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AN INVESTIGATION OF THE LAPSE RATE OF TEMPERATURE IN THE LOWEST HUNDRED METRES OF THE ATMOSPHERE

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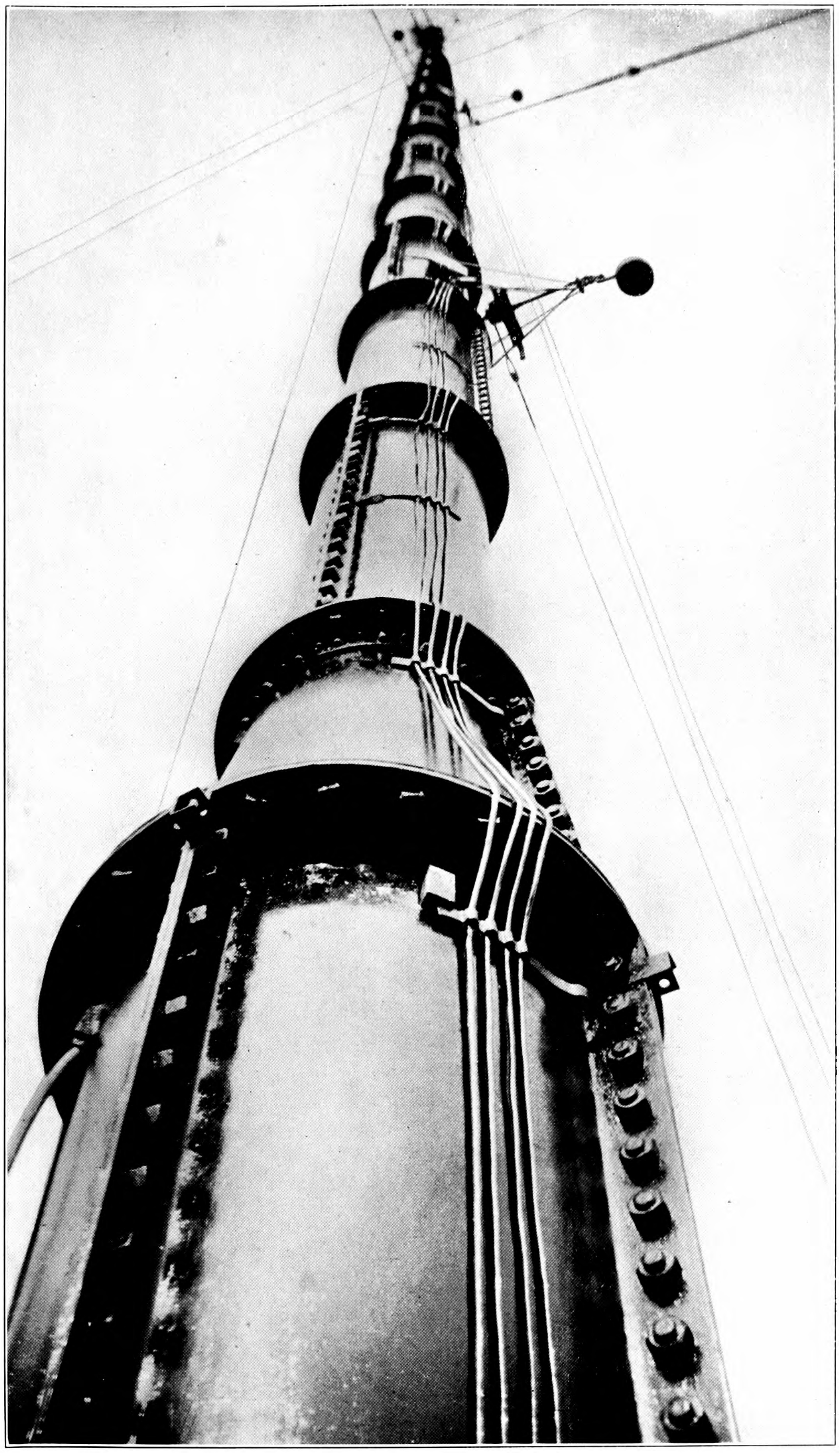

FIG. 1.—MAST AT LEAFIELD VIEWED FROM BELOW.

AN INVESTIGATION OF THE LAPSE RATE OF TEMPERATURE IN THE LOWEST HUNDRED METRES OF THE ATMOSPHERE

INTRODUCTORY

A description has already been given (1)* of the instrumental equipment which was erected in 1922 at Porton, Wilts, to investigate the lapse rate of temperature in the lowest 17m. of the atmosphere. At the suggestion of Professor D. Brunt it was decided to take advantage of the G.P.O. wireless masts which exist at Leafield, Oxon, to extend the observations of air temperature and wind velocity up to a height of approximately 100m.

The present paper describes the instrumental equipment employed at Leafield, and gives a detailed analysis of the records obtained over a period of five years. The account also shows the steps which were taken to determine the characteristics and possible sources of error in the more important of the instruments. The results obtained by analysis of the records secured during the five years are set out in detail in the various tables and diagrams. The final Part is devoted to a more detailed discussion of some of the observational results.

PART I—THE INSTRUMENTS

§ 1—GENERAL

An attempt was made to establish at Leafield as complete a meteorological station as circumstances permitted. All the instruments of a normal meteorological station were provided in addition to the special temperature and wind-velocity recording apparatus.

Continuous records were made of the following meteorological quantities :—

1. Aspirated dry- and wet-bulb temperatures at a height of 1·2m. (4ft.).
2. Differences in air temperature over various height intervals between 1·2m. and 87·7m. (288ft.).
3. Wind velocity at a height of 12·7m. (42ft.).
4. Wind direction at the same height.
5. Wind velocity at a height of 94·5m. (310ft.).
6. Sunshine.
7. Starshine.

* The numbers in brackets refer to the bibliography on p. 50.

The means employed for measuring the air temperature and the wind velocity at 94·5m. are described later. A brief account of the " night sky camera " will be given, further details being reserved for a future paper.

§ 2—SITE

The meteorological station at Leafield was situated in latitude 51° 50½′ N. and longitude 1° 34½′ W The ground level is 186·5m. (612ft.) above M.S.L., the site of the station being on the south-east edge of the Cotswold Hills. In an east—west direction the ground remains sensibly level for several kilometres both ways. To the north it drops rather rapidly to a level of 100m. (328ft.) at a distance of about 3Km. To the south there is a similar fall, although in this case not quite so rapid, the 100m. level being reached at a distance of between 4 and 5Km. The exposure of the station is exceptionally good. The horizon to the south and south-east is formed by the Berkshire Downs and Chiltern Hills at distances of 31 and 48Km. respectively, whilst to the north one looks over the Evenlode valley to a sky-line some 10Km. away. The approximately horizontal nature of the ground towards the east and west restricts the vision in these directions, although there are no great elevations in either direction.

The station is situated on grass land, and the country immediately surrounding it consists entirely of open farm land with one or two farms and a few detached copses.

§ 3—MAST

The tubular wireless mast which carried the temperature-measuring devices is noteworthy on account of its slenderness. We are indebted to Mr. B. K. Chandler for the photograph of it reproduced in Fig. 1. It rises to a height of 94·5m. (310ft.), and apart from the lowest 4·6m., its diameter is only 0·76m. (2½ft.) decreasing to 0·61m. (2ft.) at the top. The lowest section of 4·6m. has a diameter of 1·07m. The mast is, of course, braced by stays. It is painted the usual service grey colour, although it would have been better painted white in order to minimise radiation effects.

The extreme slenderness of the mast, combined with the fact that the thermometer housings were all mounted on the prevailing-windward side of it, provide an arrangement from which air temperature records of a high degree of accuracy may be expected.

§ 4—TEMPERATURE-RECORDING APPARATUS

(*a*) *Temperature-Measuring Elements.*—As in the Porton apparatus, the temperature of the air was measured by means of platinum resistance thermometers connected in a Wheatstone bridge circuit. The resistance elements employed at Leafield were of the all-metal type illustrated in Fig. 1 of *Geophysical Memoirs*, No. 46. The characteristics shown for this type of element in Fig. 2 of the same paper therefore apply to the Leafield instruments.

(*b*) *Housings for the Resistance Elements.*—The housings in which the resistance thermometers were mounted are shown in Figs. 2 and 3. A sectional drawing of this type of housing was given in Fig. 4 of the previous paper. The element is fitted inside a central aspiration tube of white glazed porcelain which is surrounded by a louvred housing. As usual, the whole of the housings were stove-enamelled white. The type of housing originally installed at Leafield, and in use from 1925 to September, 1928 (when replaced by the present type) was a slightly modified form of the housing illustrated in Fig. 3 of the previous paper. In this the central tube was of metal, with air inlets at the lower end. The modification consisted of a conical shield or " umbrella " attached to the central tube immediately above the openings through which air enters. The object of this " umbrella " was to reduce the risk of admitting to the central tube air the temperature of which had become affected by contact with the outer spinnings of the housing.

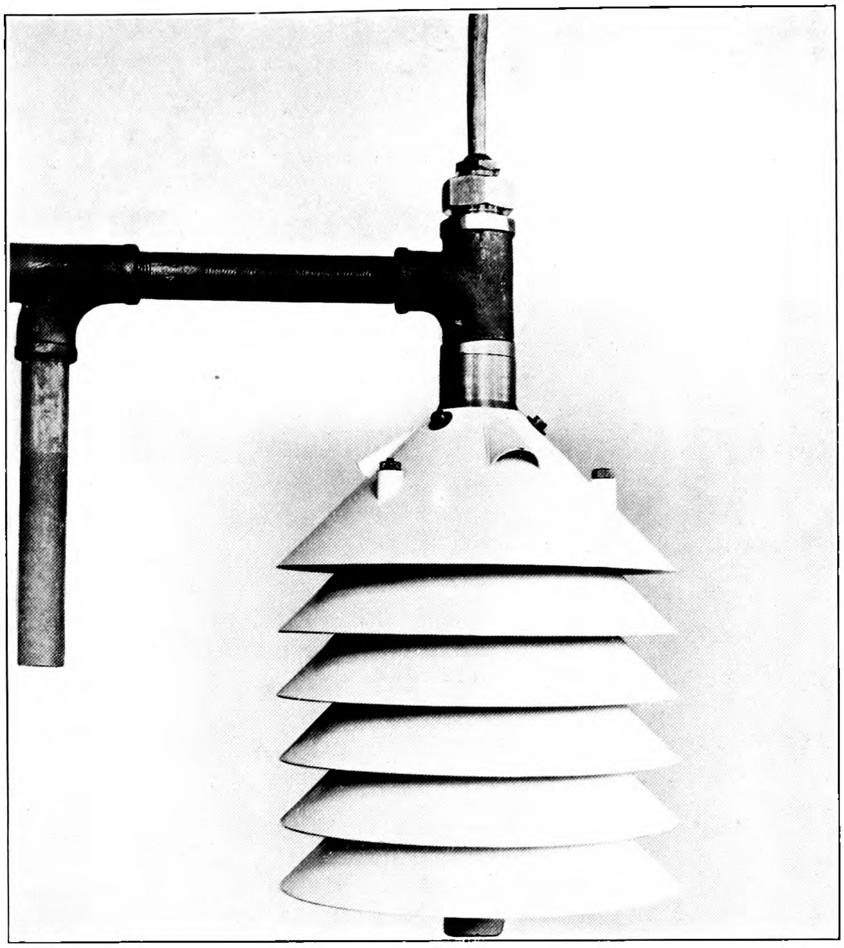

FIG. 2.—HOUSING FOR RESISTANCE THERMOMETER ON MAST (ASSEMBLED).

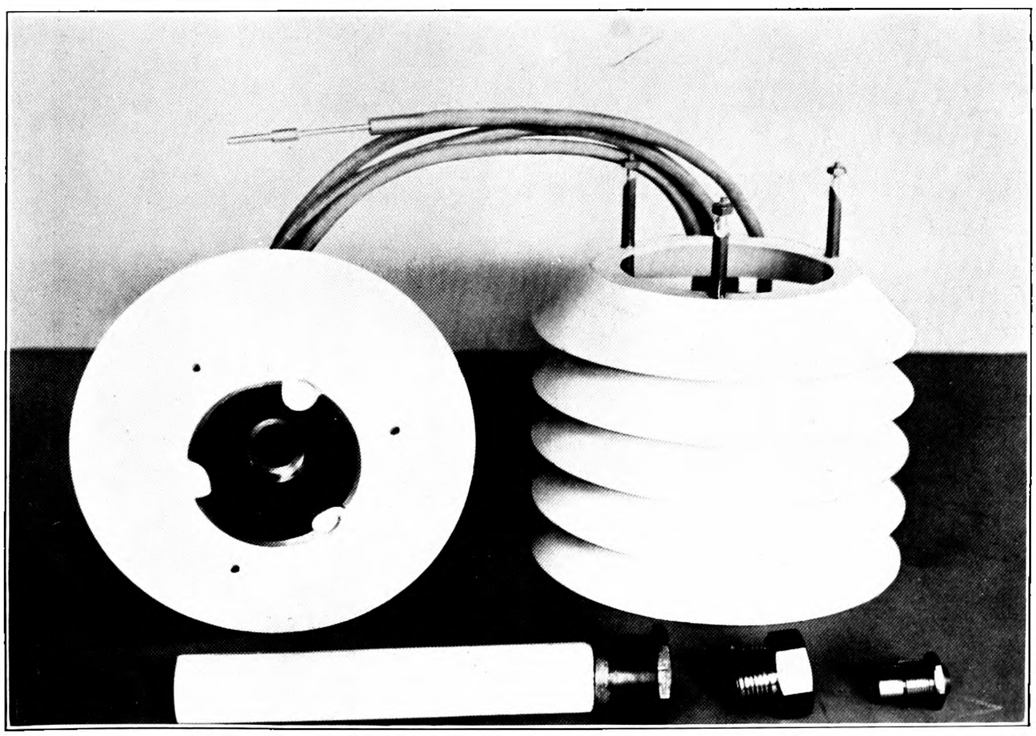

FIG. 3.—HOUSING FOR RESISTANCE THERMOMETER ON MAST (PARTIALLY DISMANTLED).

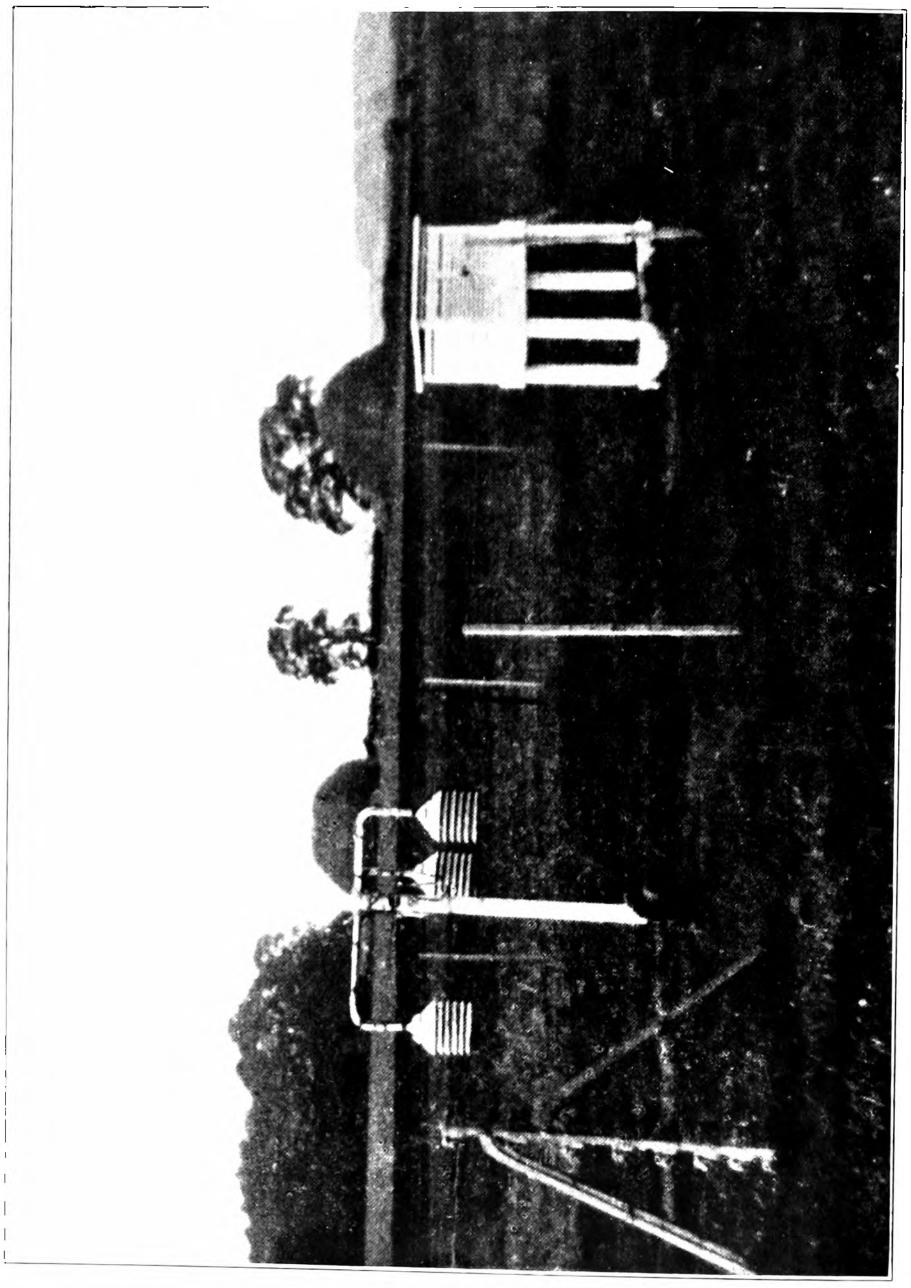

FIG. 4. HOUSING FOR RESISTANCE THERMOMETER IN ENCLOSURE.

(*c*) *Disposition of the Resistance Thermometers.*—Resistance thermometers, each mounted in its own housing and aspirated continuously, were arranged to give records of the following quantities :—

1. Dry-bulb temperature at a height of 1·2m.
2. Wet-bulb ,, ,, ,, ,, ,,
3. Difference in temperature between heights of 1·2m. and 12·4m.
4. ,, ,, ,, ,, ,, ,, 12·4m. and 30·5m.
5. ,, ,, ,, ,, ,, ,, 30·5m. and 57·4m.
6. ,, ,, ,, ,, ,, ,, 57·4m. and 87·7m.

The dry- and wet-bulb housings were erected in an enclosure situated about 50m. to the west of the foot of the mast. Beside them also was the housing containing the element which gave the temperature difference over the interval of height between 1·2m. and 12·4m. A photograph of these three housings is shown in Fig. 4. The ground level in the enclosure is 0·7m. lower than that at the foot of the mast. The heights given are all measured from the ground vertically beneath the element in question.

The temperature differences enumerated at 3, 4, 5 and 6 above were obtained by two independent circuits, each of which had a resistance element in its own housing at a height of 30·5m. Thus there were two housings at this height on the mast, and one each at the other heights. These housings were all carried at a distance of 0·9m. from the face of the mast, and their bearings from the centre of the mast were as follows :—south-south-east at 12·4m., west-south-west at 30·5m. (lower circuit), south-south-east at 30·5m. (upper circuit), south-south-west at 57·4m., and south at 87·7m.

Fig. 5 illustrates the manner in which the housings and aspirating units were supported.

(*d*) *Aspiration.*—At Porton, aspiration of all the elements was effected by means of a single motor at ground level. At Leafield the difficulty of securing the necessary piping to the mast led to the provision of a separate aspirating unit at the height of each housing. As these motors had to run for periods up to six months without any attention whatsoever, alternating current motors with squirrel-cage armatures were employed. All brush gear was thus eliminated. The motors were incorporated into rotary blowers, one such unit being shown in Fig. 5. The motors were fed with three-phase current, the voltage being 70 volts between phases with a frequency of 50 cycles per second, and their speed was 2800 r.p.m. In spite of this comparatively high speed, and the very little attention which it was possible to give them, these motors proved extremely satisfactory. They ran almost continuously, day and night, for over six years, during which time only three instances occurred of an involuntary stoppage.

In the description of the Porton apparatus it was shown (1) that the temperature recorded by the type of resistance thermometer here employed depends upon the velocity of aspiration. The velocity of aspiration was therefore adjusted to approximate equality for all the resistance elements, when the apparatus was first set up, by inserting into each pipe-line a diaphragm of appropriate aperture. The actual velocity of the air current past the bulb of the resistance thermometer exceeded 3 m/sec. in every case.

(*e*) *Electrical Circuits.*—Before installing the electrical apparatus at Leafield, some preliminary experiments were carried out to ascertain the possibility of using delicate recording instruments at this particular site. As already mentioned, the mast on which it was proposed to mount the resistance thermometers supports the wireless aerial of the G.P.O. Station, which radiates at very high power. The extent to which induction effects were produced in conductors in the neighbourhood was therefore investigated. On hauling a 30m. length of rubber covered wire up the mast until the lower end was just leaving the ground, it was found that as the bare end trailed across the ground it sparked vigorously. On connecting it to an electrostatic voltmeter, a reading of several hundred volts was shown, which rapidly increased to a thousand volts when the wire was drawn one or two metres away from the mast. A shorter length of wire kept close to the mast was found to produce steady deflections in a moving coil galvanometer. On the other hand the conductor in a length of lead-covered cable was found to be quite inert, provided that the lead casing was earthed. In designing the temperature-recording circuits, therefore, it was laid down as essential that the entire length of all circuits must be enclosed in an earthed metal casing. This principle was rigidly adhered to. On one occasion an adjoining mast was struck by lightning without any effect being shown on the recorder traces.

The electrical circuit employed for recording the dry- and wet-bulb temperatures was similar to that shown in Fig. 6 of *Geophysical Memoirs*, No. 46. Since, however, the recorder was situated some 50m. from the elements, compensating leads were provided.

In the case of the differential traces, two separate circuits were employed. In the case of the lower differential circuit the element at 12·4m. was balanced alternately against those at 1·2m. and 30·5m. In the upper differential circuit, the element at 57·4m. was made common, and was balanced alternately against those at 30·5m. and 87·7m. These two circuits were similar to that illustrated in Fig. 7 of the previous paper. All the leads up the mast were compensated.

(*f*) *Recording Instruments.*—The various temperature traces were recorded on instruments which were essentially similar to those employed at Porton.

One important practical modification was introduced however. It was found that the change-over switches with which the instrument was fitted could not be relied upon to give a constant or negligible resistance. Repeated attempts to cure this trouble proved unsuccessful, and it was eventually decided to replace the platinum contact switches with mercury-in-glass switches. Fig. 6 shows one of the instruments so fitted. The two mercury switches at B and M are mounted on bakelite panels screwed to a brass plate P pivoted at its centre. Behind the cam C, which operates the thread-changing mechanism T, is fitted a crank which tilts the mercury switches through the connecting rod R. The degree of tilt imparted can be adjusted by selecting the appropriate hole in the vertical extension of the plate P.

Switches of this type have been in use on both the Porton and Leafield instruments now for many years, and have proved exceptionally reliable. Laboratory tests, in which switches were rocked for over a million oscillations with a current of 40 milliampères passing through them, have failed to produce any detectable alteration in them.

Certain other minor improvements were made to the instruments. The ebonite panels of the recorders were found to be unsatisfactory in damp weather, and were replaced by bakelite. Mercury switches were also substituted for the plug contacts originally used for obtaining zero and test deflections.

The dry- and wet-bulb charts call for little comment. On the other hand, a few words are necessary regarding the arrangement of the differential traces. At Porton the lowest element was used as the " common " element against which the others were balanced in turn. At Leafield, however, the greater separation of the elements necessitated the middle element of each set being made " common," in order to ensure that excessive lapse rates did not cause the traces to leave the charts, while retaining the same scale of chart as at Porton. Further, in order to keep the number of switches down to a minimum, it was necessary to have the two traces moving in opposite directions. Since the spacing of the temperature rulings is not quite uniform on the charts, being greater at the bottom than at the top, the foregoing arrangement necessitates a small correction to the trace which moves in the " wrong " sense. Actually this correction only becomes appreciable in the case of lapse rates of large magnitude. On such occasions the necessary correction was applied when taking readings off the charts.

(*g*) *Calibration.*—The primary method of calibrating the Leafield apparatus was by direct comparison with Assmann psychrometers. One Assmann psychrometer being suspended beside the housing at 1·2m., the other was taken up the mast by an observer in a bo'sun's chair, and suspended in turn beside each of the other housings. Simultaneous readings of both psychrometers were made every minute for twenty minutes at each position. The mean lapse rate obtained from these readings was

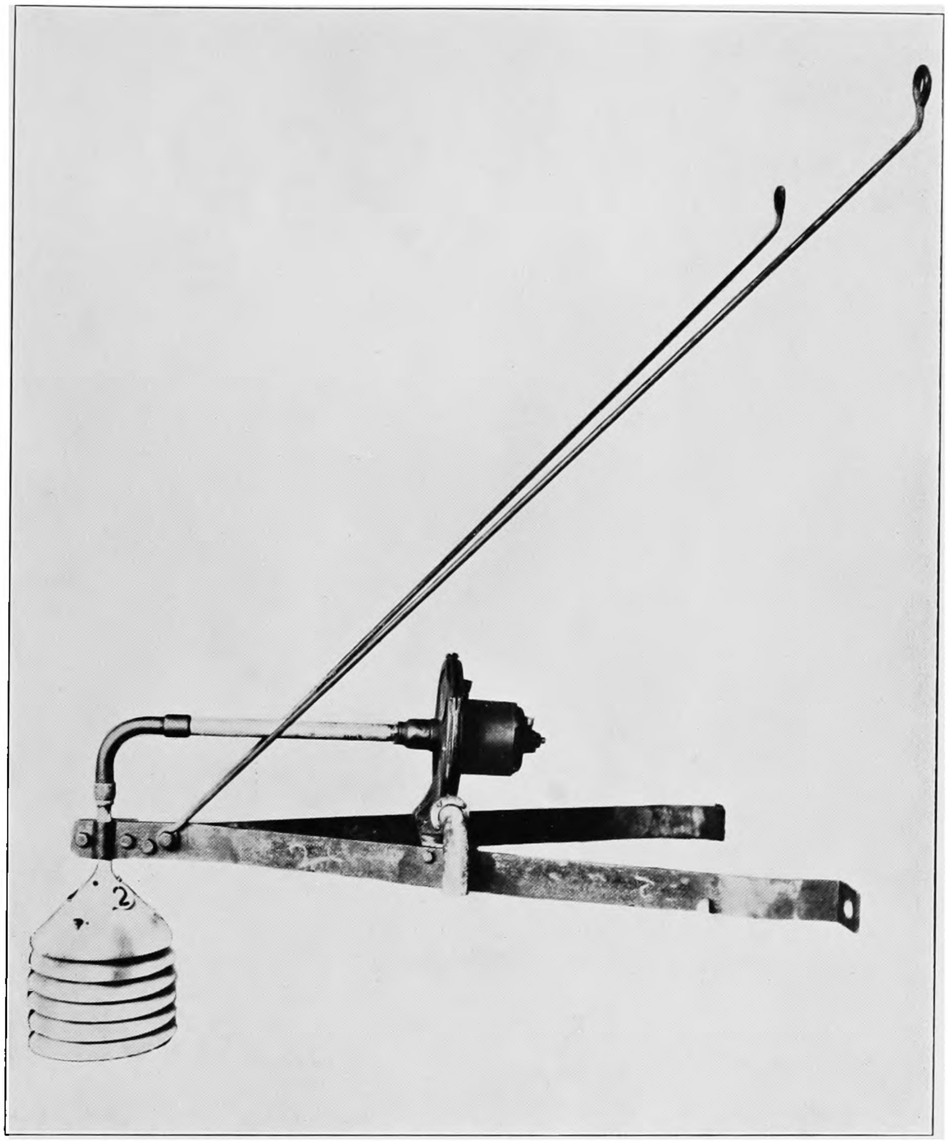

FIG. 5.—BRACKET SUPPORTING HOUSING AND ASPIRATION UNIT.

