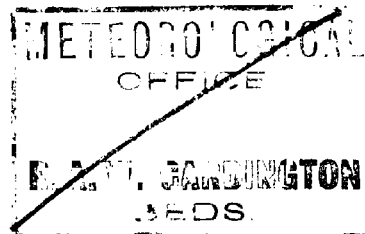


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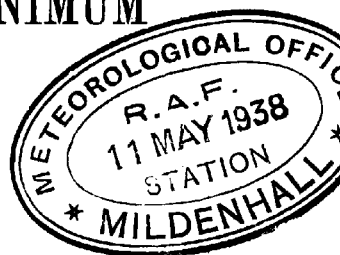
PROFESSIONAL NOTES No. 43

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SOME EFFECTS PRODUCED BY PROTECTIVE SHIELDS ON THE READINGS OF GRASS MINIMUM THERMOMETERS

By

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SOME EFFECTS PRODUCED BY PROTECTIVE SHIELDS ON THE READINGS OF GRASS MINIMUM THERMOMETERS

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ABSTRACT.

The paper describes five series of experiments conducted at Kew Observatory with the object of determining the extent of the influence of shields (in the form of rectangular wire cages) on the temperatures recorded by grass minimum thermometers. The results are discussed in detail, some considerations on the probable reasons for the effects obtained are submitted and a recommendation based on the results is proposed for the use of observers.

It has long been known that the temperature recorded by grass minimum thermometers was influenced by the proximity of neighbouring bodies. When, therefore, the necessity arose of recommending some kind of protective covering to observers whose thermometers were exposed near tennis courts or golf courses, systematic observations were required to determine the magnitude of error which would be introduced by the use of a shielding wire cage and to decide whether differences in the means of support of the cages would have any decided effect on the records obtained. With this end in view several series of observations have been conducted at Kew Observatory using three grass minimum thermometers and two wire cages. The conditions were varied in each series either by dismantling parts of the cages, altering the methods of support or arranging that different distances separated them on the ground, thus ensuring varying conditions of mutual shielding.

Series I.—The most extensive series* of observations was made with the thermometers exposed under conditions shown† in Fig. I.

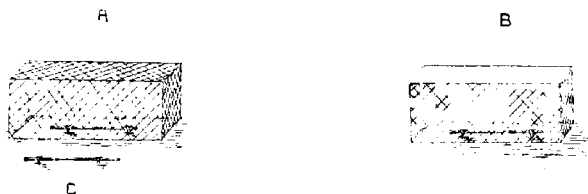


FIG. 1.

In position A the thermometer was centrally supported 1 inch from the ground on Y-shaped pegs under an enclosing wire cage (20 in. \times 10 in. \times 7 in.) of galvanised iron wire $\frac{3}{4}$ -in. mesh and $\frac{1}{16}$ -in. diameter. In position B a second thermometer was

* See Note I. (p. 14).

† See Note II. (p. 14).

supported within a similar cage from which the "lid" had been removed; while the thermometer indicated in position C was freely exposed except in so far as its supports lay only some 6 inches to the west of cage A. The bulbs were in each case oriented towards north with thermometer B south of A. They were set each day at 18 h. and read at 9 h. the following day. To eliminate any individual peculiarities which might exist even after the appropriate corrections had been applied to the recorded temperatures, the thermometers were systematically interchanged in their positions of exposure weekly. Finally, the overhead conditions obtaining on each night of exposure were noted from the observational Pocket Register and the classification into five groups made on that basis.

