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VERTICAL TEMPERATURE GRADIENT IN THE FIRST 2,000 FT.

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Introduction.—A number of publications have described in detail the variations which occur in the vertical temperature gradient in the surface layer of the atmosphere up to a height of 300–400 ft. The data for such investigations have usually been obtained from instruments mounted on a tower or mast, and it is this which has limited the height to which the observations were made. Temperature gradient in the atmosphere from 2,000 ft. upwards has also been extensively studied on the basis of radio-sonde observations. The region between about 350 ft. and 1,500 ft. is an awkward one since it is normally out of reach of towers and masts, and the radio-sonde is quite unsuitable for giving anything other than a very broad picture of the temperature variations which occur at these heights. Yet this region is of considerable interest meteorologically.

For a number of years a captive balloon has been used at Cardington, Bedfordshire, to lift meteorological instruments to heights which have varied with circumstances to a maximum of about 4,000 ft. The routine ascents have been made at 0730, 1200 and 1800 G.M.T. (0700 instead of 0730 in late spring, summer and early autumn) and observations of dry-bulb and wet-bulb temperatures and wind speed have been taken at fixed heights up to the ceiling of the balloon. During most of the period under review these heights were 4, 30, 50, 100 and 250 ft. and then at intervals of 250 ft. They were based upon the length of balloon cable paid out, and inevitably this introduced some error in the assumed height of the instruments, but it is believed that the error seldom exceeded 10 per cent. of the nominal height, and in light winds would be appreciably less. Although every effort was made to ensure regularity a number of ascents were missed for the usual reasons associated with kite balloons. The usual surface meteorological observations were also made at the time of each ascent.

In order to ensure homogeneity in the observations used the investigation described below was restricted to the lowest 2,000 ft., that height having been reached by the balloon on all the ascents analysed.

Analysis of the data obtained from the routine balloon ascents made during a period of four years from March 1949 to February 1953 has not yielded any surprising results. The value of the analysis resides in the fact that it has provided quantitative and detailed data for a region of the atmosphere on which there is little detailed published information. For this reason it has been considered preferable to present the results in the form of tables, which are easy to read, rather than in the form of graphs, which have a greater visual appeal but are less suitable for giving numerical answers.

The variables which might be expected to affect the vertical temperature gradient are time of day, season, state of sky and wind speed. The observations were therefore grouped according to these parameters. State of sky was divided into three categories, 0 or 1 okta of low or medium cloud, 2–6 oktas of low or medium cloud and 7 or 8 oktas of low or medium cloud. In the following paragraphs these states have been designated clear sky, cloudy sky and overcast respectively for convenience of writing. Wind speed was divided into the classes 0–10 kt., 11–20 kt., etc., the wind being measured at 1,500 ft. Foggy occasions have been treated separately.

Midday temperature gradient.—A survey of the mean results for 1200 G.M.T. showed that almost all conformed to a common pattern. In the lowest layers there was a rapid fall of temperature with height, the magnitude of the lapse rate decreasing with increasing height. At greater heights the temperature can be represented by a linear function of height. The mean temperatures at each height for each of four seasons, three states of sky and three wind-speed groups were plotted (36 curves in all), and it was found that all sets of points except one could be fitted reasonably well by a curve from 4 to 250 ft. and a straight line from 250 to 2,000 ft. Since the main purpose of this note is to describe the temperature structure between 250 and 2,000 ft. Table I accordingly gives the fall of temperature from 4 to 250 ft., the mean temperature gradient from 250 to 2,000 ft. and the number of ascents upon which the figures are based. Eight points were plotted on each curve from 250 to 2,000 ft. inclusive. A quick examination showed that in 35 of the 36 curves the departures of the points from the straight lines were less than 0·3°F. for 261 of the 280 points plotted, never exceeded 0·5°F., and were not systematic. It must be borne in mind, however, that the curves themselves are mean curves.

TABLE I—VERTICAL TEMPERATURE STRUCTURE* AT 1200 G.M.T.

State of sky	Temperature change between 4 and 250 ft. for wind speeds			Temperature gradient between 250 and 2,000 ft. for wind speeds			Number of ascents with wind speeds		
	0–10 kt.	11–20 kt.	21–30 kt.	0–10 kt.	11–20 kt.	21–30 kt.	0–10 kt.	11–20 kt.	21–30 kt.
oktas	*degrees Fahrenheit*			*degrees Fahrenheit per 1,000 ft.*					
Spring (March–May)									
0, 1	−2·5	−2·7	−2·7	−4·2	−3·9	−3·2	15	11	5
2–6	−2·2	−2·6	−2·2	−4·5	−4·5	−4·1	21	24	3
7, 8	−2·1	−1·7	−1·3	−4·5	−4·3	−3·7	16	25	5
Summer (June–August)									
0, 1	−3·1	−4·1	−3·0	−4·8	−4·9	−4·5	10	8	5
2–6	−2·7	−3·4	−2·5	−4·7	−4·8	−4·6	34	42	8
7, 8	−2·3	−2·8	−2·1	−4·5	−4·5	−4·1	18	24	6
Autumn (September–November)									
0, 1	−3·1	−2·2	−1·3	−4·2	−4·1	−3·6	11	9	8
2–6	−2·7	−2·6	−2·0	−4·4	−4·4	−3·6	15	35	10
7, 8	−1·8	−1·6	−1·4	−3·6	−3·9	−3·6	19	42	24
Winter (December–February)									
0, 1	0·0	−1·1	−1·2	†	−2·9	−3·6	8	21	12
2–6	−1·7	−1·4	−1·0	−4·5	−3·4	−3·1	7	17	17
7, 8	−1·0	−1·1	−0·9	−2·5	−2·9	−2·2	25	31	26

*An inversion is indicated by a positive sign, a lapse by a negative.

†Temperature structure in different form.

Table I shows that the variation of temperature gradient with state of sky and wind speed is small and not well defined. The main variation however is seasonal, the mean seasonal values of temperature gradient being 4·1, 4·6, 3·9 and 3·1 °F./1,000 ft. in spring, summer, autumn and winter respectively. The variation of temperature change below 250 ft. with wind speed is small and rather irregular. There are however clear indications that it decreases with increasing cloudiness.

The mean of the ascents made in winter with light winds and clear skies did not conform to the general picture, there being a more or less isothermal region from 4 to 750 ft. surmounted by a lapse rate of about 1·9°F./1,000 ft. Examination of the weather reports for these eight ascents showed that mist was of frequent occurrence and this probably accounts for the rather irregular result.

Temperature structure at 1800.—The temperature structure at 1800 G.M.T. is set out in detail in Table II, and follows a fairly coherent pattern. In the summer the lapse from 4 to 250 ft. decreases from the midday value to about 1·0–2·0°F. and at 1800 is not much affected by either cloud amount or wind speed. Above 250 ft. the lapse rate remains approximately the same as at midday irrespective of wind and cloud.

By 1800 in autumn however the surface inversion has become established. Under typical radiation conditions—light winds and clear sky—it reaches a height of about 300 ft. with a temperature there about 5°F. warmer than at 4 ft. Increasing cloud both lowers the height of the inversion and diminishes the magnitude, overcast skies and light winds being associated with an inversion reaching to lower than 100 ft. and with a magnitude less than 1°F. The effect of increasing wind (at 1,500 ft.) is not quite so straightforward. Under clear and cloudy skies an increase from 5 to 15 kt. in the mean wind speed has little effect on the height of the inversion though the magnitude is diminished. A further increase in wind speed both lowers the top of the inversion and again decreases the strength. Under overcast skies the height and strength of the inversion are so small even with 5-kt. winds that one can deduce no more than a weakening of the inversion and lowering of the top with increasing wind speed. In all circumstances the inversion is surmounted by a lapse rate a little smaller than that occurring in the summer.

The winter table seems somewhat irregular. Generally the inversion reaches to 300–500 ft. under clear and cloudy skies and to 100–200 ft. under overcast skies irrespective of wind speed. The magnitude of the inversion tends to diminish with increasing cloud but the variation with wind speed is irregular. In an attempt to clarify the picture the December and January figures were separated from the February values thereby ensuring that all ascents were made after sunset. The irregularities remained. It seems likely that the irregularities are associated with the greater liability to mist in the winter months.

The spring ascents present a comparatively simple picture. The inversion is very weak at 1800 and is restricted to the lowest 100 ft. Above this height the normal lapse rate occurs.

Temperature structure at 0700.—In summer Table III shows that a lapse occurs from 4 to 2,000 ft. in all conditions. With clear or cloudy skies and light winds the lapse rate is small, since the inversion established during the night must be broken down before the normal day-time lapse can become established.

TABLE II—VERTICAL TEMPERATURE STRUCTURE* AT 1800 G.M.T.

