	125·2	157·3	0·8	1·7
	13–14	4	13·5	—	20·2	26·0	38·4	1·7	1·2
	14–15	6	38·2	—	44·8	59·2	101·3	1·2	0·9
	15–16	2	6·3	—	7·2	8·6	12·5	0·9	0·3
	20–21	5	30·7	33·4	36·5	42·9	56·2	0·6	1·0
	21–22	3	6·5	7·2	8·2	8·7	12·7	1·0	0·4
	23–24	3	3·3	3·9	4·1	5·2	8·1	0·3	0·0
	27–28	4	11·7	12·9	13·7	16·2	24·9	0·7	0·7
	30– 1	14	66·6	68·2	81·2	116·0	199·9	1·2	0·5
September	17–18	7	15·4	—	18·2	—	28·0	0·4	0·7
	17–18	6	12·8	13·2	14·9	—	22·6		
	18–19	5	13·0	14·6	14·5	21·8	31·8	0·7	0·2
	19–20	4	13·3	12·2	12·4	17·0	20·3	0·2	0·3
	20–21	4	6·2	7·5	6·9	10·3	11·8	0·3	0·0
	22–23	7	11·3	12·1	11·8	16·9	19·9	0·0	0·3
	23–24	4	8·4	9·7	9·7	12·2	13·1	0·3	0·5
	24–25	2	4·7	5·2	5·3	6·8	7·9	0·5	0·3
	25–26	6	11·7	12·7	—	17·0	19·7	0·3	1·7
	25–26	3	6·8	7·2	7·2	10·2	12·2		
	26–27	25	215·7	250·1	—	332·3	—	1·7	2·0
	26–27	15	138·3	157·7	—	214·4	278·9		
	27–28	18	253·7	289·1	—	—	—	2·0	1·2
	27–28	17	230·3	261·6	—	356·5	—		
	27–28	17	225·7	257·9	—	—	579·8		
	28–29	8	25·7	28·2	—	38·5	50·4	1·2	0·8
	29–30	3	16·1	19·1	—	26·9	32·8	0·8	0·7
	30– 1	2	5·8	7·5	—	11·0	12·2	0·7	0·4
October	4– 5	2	5·1	5·3	—	—	7·1	0·0	0·3
	7– 8	6	7·2	—	7·8	11·0	13·1	0·1	0·5
	8– 9	2	7·4	—	8·5	11·4	15·1	0·5	0·2
	10–11	3	20·8	—	21·4	29·0	37·8	0·8	0·9
	12–13	2	10·0	9·8	10·5	13·5	18·9	0·7	0·1
	14–15	10	41·9	45·1	46·7	59·5	81·8	0·7	1·9
	15–16	24	280·5	—	299·5	385·0	—	1·9	2·0
	15–16	20	241·2	257·0	257·0	328·6	—		
	15–16	13	185·8	197·8	197·2	258·3	368·6		
	16–17	37	356·9	—	389·8	528·9	843·0	2·0	1·6
	16–17	27	232·5	255·4	253·6	346·2	582·5		
	17–18	8	54·9	—	59·8	74·8	86·3	1·6	1·4
	18–19	10	84·1	—	96·0	119·3	168·7	1·4	1·0
	19–20	7	32·4	31·3	31·5	43·5	54·6	1·0	0·6
	20–21	12	30·2	25·5	27·8	40·4	54·4	0·6	0·2
	22–23	2	3·6	4·0	3·7	5·2	6·0	0·3	0·0
	25–26	8	15·5	16·2	16·7	22·7	31·3	0·3	0·4
	26–27	15	40·2	41·0	42·7	57·6	68·7	0·4	0·9
	27–28	3	14·7	15·0	16·2	21·2	31·3	0·9	0·2
November	– 1	10	47·8	51·6	52·2	69·2	90·7	0·8	0·8
	1– 2	9	33·9	33·3	—	49·3	54·4	0·8	1·3
	2– 3	14	62·3	69·9	—	96·7	128·2	1·3	0·8
	3– 4	4	6·2	6·9	7·3	9·3	12·4	0·8	0·1
	4– 5	2	2·7	2·7	2·8	4·5	4·6	0·1	0·1
	7– 8	6	38·3	40·4	40·5	55·5	78·0	0·6	0·1
	8– 9	3	5·4	5·4	6·2	7·4	8·9	0·1	0·1
	9–10	2	2·3	2·6	2·8	4·3	6·6	0·1	0·1
	11–12	10	13·8	12·9	14·2	20·5	26·6	0·1	0·9
	12–13	10	60·0	64·3	66·0	84·3	120·0	0·9	0·7

ordinate of a peak or hollow is as great whether the movement is small or large, there is greater uncertainty in the estimate of a small than of a large movement. Partly for this reason and partly for brevity, we give here only the aggregate of the amplitudes measured on any one night. So far as Britain is concerned, it would have been advantageous for the treatment of magnetic disturbance if the day had commenced at Greenwich noon rather than Greenwich midnight. In the absence of magnetic character figures for the night, international character figures are given for the two successive Greenwich days to which the night belonged.

Irregular movements in a particular element can hardly be measured unless curves for that particular element exist. It was only in the end of May that *D* records from Eskdalemuir became available. In some nights results are given for more than one group of movements. For example, on 22nd-23rd April there are results for groups of 17 and of 11. The 11 were really members of the 17, and included all the movements which could be satisfactorily measured at Lerwick. To have confined ourselves in all cases to movements measurable at all the stations would have considerably reduced the material available for comparing pairs of stations. There were occasions, *e.g.*, 26th-27th September and 15th-16th October, when only some of the movements could be satisfactorily identified at Lerwick. This difficulty was never experienced in *D* as between Kew and either Sandwell Park Station, and very rarely at Eskdalemuir. Blanks at Sandwell Park represent loss or imperfection of trace. Thus, the S.S. data for the final days of September had to be omitted owing to the defect already mentioned.

As the magnetic characters show, the majority of the movements are from days of considerable disturbance, but a substantial minority are from days which were decidedly quiet. The movements from the quietest days were, however, all small, so their joint contributions to the monthly aggregates were not large.

TABLE XXI.—DECLINATION IRREGULAR MOVEMENTS. AGGREGATES AND RATIOS.

Month.	Kew and Sandwell Underground.				Kew and Sandwell Surface.			
	Number of Movements	K.	S.U.	S.U./K.	Number of Movements	K.	S.S.	S.S./K.
		′	′			′	′	
March ..	27	97·9	116·7	1·19	13	40·9	57·8	1·41
April ..	70	385·9	413·7	1·07	89	459·5	528·3	1·15
May ..	63	277·5	308·3	1·11	39	120·1	133·8	1·11
June ..	41	155·0	164·9	1·06	65	313·1	373·4	1·19
September ..	94	598·4	681·2	1·14	36	79·1	86·0	1·09
October ..	108	667·3	705·6	1·06	149	1000·3	1078·6	1·08
November ..	70	272·7	290·0	1·06	47	176·5	192·0	1·09
Total ..	473	2454·7	2680·4	1·09	438	2189·5	2449·9	1·12

TABLE XXII.—DECLINATION IRREGULAR MOVEMENTS. AGGREGATES AND RATIOS.

Month.	Kew and Eskdalemuir.				Kew and Lerwick.			
	Number of Movements	K.	E.	E./K.	Number of Movements	K.	L.	L./K.
		′	′			′	′	
March ..	—	—	—	—	27	97·9	221·4	2·26
April ..	—	—	—	—	85	418·7	805·0	1·92
May ..	7	32·1	49·6	1·55	63	277·5	581·8	2·10
June ..	56	291·1	445·2	1·53	64	310·9	697·2	2·24
September ..	87	562·2	867·2	1·54	84	495·6	1106·6	2·23
October ..	149	1000·3	1423·0	1·42	140	910·7	1886·7	2·07
November ..	70	272·7	401·0	1·47	70	272·7	530·4	1·94
Total ..	369	2158·4	3186·0	1·48	533	2784·0	5829·1	2·09

Corresponding monthly aggregates of the irregular *D* movements at pairs of stations are compared in Tables XXI to XXIII. If we omit March, in which the number of movements was somewhat small, especially at S.S., the ratio of the representative S.U. or S.S. movement in Table XXI to the corresponding Kew movement showed only minor fluctuations from month to month. The final mean values of the ratios as derived from the aggregates of 473 common movements at Kew and S.U., and from the aggregates of 438 common movements at Kew and S.S., were respectively 1·09 and 1·12. Each of these ratios is decidedly larger than the corresponding 5 or 6 month mean ratio for either the ranges or the A.D.s in the diurnal inequality from either quiet or disturbed days.