The Basis of Comparison.—In the tables which give the results of this and subsequent observations, the entries are mean corrected temperatures in degrees Fahrenheit attained under the conditions shown in the first column. The mean differences in the fourth and fifth columns are measures of the elevation of temperature produced by protections A and B over that of the freely exposed record and it is to be noted that these differences are not precisely the same differences as would have been obtained had the exposure of C been perfectly free. For, with the exception of one or two of the series, the configuration of the thermometers was such that the distance of neighbouring cages was not sufficiently great to ensure that no protection was afforded. This was made evident when the temperatures recorded by C were compared with those of the Kew standard grass minimum thermometer over the same series of exposures. This suggests that the records of the Kew instrument would serve as a better standard of reference from which to gauge the protective influence of the cages in their various positions than the thermometer C. But a difficulty arises from the fact that it cannot be assumed that the Kew standard thermometer itself is entirely free from protective influence.* For a low square metal fence six feet side and 12 inches high round the site of exposure serves to warn night observers of the proximity of exposed glass; and, further, although the shielding effect of such a fence may be small, and was certainly constant throughout a series, the same guard ring was not in use throughout all the experiments to be described, a different (somewhat higher) fence having served the same purpose prior to March 1923. Since that formerly in use was destroyed when replaced by the newer fence it becomes impossible to obtain a definite estimate of the comparative protections offered. The records of the temperatures of C will therefore be used as reference for comparison with those of A and B in the present investigations. In several of the series of observations the mean difference obtaining between C and the standard exposure (over the individual series) will allow an estimate to be made of the relative amounts of shielding arising from the proximity of the cage to the "freely exposed" C.

* See Note III. (p. 14).

TABLE I.—MEAN TEMPERATURES AND OVERHEAD
CONDITIONS IN SERIES I.

Conditions of Exposure.	No. of Obs.	A	B	C	A—C	B—C
		° F.	° F.	° F.	° F.	° F.
All Available Nights - -	327	37·7	37·5	37·1	0·6	0·4
Overcast Nights - - -	131	39·6	39·5	39·2	0·4	0·3
Nights of Rain - -	93	39·0	38·9	38·6	0·4	0·3
Mainly Clear Nights - -	57	36·3	36·0	35·5	0·8	0·5
Nights of Frost - -	82	25·1	24·8	24·2	0·9	0·6
Nights of Fog - -	21	30·3	29·9	29·4	0·9	0·5

Results.—Table I gives a resumé of the results obtained from a series of 327 settings of the thermometers in the positions indicated in Fig. 1. For practical purposes, the differences (A—C) and (B—C) in columns 4 and 5 may be grouped into two classes: first, that derived from nights of rain and overcast skies when effective radiation was very much restricted: and, secondly the group comprising nights of clear or mainly clear sky, nights of frost and nights of fog. In the first class, the influence of the two cages on the thermometers beneath (as gauged from the magnitude of the differences, 0·4° and 0·3° F.) was masked by the more general protection offered by cloud and increased humidity. Even the absence of the “lid” does not make itself markedly felt. In the other group of overhead conditions, except for nights of fog, the comparatively clear sky allowed scope for extensive radiation on the part of C, while the effect of the obstruction offered by the cages is shown by correspondingly increased differences, 0·9° and 0·5° F. The position of nights of fog at first sight seems an anomalous one for fog would appear to function as a “blanket” as effectively as a clouded sky in restricting radiation. The fact that the depression of the temperature of C is comparable with that of clear sky conditions seems to indicate that over the range of these observations at Kew, the majority of fogs must have been of the radiation type in which the minimum temperature was attained just prior to, or during, the actual formation of fog.

In this series of experiments the mean excess of the recorded temperature C over that of the Kew standard was 0·2° F. This means that the proximity of the cage A to the “freely exposed” thermometer C exerted a greater shielding influence on the latter than the guard exerted on the Kew thermometer to the extent of 0·2° F. Hence the mean differences (A—C) and (B—C) for all available nights in columns 4 and 5 of Table I require to be increased by 0·2° F. to allow a direct comparison with the Kew standard exposure. That is, if the shielding effect of the low fence round the standard site be assumed to have a

negligible influence, the virtual effects of the cages A and B on all nights are to raise the temperatures of the enclosed thermometers by 0.8° and 0.6° F. respectively. Corresponding adjustments require to be made to the mean differences derived from each specific set of overhead conditions.

Table II shows the distribution of differences (A-C) and (B-C) for intervals of 0.2° F.

TABLE II.—DISTRIBUTION OF DIFFERENCES (A-C) AND (B-C) FOR INTERVALS 0.2° F.