Wind at 1,500 ft.	State of sky	Difference between temperatures at 4 ft. and at a height (in feet) of 30	50	100	250	500	750	1,000	1,250	1,500	1,750	2,000	Number of ascents
kt.	oktas	*degrees Fahrenheit*											
		Spring (March–May)											
0–10		+0·5	+0·5	+0·6	+0·1	−0·9	−2·2	−3·2	−4·4	−5·7	−6·6	−7·6	16
11–20	0, 1	+0·1	0·0	0·0	−0·4	−1·5	−2·7	−3·7	−4·6	−5·5	−6·4	−7·6	18
21–30		0·0	0·0	−0·1	−0·6	−1·6	−2·5	−3·1	−3·7	−4·5	−5·2	−5·9	8
0–10		+0·5	+0·5	+0·4	−0·2	−1·4	−2·5	−3·7	−5·0	−6·3	−7·4	−8·7	14
11–20	2–6	+0·7	+0·9	+1·0	+0·6	−0·2	−1·3	−2·6	−3·6	−4·9	−6·1	−7·3	18
21–30		+0·3	+0·4	+0·2	−0·2	−1·1	−2·0	−3·2	−4·3	−5·5	−6·5	−7·8	4
0–10		+0·8	+0·8	+0·5	−0·1	−1·2	−2·5	−4·1	−5·3	−6·2	−7·3	−8·2	3
11–20	7, 8	−0·1	−0·1	−0·3	−0·8	−1·8	−2·9	−4·2	−5·4	−6·6	−7·8	−8·9	13
21–30		+0·1	+0·1	−0·2	−0·9	−2·0	−2·8	−3·6	−4·2	−4·9	−5·6	−6·3	8
		Summer (June–August)											
0–10		−0·2	−0·1	−0·2	−1·0	−2·3	−3·4	−4·8	−5·9	−7·3	−8·6	−9·6	14
11–20	0, 1	−0·6	−0·9	−1·1	−1·9	−3·2	−4·4	−5·6	−7·1	−8·2	−9·2	−10·3	17
21–30		−0·5	−0·7	−1·1	−1·5	−2·9	−4·3	−5·4	−6·4	−7·6	−8·5	−9·5	4
0–10		−0·1	−0·3	−0·5	−1·2	−2·2	−3·5	−4·8	−6·1	−7·4	−8·6	−9·9	20
11–20	2–6	−0·4	−0·6	−0·9	−1·5	−2·7	−3·8	−5·2	−6·5	−7·6	−8·8	−10·9	26
21–30		−0·5	−0·7	−0·9	−1·5	−2·4	−3·6	−4·8	−6·0	−7·3	−8·5	−9·6	7
0–10		−0·3	−0·6	−0·8	−1·4	−2·5	−3·8	−4·9	−6·0	−7·2	−8·3	−9·3	18
11–20	7, 8	−0·3	−0·2	−0·6	−1·3	−2·4	−3·4	−4·6	−5·9	−7·0	−8·1	−9·3	15
21–30		−0·3	−0·6	−1·0	−1·7	−2·8	−4·2	−5·3	−6·5	−7·4	−8·5	−9·5	8
		Autumn (September–November)											
0–10		+2·2	+3·0	+3·9	+4·9	+4·6	+3·6	+2·6	+1·7	+0·6	−0·2	−1·2	18
11–20	0, 1	+1·6	+2·2	+3·0	+3·5	+3·5	+2·8	+1·8	+0·8	−0·3	−1·2	−2·2	23
21–30		+1·3	+1·9	+2·2	+2·6	+2·5	+2·5	+2·0	+1·2	+0·3	−0·8	−1·8	16
31–40		+1·0	+1·5	+1·5	+1·4	+0·8	+0·3	−0·3	−1·0	−1·7	−2·4	−2·9	7
0–10		+1·0	+1·5	+2·4	+2·7	+2·2	+1·5	+0·4	−0·7	−1·9	−3·1	−4·2	10
11–20	2–6	+0·8	+1·5	+1·8	+1·9	+1·5	+0·5	−0·6	−1·7	−2·8	−3·9	−4·7	18
21–30		+0·5	+0·6	+0·8	+0·5	−0·1	−1·0	−2·0	−3·2	−4·4	−5·3	−6·4	9
31–40		+0·4	+0·4	+0·6	+0·6	+0·5	+0·3	0·0	−0·4	−1·0	−1·4	−2·0	2
0–10		+0·5	+0·7	+0·7	+0·3	−0·5	−1·3	−2·3	−3·2	−4·2	−5·1	−5·9	15
11–20	7, 8	+0·1	+0·1	0·0	−0·3	−0·9	−1·8	−2·7	−3·6	−4·5	−5·5	−6·4	18
21–30		+0·2	+0·3	+0·3	−0·1	−0·8	−1·7	−2·5	−3·4	−4·3	−4·9	−5·6	19
31–40		−0·1	−0·3	−0·2	−0·6	−1·3	−2·3	−3·0	−3·7	−4·0	−4·9	−5·6	3
		Winter (December–February)											
0–10		+1·5	+2·1	+2·8	+3·3	+3·2	+2·9	+2·1	+1·5	+0·5	−0·7	−1·6	10
11–20	0, 1	+1·3	+1·7	+2·2	+2·6	+2·4	+2·0	+1·3	+0·4	−0·4	−1·4	−1·9	17
21–30		+1·0	+1·4	+1·9	+2·5	+2·9	+2·6	+2·0	+1·1	+0·1	−0·9	−1·7	21
31–40		+2·1	+2·4	+2·6	+2·8	+2·8	+2·6	+2·2	+1·6	+1·3	+0·9	+1·0	5
0–10		+0·7	+1·1	+1·6	+1·7	+1·0	0·0	−0·8	−2·0	−2·7	−3·7	−4·7	5
11–20	2–6	+1·1	+1·7	+2·6	+2·9	+2·8	+2·2	+1·5	+0·7	−0·1	−0·8	−1·6	10
21–30		+1·7	+2·3	+2·7	+3·0	+3·6	+3·3	+2·6	+2·0	+1·1	−0·1	−0·8	4
31–40		...	...	...	...	...	...	...	...	...	...	...	0
0–10		+0·5	+0·6	+0·7	+0·7	+0·1	−0·8	−1·6	−2·6	−3·6	−4·6	−4·9	13
11–20	7, 8	+0·4	+0·6	+0·7	+0·7	+0·4	−0·3	−0·8	−1·3	−2·0	−2·8	−3·7	19
21–30		+0·2	+0·4	+0·3	0·0	−0·5	−1·3	−2·0	−2·7	−3·4	−3·8	−4·5	21
31–40		+0·2	+0·6	+0·6	+0·5	0·0	−0·6	−1·2	−1·3	−1·4	−1·7	−2·4	2

*An inversion is indicated by a positive sign, a lapse by a negative.

The figures for autumn reflect the conditions shortly after sunrise following 10–15 hr. of darkness. With light winds and a clear sky the inversion extends up to 1,000 ft. with a magnitude exceeding 9°F. A cloudy sky reduces the height to about 700 ft. without greatly affecting the magnitude of the inversion, but an overcast sky has a marked effect, bringing the inversion top down to 250 ft. and the magnitude of the inversion to 0·6°F. In passing it may be noted that an overcast sky probably has a greater effect than indicated here since the number of ascents made in November for the three lines of this part of the table referring to 0–10 kt. were 0, 1 and 6 respectively. The figures for an overcast sky are thus more nearly representative of sunrise conditions than the values for clear and cloudy skies. The effect of increasing wind speed is to diminish the magnitude of the inversion, but under clear or cloudy skies the height is not affected until the wind at 1,500 ft. exceeds 30 kt.

TABLE III—VERTICAL TEMPERATURE STRUCTURE* AT 0700 G.M.T.

Wind at 1,500 ft.	State of sky	Difference between temperatures at 4 ft. and a height (in feet) of 30	50	100	250	500	750	1,000	1,250	1,500	1,750	2,000	Number of ascents
kt.	oktas	degrees Fahrenheit											
		Spring (March–May)											
0–10	0, 1	−0·3	−0·1	−0·2	−0·3	+0·3	+0·7	+1·2	+1·2	+0·9	+0·3	−0·6	17
11–20		+0·2	+0·3	+0·3	+0·4	+0·4	+0·4	+0·5	+0·3	+0·1	−0·5	−1·2	19
21–30		−0·1	0·0	−0·2	−0·7	−1·4	−1·7	−2·0	−2·2	−2·3	−2·9	−3·3	20
0–10	2–6	−0·4	−0·5	−0·8	−1·2	−2·3	−2·6	−3·0	−3·3	−4·2	−5·0	−5·8	6
11–20		−0·2	−0·4	−0·5	−0·9	−1·8	−2·4	−2·6	−2·8	−3·5	−3·8	−4·2	9
21–30		−0·3	−0·1	−0·5	−1·0	−1·8	−2·4	−3·5	−4·4	−5·0	−5·8	−6·7	11
0–10	7, 8	0·0	−0·1	−0·2	−0·5	−1·2	−1·7	−2·3	−3·0	−3·6	−4·5	−5·4	16
11–20		−0·2	−0·2	−0·5	−0·8	−1·7	−2·2	−2·8	−3·1	−3·2	−3·7	−4·3	21
21–30		−0·2	−0·1	−0·3	−0·7	−1·5	−2·2	−2·5	−2·8	−2·8	−3·1	−3·6	26
		Summer (June–August)											
0–10	0, 1	−0·2	−0·3	−0·5	−0·9	−1·0	−1·1	−1·3	−1·8	−2·5	−3·1	−3·7	33
11–20		−0·8	−0·9	−1·2	−1·5	−2·1	−2·5	−2·7	−3·0	−3·5	−4·0	−4·4	28
21–30		−0·5	−0·6	−0·8	−1·4	−2·5	−3·2	−3·5	−3·4	−3·8	−4·5	−5·0	14
0–10	2–6	0·0	−0·2	−0·3	−0·4	−1·0	−1·4	−2·0	−2·5	−3·2	−3·7	−4·1	14
11–20		−0·6	−0·9	−1·2	−1·9	−3·0	−4·1	−4·9	−5·7	−6·5	−7·2	−7·9	23
21–30		−0·5	−0·7	−1·0	−1·6	−2·7	−3·5	−4·2	−4·9	−5·8	−6·6	−7·0	11
0–10	7, 8	−0·2	−0·4	−0·7	−1·2	−2·1	−2·9	−3·8	−4·3	−4·9	−4·9	−5·4	18
11–20		−0·5	−0·6	−0·8	−1·7	−2·2	−2·7	−2·8	−2·9	−3·5	−4·2	−4·8	17
21–30		−0·2	−0·4	−0·5	−1·3	−2·3	−3·1	−3·6	−4·2	−4·8	−5·4	−6·2	20
		Autumn (September–November)											
0–10	0, 1	+0·6	+1·1	+2·5	+4·4	+7·9	+9·0	+9·3	+8·7	+8·2	+7·9	+7·4	8
11–20		+0·5	+0·9	+1·6	+2·3	+4·6	+5·8	+5·9	+5·6	+4·9	+4·1	+3·3	11
21–30		+0·3	+0·7	+0·7	+0·7	+1·1	+1·7	+2·3	+1·8	+1·4	+0·8	+0·1	11
31–40		+0·1	+0·2	+0·3	+0·4	−0·1	−0·3	−0·7	−0·4	−0·7	−0·9	−1·5	4
0–10	2–6	+2·5	+3·0	+4·1	+6·2	+8·3	+8·3	+7·7	+6·9	+6·2	+5·2	+4·5	6
11–20		+0·3	+0·5	+0·7	+1·0	+1·3	+1·5	+1·6	+1·1	+0·4	−0·5	−1·3	21
21–30		+0·3	+0·6	+0·8	+0·9	+1·5	+1·4	+1·5	+1·0	+0·4	−0·4	−1·2	20
31–40		+0·4	+0·3	+0·4	+0·1	0·0	−0·5	−0·9	−1·1	−1·1	−1·2	−1·8	4
0–10	7, 8	+0·1	+0·4	+0·4	+0·6	+0·5	+0·4	+0·1	−0·6	−1·3	−2·3	−2·4	12
11–20		0·0	0·0	0·0	−0·1	−0·1	−0·2	−0·5	−0·9	−1·4	−2·1	−2·8	30
21–30		+0·1	+0·1	−0·1	−0·5	−1·2	−1·9	−2·4	−2·9	−3·6	−4·2	−4·7	40
31–40		−0·3	−0·2	−0·3	−0·4	−1·3	−2·0	−2·4	−2·3	−2·0	−2·4	−2·3	4
		Winter (December–February)											
0–10	0, 1	+0·7	+1·2	+1·7	+2·7	+5·0	+6·5	+6·9	+6·4	+5·5	+4·5	+3·8	12
11–20		+1·0	+1·4	+1·8	+2·3	+3·2	+3·9	+3·7	+2·8	+2·0	+1·0	+0·2	15
21–30		+1·0	+1·4	+1·6	+2·0	+2·5	+3·4	+3·5	+2·9	+2·1	+1·1	+0·2	19
31–40		+1·2	+1·5	+1·6	+1·5	+1·4	+1·5	+1·5	+1·1	+0·8	+0·2	−0·6	11
0–10	2–6	+0·3	+0·8	+1·3	+2·3	+3·8	+4·6	+3·9	+3·2	+2·3	+1·8	+1·7	4
11–20		+1·1	+1·4	+2·0	+2·3	+3·2	+3·9	+3·7	+3·0	+2·4	+1·6	+0·7	10
21–30		+0·2	+0·5	+0·6	+0·4	−0·1	−0·5	−1·1	−2·0	−2·5	−3·4	−4·3	9
31–40		+0·3	+0·7	+0·7	0·0	0·0	−0·7	−1·3	−2·0	−2·7	−3·4	−4·3	7
0–10	7, 8	+0·3	+0·5	+0·9	+1·5	+1·8	+1·4	+0·9	+0·3	−0·7	−1·4	−2·0	15
11–20		+0·3	+0·3	+0·3	+0·4	+0·6	+0·5	+0·2	−0·6	−1·3	−2·1	−2·7	35
21–30		+0·2	+0·4	+0·3	+0·1	−0·5	−0·9	−1·4	−1·9	−2·0	−2·2	−2·7	29
31–40		0·0	+0·2	+0·1	−0·1	−0·5	−0·9	−1·3	−1·5	−2·3	−2·8	−3·1	7

*An inversion is indicated by a positive sign, a lapse by a negative.