Similar remarks apply to the Eskdalemuir-Kew and Lerwick-Kew ratios in Table XXII. The final mean value of the former ratio, 1·48, is less than the value 1·54 derived from 295 *D* movements common to Eskdalemuir and Kew during the months June to December, 1919. The mean monthly values of the ratio in 1919 varied from 1·32 to 1·68. As 1919 was a year of comparatively many sunspots, and 1923 a year of very few, we might be tempted to conclude that the ratio of these irregular movements at a given pair of stations does not vary much from year to year. But in 1908-9 the lowest value of the Eskdalemuir-Kew ratio in any single month was 1·83, and the final mean for the whole period from 433 common movements was 2·14. The mean ratios in Table XXII, 1·48 for Eskdalemuir-Kew, and 2·09 for Lerwick-Kew, compare respectively with 1·15 and 1·33 in the case of the range of the disturbed day diurnal inequality. Increase of latitude is thus responsible for a much larger relative increase of the short period irregular movements than of the slow regular movements.

Table XXI supplies an indirect comparison of S.U. and S.S., but a direct comparison employing only movements recorded at both stations appeared desirable, and its results are embodied in Table XXIII. In this table the aggregate of the movements is larger at S.S. than at S.U. in every month. If there were any error in scale value in either of the *D* instruments in use at Sandwell Park, we should expect it to influence in opposite directions the results from the first four and the last three months. The average ratio for the first four months exceeds that for the last three, while the last three months supply considerably more than the half of the aggregate of movements. The natural conclusion is that if there were any error in the scale values, the final mean ratio 1·04 is too low. At first sight an excess of 4 per cent. in the amplitude of irregular movements at the surface station seems improbable, in view of the practical equality shown by Tables IV and V between the ranges and the A.D.s on disturbed days at the two stations. But the majority of the irregular movements compared in Table XXIII did not come from highly disturbed days. Also the causes affecting the regular diurnal variation and the irregular movements must be widely different, because from Kew to Eskdalemuir the latter increase much more rapidly with the latitude than the former.

The direct comparison made between Eskdalemuir and Lerwick in Table XXIII appeared advisable in view of the stoppage of magnetic registration at Kew Observa-

TABLE XXIII.—DECLINATION IRREGULAR MOVEMENTS. AGGREGATES AND RATIOS.

Month.	Sandwell Underground and Surface.				Eskdalemuir and Lerwick.			
	Number of Movements	U.	S.	S./U.	Number of Movements	E.	L.	L./E.
		′	′			′	′	
March ..	13	50·4	57·8	1·15	—	—	—	—
April ..	67	403·2	431·9	1·07	—	—	—	—
May	39	132·7	133·8	1·01	7	49·6	89·0	1·79
June.. ..	41	164·9	183·6	1·11	56	445·2	655·3	1·47
September ..	35	81·7	82·7	1·01	76	708·7	1024·8	1·45
October ..	106	700·3	706·4	1·01	138	1296·3	1879·6	1·45
November ..	47	186·8	192·0	1·03	70	401·0	530·4	1·32
Total ..	348	1720·0	1788·2	1·04	347	2900·8	4179·1	1·44

tory. In the future it will be natural to compare other stations with Eskdalemuir. It will be noticed that during 1923 the amplitude of irregular short period movements at Eskdalemuir was roughly a geometrical mean between the amplitudes at Kew and Lerwick.

Table XXIV gives the results of an attempt to find whether the size of the movement or the general magnetic character of the night influenced the ratio between the amplitudes of the movements at the more northern stations and the amplitude at Kew. The first line employed only those movements which exceeded 10′ at Kew. The second line took only those movements which occurred on nights common to two days each of which had an international character figure of at least 1·0. While the third line included movements from nights common to days neither of which had an international character figure exceeding 0·5. There is a slight suggestion that Lerwick movements are relatively enhanced on nights of higher general disturbance, but this wants confirmation.

TABLE XXIV.—RATIOS OF IRREGULAR *D* MOVEMENTS UNDER DIFFERENT CONDITIONS.

Conditions.	Sandwell U. / Kew		Sandwell S. / Kew		Eskdalemuir / Kew		Lerwick / Kew	
	Number	Ratio.	Number	Ratio	Number	Ratio	Number	Ratio
Movements > 10′ at Kew ..	53	1·10	44	1·09	56	1·43	49	2·04
Character not less than 1·0 ..	146	1·11	119	1·11	132	1·48	154	2·19
Character not greater than 0·5	51	1·07	57	1·10	49	1·48	58	1·85

§ 17. IRREGULAR HORIZONTAL FORCE MOVEMENTS.

Table XXV gives the results of measurements of irregular movements of *H*. In this case, unfortunately, only three stations are represented. This is the more unfortunate because on quite an appreciable number of cases movements which closely resembled one another at Kew and Sandwell Park could not be satisfactorily identified at Lerwick. In the case of one movement on 12th-13th June and twelve movements on 26th-27th September, while movements were identified at Lerwick they were on a relatively gigantic scale. The results thus obtained are enclosed in brackets, and they were omitted from the monthly means given in Table XXVI. There was nothing exceptional in the appearance of the movements on these two occasions at Kew and Sandwell Park. The absence of Eskdalemuir records is much to be regretted.

On the average the Lerwick movement was considerably larger than the Kew movement, but apart from the exceptional cases mentioned above its excess was much less than in the case of *D*, even when allowance is made in the case of the *D* movements for the reduced value of *H* at Lerwick. Also there were occasions when the *H* movements appeared to be nearly constant, or even to diminish as we went north. The following are examples: 7th-8th, 10th-11th, 11th-12th April; 7th-8th, 8th-9th, 14th-15th, 16th-17th, 22nd-23rd, 24th-25th May; 19th-20th, 23rd-24th, 29th-30th June; 5th-6th October.

On 15th-16th October three movements which had been marked for measurement in the Kew *H* curve could not be satisfactorily identified at Sandwell Park. This was the only occasion of the kind.

There were numerous individual cases when the movement at Sandwell Park (underground) exceeded that at Kew, and this was true, as Table XXVI shows, even of the average movement in September and November, but in a distinct majority of cases the Sandwell Park movement was the smaller, and in the aggregate from the 514 movements measured there was a deficiency of 1 per cent. The focussing of the Sandwell Park curve was poor for part of the time, and suspicion was felt that this might have prejudiced the result. The irregular movements from the months which

TABLE XXV.—HORIZONTAL FORCE. IRREGULAR CHANGES.

Date.		Number of movements	K.	S.U.	L.	International Character.	
			γ	γ	γ		
March	28–29	6	117	111	—	0·8	0·6
	29–30	3	50	53	—	0·6	0·3
	30–31	2	61	52	—	0·3	0·4
April	6–7	2	36	32	45	0·1	0·3
	7–8	1	16	15	12	0·3	0·6
	8–9	7	92	93	157	0·6	0·6
	9–10	3	41	45	65	0·6	0·9
	10–11	2	100	96	83	0·9	0·8
	11–12	4	159	156	160	0·8	0·9
	12–13	4	137	132	185	0·9	1·1
	13–14	7	237	236	328	1·1	0·8
	14–15	3	66	63	75	0·8	0·3
	20–21	18	356	332	438	0·9	1·2
	21–22	10	222	219	346	1·2	1·2
	22–23	16	398	371	—	1·2	1·0
	22–23	9	239	227	343		
	23–24	6	187	184	—	1·0	0·8
	24–25	7	146	154	223	0·8	0·2
	27–28	2	19	24	26	0·1	0·1
	29–30	2	40	46	67	0·2	0·2
May	3–4	9	241	243	—	1·0	0·8
	3–4	6	171	173	219		
	7–8	9	164	154	141	0·4	0·8
	8–9	3	92	90	76	0·8	0·3
	14–15	5	69	56	60	0·4	0·3
	16–17	7	86	70	—	0·2	1·6
	16–17	4	40	32	38		
	17–18	17	753	774	—	1·6	1·3
	17–18	14	611	641	1189		
	18–19	10	160	171	248	1·3	0·9
	19–20	3	62	61	89	0·9	0·7
	20–21	10	175	187	310	0·7	0·5
	21–22	4	84	75	93	0·5	0·1
	22–23	2	25	26	25	0·1	0·2
	24–25	3	25	23	24	0·1	0·3
	25–26	4	61	61	82	0·3	0·2
	29–30	15	336	312	—	1·2	1·1
	29–30	6	187	172	217		
	30–31	5	181	174	237	1·1	0·3
June	1–2	3	31	32	46	0·2	0·2
	3–4	7	135	126	161	0·5	1·0
	4–5	17	265	246	—	1·0	0·9
	4–5	11	163	148	169		
	6–7	7	170	169	220	0·7	0·2
	7–8	2	16	17	20	0·2	0·1
	8–9	3	54	52	121	0·1	0·1
	12–13	12	297	269	—	0·8	1·7
	12–13	6	140	116	128		
	12–13	(1)	(48)	(58)	(233)		
	13–14	11	339	330	—	1·7	1·2
	13–14	7	212	212	342		