Difference.	-0.9 or -1.0	-0.7 or -0.8	-0.5 or -0.6	-0.3 or -0.4	-0.1 or -0.2	0	0.1 or 0.2	0.3 or 0.4
A-C	—	2	3	7	16	23	60	46
B-C	1	1	1	6	30	36	98	37

0.5 or 0.6	0.7 or 0.8	0.9 or 1.0	1.1 or 1.2	1.3 or 1.4	1.5 or 1.6	1.7 or 1.8	1.9 or 2.0	2.1 or 2.2	2.3 or 2.4
32 32	40 34	35 24	24 11	13 9	8 4	8 —	7 1	1 2	2 —

The effect of the greater completeness of the shield A is shown by the greater dispersion of the higher differences of (A-C) throughout the table. Thus, while only 85 (or 26 per cent.) of the total number of exposures of B recorded temperatures greater than 0.6° F. in excess of those of C, 138 (or 42 per cent.) out of the 327 showed A with a temperature exceeding C by more than 0.6° F. The number of occasions on which A read the same as, or differed by only 0.1° or 0.2° from, C is correspondingly small. The occurrences of records of A and B below that of C seem to be unwarrantably large. But of these, while a few are accounted for by the failure of one or other of the thermometers either through undetected rupture of the thread, imperfect setting or erroneous reading, a larger proportion seem to be attributable to the difficulty of reading precisely to 0.1° F. Of the total number of 28 occurrences of negative differences for (A-C), 12 (or 43 per cent.) are only -0.1° and 16 (or 57 per cent.) either -0.1° or -0.2° : of the negative differences of (B-C), 19 (or 49 per cent.) and 30 (or 77 per cent.) fall into the corresponding categories.

Finally, Table III shows for this series of experiments the frequency and mean magnitude of the differences (A-C) and (B-C) for intervals of 5° F., the intervals being defined by the temperature recorded by C.

TABLE III.—FREQUENCY AND MEAN MAGNITUDE OF THE DIFFERENCES (A-C) AND (B-C).

Temperature, °F., by C.	10.1 to 15	15.1 to 20	20.1 to 25	25.1 to 30	30.1 to 35
No of Observations - -	1	15	28	43	62
Mean Magnitude (A-C) ° F. -	1.1	1.3	0.9	0.7	0.5
Mean Magnitude (B-C) ° F. -	0.8	0.8	0.4	0.3	0.5

35.1 to 40	40.1 to 45	45.1 to 50	50.1 to 55	55.1 to 60	60.1 to 65
45	53	41	26	12	1
0.7	0.5	0.3	0.3	0.5	0.1
0.5	0.3	0.2	0.1	0.2	0.2

In the region of moderate ground temperatures as recorded by the least protected of the thermometers C, the mean difference (A-C) is greater by one or two tenths of a degree Fahrenheit than the mean difference (B-C). Further, the excess of the former becomes greater as the temperature indicated by C is further removed from the neighbourhood of 32° F., especially on the lower side. This result seems evident in view of the differences considered in Table I. Nights of unusually low temperatures are, in the main, nights of clear sky and, therefore, most efficiently conducive to extensive radiation. In these cases, the shielding effect of the lid of cage A is of relatively greater importance than in nights of moderate or higher ground temperature which are the usual concomitants of cloudy or overcast skies.

Series II.—The general deductions to be drawn from the experiments described above are also indicated in two other sets of observations made with the three thermometers under different conditions of protection and proximity. In the first of these the same two cages were used. But while exposure A remained unchanged B was fitted with its lid and mounted 1½ inches from the ground by inserting four wooden pegs at

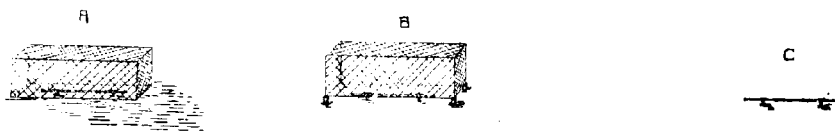


FIG. 2.

the corners. The position of C was changed from being west of A at a distance of 6 in., to south of both A and B. Some 6 ft. separated B from both A and C so that, in this series, the exposure of C did approximate to more perfect freedom from shielding. The relative position of the three thermometers is shown in Fig. 2. Readings were taken for about three months in the early part of 1923. The results are set out in Table IV.

TABLE IV.—MEAN TEMPERATURE, DIFFERENCES AND OVERHEAD CONDITIONS IN SERIES II.