The picture in winter is generally similar to that in autumn though the inversions under radiation conditions do not attain the same magnitude as in autumn. The reason may well be the prevalence of mist as mentioned in connexion with the temperature structure at 1800. The 76 ascents contributing to the clear sky, wind 0–30 kt., parts of the table for autumn and winter were examined individually and the height of the inversion determined. The distribution of the heights was as follows:—

250 ft. or below	12 ascents	1,000 ft. ...	27 ascents
500 ft. ...	2 ascents	1,250 ft. ...	7 ascents
750 ft. ...	28 ascents		

Winter contributed 9 of the 12 low heights and both the 500 ft. inversions but otherwise there was very little difference between the two seasons.

The figures for clear skies and light winds in spring are interesting for showing that by 0700 the early morning sun has established a weak lapse in the lowest layer, but that the inversion still persists at higher levels. With 11–20-kt. winds at 1,500 ft. the greater turbulence has caused greater mixing and the atmosphere is practically isothermal up to 1,500 ft. The 21–30-kt. winds were probably associated with weaker and lower inversions during the preceding night and the early morning sun is thus able to build a lapse throughout the whole layer. The figures for cloudy and overcast skies call for little comment other than to say that the lapses shown probably follow comparatively weak and shallow inversions during the night.

Temperature structure through early morning fog.—The inversion of temperature which is found in the lower layer of the atmosphere following a clear calm night results from the cooling of the earth's surface by outgoing radiation. If fog forms in this layer the passage of radiation through the layer is hindered but the fog itself radiates. Provided the fog is sufficiently dense there will then be very little net loss of radiation from the surface of the earth but considerable cooling will occur at the upper surface of the fog. Within the fog mixing will be promoted by the sinking of air which has been cooled by radiation from the upper surface. The vertical temperature profile would therefore be expected to consist of a region with a lapse rate between the isothermal and saturated-adiabatic in the fog, and an inversion above the fog top. The inversion should be limited to a depth comparable with the depth of the inversion above the surface after a clear night and the temperature gradient should then change first to isothermal and then to a lapse with increasing height. Such a structure has in fact been discussed in *Geophysical Memoirs* No. 89[1] in relation to observations made on a tower extending to 350 ft. above the surface, but, apart from an isolated meteorograph ascent in fog by L. H. G. Dines (reported by Capt. F. Entwistle[2]), there are little published data supporting this theoretical structure for greater heights.

A preliminary inspection showed that on many occasions when fog was reported at the time of the early morning ascent at Cardington the vertical temperature structure did conform to the pattern outlined. However, even after discarding a few occasions when there were indications of cloud above the fog, there were some occasions when the observations did not fit this picture. In passing it may be emphasized here that the data available did not allow certainty regarding the state of sky above fog. Accordingly the following analysis was carried out. For each occasion on which fog was reported at the time of the early morning ascent and there was no definite evidence of low cloud the temperature profile was examined to see whether it conformed to the pattern described above. Out of the 45 ascents made in fog in the early morning (and with no definite evidence of cloud above the fog) 33 profiles were of the shape expected and 12 were not. On these latter 12 occasions there was an isothermal layer near the surface but no well marked inversion at greater heights. The 33 profiles which fitted the pattern were then further examined, and an assessment made of the height of the top of the surface isothermal layer and of the height at which the temperature ceased to rise steeply. These assessments were based solely on the dry-bulb temperature. Naturally there were minor irregularities in the temperature profiles and to some extent these assessments were necessarily subjective, particularly with respect to the second height mentioned. In order to reduce the subjective element as much as possible the assessments were all made in terms of the actual heights at which observations were made. The total temperature increase between the first and second heights was also noted. A typical ascent is shown in Fig. 1. The results of this analysis are shown in Tables IV and V in terms of the height of the surface isothermal layer, the depth of the layer over which the temperature increased rapidly with height and the temperature increase through the inversion layer.

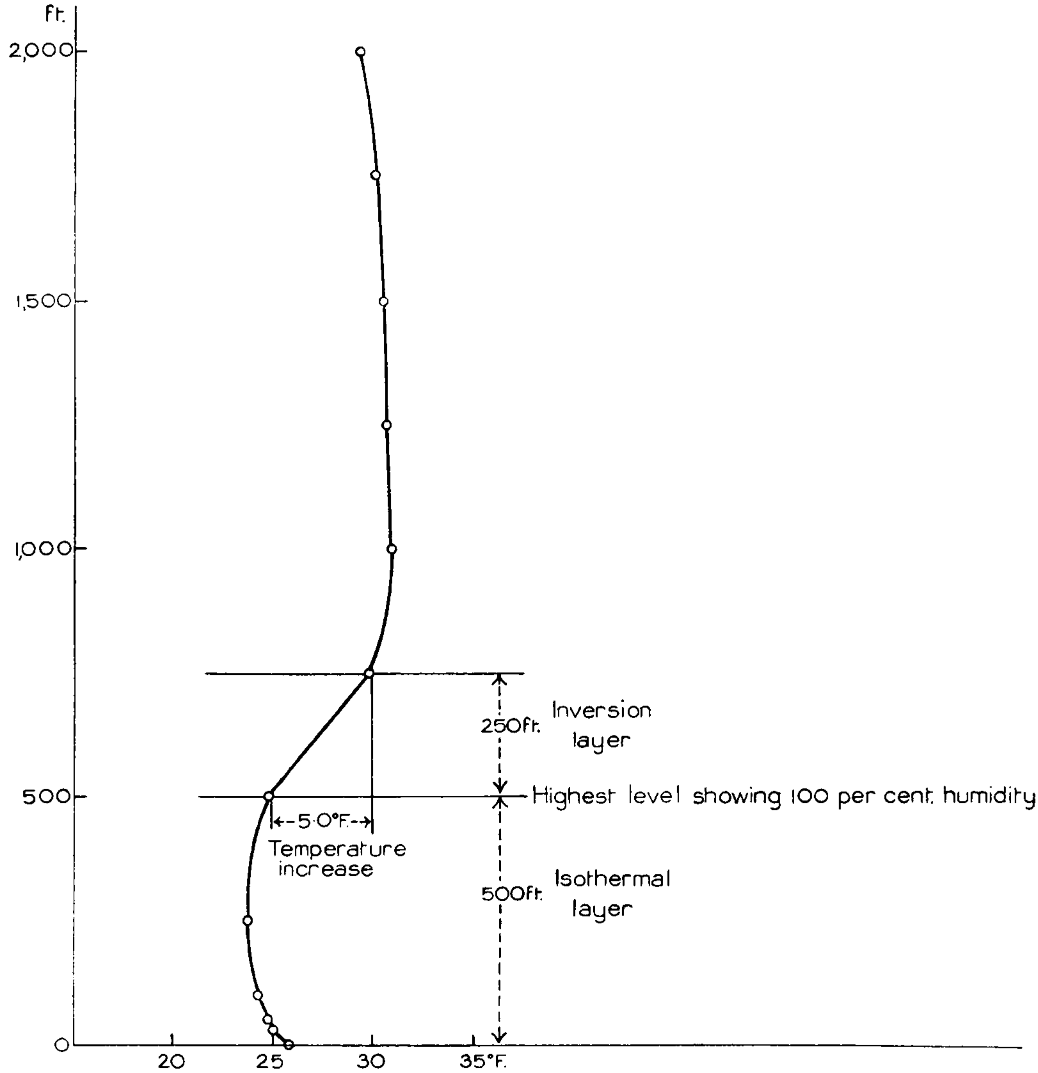

FIG. 1—TYPICAL BALLOON ASCENT THROUGH FOG, JANUARY 30, 1951
Surface visibility 250 yd.

Too much emphasis should not be placed on the details of these tables since, as already explained, the analysis was to some extent subjective and the assessments were restricted to heights at which observations were actually made. Nevertheless it does appear that in autumn the height of the isothermal layer tends to be smaller, and the thickness of the inversion layer greater, than in the other two seasons. There is little significance in the low frequency with inversion temperature increase less than 5°F. Small inversions would imply that the pattern is not easily recognizable, and may well have occurred in the 12 ascents which did not fit the pattern.

TABLE IV—FREQUENCY OF DEPTHS OF ISOTHERMAL AND INVERSION LAYERS ASSOCIATED WITH EARLY MORNING FOG

	Frequency of layers of depth 50–200 ft.	250–500 ft.	600–750 ft.	Mean depth	Number of ascents
	number of occasions			ft.	
	Surface isothermal layer				
Spring	3	6	5	430	14
Autumn	9	4	1	210	14
Winter	1	4	0	320	5
	Inversion layer				
Spring	2	11	1	390	14
Autumn	0	7	7	540	14
Winter	0	5	0	380	5

TABLE V—FREQUENCY OF INVERSIONS OF VARIOUS MAGNITUDES ABOVE FOG AT 0700 G.M.T.

	Frequency of inversion with increase of temperature < 5°F.	5–10°F.	10–15°F.	15–20°F.	Mean	Number of ascents
	number of occasions				°F.	
Spring ...	0	10	3	1	8·3	14
Autumn ...	1	8	5	0	9·5	14
Winter ...	0	4	1	0	7·8	5

The humidity observations for the 33 ascents were next examined. Naturally the lowest heights showed 100 per cent. relative humidity. The greatest height at which saturation was reported was noted for each occasion. On 19 of the ascents this coincided with the height of the isothermal layer; on 12 ascents saturation was reported above the top of the isothermal layer; on 1 occasion only the top of the isothermal layer had relative humidity less than 100 per cent. and on 1 occasion the humidity observations were missing. It seems a reasonable conclusion that what has so far been described as the isothermal layer is in fact the fog layer but that 100 per cent. relative humidity does occur above the top of the fog.

Reference was made on p. 238 to the necessity for the fog to be sufficiently dense if the temperature profile is to fit the simple pattern discussed. This suggests a reason for 12 of the profiles failing to fit the pattern. To test this the frequency distribution of visibilities for both the 33 cases which do fit and the 12 cases which do not was determined. The results are given in Table VI.