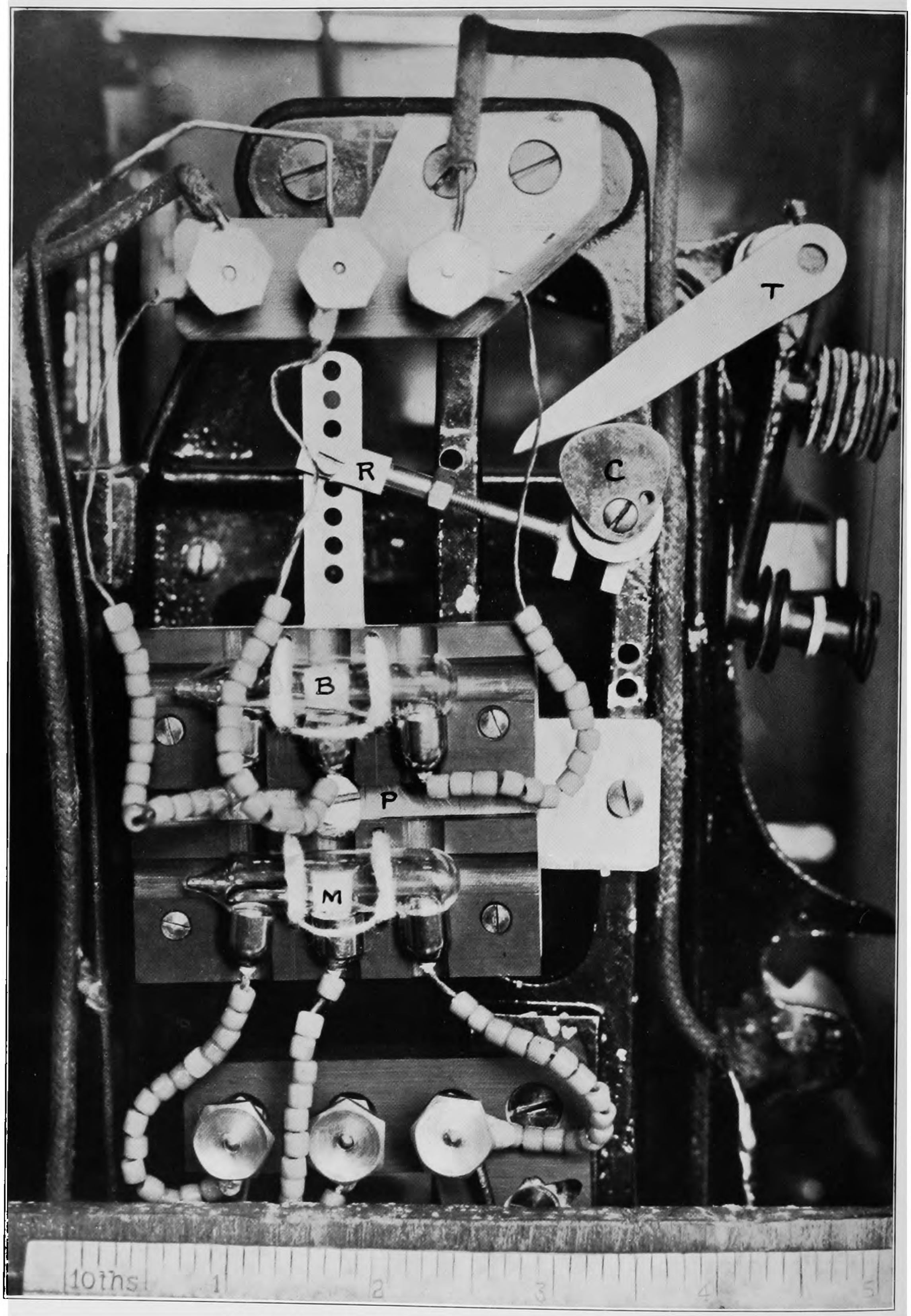

FIG. 6.—MERCURY SWITCHES FITTED TO THREAD-RECORDER.

then compared with the corresponding value shown on the chart of the recording instrument. In practice, attention has to be paid to numerous details which need not be discussed here. It is, however, to be noted that it was found possible to obtain accurate mean values only when there was a uniformly overcast sky and a moderate or fresh wind. In other words, the lapse rate had to be small and steady. Under other conditions the temperature fluctuates too rapidly and by too large an amount to permit of accurate calibration.

This condition necessarily limited the number of occasions on which it was possible to carry out a calibration. A further restriction was imposed by the fact that it was only possible to ascend the mast on Sundays, when transmission of wireless messages was suspended.

As a result, only three complete calibrations were obtained, though several more were made for the lower height intervals. It was consequently necessary to devise some method whereby the corrections to the traces could be checked at more frequent intervals. The method used consisted in comparing the mean temperature structure, as read from the traces on overcast windy nights, with a curve representing the temperature structure on such nights as determined by the method indicated below. Only those nights were included during which the wind velocity exceeded 5 m/sec., the sky was heavily overcast and the dry-bulb temperature remained practically constant for several hours. Under these conditions the differential temperature traces were extremely steady, and it was found that the temperature structure on such occasions was the same at all times of the year.

In order to construct the curve representing the true overcast windy night temperature structure, the rather scanty data from the Leafield calibrations were supplemented by special temperature observations taken on the tower at Porton, and by an analysis of the Eiffel Tower temperature records given in the *Annales du Bureau Central Meteorologique de France*. These observations also showed that there is no seasonal variation in the temperature structure on overcast windy nights.

The following table gives the temperature structure on overcast windy nights as determined from the combined Porton, Leafield and Eiffel Tower observations.

TEMPERATURE STRUCTURE ON OVERCAST WINDY NIGHTS

Height	Temperature differences
m.	°F.
87·7	
	—0·39
57·4	
	—0·32
30·5	
	—0·16
12·4	
	—0·05
1·2	

(*h*) *Possible Sources of Error*.—In discussing the Porton apparatus careful consideration was given to the following possible causes of inaccuracy in the records:—

1. Differences in the velocities of aspiration in the various housings.
2. Adiabatic cooling of the aspirating air stream.
3. Heating of the resistance elements by the passage of the electric current.
4. Differences in this heating effect, due to the fact that some of the resistance elements are continuously in circuit, whilst others are only intermittently so.
5. Conduction of heat down the metal sheath and the electrical leads which communicate with the resistance winding.

Factor 1 has already been dealt with in § 4 (d) above. The remaining sources of error are identical in magnitude with those found for the Porton apparatus. Factors 2, 3 and 4 are allowed for in the calibration, while factor 5 is negligible.

In addition to the above, however, there are several factors which require consideration in the case of the Leafield arrangement. The first of these arises from the fact that the housings at Leafield were fixed to one side of the mast, instead of symmetrically in the centre of an open lattice tower as at Porton. For certain wind directions, therefore, there is a possibility of the air entering the housing having become warmed by contact with the mast. By means of a careful series of observations with an Assmann psychrometer, it has been found that no difference can be detected in the temperature of the air due to its contact with the mast. The observations were made in full sunshine in summer at a distance of 0·9m. from the face of the mast on its lee side. The temperature of the air at this position was found to be identical with that at the same height and at an equal distance to the windward of the mast. Thus the mean of sixteen readings on the leeward side of the mast gave a value of 69·83° F., whilst the mean of an equal number of observations taken during the same period to windward of the mast gave 69·84° F.

A second new possible source of error in the records obtained with this apparatus arises from the setting up of convection currents inside the case of the recording instrument. With some instruments it has been found that the " zero line," traced out when all connexions are removed, is not quite straight. The magnitude of this effect may amount in some cases to 0·3° F. Its cause has been shown to be a convective circulation which arises through the asymmetric distribution of mass inside the instrument case, resulting in a non-uniform temperature distribution whenever the instrument is warming or cooling. The effect is naturally most marked in summer when the diurnal temperature variation is largest. Moreover, the effect may be large in one instrument, whilst in another, apparently identical, it is small. The recorder of the differential traces at Leafield was examined for this effect, which was found not to exceed 0·05° F. provided sunlight was not allowed to fall directly on the recorder case. Precautions were taken to ensure this.

Thirdly, it was found that the Leafield traces were sometimes unreliable in rainy or foggy weather. Under these conditions moisture may collect on the lower end of the aspiration tubes, and be drawn up on to the elements, which subsequently dry off at different times after rain. Some are then acting as dry bulbs while others are still wet bulbs, and an error is introduced. The faulty traces on these occasions are easily recognised, and have been omitted in the analysis.

The possibility of the thermometer elements becoming slightly warmed by direct solar radiation falling on the housings was also investigated. Two elements, in adjacent housings at 1·2m., were connected up to a recorder to form two arms of a Wheatstone bridge. The other two arms were fixed. The recorder was run for six hours. During successive hourly periods alternate housings were shaded from direct sunshine, the other housing being left fully exposed. The results showed that the effect of insolation was to raise the recorded temperature, in one of the housings by 0·05° F. and in the other housing by 0·09° F This experiment was carried out between 1000 and 1600 on a bright summer day. Under these conditions it appears that insolation may introduce an error into a differential trace of the order of 0·05° F. Under most conditions the effects of insolation would thus be negligible.

§ 5—STANDARD METEOROLOGICAL INSTRUMENTS

In addition to the special apparatus described in the previous section, the installation at Leafield included the following instruments :—

1. Dines pressure tube anemometer (height of head 12·7m.).
2. Baxendell wind-direction recorder.
3. Stevenson screen containing the usual thermometers, etc.
4. Hyetograph and standard rain-gauge.
5. Campbell Stokes sunshine recorder.
6. Barometer, barograph and microbarograph.

As a detail of practical interest, mention may be made of the method of mounting the sunshine recorders at both Porton and Leafield. A subsidiary base-plate, made of metal ¼ inch (6mm.) thick, was drilled and slotted as shown in Fig. 7. Metal bolts cemented into the top of the brick pillar passed through the four holes in the corners of the plate, and were locked by nuts above and below the plate. The slots X Y Z are described from the hole A as centre. Four bolts pass through these and hold the sunshine recorder to the plate. By this device the adjustment of the recorder for both level and azimuth was very much facilitated. Since this modification was introduced at Leafield, a new pattern of sunshine recorder has been adopted by the Meteorological Office incorporating the same features. The improvisation made at Leafield may, however, be of interest to those who still possess recorders of the old pattern.

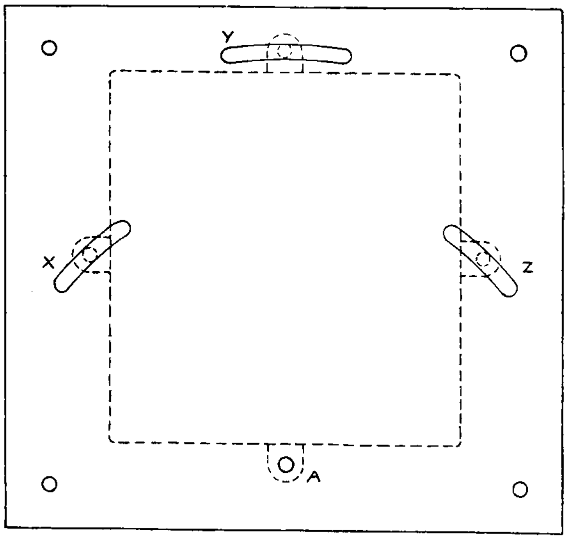

FIG. 7.—BASE PLATE FOR CAMPBELL STOKES SUNSHINE RECORDER (OLD PATTERN).

§ 6—RECORDING ROBINSON ANEMOMETER AT 94·5M.

A second anemometer was mounted above the top of the mast which carried the temperature gradient apparatus. This instrument was of the Robinson pattern with four arms, and had 6 in. (15·2cm.) cups. The radius from the spindle to the centre of the cups was 11½ in. (29·2cm.). The lower end of the spindle was coupled direct to an electric generator, and the current so produced was led down to the recorder in the hut. The recorder consisted virtually of a recording voltmeter, but was graduated to read in metres per second. The complete instrument was calibrated at the National Physical Laboratory. It was made for us by Messrs. Elliott Bros., and was found very satisfactory.

A discussion of certain results obtained from the Leafield anemometers has been given in a previous paper. (2).

§ 7—NIGHT-SKY CAMERA

The night-sky cameras used at Porton and Leafield are identical. An achromatic lens of 23mm. aperture and 25cm. focal length is mounted in the front panel of the mahogany body. Over the lens is built the clockwork shutter mechanism by means of which the lens is uncovered every evening at dark, and covered again shortly before dawn. The two striking arms controlling the time of opening and shutting are altered every week. The back of the camera body carries a ¼-plate roll film. Each night a portion of film measuring 8cm. × 8cm. is exposed, so that a six-exposure ¼-plate film lasts for a week. A series of windows in the camera back enables the ordinary numbering on the film to be utilised. The camera is fitted inside an outer housing to protect it from the weather, and is directed to the pole of the heavens. Although the traces of a large number of stars are usually to be found on the negatives, only that of Polaris is measured up, a circular photographic scale being used to ascertain the time during which that star was visible each night. These records were found to be of great value in the analysis and discussion of the temperature records.

As already indicated, it is proposed to publish more complete details of this instrument in a separate paper.

PART II—THE RECORDS

§ 8—METHOD OF ANALYSING CHARTS

All temperatures are given in degrees Fahrenheit, and Greenwich mean time is used throughout. Hourly values were extracted from the four differential traces for the five years 1926-30, the value allotted to each hour being the mean value of the temperature difference over a period of 20 minutes centred on the hour in question. The temperature differences are taken as positive when temperature increases with height, and negative when it decreases upwards. The former of these conditions is generally known as an inversion, whilst the latter will be referred to as a " lapse."

It is convenient at times to refer to the temperature differences between 1·2m. and successive heights on the mast. These will be designated by the letters A to D, the values of the dry adiabatic lapse rate over each of these height intervals being as follows :—

Interval	A	1·2m. to 12·4m.	—0·20° F.
,,	B	1·2m. to 30·5m.	—0·52° F.
,,	C	1·2m. to 57·4m.	—1·00° F.
,,	D	1·2m. to 87·7m.	—1·54° F.

§ 9—MEAN HOURLY VALUES AND DIURNAL VARIATION OF LAPSE RATE

The mean hourly values of the temperature differences over each height interval for each month are given in Table 1. These values have been plotted in two ways.

In Fig. 8 they are plotted to show the mean variation of temperature with height for each hour. Taking the curves as a whole, the most obvious feature is the rapid decrease of lapse rate with height. Except in the early morning and late afternoon, and during the day in midwinter, the lapse rate always falls off rapidly above 12m. It is probable that the gradients are curved even more sharply than has been indicated in the figure, and that the really steep lapse rates of both signs are confined to the lowest few metres of the atmosphere.

During the middle of the day in all months the rate of change of temperature with height is nearly uniform above the level of 12m.—in fact on summer days the lapse rates between 12m. and 88m. are straight lines, within the limits of accuracy of the plotted points. The contrast between the large midday lapse rate in summer and the small lapse rate in winter is noteworthy. These values can be compared with the dry adiabatic lapse rate, which is shown on the graphs. In January at noon the mean lapse rate between 1·2m. and 12m. is equal to the adiabatic rate ; the lapse rate between 1·2m. and 88m. is about two-thirds of the adiabatic. In June the mean lapse rates over the same height intervals are respectively 8·0 and 2·2 times the adiabatic.

The smallness of the midday lapse rate near the ground in winter is noteworthy. Moreover, in the middle of the day in December and January the mean lapse rate shows no appreciable increase as the ground is approached. On examining the temperature structure on individual days, it was found that at noon in winter there is often an actual inversion, of the order of +0·2° F., between 1·2m. and 12m. ; this happens on about one day in every five in December and January. Many of these inversions were found to be due to a southerly current of warm air blowing over ground which had been cooled the previous night. Midday inversions of this type have also been observed at Porton. Inversions near the surface also tend to persist throughout the day when the ground is snow-covered, or when there is a persistent shallow fog. Again, when the sky is clear in the zenith on a winter day, but the sun is obscured, an inversion will form. The occurrence of these daytime inversions accounts for the smallness of the mean lapse rate between 1·2m. and 12m. during the day in winter.

Fig. 8 also illustrates the nature of the changes in temperature structure towards sunrise and sunset. In the morning there is a nearly simultaneous change at all heights from inversion to lapse ; in the evening, on the other hand, the inversion is built up gradually.

Fig. 9 shows in another way the diurnal variation of the lapse rate for each month. In January an inversion of temperature is seen to predominate. From 1700 to 0700 the curve for interval A shows a nearly steady inversion of about +0·6° F. Curve D shows an inversion increasing during the early part of the night, and reaching a steady value of about +1·2° F., which is maintained from 0200 to 0700. Curves B and C are intermediate in character. Between 1000 and 1010 all the curves change over from inversions to lapses. The smallness of the daytime lapse rate shown by curve A has already been mentioned, and Fig. 9 shows that the lapse persists for little more than four hours, reaching a maximum of only —0·22° F. at about midday. Curve D does not reach its maximum lapse of —0·97° F. until 1300. In the afternoon, curve A changes from lapse to inversion just after 1400, and the other curves cross the zero line in succession.

The sequence of changes which has been described for January is repeated in all the other months. From February to May the curves change sign progressively earlier in the morning and later in the evening, while the daytime lapses and nocturnal inversions on the whole become steadily larger. The curves for March do not fit very easily into this sequence, for the nocturnal inversions for this month are larger than those of either February or April ; in fact the maximum inversion of +2·77° F. reached by curve D at 0400 in March is the largest for the whole year. This is due to the exceptionally large inversions recorded in March, 1929, a month during which an unusually large number of nights were clear. The monthly curves plotted in Fig. 9 should therefore be regarded as a whole, and too much attention should not be paid to the individual features of any one month.

The curves for June and July show the culmination of the various features. The nocturnal inversions are larger than in winter, but persist for a much shorter time. Curve A in June shows a steady inversion of about +1·2° F. for only seven hours (2100 to 0400) ; while curve D continues to rise until it reaches a maximum of +1·93° F. at 0200, but never becomes steady. The lapses during the day are large and prolonged. The times of maximum lapse appear to be close to noon at all heights ; the maximum values are —1·61° F. for curve A and —3·38° F. for curve D.

From August to December the curves show a similar sequence to those of the first half of the year. The duration and magnitude of the daytime lapses decrease steadily, whilst the nocturnal inversions increase in duration, and, on the whole, decrease in magnitude. September, like March, shows unusually large inversions.

Reviewing the whole series of curves, the most striking feature is the growth of the midday lapse rate from an almost negligible value in winter to several times the adiabatic value in midsummer. The nocturnal inversion in the lowest 12m. during summer is rather less than twice that in winter.

Certain other features of the curves deserve closer examination. In the first place it is of interest to estimate the amount of lag with increasing height of the time of maximum lapse rate. Curve A is always closely symmetrical about the time of maximum lapse rate, which occurs at approximately noon G.M.T. This confirms the result found at Porton (1), that the steepest lapse rate near the ground occurs at noon, and not at the time when the air temperature reaches its maximum. During the four months November to February the time of maximum lapse rate shows a definite lag with increasing height, and the turning point of curve D occurs about one hour after that of curve A. From April to October no appreciable lag can be detected in the times of maximum lapse rate. March appears to be intermediate in character.

At night the curves show no definite peaks of maximum inversion (except in the case of the D trace in midsummer, already mentioned), but it is interesting to note the time required for the inversion to be built up to the level of the highest thermometer. The point at which curve A crosses the zero line gives the time when the temperature is the same at 1·2m. and 12·4m. ; the point at which curves C and D cross one another gives the time when temperature is the same at 57·4m. and 87·7m. The interval between these two points will give the time taken by the top of the inversion to rise from about 7m. to 70m. say. This is found to be roughly eight hours at all times of the year. Consequently during the short nights of midsummer the top

TABLE I—MEAN HOURLY VALUES OF THE TEMPERATURE DIFFERENCE IN °F. OVER FOUR

Month	Hour, G.M.T. / Height Interval (m.)	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
Jan.	87·7—57·4	0·03	0·05	0·08	0·09	0·08	0·10	0·11	0·10	0·08	0·02	−0·12
	57·4—30·5	0·26	0·28	0·29	0·25	0·31	0·30	0·31	0·28	0·29	0·06	−0·12
	30·5—12·4	0·25	0·28	0·32	0·26	0·25	0·26	0·26	0·23	0·20	0·02	−0·16
	12·4— 1·2	0·62	0·63	0·54	0·52	0·53	0·50	0·50	0·42	0·26	0·00	−0·17
Feb.	87·7—57·4	0·02	−0·02	0·01	−0·01	−0·04	0·04	0·07	0·09	0·03	−0·10	−0·27
	57·4—30·5	0·17	0·19	0·16	0·22	0·21	0·19	0·21	0·23	0·06	−0·21	−0·34
	30·5—12·4	0·18	0·25	0·16	0·19	0·22	0·18	0·18	0·14	−0·04	−0·25	−0·29
	12·4— 1·2	0·59	0·57	0·56	0·55	0·53	0·54	0·48	0·31	−0·08	−0·36	−0·52
Mar.	87·7—57·4	0·12	0·15	0·11	0·23	0·22	0·23	0·25	0·16	−0·05	−0·39	−0·47
	57·4—30·5	0·37	0·34	0·45	0·39	0·41	0·42	0·40	0·23	−0·14	−0·49	−0·53
	30·5—12·4	0·50	0·60	0·53	0·59	0·57	0·58	0·54	0·26	−0·10	−0·39	−0·42
	12·4— 1·2	1·32	1·26	1·20	1·26	1·15	1·11	0·85	0·14	−0·39	−0·81	−1·04
Apr.	87·7—57·4	0·03	0·02	0·07	0·09	0·10	0·17	−0·02	−0·27	−0·37	−0·45	−0·44
	57·4—30·5	0·10	0·12	0·12	0·19	0·18	0·20	−0·08	−0·29	−0·46	−0·55	−0·58
	30·5—12·4	0·30	0·33	0·35	0·33	0·26	0·20	−0·07	−0·26	−0·36	−0·45	−0·47
	12·4— 1·2	0·97	0·97	0·89	0·76	0·69	0·42	−0·22	−0·68	−0·96	−1·15	−1·28
May	87·7—57·4	−0·12	−0·08	−0·02	0·01	0·09	0·04	−0·15	−0·41	−0·52	−0·57	−0·59
	57·4—30·5	0·14	0·13	0·19	0·25	0·21	0·12	−0·10	−0·32	−0·49	−0·52	−0·62
	30·5—12·4	0·31	0·33	0·37	0·36	0·36	0·06	−0·32	−0·43	−0·47	−0·51	−0·49
	12·4— 1·2	1·09	1·23	1·13	1·08	0·80	−0·11	−0·59	−0·91	−1·12	−1·39	−1·46
June	87·7—57·4	−0·04	−0·03	0·01	0·03	0·01	−0·11	−0·36	−0·54	−0·59	−0·62	−0·63
	57·4—30·5	0·24	0·32	0·34	0·33	0·30	0·04	−0·33	−0·43	−0·55	−0·60	−0·62
	30·5—12·4	0·38	0·43	0·37	0·40	0·29	−0·12	−0·38	−0·46	−0·50	−0·48	−0·50
	12·4— 1·2	1·21	1·21	1·12	1·15	0·44	−0·35	−0·78	−1·16	−1·35	−1·52	−1·61
July	87·7—57·4	−0·06	−0·04	0·02	0·04	0·02	0·05	−0·32	−0·49	−0·57	−0·57	−0·60
	57·4—30·5	0·16	0·16	0·20	0·23	0·25	0·02	−0·27	−0·36	−0·49	−0·48	−0·51
	30·5—12·4	0·49	0·42	0·44	0·45	0·30	−0·07	−0·36	−0·46	−0·45	−0·46	−0·49
	12·4— 1·2	1·17	1·20	1·18	1·04	0·64	−0·22	−0·64	−0·97	−1·13	−1·33	−1·40
Aug.	87·7—57·4	0·07	0·05	0·05	0·10	0·13	0·08	−0·11	−0·36	−0·48	−0·53	−0·55
	57·4—30·5	0·25	0·28	0·24	0·33	0·20	0·11	−0·20	−0·43	−0·56	−0·61	−0·58
	30·5—12·4	0·33	0·38	0·38	0·35	0·34	0·13	−0·22	−0·38	−0·43	−0·44	−0·45
	12·4— 1·2	1·16	1·08	1·05	1·03	0·94	0·30	−0·37	−0·72	−1·07	−1·26	−1·32
Sept.	87·7—57·4	0·03	0·09	0·11	0·11	0·16	0·21	0·17	−0·08	−0·35	−0·50	−0·56
	57·4—30·5	0·30	0·25	0·33	0·27	0·29	0·29	0·18	−0·15	−0·35	−0·50	−0·56
	30·5—12·4	0·55	0·55	0·59	0·58	0·62	0·55	0·27	−0·09	−0·29	−0·37	−0·41
	12·4— 1·2	1·33	1·33	1·28	1·16	1·24	0·93	0·11	−0·42	−0·77	−1·05	−1·17
Oct.	87·7—57·4	−0·01	0·01	0·05	0·06	0·10	0·10	0·09	0·01	−0·20	−0·39	−0·48
	57·4—30·5	0·22	0·29	0·30	0·27	0·30	0·24	0·25	0·01	−0·22	−0·39	−0·44
	30·5—12·4	0·46	0·50	0·49	0·47	0·46	0·48	0·42	0·14	−0·11	−0·28	−0·30
	12·4— 1·2	0·99	1·00	0·87	0·95	0·89	0·89	0·68	0·01	−0·41	−0·60	−0·72
Nov.	87·7—57·4	0·07	0·04	0·14	0·14	0·18	0·12	0·13	0·11	0·06	−0·12	−0·19
	57·4—30·5	0·13	0·16	0·11	0·19	0·17	0·20	0·14	0·18	0·04	−0·18	−0·34
	30·5—12·4	0·39	0·40	0·34	0·35	0·36	0·35	0·35	0·35	0·16	−0·05	−0·21
	12·4— 1·2	0·78	0·82	0·93	0·78	0·77	0·74	0·72	0·63	0·16	−0·09	−0·22
Dec.	87·7—57·4	0·10	0·07	0·03	0·10	0·10	0·08	0·06	0·02	0·09	0·06	0·01
	57·4—30·5	0·18	0·17	0·16	0·17	0·14	0·15	0·18	0·22	0·15	0·06	−0·07
	30·5—12·4	0·29	0·29	0·27	0·28	0·29	0·34	0·35	0·37	0·33	0·13	−0·07
	12·4— 1·2	0·48	0·47	0·52	0·53	0·58	0·59	0·59	0·54	0·33	0·10	−0·08