Conditions.	No. of Obs.	A	B	C	A - C	B - C
All available nights.	94	° F. 35.2	° F. 35.0	° F. 34.2	° F. 1.0	° F. 0.8
Overcast - - -	43	39.3	39.2	38.5	0.8	0.7
Rain - - -	47	37.6	37.3	36.7	0.9	0.6
No Frost - - -	65	38.2	38.1	37.5	0.7	0.6
Nights of Clear Sky - - -	20	30.8	30.7	29.2	1.6	1.5
Frost - - -	29	28.5	28.1	26.7	1.8	1.4
Nights of Fog - - -	20	32.1	32.0	31.0	1.1	1.0

Results.—Most noticeable are the uniformly higher differences (A-C) and (B-C) obtained with the thermometers in the present situation as compared with those of the larger series of observations discussed above. This *apparently* greater protection may be due to several causes. The results are derived from a smaller number of exposures (94) made at a season of the year when the mean ground temperature is lower than a truly representative set would require. Out of the total number of 94 nights of the observations, frost occurred on 29 (or 31 per cent.) while of the previous set only 25 per cent. were made under similar conditions. Now Table III showed a tendency to exaggeration of the difference with decreasing temperature, so that it is probable that at least part of the effect may be attributed to these facts. Again, the new position of C indubitably contributes a few tenths of a degree to the increased differences. For a mean of the Kew standard readings covering the time of exposure in this series gives a result of 24.4° F. which is 0.2° F. *higher* than that derived from the thermometer in the C position. This seems to point to the fact that either the old protecting guard which was in use at this time put the standard in a less favourable position from the point of view of a minimum of shielding consistent with good protection than that installed after March of that

year—or else there may have been some individual peculiarities existing between the three thermometers used in these experiments and the standard, peculiarities which were not eliminated by systematic interchanging. It is impossible to assign the cause of the relation between C and the standard definitely to either of these facts, but since the difference between the two guards cannot have been very great, certainly not great enough to account for all of the 0.4°F. difference between C and the standard in this and the previous series, C must have been in a decidedly less shielded site in the present series of exposures. Part of the increase in the mean differences (A-C) and (B-C) is, therefore, undoubtedly due to this fact. With these considerations in mind the mean excesses of the temperatures of A and B over C do not appear so unaccountably large in comparison with the longer set. Then it only remains to point out that the difference between the entries in the two columns of differences has been reduced in the direction to be expected from the results of the other series.

Series III.—To test whether the remaining differences depend more on the fact that cage B was insulated and raised from the ground slightly above the level of the bulb than that the entire cage is further from the bulb and, therefore, subtends a smaller angle there another configuration of the cages was arranged as shown in Fig. 3.

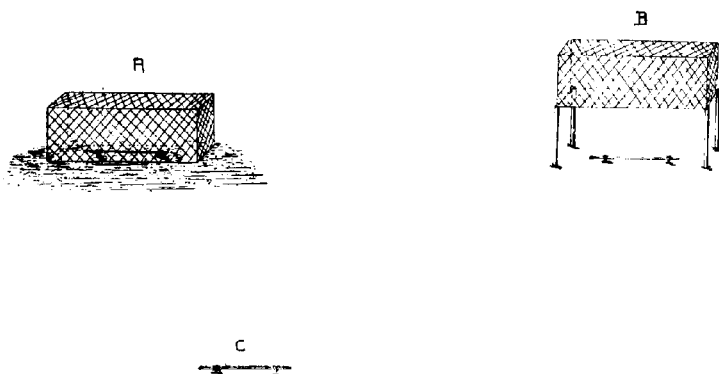


FIG. 3.

While exposure A was maintained unaltered, cage B was mounted on four wooden corner supports of such a height that the lower edge of the frame was 9 in. from the ground. Both cages were fitted with lids and provision was made to eliminate mutual protection as far as possible by placing the thermometer supports so that their bulbs would form an equilateral triangle of 5 ft. side. The mean corrected temperatures recorded from a series of approximately two months (June and July, 1924) are shown in Table V.

TABLE V.—MEAN TEMPERATURES AND OVERHEAD CONDITIONS
IN SERIES III.