Date.		Number of movements	K.	S.U.	L.	International Character.	
			γ	γ	γ		
June	14–15	10	314	300	—	1·2	0·9
	14–15	2	98	95	108		
	15–16	3	35	36	53	0·9	0·3
	19–20	2	30	28	26	0·3	0·6
	20–21	8	175	155	—	0·6	1·0
	20–21	7	156	136	163		
	21–22	2	42	38	47	1·0	0·4
	23–24	2	23	20	18	0·3	0·0
	26–27	7	67	59	—	0·2	0·7
	26–27	5	59	52	75		
	27–28	12	272	244	317	0·7	0·7
	28–29	2	38	38	47	0·7	0·2
	29–30	2	23	18	16	0·2	1·2
	30– 1	19	581	542	—	1·2	0·5
Sept.	18–19	2	48	45	59	0·7	0·2
	19–20	2	20	28	35	0·2	0·3
	20–21	3	50	47	62	0·3	0·0
	23–24	3	53	58	73	0·3	0·5
	24–25	2	53	50	59	0·5	0·3
	26–27	14	803	950	—	1·7	2·0
	26–27	(12)	(756)	(903)	(3651)		
	27–28	18	730	689	—	2·0	1·2
	28–29	6	170	158	179	1·2	0·8
	29–30	2	53	43	—	0·8	0·7
October	–1	1	15	18	34	0·7	0·4
	4–5	2	13	18	25	0·0	0·3
	5–6	2	26	21	15	0·3	0·4
	7–8	3	64	55	72	0·1	0·5
	8–9	2	19	21	41	0·5	0·2
	9–10	2	31	28	39	0·2	0·8
	10–11	3	55	59	103	0·8	0·9
	14–15	10	280	270	285	0·7	1·9
	15–16	14	849	854	—	1·9	2·0
	16–17	22	957	929	—	2·0	1·6
	17–18	4	192	195	—	1·6	1·4
	17–18	2	96	104	181		
	18–19	4	253	236	—	1·4	1·0
	18–19	2	84	69	95		
	20–21	2	62	52	—	0·6	0·2
	22–23	2	29	28	51	0·3	0·0
	25–26	6	78	71	—	0·3	0·4
	26–27	6	142	135	171	0·4	0·9
	27–28	2	37	43	72	0·9	0·2
	28–29	2	21	19	31	0·2	0·1
Nov.	–1	5	94	119	176	0·8	0·8
	2–3	10	267	323	407	1·3	0·8
	3–4	2	12	17	22	0·8	0·1
	6–7	2	16	20	24	0·3	0·6
	7–8	4	52	62	69	0·6	0·1
	12–13	8	191	202	257	0·9	0·7

TABLE XXVI.—*H*. IRREGULAR CHANGES. AGGREGATES AND RATIOS.

Month.	Kew and Sandwell Park.				Kew and Lerwick.			
	Number of Movements	K.	S.U.	S.U./K.	Number of Movements	K.	L.	L./K.
		γ	γ			γ	γ	
March ..	11	228	216	0·95	—	—	—	—
April ..	94	2252	2198	0·98	81	1906	2553	1·34
May ..	106	2514	2477	0·99	88	2107	3048	1·45
June.. ..	131	2907	2719	0·93	85	1697	2077	1·22
September ..	52	1980	2068	1·04	18	394	467	1·19
October ..	89	3123	3052	0·98	41	912	1215	1·33
November ..	31	632	743	1·18	31	632	955	1·51
Total ..	514	13636	13473	0·99	344	7648	10315	1·35

suffered were accordingly remeasured, any doubt encountered being given in favour of a larger amplitude, but the difference on the aggregate from the original measurements was very small. The revised figures were used in all cases.

An inquiry was instituted as to whether the ratio S.U. to Kew for irregular *H* movements varied with the size or rapidity of the movement, or with the magnetic character of the day. A mean from 48 of the largest and most rapid movements gave for the ratio S.U. to Kew the value 1·00 ; in some months the ratio was greater than unity, in other months less. From 145 movements on nights when the international character figure did not fall short of 1·0 on either of the successive days the value of the ratio was 1·00, while 0·96 was obtained from 65 movements on nights when the international character figure did not exceed 0·5 on either of the successive days. On the whole there seems a slight tendency for the ratio to increase when disturbance is large.

In view of the very substantial excess which Table XII shows in the amplitude of the regular diurnal variation in *H* at Sandwell Park over that at Kew, the fact that the irregular movements should be if anything smaller at the former station is surprising. In the absence of records from a surface station at Sandwell Park it is impossible to say what part was played by the fact that the Sandwell Park station was underground. But the fact that the irregular *H* movements at Lerwick were very substantially larger on the average than those at Kew would certainly lead us to expect a very sensible excess in the irregular movements at a surface station at Sandwell Park. There is thus a presumption that the reduction in the amplitude of the irregular *D* movements observed at the underground station was also true of *H*.

In considering the comparative results in Table XXVI for Kew and Lerwick, it should be remembered that on a good many occasions in September and October satisfactory identification was not possible between movements at Lerwick and those at Kew or Sandwell Park. On most, if not all, of these occasions a movement appeared in progress at Lerwick which had apparently nothing to do with the short-period movements which alone were pronounced at Kew. What was a peak at Kew or Sandwell Park might be represented by a retardation or slight temporary reversal of a slower but larger depression at Lerwick. Any measurements made in such a case would have been misleading. It should also be remembered that Table XXVI omits a few cases in which peaks and hollows appeared simultaneously, or nearly so, at Kew and Lerwick, but when the movements at Lerwick were on quite a different scale from those at the other stations. On one of the nights 27th-28th September, when identification was not possible at Lerwick, the range for the night at Lerwick exceeded 900γ, while the corresponding range at Kew was only about 140γ.

Thus the comparison in Table XXVI between Kew and Lerwick represents on the whole only the less disturbed days, and applies only to cases in which the phenomena at Lerwick were generally similar to those further south. Still 344 movements are included in Table XXVI, and all the months are represented. It is thus noteworthy that the final ratio is only 1·35, as against 2·09 the corresponding result given in Table XXII for *D*. This latter value becomes 1·67 if we convert declination changes into their force equivalents.

A comparison was instituted between such of the movements utilized in the Lerwick-Kew comparison in Table XXVI as occurred on two groups of nights, the first group including the occasions on which the international character figure did not fall short of 1·0 on either of the successive days, the second group including occasions on which the character figure did not exceed 0·5 on either day. The mean values thus obtained for the Lerwick : Kew ratio were for the first group (50 movements) 1·64, for the second group (57 movements) 1·31.

§ 18. Selected Irregular Movements, Individually Considered.

The cases in which *H* movements at Lerwick were not identifiable were investigated singly. Measurements were made of the *D* as well as the *H* curves. The results are shown as differences between successive mean hourly values, the positive sign indicating that the element was increasing. One reason for this was a considerable instrumental drift which unfortunately affected the base line value of the H curves at Lerwick. In the case of large hourly changes this was quite immaterial, and it would have only a trifling effect in such cases as are given below of large changes extending over a few hours.

The really serious source of uncertainty is that mean hourly values cannot claim an accuracy approaching 1γ on highly disturbed days, especially at stations such as Lerwick. The equivalent of 1 mm. of ordinate at Lerwick was 1′·93 in D, and usually from 7γ to 8γ in H. Thus the effects of uncertainties of even 0·5 mm. in mean hourly ordinates were sensible. If the element is altering on the whole in one direction, a mistake in one hourly value influences two successive hourly changes in opposite directions, enhancing the one and diminishing the other. This possibility should be borne in mind. The D and H results are in all cases grouped separately, the D above, the H below.

April 13th–14th.—So far as D is concerned, the hourly changes at the several stations appear very fairly parallel, with a gradual but decided tendency to an increase as we go north. An apparent irregularity such as the increased fall of D between 20^h and 21^h at S.U., as compared with Kew or S.S., *might* arise from a slight underestimate of the 21^h ordinate at S.U., the consequence being to enhance the hourly change from 20^h to 21^h at the expense of the change from 21^h to 22^h. Similarly the apparent rise from 3^h to 4^h at Lerwick *might* be due to underestimate of the ordinate at 3^h, an explanation suggested by the small excess of the rise between 2^h and 3^h at Lerwick over the corresponding rise at Eskdalemuir. In this, as in a good many other cases, the D results for Eskdalemuir were derived from the measurements of N and W curves. On this occasion the parallelism between the H changes at Kew, Sandwell Park and Eskdalemuir is quite good. There is, however, a recognisable lack of parallelism between the H changes at Lerwick and those at the other stations.