HEIGHT INTERVALS FOR EACH MONTH (BASED UPON FIVE YEARS' RECORDS, 1926—30)

1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	Hour / Month
−0·23	−0·32	−0·31	−0·26	−0·18	−0·17	−0·14	−0·12	−0·13	−0·06	−0·05	−0·06	0·00	Jan.
−0·21	−0·25	−0·26	−0·18	−0·09	0·03	0·09	0·12	0·15	0·17	0·20	0·20	0·21	
−0·18	−0·18	−0·19	−0·11	0·02	0·13	0·18	0·19	0·18	0·22	0·25	0·23	0·23	
−0·22	−0·22	−0·06	0·11	0·44	0·57	0·57	0·56	0·51	0·56	0·56	0·54	0·60	
−0·37	−0·44	−0·46	−0·45	−0·39	−0·28	−0·23	−0·19	−0·20	−0·13	−0·12	−0·09	−0·02	Feb.
−0·39	−0·40	−0·43	−0·39	−0·29	−0·17	−0·06	0·01	0·05	0·12	0·17	0·17	0·16	
−0·33	−0·31	−0·30	−0·23	−0·14	0·00	0·09	0·16	0·18	0·21	0·22	0·20	0·20	
−0·56	−0·60	−0·46	−0·24	0·09	0·50	0·68	0·74	0·72	0·72	0·71	0·65	0·56	
−0·55	−0·57	−0·58	−0·59	−0·57	−0·53	−0·43	−0·31	−0·23	−0·19	−0·15	−0·05	0·06	Mar.
−0·55	−0·59	−0·54	−0·52	−0·49	−0·39	−0·20	−0·01	0·12	0·23	0·25	0·24	0·38	
−0·40	−0·37	−0·37	−0·30	−0·19	−0·07	0·16	0·32	0·38	0·45	0·47	0·58	0·54	
−1·06	−1·07	−1·00	−0·76	−0·31	0·32	0·96	1·28	1·34	1·29	1·20	1·23	1·28	
−0·54	−0·54	−0·50	−0·48	−0·45	−0·43	−0·39	−0·33	−0·27	−0·19	−0·15	−0·08	−0·03	Apr.
−0·62	−0·61	−0·59	−0·56	−0·49	−0·46	−0·36	−0·20	−0·09	−0·08	−0·04	0·03	0·02	
−0·48	−0·42	−0·40	−0·35	−0·27	−0·18	−0·04	0·14	0·27	0·28	0·29	0·29	0·27	
−1·32	−1·21	−1·13	−0·94	−0·59	−0·30	0·15	0·78	0·87	0·94	0·92	0·98	0·98	
−0·60	−0·60	−0·57	−0·54	−0·56	−0·53	−0·48	−0·44	−0·35	−0·26	−0·18	−0·17	−0·12	May
−0·60	−0·61	−0·58	−0·55	−0·51	−0·48	−0·39	−0·29	−0·11	−0·03	0·03	0·06	0·11	
−0·48	−0·47	−0·45	−0·40	−0·33	−0·26	−0·13	0·03	0·22	0·28	0·28	0·28	0·30	
−1·47	−1·38	−1·25	−1·01	−0·69	−0·39	−0·02	0·53	0·99	1·01	1·02	1·06	1·13	
−0·63	−0·66	−0·67	−0·64	−0·62	−0·59	−0·56	−0·52	−0·43	−0·33	−0·25	−0·15	−0·08	June
−0·60	−0·65	−0·58	−0·56	−0·54	−0·48	−0·41	−0·30	−0·16	0·00	0·09	0·11	0·16	
−0·52	−0·55	−0·49	−0·44	−0·41	−0·33	−0·27	−0·13	0·08	0·24	0·33	0·32	0·34	
−1·54	−1·52	−1·33	−1·12	−0·91	−0·64	−0·23	0·30	0·89	1·16	1·15	1·23	1·15	
−0·64	−0·63	−0·63	−0·61	−0·61	−0·59	−0·59	−0·52	−0·42	−0·32	−0·21	−0·17	−0·10	July
−0·53	−0·55	−0·54	−0·57	−0·55	−0·49	−0·43	−0·30	−0·13	0·02	0·08	0·12	0·18	
−0·47	−0·46	−0·43	−0·38	−0·36	−0·29	−0·18	−0·02	0·22	0·33	0·37	0·41	0·42	
−1·52	−1·40	−1·28	−1·07	−0·94	−0·60	−0·22	0·35	0·89	1·13	1·15	1·28	1·18	
−0·56	−0·55	−0·57	−0·52	−0·51	−0·50	−0·46	−0·35	−0·25	−0·15	−0·11	−0·10	0·03	Aug.
−0·58	−0·59	−0·55	−0·52	−0·51	−0·42	−0·29	−0·11	0·03	0·10	0·12	0·14	0·23	
−0·46	−0·40	−0·40	−0·35	−0·30	−0·20	−0·04	0·17	0·35	0·39	0·43	0·36	0·38	
−1·28	−1·18	−1·11	−0·81	−0·58	−0·30	0·20	0·84	1·28	1·27	1·30	1·14	1·15	
−0·62	−0·61	−0·58	−0·56	−0·53	−0·52	−0·42	−0·28	−0·17	−0·06	−0·08	−0·07	0·04	Sept.
−0·55	−0·53	−0·53	−0·51	−0·45	−0·37	−0·21	−0·05	0·01	0·07	0·09	0·09	0·17	
−0·37	−0·34	−0·31	−0·26	−0·20	−0·06	0·21	0·41	0·43	0·45	0·50	0·54	0·54	
−1·22	−1·17	−0·99	−0·77	−0·36	0·16	0·92	1·31	1·38	1·42	1·36	1·40	1·39	
−0·54	−0·54	−0·54	−0·47	−0·44	−0·40	−0·29	−0·20	−0·15	−0·10	−0·08	−0·08	−0·04	Oct.
−0·48	−0·46	−0·43	−0·40	−0·30	−0·20	−0·02	0·06	0·12	0·13	0·15	0·18	0·26	
−0·32	−0·26	−0·23	−0·16	−0·01	0·17	0·37	0·40	0·45	0·44	0·43	0·46	0·48	
−0·76	−0·69	−0·47	−0·23	0·15	0·75	1·03	1·03	0·90	0·93	0·99	1·05	0·97	
−0·27	−0·37	−0·37	−0·30	−0·23	−0·15	−0·10	−0·08	−0·04	0·04	−0·01	0·04	0·07	Nov.
−0·42	−0·45	−0·42	−0·36	−0·23	−0·12	−0·06	0·01	0·04	0·03	0·04	0·07	0·11	
−0·22	−0·22	−0·19	−0·09	0·08	0·21	0·25	0·29	0·29	0·31	0·31	0·28	0·33	
−0·27	−0·23	−0·09	0·18	0·63	0·81	0·86	0·87	0·87	0·81	0·79	0·77	0·83	
−0·18	−0·24	−0·23	−0·25	−0·15	−0·10	−0·11	−0·11	−0·04	0·00	−0·01	0·02	0·06	Dec.
−0·22	−0·20	−0·23	−0·15	−0·09	0·04	0·01	0·08	0·07	0·13	0·12	0·15	0·13	
−0·13	−0·12	−0·10	0·01	0·19	0·23	0·25	0·28	0·25	0·27	0·26	0·34	0·27	
−0·15	−0·11	0·02	0·27	0·55	0·64	0·62	0·59	0·61	0·62	0·56	0·62	0·57	

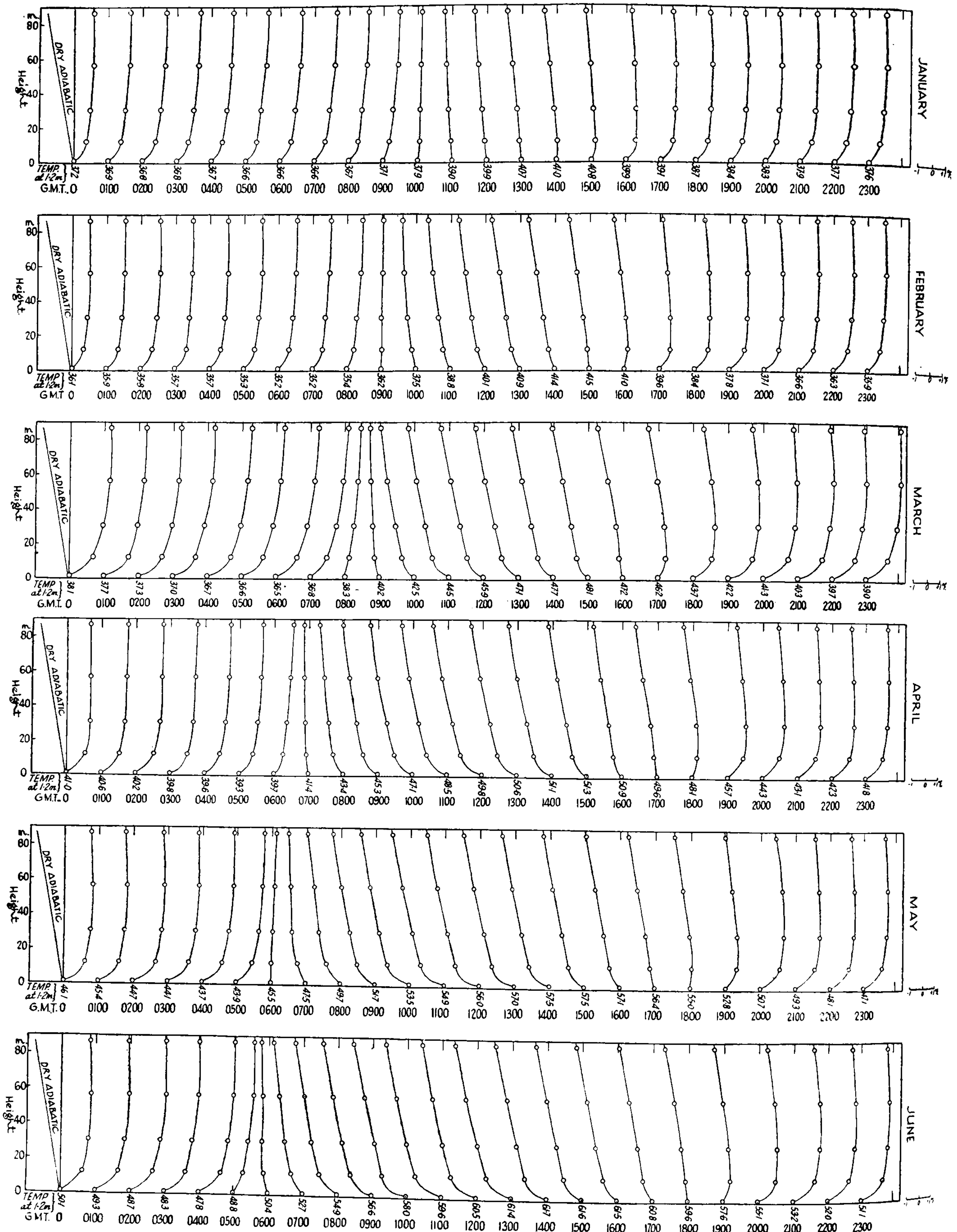

FIG. 8.—MEAN VARIATION OF TEMPERATURE WITH HEIGHT FOR EACH HOUR, JANUARY TO JUNE.

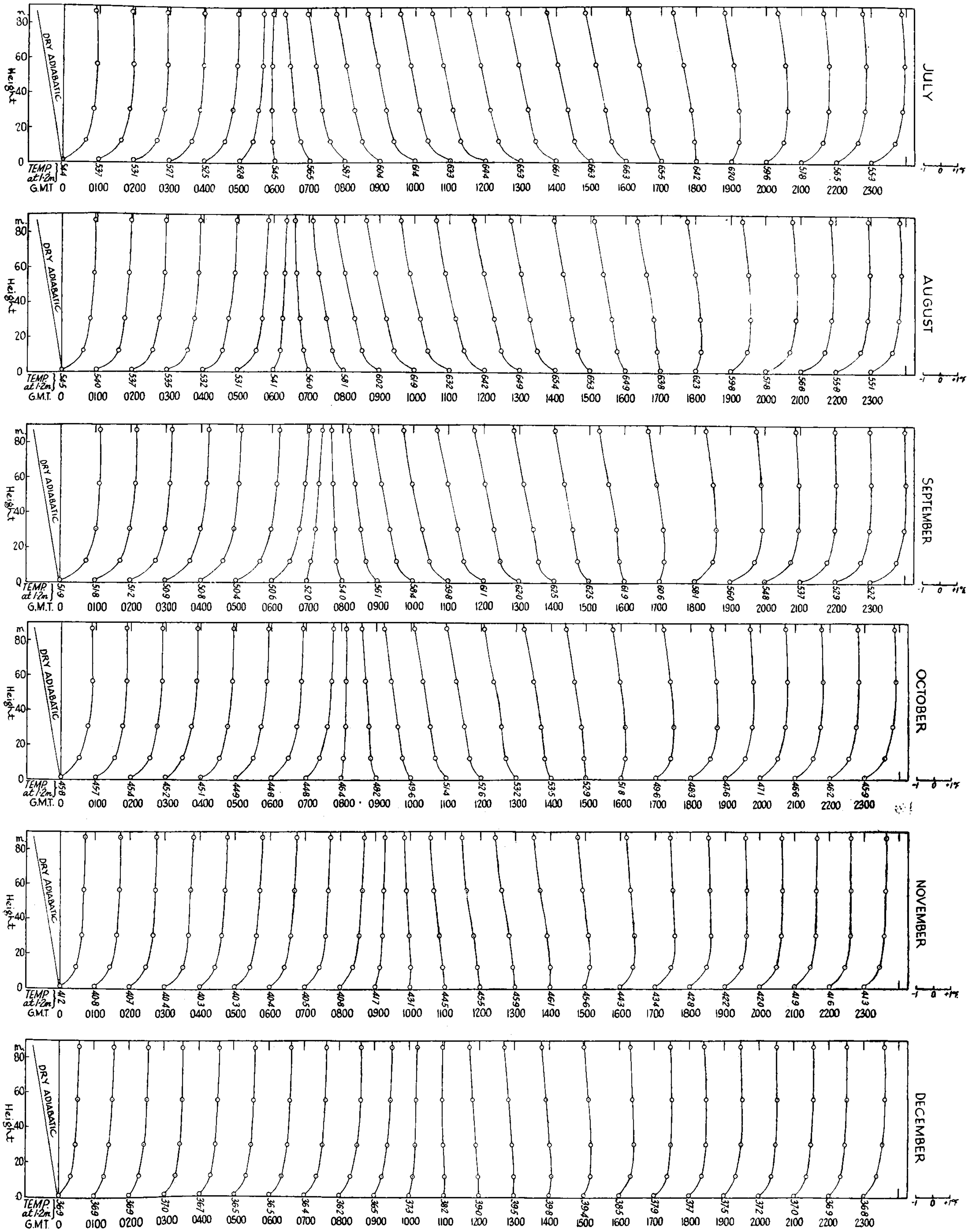

FIG. 8.—MEAN VARIATION OF TEMPERATURE WITH HEIGHT FOR EACH HOUR, JULY TO DECEMBER.

of the inversion has, on the average, only just reached 70m. by the time the rising sun causes its breakdown at all heights. In winter, on the other hand, there is time for the inversion to reach up to 70m. by about midnight, and it probably continues to grow slowly above this height during the small hours of the morning. The curves for December and January show however that the average inversion between 57m. and 88m. never exceeds about 0·1° F., so it is unlikely that the inversion reaches a much greater height than 100m. even in winter.

It should be noted that these remarks refer to the mean curves for each month. The rate of upward propagation of inversions under particular conditions is discussed later.

Another feature worth examining is the way in which the curves cross the zero line. In the morning, at all times of the year, curve A crosses the zero line some one and a half to two hours after sunrise, and the other curves cross over with a lag of only a few minutes after curve A. Thus the change-over from inversion to lapse takes place nearly simultaneously at all heights. The change-over from lapse to inversion in the evening is of quite a different nature ; in all months curve A crosses the zero line first, about two hours before sunset, and the other curves follow at appreciable intervals. On the average, curve D crosses over about an hour after curve A. It is noteworthy that in summer an inversion forms near the ground so long before sunset.

§ 10—MEAN MONTHLY AND YEARLY VALUES OF LAPSE RATE

The hourly values of the temperature differences given in Table I have been meaned by months, and the results are given in Table II. These values have been plotted in Fig. 10.

TABLE II—MEAN VALUES OF THE TEMPERATURE DIFFERENCE IN °F. OVER FOUR HEIGHT INTERVALS FOR EACH MONTH, (BASED UPON FIVE YEARS' RECORDS, 1926—30)

Month	Height interval			
	1·2 m. to 12·4 m.	12·4 m. to 30·5 m.	30·5 m. to 57·4 m.	57·4 m. to 87·7 m.
January ...	+0·37	+0·13	+0·11	−0·06
February ...	+0·28	+0·04	−0·01	−0·15
March	+0·45	+0·19	−0·01	−0·17
April	+0·02	−0·02	−0·21	−0·23
May	−0·03	−0·07	−0·21	−0·32
June	−0·13	−0·10	−0·20	−0·38
July	−0·06	−0·04	−0·20	−0·36
August ...	+0·11	0·00	−0·16	−0·26
September ...	+0·37	+0·17	−0·10	−0·21
October ...	+0·42	+0·21	−0·02	−0·19
November ...	+0·54	+0·18	−0·04	−0·05
December ...	+0·42	+0·20	+0·06	−0·03
Annual Mean	+0·23	+0·07	−0·08	−0·20

It will be seen that in every month except May, June and July the average temperature structure between 1·2m. and 12m. is an inversion. The mean inversion diminishes with increasing height, and over the interval 57m. to 88m. there is a slight mean lapse at all times of the year. The monthly means over the height interval 1·2m. to 12m. range from +0·54° F. in November to −0·13° F. in June ; over the interval 57m. to 88m. the range is from −0·03° F. in December to −0·38° F. in June. The exceptional inversions of March, 1929, again show in the monthly means.

The mean annual lapse rate, obtained by averaging the monthly means, is entered at the foot of Table II, and plotted in Fig. 10. For the five years under consideration, the average condition was an inversion near the ground, changing to a slight lapse above 30m.

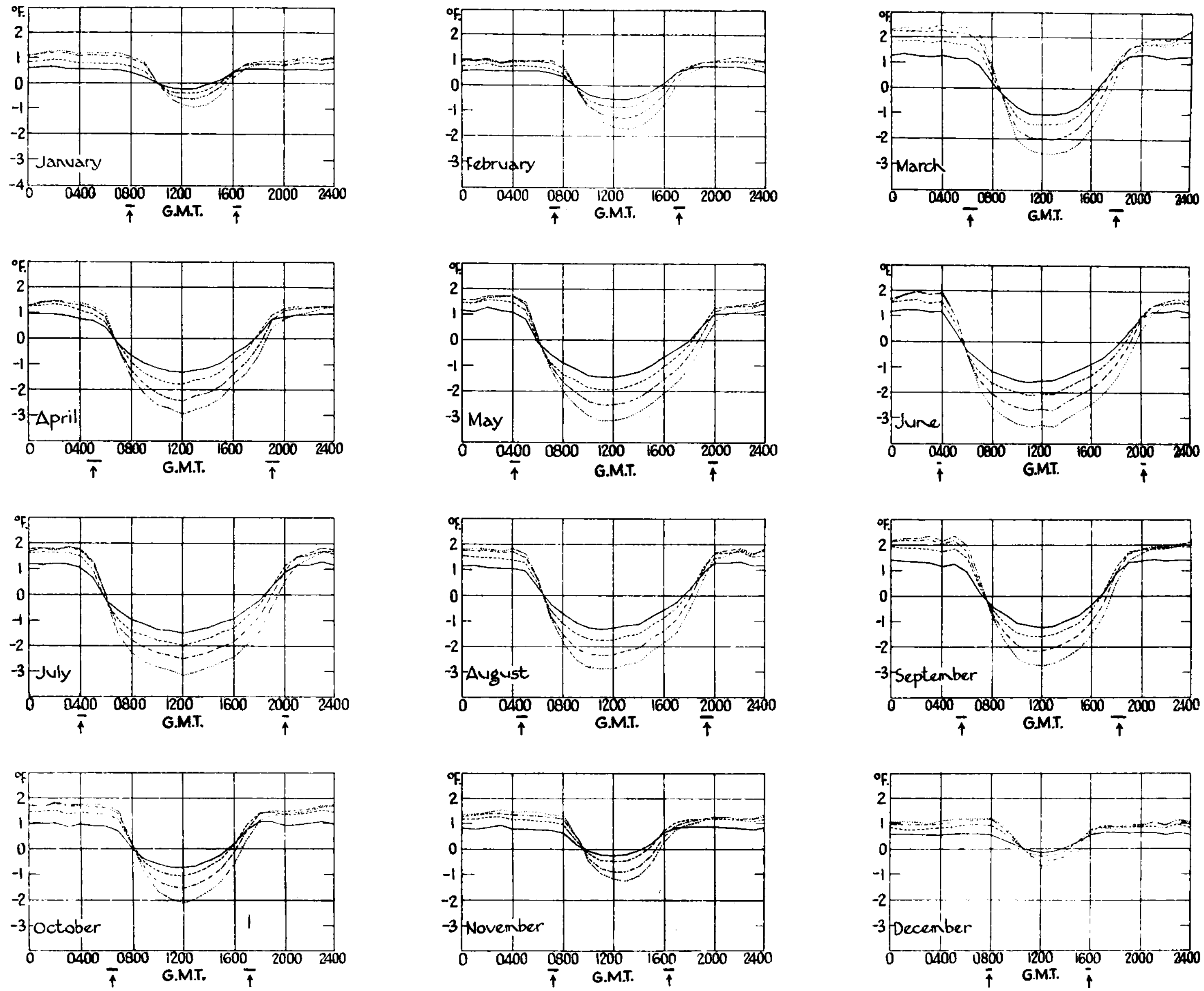

FIG. 9. DIURNAL VARIATION OF LAPSE RATE FOR EACH MONTH

The curves show the temperature differences (°F.) over the following height intervals, ······ 1·2 to 12·4m.; —·—·— 12·4 to 30·5m.; ---- 30·5 to 57·4m.; — 57·4 to 87·7m.

The arrows indicate times of sunrise and sunset, the limits for each month being shown by the length of the bar immediately above them.

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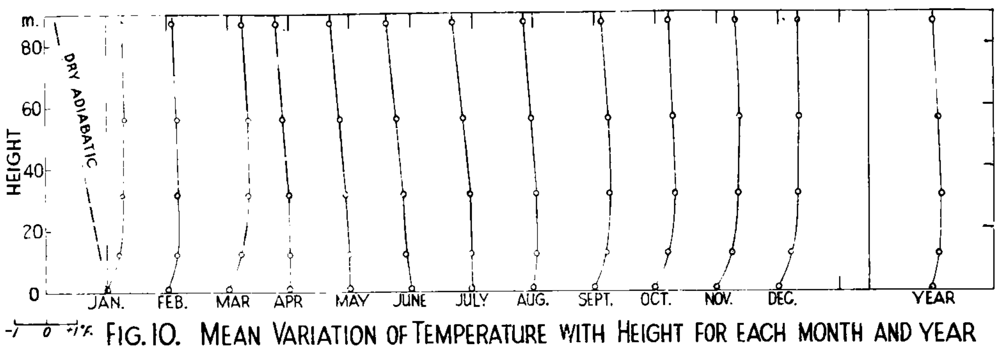


FIG. 10. MEAN VARIATION OF TEMPERATURE WITH HEIGHT FOR EACH MONTH AND YEAR

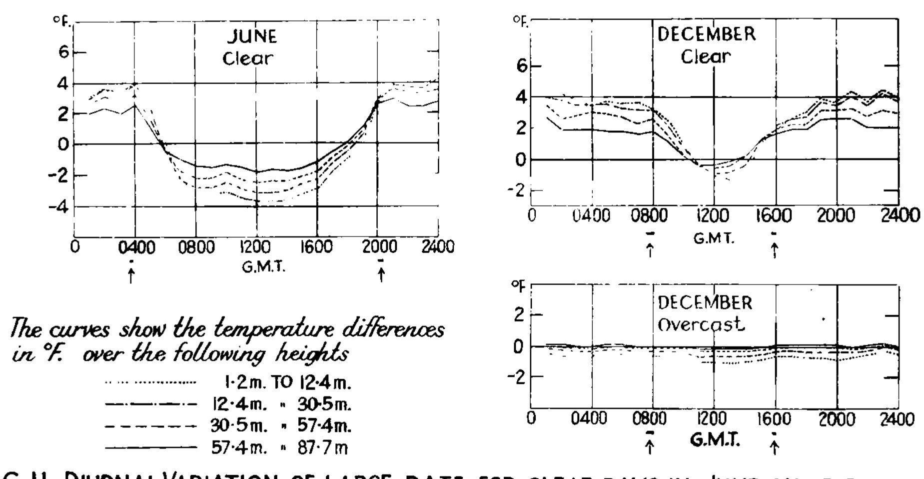


FIG. 11. DIURNAL VARIATION OF LAPSE RATE FOR CLEAR DAYS IN JUNE AND FOR CLEAR AND OVERCAST DAYS IN DECEMBER. *NOTE. The arrows indicate times of sunrise and sunset, the limits for each month being shown by the length of the bar immediately above them.*

§ 11—LAPSE RATES ON CLEAR AND OVERCAST DAYS

In this section it is proposed to examine the effect which the state of the sky produces upon the lapse rate. June will be taken as representative of summer, December of winter. In both of them the times of sunrise and sunset remain approximately constant ; consequently the morning and evening portions of the mean diurnal curves will resemble closely the actual changes occurring on an average day.