Conditions.	No. of Obs.	A	B	C	A—C	B—C
		° F.	° F.	° F.	° F.	° F.
All available nights -	59	48·0	48·0	47·5	0·5	0·5
Overcast nights -	14	48·6	48·7	48·3	0·3	0·4
Nights of Rain - -	23	49·6	49·7	49·4	0·2	0·3
Clear Sky - - -	20	45·4	45·1	44·6	0·8	0·5

Results.—The effectiveness of the isolation of thermometer C in the position shown may be gauged from the fact that its mean recorded temperature over the range of observations is 47°·5 F., an exact agreement with that of the standard Kew instrument. Hence, since the new guard fence surrounding the latter is taken as having an inappreciable shielding effect, the differences (A—C) and (B—C) in the 4th and 5th columns are real measures of the efficiency of the protection afforded by the cages. The mean excesses of the readings of A and B over those of C for all available nights show an equality which is at first surprising in view of the differences of angle subtended by the cage in the two cases. The inverted direction of difference in the groups “rain” and “overcast” is no less surprising. Neglecting the fact that the duration of this series of tests was not long enough to justify perfectly representative deductions, the results appear to illustrate the equalising tendency shown in part in the previous experiments. In Series II, though the cage in position B was further removed from the bulb than A and even offered $\frac{1}{2}$ in. of free space between the bottom edge of the cage and the horizontal plane through the bulb, the expected differences in columns A and B seemed to be largely offset by some other opposing factor arising either from the insulation or the elevation of the cage. The influence of the equalising factor (or factors) has gained in importance when B has been raised another $7\frac{1}{2}$ in., till now the means (A—C) and (B—C) are identical and with clouded overhead conditions, the relative positions of A and B have been inverted. With clear sky, however, the difference between the protection in the two exposures seems to be of the same order of magnitude as before.

The results of these last two series of observations suggest that the raising of the cage introduces some new factor, possibly of a convectional nature, which tends to neutralize the opposing tendency of enhanced scope for pure radiation. While this effect has a preponderating influence on overcast nights, simple radiation still seems to be the most potent factor in deciding the minimum temperature attained under clear sky conditions which are

43. 10 *Prof. Notes, 43.—Some Effects produced by Protective*

generally co-existent with still air. With allowance for the excess of mean temperatures indicated by C over the standard Kew grass minimum thermometer in the first set of experiments described, the mean differences (A-C) in that and the present series are quite comparable—of the order of 0.5° F. for all available nights and 0.8° and 0.3° F. for clear and overcast conditions, respectively. The differences (B-C) are likewise comparable except under the circumstances discussed above.

Table VI shows the frequency of the distribution of the differences (A-C) and (B-C) for this series of experiments. It does not lend any new aspect to the discussion.

TABLE VI.—FREQUENCY OF DISTRIBUTION OF DIFFERENCES (A-C) AND (B-C) IN SERIES III.

Difference.	—0.6	—0.3	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.1
	to —0.4	to —0.1	to 0.2	to 0.5	to 0.8	to 1.1	to 1.4	to 1.7	to 2.0	to 2.3
(A-C) -	-	5	18	12	10	6	5	1	2	-
(B-C) -	2	3	13	16	12	8	4	-	-	1

Series IV.—Another question which calls for attention in a consideration of the general effects produced by cage protections is that of the existence of any marked influence derivable from direct conduction of heat through the frame in the case of the cage resting immediately on the ground. This was fairly well settled by $2\frac{1}{2}$ months of observations under conditions shown in Fig. 4.

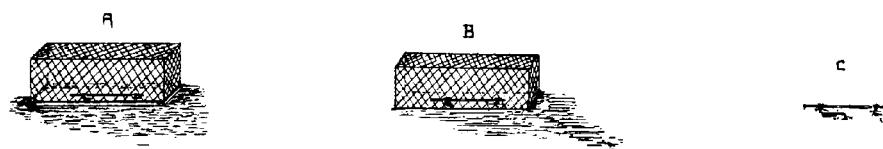


FIG. 4.

The protected thermometers A and B were under similar cages (those used in previous experiments) both being fitted with lids. But while the cage covering B was placed directly on the ground, that covering A rested on a wooden frame $\frac{1}{2}$ -in. thick and of sufficient breadth to allow the cage a seating. This minimised direct conduction and at the same time permitted no open space which might introduce other factors.