TABLE VI—FREQUENCY DISTRIBUTION OF VISIBILITIES IN THE EARLY MORNING FOGS

	Visibility (yd.) <101	101–200	201–300	301–400	401–500	501–600	601–700	701–800
Well marked inversion ...	17	11	3	1	1	...	...	...
No well marked inversion ...	1	2	3	...	3	...	1	2

We may conclude from this table that if the visibility is less than 200 yd. the temperature profile will probably contain a well marked inversion above the fog (this refers to early morning and radiation fogs only of course) but that if the visibility exceeds 300 yd. the inversion is not likely to be well marked. It is tempting to conclude that there might be a relation between the strength of the inversion and the visibility, but the observations do not show this. It is true that the greatest visibility noted which was associated with an inversion (440 yd.) accompanied the smallest inversion (temperature increase 2·1°F.) noted in the 33 cases, but the second greatest visibility in this class (400 yd.) was associated with an inversion temperature increase of 13·9°F.

The data available were tested for several other possible relations but without success. This is not surprising since the temperature profile through fog in the early morning is the result of the operation of several factors during the whole of the preceding night.

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SPEED OF MOVEMENT OF WARM FRONTS ON THE ATLANTIC

By C. H. HINKEL, B.Sc. and W. E. SAUNDERS, B.Sc.

Introduction.—One of the present writers, in the course of weather-forecasting duties, noted a tendency for warm fronts to move faster over the ocean than would be expected from empirical relations deduced from the movements of fronts over Great Britain. The relation of the motion of warm fronts to the geostrophic wind speed has been studied by Matthewman[1] for fronts over the British Isles, and it was decided to make a similar study of the motion of warm fronts on the eastern Atlantic. This note describes the results.

Data.—Surface working charts covering the period from January 1, 1951, to June 30, 1953, were examined for examples of warm fronts approaching the British Isles from the west or south-west which would satisfy the following conditions:—

(i) front well marked on the surface chart

(ii) both western and eastern positions of front fixed with reasonable accuracy from ships' observations and coastal stations of west Ireland, using the normal surface properties of warm fronts

(iii) network of observations such that the isobars were reliably determined

(iv) small isobaric curvature.

During the period considered 52 such examples occurred. The selected fronts were examined by measuring the distance moved by the front from its western to its eastern position. From this the mean speed of the front (u_F) was calculated. Next, the components of the geostrophic wind normal to the front at the initial and final positions were measured, and the mean of these two values was assumed to be the mean geostrophic component perpendicular to the front (u_J) during the period considered. Finally this last set of measurements was repeated using the normal component of the geostrophic wind 75–100 nautical miles ahead of the front and the mean of the two values (u_J') was obtained as before.

Method.—The regression equation of u_F on u_J (both measured in knots) was calculated to be

$$u_F = 0{\cdot}75\, u_J + 3{\cdot}7 \qquad \text{..........} \qquad (1)$$

with a root-mean-square residual of 5·9 kt. The correlation coefficient between u_F and u_J was found to be 0·87 and the regression line is illustrated in Fig. 1.

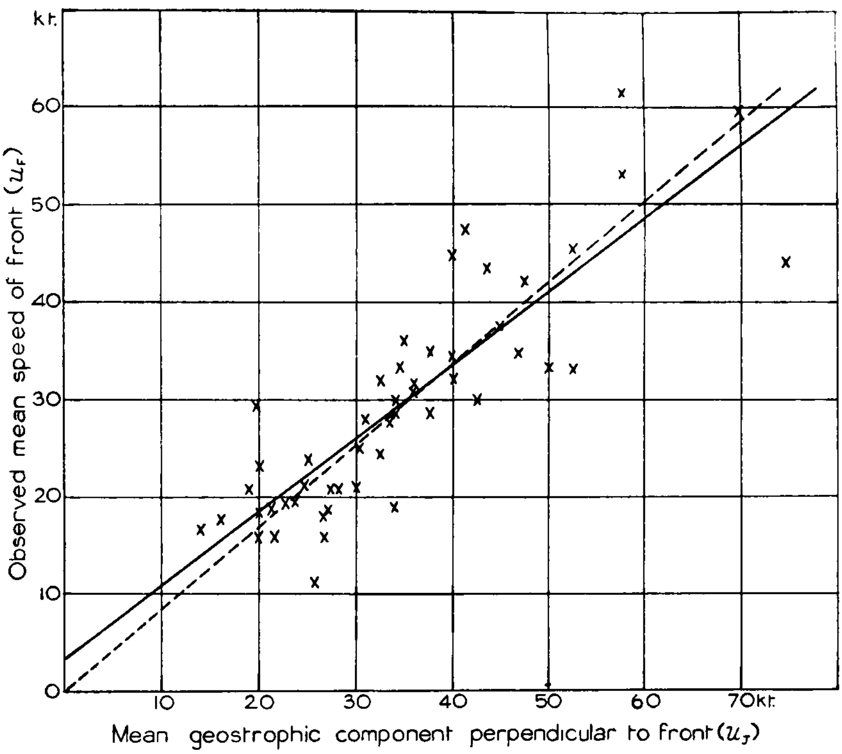


FIG. 1—RELATION BETWEEN SPEED OF FRONT AND GEOSTROPHIC WIND ACROSS THE FRONT

Full line represents regression line $u_F = 0 \cdot 75 u_J + 3 \cdot 7$

Broken line represents best fit through the origin $u_F = 0 \cdot 84 u_J$

The range of values of u_J in the 52 cases was from 11 to 70 kt., and as the constant term in the regression equation is small compared with such speeds, one would suppose that for practical purposes the use of a simple proportion of the geostrophic speed would be justified by the added convenience. The line of best fit through the origin was, therefore, calculated and found to be

$$u_F = 0 \cdot 84 \, u_J. \qquad \ldots\ldots\ldots\ldots \quad (2)$$

Following the procedure adopted by Matthewman, the above analysis was repeated using u_J' instead of u_J and the regression equation was found to be

$$u_F = 0 \cdot 91 \, u_J' + 2 \cdot 6 \qquad \ldots\ldots\ldots\ldots \quad (3)$$

with a root-mean-square residual of 4·6 kt. Fig. 2 shows the fit between this regression line and the data. The improved correlation (0·92) can be seen in the reduced scatter of the points about the line, and in this connexion it is worth noting that Matthewman obtained a similar improvement by using the geostrophic flow 75–100 miles ahead of the warm front.

The line of best fit through the origin was found to be

$$u_F = 0 \cdot 99 \, u_J'. \qquad \ldots\ldots\ldots\ldots \quad (4)$$

The main statistical results are summarized in Table I.

A comparison between the regression coefficients of equations (1)–(4) and the corresponding values obtained by Matthewman (see Table I) shows that the warm fronts over the Atlantic tended to move with a greater fraction of the geostrophic wind speed than those over land. In order to determine whether

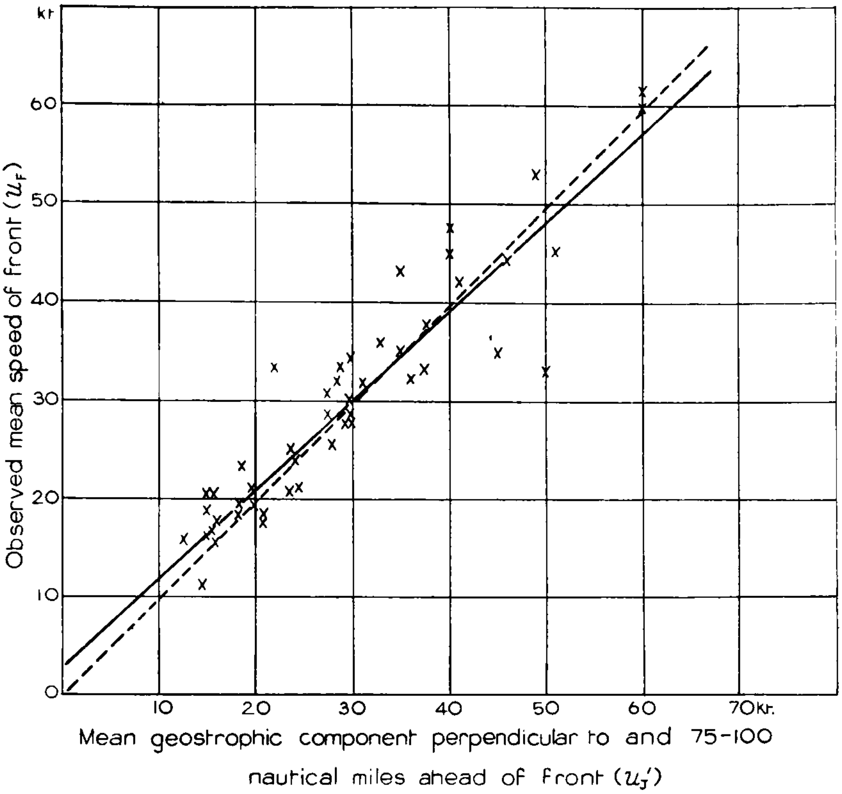


FIG. 2—RELATION BETWEEN SPEED OF FRONT AND GEOSTROPHIC WIND 75–100 MILES AHEAD OF FRONT

Full line represents the regression line $u_F = 0 \cdot 91\ u_J' + 2 \cdot 6$

Broken line represents the best fit through the origin $u_F = 0 \cdot 99\ u_J'$

this difference is significant, the differences between corresponding members of the four pairs of regression coefficients given in Table I were tested using "Student's" *t*-test and were found to be significant at the levels indicated in the third column of Table I. These levels vary from 4 to 12 per cent. and can be regarded as strong, but not conclusive evidence in favour of the contention stated above. It is, however, possible that the differences between the regression coefficients arose as a result of the method of selection of the data. In this

TABLE I—RELATIONS BETWEEEN u_F AND u_J OR u_J'

	Relations found in this note	Relations found by Matthewman	*t*-test significance level
			%
Number of cases … …	52	37	…
Correlation coefficients:			
u_F on u_J … … …	0·87	0·82	…
u_F on u_J' … … …	0·92	0·85	…
Regression lines:	*knots*		
u_F on u_J … … …	$u_F = 0 \cdot 75u_J + 3 \cdot 7$	$u_F = 0 \cdot 60u_J + 2 \cdot 1$	12
u_F on u_J' … … …	$u_F = 0 \cdot 91u_J' + 2 \cdot 6$	$u_F = 0 \cdot 70u_J' + 2 \cdot 3$	4
Root-mean-square residuals			
u_F on u_J … … …	5·9	5·2	…
u_F on u_J' … … …	4·6	4·7	…
Line of best fit through origin			
u_F on u_J … … …	$u_F = 0 \cdot 84u_J$	$u_F = 0 \cdot 67u_J$	8
u_F on u_J' … … …	$u_F = 0 \cdot 99u_J'$	$u_F = 0 \cdot 79u_J'$	5

connexion condition (iv), small isobaric curvature, is the only one which might conceivably affect the results. This condition was introduced in order that the geostrophic winds derived from the charts might approximate more closely to the actual winds. Matthewman's original data were therefore examined for examples of warm fronts which would have been excluded from the present analysis on these grounds, and nine cases falling into the category were found. The statistical relations previously obtained were recalculated using this revised data. The values obtained from this determination did not differ appreciably from the original set. However, it was thought desirable to apply the significance test to the new set of regression coefficients; the significance levels were not found to be materially changed. It is, therefore, justifiable to assume that the differences between the pairs of regression coefficients are genuine and did not arise as a result of either sampling or the selection conditions imposed. No attempt is made here to put forward a rigorous explanation for the increased speed of warm fronts over the Atlantic compared with speeds over land. We confine ourselves to suggesting that the result merely reflects the differences in frictional drag over the two types of surface.