Table III gives the mean hourly values of the temperature differences over the four height intervals, for clear days in June and for clear and overcast days in December. The results are plotted in Fig. 11. The criterion for a clear day has been continuous, or almost continuous, traces on the sunshine recorder and night-sky camera over the 24-hour period from midnight to midnight. For an overcast day a complete absence of any trace on both recorders has been required. The additional restriction was imposed in both cases, that a day should be included only if the sky during the preceding twelve hours conformed to the same criteria, for it was found that the lapse rate was affected by the state of the sky during the previous day Not many days conform to these strict conditions ; the actual numbers are given in the last column of Table IV. Being based on so few observations, the curves are naturally not very smooth. No completely overcast June days, as defined above, occurred during the five years.

On clear days in June the maximum lapses are —1·9° F. for curve A and —3·7° F. for curve D, compared with —1·6° F. and —3·4° F. already given as the corresponding values for all states of the sky. On clear nights in June the inversions reach values of +2·9° F. and +4·5° F. for the two curves, as compared with values of +1·2° F. and +1·9° F. given in Table I. The apparent decrease in lapse rate occurring at all heights at 1000 is due to the fact that on three of the seven days from which the means were taken the sun happened to be clouded over temporarily at about that time. On the whole, the curves for clear days in June are similar to the mean curves for June given in Fig. 9, except that the growth of the inversion is much more rapid on clear evenings ; curves C and D cross one another at 2200, instead of just before sunrise the following morning.

Turning to the December curves ; on clear days the maximum lapses are —0·3° F. for curve A and —1·3° F. for curve D. On clear nights in December the two curves reach inversions of +2·7° F. and +4·4° F. These values are several times greater than the corresponding means given in Table I. The lag with height of the time of maximum lapse rate is well shown by the curves for clear December days. The upward growth of the inversion is also much more rapid than on the average evening.

The overcast days and nights in December show extremely little variation in the temperature differences. Between 1·2m. and 12m. the difference ranges from an inversion of +0·2° F. at night to a lapse of —0·1° F. during the middle of the day. Above 12m. there is a slight decrease of temperature with height at all times of the day and night.

Table IV gives the mean hourly wind velocities for each of the above groups of days, as recorded by the Dines pressure tube anemometer. The ordinary diurnal variation of wind velocity is well marked on clear days in June, while there is very little variation on overcast days in December.

§ 12—MAXIMUM VALUES OF THE LAPSE RATE

From the hourly analysis of the temperature differences over the four height intervals, the largest hourly values of both lapses and inversions occurring during each month have been extracted. These values are given in Tables V and VI together with the hour of occurrence. The state of the sky and the wind velocity at 13m. are also given. The day of the month is included in Table V.

(a) *Maximum Lapses.*—During the five years, the greatest hourly lapse was —4·3° F. between 1·2m. and 12m. and —1·9° F. between 57m. and 88m. ; the first of these is equivalent to 21 times the dry adiabatic rate, the second 3·5 times. They both occurred in June. In midwinter the greatest lapse rates over the same height intervals were respectively 9·0 and 2·6 times the adiabatic value.

TABLE III—MEAN HOURLY VALUES OF THE TEMPERATURE DIFFERENCE IN °F. OVER FOUR

Height interval (metres) \ Hour, G.M.T.	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200
June — Clear Days												
87·7—57·4	+0·1	0·0	+0·2	+0·1	+0·2	+0·5	+0·1	−0·4	−0·5	−0·6	−0·6	−0·6
57·4—30·5	+0·3	+0·5	+0·5	+0·7	+0·8	+0·2	−0·5	−0·6	−0·6	−0·6	−0·6	−0·6
30·5—12·4	+0·6	+0·8	+0·7	+0·7	+0·6	0·0	−0·7	−0·7	−0·6	−0·5	−0·7	−0·6
12·4— 1·2	+2·0	+2·3	+2·0	+2·5	+1·0	−0·5	−1·1	−1·5	−1·6	−1·4	−1·6	−1·9
December — Clear Days												
87·7—57·4	+0·1	+0·5	+0·4	−0·1	+0·2	+0·3	+0·5	0·0	+0·3	+0·1	+0·3	−0·1
57·4—30·5	+0·5	+1·1	+0·6	+0·5	+0·6	+0·5	+0·8	+0·5	+0·6	+0·4	+0·1	−0·4
30·5—12·4	+0·8	+0·7	+0·9	+1·1	+1·1	+0·9	+0·7	+0·8	+0·4	+0·1	−0·1	−0·2
12·4— 1·2	+2·7	+1·9	+1·9	+1·9	+1·8	+1·8	+1·6	+1·8	+1·1	+0·2	−0·3	−0·3
Overcast Days												
87·7—57·4	−0·3	−0·4	−0·4	−0·3	−0·3	−0·3	−0·3	−0·3	−0·3	−0·3	−0·3	−0·4
57·4—30·5	−0·1	−0·2	−0·2	−0·2	−0·2	−0·2	−0·2	−0·2	−0·2	−0·3	−0·4	−0·3
30·5—12·4	−0·1	0·1	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	−0·2	−0·2
12·4— 1·2	+0·1	+0·1	0·0	0·0	+0·1	+0·1	0·0	0·0	0·0	0·0	−0·1	−0·1

Note.—There were no completely

TABLE IV—MEAN HOURLY VALUES OF WIND VELOCITY IN METRES PER

Hour, G.M.T.	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200
JUNE Clear ...	3·1	2·4	2·6	2·5	2·6	2·6	3·0	3·4	3·7	3·5	4·3	4·5
DECEMBER Clear ...	4·5	4·3	4·6	4·9	5·2	5·4	5·7	5·7	3·8	4·3	4·1	4·7
Overcast	3·8	4·1	4·0	4·5	4·3	4·2	4·3	3·9	3·8	3·8	4·1	3·9

The times of occurrence of maximum lapse rate are of interest. In summer near the ground (1·2m. to 12m.), the values are closely grouped about noon—24 occur within one hour of noon, and the remaining 13 within two hours. On the other hand, maximum lapse rates over the three upper height intervals may occur quite early in the morning in summer ; for instance, over the height interval 12m. to 30m., the maximum lapse rate occurred at 0800 on five occasions. Reference to Fig. 7 shows that on the average there is hardly any increase in lapse rate over the height intervals 12m. to 30m. and 30m. to 57m. after 0800 on a midsummer morning. The maximum lapse rates over these height intervals may thus occur at any time between 0800 and the early afternoon. In winter the times of maximum lapse rate are more closely grouped about noon.

As regards the state of the sky, the largest lapse rates near the ground almost always require the sky clear or only partially clouded. Over the topmost height interval, however, there are many occasions with a cloudy or even overcast sky, particularly in winter. The traces representing the temperature difference between 57m. and 87m. show little diurnal variation in winter, and large lapse rates at that

HEIGHT INTERVALS FOR CLEAR DAYS IN JUNE AND CLEAR AND OVERCAST DAYS IN DECEMBER

1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	Hour / Height Interval
						June						
and Nights												
−0·6	−0·6	−0·6	−0·6	−0·5	−0·5	−0·4	−0·3	−0·1	+0·1	+0·1	+0·3	87·7—57·4
−0·7	−0·6	−0·5	−0·5	−0·4	−0·3	−0·3	0·0	+0·3	+0·4	+0·3	+0·7	57·4—30·5
−0·7	−0·6	−0·5	−0·6	−0·4	−0·3	−0·1	+0·3	+0·7	+0·9	+0·9	+0·8	30·5—12·4
−1·7	−1·8	−1·6	−1·2	−0·5	+0·1	+0·9	+2·6	+2·9	+2·4	+2·4	+2·7	12·4— 1·2
						December						
and Nights												
−0·5	−0·5	−0·4	−0·3	0·0	+0·2	+0·2	+0·2	+0·3	+0·2	+0·2	+0·3	87·7—57·4
−0·4	−0·5	−0·1	+0·2	+0·3	+0·5	+0·5	+0·3	+0·8	+0·7	+1·1	+0·7	57·4—30·5
−0·3	−0·1	0·0	+0·3	+0·3	+0·3	+0·6	+0·5	+0·6	+0·7	+1·1	+0·9	30·5—12·4
−0·1	+0·2	+1·2	+1·6	+1·9	+1·9	+2·5	+2·6	+2·6	+2·0	+2·0	+2·0	12·4— 1·2
and Nights												
−0·5	−0·4	−0·3	−0·3	−0·4	−0·4	−0·4	−0·5	−0·4	−0·3	−0·3	−0·3	87·7—57·4
−0·3	−0·3	−0·3	−0·3	−0·2	−0·3	−0·3	−0·3	−0·2	−0·2	−0·2	−0·1	57·4—30·5
−0·2	−0·2	−0·2	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1	30·5—12·4
−0·1	−0·1	0·0	+0·1	+0·1	+0·1	+0·1	+0·1	0·0	+0·1	+0·2	0·0	12·4— 1·2

overcast days in June.

SECOND CORRESPONDING TO THE OCCASIONS SHOWN IN TABLE III

1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	Hour / No. of Days.
4·4	4·4	4·3	4·3	4·2	3·2	2·6	2·2	2·6	2·3	2·3	2·3	7
5·2	4·8	4·5	4·0	3·3	3·2	2·9	3·3	3·5	4·1	3·5	4·1	4
3·7	4·0	3·7	3·6	3·8	4·1	4·1	4·6	3·9	3·5	3·2	3·3	10

height seem to be dependent not so much on the heating of the ground, as on the past history of the air. Thus, the majority of the extremes in question occurred with northerly winds, which normally produce a steep lapse rate owing to the warming of the lowest layers of the air by contact with the ground, which becomes progressively warmer as the latitude decreases.

Turning now to the wind velocity at times of maximum lapse rate, it is at once apparent that a calm is by no means necessary for the formation of the latter. In fact, at times of maximum lapse over the lowest height interval, the average wind velocity is about 5m./sec. Over the other height intervals moderately strong winds are also the rule, and velocities of even more than 10m/sec. are sometimes found at times of maximum lapse over the height interval 57m. to 88m. This result will be discussed further in Part III.

(b) *Maximum Inversions.*—During the five years, the greatest hourly inversions were +10·0° F. between 1·2m. and 12m., and +8·8° F. between 57m. and 88m. Both these very large inversions were recorded in March, 1929.

TABLE V—MAXIMUM HOURLY VALUES OF TEMPERATURE LAPSE IN EACH MONTH

Month	1926					1927					1928					1929					1930				
	Day	Max. Lapse	G.M.T. of Occurrence	Sky	Wind	Day	Max. Lapse	G.M.T. of Occurrence	Sky	Wind	Day	Max. Lapse	G.M.T. of Occurrence	Sky	Wind	Day	Max. Lapse	G.M.T. of Occurrence	Sky	Wind	Day	Max. Lapse	G.M.T. of Occurrence	Sky	Wind
		° F.			m./sec.		° F.			m./sec.		° F.			m./sec		° F			m./sec.		° F.			m./sec.
Over the Height Interval 1.2m. to 12.4m.																									
Jan.	12	−1·2	1200	bm$_o$	..	15	−1·7	1300	bc	3·2	..	..	..	..	..	25	−0·8	1100 1200	bc b	5·0 4·5	21	−0·8	1300	bc	2·7
Feb.	28	−1·8	1200	b	4·3	..	..	..	..	..	28	−1·8	1100	b	6·1	12	−2·2	1300	b	6·6	19 28	−1·5	1300 1200	bc c	5·2 5·8
Mar.	22	−3·5	1300	bc	10·5	..	..	..	..	..	10	−2·5	1100	bc	7·2	23	−2·3	1100	bc	5·3	24 30	−2·6	1100 1200	bc bc	8·7 7·1
Apr.	12	−3·4	1100	bc	4·6	17	−3·1	1300	b	4·0	24	−3·1	1200	b	10·0	24	−3·1	1000	b	7·1	23	−2·0	1200	b	9·8
May	4	−3·5	1100	bc	5·4	20	−4·1	1200	bc	5·0	19	−3·1	1000	bc	4·3	30	−2·9	1300 1400	bc bc	7·0 7·0	28	−2·8	1400	bc	6·8
June	20	−2·9	1100	c	4·7	3 4	−4·2	1400 1000	bc bc	5·0 2·8	24	−3·4	1200	b	5·0	29	−3·4	1100	bc	4·9	16	−2·3	1200	bc	4·5
July	8	−3·0	1000	bc	c	25	−4·0	1400	t	5·1	24	−3·2	1300	bc	8·3	11	−3·3	1200	bc	5·5	11	−2·7	1300	bc	7·7
Aug.	23 25	−3·0	1300 1200	c bc	5·5 5·9	3	−3·4	1200	bc	c	11	−2·9	1400	bc	4·0	10	−3·0	1100	bc	2·2	19	−2·3	1000	bc	7·0
Sept.	10 14	−3·0	1100 1300	bc bc	3·3 5·7	2 26	−2·3	1000 1200	bc bc	3·3 5·3	18	−2·5	1000 1300	bc bc	4·0 4·2	19	−3·2	1200	bc	4·3	4	−1·7	1200	c	5·5
Oct.	2	−2·9	1100	bc	c	18	−2·4	1200	bc	5·8	3	−1·8	1100 1200	b b	4·5 4·0	1	−1·9	1100	bc	2·4	12	−1·9	1200	bc	7·0
Nov.	24	−2·0	1300	b	c	6	−1·6	1200 1300	bc bc	5·8 5·1	3	−1·3	1100	bc	4·2	10	−1·0	1200 1300	bc bc	8·7 9·0	10	−1·1	1200	bc	8·2
Dec.	11	−1·2	1200	bc	3·1	19	−1·0	1100	b	5·8	17	−0·7	1200	bc	5·9	2	−0·6	1300	bc	5·3	6	−0·6	1200	om	2·9
Over the Height Interval 12.4m. to 30.5m.																									
Jan.	13	−0·7	1400	b	7·5	15	−0·9	1300	bc	3·2	27	−0·5	1100	bc	8·6	28	−1·0	1400 1500	c c	2·9 3·3	29	−0·6	1400	c	c
Feb.	13	−1·2	1300	b	3·5	..	..	..	..	..	24	−0·5	1400	bc	3·9	14 15	−0·8	1000 1100	bc bc	c c	5 16	−1·0	1300 1000	c b	7·3 6·3
Mar.	27	−1·3	1500	bc	5·5	..	..	..	..	..	9	−1·0	1500	bcps	6·3	5 17	−1·3	1100 1500	b b	4·7 c	12	−1·2	1000	b	c
Apr.	24	−1·8	1100	bc	5·2	30	−1·3	1100	b	2·8	29	−1·0	1000	c	7·7	2	−1·0	1300	b	8·0	6	−1·3	1000	bc	7·2
May	4	−1·8	1100	bc	5·4	28	−1·4	0800 0900	b bc	4·5 3·4	18	−1·0	1400	bc	9·6	12	−1·2	1000	c	3·6	8	−1·0	0900 1100	bc bc	7·5 7·0
June	3	−1·4	1300	bc	5·1	14	−1·3	1200	bc	5·7	2	−0·6	1300	b	8·9	25	−1·2	0800	b	4·3	29	−1·2	1000 1300	b bc	4·7 5·5
July	4	−1·7	0900	bc	5·8	27	−1·2	1400	bc	4·8	17 18	−0·7	0800 1200	bc bc	c 7·2	5	−1·1	1300	cjp	12·0	5 11	−1·5	0800 1300	b bc	c 7·7
Aug.	27	−1·6	1000	b	3·0	31	−0·8	1200	bc	3·4	28	−1·0	1300	bc	6·8	18	−1·0	1500	cp	5·2	17	−1·0	1000	t	4·6
Sept.	30	−1·5	0900 1100	c c	c c	7	−1·0	1100 1300	bc bc	4·0 6·7	30	−0·9	0800	b	5·8	14 25	−0·9	1000 1100	t t	c 2·1	15	−1·1	1000	b	6·4
Oct.	18	−1·3	1300	b	6·0	3	−1·2	1400	b	c	1 13	−0·9	1000 1100	b bc	3·4 5·1	26 27	−1·0	1000 1200	b b	5·9 5·2	9	−1·0	1200	bc	6·0
Nov.	7	−1·1	1200	bc	5·0	6	−0·9	1400 1500	bc bc	4·5 3·8	9	−0·9	1100	b	3·9	1	−1·0	1200	bc	2·9	8	−0·7	1100	bc	5·3
Dec.	10	−0·7	1100	bc	5·5	19	−0·6	1100	b	5·8	14	−0·9	1500	b	2·0	16	−0·8	1200	b	2·0	20	−0·2	1200	bc	4·3

TABLE V—(*continued*)

Month	1926 Day	1926 Max. Lapse	1926 G.M.T. of Occurrence	1926 Sky	1926 Wind	1927 Day	1927 Max. Lapse	1927 G.M.T. of Occurrence	1927 Sky	1927 Wind	1928 Day	1928 Max. Lapse	1928 G.M.T. of Occurrence	1928 Sky	1928 Wind	1929 Day	1929 Max. Lapse	1929 G.M.T. of Occurrence	1929 Sky	1929 Wind	1930 Day	1930 Max. Lapse	1930 G.M.T. of Occurrence	1930 Sky	1930 Wind
		° F.			m./sec.		° F.			m./sec.		° F.			m./sec.		° F.			m./sec.		° F.			m./sec.
Over the Height Interval 30.5m. to 57.4m.																									
Jan.	12	—1·4	1200	bm_o	..	31	—1·1	1200 1300	bc bc	6·3 6·9	4	—1·0	1700	c	10·4	25	—1·0	1400	bc	5·9	25 29	—0·5	1300 1500	b bc	3·7 c
Feb.	15	—0·7	1400	bc	8·0	..	..	..	..	..	24	—1·4	1600	bc	5·7	10	—0·7	1300 1400	bc bc	10·2 10·3	16 17	—1·0	1100 1000	b b	6·2 3·9
Mar.	20 22	—1·8	1000 1100	bc bc	6·9 9·9	..	..	..	..	..	14	—0·9	1100	bc	2·7	11	—1·3	1500	b	3·6	12	—1·4	1000	b	c
Apr.	30	—1·3	1500	c	2·7	21	—1·5	1200 1300	bc c	11·3 10·2	27	—1·4	1400 1500	c c	8·1 8·3	2	—1·1	1300	b	8·0	6 17	—1·0	1000 1400	bc cp	7·2 9·2
May	23	—1·5	0900	c	c	8	—2·0	1200	b	6·5	2	—1·2	1300	c	3·0	9	—1·1	0900	t	3·3	8	—1·1	1000 1100	bc bc	7·9 7·0
June	21	—1·5	1300	bc	6·2	24	—1·2	1400	bcp	10·4	1	—1·1	1200	c	6·8	25	—1·2	0800	b	4·3	2	—1·0	1200 1300	bc bc	3·2 4·7
July	9	—1·3	1500	bc	7·8	25	—1·0	1500	b	5·4	..	..	..	..	..	8 12	—1·2	0700 1200	b bc	2·3 3·7	31	—1·2	0800	b	3·4
Aug.	9	—1·0	1400	bc	4·5	23	—0·9	1200	bc	7·1	5	—1·0	1700	b	c	2	—1·1	1500	bc	4·1	30 31	—1·2	1000 1300	b c	4·5 5·5
Sept.	25	—1·2	1500	bc	6·3	15	—1·3	1300	c	5·3	..	..	..	..	..	14	—1·1	0900	b	3·2	15	—1·2	1000	b	6·4
Oct.	23	—1·9	1100	bc	7·4	4	—1·2	1500	bc	c	1	—1·5	1000	b	3·4	27	—1·0	1000 1100	t t	5·1 4·9	9	—1·2	1200	bc	6·0
Nov.	24	—1·1	1300	t	c	4 6	—1·1	1400 1200	bc bc	6·0 5·8	2	—0·8	1100 1300	bc bc	6·7 6·7	13	—1·1	1200	b	4·7	4	—1·0	1100	bc	6·0
Dec.	16 18	—1·0	1200 1100	bc c	5·2 10·6	12	—0·8	1200	o	5·5	5 8	—1·1	1400 1200	b b	4·9 4·3	16	—0·9	1200	b	2·0	21	—0·9	1300	b	6·0
Over the Height Interval 57.4m. to 87.7m.																									
Jan.	13	—0·6	1300	b	6·9	27	—1·3	1200	c	14·8	17	—0·7	1300	b	4·7	11	—0·8	1200	c	5·7	3	—0·8	1600	bc	4·5
Feb.	13	—0·8	1300	bc	3·5	..	..	..	..	..	19	—1·1	1500	bc	..	17	—0·7	1500	b	c	28	—1·0	1300	c	4·0
Mar.	3	—1·1	1500	bc	12·5	..	..	..	..	..	9	—1·0	1200	c	7·2	17	—0·9	1400	b	c	1	—0·8	1300	b	6·8
Apr.	13	—1·8	1200	b	c	8 27	—1·3	1000 0900	bc bc	5·3 5·8	4	—1·1	1100	bc	5·0	15	—0·8	1200	bc	6·3	27	—0·9	1300	b	11·2
May	30	—1·2	1100	cph	6·0	13 18	—1·2	1100 1300	bc bc	2·8 c	6	—1·2	1100	b	3·8	28	—0·9	1300	t	7·8	23	—0·9	1300	bc	8·8
June	4 7	—1·2	1300 1100	bc b	3·0 3·5	28	—1·9	1100	bc	3·0	3	—0·8	1100	bc	5·7	2	—0·8	1300	bc	8·3	17	—0·9	1300	c	c
July	14	—1·3	1600	bc	3·0	27	—1·8	1100	cp	8·2	17	—1·1	1500	b	c	13	—0·9	1200 1300	b t	2·0 c	2	—0·9	1800	c	7·8
Aug.	.	..	..	..	..	3	—1·3	1200	bc	c	2	—1·1	1400	bc	2·5	18	—0·9	1400	cp	5·2	10	—0·6	1100 1200	bc bc	6·0 5·8
Sept.	10	—1·2	1400	bc	5·7	19	—1·3	1400	c	7·5	26	—1·6	1200	bc	3·8	2	—1·2	1200	b	c	20	—0·7	1300	bc	2·5
Oct.	13	—1·1	0900	b	10·3	2	—1·2	1000 1200	od od	8·4 11·8	17	—1·1	1300	c	4·8	16	—0·9	1200	b	6·3	8	—0·8	1200	cp	13·1
Nov.	17	—0·8	1500	or	3·9	6	—0·8	1400	bc	4·5	3	—0·8	1100 1200	bc bc	4·2 3·7	1	—1·0	1000	b	c	22	—0·7	1300	bc	9·5
Dec.	25	—0·8	1400	cr_c	8·8	2	—1·4	1200	b	3·8	11	—0·8	1300	b	3·3	8	—0·8	1700	bcp	10·6	1 2	—0·5	2400 1200	o bc	2·7 7·0

TABLE VI—EXTREME HOURLY VALUES OF TEMPERATURE INVERSION IN EACH MONTH

Month	1926				1927				1928				1929				1930			
	Maximum Inversion	G.M.T. of Occurrence	Sky	Wind	Maximum Inversion	G.M.T. of Occurrence	Sky	Wind	Maximum Inversion	G.M.T. of Occurrence	Sky	Wind	Maximum Inversion	G.M.T. of Occurrence	Sky	Wind	Maximum Inversion	G.M.T. of Occurrence	Sky	Wind
	° F.			m./sec.	° F.			m./sec.	° F.			m./sec.	° F.			m./sec.	° F.			m./sec.
Over the Height Interval 1.2m. to 12.4m.																				
Jan.	5·0	1900 0400	b bc	c ..	4·7	0100	bf	c	..	..	..	..	4·4	0100	bf	c	3·8	2100	b	3·0
Feb.	5·0	2200	bc	3·5	..	..	..	..	4·6	0100	b	..	4·7	2300	b	2·7	3·4	0300	bcf	3·1
Mar.	5·3	2400	b	c	..	..	..	..	4·2	1900	bc	3·2	10·1	1900	b	2·9	4·6	0400	bc	c
Apr.	6·1	0600	b	c	6·5	0200	bc	2·0	5·5	2100	b	2·8	3·9	2400 0100	bc bc	2·7 3·0	6·2	2400	b	4·0
May	4·0	2100 0400	bc bcF	3·0 c	4·3	0400	b	c	5·6	0300	b	c	8·5	2200	b	c	5·2	0200 0300	b b	c c
June	5·3	0100	b	c	3·6	2400	b	2·3	7·4	0400	bc	c	6·2	2100	b	2·3	5·7	0400	b	c
July	6·6	0400	bc	c	4·4	0100	b	c	8·2	0400	b	c	7·2	2400	b	c	5·5	0200	b	c
Aug.	6·4	2200	b	..	5·2	2300	b	c	6·1	2400	bc	c	5·1	2400	b	c	4·6	0100	b	c
Sept.	5·5	2000	b	3·7	5·7	0400	b	c	7·5	0500	bf	2·3	7·2	0600	b	2·0	5·4	2400	b	2·2
Oct.	5·8	0400	b	2·1	7·0	0500	bcm	c	5·4	0300 0400	b b	2·9 2·2	6·6	0200	b	c	5·7	0200	b	2·0
Nov.	6·6	0400	bF	c	5·0	2000 2400	b b	c c	4·7	2200	b	c	7·7	0600	bf	c	6·3	0800	b	c
Dec.	4·1	0400	bf	c	3·2	2100	cf	c	4·6	0100	b	2·5	4·6	1800	b	2·5	4·5	0500	bc	c
Over the Height Interval 12.4m. to 30.5m.																				
Jan.	3·4	0700	bF	..	4·2	1900	bcFF	3·7	2·3	0300	cf	c	3·1	1000	b	4·1	4·6	0800	bcFF	c
Feb.	2·5	0600	bc	..	..	..	..	..	5·0	0500	bc	3·3	3·6	0600	cff	c	1·9	2200	bc	3·6
Mar.	4·2	0200	cf	2·7	..	..	..	..	3·3	0400	bf	..	8·7	0700	b	2·8	2·6	0800	cF	2·0
Apr.	3·9	0400	b	c	3·2	0300	bc	c	3·1	0500	bf	c	3·2	0400	b	4·2	3·6	0800	bf	c
May	3·9	0600	bcF	c	2·0	0100	b	3·2	3·6	0600	b	3·2	3·3	0400	b	3·8	3·8	0200	bc	c
June	3·4	0400	b	c	2·4	0500	b	c	3·8	0500	bc	c	3·6	0400	b	c	3·3	0200	bc	2·0
July	4·0	0300	bc	c	2·6	2400 0300	b bc	c 2·1	4·8	0400	b	2·9	4·4	0100	b	2·3	1·9	2100	b	4·1
Aug.	3·2	0500	b	c	2·6	0300 0400	bc b	2·4 c	2·6	0500	bc	2·5	3·0	0400	b	c	2·5	0400	b	3·8
Sept.	2·9	0300	bc	c	5·3	0500	bF	2·7	4·7	0600	bf	2·1	4·2	0500	b	c	3·7	2400	b	c
Oct.	3·5	0800	b	c	3·7	0900	bF	2·8	2·7	0200	b	c	4·1	0500	bc	2·0	2·7	2100 0500	off bc	2·7 3·2
Nov.	6·1	0500	bF	c	4·5	0900	bcf	..	6·1	0100	bf	2·1	4·0	0400	bf	c	4·3	2200 0200	bF bF	3·0 3·1
Dec.	2·7	0500	bf	c	3·2	0400	bc	c	5·4	1600	bcif	c	2·8	0500	bc	2·2	9·2	0900	bF	c