Table VII gives a summary of the results obtained.

TABLE VII.—MEAN TEMPERATURES AND OVERHEAD CONDITIONS IN SERIES IV.

Conditions of Exposure.	No. of Obs.	A	B	C	(A-C)	(B-C)
		° F.	° F.	° F.	° F.	° F.
All available nights -	77	32.5	32.5	32.0	0.5	0.5
Overcast nights -	42	35.7	35.7	35.3	0.4	0.4
Nights of Rain - - -	25	32.7	32.6	32.2	0.5	0.4
No Frost - - - -	35	38.1	38.1	37.9	0.2	0.2
Clear Sky - - - -	25	26.8	26.7	26.0	0.8	0.7
Frost - - - -	42	27.9	27.9	27.1	0.8	0.8
Fog - - - -	18	30.8	30.6	30.0	0.8	0.6

Results.—Although there will be a slight difference in angle subtended by the cage wires at the bulbs of the thermometers in the two cases, the consequent effect in stopping radiation (as shown by the previous experiments) cannot influence the records to a greater extent than one or two tenths of a degree. Hence the mean differences (A-C) and (B-C) in the last two columns show conclusively that the insertion of the insulating frame has no appreciable effect in deciding the final temperature. This is equally true of all groups of overhead conditions. A table of the distribution of the differences shows no new features.

Series V.—Any effects produced by unrestrained air currents under the wire shields were not permitted by the direct contact of wooden and wire frames in the last experiment. In order to get an idea of the magnitude of the influence of any such effects a limited number of exposures were made in which the cage A with its frame was raised on four wooden blocks 1½ in. high; Cage B (without the frame) was raised to the same height by similar pegs. Otherwise the relative positions of the thermometers and protections were the same as in the experiment just described.

TABLE VIII.—MEAN TEMPERATURES AND OVERHEAD CONDITIONS IN SERIES V.

Conditions of Exposure.	No. of Obs.	A	B	C	A-C	B-C
		° F.	° F.	° F.	° F.	° F.
All available nights - -	7	27.8	27.4	25.9	1.9	1.5
Overcast nights	4	30.0	29.7	28.5	1.5	1.2
Nights of no Frost	1	38.0	38.0	37.0	1.0	1.0
Nights of Clear Sky	3	24.9	24.3	22.3	2.6	2.0
Nights of Frost - -	6	26.1	25.6	24.0	2.1	1.6

Table VIII shows the mean recorded temperatures in the three positions. Although both columns (A-C) and (B-C) include differences which would tend to point to a very real effect in the raising of the two cages, the description of the conditions obtaining over the exposures (especially the large percentage of nights of frost) and the very limited number of exposures made would not allow any definite deductions to be drawn from them.

Note on the Estimation of the Angle Subtended by the Cage at the Bulb of the Thermometer.—In one or two of the configurations of the cages described in the foregoing experiments an attempt was made to estimate the solid angle subtended by the cage wires at the bulb of the thermometer beneath with a view to assisting in deciding whether an observed set of differences could be attributed to pure radiation or extraneous effects. For it seems that, if, in the long series of experiments I, say, the excess of the difference (A-C) over (B-C) on nights of clear sky corresponded with the excess of solid angle subtended by the material of cage A over that subtended by the material of cage B at the respective bulbs (since B had no lid) then, in any other similar configuration it might be possible to judge from the divergence of the differences (A-C) and (B-C) from those given by the ratio, $\frac{A-C}{B-C} = \frac{\text{Solid angle subtended by A.}}{\text{Solid angle subtended by B.}}$ whether any other factors played an extensive part in the recorded temperatures.

To estimate the angle in series I, exposure A, the area of a longitudinal cross-section of an inch of the cage wire was integrated over all the wires of each face of the cage. The cage was then considered as divided into two portions by a vertical plane perpendicular to the thermometer, one portion symmetrical with the bulb, the remaining part further removed from it. The integrated areas of wire for each face were sectioned in the same way as the faces, concentrated into continuous surfaces and treated as sections of spherical surfaces at the respective mean distances. That portion of the cage below a horizontal plane through the bulb was disregarded, as contributing no obstruction to radiation additional to the ground itself.