April 13–14, *Hourly Changes.*

Station.	19–20 h.	20–21 h.	21–22 h.	22–23 h.	23–24 h.	0–1 h.	1–2 h.	2–3 h.	3–4 h.
	′	′	′	′	′	′	′	′	′
Kew	0·0	−0·8	−5·5	−3·3	+5·8	+1·4	−0·8	+6·0	−1·0
Sandwell Park, Underground	−0·2	−1·4	−5·5	−3·2	+6·7	+0·6	−0·5	+6·4	−1·5
Sandwell Park, Surface	−0·3	−1·2	−6·0	−3·7	+6·8	+0·2	−0·9	+6·5	−0·8
Eskdalemuir	−0·6	−0·4	−7·4	−5·3	+8·9	+1·4	−1·2	+8·0	−0·9
Lerwick	−0·6	−1·7	−8·5	−5·8	+10·8	+2·7	−3·3	+8·1	+1·2
	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	−1	+4	+ 8	−13	−18	+20	−16	−13	+14
Sandwell Park ..	−1	+5	+11	−15	−18	+26	−19	−12	+16
Eskdalemuir	−1	+4	+ 5	−22	−16	+34	−20	−15	+26
Lerwick	+1	+4	− 7	−17	−23	+23	+ 4	−26	+32

April 22nd.—There is the usual tendency to an increase in the D movements as we go north, but the only decided lack of parallelism is in the H changes at Lerwick after

April 22, *Hourly Changes.*

Station.	15–16 h.	16–17 h.	17–18 h.	18–19 h.	19–20 h.	20–21 h.	21–22 h.	22–23 h.	23–24 h.
	′	′	′	′	′	′	′	′	′
Kew	−2·8	−3·3	+1·3	−3·6	−0·5	−0·3	−1·8	+2·3	+1·6
Sandwell Park, Underground	−3·7	−2·2	+0·6	−3·2	+0·1	+0·1	−3·0	+2·2	+2·2
Sandwell Park, Surface	−3·3	−2·6	+0·3	−2·6	−0·8	−0·1	−2·3	+3·2	−0·5
Eskdalemuir	−3·3	−3·7	+2·0	−4·3	−0·7	+0·2	−3·0	+3·5	+0·9
Lerwick	−4·4	−4·1	+3·3	−3·7	−1·2	+2·1	−6·8	+1·5	+3·9
	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	+1	+21	−11	+14	−16	+ 7	−14	+12	+12
Sandwell Park ..	+2	+23	− 9	+14	−15	+ 5	−11	+13	+10
Eskdalemuir	+6	+29	−16	+18	−25	− 7	− 7	+20	− 1
Lerwick	+7	+40	−14	+ 7	−20	−52	+21	− 3	− 7

20^h. It will be noticed, however, that while the change in *H* at Eskdalemuir from 20^h to 21^h is comparatively small, as at the more southern stations, it is a fall not a rise. It was presumably influenced to a minor extent by the forces which caused the big fall at Lerwick. Similarly the reduction in the fall at Eskdalemuir from 21^h to 22^h, as compared with the falls at Kew and Sandwell Park, *may* represent the influences which led at Lerwick to a rise of force.

May 29th-30th.—The general parallelism in the case of the *D* hourly changes is remarkably close. The entry under 23^h-24^h at Kew is the only one which differs in sign from the other entries in its column. The largest hourly change is encountered at Lerwick in each of the first seven hours.

In the case of *H* the changes at Kew, Sandwell Park and Eskdalemuir all agree in sign. But the enhanced fall at Eskdalemuir between 23^h and 24^h is presumably associated with the still more pronounced fall at Lerwick, while the reduction in the fall between 0^h and 1^h at Eskdalemuir suggests a transition to the considerable rise at Lerwick. *H* was lower at 24^h than at 18^h by 21γ at Kew, 15γ at Sandwell Park, and 51γ at Eskdalemuir, but by no less than 110γ at Lerwick.

May 29–30, Hourly Changes.

Station.	18–19 h.	19–20 h.	20–21 h.	21–22 h.	22–23 h.	23–24 h.	0–1 h.	1–2 h.	2–3 h.	3–4 h.
Kew	−3′·8	+1′·2	−3′·9	+4′·1	+0′·7	+0′·4	−4′·6	+0′·6	−1′·1	−1′·5
Sandwell Park, Underground	−3·9	+0·4	−3·9	+4·5	+1·0	−1·0	−4·5	+0·7	−1·0	−1·7
Sandwell Park, Surface	−4·0	+0·5	−3·7	+4·8	+1·6	−0·8	−5·1	+0·5	−1·1	−1·4
Eskdalemuir	−4·2	+0·6	−4·6	+5·4	+1·7	−1·7	−5·6	+0·4	−1·5	−1·2
Lerwick	−5·2	+1·7	−6·9	+6·9	+3·7	−4·8	−6·9	+0·2	−1·2	−1·5
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	−20	+10	− 7	− 2	+13	−15	−13	− 4	+ 4	+ 4
Sandwell Park ..	−14	+ 6	− 5	− 4	+ 8	− 6	−12	− 5	5	+ 3
Eskdalemuir	−26	+ 7	−13	− 5	+15	−29	− 1	− 6	−10	+ 2
Lerwick	−31	−14	− 9	−17	+ 8	−47	+31	− 6	−10	+ 4

June 12th-13th.—Up to 2^h the parallelism between the hourly changes at the four stations is good. But the fall of *H* at Lerwick from 2^h to 3^h and the rise from 3^h to 4^h are relatively very large. It was only during the last two hours that the tendency in the *H* changes to increase with the latitude is pronounced. Somewhat curiously the *D* changes during these two hours are smaller at Lerwick than elsewhere.

June 12–13, Hourly Changes.

Station.	19–20 h.	20–21 h.	21–22 h.	22–23 h.	23–24 h.	0–1 h.	1–2 h.	2–3 h.	3–4 h.
Kew	+0′·9	+1′·0	−0′·1	−0′·6	−2′·4	−3′·2	3′·7	+9′·1	−7′·0
Sandwell Park, Surface	+0·5	+1·0	+0·5	−0·5	−4·4	−3·9	−3·7	+9·3	−7·6
Eskdalemuir	+0·9	+0·8	+0·4	−0·6	−3·4	−4·6	−5·8	+12·4	−9·5
Lerwick	+0·6	+1·4	0·0	−0·8	−4·1	−2·1	−9·3	+7·3	−5·8
	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	+ 6	+18	+11	+ 1	−13	−28	1	−28	+13
Sandwell Park ..	+ 7	+17	+ 9	+ 3	−11	−24	0	−38	+17
Eskdalemuir	+ 9	+18	+12	+ 2	−23	−25	− 3	−59	+45
Lerwick	+ 7	+17	+ 9	+ 8	−32	−28	1	−165	+116

June 13th-14th.—In the case of *D* the fall at Lerwick between 23^h and 24^h is the chief irregular feature. At Lerwick *H* was lower at 2^h than at 0^h by 42γ, as compared with 2γ at Sandwell Park and Eskdalemuir, the Kew value at 2^h being even slightly in excess. The large rise in *H* at Lerwick between 2^h and 3^h is hardly represented elsewhere. It represents presumably the recovery from the previous depression.

June 13–14, *Hourly Changes.*

Station.	20–21 h.	21–22 h.	22–23 h.	23–24 h.	0–1 h.	1–2 h.	2–3 h.	3–4 h.
Kew	−0′·5	−1′·6	+1′·0	+0′·1	+1′·7	+1′·4	−0′·1	−2′·3
Sandwell Park, Surface.. ..	−0·9	−1·6	+1·3	+0·1	+1·7	+0·9	−0·1	−2·3
Eskdalemuir	−1·4	−2·0	+1·9	−0·4	+2·4	+0·7	0·0	−3·0
Lerwick	−1·0	−3·1	+3·9	−2·5	+1·9	+1·9	+1·2	−4·2
	γ	γ	γ	γ	γ	γ	γ	γ
Kew	+ 4	−12	− 2	− 6	− 5	+ 8	− 1	+ 5
Sandwell Park	+ 3	− 5	−10	− 1	− 7	+ 5	+ 3	+ 4
Eskdalemuir	0	−20	+ 3	− 7	− 8	+ 6	+ 6	+ 6
Lerwick	− 3	−27	− 9	+ 4	−18	−24	+42	+14

June 14*th*-15*th*.—Except during the first hour, 20-21^h which was relatively quiet, the D change at Lerwick was invariably the largest. The outstanding features in H are the large fall at Lerwick from 21^h to 22^h, and the large rise in the following hour. The Eskdalemuir H changes during these two hours seem to show traces of the influence which prevailed at Lerwick.