TABLE VI—(*continued*)

Month	1926 Maximum Inversion	1926 G.M.T. of Occurrence	1926 Sky	1926 Wind	1927 Maximum Inversion	1927 G.M.T. of Occurrence	1927 Sky	1927 Wind	1928 Maximum Inversion	1928 G.M.T. of Occurrence	1928 Sky	1928 Wind	1929 Maximum Inversion	1929 G.M.T. of Occurrence	1929 Sky	1929 Wind	1930 Maximum Inversion	1930 G.M.T. of Occurrence	1930 Sky	1930 Wind
	° F.			m./sec.	° F.			m./sec.	° F.			m./sec.	° F.			m./sec.	° F.			m./sec.
Over the Height Interval 30.5m. to 57.4m.																				
Jan.	5·9	0600	bF	..	5·3	0900	bcF	3·4	2·4	2000	bf	5·3	6·5	0900	bFF	3·1	4·5	0900	bcFF	c
Feb.	2·2	0800	c	..	..	..	..	..	4·1	0700	bc	3·7	4·9	2300	bcf	3·0	2·8	2300	bcf	c
Mar.	6·9	2400	b	2·1	..	..	..	..	2·3	0700	bcFF	..	10·2	0100 0700	b bcF	2·5 5·0	3·3	0800	cF	2·0
Apr.	4·4	0400	bff	3·6	2·3	0600	b	c	2·7	0100	b	c	4·8	0500	bFF	c	2·1	0400	bc	5·1
May	3·1	0500	bc	c	2·8	0700	bc	c	2·6	0600	bF	c	4·2	0300	bc	c	3·4	0400	bc	2·3
June	3·2	0300 0600	b b	c c	1·8	0500	bc	..	2·9	0600	bc	c	2·4	0100	b	2·0	2·5	2400	bc	2·0
July	3·5	0600	b	c	2·4	0400	bcF	2·0	..	..	..	..	3·3	0500	bc	2·6	1·3	0400	b	2·2
Aug.	..	..	..	..	3·1	0400	bc	2·0	..	..	..	..	2·4	0300 0400	bc b	2·1 c	2·1	0100	cf	2·8
Sept.	2·5	0500	bc	3·9	2·4	0700	bcf	..	..	..	..	..	2·7	0800	b	2·7	4·5	0300	b	2·2
Oct.	3·0	0200	b	2·1	6·4	1000	bF	..	2·6	0500	bc	5·0	3·6	0300	bcF	2·5	2·7	0500	b	4·0
Nov.	3·4	0600	b	5·0	5·1	0700	bcF	..	7·9	0200	bf	2·8	3·1	1000	bf	3·2	3·1	0800	b	3·3
Dec.	4·0	0800	bf	4·1	2·0	0400	bcf	c	4·9	2000	oF	2·0	4·3	2400	bcff	c	8·0	1000	bF	2·0
Over the Height Interval 57.4m. to 87.7m.																				
Jan.	3·2	2400	b	c	5·3	1000	bcF	3·7	3·2	0700	bf	..	2·5	1500	off	2·7	4·4	1100	bcFF	2·3
Feb.	2·5	0900	bf	2·8	..	..	..	..	3·0	0800	b	6·0	3·8	2400	b	2·8	3·6	2400	bcf	2·7
Mar.	4·1	0800	bc	..	..	..	..	..	3·2	0800	cf	..	8·8	0500	bF	3·7	2·4	0900	cF	3·8
Apr.	5·5	0600	bff	3·2	1·8	0100	b	2·5	4·1	0600	bf	2·9	5·5	0400	bFF	c	1·0	0400	bc	5·1
May	..	..	..	..	3·8	0500	bc	3·2	2·8	0500	b	3·3	5·2	0700	b	3·3	3·6	0800	cFF	2·9
June	..	..	..	..	1·4	0500	bc	c	2·0	0400	b	c	3·3	0300	bcf	c	2·4	0400	bf	c
July	..	..	..	..	1·7	0200	bc	3·0	6·4	0300	b	3·6	2·4	0400	b	c	1·3	0300	bc	3·7
Aug.	..	..	..	..	3·7	0600	bf	..	2·3	0600	bc	4·4	6·2	0500	off	2·0	2·8	2400	b	c
Sept.	2·1	0800	bcf	c	3·2	2400	bf	3·1	4·0	0700	bF	3·2	2·9	0800	bf	3·5	1·7	0100 0200	b b	3·8 3·5
Oct.	2·6	0600	b	3·5	6·5	0800	bF	2·8	2·1	0500	b	2·0	2·9	0600	bcFF	2·9	2·8	0500 0600	bff bff	3·0 3·0
Nov.	3·6	0500	b	..	7·8	2100	bcf	..	6·6	0300	bf	3·2	5·9	1200	oFF	3·0	3·3	0700	bF	4·2
Dec.	3·9	1100	bc	3·8	2·6	0900	cf	2·7	6·3	1600	oFF	2·0	2·4	0200	bm	3·4	3·7	1700 0400	bcF bf	3·7 4·9

Extreme inversions occur at all times of the night near the ground, whilst over the upper height intervals they usually occur after midnight and sometimes quite late in the morning. This is due to the time taken by the inversion to grow upwards to the level of the highest thermometer element, as already mentioned.

The sky is almost invariably clear or only partially clouded at times of maximum inversion over the height interval 1·2m. to 12m. Over the upper three height intervals extreme inversions often occur during fog ; no less than 33 of the 57 values for the interval 57m. to 88m. were occasions of fog. Radiation fogs are frequently less than 88m. in depth, and usually have a very large inversion just above the level of their upper surface (3) ; these are the inversions which appear as extremes in Table V. Actually, over the three upper height intervals, the greatest inversion in any one year was almost always a fog inversion. On many occasions the maximum inversions occurred with fogs which had persisted well into the morning.

The wind velocity at times of maximum inversion is invariably small ; a moderate or strong wind destroys a large inversion, though it is not necessarily fatal to a large lapse. It appears, however, that the fogs which so often give rise to extreme inversions over the upper height intervals are not usually accompanied by dead calms. In order that a fog may develop up to this height, a slight breeze is essential to produce the necessary mixing of the air (4). The majority of deep radiation fogs occurring at Leafield have been found to be accompanied by winds of more than 2m./sec. velocity.

§ 13—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES

The hourly values of temperature difference over the height intervals 1·2m. to 12m. and 57m. to 88m. during the five years 1926-30 have been analysed to show the frequency of occurrence of temperature differences of various magnitudes. Table VII shows the monthly frequencies of temperature differences between stated limits, expressed as percentages of the total number of hourly readings.

For the interval 1·2m. to 12m. it will be seen that the maximum frequency lies between the values 0·0° F. and +0·9° F. in winter, while in midsummer the maximum lies between —0·1° F. and —1·0° F. This may be compared with the mean monthly curves given in Fig. 10, which show that the average condition near the ground is an inversion except at midsummer. Whilst large lapses are, of course, most frequent in midsummer, large inversions may occur at any time of year. No

TABLE VIIA—PERCENTAGE FREQUENCY OF OCCURRENCE OF TEMPERATURE DIFFERENCES (°F) OF VARIOUS VALUES BETWEEN HEIGHTS OF 1.2M. AND 12·4M.

Month	Lapses					Inversions									
	−4·1 to −5·0	−3·1 to −4·0	−2·1 to −3·0	−1·1 to −2·0	−0·1 to −1·0	0·9 to 0·0	1·9 to 1·0	2·9 to 2·0	3·9 to 3·0	4·9 to 4·0	5·9 to 5·0	6·9 to 6·0	7·9 to 7·0	8·9 to 8·0	9·9 to 9·0
Jan.	..	..	..	0·6	22·3	*61·7*	10·5	3·3	1·2	0·4	0·1	..	..	..	..
Feb.	..	..	..	2·1	29·0	*52·8*	9·5	4·5	1·5	0·6	..	..	..	..	..
Mar.	..	0·1	1·1	8·2	29·0	*36·8*	10·2	6·4	3·7	2·3	1·2	0·3	0·4	0·2	0·1
Apr.	..	0·2	3·9	11·5	*33·8*	32·1	9·8	4·7	3·1	0·6	0·2	0·1	..	..	..
May	0·1	0·5	4·3	14·3	*34·2*	26·7	9·0	5·8	3·7	0·9	0·4	0·1	..	..	..
June	0·1	1·2	6·2	17·3	*33·2*	24·8	6·9	4·3	3·4	2·0	0·5	0·1	..	..	..
July	..	0·3	4·9	15·3	*32·3*	28·4	8·7	5·4	2·6	1·3	0·6	0·1	..	..	..
Aug.	..	0·1	3·2	14·0	28·8	*33·4*	10·0	5·1	3·3	1·5	0·5	0·1	..	..	..
Sept.	..	0·1	2·1	10·4	30·0	*32·0*	9·9	6·6	5·1	2·3	1·2	0·2	0·1	..	..
Oct.	..	..	0·3	3·7	26·6	*46·1*	12·4	5·7	3·0	1·4	0·7	0·1	..	..	..
Nov.	..	..	..	0·7	21·3	*56·3*	12·1	5·0	3·0	1·1	0·2	0·2	0·1	..	..
Dec.	..	..	..	0·1	22·7	*57·1*	12·4	5·4	1·9	0·4	..	..	..	..	..
Year	..	0·2	2·2	8·2	28·6	40·7	10·1	5·2	3·0	1·2	0·5	0·1	..	..	..

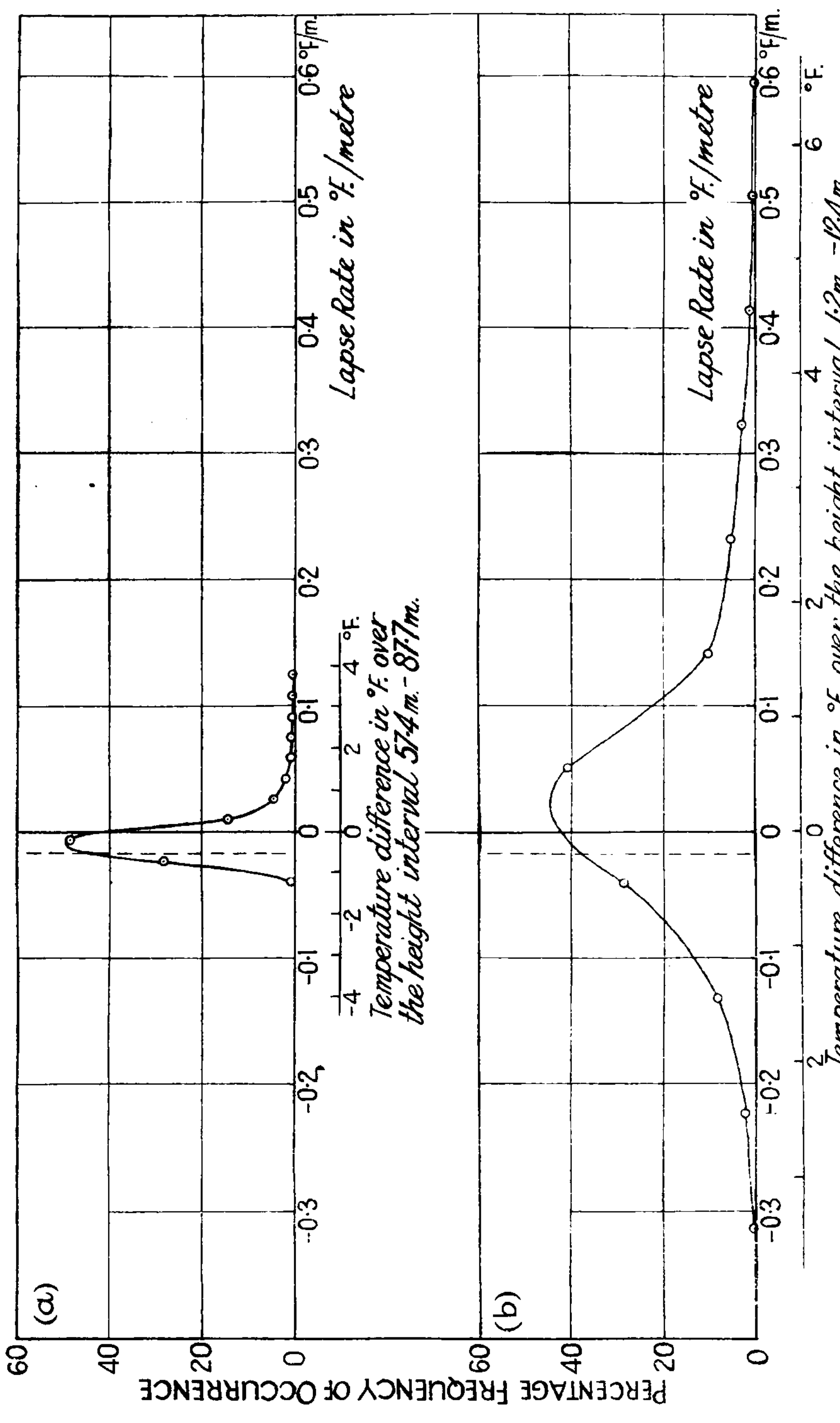
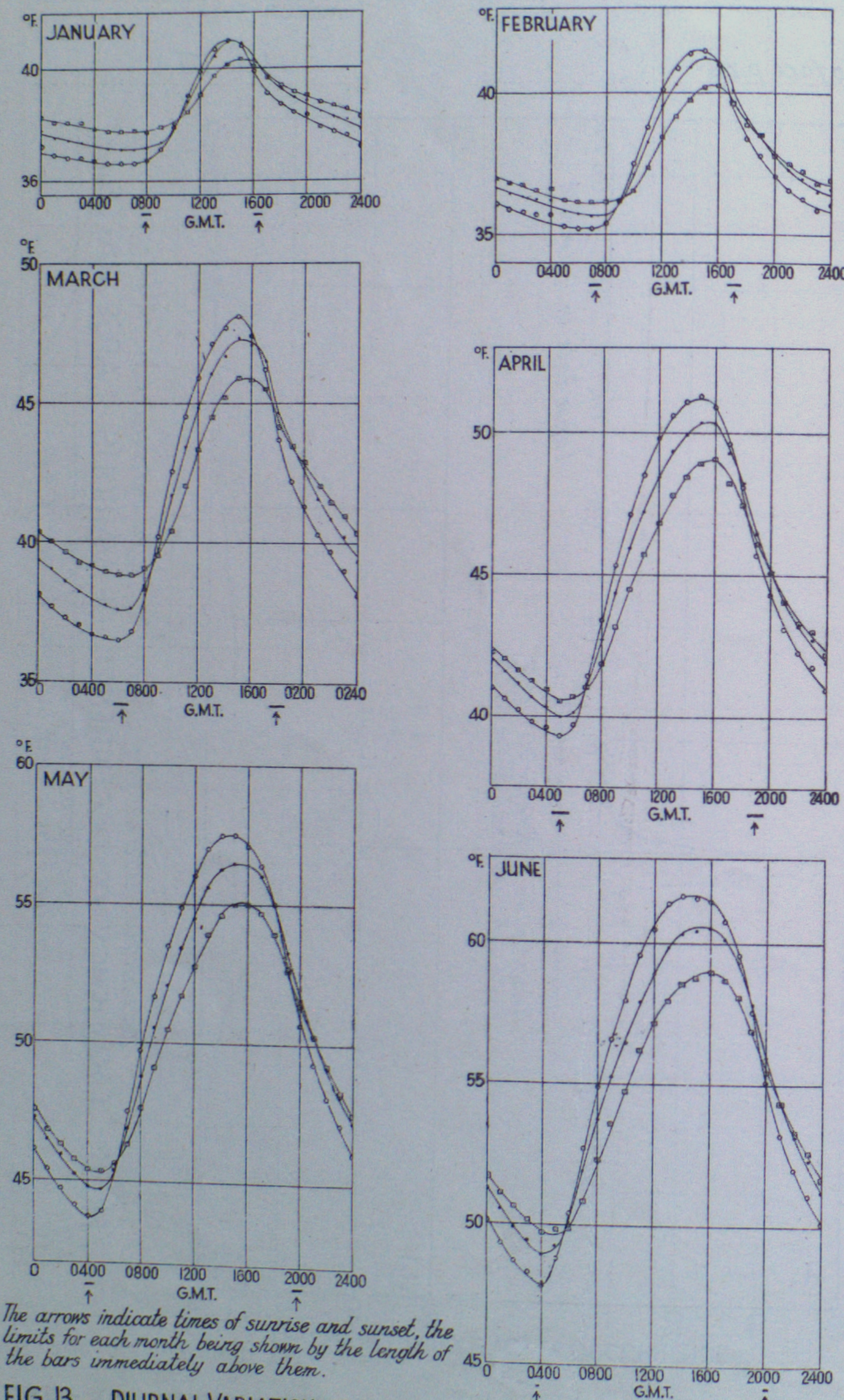


FIG. 12 FREQUENCY OF OCCURRENCE OF VARIOUS LAPSE RATES

(a) Over the height interval 57·4 m - 87·7 m

(b) Over the height interval 1·2 m - 12·4 m



The arrows indicate times of sunrise and sunset, the limits for each month being shown by the length of the bars immediately above them.

FIG. 13. DIURNAL VARIATION OF TEMPERATURE AT THREE HEIGHTS, JAN.-JUNE

Temperature at height of { 1·2 m. = ○——○; 30·5 m. = ●——●; 84·7 m. = □——□ }

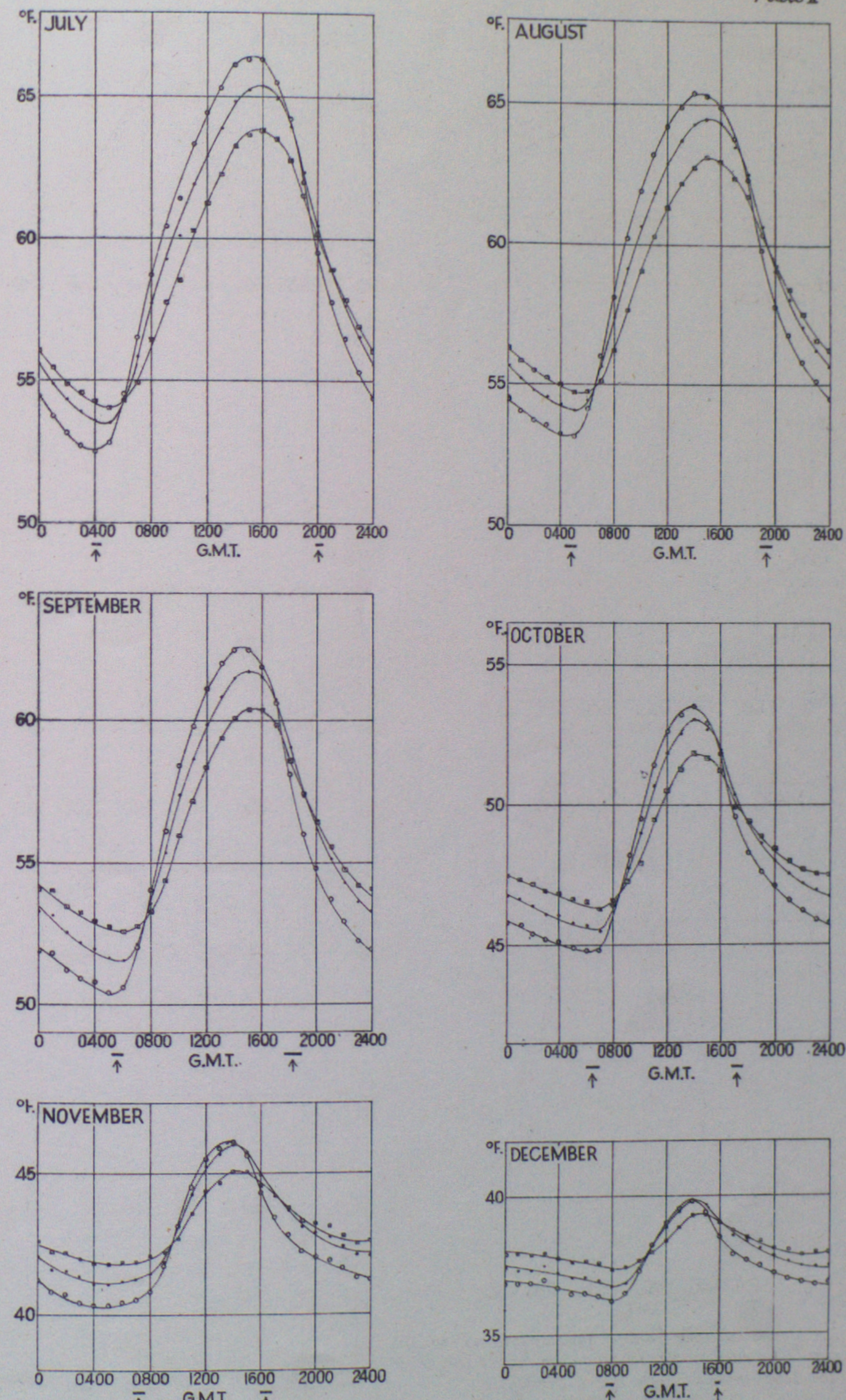


FIG. 13. DIURNAL VARIATION OF TEMPERATURE AT THREE HEIGHTS, JULY – DEC.

The arrows indicate times of sunrise and sunset, the limits for each month being shown by the length of the bars immediately above them.

Temperature at height of 1·2m. ○——○ ; 30·5m. ●——● ; 84·7m. ▫——▫

TABLE VIIB—PERCENTAGE FREQUENCY OF OCCURRENCE OF TEMPERATURE DIFFERENCES (°F.) OF VARIOUS VALUES BETWEEN HEIGHTS OF 57·4M. AND 87·7M.

Month	Lapses				Inversions												
	−1·5 to −1·9	−1·0 to −1·4	−0·5 to −0·9	0·0 to −0·4	0·5 to 0·1	1·0 to 0·6	1·5 to 1·1	2·0 to 1·6	2·5 to 2·1	3·0 to 2·6	3·5 to 3·1	4·0 to 3·6	5·0 to 4·1	6·0 to 5·1	7·0 to 6·1	8·0 to 7·1	9·0 to 8·1
Jan.	..	0·7	13·4	*51·1*	23·7	6·5	2·2	1·2	0·6	0·4	0·1	..	0·1	..	..	..	..
Feb.	..	..	18·6	*57·0*	16·8	4·6	1·9	0·6	0·3	0·1	..	0·1	..	..	..	..	..
Mar.	..	0·1	34·9	*42·1*	13·0	4·9	2·1	1·2	0·7	0·5	0·2	0·2	0·1	..	..	..	..
Apr.	..	0·9	31·9	*46·7*	13·6	4·3	1·4	0·8	0·1	..	0·1	..	0·1	0·1	..	..	..
May	..	0·9	*43·3*	42·4	8·2	3·0	1·2	0·6	0·2	0·1	..	0·1	..	..	..	..	..
June	0·3	2·4	*48·2*	36·0	9·1	2·6	0·8	0·5	0·1	..	..	..	..	..	..	..	..
July	0·1	1·3	40·3	*44·6*	9·1	2·5	1·4	0·3	0·2	0·2	..	..	..	..	..	..	..
Aug.	..	1·5	23·2	*56·6*	13·1	3·8	1·2	0·4	0·1	0·1	..	..	..	..	..	..	..
Sept.	..	1·5	29·8	*46·0*	13·4	5·2	2·4	1·1	0·3	0·2	0·1	..	..	..	..	..	..
Oct.	..	0·2	25·8	*50·5*	15·3	5·0	1·6	0·7	0·4	0·2	0·1	0·1	..	0·1	..	..	..
Nov.	..	..	13·8	*56·4*	18·5	5·6	3·0	1·3	0·6	0·4	0·2	..	0·1	..	0·1	..	..
Dec.	..	0·4	13·8	*54·8*	17·8	7·1	3·0	1·3	0·7	0·4	0·3	0·1	0·1	0·1	0·1	..	..
Year	..	0·8	28·1	48·7	14·3	4·6	1·9	0·8	0·4	0·2	0·1	0·1	..	..	..	..	..

lapses of over —5·0° F. were observed, whereas inversions of over +5·0° F. form an appreciable percentage of the total.