Conclusion.—It would appear that for warm fronts moving over the ocean, the "two-thirds geostrophic speed" rule commonly used over the land may on most occasions be replaced by "five-sixths geostrophic speed". A better estimate is given by the full value of the geostrophic wind component perpendicular to the front measured 75–100 nautical miles ahead of the front.

REFERENCE

1. MATTHEWMAN, A. G.; Speed of warm fronts. *Met. Mag., London*, **81**, 1952, p. 266.

EFFECTS OF A WIND-BREAK ON THE SPEED AND DIRECTION OF WIND

By E. N. LAWRENCE, B.Sc.

Summary.—The following note describes the wind speed and direction to leeward of a wind-break, first in the horizontal plane at a height of about 6 ft. (referred to as ground level), and secondly in the vertical plane which passes at right angles through the centre of the barrier. The wind field at the end of the wind-break is also examined.

Two types of wind barrier are considered, one of which has a greater density than the other in the upper part of the screen.

The degree of shelter and the effect on wind direction were measured for a range of wind velocities and angles of incidence to the barrier. The wind speeds in the sheltered area have been calculated in terms of the speed of the "undisturbed" or "free" wind at the corresponding level for two types of atmospheric temperature lapse rate, which may be described as "large lapse rate" (referred to as unstable or lapse conditions) and "zero or small lapse rate" (referred to as stable or near neutral conditions).

Introduction.—During the period August 1937 to January 1938, a series of observations was made at Manby, Lincolnshire, to explore the suitability of wind screens for the reduction of the wind across runways[1]. The influence on wind of the two artificial barriers examined may be compared with that of natural shelter-belts of trees and shrubs of similar density, the use of which in agricultural work has commanded considerable attention in recent years. In conjunction with the Manby field experiment, wind-tunnel investigations were carried out at South Farnborough in August 1936 and October 1938; the results therefrom are summarized in the Appendix.

Method.—The wind-breaks were approximately 50 ft. high, 1,600 ft. long and 10 ft. wide and are shown in the photographs in the centre of this magazine. Details of the structure of the two barriers, given in Fig. 1, show that they consisted of three parallel frames, the two external frames being similar. The modified barrier was constructed by adding slats (shown by shading in Fig. 1) to the upper parts of the frames of the original barrier.

Wind speeds were measured by cup anemometers mounted on tripods for ground-level winds (at 6 ft.), and by cup anemometers mounted on a telescopic ladder (see photograph in the centre of this magazine) for winds at 30–55 ft. above ground. Each speed was obtained by averaging two or three runs, each run taking 3 min. For heights greater than those reached by the ladder (60 ft. upwards) winds were measured with zero-lift balloons. Flow conditions around the barrier were studied by means of balloons and smoke candles, the latter being observed every 10 sec. for several minutes. Wind directions were estimated by means of light tape fixed at one end to a cup anemometer. These observations were aided by ground markings, consisting of white lines, parallel to the barrier. The mean direction was obtained from observations every 5 sec. over a period of 1 min. Wind observations by cup anemometer were made at a height

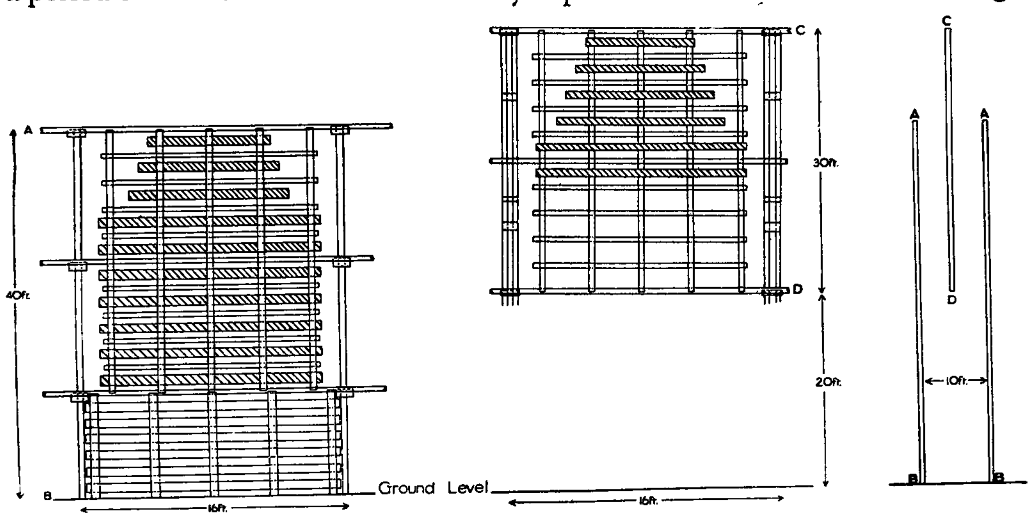


FIG. 1—DETAILED CONSTRUCTION OF THE WIND-BREAK

AB = external frame CD = internal frame

The additional slats of the modified wind-break are shown shaded.

of 6 ft. and at intervals of 5 ft. from 30 ft. to 55 ft. inclusive. In a horizontal plane, observations were made at 150-ft. intervals up to 450 ft. to leeward of the barrier and at 150-ft. intervals parallel to the barrier; at the "sheltered" end of the barrier, on the leeward side, the observation network was denser and generally on a 30-ft. or 60-ft.basis over the area in which the lines of equal "shelter" showed great curvature. Only one telescopic ladder was in use and observations were not simultaneous. It was not the general rule to "average" values for each point, although on occasions, two or more sets of observations were obtained for different values of the magnitude of the "free" wind. The speed and direction of the "free" wind were measured by a pressure-tube anemometer erected at the centre of the barrier-top. This instrument was suitably time marked against a stop-watch, so that observations of "free" wind could be compared with observations to leeward of the barrier.

Undisturbed winds below 9 m.p.h. were not sufficiently strong to give any definite results and the range of free speeds used in the calculations was 9–30 m.p.h. The wind directions were those corresponding to angles of incidence with the barrier of 0°, 15°, 30°, 45° and 60° for horizontal gradients and 15°, 30° and 45° for vertical gradients and 15° only for the examination of "end effect" of the wind field near the barrier end.

Calculation and representation of results.—Let v be the pressure-tube anemometer reading and assume* that this is the speed of the "free" wind at 50 ft.

Using Sutton's velocity-profile formula[2], we obtain

$$v_z = v\left(\frac{z}{50}\right)^{n/(2-n)}$$

where v_z is the free wind at the height z. According to Sutton[3], in lapse conditions $n = 1/5$, and in near neutral conditions $n = 1/4$, giving respectively

$$v_z = v\left(\frac{z}{50}\right)^{1/9}$$

and

$$v_z = v\left(\frac{z}{50}\right)^{1/7}.$$

Let u_z be the observed wind to leeward of the barrier at a height z and let $u_z = kv_z$. Then

$$u_z = kv\left(\frac{z}{50}\right)^{1/9} = k'v \text{ say (lapse conditions)}$$

and

$$u_z = kv\left(\frac{z}{50}\right)^{1/7} = k''v \text{ (near neutral conditions).}$$

Now the available data give the values of k' and k'' at different points. The corresponding values of k are given by:—

$$k = k'\left(\frac{50}{z}\right)^{1/9} \quad \text{(lapse conditions)} \quad \ldots\ldots\ldots\ldots \quad (1)$$

and

$$k = k''\left(\frac{50}{z}\right)^{1/7} \quad \text{(near neutral conditions).} \quad \ldots\ldots\ldots\ldots \quad (2)$$

All the observations were made during the day-time and not normally under inversion conditions. If we assume a high lapse rate (lapse conditions), then,

---

*The assumption that v is the speed in the open at 50 ft. appears to be reasonable in view of the vertical cross-section obtained by Bates and Stoeckeler of the United States Forest Service[4]. For a half-solid, 16-ft. barrier, the speed at a short distance above the top was found to be near to 100 per cent. of the speed at a corresponding height in the open. In the following results the degree of shelter would be over-estimated if the speed at the barrier top were under-estimated or if the height in the free air corresponding to this speed were under-estimated. For example, if the pressure-tube anemometer were actually recording 110 per cent. of v_{50},

$$v = (11/10)v_{50}$$
$$= (11/10)v_z(50/z)^{1/9} \text{ or } (11/10)v_z(50/z)^{1/7}$$

using Sutton's formula[2]. If the true value of k is k_T, then

$$k_T = u_z/v_z$$
$$= (11/10)\ (u_z/v)\ (50/z)^{1/9} \text{ or } (11/10)\ (u_z/v)\ (50/z)^{1/7}$$
$$= 11k/10.$$

Thus if v were actually 110 per cent. of the unobstructed wind at 50 ft. all values of k would have to be increased by 10 per cent.

using equation (1) and substituting the values of k' and k'' for different points, we obtain a set of curves on which $k = 0\cdot 2$, $0\cdot 4$, $0\cdot 6$, etc. Similarly, using equation (2) we obtain a set of curves for small lapse rates or near neutral conditions. These two sets of curves are a measure of the bounding positions of the lines of equal "shelter" or lines along which the ratio of the sheltered wind speed to the free wind speed at the corresponding height is constant. On a horizontal section, these lines would be lines of equal speed.

The results are shown in Figs. 2–8, speed of the wind being given by isopleths of the distribution of k and wind direction by means of arrows. Figs. 2–5 apply to the unmodified wind-break; Figs. 6–8 apply to the modified wind-break. It should be noted that the wind direction is within 5° of the angle of incidence quoted.

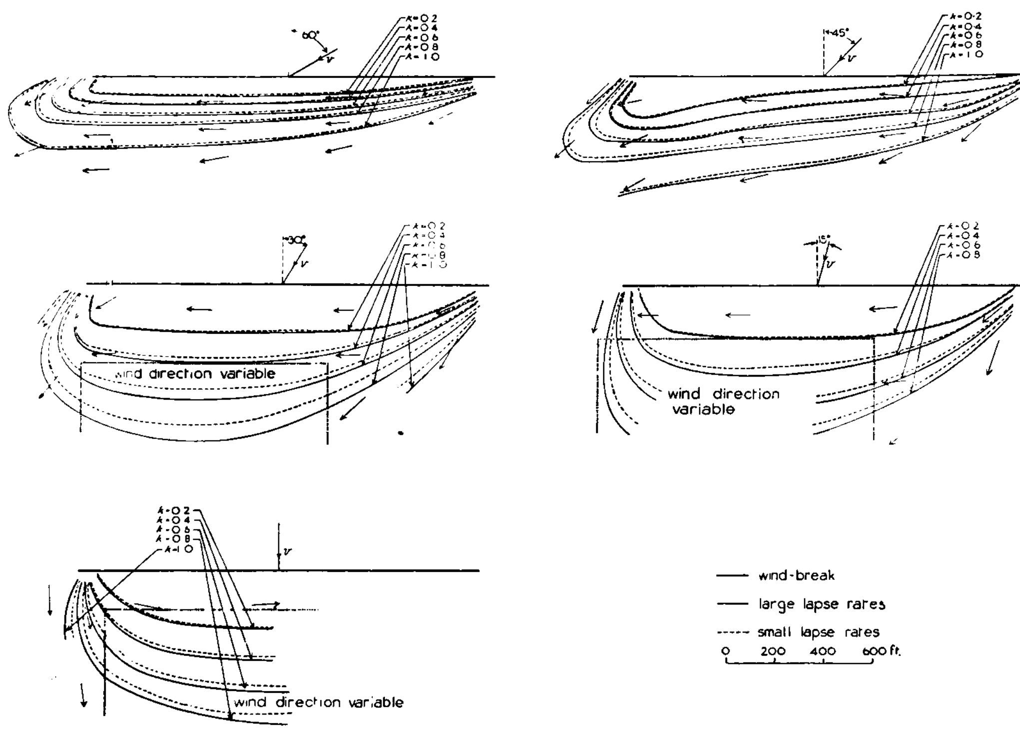


FIG. 2—HORIZONTAL DISTRIBUTION OF k AT GROUND LEVEL BEHIND THE ORIGINAL WIND-BREAK

Conclusions.—As the observations were carried out with a wind-break of height 50 ft. and length 1,600 ft. approximately, the conclusions apply primarily to a barrier with dimensions of this order. The same results cannot be expected with a barrier in which the aspect ratio (i.e. ratio of length to height) is much smaller.