June 14–15, *Hourly Changes.*

Station.	20–21 h.	21–22 h.	22–23 h.	23–24 h.	0–1 h.	1–2 h.	2–3 h.	3–4 h.
Kew	−0′·3	−1′·7	−1′·3	+1′·7	+3′·2	−1′·5	−0′·3	+0′·8
Sandwell Park, Surface.. ..	−0·5	−1·8	−2·1	+1·0	+3·6	−1·7	−0·4	+1·2
Eskdalemuir	−0·8	−2·1	−1·6	+1·0	+5·0	−3·2	0·0	+0·5
Lerwick	−0·2	−3·7	−2·5	+2·3	+7·3	−5·2	−1·9	+1·7
	γ	γ	γ	γ	γ	γ	γ	γ
Kew	+ 2	+ 9	−22	+ 1	+ 4	−11	− 4	+ 3
Sandwell Park	+ 2	+ 8	−20	+ 3	+ 2	− 9	− 6	0
Eskdalemuir	+ 1	− 9	−13	+ 8	+ 3	−14	− 7	+ 4
Lerwick	− 9	−52	+39	0	−13	0	+ 2	− 8

June 21*st*.—The variation of D with latitude appears less than usual. The most irregular feature is the fall of H between 2^h and 3^h at Lerwick.

June 21, *Hourly Changes.*

Station.	0–1 h.	1–2 h.	2–3 h.	3–4 h.	4–5 h.	5–6 h.
Kew	−0′·1	−0′·9	+4′·2	−2′·8	−2′·7	+0′·7
Sandwell Park, Underground ..	−0·2	−1·0	+5·3	−4·2	−2·9	+1·1
Sandwell Park, Surface	−0·2	−1·3	+5·4	−3·7	−2·8	+0·6
Eskdalemuir	−0·2	−1·2	+5·9	−4·5	−3·1	+0·6
Lerwick	−0·8	−1·0	+5·8	−2·1	−6·2	+1·2
	γ	γ	γ	γ	γ	γ
Kew	+3	−3	+2	+13	−3	−4
Sandwell Park	+2	−4	−1	+15	−3	−6
Eskdalemuir	0	−2	−2	+18	−6	−7
Lerwick	+7	−1	−16	+16	+3	+2

June 30*th*.—The parallelism between the D hourly changes at Kew, Sandwell Park and Eskdalemuir appears as close as usual, but the phenomena at Lerwick present special features. The excess of D at 17^h over D at 13^h is 20′·3 at Lerwick, as compared with 4′·9 at Eskdalemuir and smaller amounts at the other stations.

H was larger at 17^h than at 13^h by 30γ at Kew, 39γ at Sandwell Park, 83γ at Eskdalemuir, and 234γ at Lerwick; and it was smaller at 20^h than at 17^h by 24γ at Kew, 22γ at Sandwell Park, 68γ at Eskdalemuir and 203γ at Lerwick. Eskdalemuir phenomena in this case in both D and H give a hint, as it were, of those at Lerwick.

June 30, Hourly Changes.

Station.	13–14 h.	14–15 h.	15–16 h.	16–17 h.	17–18 h.	18–19 h.	19–20 h.
Kew	+3′·8	−0′·1	−1′·5	−0′·3	−3′·9	−6′·4	−0′·5
Sandwell Park, Underground	+3·6	+0·1	−1·0	−0·1	−3·2	−6·7	−0·9
Sandwell Park, Surface ..	+4·4	−1·1	−0·3	+0·6	−5·9	−6·3	−0·1
Eskdalemuir	+4·1	−0·3	−0·4	+1·5	−5·2	−7·6	−0·3
Lerwick	+2·5	+7·5	+1·0	+9·3	−5·8	−12·4	0·0
	γ	γ	γ	γ	γ	γ	γ
Kew	+13	+ 1	+ 8	+ 8	−25	−13	+14
Sandwell Park	+10	+ 8	+ 8	+13	−22	−13	+13
Eskdalemuir	+28	+ 7	+25	+23	−56	−22	+10
Lerwick	+40	+66	+95	+33	−58	−124	−21

September 26th-27th.—This was one of the largest storms recorded. As already mentioned, the S.S. trace was unsatisfactory. Considering the uncertainties in measurements of highly disturbed curves, the parallelism between the *D* changes at Kew, Sandwell Park and Eskdalemuir is pretty fair, and the same is true of Lerwick up to midnight. But the fall and rise of *D* between midnight and 2[h] are immensely larger at Lerwick than at the other stations.

September 26-27, Hourly Changes.

Station.	16–17 h.	17–18 h.	18–19 h.	19–20 h.	20–21 h.	21–22 h.	22–23 h.	23–24 h.
Kew	−0′·5	−3′·6	+0′·3	−3′·2	−11′·5	−1′·6	−4′·6	0′·0
Sandwell Park, Underground ..	−0·1	−4·6	+0·6	−3·9	−13·3	−1·4	−5·1	+0·9
Eskdalemuir	0·0	−5·1	+0·3	−4·2	−14·9	−2·4	−7·0	+3·3
Lerwick	−0·2	−6·2	+0·4	−3·1	−18·5	−6·6	−8·1	+7·5
	γ	γ	γ	γ	γ	γ	γ	γ
Kew	+ 7	− 7	− 3	−11	−13	+ 4	− 1	−11
Sandwell Park	+12	− 6	+ 4	− 5	0	+ 5	+1	−12
Eskdalemuir	+ 9	−13	+ 2	− 7	−23	− 4	− 9	−19
Lerwick	+10	0	− 4	− 1	−23	−14	−39	−115

September 26-27, Hourly Changes—continued.

Station.	0–1 h.	1–2 h.	2–3 h.	3–4 h.	4–5 h.	5–6 h.	6–7 h.	7–8 h.
Kew	+2′·1	+4′·3	+ 9′·4	+1′·2	+6′·4	+1′·9	−8′·3	+0′·1
Sandwell Park, Underground ..	+3·2	+2·3	+13·8	−1·8	+8·7	+0·5	−8·4	+0·7
Eskdalemuir	−1·1	+4·5	+16·4	0·0	+10·9	+0·9	−10·9	+0·4
Lerwick	−24·5	+16·0	+28·2	+2·9	+12·7	+4·1	−15·1	+1·9
	γ	γ	γ	γ	γ	γ	γ	γ
Kew	−11	+ 8	+25	− 3	−21	− 5	−18	+ 9
Sandwell Park	−26	+24	−10	+27	−51	+ 9	− 6	+ 4
Eskdalemuir	−52	+ 8	+62	+39	−57	+14	− 7	+17
Lerwick	−148	+ 8	+120	+119	−79	+34	+107	+22

The outstanding features in *H* are the large fall and rise at Lerwick. *H* was lower at 1[h] than at 20[h] by 339γ at Lerwick, as against 107γ at Eskdalemuir, and 32γ at Sandwell Park and Kew; and it was higher at 8[h] than at 1[h] by 331γ at Lerwick, as against 76γ at Eskdalemuir, the values at Sandwell Park and Kew being slightly reduced.

September 27th-28th.—This was also a highly disturbed night. The increase in the *D* changes with latitude is well marked. The changes in *D* at Lerwick are not outstanding, and the parallelism between Lerwick and the more southern stations is not at all bad.

The changes, however, in *H* at Lerwick are quite outstanding. The differences between Eskdalemuir and Sandwell Park or Kew give only a hint of the large differences between Eskdalemuir and Lerwick. At Kew and Sandwell Park *H* was

September 27-28, *Hourly Changes.*

Station.	16–17 h.	17–18 h.	18–19 h.	19–20 h.	20–21 h.	21–22 h.	22–23 h.	23–24 h.	0–1 h.	1–2 h.	2–3 h.	3–4 h.
Kew	− 1′·8	−14′·4	− 3′·6	+ 6′·9	+ 2′·5	+ 2′·8	− 6′·2	− 0′·9	+ 9′·0	+ 4′·9	− 9′·0	+ 1′·5
Sandwell Pk.— Underground	− 1·0	−17·3	− 2·8	+ 7·2	+ 2·9	+ 4·1	−10·1	+ 2·3	+ 8·3	+ 3·2	− 8·7	+ 1·8
Eskdalemuir ..	− 1·3	−19·7	− 2·2	+ 7·4	+ 3·9	+ 6·6	−14·0	+ 1·3	+10·9	+ 5·7	−12·7	+ 2·6
Lerwick ..	+ 0·6	−20·1	− 3·9	+ 6·0	+ 8·1	+ 9·1	−23·9	− 0·6	+15·4	+11·6	−19·7	+ 3·1
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	− 8	+ 3	+ 8	−14	+ 9	+28	− 1	−21	+20	+32	−23	− 1
Sandwell Park	0	+16	+ 7	−22	+11	−15	+ 4	−13	+14	+18	− 9	0
Eskdalemuir ..	+ 4	0	−22	−13	+14	+ 4	+17	−28	+25	+30	−18	+ 7
Lerwick ..	+68	+ 2	−130	−28	−46	−269	+228	+37	+11	+11	+87	+24

higher at 22^h than at 18^h, and at Eskdalemuir the 22^h value was the lower by only 17γ, but at Lerwick it was the lower by 473γ. So again H was higher at 4^h than at 22^h by only 6γ at Kew, 14γ at Sandwell Park, and 33γ at Eskdalemuir, but by 398γ at Lerwick.