The estimate by this method of the solid angle subtended by the complete cage at the bulb of the thermometer (as in series I, exposure A) is $2\frac{1}{3} \omega^*$, while that for the cage without lid as in B is approximately $1\frac{1}{3} \omega$. Thus in position A the solid angle subtended is some 80 per cent. greater than in B. But now, if, as mentioned in the discussion of the results of experiment I, fog at Kew be considered largely radiational and, therefore, generally indicative of existing clear sky conditions, the mean elevation produced by A on clear sky nights is $0.9^\circ \text{ F. } (\frac{1}{3}\{0.9 + 0.8 + 0.9\})$: while that by B is $0.5^\circ \text{ F. } (\frac{1}{3}\{0.6 + 0.5\})$

*Where ω is one "solid radian" or the solid angle subtended at the centre of a sphere by an area on the surface of the sphere equal to the square of the radius.

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The estimate by this method of the solid angle subtended by the complete cage at the bulb of the thermometer (as in series I, exposure A) is $2\frac{1}{4} \omega^*$, while that for the cage without lid as in B is approximately $1\frac{1}{4} \omega$. Thus in position A the solid angle subtended is some 80 per cent. greater than in B. But now, if, as mentioned in the discussion of the results of experiment I, fog at Kew be considered largely radiational and, therefore, generally indicative of existing clear sky conditions, the mean elevation produced by A on clear sky nights is $0.9^\circ \text{ F. } (\frac{1}{3}\{0.9 + 0.8 + 0.9\})$: while that by B is $0.5^\circ \text{ F. } (\frac{1}{3}\{0.6 + 0.5^\circ$

*Where ω is one "solid radian" or the solid angle subtended at the centre of a sphere by an area on the surface of the sphere equal to the square of the radius.

+ 0.5° }), that is, the percentage elevation produced by the lid of A is of the order of 80 per cent. above that of B. For the group "overcast" the mean value (A-C) is 0.4° F., and (B-C) 0.3° F., that is, A's capacity for protection is apparently so reduced as to be only 33 per cent. better than B's. This seems to indicate that, if it be assumed that the effect of the screen on clear sky nights is almost entirely one of prevention of radiation, other factors (among which convection may not be the least important) become more potent in deciding the final minimum under conditions of rain or overcast sky. The results of the other series of experiments may be considered on the same basis.

It is to be noticed that in the above crude method of arriving at an estimate of the angles formed by the cages, mere area of wire has been considered. No account has been taken of the fact that for radiation purposes (as to a much greater extent in the electrical analogue) the shielding effect of a wire may require a considerable extension of its influencing field beyond the wire itself. To test this point the wire protections used in all the above observations have been replaced by circular metal discs supported by thin wire rods. The angles subtended by these discs at the bulbs of the thermometers placed centrally beneath them could be estimated. One disc, in particular, was of such an area as to subtend an angle equal to that estimated for the entire cage resting immediately on the ground. The results obtained, though not sufficiently numerous to show a decided relation, seem to indicate that there is a physical basis for the assumption that the "field" of the wire extends no further than the metal.

Final recommendation for observers.—The tenor of the foregoing experiments and the outstanding facts which it would be to the advantage of observers to keep in mind are summarized below :—

(1) Any form of screen in the vicinity of a grass minimum thermometer will result in an increase of the temperature recorded. Even a screen situated entirely on one side of it and not actually extending over it produces an appreciable effect.

(2) Hence, if the thermometer is to serve its proper function of recording the *lowest* temperature, its exposure should be as perfectly open as it is possible to make it.

(3) If any screen is used, it is desirable that the wires be as thin as possible.

ADDITIONAL NOTES

I. (p. 2). The series was actually the fourth in order of time, the observations being made between May 1923 and May 1924. All the thermometer readings taken prior to 31st December 1924 were made by Mr. C. H. Kellett, then Resident Observer at Kew; only those subsequent to that date were made by the author of the present paper.

II. (p. 2). The wires of the back and further side of the cages in this and subsequent diagrams are omitted for clearness.

III. (p. 3). Throughout the experiments described in this paper, the exposure site for the thermometers was on the lawn in the grounds of the Observatory, the only considerable natural shield being provided by a hedge 4 feet high, at a mean distance of 30 feet.