Over the interval 57m. to 88m. the maximum frequency lies between 0·0° F. and —0·9° F. at all times of the year, although a slight shift of the maximum towards greater lapse is discernible in midsummer. In all months the total range of temperature differences is much smaller at the upper height interval than at the lower.

The average frequencies for the year over each height interval are given in Table VII, and are plotted in Fig. 12. The limits of temperature difference were divided by the height interval in question, so that both curves could be plotted on the same temperature scale of degrees Fahrenheit per metre. These curves emphasise how very large is the range of temperature gradient near the ground compared with that higher up. The peak of the curve for the lower height interval corresponds with a slight inversion ; for the upper height interval the peak occurs at about two-thirds of the dry adiabatic value. As the average lapse rate in the free atmosphere is also about two-thirds of the adiabatic, it would appear that the peak of the curve does not change its position with further increase in height. Reference to the frequency table for the height interval 1·2m. to 12m. will show that about 69 per cent. of all the readings fall within 1·0° F on either side of the isothermal line. Of the remaining readings, 11 per cent. are lapses and 20 per cent. are inversions. For the upper height interval about 96 per cent. of the readings fall within 1·0° F. of the isothermal line.

§ 14—MEAN DIURNAL TEMPERATURE VARIATION AT THREE HEIGHTS

(a) *Five-year Means.*—Up to this point the results obtained from the temperature gradient recorder have been presented as differences in temperature between stated heights, which is the manner in which the results are given on the charts of the recording instrument. Curves showing the actual temperatures at various heights are also instructive. Such curves have been constructed by adding the values of the temperature differences over successive height intervals (Table I) to the records of the aspirated dry-bulb element at a height of 1·2m. as given in Table VIII. The dry-bulb charts were analysed in the same way as the differential temperature charts ; that is, the hourly values of temperature were taken as the mean value over a period of 20 minutes centred on the hour. In order to avoid overcrowding, curves showing the temperature at 1·2m., 12·4m. and 87·7m. only have been plotted in Fig. 13.

TABLE VIII—MEAN HOURLY VALUES OF AIR TEMPERATURE (°F.) AT A HEIGHT

Hour G.M.T. / Month	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200
January	36·9	36·8	36·8	36·7	36·6	36·6	36·6	36·7	37·1	37·9	39·0	39·9
February	35·9	35·8	35·7	35·7	35·3	35·2	35·2	35·4	36·2	37·5	38·8	40·1
March	37·7	37·3	37·0	36·7	36·6	36·5	36·8	38·3	40·2	42·5	44·5	45·9
April	40·6	40·2	39·8	39·6	39·3	39·7	41·4	43·4	45·3	47·1	48·5	49·8
May	45·4	44·7	44·1	43·7	43·9	45·5	47·5	49·7	51·7	53·5	54·9	56·0
June	49·3	48·7	48·3	47·8	48·8	50·4	52·7	54·9	56·6	58·0	59·6	60·5
July	53·7	53·1	52·7	52·5	52·8	54·5	56·5	58·7	60·4	61·4	63·3	64·4
August	54·0	53·7	53·5	53·2	53·1	54·1	56·0	58·1	60·2	61·9	63·2	64·2
September	51·8	51·2	50·9	50·8	50·4	50·6	52·0	54·0	56·1	58·4	59·8	61·1
October	45·7	45·4	45·2	45·1	44·9	44·8	44·8	46·4	48·2	49·6	51·4	52·6
November	40·8	40·7	40·4	40·3	40·3	40·4	40·5	40·8	41·7	43·1	44·5	45·5
December	36·9	36·9	37·0	36·7	36·5	36·5	36·4	36·2	36·5	37·3	38·2	39·0

During the early hours of the morning the rate of fall of temperature is very nearly equal at all heights. The minimum temperature at 1·2m. is reached at about the time of sunrise, and in all months the mean temperature at the two upper levels definitely begins to rise while there is still a considerable inversion below 12m.

It will be noticed that in midwinter the maximum temperature at 1·2m. is very little higher than that at 12m. In other words the middle day lapse between 1·2m. and 12m. is very small at this time of year; this fact has already been noted, and reasons for it have been suggested.

The diurnal ranges of temperature at different heights in summer and winter are given in Table XII. These will be discussed later.

The times of occurrence of maximum temperature at each height have been determined by the accurate plotting of the temperature observations on an open scale. The results for the months of June and December are shown in the upper part of Table XIV, together with the lag in the time of maximum over each interval of height. In June the time of maximum temperature at 1·2m. occurs at 1455, whilst at 87m. it does not take place until 85 minutes later. In December the maximum near the ground occurs nearly an hour earlier than in summer, and the lag at 87m. is then only 45 minutes. The winter lag is thus about half that of summer.

(b) *Means for Clear and Overcast Days.*—The temperatures at three heights have been plotted for clear and overcast days in the same way as the mean temperature curves just considered. The records of the aspirated dry-bulb element at 1·2m. were meaned for those days which were used in constructing Table III, and the results are given in Table IX. The addition of Table III to Table IX gives the mean hourly values of temperature at each height on clear days in June and clear and overcast days in December. The values for 1·2m., 12m. and 88m. have been plotted in Fig. 14.

TABLE IX—MEAN HOURLY VALUES OF AIR TEMPERATURE (°F.) AT A HEIGHT OF

Hour	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200
JUNE												
Clear	46·6	45·8	44·9	44·5	46·3	49·3	52·7	54·9	57·3	58·4	59·7	61·4
DECEMBER												
Clear	33·7	34·1	33·9	34·3	34·1	33·4	33·7	33·2	33·5	35·9	36·9	38·1
Overcast	39·4	39·2	39·2	39·1	39·1	39·3	39·2	39·2	39·2	39·4	39·5	39·8

On clear days in June the range of temperature at each height is very great (19·5° F. at 1·2m. and 12·6° F. at 88m.). The minimum temperature occurs roughly simultaneously at all heights very soon after sunrise.

OF 1·2M. FOR EACH MONTH (BASED UPON FIVE YEARS' RECORDS, 1926—30)

1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	Hour / Month
40·7	41·0	40·8	39·9	39·1	38·7	38·4	38·3	37·9	37·7	37·6	37·2	January
40·9	41·4	41·5	41·0	39·6	38·4	37·8	37·1	36·6	36·3	35·9	36·1	February
47·1	47·7	48·1	47·4	46·2	43·7	42·2	41·3	40·3	39·7	39·0	38·1	March
50·6	51·1	51·3	50·9	49·6	48·1	45·7	44·3	43·1	42·3	41·8	41·0	April
57·0	57·5	57·5	57·1	56·4	55·0	52·8	50·7	49·3	48·1	47·1	46·1	May
61·4	61·7	61·6	61·5	60·8	59·6	57·6	55·1	53·2	52·0	51·1	50·1	June
65·3	66·1	66·3	66·3	65·5	64·2	62·0	59·6	57·8	56·5	55·3	54·4	July
64·9	65·4	65·3	64·9	63·8	62·3	59·8	57·8	56·8	55·8	55·1	54·5	August
62·0	62·5	62·5	61·9	60·6	58·1	56·0	54·8	53·7	52·9	52·2	51·9	September
53·2	53·5	52·9	51·8	49·6	48·3	47·6	47·1	46·6	46·2	45·9	45·8	October
45·9	46·1	45·6	44·3	43·4	42·8	42·2	42·0	41·9	41·6	41·3	41·2	November
39·5	39·8	39·4	38·5	37·9	37·7	37·5	37·2	37·0	36·9	36·8	36·9	December

On clear days in December the morning minima again occur roughly simultaneously at about the time of sunrise. The maximum temperature at 12m. is very nearly as great as the maximum at 1·2m. The diurnal variation of temperature at 88m. is slight on a clear day in winter; in fact the total range of temperature at this height is only 1·7° F. as compared with a range of 5·7° F. at 1·2m.

The curves for overcast days in December show extremely little variation of temperature with time or with height.

Incidentally these curves show that on a clear day in June the temperature is appreciably higher (about 1·7° F.) at the end of the 24-hour period than at the beginning. On clear days in December, on the other hand, there is a net fall in temperature over the 24 hours.

The times of occurrence of maximum temperature on clear days in June and December have been carefully ascertained and they are shown in the lower part of Table XIV. On clear June days the maximum at 1·2m. occurs as late as 1545. At 87m. the lag is as much as 99 minutes, the maximum temperature not being reached until 1724. Compared with the mean June results, the difference consists primarily in an increase in the lag between 1·2m. and 30·5m. from 55 min. to 75 min. The results found for clear days in December are even more striking. The maximum temperature at 1·2m. now occurs as early as 1330, and the lag up to 87m. is 104 min. But whereas in summer the greater portion of the lag occurs between 1·2m. and 30·5m., it now takes place between 30·5m. and 87·7m.

The explanation of this result is to be found in the fact that with a clear sky in winter the nocturnal inversion near the ground persists until about 1030, and above 30m. it is not destroyed until about midday. The temperature wave which is

1·2M. FOR CLEAR DAYS IN JUNE AND CLEAR AND OVERCAST DAYS IN DECEMBER

1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	G.M.T.
												JUNE
62·4	63·3	63·7	64·0	63·0	62·1	59·8	55·5	52·7	50·5	49·6	48·3	Clear
												DECEMBER
38·9	38·8	37·2	35·7	34·2	33·8	32·5	32·3	31·8	31·8	31·4	31·9	Clear
40·0	40·1	39·9	39·8	39·5	39·5	39·4	39·3	39·2	39·1	38·5	38·4	Overcast

propagated to heights above 30m. does not really start, therefore, until about noon, and the time of maximum temperature at these greater heights is correspondingly delayed.

(c) *Single Clear June Day.*—The temperature of the air depends on many meteorological factors, and for this reason a detailed analysis of the temperature variation on a single day is in some ways more instructive than the curves representing the mean of several days, which include a variety of conditions. Fig. 15 illustrates the changes in air temperature at five heights on June 18, 1929. This day was selected because the meteorological conditions were exceptionally constant throughout the 24 hours. The traces of the sunshine recorder and night-sky camera showed no breaks during the whole period, and the sky had also been clear since 1200 the previous day. The hourly mean wind velocity at 13m. never exceeded 3·3 m./sec. There were, however, considerable variations in the wind direction, which caused some unsteadiness in the temperature curves.

In order to show as much detail as possible, the mean readings for every ten minutes were taken from the differential temperature traces and the 1·2m. aspirated dry-bulb trace. The temperature gradients for each hour of the day are shown, the values taken being the means for ten minutes centred on the hour. The mean wind direction has also been plotted.

In general the temperature curves resemble the mean curves for clear June days, though naturally they are much less steady. Sudden irregular changes of temperature occur simultaneously at all heights, especially at night. Since the sky was uniformly clear, these irregularities cannot be accounted for by short-period changes in incoming or outgoing radiation. Comparison with the wind-direction record shows that changes in wind direction are undoubtedly responsible for many of these changes in temperature.

PART III—DISCUSSION OF RESULTS

§ 15—COMPARISON OF LAPSE RATES AT LEAFIELD AND PORTON

If a comparison is made of the values of the lapses and inversions given in the various tables of this paper with the values shown in the corresponding tables of the Porton observations, it is seen at once that the Leafield values are considerably smaller than those at Porton. This is true of both lapses and inversions. In order to facilitate the comparison the Porton results have been interpolated to show the temperature differences between 1·2m. and 12·4m., which are the heights of the lowest elements at Leafield. Table X gives the mean values for midday and night for the months of January and June. It might at first be thought that this difference was due to the somewhat higher mean wind velocity at Leafield resulting from its greater elevation. Although this argument might be applied to the inversions, it cannot be used in the case of the midday lapses, since it has already been shown that the latter are only slightly affected by the wind velocity.

TABLE X—COMPARISON OF LAPSES AND INVERSIONS AT LEAFIELD AND PORTON

Month	G.M.T.	Mean temperature difference between 1·2 m. and 12·4 m.	
		Leafield	Porton
		° F.	° F.
January ...	0100—0300	+0·60	+1·02
	1100—1300	−0·20	−0·53
June	0100—0300	+1·18	+1·35
	1100—1300	−1·56	−2·20

On clear June days we find that the mean temperature difference between 1·2m. and 12·4m. from 0900 to 1500 is —3·0° F. at Porton and only —1·66°F. at Leafield. Moreover the mean wind velocities for these two cases are almost identical, viz. 3·9 m./sec. and 4·1 m./sec. respectively. It follows therefore that the difference in the lapses cannot be explained in terms of wind velocity.

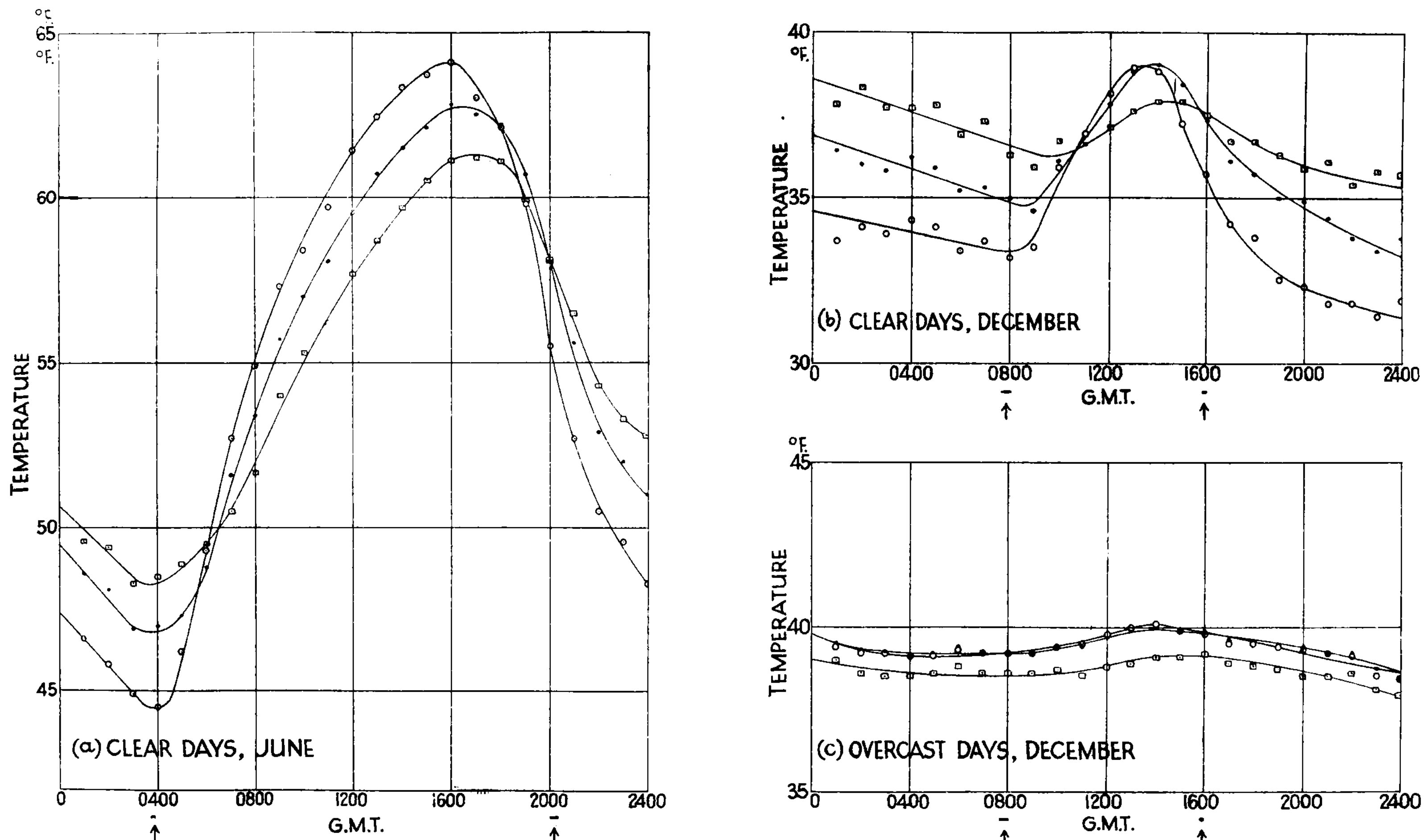


FIG. 14. DIURNAL VARIATION OF TEMPERATURE AT VARIOUS HEIGHTS FOR CLEAR DAYS IN JUNE AND FOR CLEAR AND OVERCAST DAYS IN DECEMBER

The arrows indicate times of sunrise and sunset, the limits for each month being shown by the length of the bars immediately above them.

Temperature at height of 1·2 m. = ○——○; 30·5 m. = ●——●; 87·7 m. = □——□

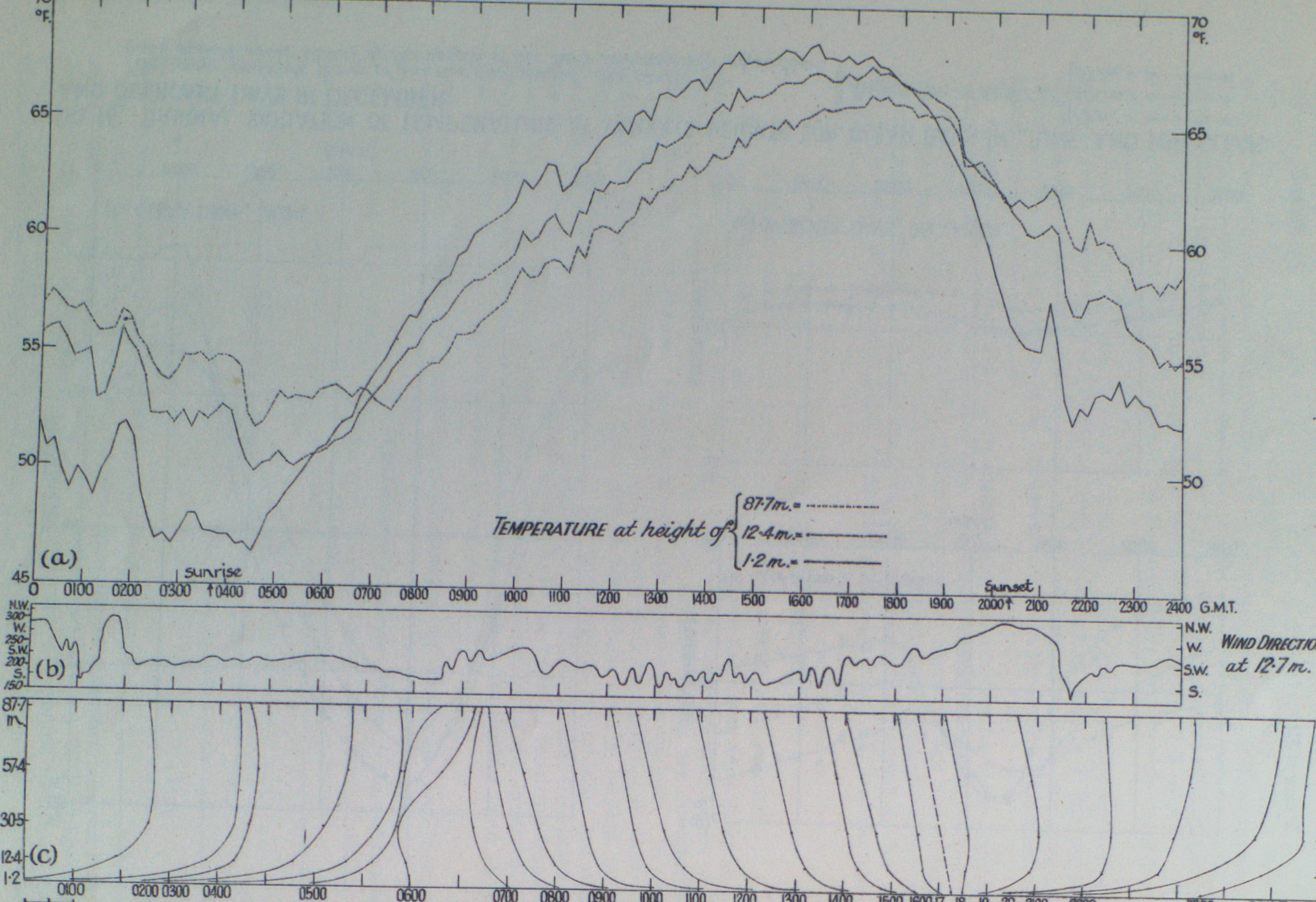


FIG. 15. TEMPERATURE & WIND VARIATION ON JUNE 18, 1929.

(a) Temperature at three heights. (b) Wind direction at 12·7m. (c) Temperature structure at each hour.

In the same way the mean nocturnal inversions over the same height interval between the hours of 2100 and 0400 in clear June weather are +3·0° F. at Porton and +2·4° F. at Leafield. The mean wind velocities corresponding to these inversions are 1·5 m./sec. and 2·5 m./sec. In this case it is probable that the difference in the observed inversions is due in part, at least, to the effects of wind velocity. In order to seek an explanation of the difference in the Porton and Leafield lapse rates during the daytime it is desirable to examine the effects of two factors. The first of these is topography, and the second the thermal conductivity of the soil.

The main topographical difference between Leafield and Porton lies in the fact, that Leafield is situated on a spur of the Cotswold Hills whilst Porton lies on the undulating surface of Salisbury Plain. One would therefore expect that, during the daytime when the air flow is turbulent (i.e. not streamline), the air at Leafield would contain a proportion which had come from a considerable height above the surrounding ground, and that it would consequently tend to possess the temperature structure corresponding to this greater height. The layers of air near the ground at Leafield would thus be admixed with this cooler air, and both the temperature and the lapse rate would be less than at a place like Porton, where the air has been in close proximity to the ground for a considerable part of its previous trajectory.

Table XI shows, side by side, certain meteorological elements for both Leafield and Porton, from which it will be seen that the differences in the daytime temperatures and lapse rates are as anticipated above. It is to be noted, moreover, that the air temperature at 0400 on clear June mornings is higher at Leafield than at Porton. The topographical explanation will also account qualitatively for this result, the cooling effect of the ground upon the air having had less time to operate at Leafield than at Porton.

TABLE XI—COMPARISON OF CERTAIN METEOROLOGICAL ELEMENTS AT LEAFIELD AND PORTON IN JUNE WITH CLEAR SKY

Element	Value at	
	Leafield	Porton
Mid-day air temperature at 1·2 m.	61·3° F.	65·8° F.
,, temperature difference, 1·2 m.—12·4 m....	−1·66° F.	−3·0° F.
,, Wind velocity	4·1 m./sec.	3·9 m./sec.
Nocturnal* air temperature at 1·2 m.	48·0° F.	48·2° F.
,, temperature difference, 1·2 m.—12·4 m.	2·4° F.	3·0° F.
,, wind velocity	2·5 m./sec.	1·5 m./sec.
Maximum air temperature at 1·2 m.	64·0° F.	68·8° F.
Minimum ,, ,, ,, ...	44·5° F.	42·0° F.
Diurnal range at 1·2 m.	19·5° F.	26·8° F.
Absolute humidity at 0700	11mb.	12mb.

* Mean from 2100 to 0400.

Let us now consider the manner in which an appreciable difference in the thermal conductivity of the soil would affect the meteorological conditions. A high conductivity would result in a reduced midday temperature of the soil surface, and hence in a diminished air temperature and lapse rate. At night the surface temperature of the soil would be maintained by the outward flow of heat from below, resulting in a higher night minimum and a smaller temperature inversion.

Now both Leafield and Porton are situated on grassland. In both cases however, there are only a few inches of soil, below which we pass at once to sandstone at Leafield and to chalk at Porton. According to Landolt and Bornstein (5) the thermal conductivity of sandstone is 0·007 whilst that of "Kalkstein" ranges from 0·002 to 0·006, the lower value referring to the light variety (chalk). Apart from the topmost few inches of soil which are similar, the conductivity of the soil at Leafield is thus about three times as great as that at Porton. Reference to Table XI shows that the differences observed at Leafield and Porton in the midday air temperature and lapse rate and in the nocturnal air minimum and inversion all conform to what would be expected from the known differences in the conductivities of the soils at the two places.

It will be seen, therefore, that both the topographical and the conductivity effects operate to produce similar results, and the meteorological observations do not enable us to decide how much of the observed difference is due to each of these causes. A comparison of the conditions at two stations in similar topographical situations but possessing soils of different conductivities might afford some information on this point. In the meantime it is important to remember that the meteorological conditions at Leafield may be affected by the special topographical situation of the station.

§ 16—ATMOSPHERIC TURBULENCE CALCULATED FROM THE TEMPERATURE CURVES

It has been pointed out by many writers that the classical equation of conductivity,

$$\frac{d\theta}{dt} = \kappa \frac{d^2\theta}{dz^2} \qquad \ldots\ldots\ (\mathrm{i})$$

first applied to the atmosphere by G. I. Taylor (6) suffers from the fact that κ is a function of z, and that the equation cannot consequently be applied with accuracy to intervals of height over which κ is liable to large variations. This difficulty will be overcome in the present instance by conducting the analysis by a step-by-step process, and investigating the conditions in each of the relatively shallow layers between the thermometer elements on the Leafield mast. Equation (i) also clearly implies that κ is independent of time, whereas it is well known that during the daytime atmospheric turbulence is usually vastly greater than at night.

Brunt (7) has shown that the diurnal temperature curve can be regarded as consisting of two parts—an harmonic portion from sunrise till shortly before sunset, and a parabola from then onwards till sunrise again. The use of equation (i) will be confined to a study of the temperature changes between sunrise and the time of maximum, so that the values obtained for κ may be regarded as mean values for this period and corresponding approximately to the actual values at, or somewhat before, noon.

If the diurnal variation of temperature at the ground is taken as

$$\theta = A \sin \frac{2\pi t}{T}$$

with the usual notation, then the solution of equation (i), representing the temperature at any height z is

$$\theta = A\, e^{-bz} \sin\left(\frac{2\pi t}{T} - b\, z\right) \qquad \ldots\ (\mathrm{ii})$$

in which b is defined by the relation

$$b^2 = \frac{\pi}{T\kappa} \qquad \ldots\ (\mathrm{iii})$$

If R_1 and R_2 are the diurnal ranges of temperature at heights z_1 and z_2 it follows at once from (ii) that

$$\log_e \frac{R_1}{R_2} = b\,(z_2 - z_1)$$

whence from (iii)

$$\kappa = \frac{\pi\,(z_2 - z_1)^2}{T\left(\log_e \frac{R_1}{R_2}\right)^2} \qquad \ldots\ (\mathrm{iv})$$

This relationship may thus be employed to derive a mean value of κ over the height interval z_1 to z_2 from measurements of the diurnal amplitude of the temperature variation at the heights z_1 and z_2.