The difference in sign of the changes in H between 18^h and 19^h at Sandwell Park and Eskdalemuir, the progressive decline in the rises of H between 21^h and 22^h at Kew, Sandwell Park and Eskdalemuir, and the increase in the change between 22^h and 23^h as we pass from Sandwell Park to Eskdalemuir, give some indication of the forces which produced so large an effect at Lerwick, but the indication is only a faint one.

September 29th-30th.—The parallelism in the changes of D at the several stations is very good throughout, and in no hour is the Lerwick change exceeded at any other station. The changes in H at Lerwick show little parallelism with those elsewhere, and are mostly smaller than the changes at Eskdalemuir.

September 29-30, *Hourly Changes.*

Station.	21–22 h.	22–23 h.	23–24 h.	0–1 h.	1–2 h.	2–3 h.	3–4 h.
Kew	−0′·6	−0′·8	+1′·0	−2′·5	+1′·2	−0′·2	+1′·2
Sandwell Park, Underground ..	−0·6	−0·5	+1·1	−3·4	+1·6	−0·3	+1·4
Eskdalemuir	−0·6	−0·2	+0·6	−3·8	+2·1	−0·3	+1·4
Lerwick	−0·8	−0·8	+1·5	−4·6	+2·1	−0·8	+1·9
	γ	γ	γ	γ	γ	γ	γ
Kew	+ 2	− 3	+12	−19	− 6	+ 4	0
Sandwell Park	+ 1	+ 2	+ 7	10	− 7	+ 2	− 1
Eskdalemuir	− 2	−13	+20	−19	+ 2	+ 2	− 4
Lerwick	0	+ 1	−16	+14	− 4	− 1	− 6

October 15*th.*—As the comparison in this case extends over the whole day allowance was made for the instrumental drift in H at Lerwick. The disturbance during the first few hours was comparatively small, but the greater part of the day was highly disturbed. It was a case in which quite small time errors might sensibly affect an hourly mean. The parallelism between the hourly changes of D was surprisingly good at all the stations. It appears good even in the case of H as between Kew, Sandwell Park and Eskdalemuir. But there was, as a matter of fact, between 21^h and 24^h a decided difference in the nature of the Kew and Sandwell Park H traces. This is one of the cases in which Eskdalemuir H curves would have been of special value. Conspicuous as the differences are between the hourly changes of H at Lerwick and at the more southern stations, they give only an imperfect idea of the difference in appearance of the curves. At Kew, Sandwell Park and Eskdalemuir the hourly changes of H alter their sign several times between 16^h and 23^h, but at Lerwick there appears a continuous fall of H. The value of H at 23^h exceeds that at 16^h by 41γ at Kew, and by 38γ at Sandwell Park, and at Eskdalemuir the value at 23^h

is less than that at 16^h by only 10γ, but at Lerwick the deficiency at 23^h is 349γ. The rise of H from 23^h to 24^h shows a marked advance as we pass from Sandwell Park to Eskdalemuir, and a still more marked advance as we pass from Eskdalemuir to Lerwick.

October 15, *Hourly Changes.*

Station.	0–1 h.	1–2 h.	2–3 h.	3–4 h.	4–5 h.	5–6 h.	6–7 h.	7–8 h.	8–9 h.	9–10 h.	10–11 h.	11–12 h.
Kew	+ 0′·2	+ 1′·5	+ 0′·0	+ 2′·3	+ 0′·6	+ 3′·2	− 1′·0	− 3′·1	+ 1′·7	+ 1′·8	− 1′·6	+ 3′·3
Sandwell Pk.—												
Underground	+ 0·4	+ 1·5	+ 0·2	+ 1·9	+ 0·3	+ 4·0	− 2·0	− 2·4	+ 1·7	+ 0·9	− 1·3	+ 3·0
Surface ..	+ 0·3	+ 1·6	+ 0·4	+ 2·3	+ 0·2	+ 3·7	− 1·5	− 2·7	+ 1·8	+ 0·6	− 1·1	+ 4·0
Eskdalemuir ..	+ 1·0	+ 1·6	+ 0·3	+ 2·7	+ 0·3	+ 4·3	− 1·4	− 3·6	+ 2·7	+ 0·7	− 1·9	+ 4·2
Lerwick ..	+ 1·5	+ 1·6	− 0·8	+ 4·5	+ 1·3	+ 3·3	+ 1·3	− 6·1	+ 2·3	+ 0·7	− 1·1	+ 4·0
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	− 5	+ 1	+ 1	+ 6	+10	− 3	+ 4	−39	−27	+ 2	+ 9	+ 8
Sandwell Pk. ..	+ 2	− 1	+ 2	+ 1	+ 0	− 7	+ 7	−32	−31	0	+12	− 1
Eskdalemuir ..	− 7	+ 2	0	+ 9	+10	−10	+ 8	−12	−69	+21	+ 4	+ 8
Lerwick ..	− 5	− 1	− 3	+ 5	+ 8	−15	+11	−41	28	+ 5	+18	+10

October 15, *Hourly Changes*—continued.

Station.	12–13 h.	13–14 h.	14–15 h.	15–16 h.	16–17 h.	17–18 h.	18–19 h.	19–20 h.	20–21 h.	21–22 h.	22–23 h.	23–24 h.
Kew	+ 3′·3	− 0′·7	+ 1′·6	− 4′·6	−14′·4	+10′·4	− 7′·8	− 2′·5	+ 0′·9	+ 2′·0	+ 5′·9	− 0′·5
Sandwell Pk.—												
Underground	+ 3·9	− 0·4	+ 1·2	− 1·7	−17·9	+11·0	− 6·4	− 4·6	+ 1·8	+ 0·5	+ 8·3	− 0·5
Surface ..	+ 3·0	− 1·4	+ 2·9	− 5·9	−13·8	+11·2	− 8·9	− 2·3	+ 0·8	+ 2·1	+ 5·8	− 0·2
Eskdalemuir ..	+ 3·7	− 1·0	+ 3·4	− 7·1	−15·8	+12·7	−12·2	0·0	− 0·9	+ 4·8	+ 5·7	− 0·9
Lerwick ..	+ 3·1	− 1·7	+ 4·2	− 8·5	−21·8	+19·9	−12·3	− 3·7	+ 1·2	+ 3·0	+ 8·2	+ 3·6
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	−12	−32	+34	−19	+ 7	− 7	+25	+45	−26	−24	+21	+25
Sandwell Pk. ..	−11	−29	+29	−14	+23	−23	+24	+60	−25	−25	+ 4	+25
Eskdalemuir ..	−12	−32	+47	−16	+ 2	−12	+18	+35	−29	−30	+ 6	+56
Lerwick ..	0	−18	+49	+39	−17	−11	−27	− 5	−42	−95	−152	+163

October 16th.—Instrumental drift in H at Lerwick was allowed for as on the previous day. There was an unfortunate holding up of the drum of the underground D instrument at Sandwell Park for more than an hour near midnight. The total change from 22^h to 24^h was divided arbitrarily between the two hours, the results being enclosed in brackets. Subsequently to this registration proceeded as usual. The light, however, had been rather poor most of the night, and parts of the trace were very faint. So far as could be seen, there were in this case slight visible differences between the underground and surface D records from 16^h to 18^h. This was unfortunately a time when artificial disturbance was large at Kew, so the Kew curves were of little use for the comparison of minute details. The Eskdalemuir curves had most resemblance to the Sandwell Park surface curves.

October 16, *Hourly Changes.*

Station.	0–1 h.	1–2 h.	2–3 h.	3–4 h.	4–5 h.	5–6 h.	6–7 h.	7–8 h.	8–9 h.	9–10 h.	10–11 h.	11–12 h.
Kew	− 4′·1	+ 1′·6	+ 4′·9	+ 0′·8	+ 0′·4	+ 4′·6	− 3′·5	− 2′·2	− 0′·4	+ 1′·4	+ 1′·0	+ 1′·2
Sandwell Pk.—												
Underground	− 4·4	+ 0·3	+ 5·0	+ 2·1	− 0·3	+ 5·1	− 3·0	− 1·9	− 1·2	+ 0·6	+ 1·7	+ 1·1
Surface ..	− 4·3	+ 0·9	+ 4·9	+ 1·6	+ 0·7	+ 4·7	− 3·7	− 1·9	− 0·7	+ 1·9	+ 0·7	+ 1·8
Eskdalemuir ..	− 5·2	+ 1·7	+ 5·0	+ 2·9	+ 0·4	+ 6·0	− 4·2	− 2·4	− 0·3	+ 0·9	+ 1·3	0·0
Lerwick ..	− 8·5	+ 0·6	+ 1·9	+ 9·3	− 3·3	+11·0	− 6·0	− 3·3	− 0·9	+ 1·3	+ 2·0	− 2·4
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	− 6	− 5	−12	+14	−15	+23	+ 2	− 4	−23	−21	+ 7	−23
Sandwell Pk. ..	+ 5	− 5	−26	+20	−16	+16	+ 8	− 7	−25	−13	− 3	−14
Eskdalemuir ..	0	− 7	−48	+55	−16	+24	− 2	− 8	−26	−18	+12	−20
Lerwick ..	+115	+ 2	−95	+79	− 4	+17	+21	− 5	−22	−22	+18	+12

October 16, *Hourly Changes*—continued.