Original wind-break.—The general form of the isopleths of k at ground level is similar for all wind directions. The shielded area decreases as the angle of incidence of the wind to the barrier increases, and the direction of the wind is altered so that the flow becomes approximately parallel to the screen and is smooth. The extent of the area in which the flow is parallel to the screen varies greatly with the angle of the wind. At the leeward end of the screen the flow is not smooth.

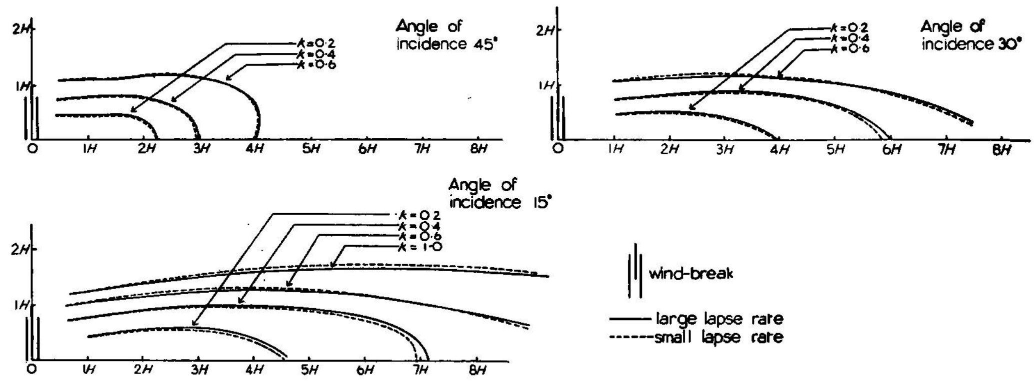


FIG. 3—VERTICAL DISTRIBUTION OF k BEHIND THE CENTRE OF THE ORIGINAL WIND-BREAK

The vertical cross-sections through the centre of the screen and at right angles to it are very similar for different wind directions and at a distance H from the screen are almost identical where H is the height of the screen. Up to a height of about $0 \cdot 7H$, there is a tendency for the flow to become parallel to the wind-break, but above this height the direction of flow is approximately that of the "undisturbed" wind.

At distances down wind greater than $4\frac{1}{2}H$ from the wind-break, the wind direction at "ground level" was very variable for angles of incidence smaller than 20°. With an angle of incidence of about 25°, at a distance from the screen between $4\frac{1}{2}H$ and $9H$, the flow near the ground was generally along the direction of the barrier, but gusts were observed towards and less frequently away from the screen. With a wind nearly perpendicular to the barrier the flow near the ground at distances greater than about $4\frac{1}{2}H$ from the barrier consisted of a series of weak gusts in almost every direction, the average speed at $6H$ being approximately $0 \cdot 25v_{50}$.

With the wind nearly perpendicular, smoke released from the top of the barrier showed a steady stream with small eddies rising to about $1 \cdot 2H$ above the ground at $3H$ from the barrier. Almost all the smoke reached the ground at distances greater than $6H$ from the barrier. Occasionally some smoke was brought down to the ground by large slow eddies at distances as near as $1\frac{1}{2}H$ from the barrier. The general flow is illustrated in Fig. 5 and photographic observations of eddies are shown facing p. 249. Occasionally a balloon with no lift and floating a few feet above the ground to leeward of the barrier would be

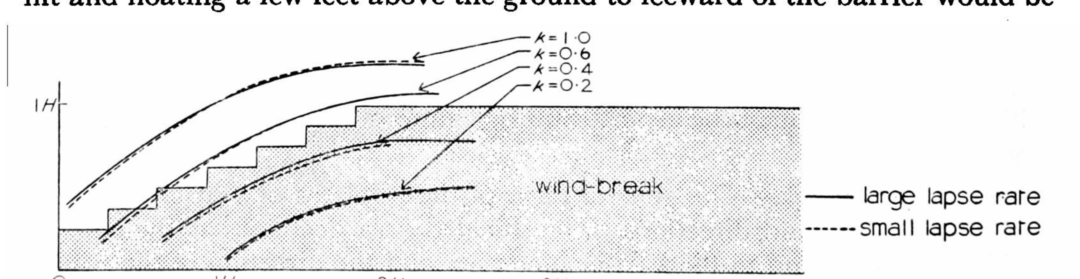
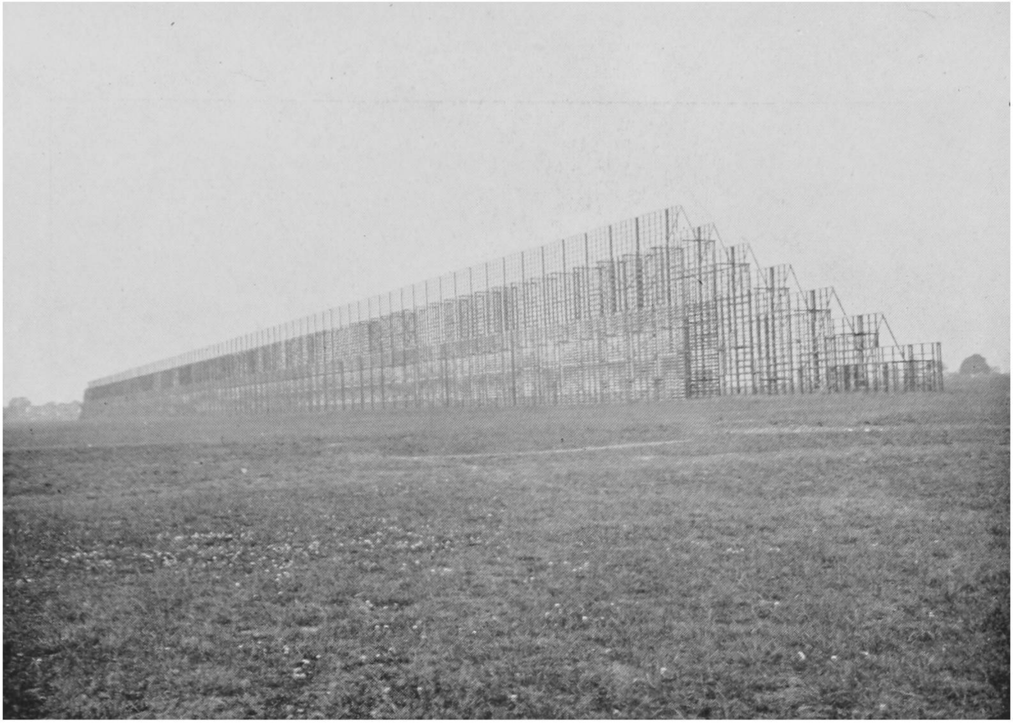


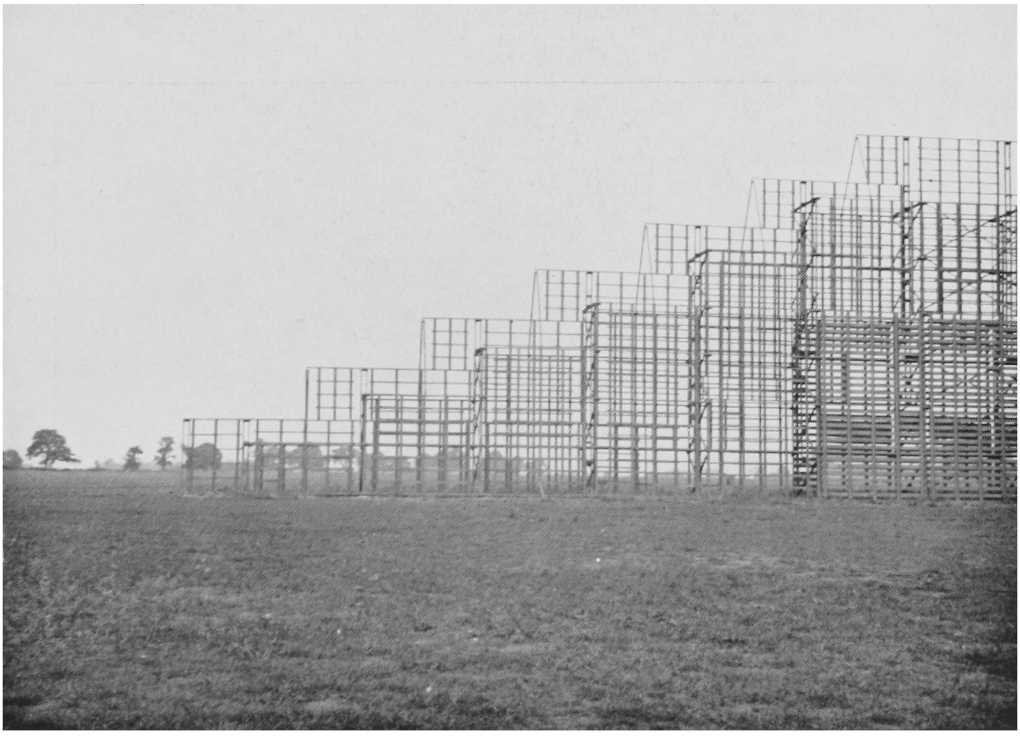
FIG. 4—VERTICAL DISTRIBUTION OF k NEAR THE END OF THE ORIGINAL WIND-BREAK, 60 FT. DOWN WIND