From equation (ii) it can also readily be shown that the lag between the times of maximum temperature at heights z_1 and z_2 is given by

$$L = \frac{z_2 - z_1}{2} \sqrt{\frac{T}{\pi \kappa}}$$

$$\text{whence} \qquad \kappa = \frac{T (z_2 - z_1)^2}{4\pi L^2} \qquad \ldots . \text{(v)}$$

From equation (v) the value of κ over the range z_1 to z_2 can also be calculated from observations of the time of occurrence of maximum temperature at these two heights.

The two methods of determining κ indicated by equations (iv) and (v) have been applied to the Leafield observations.

TABLE XII—DIURNAL RANGE OF TEMPERATURE AT VARIOUS HEIGHTS AT LEAFIELD

Month	Mean diurnal range in °F. at stated heights				
	1·2 m.	12·4 m.	30·5 m.	57·4 m.	87·7 m.
January	4·4	3·8	3·5	3·0	2·7
February	6·3	5·6	5·1	4·5	4·1
March	11·6	9·7	8·8	7·9	7·1
April	12·0	10·4	9·8	9·1	8·6
May	13·9	11·7	11·1	10·3	9·7
June	14·0	11·6	10·6	9·8	9·2
July	13·8	11·8	11·2	10·5	9·9
August	12·3	10·5	9·7	9·0	8·4
September	12·1	10·1	9·2	8·6	7·8
October	8·7	7·5	6·9	6·3	5·6
November	5·8	4·9	4·4	3·9	3·3
December	3·6	3·1	2·6	2·2	2·0
June					
Clear days	19·5	15·8	14·5	13·3	12·6
December					
Clear days	5·7	3·9	2·8	2·1	1·7
Overcast days	1·0	0·9	0·8	0·8	0·7

Table XII shows the mean diurnal range of temperature at various heights at Leafield for each month. The corresponding values for clear days in June and for clear and overcast days in December are added at the foot of the table. In Table XIII the same data are expressed as ratios of the diurnal range at 1·2m. In order to eliminate the accidental variations which are apparent in these figures, the values for May, June and July have been meaned to give a representative value for June, and the months of November, December and January have been averaged to yield a reliable mean value for December. The employment of these figures in equation (iv) leads to the values of κ (Range) shown in Table XV.

To obtain the lag in the times of occurrence of maximum temperature, the afternoon portions of Fig. 13 were carefully plotted on an open scale. The values derived in this way for the times of maximum temperature are given in Table XIV. These results have been employed in conjunction with equation (v) to obtain the values of κ which are designated κ (Lag) in Table XV. The corresponding values for κ (Range) and κ (Lag) for clear days in June and December are given in Table XVI.

TABLE XIII—DIURNAL RANGES OF TEMPERATURE AT VARIOUS HEIGHTS EXPRESSED AS A RATIO OF THE RANGE AT 1·2M.

Month	$\frac{R(12\cdot4)}{R(1\cdot2)}$	$\frac{R(30\cdot5)}{R(1\cdot2)}$	$\frac{R(57\cdot4)}{R(1\cdot2)}$	$\frac{R(87\cdot7)}{R(1\cdot2)}$
January	0·86	0·80	0·68	0·61
February	0·89	0·81	0·71	0·65
March	0·84	0·76	0·68	0·61
April	0·87	0·82	0·76	0·72
May	0·84	0·80	0·74	0·70
June	0·83	0·76	0·70	0·66
July	0·85	0·81	0·76	0·71
August	0·85	0·79	0·73	0·68
September	0·83	0·76	0·71	0·65
October	0·86	0·79	0·72	0·64
November	0·85	0·76	0·68	0·57
December	0·86	0·72	0·61	0·55
June				
Clear days	0·81	0·75	0·68	0·65
December				
Clear days	0·69	0·49	0·37	0·30
Overcast days	0·9	0·8	0·8	0·7

The temperature changes on overcast December days are too small to enable either method of calculation to be employed with any reasonable accuracy.

Examination of Table XV shows that the values of κ derived by the two different methods are in fairly good agreement. An exception occurs in the case of the lowest height interval in December.

TABLE XIV—TIMES OF OCCURRENCE OF MAXIMUM TEMPERATURE AT VARIOUS HEIGHTS

Month	G.M.T. of maximum temperature at stated heights								
	1·2 m.		12·4 m.		30·5 m.		57·4 m.		87·7 m.
Mean June	1455	(40)	1535	(15)	1550	(16)	1606	(14)	1620
Mean December	1405	(21)	1426	(8)	1434	(8)	1442	(8)	1450
Clear June	1545	(50)	1635	(25)	1700	(14)	1714	(10)	1724
Clear December	1330	(12)	1342	(18)	1400	[38]	[1438]	[36]	[1514]

Note.—The figures shown in round brackets ( ) are the lags between successive heights. The values given in square brackets [ ] are of doubtful accuracy for the reasons explained in the text.

It should here be noted that in applying equations (iv) and (v), the value of T has been taken as 24 hours for the June observations and as 7 hours for December. The lower value for December corresponds to the observed time of about $3\frac{1}{2}$ hours which occurs between the disappearance of the nocturnal inversion and time of maximum temperature in mid-winter. Similarly in deriving the values of κ in Table XVI for clear December days, the value of T has been taken as $6\frac{1}{2}$ hours, since in this case the strong nocturnal inversion is not destroyed until about $3\frac{1}{4}$ hours before the time of maximum temperature.

Taking the mean values of κ in June from Table XV, the outstanding feature is the rapid increase of κ with height, particularly near the ground. Thus between mean heights of about 7 and 21m. the value of κ is increased twenty-fold. The rate of increase diminishes with height, the increase between 21m. and 72m. being about 3 fold.

TABLE XV—MEAN VALUES OF κ AT VARIOUS HEIGHTS FOR JUNE AND DECEMBER

Height interval	June			December		
	κ (Range)	κ (Lag)	Mean κ	κ (Range)	κ (Lag)	Mean κ
m.						
57·4—87·7	$1·1\times10^5$	$9·0\times10^4$	$1·0\times10^5$	$6·9\times10^4$	$9·0\times10^4$	$8·0\times10^4$
30·5—57·4	$4·3\times10^4$	$5·4\times10^4$	$4·8\times10^4$	$4·5\times10^4$	$6·4\times10^4$	$5·4\times10^4$
12·4—30·5	$3·1\times10^4$	$2·8\times10^4$	$2·9\times10^4$	$2·4\times10^4$	$2·9\times10^4$	$2·6\times10^4$
1·2—12·4	$1·5\times10^3$	$1·4\times10^3$	$1·4\times10^4$	$6·5\times10^3$	$1·5\times10^3$	$4·0\times10^3$

On clear June days, Table XVI, the rate of increase of κ with height is even more rapid, the value at 72m. being 200 times that at 7m., as compared with the factor of 60 just found for the same range from the mean June observations.

TABLE XVI—VALUES OF κ AT VARIOUS HEIGHTS FOR CLEAR DAYS IN JUNE AND DECEMBER

Height interval	June			December		
	κ (Range)	κ (Lag)	Mean κ	κ (Range)	κ (Lag)	Mean κ
m.						
57·4—87·7	$1·7\times10^5$	$1·8\times10^5$	$1·7\times10^5$	$2·8\times10^4$	$(4·1\times10^3)$	..
30·5—57·4	$2·9\times10^4$	$7·0\times10^4$	$4·9\times10^4$	$1·3\times10^4$	$(2·7\times10^3)$	
12·4—30·5	$1·9\times10^4$	$1·0\times10^4$	$1·4\times10^4$	$3·7\times10^3$	$7·7\times10^3$	
1·2—12·4	$1·1\times10^3$	$0·9\times10^3$	$1·0\times10^3$	$1·3\times10^3$	$4·3\times10^3$	

Note.—The figures shown in brackets are of doubtful accuracy.

The mean December values for κ show a less rapid increase with height, whilst on clear December days the increase is still less. In the last mentioned case, the values of κ derived from the lag of time of maximum temperatures are subject to some uncertainty, first owing to the flatness of the temperature curves and the consequent difficulty in deciding the time of maximum, and secondly owing to the small number of observations upon which the curves are based. The uncertainty is greatest in the case of the higher levels and the corresponding values of κ are enclosed in brackets.

The rate of change of κ with height has been calculated for the various cases mentioned above on the assumption that the relationship can be expressed in the form

$$\kappa = Az^n \qquad \ldots\ldots \text{(vi)}$$

By plotting the logarithms of κ and z given in Tables XV and XVI, the values of n are readily obtainable. The values allotted to z are, of course, those corresponding to the mid points of each of the height intervals considered. The resulting values of n are given in Table XVII. In most cases it was found that the three upper points in the plots lay in a straight line, indicating that the value of n is sensibly constant from a height of 21m. up to 72m. On the other hand, the lines joining the points corresponding to 6m. and 21m. gave larger values of n. Thus for mean June days

TABLE XVII—VALUES OF THE INDEX n IN THE RELATION $\kappa = Az^n$ UNDER VARIOUS CONDITIONS

Occasion	Value of n over height interval stated.	
	6 to 21 m.	21 to 72 m.
Mean June Days	2·6	0·95
Clear June Days	2·3	1·9
Mean December Days	1·6	0·95
Clear December Days	0·9	..

the value of the index n is 2·6 from 6m. to 21m., and 0·95 above 21m. On clear June days the index is about the same up to 21m., but above this height it still remains nearly equal to 2. In December, the rate of increase of κ with height is represented in the mean by a value of n of 1·6 up to 21m., and 0·95 thereafter. On clear December days the value of n between 6 and 21m. is about 0·9, the value above that height being uncertain.

These results may be compared with that obtained by Best (8). By combining observations made at all times of the year, Best found a value for the index of z of about 1·8 over the height range 2·5m. to 17m. The present analysis confirms this as an average figure, but it also brings to light the difference between the turbulence structure in summer and winter. Under summer conditions the value of n exceeds Best's value below a height of about 20m., but drops to about half this value for the next 50m., except with a clear sky when it remains almost equal to 2. In winter, on the other hand, the mean value of the index of z is somewhat below Best's figure up to about 20m., falling to about unity from there up to 70m. With a clear sky in winter the midday value of n is below unity even from 6m. to 21m.

The effect of lapse rate upon the turbulence structure is thus clearly brought out. With the maximum summer lapse rate, turbulence increases upwards as the square of the height to at least 70m. With an average summer lapse rate the square law holds only up to about 20m., and a linear law represents the mean condition over the next 50m. With the smaller lapse rate of a winter day the turbulence still increases with height, but in the mean the index of z is about 1·5 up to 20m., and about unity from there up to 70m. With the very small lapse rate of a clear winter day, turbulence increases upwards roughly in proportion to the height within the lowest 20m. Its behaviour above this height is somewhat uncertain.

This seasonal variation in the index of z may be examined in terms of Prandtl's expression for κ (9). According to this

$$\kappa = k_0 l^2 \frac{\partial u}{\partial z} \qquad \ldots . \text{(vii)}$$

in which l is the mixing length of the eddies. Under conditions of steep lapse rate $\partial u/\partial z$ is most nearly constant with height, and it will be seen later in §18 that under these conditions l becomes synonymous with z. With a clear sky in summer therefore, one would expect κ to increase approximately as the square of the height—a result to which our present observations conform.

The comparison of the values of κ under the various conditions of Tables XV and XVI is given greater significance by a knowledge of the wind velocity in each case. This has accordingly been determined for 1300, and the values are shown in Table XVIII. It will be seen that the mean wind velocities corresponding to these various conditions do not differ much. It therefore follows that the differences in the turbulence structure indicated in Tables XV and XVI are caused primarily by differences in the temperature gradient. It would appear that with a wind velocity of 5 m./sec. the mean value of κ at about 40m. approximates to 5×10^4 at midday in both summer and winter. In summer, moreover, the value of κ is not appreciably affected by the state of the sky, but a clear sky in winter appears to reduce the value at 40m. to about a quarter of its average value. Although the values of κ at 40m. are thus seen to be the same under these different conditions, the values at other heights differ in accordance with the manner in which κ varies with height as already described.

TABLE XVIII—WIND VELOCITY IN M./SEC. AT 1300 IN JUNE AND DECEMBER

Occasion	Wind Velocity
Mean June Days	5·2
Clear June Days	4·4
Mean December Days	5·9
Clear December Days	5·2

§ 17—EFFECT OF WIND VELOCITY UPON LAPSE RATE AND TURBULENCE

It has been pointed out in §12 (a) that the largest lapses are frequently associated with moderately strong winds. If we examine the records given in Table V for the summer months (May, June, July, August), we find in fact that there is no very marked relation between the magnitude of the lapse and the velocity of the wind. The temperature lapses appear on the whole to be as large when the wind exceeds 6 m./sec. as when it is very light (0-3 m./sec.). The same result is found to obtain at Porton, as can be seen from Table V, B of the previous paper (1). It will be further seen that the wind velocity has approximately the same average value at the time of greatest lapse rate at all heights. Thus steep lapse rates at the upper heights are not associated with stronger winds, as might perhaps have been anticipated.

It will be shown later however, that there is a small but definite relation between the lapse rate and the wind velocity. Above 12m. the magnitude of the effect does not exceed a few hundredths of a degree Fahrenheit, and it is probably masked in Table V by other factors such as the amount of cloud.

These results may be compared with those given by Best in his study of the temperature structure of the lowest metre of the atmosphere (8). Best's Fig. 6 shows that, whilst the lapse rate between 2·5cm. and 30cm. shows a definite decrease with increasing wind velocity, this effect is much less pronounced over the interval 30cm. to 120cm. The present results conform to this tendency.

In contrast with the relative independence of lapses upon the wind velocity, we have previously described, in § 12 (b), the sensitiveness of inversions near the ground to the strength of the wind. Under inversion conditions turbulence is enormously reduced, and, in the complete absence of wind, the temperature structure is determined by " radiation diffusion," the magnitude of which is small compared with the " eddy diffusion " produced by even a light wind (10). The growth of a wind during an inversion therefore has a pronounced effect upon the total diffusivity of the atmosphere, and hence also upon the temperature structure.

In order to study the relationship between the temperature structure and wind velocity in greater detail, the Leafield temperature gradient records have been analysed for days of light and strong winds. The months of May, June and July for the five years were selected, and each day was classified according to whether the mean wind velocity at 0700 and 1300 lay between Beaufort force 0-2½ on the one hand or above force 3½ on the other. The former group was taken as constituting light winds and the latter strong winds. Days in which there was a large increase or decrease in the wind velocity between the two hours mentioned were omitted. The number of days in the two groups were 166 and 162. Taking the wind velocities in metres per

TABLE XIX—TEMPERATURE STRUCTURE

Height interval	Temperature difference (° F.) at									
	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000
m.										
57·4—87·7	−0·06	−0·02	0·11	0·11	0·14	0·14	−0·16	−0·47	−0·61	−0·64
30·5—57·4	0·30	0·38	0·42	0·46	0·47	0·33	−0·12	−0·32	−0·61	−0·63
12·4—30·5	0·68	0·58	0·52	0·62	0·54	0·13	−0·38	−0·52	−0·52	−0·49
1·2—12·4	1·56	1·62	1·51	1·49	0·97	−0·16	−0·63	−1·03	−1·22	−1·47
Temperature at 1·2 m. ...	48·9	47·9	47·2	46·8	47·4	49·2	51·4	54·1	56·1	57·8

TABLE XX—TEMPERATURE STRUCTURE

Height interval	Temperature differences (° F) at									
	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000
m.										
57·4—87·7	−0·15	−0·16	−0·16	−0·13	−0·12	−0·28	−0·39	−0·50	−0·52	−0·49
30·5—57·4	0·00	0·05	0·06	0·09	0·05	−0·18	−0·32	−0·38	−0·45	−0·44
12·4—30·5	0·11	0·13	0·14	0·14	0·06	−0·19	−0·33	−0·41	−0·46	−0·32
1·2—12·4	0·44	0·48	0·47	0·38	0·17	−0·34	−0·59	−0·87	−1·00	−1·07
Temperature at 1·2 m. ...	49·4	48·9	48·5	48·3	48·8	50·2	51·8	53·7	55·1	56·5

second corresponding to their Beaufort forces (11), the weighted mean velocities for the light and strong wind groups were found to be 2·5m./sec. and 7·4m./sec. respectively.

Tables XIX and XX give the mean hourly values of the temperatures at 1·2m., and the temperature differences over the various height intervals up the mast. If the midday readings are compared, it is seen that the lapse between 1·2m. and 12·4m. is reduced by the wind from —1·60° F. to —1·29° F. Over the succeeding height intervals the diminution in the lapses due to the wind is only about 0·05° F. The smallness of these effects is somewhat surprising. The wind velocity during the forenoon is not necessarily always a reliable indication of the velocity during the following night, and some slight uncertainty must therefore exist as to the physical significance of the values for the nocturnal inversions shown in Tables XIX and XX.

TABLE XXI—DIURNAL RANGE OF TEMPERATURE AT VARIOUS HEIGHTS IN SUMMER WITH LIGHT AND STRONG WINDS

Height	Light Winds (2·5 m./sec.)		Strong Winds (7·4 m./sec.)	
	Range	Ratio $\frac{R(m)}{R(1·2)}$	Range	Ratio $\frac{R(m)}{R(1·2)}$
m.	° F.		° F	
87·7	10·25	0·65	8·5	0·73
57·4	11·0	0·70	8·9	0·77
30·5	11·9	0·76	9·5	0·82
12·4	12·8	0·815	10·1	0·87
1·2	15·7	1·00	11·6	1·00

For our present purpose, however, we need to employ only the results from 0400 to about 1600, over which period the classification obviously holds good. In Table XXI are accordingly given the diurnal ranges of temperature at each height from 1·2m. to 87·7m., each amplitude being also expressed as a ratio of that at 1·2m.

IN SUMMER WITH LIGHT WINDS

stated times (G.M.T.).

1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
−0·67	−0·68	−0·69	−0·71	−0·67	−0·65	−0·62	−0·59	−0·52	−0·48	−0·32	−0·25	−0·18	−0·12
−0·59	−0·56	−0·60	−0·55	−0·57	−0·54	−0·48	−0·36	−0·25	−0·05	0·06	0·18	0·23	0·31
−0·51	−0·51	−0·51	−0·46	−0·42	−0·39	−0·31	−0·22	−0·01	0·20	0·27	0·40	0·34	0·31
−1·51	−1·60	−1·49	−1·38	−1·10	−0·93	−0·59	−0·21	0·43	1·06	1·23	1·29	1·35	1·39
59·3	60·5	61·5	62·3	62·5	62·4	61·7	60·1	58·1	55·8	54·0	52·5	51·4	50·6

IN SUMMER WITH STRONG WINDS

stated times (G.M.T.).

1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
−0·53	−0·61	−0·62	−0·59	−0·56	−0·54	−0·53	−0·52	−0·46	−0·39	−0·32	−0·23	−0·20	−0·15
−0·46	−0·53	−0·55	−0·51	−0·50	−0·47	−0·44	−0·41	−0·29	−0·15	−0·04	−0·01	−0·03	0·04
−0·46	−0·48	−0·48	−0·45	−0·40	−0·42	−0·35	−0·27	−0·11	0·10	0·20	0·21	0·24	0·26
−1·19	−1·29	−1·27	−1·11	−0·93	−0·72	−0·48	−0·22	0·19	0·63	0·77	0·83	0·85	0·83
57·5	58·5	59·3	59·7	59·7	59·3	58·6	56·9	55·4	53·2	51·6	50·6	49·7	49·0

Table XXII shows the times of occurrence of maximum temperature at each height with both light and strong winds.

Employing equations (iv) and (v) above, the values of κ for light and strong winds have been calculated and are given in Table XXIII.

It will be seen that on the whole the agreement between the values of κ derived by the two methods is again reasonably good. The values obtained by the "lag method" are generally somewhat higher than those found from the amplitude of the diurnal variation. This result is probably due in part to the fact that T in the above equations has been taken as 24 hours, whereas the half period, corresponding to the portion of the diurnal curve from minimum (0400) to maximum (1400), is actually only about 10 hours. The values of κ computed by the amplitude method

TABLE XXII—TIMES OF OCCURRENCE OF MAXIMUM TEMPERATURE AT VARIOUS HEIGHTS IN SUMMER WITH LIGHT AND STRONG WINDS

Height	Light Winds (2·5 m./sec.)		Strong Winds (7·4 m./sec.)	
	G.M.T. of Maximum	Lag	G.M.T. of Maximum	Lag
m.		min.		min.
87·7	1630		1532	
		14		10
57·4	1616		1522	
		16		10
30·5	1600		1512	
		14		12
12·4	1546		1500	
		41		30
1·2	1505		1430	

are consequently about 20 per cent. low, whilst those calculated by the lag method are high by about the same amount. In the mean values of Table XXIII this difference is eliminated. The last column of the table shows the ratio of the values of κ for light and strong winds, the mean value of this ratio being about 1·9. The ratio of the wind velocities for the two classes of observation is $7\cdot4/2\cdot5 = 3\cdot0$ approx.

TABLE XXIII—VALUES OF κ AT VARIOUS HEIGHTS FOR LIGHT AND STRONG WINDS IN SUMMER

Height interval	Light Winds (2·5 m./sec.)			Strong Winds (7·4 m./sec.)			Ratio $\frac{\kappa \text{ strong winds}}{\kappa \text{ light winds}}$
	κ (Range)	κ (Lag)	Mean κ	κ (Range)	κ (Lag)	Mean κ	
m.							
57·4—87·7	$7\cdot2\times10^4$	$9\cdot0\times10^4$	$8\cdot1\times10^4$	$1\cdot7\times10^5$	$1\cdot8\times10^5$	$1\cdot7\times10^5$	2·1
30·5—57·4	$4\cdot3\times10^4$	$5\cdot4\times10^4$	$4\cdot9\times10^4$	$6\cdot4\times10^4$	$1\cdot4\times10^5$	$1\cdot0\times10^5$	2·0
12·4—30·5	$2\cdot2\times10^4$	$3\cdot2\times10^4$	$2\cdot7\times10^4$	$3\cdot0\times10^4$	$4\cdot4\times10^4$	$3\cdot7\times10^4$	1·4
1·2—12·4	$1\cdot1\times10^3$	$1\cdot4\times10^3$	$1\cdot3\times10^3$	$2\cdot4\times10^3$	$2\cdot7\times10^3$	$2\cdot5\times10^3$	1·9
						Mean ...	1·9

The results thus show that a threefold increase in the wind velocity approximately doubles the magnitude of the dynamical turbulence. This conclusion may be generalised by saying that the thermal diffusivity increases rather less rapidly than in direct proportion to the velocity of the wind.

§ 18—SHORT PERIOD TEMPERATURE VARIATIONS

We have so far considered only diurnal temperature variations, but it is a matter of some interest to examine the more rapid fluctuations of temperature which normally occur at all heights. The existence of these fluctuations is indicated in the scatter of the points which constitute the temperature traces given by a thread-recorder, and which impart a definite width to the trace. The phenomenon is to be seen in the dry- and wet-bulb charts, and also in the differential traces. The effect is most marked under conditions of strong insolation, and it seems quite clear that it arises from the formation of layers of heated air in the vicinity of the ground, which eventually becomes unstable and ascend. According to this view, the temperature fluctuations due to this cause should be greatest near the ground, the mixing of the ascending masses with the surrounding air causing the temperature variations to diminish at greater heights. These temperature changes are not periodic in the mathematical sense, but are of an irregular nature, although on the average they follow each other at an interval of the order of a minute.

In order to examine certain of their characteristics we have selected seven sunny June days, and measured the mean widths of the four differential traces over hourly periods when the conditions were steady. The mean observed widths of these four traces are shown in the second column of Table XXIV, being 1·29° F. for the interval 1·2m. to 12·4m., and falling to 0·41° F. for the highest interval 57·4m. to 87·7m. Column 3 shows the semi-amplitudes of the recorded temperature variations which are taken as applying to the mid height of each vertical interval. The intermediate figures shown in brackets in column 3 are the interpolated values corresponding to the actual heights of the thermometer elements. These will be found to be more convenient for comparison with some of the earlier results given in this paper. The last column of the table gives the mean lapse rate for the occasions under discussion.

The width of each differential trace may be regarded as representing the sum of the semi-amplitudes of the temperature oscillations occurring at the positions occupied by the two differential elements. Thus if α and β are the semi-amplitudes of the temperature variations at 1·2m. and 12·4m. respectively, then the width of

TABLE XXIV—SHORT PERIOD TEMPERATURE VARIATIONS AT DIFFERENT HEIGHTS IN SUMMER

Height	Observed width of temperature gradient trace	Observed semi-amplitude of temperature variation	Temperature difference over height interval
m.	° F.	° F.	° F.
87·7		(0·19)	
	0·41	0·21	−0·6
57·4		(0·24)	
	0·56	0·28	−0·6
30·5		(0·35)	
	0·83	0·41	−0·6
12·4		(0·52)	
	1·29	0·65	−1·6
1·2		(0·80)	

the lowest differential trace can be expected to be $\alpha + \beta$. On measuring the width of the dry-bulb traces corresponding to the periods selected above, it was found that the mean value was 1·74° F. instead of about 0·8° F. as anticipated on the above basis. This discrepancy is due to the fact that the lag of the galvanometer recording the differential trace is greater than that of the dry-bulb instrument, and that the former trace is correspondingly reduced. The dry-bulb trace itself is almost certainly reduced to some extent by this factor of instrumental lag, so that it will be seen that the differential traces are reduced to less than a half of the true values due to this cause alone.

It has further been shown by Bilham (12), that the known lag of the platinum resistance elements employed in these circuits also causes a reduction in the recorded amplitude of temperature changes of short period. Bilham discusses two cases. In the first he assumes that the temperature variations are of simple harmonic form, and finds that the ratios of the recorded to the true amplitudes are as follows :—

Assumed period of the oscillation (sec.) ...	15	30	60	120	240
Ratio : recorded amplitude/true amplitude ...	0·074	0·148	0·287	0·513	0·767

In the second case he assumes that the air temperature makes sudden excursions about its mean value from $+\alpha$° F. to $-\alpha$° F., resting for 30 sec. at each extreme. He finds that the recorded temperature oscillation will then be $0 \cdot 44\, \alpha$. In both these cases it has been assumed that the lag of the recording galvanometer can be neglected. It will be seen, therefore, that the thermal inertia of the Leafield thermometer elements causes the recorded traces to be appreciably reduced in the case of temperature oscillations of about 1 minute " period," which is believed to be approximately the actual mean value. We shall probably not be far wrong if we assume that the amplitude of the recorded traces are reduced in this way to about two-fifths of the true temperature variation.