Station.	12–13 h.	13–14 h.	14–15 h.	15–16 h.	16–17 h.	17–18 h.	18–19 h.	19–20 h.	20–21 h.	21–22 h.	22–23 h.	23–24 h.
Kew	+ 1′·9	− 0′·1	− 3′·1	− 6′·9	− 6′·6	+ 2′·5	− 2′·0	− 0′·2	+ 0′·4	− 8′·5	+ 3′·9	+ 6′·8
Sandwell Pk.—												
Underground	+ 2·4	− 0·6	− 2·6	− 9·4	− 4·8	+ 2·6	− 2·4	+ 0·5	− 2·3	− 7·8	(+ 5·7)	(+ 5·8)
Surface ..	+ 2·4	− 1·8	− 2·1	− 7·5	− 7·1	+ 3·9	− 1·9	− 1·9	+ 2·0	−11·4	+ 3·8	+ 8·8
Eskdalemuir ..	+ 3·1	− 0·6	− 2·3	− 8·9	− 7·9	+ 3·9	− 0·8	− 2·2	− 1·3	−10·5	+ 4·8	+ 7·0
Lerwick ..	+ 1·4	+ 0·8	− 1·0	−10·4	− 5·6	+ 4·4	− 0·6	− 5·4	− 3·4	−18·6	+11·0	+ 6·0
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
Kew	− 6	+11	0	− 8	+23	−48	+ 3	−13	+25	− 2	+ 8	+10
Sandwell Pk. ..	− 9	+14	+ 5	+ 3	+15	−37	− 9	− 8	+19	+12	+ 1	− 9
Eskdalemuir ..	+ 8	+11	+11	−11	+15	−72	−23	− 8	+19	−10	+16	−21
Lerwick ..	+41	+ 2	+37	− 5	−43	−35	−138	−85	−47	−35	+21	−92

On the whole, considering the uncertainties unavoidable in measuring highly disturbed curves, the parallelism in the *D* hourly changes at all the stations is not at all bad.

As usual, the differences in the *H* changes are more notable. In the first place there is a large rise between 0^h and 1^h at Lerwick, practically unrepresented elsewhere. This represents, presumably, recovery from a big depression at 23^h on the 15th, which was limited to Lerwick. There is a fall from 2^h to 3^h, and a rise from 3^h to 4^h, the progressive increase of which as we go north is very conspicuous. At Lerwick *H* is higher at 13^h than at 11^h by 53γ, whereas the 11^h value is the larger by 29γ at Kew, by 23γ at Sandwell Park, and by 12γ at Eskdalemuir. At Lerwick there was a progressive decline of *H* from 15^h to 22^h, the total fall amounting to 388γ. At the other stations there are several rises and falls in this time, but the aggregate is in all cases a fall, amounting to 20γ at Kew, 5γ at Sandwell Park, and 90γ at Eskdalemuir. While *H* was rising at Kew from 23^h to 24^h, it was falling at the more northern stations, the fall at Lerwick being quite large.

October 17th, morning.—This is a case in which the hourly changes of *D* give a very imperfect idea of what was happening. They suggest a steady rise from 1^h to 5^h, amounting to 15′·8 at Kew, 17′·4 at both Sandwell Park stations, 25′·0 at Eskdalemuir, and 39′·0 at Lerwick. In reality there was a succession of considerable oscillations, with a generally upward trend. A good general parallelism between the *D* changes extends up to Lerwick.

October 17, *Hourly Changes.*

Station.	0–1 h.	1–2 h.	2–3 h.	3–4 h.	4–5 h.	5–6 h.	6–7 h.	7–8 h.
Kew	−0′·6	+1′·0	+4′·4	+6′·1	+4′·3	−1′·7	−0′·7	−2′·3
Sandwell Park, Underground ..	—	+1·7	+4·8	+6·4	+4·5	−0·9	−1·9	−1·2
Sandwell Park, Surface.. ..	−1·8	+1·5	+4·2	+6·9	+4·8	−0·9	−1·9	−1·9
Eskdalemuir	−2·4	+2·2	+6·6	+8·7	+7·5	−2·9	−2·4	−1·8
Lerwick	−6·9	+5·0	+11·0	+17·6	+5·4	−4·6	−2·7	−0·6
	γ	γ	γ	γ	γ	γ	γ	γ
Kew	+32	+ 4	−14	+16	−19	−16	+ 9	+ 5
Sandwell Park	+41	+11	−21	+ 8	−20	−15	+ 9	+ 6
Eskdalemuir	+57	+12	− 3	+30	−27	−11	+19	+ 9
Lerwick	+170	+41	− 8	+50	+11	+22	+36	+34

The parallelism in the *H* changes is fair at the three more southern stations, but does not extend to Lerwick. A rise was in progress there nearly the whole time, while at the other stations this was interrupted by substantial falls. *H* was much depressed at Lerwick at midnight on the 16th, and the rise throughout the morning of the 17th was presumably a recovery from this.

October 17th-18th.—Disturbance on this night was comparatively trifling, but in spite of that only some of the selected irregular *H* movements could be identified at Lerwick. The differences between the *H* changes at Lerwick between 21^h and 24^h and those at the other stations are noteworthy.

October 17–18, *Hourly Changes.*

Station.	20–21 h.	21–22 h.	22–23 h.	23–24 h.	0–1 h.	1–2 h.
	′	′	′	′	′	′
Kew	−3·0	+3·4	−1·0	+1·7	+0·8	−0·9
Sandwell Park Surface	−2·8	+1·7	+0·9	+0·4	+1·6	−0·9
Eskdalemuir	−4·1	+3·8	−0·6	+2·4	+1·6	−1·1
Lerwick	−4·6	+4·1	+2·3	+1·5	+1·9	−1·7
	γ	γ	γ	γ	γ	γ
Kew	+ 6	− 6	+32	−25	+ 3	− 2
Sandwell Park	+ 7	− 3	+27	−25	+ 3	0
Eskdalemuir	+13	−20	+37	−20	+ 7	− 2
Lerwick	+13	−39	+15	+22	0	− 8

October 18th, evening.—The movements at Kew were larger on this than on the previous night. Still it was only a minor disturbance. Nevertheless only some of the *H* movements were identified at Lerwick. The parallelism of the *D* changes at the several stations is good, and their increase with latitude is decided. But in *H* the rise from 20^h. to 21^h is less at Eskdalemuir than at Sandwell Park, and it becomes a fall at Lerwick. Also the fall between 21^h and 22^h shows no increase from Sandwell Park to Eskdalemuir, and is much reduced at Lerwick. At the same time, the irregular movements which were identified at Lerwick exceeded the corresponding movements at Kew and Sandwell Park.

October 18, *Hourly Changes.*

Station.	18–19 h.	19–20 h.	20–21 h.	21–22 h.	22–23 h.	23–24 h.
	′	′	′	′	′	′
Kew	+0·6	−7·7	−3·2	+6·7	+3·5	+0·4
Sandwell Park, Surface	+1·1	−8·5	−4·3	+7·3	+4·4	+0·2
Eskdalemuir	+1·7	−11·5	−2·9	+8·4	+4·8	+0·8
Lerwick	+1·9	−11·8	−5·6	+9·3	+6·2	+0·8
	γ	γ	γ	γ	γ	γ
Kew	− 6	+ 1	+26	−49	+ 9	+ 3
Sandwell Park	− 2	+ 8	+30	−50	+ 2	+ 6
Eskdalemuir	− 4	+ 8	+14	−50	+16	+ 7
Lerwick	− 4	+13	− 5	−24	+ 8	+ 5

October 20th.—The hourly changes on this night are trifling everywhere, and yet the selected irregular movements could not be satisfactorily identified at Lerwick.