Angle of incidence of wind 15°

[To face p. 248

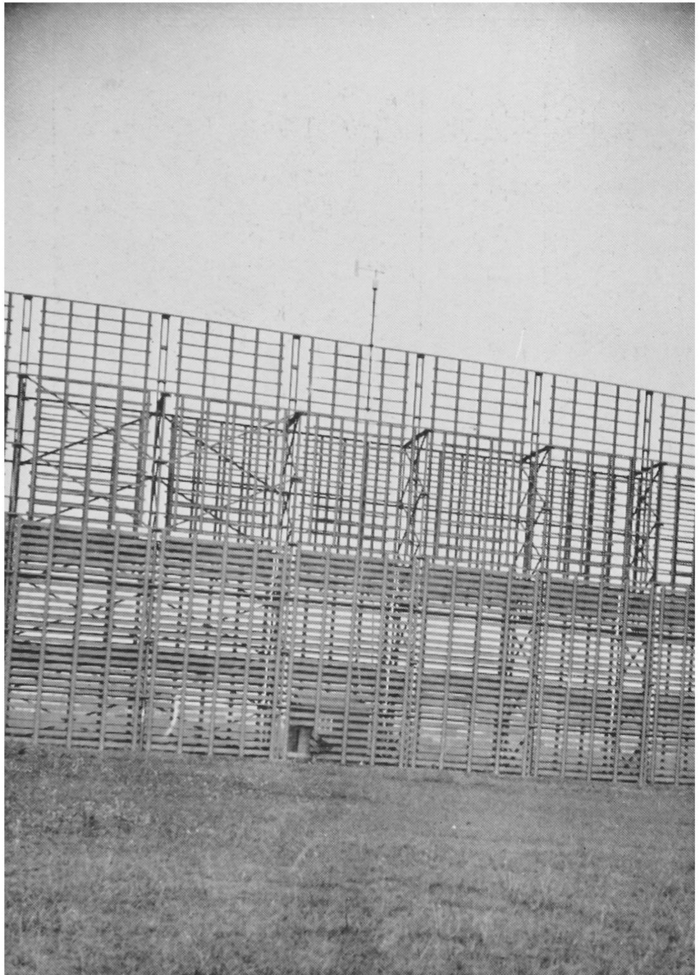


GENERAL VIEW OF THE ORIGINAL WIND-BREAK

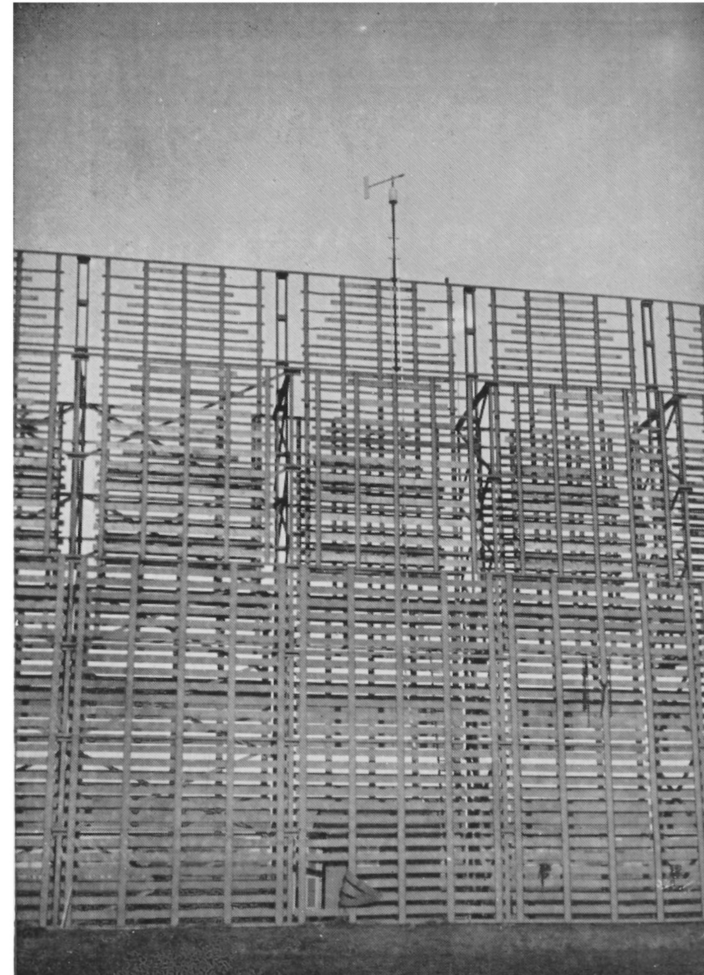


END OF THE WIND-BREAK SHOWING THE TAPER AND GRADUAL REDUCTION IN DENSITY

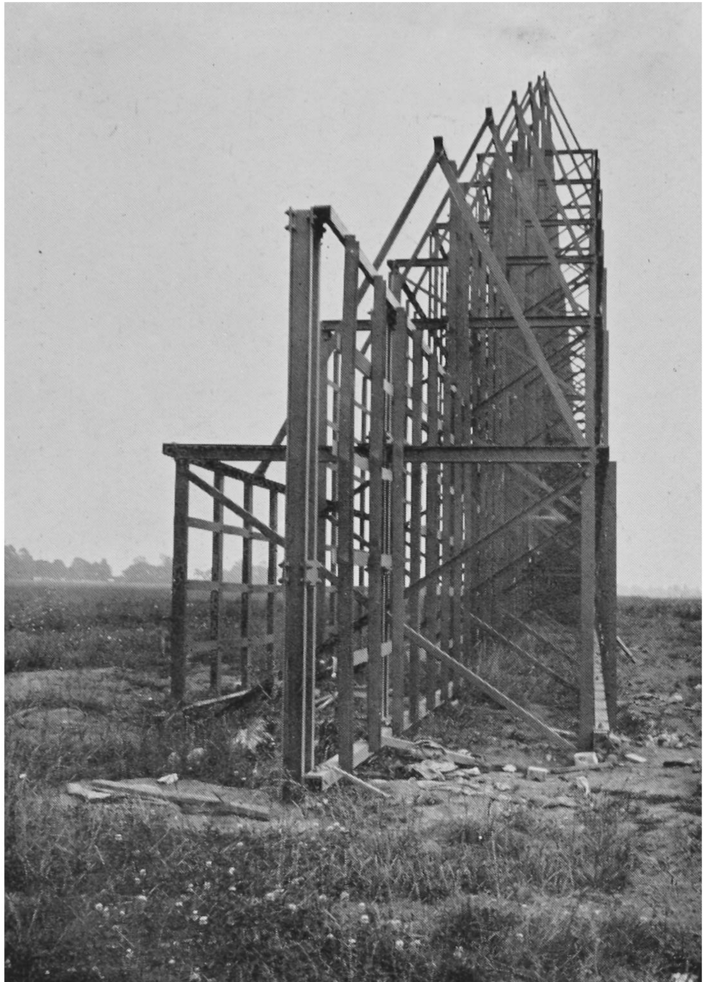
ARTIFICIAL WIND-BREAK AT MANBY, LINCOLNSHIRE
(see p. 244)



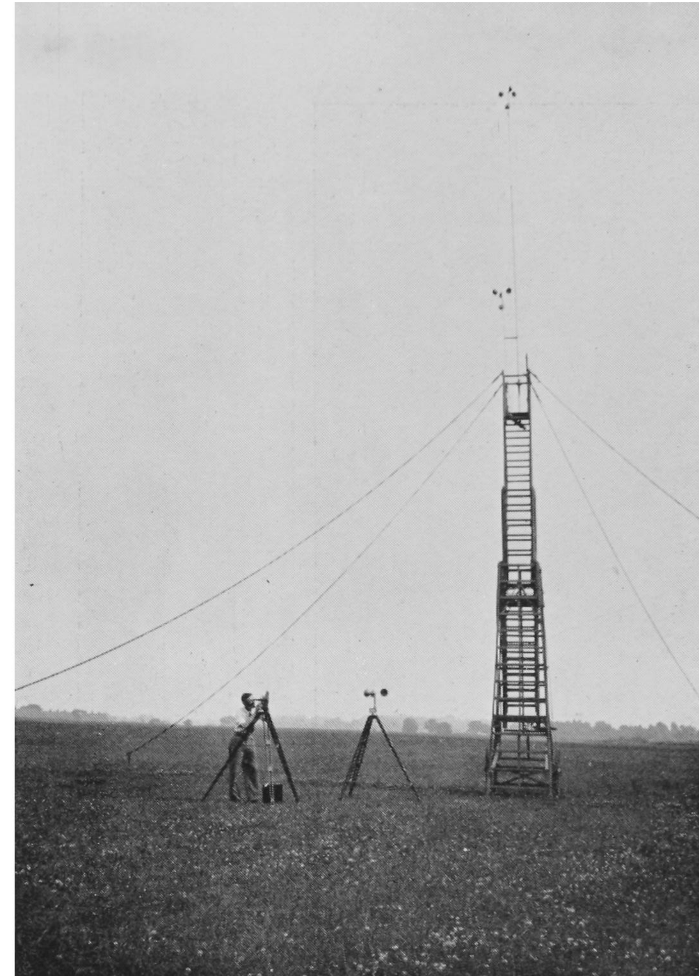
CENTRAL PORTION OF ORIGINAL WIND-BREAK SHOWING PRESSURE-TUBE ANEMOGRAPH



CENTRAL PORTION OF MODIFIED WIND-BREAK

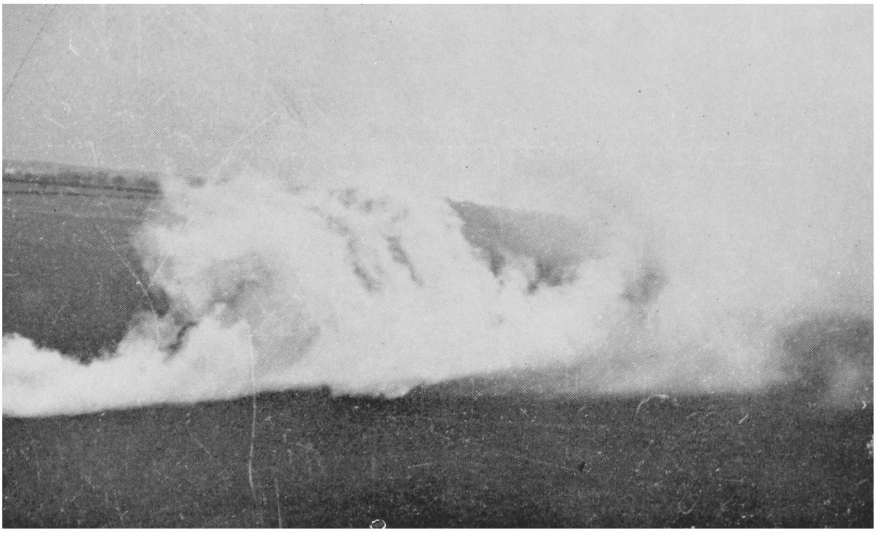


END VIEW OF THE ORIGINAL WIND-BREAK



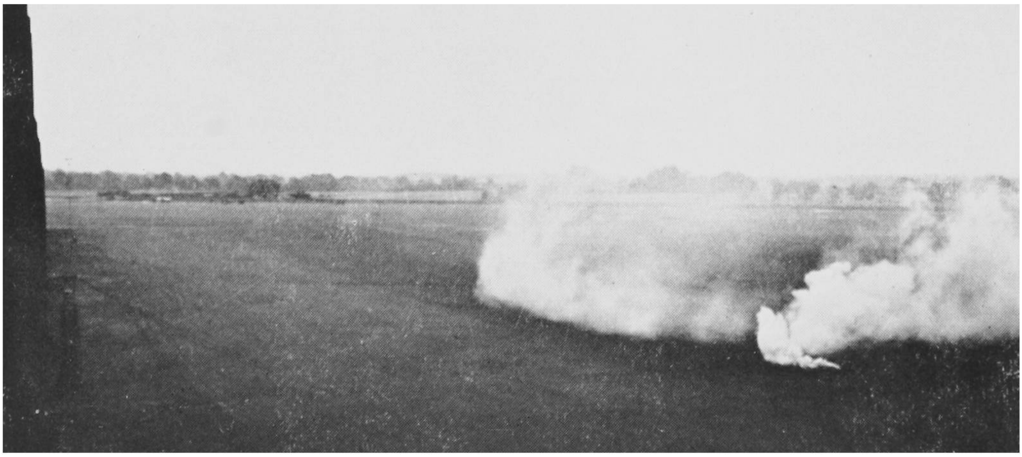
CUP ANEMOMETERS MOUNTED ON TELESCOPIC LADDER
The theodolite is used for reading the anemometers