We have however already seen that the lag of the galvanometers reduces the width of the differential traces by at least a half, from which it follows that the amplitudes of the short-period oscillations shown in the differential traces are probably only about one-fifth of the actual temperature variations of the air. Thus on a fine summer day the air temperature at 1·2m. is apparently oscillating over a total range of about 4° F., whilst at a height of 80m. the extent of the oscillation is still about 1° F.

These results are shown graphically in Fig. 16, in which the full line curve indicates the mean temperature structure, and the two broken curves show the extent of the temperature oscillations.

It has been suggested to the writers by Professor Brunt that it might be possible to deduce from these curves the manner in which the mixing length of the eddies varies with height. Thus, if it is assumed that the temperature at the point A is due to the rising of a mass of warm air, then the mean temperature of this warm air will be given by the point B, which is obtained by drawing the dry adiabatic through A.

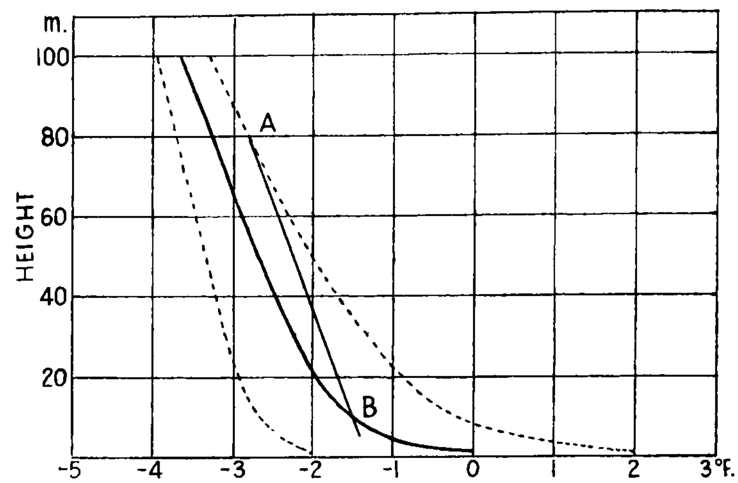


FIG. 16—SHORT PERIOD TEMPERATURE OSCILLATIONS AT VARIOUS HEIGHTS ON CLEAR JUNE DAYS.
The full line curve shows the mean temperature distribution whilst the two broken line curves indicate the extent of the temperature oscillations at any height.

In other words, the difference in height between A and B is the mixing length of the air mass arriving at A. The application of this procedure to a number of points on the uppermost curve of Fig. 16 yields the interesting result that, up to heights of about 80m. the masses of heated air appear, on the foregoing assumption, to originate within 10m. of the ground. It seems unlikely, however, that the simple theory just outlined really represents what occurs. It would appear inevitable that the rising air masses must mix to some extent with the surrounding air, and that their temperature consequently decreases more rapidly than at the dry adiabatic rate. On this basis the warm air masses would originate even nearer the ground than the simple theory suggests. These observations would thus seem to provide direct evidence that the turbulence in the lowest 100m. of the atmosphere, on summer days, consists of the convective rising of heated air masses originating close to the ground. The mixing length at any height within the first 100m. above the ground is, in fact, approximately equal to that height.

* * * * *

The temperature fluctuations which occur at night are totally different in character from the daytime oscillations. On clear calm nights temperature inversions of about 5° F. build up steadily in the lowest 10m. over a period of perhaps an hour or two, and then break down again, presumably due to horizontal movement of the air. Temperature variations near the ground at night appear frequently to be almost confined to the lowest layers (say 10m.), the upper differential traces at Leafield often showing little, if any, evidence of their effects. The nocturnal variations as a whole appear to be so irregular that it is almost impossible to detect any numerical relationship between the magnitudes of the variations at different heights.

§ 19—EXTREME VALUES OF THE LAPSE RATE

In Table V we have given the largest mean hourly values of the lapses which occurred each month. These mean hourly values are, of course, measured from the middle of the traces. In §18 we have seen that the temperature difference between any two heights fluctuates, and that, for short spaces of time, the actual temperature difference on a clear summer day may exceed the mean value by an amount which is about 3·2° F. between 1·2m. and 12·4m., decreasing to about 1·0° F. between 57·4m. and 87·7m. The addition of these amounts to the maximum values of temperature lapse of Table V, will give the extreme values of the temperature differences which exist for short periods under these conditions of strong insolation. Table XXV has been constructed in this way from the largest values corresponding to the summer months in Table V.

TABLE XXV—EXTREME TEMPERATURE LAPSES

Height interval	Maximum hourly summer lapse	Semi-amplitude of short period variation	Extreme temperature difference	Ratio $\frac{\text{Extreme}}{\text{Adiabatic}}$
m.	° F.	° F.	° F.	
57·4—87·7	−1·9	1·0	−2·9	5
30·5—57·4	−1·5	1·4	−2·9	6
12·4—30·5	−1·7	2·0	−3·7	11
1·2—12·4	−4·2	3·2	−7·4	37

The last column of this table shows that the extreme temperature lapses rates, which can exist between 1 and 12m. for short periods under summer conditions, are 37 times as steep as the dry adiabatic lapse rate, the ratio diminishing to 5 at a mean height of about 70m.

§ 20—RATE OF GROWTH OF NOCTURNAL INVERSIONS

It has been shown by Brunt (13), that the propagation of heat through the atmosphere by radiation should follow a law similar to that which applies in the case of heat transference by dynamical turbulence. The combined effects of radiation and turbulence are represented by the equation

$$\frac{d\theta}{dt} = (\kappa_R + \kappa_E)\,\frac{d^2\theta}{dz^2} \qquad \ldots\ldots \text{(viii)}$$

in which θ is absolute temperature, t is time and z height, whilst κ_R and κ_E are the coefficients of radiative and eddy diffusivity.

The solution of this equation representing the upward propagation of a change of temperature originating near the ground is shown to be given approximately by

$$z^2 = 4\,(\kappa_R + \kappa_E)\,t \qquad \ldots\ldots \text{(ix)}$$

The numerical value of κ_R can be calculated from the water content of the atmosphere, and Brunt shows that for an absolute humidity of 10 mb. its value is about 650. The value of κ_E on the other hand is usually of the order 10^5 during the daytime, but decreases rapidly towards evening. The radiation effect is thus negligible during the day but may become an important factor on calm clear evenings.

In order to ascertain whether the evening inversion is propagated upwards according to equation (ix), four occasions have been selected from the Leafield records for the month of June. The following conditions were demanded :—

Conditions at 1800
- Wind force 1
- State of sky b (on one occasion bc.)

Conditions at following 0700
- Wind force 0 or 1
- State of sky b (on one occasion m).

It is noteworthy that no occasion of calm (Force 0) could be found at 1800, with a clear sky. The explanation may be that katabatic flow normally causes sufficient air movement to prevent the formation of an actual calm.

The absolute humidities at 1800 on the four occasions were 10·7 mb., 13·0 mb., 11·4 mb. and 12·7 mb., giving a mean of 11·9 mb. The temperature structure for each hour from 1800 to 2300 was extracted from the records for these four days,

TABLE XXVI—TEMPERATURE STRUCTURE AT SUCCESSIVE HOURS ON CLEAR JUNE EVENINGS

Height interval	Temperature difference over each height interval at stated G.M.T.				
	1800	1900	2000	2100	2200
m.	° F.	° F	° F.	° F.	° F.
57·4—87·7	−0·5	−0·4	−0·3	−0·1	0·2
30·5—57·4	−0·4	0·4	−0·2	0·1	0·25
12·4—30·5	−0·25	−0·1	0·05	0·4	1·1
1·2—12·4	0·0	1·4	2·4	3·8	3·2

and gave the result shown in Table XXVI. These mean values are plotted in Fig. 17, and from the curves the height at which the surface inversion gives way to a lapse can be read off. The results obtained in this way for calm June evenings are shown in Table XXVII. For the sake of comparison the corresponding values obtained from the data in Table III for clear June and clear December days are also given.

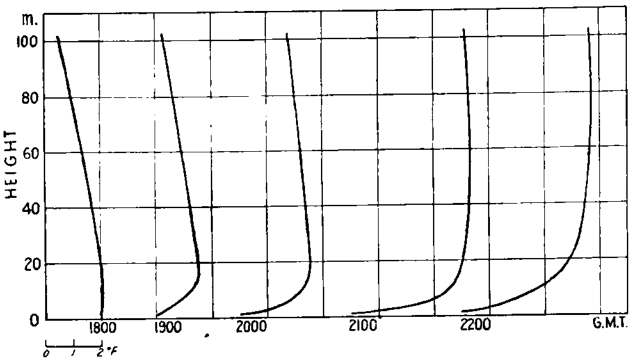


FIG. 17.—RATE OF DEVELOPMENT OF TEMPERATURE INVERSION ON CLEAR JUNE NIGHTS.

If these results are plotted, it will be seen that in each case the slope of the graphs is small to begin with but later increases, the points in this latter portion lying on straight lines. This result is quite different from that suggested by equation (ix), viz: a parabola concave downwards. To find an explanation of these results it is necessary to consider the two portions of the curves separately. At the lower heights radiation is probably dominant. Neglecting κ_E, the value of κ_R may be taken as approximately 700, which would require a time interval of about 60 min. for the inversion to rise from 5m. to 25m. The observed

TABLE XXVII—RATE OF UPWARD PROPAGATION OF INVERSIONS ON CLEAR EVENINGS

Month	Wind Velocity	Height reached by inversion at stated G.M.T.				
		1800	1900	2000	2100	2200
June	Force 1	m. 5	m. 14	m. 25	m. 45	m. 70
	2·6 m./sec.	5	17	42	65	90±
December		1400	1500	1600	1700	..
	4·0 m./sec.	m. 10	m. 25	m. 45	m. 75	m. ..

time (wind force 1) is about 200 min. which implies a value for κ_R of only 210. As suggested by Brunt (13), however, the effective value of κ_R within the lowest layer required to absorb completely the outgoing W-radiation is probably less than the value (700) in the free air. The observed value (210) is nevertheless smaller than might have been anticipated. Above about 25m. it is probable that dynamical turbulence comes into play as well. The value of $(\kappa_R+\kappa_E)$ over the interval 25m. to 75m. is found to be about 1700. It will be seen therefore that, even under inversion conditions, dynamical turbulence corresponding to wind force 1 is a more potent factor in heat propagation than are the radiative processes in the atmosphere.

§ 21—RADIATION TEMPERATURE STRUCTURE

Although §20 indicates that the dynamical effects of the wind are appreciable during the early parts of " still," clear nights, it would seem likely that these effects will diminish as the night progresses, so that the temperature structure just before sunrise will be determined largely, if not entirely, by radiation effects. It is therefore of some interest to examine what the temperature structure is at such times.

TABLE XXVIII—EARLY MORNING TEMPERATURE STRUCTURE AFTER CLEAR NIGHTS IN JUNE

Height (m.)	1·2	12·4	30·5	57·4	87·7
Temperature (° F.) ...	44·5	48·3	49·7	50·7	51·1
Temperature difference ...	3·8	1·4	1·0	0·4	

Grass minimum temperature ... 33° F.
Water vapour pressure ... ... 11·5 mb.

Seven June mornings were found in the Leafield records in which the wind at 0700 was of either force 0 or 1, following clear, still nights. The mean temperature structure just before sunrise (at 0400) was found to be as shown in Table XXVIII. On only three June mornings was there actually no wind (force 0), and the mean temperatures at the same heights on these occasions was as given in Table XXIX and Fig. 18. It will be observed that there is very little difference between the temperature differences in the two cases, which would seem to confirm the suggestion made above that these temperature structures are determined primarily by radiation.

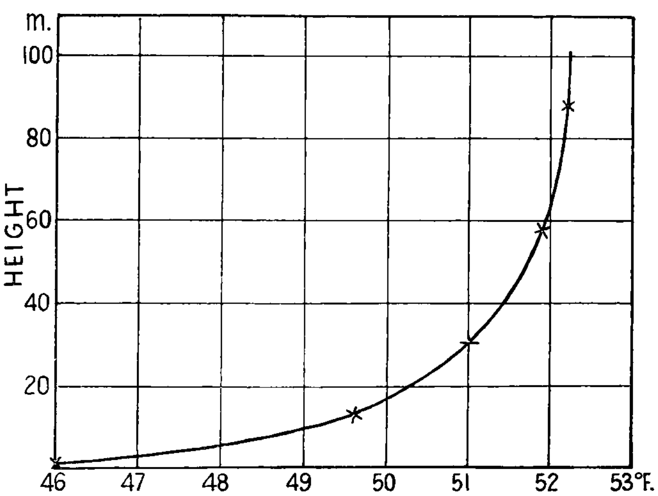


FIG. 18.—RADIATION TEMPERATURE STRUCTURE ON CLEAR CALM MORNINGS IN JUNE.

The temperature distribution on the calm mornings is well represented by the equation

$$T = 30+11\cdot 88\,(z - 50)^{0\cdot 0704} \qquad \text{(x)}$$

in which T is the temperature in degrees Fahrenheit at height z cm.* Little physical significance can be attached to this equation, since it implies an air temperature of 30° F. at a height of 50 cm., whereas the grass minimum temperature was 34° F. It also gives imaginary values below 50 cm. The equation must therefore be regarded as empirical and applying only between heights of 1·2m. and 90m.

It has been suggested by Brunt (13), that the lapse rate near the ground under these conditions should have a value, which is numerically twice as great as that at

* The corresponding equation for the temperature structure on the seven mornings which include wind force 1 as well is

$$T = 30 + 10\cdot 32\,(z—50)^{0.0805}$$

TABLE XXIX—EARLY MORNING TEMPERATURE STRUCTURE AFTER CLEAR CALM NIGHTS IN JUNE

Height (m.)	1·2	12·4	30·5	57·4	87·7
Temperature (° F.) ...	46·0	49·6	51·0	51·9	52·2
Temperature difference ...	3·6	1·4	0·9	0·3	

Grass minimum temperature ... 34° F.
Water vapour pressure ... ... 12·5 mb.

the height at which the outgoing W-radiation from the ground has just been completely absorbed. This height l is given by the expression

$$l = \frac{139\,\theta}{pw}$$

in which θ is the absolute temperature of the air and pw the water vapour pressure in millibars. For the case of the calm mornings this gives a value of l of 31 metres.

The observed gradient on calm mornings is 0·048° F./m. at a height of 31m. The corresponding value at the ground is not ascertainable from these observations, but at a height of 2m. it is 0·34° F./m. This is about seven times the value at 31m., and this factor must increase still more as the ground is approached. It is seen therefore that the ratio of two to one suggested by Brunt is not confirmed by the Leafield observations.

§ 22—RADIATION FOG

Some observations upon the temperature structure of radiation fog have already been described (3) by one of us. It was shown that the gradient in the lower part of such fogs normally consists of a small lapse, whilst above the fog there is a marked

TABLE XXX—STANDARD METEOROLOGICAL OBSERVATIONS ASSOCIATED WITH RADIATION FOG ON THE MORNING OF FEBRUARY 1, 1932

Meteorological Element	January 31	February 1	
	1800	0700	1300
Form of low cloud Amount of low cloud Base of cloud (ft.)	Sc. 8/10 3500	St. 10/10 0	St. 6/10 500
Weather since last observation Weather at time	c c	b x F F e F	F F b c c c
Wind {direction Wind {Beaufort Force	NE 2	NW. by N. 3	NNW. 3
Barometer (corr. to M.S.L.)	1044·8	1041·6	1040·1
Screen temperature {dry-bulb Screen temperature {wet-bulb	37·9 36·0	32·6 31·7	42·0 41·5
Visibility	6 mi.	100 yds.	2½ mi.

temperature inversion. A description will now be given of the life history of a typical radiation fog, and we shall be able to follow the sequence of events and the physical processes which led up to its formation, and to its ultimate dispersion or "lifting." The occasion selected is the morning of February 1, 1932. The normal meteorological observations made at 1800 on the previous day, and at 0700 and 1300 on the day itself are given in Table XXX. Details of the temperature structure of the atmosphere throughout this period are shown in Table XXXI.

TABLE XXXI—TEMPERATURE STRUCTURE DURING RADIATION FOG ON THE MORNING OF FEBRUARY 1, 1932

Date	G.M.T.	Temperature at the stated heights				
		1·2 m.	12·4 m.	30·5 m.	57·4 m.	87·7 m.
		° F.	° F.	° F	° F.	° F
January 31, 1932	1800	36·7	37·6	37·7	37·6	37·3
	1900	35·4	37·4	37·5	37·3	37·1
	2000	34·0	36·0	36·4	36·4	36·2
	2100	31·7	35·3	35·9	36·2	35·9
	2200	31·5	34·5	35·3	35·5	35·6
	2300	29·5	33·0	34·3	34·6	34·8
	2400	30·5	34·0	34·9	35·8	36·4
February 1, 1932	0030	28·9	33·2	34·3	35·5	35·6
	0045	28·5	33·1	34·4	35·4	35·3
	0100	27·5	30·3	31·9	32·5	33·4
	0115	28·8	29·0	29·6	30·7	32·6
	0130	29·1	28·8	28·8	31·2	33·8
	0200	29·3	28·9	28·7	32·1	35·3
	0300	28·3	28·3	31±	35±	37±
	0400	28·6	28·3	28·2	31·5	34±
	0500	30·2	30·2	30·7	31·4	33·2
	0600	31·0	30·8	31·9	33·5	34·4
	0700	32·5	32·6	33·3	33·6	34·3
	0800	34·5	34·7	35·0	35·6	36·2
	0900	36·4	36·3	36·5	36·7	37·1
	1000	38·4	38·0	37·9	37·7	37·8
	1100	39·6	38·8	38·6	38·3	38·2
	1200	42·6	41·6	41·3	40·9	40·8
	1300	42·1	42·6	42·4	42·2	41·9

Starting from 1800 on January 31, the sequence of events was as follows :—

Stage I (1800—2330).—The air temperature at 1·2m. fell progressively, exhibiting the fluctuations which are characteristic of strong outgoing radiation. The rate of fall of temperature was less rapid at greater heights, and thus produced the usual nocturnal inversion which, by about midnight, had reached a value of nearly 7° F between 1·2m. and 87·7m. Rather more than half this temperature difference occurred between 1·2m. and 12·4m. The dew point was reached at 2220, and at about 2230 the starshine trace was temporarily broken for some 35 minutes. It seems probable that this was caused by the temporary formation of some cloud of the alto type rather than fog, since the pole star again became visible from 2305 until 2330, when it was finally extinguished for the remainder of the night.

Stage II (2330—0045).—Although by this time the fog was sufficiently dense to obscure the sky, no apparent change occurred in the progress of the thermal phenomena until 0045—75 min. later. During this period the 1·2m. temperature trace retained its previous characteristics and the temperature inversion continued to grow. The fog was clearly allowing the long wave radiation from the ground to escape.

Stage III (0045—0200).—By 0045 the fog had attained sufficient density to stop an appreciable fraction of the outgoing radiation, and during the subsequent hour the temperature structure changed completely. The change first became apparent in the lowest differential trace, which shows that at 0045 the temperature at 12·4m. began to fall rapidly. At 0100 the temperature at 1·2m. ceased to fall, and the trace assumed the steady form normally associated with an overcast sky, showing that the outgoing radiation from the ground had now been stopped. The fall in temperature at 12·4m. amounted to about 4° F. in 25 minutes, and by 0130 it had resulted in the destruction of the inversion below this height and in its replacement by a lapse. What had taken place was clearly that the radiating surface had now risen from the ground to the upper portion of the fog.

At 0055 the temperature at the 30m. level also began to drop rapidly, and by 0130 it had fallen by about the same amount (4° F.). Similar falls in the temperature occurred in succession at the heights of the upper thermometer elements, although at 87·7m. the fall was only about 1 or 2° F. The fog did not extend to this height, and radiation at this level was less than from the top of the fog. The maximum temperature inversion consequently occurred below this height.

The alterations in the vertical temperature structure which took place during this stage are illustrated in Fig. 19. It is of particular interest to note that during this period the air temperature near the ground (1·2m.) remained sensibly constant,

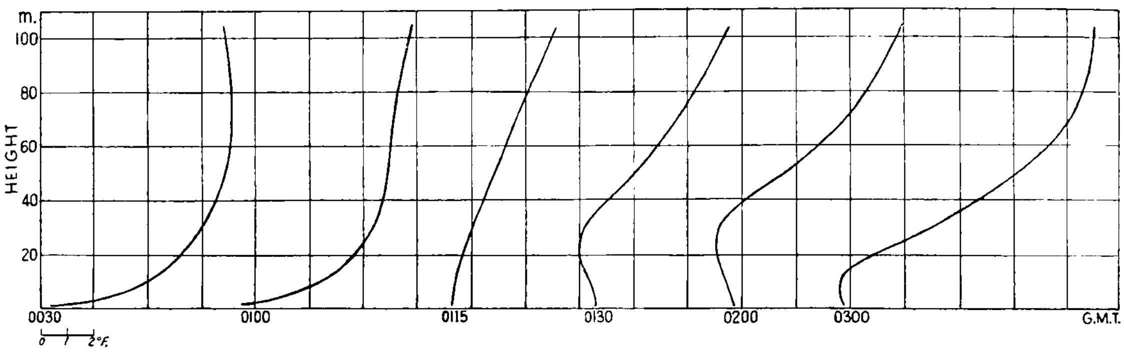


FIG. 19.—CHANGES IN LAPSE RATE DURING THE FORMATION OF RADIATION FOG ON FEBRUARY 1, 1932.

and that the changes in the temperature gradient were due almost entirely to the cooling of the air between heights of about 10m. and 50m., caused by the radiation emitted from the upper layers of the fog.

Stage IV (0200—0740).—The next stage takes us from about 0200 until sunrise, which occurred at 0740. During this period the air temperature at 1·2m., apart from a temporary fall at about 0300, rose fairly steadily. At first the rate of rise was slight, but by 0700 it had increased to 2° F. per hour. Part of this temperature rise was probably due to the inflow of warm air. At about 0100 the wind velocity had increased from 1m. sec. to about 3m./sec., whilst the wind direction gradually backed from 45° T.B. at 1800 to 330° T.B. at 0220. It is to be noted, however, that the rate of rise of temperature was more rapid at 1·2m. than at 87·7m. This difference must be attributed to the fact that the fog was behaving as a black body, and the heat radiated upwards from the ground was being absorbed in the lowest few metres of the atmosphere. Some of this heat was being conveyed upwards by eddy conduction, as is indicated by the lapse rate between 1·2m. and 12·4m., which on the average was steeper than the adiabatic value.

As the depth of the fog increased, the magnitude of the temperature inversion below 87m. steadily diminished, until at sunrise the temperature difference between 12·4m. and 87·7m. was only about $1\frac{1}{2}$° F. By this time the fog probably extended above 87·7m.

Stage V (0740—1300).—After sunrise the air temperature at 1·2m. continued to rise at 2° F. per hour until 1100, when evaporation of the fog near the ground had proceeded to a stage at which the fog appeared to break up and " lift." At this time the negative lapse rate had just reached to the top of the mast. Occasional bursts of diffused sunshine penetrated through to the ground at 1115 and 1130, but the fog eventually won the day, and at 1300 it had formed a cloud sheet with base at about 160m. (500 ft.). With the lifting of the fog, radiation from the ground was able to escape again, and accordingly we find the air temperature at 1·2m. ceasing to rise, and even falling slightly after 1200. This resulted in the formation of a small but well-marked inversion between 1·2m. and 12·4m., which reached a maximum value of 0·9° F. at 1310, and then gradually fell to zero at about 1500. The cloud sheet formed by the " lifting " of the fog was still at the same estimated height at 1800.

The main features described above occur in all radiation fogs examined, although naturally there are minor differences from one occasion to another. Thus, on the morning of October 11, 1931, the formation of a shallow fog resulted in very large and rapid fluctuations of the temperature at 1·2m. The magnitude of these fluctuations was about 6° F., and they were accompanied by a very large inversion between 1·2m. and 12·4m. On this occasion the depth and patchiness of the fog were such that the outgoing radiation from the ground was cut off only intermittently.

It is of interest to examine the lifting of the fog on February 1, 1932, in the light of thermodynamical considerations. If the aspirated dry- and wet-bulb temperatures at 0700 are plotted on a tephigram, it will be found that the irreversible saturation adiabatic through the wet-bulb temperature intersects the dry adiabatic through the dry-bulb reading at a barometric pressure corresponding to an altitude of 170m. (550 ft.) above the ground. This is the height at which the air near the ground would be expected to condense its water vapour as cloud under these conditions. The agreement between this and the estimated height of 160m. (500 ft.) to which the fog " lifted " is interesting.

In view of this apparent success in applying the tephigram, an examination was made of a number of other occasions of radiation fog, to ascertain whether the tephigram could be used to predict the behaviour of the fog from the dry and wet-bulb readings at 0700. It was found that the method failed even in the winter months. The question whether radiation fog will persist, lift or disperse is thus apparently determined in most cases by factors which affect the environment, and the application of the tephigram is possible only on the relatively few occasions when the environment is not altered by outside causes. The case of February 1, 1932, considered above appears to have been one such occasion.

ACKNOWLEDGMENTS

In concluding this preliminary account of the records obtained at Leafield, the authors wish to acknowledge with gratitude the courtesy of the G.P.O. authorities, for permitting the erection of our apparatus upon one of their wireless masts, and for the facilities which they so willingly provided for the maintenance of the meteorological station at Leafield.

We also wish to express our indebtedness to Mr. W. R. Selway, who was the Assistant there throughout the period covered by this paper. He was primarily responsible for the maintenance of the instruments and the preliminary analysis of all the charts, whilst his numerous supplementary remarks in the daily Register of observations have proved of the greatest value in our investigations.

We are indebted to Mr. R. L. Stear who was in charge of the station during the earlier part of the period, and to various members of the staff of the Meteorological Department of the Experimental Station, Porton, for the part which they played in rendering this investigation possible. In particular we would mention the names of Mr. A. J. Lander and Mr. W. A. Toms, whose mechanical skill and ingenuity were of the greatest value in the construction and erection of the technical equipment.

Finally, we wish to thank Professor Brunt for having originally suggested to us the erection of such a station at Leafield, for the interest which he has shown at all times, and for certain suggestions and criticisms which he has kindly offered in the drafting of this paper.

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