October 20, *Hourly Changes.*

Station.	18–19 h.	19–20 h.	20–21 h.	21–22 h.	22–23 h.	23–24 h.
	′	′	′	′	′	′
Kew	−1·1	−0·3	−0·2	−1·8	+0·5	+0·9
Sandwell Park, Underground ..	−1·2	+0·2	−0·6	−1·1	+0·1	+1·2
Sandwell Park, Surface	−1·3	−0·6	−0·1	−1·2	0·0	+1·0
Eskdalemuir	−2·1	0·0	−0·5	−1·5	0·0	+1·5
Lerwick	−2·5	0·0	−0·4	−0·6	−1·2	+1·0
	γ	γ	γ	γ	γ	γ
Kew	+ 4	+ 1	+ 1	+13	−21	− 4
Sandwell Park	+ 4	+ 3	0	+13	−16	− 5
Eskdalemuir	+ 6	− 3	+ 3	+13	−22	0
Lerwick	+ 8	− 4	+ 4	+ 7	−13	− 5

October 26th.—The same remarks apply here as to the 20th. One might be tempted to think that the large disturbance on 15th-16th October had some after-effect, which influenced the parallelism between the changes at Lerwick and those elsewhere. But we may have to do with some seasonal phenomenon, or with pure accident.

October 26, Hourly Changes.

Station.	0–1 h.	1–2 h.	2–3 h.	3–4 h.	4–5 h.	5–6 h.
	′	′	′	′	′	′
Kew	−0·3	+1·2	−1·4	+1·6	+0·1	+0·3
Sandwell Park, Underground ..	−1·2	+1·3	−1·5	+1·7	+0·1	+0·7
Sandwell Park, Surface	−1·0	+1·0	−1·7	+1·7	+0·2	+0·7
Eskdalemuir	−1·2	+1·4	−2·4	+2·3	+0·2	+0·9
Lerwick	−1·5	+2·7	−4·6	+2·5	+0·4	+1·5
	γ	γ	γ	γ	γ	γ
Kew	− 6	+14	− 3	− 3	0	0
Sandwell Park	− 1	+ 9	+ 2	− 6	0	− 1
Eskdalemuir	− 5	+20	−13	+ 2	− 1	0
Lerwick	+ 4	+ 5	+ 5	+ 1	0	− 1

§ 19. Practical Conclusions.

As the immediate cause of the inquiry was a wish to increase the usefulness of the weekly bulletin of magnetic information, which used to be issued from Kew Observatory and is now issued by the Astronomer Royal, it seems desirable to state the general outcome of the investigation in so far as it affects the ordinary mining engineer.

There are, however, two preliminary considerations to which attention should be called. In the first place, the stations compared differed so little from one another in longitude that the difference of local time was comparatively unimportant. But if we have to do with Wales or Western England this becomes of some importance. A careful comparison of many years' records from Kew and Falmouth showed that it was a demonstrable fact, and not a mere theoretical conclusion, that the regular magnetic diurnal variation follows local time. The maximum and minimum in the regular diurnal variation at Falmouth follow those at Kew by the time interval—about 20 minutes—corresponding with the difference of longitude of the two stations.

In the next place, there are probably mines in this country where basaltic or other magnetic rock causes appreciable local disturbance. There was, it is true, a difference between the underground and surface values of the magnetic force at Sandwell Park, but it was very small, and may have been due to very local artificial causes. At a station, however, whether underground or not, where there is sensible magnetic disturbance, the daily changes of declination may be sensibly different from what they would have been in the absence of disturbance. If the intensity of the horizontal force is, say, increased by the local disturbance, while the direction of the compass needle is unaffected, changes of declination will naturally be reduced. If, however, the direction of the compass needle is affected, the conditions are more complex, because the forces tending to cause a diurnal variation in the pointing of the needle are not the same as they would have been if the station were undisturbed.

The following conclusions apply only to stations where local disturbance is non-existent or very small.

For practical purposes, the differences between the magnetic declination changes underground and at the surface are negligible, except perhaps on days of very large disturbance. As the magnetic needle cannot be satisfactorily used anywhere for surveying purposes during a magnetic storm, the exception or possible exception to the rule hardly matters.

On quiet days the regular diurnal changes of declination vary but little throughout Britain. Thus on quiet days magnetic information from a single station should apply fairly well to the whole country. But this becomes less and less true the more disturbed the day. The general tendency on disturbed days is for all changes of declination, both regular and irregular, to increase as we go north. The increase is much larger for the irregular short period changes than for the slow regular changes.

In 1923 short period changes were on the average some 50 per cent larger at Eskdalemuir, in the south of Scotland, than at Kew ; while at Lerwick, in the Shetland Isles, they were more than twice as large. This is not unlikely to be an underestimate for the average year, because two earlier investigations, for 1908-9 and 1919 respectively, gave a larger increase in the amplitude with latitude than was observed in 1923. It is not a case of some *D* movements only increasing rapidly with latitude, but of all or practically all irregular movements increasing substantially. Large disturbance is more common by night than by day. The occurrence of a starred hour in the weekly Greenwich bulletin in an evening is not inconsistent with normal quietness in the previous forenoon, but it raises a strong presumption that adjacent evening times were also considerably disturbed, and such disturbance is not unlikely to be larger in Scotland or in the north of England than the disturbance in the south of England during the starred hour. It is only prudent to treat the adjacent hours as suspect. Disturbance phenomena vary widely on different occasions, but a general characteristic is a tendency to increased easterly pointing of the needle near midnight.

§ 20. Conclusions Partly Theoretical.

The apparatus available for the inquiry at the mine was not first-class, and both the underground and the surface stations suffered from the disturbances caused by artificial electric currents. Thus the conditions were not favourable for the detection and measurement of very small differences. During the time when records were being taken, which was on the whole a very quiet time, as was natural in a year of sunspot minimum, there was no single occasion in which large differences of detail presented themselves between the *D* movements underground and at the surface. There were, however, no cases of very large rapid oscillations. There appeared to be a very small decline in the underground amplitudes both of the regular diurnal variation on quiet days, and of short period irregular movements of *D*, which in both cases was greater than could be accounted for by the slightly enhanced value of *H* underground.

The effects of increase of latitude and increased disturbance on the amplitude of movements were widely different for *D* and *H*.

Except in October and November, the range of the regular diurnal variation on quiet days increased with latitude in both *D* and *H*, but the increase was much larger for *H* than for *D*. The increase with latitude in the amplitude of the regular diurnal variation was greater on disturbed than on quiet days. The influence of disturbance in increasing the range of the regular diurnal variation was on the whole greater for *D* than for *H* at the more southern stations, but at Lerwick the influence on *H* was considerably the greater.

Hardly a case was observed in which an irregular movement in *D* at Eskdalemuir or Lerwick was not substantially larger than the corresponding movement at Kew ; cases of apparently reduced amplitude were rare even at Sandwell Park. But in the case of *H* there were a good many cases of irregular movements in which the amplitude even at Lerwick was no bigger or even smaller than the amplitude at Kew. The average irregular movement on days of moderate disturbance at Lerwick was considerably larger than the corresponding movement at Kew, but its excess was much less than in the case of the *D* irregular movements. There were, however, occasions when the irregular *H* movements at Lerwick were of quite a different order from those at Kew, and their excess was relatively much greater than that of the Lerwick *D* movements on the same night. There were a good many occasions, especially in September and October, when the *H* curves at Lerwick differed so much in detail from those elsewhere that comparison of irregular movements was impossible. It would appear that the size of irregular changes in *H*, at least in Scotland, is more dependent than the size of irregular changes in *D* on some unknown characteristic of the particular day. This suggests that it is not unlikely that underground and surface changes of *H* may on special occasions exhibit a more decided difference than has been observed in the case of *D*.

It is at least conceivable that light would be thrown on the locus of the electrical currents causing irregular magnetic changes by a comparison of underground and surface records of the highest precision. Thus from the theoretical standpoint, a further investigation is much to be desired, if suitable apparatus could be provided, especially if a mine undisturbed by artificial electric currents were available. In this connection the present investigation points to the following conclusions : The further north the locality, the more likely is it that a sensible difference will appear between underground and surface magnetic changes. There ought to be at both the underground and the surface stations magnetographs for D, H and V (vertical force), the two sets of instruments being of the same superior pattern. They should be under the charge of a competent observer, experienced in the working of magnetic instruments, and capable of effecting any likely repairs. He should be resident on the spot, and should have absolute instruments at his disposal so that satisfactory base line values could be obtained, say, twice a week. Frequent scale values should also be taken of the force magnetographs. The instruments should be run for several months, and several magnetic storms should be recorded. If, say, only three months were available, the best would be February, March and April, or else mid-August to mid-November. The curves should be measured promptly, so that any untoward features should be noticed as soon as possible.

§ 21. Acknowledgments of Assistance.

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ERRATUM

Page 5—*the last two lines should read* :—

"years subsequent to 1916, made the incorporation of a contribution from this element to the final estimate impracticable."