ARTIFICIAL WIND-BREAK AT MANBY, LINCOLNSHIRE
(see p. 244)



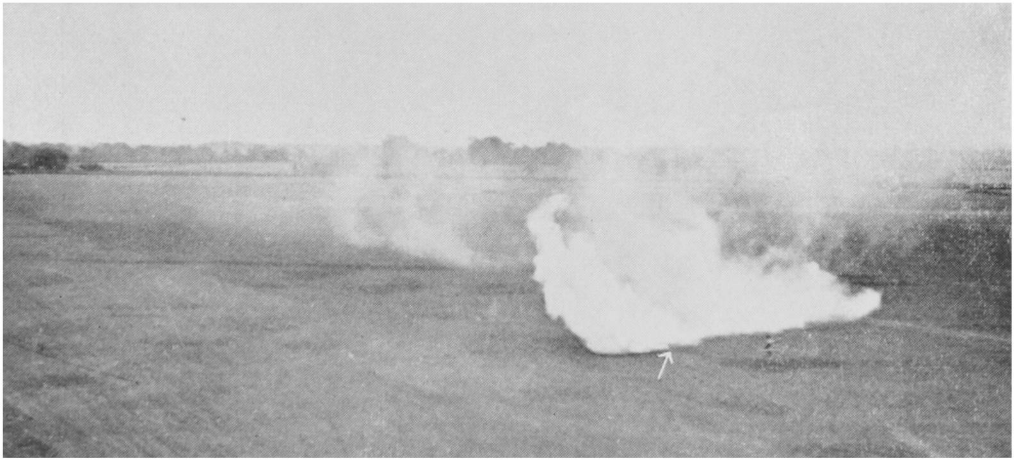
VIEW LOOKING AT RIGHT ANGLES FROM THE WIND-BREAK

The source of the smoke is just to the left of the picture; the undisturbed wind direction is from the left 15° from the perpendicular to the wind-break which is behind the camera.



VIEW FROM NEAR THE WIND-BREAK

The wind is almost at right angles to the wind-break seen on the left of the photograph. The smoke flows parallel to the wind-break at first before lifting and eddying at right angles.



VARIABILITY OF WIND DIRECTION

The source of the smoke is shown by the small arrow; it will be seen that sometimes the smoke is blown towards and sometimes away from the wind-break which is just off the picture to the left.

DEMONSTRATION OF EDDIES NEAR THE WIND-BREAK BY SMOKE CANDLES

(see p. 244)

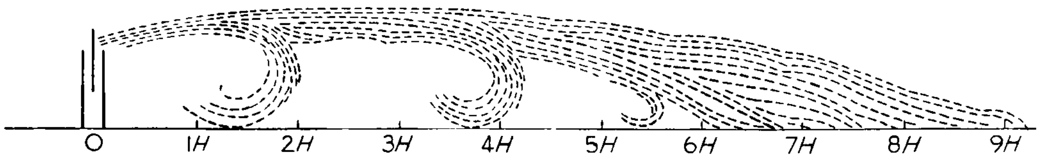


FIG. 5—LARGE EDDIES OBSERVED BEHIND THE CENTRE OF THE ORIGINAL WIND-BREAK WITH WIND ALMOST AT RIGHT ANGLES TO THE WIND-BREAK

caught in a rapid up-draught until it was carried away by the main stream over the top of the wind-break.

Modified wind-break.—The isopleths near the ground have the same general form as with the original barrier, but the shielded area is rather less than the previous area for angles of incidence of 15° and 30° and slightly greater for angles of incidence of 45° and 60°.

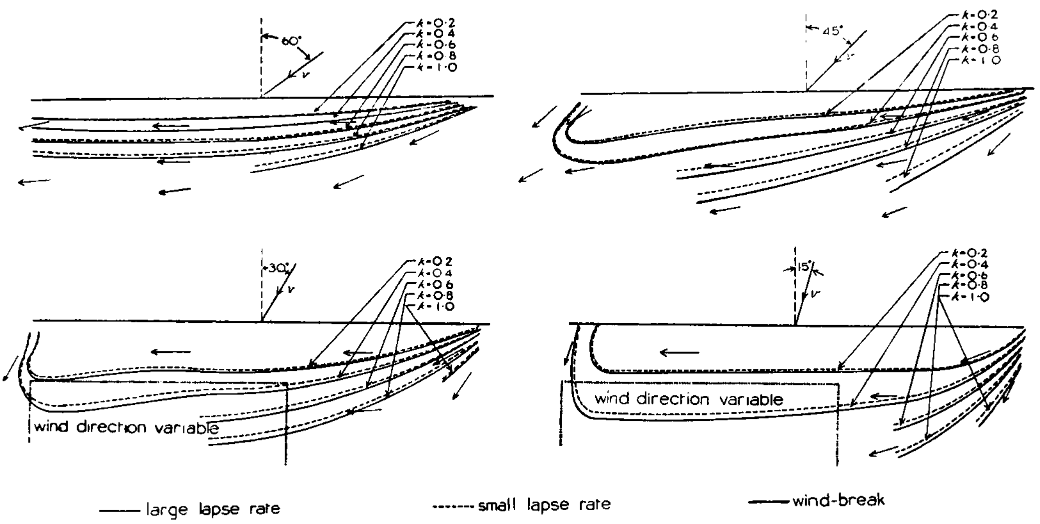


FIG. 6—HORIZONTAL DISTRIBUTION OF *k* AT GROUND LEVEL BEHIND THE MODIFIED WIND-BREAK

Similar isopleths are a few feet higher in the vertical plane than the corresponding isopleths with the original barrier up to a distance of about 6*H* from the wind-break.

The eddying conditions in the sheltered region are more disturbed than with the original barrier. As in the case of the latter, with a wind at right angles

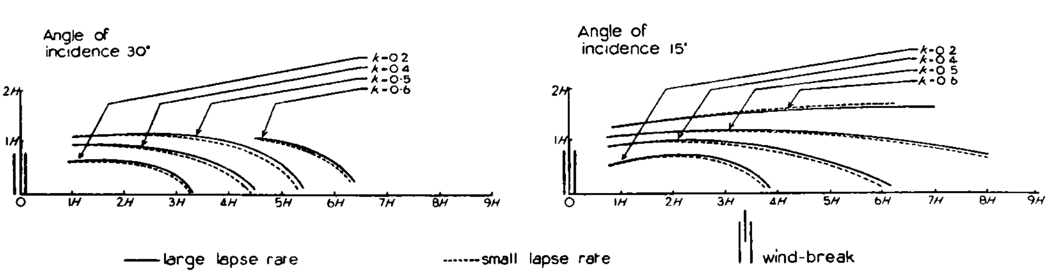


FIG. 7—VERTICAL DISTRIBUTION OF *k* BEHIND THE CENTRE OF THE MODIFIED WIND-BREAK

most of the smoke reached the ground at distances of more than $6H$ from the barrier. Large eddies which carried the smoke down to the ground were more frequent and more violent than those observed with the original barrier.

With angles of incidence of wind between 0° and 20°, the wind direction on the ground at distances of $3 \cdot 6H$ to $6H$ was very variable with fairly strong frequent gusts towards the barrier. Smoke released in this area was carried towards the barrier and generally at about $3 \cdot 6H$ distance rose rapidly to a height of $1 \cdot 2H$. These gusts did not often penetrate to within a distance of $3H$ from the wind-break. The wind roses in Fig. 8 illustrate this. At a distance of $3H$, the most frequent wind direction is approximately parallel to the screen.

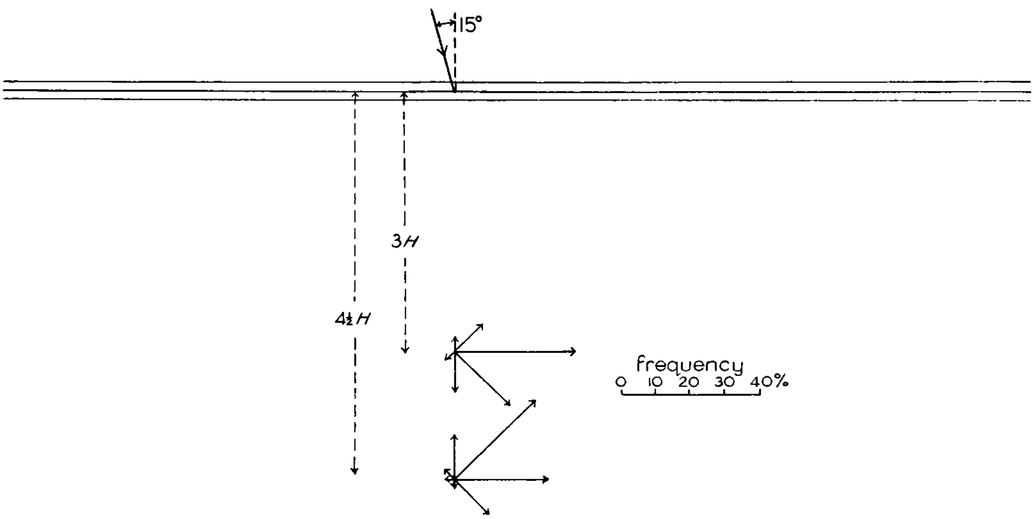


FIG. 8—WIND ROSES AT TWO FIXED POINTS BEHIND THE CENTRE OF THE MODIFIED WIND-BREAK WITH ANGLE OF INCIDENCE OF THE WIND 15°
H = height of the wind-break

Both wind-breaks.—The effect of lapse-rate differences (for positive lapse rates) is very small except below a height of approximately $\frac{1}{2}H$ and at distances from the barrier between about $2H$ and $8H$, especially for angles of incidence of about 30° or less.

The effective reduction of wind is normally greater for unstable than for stable lapse rates up to height H.

The shelter or velocity isopleths of these artificial barriers may be compared with those obtained by Nägeli[5] for a gap in a hedge. As might be expected, the shelter gradient becomes much greater near the gap and presumably the narrower the gap in the barrier, the greater will be this gradient. Also, the shelter near a gap does not extend so far beyond the "ends" of the hedge as with the single end of the artificial barriers described. The general run of the isopleths is otherwise similar.

Appendix

Wind-tunnel experiments

These experiments were originally devised to obtain, by means of a wind-break, a sufficiently extensive area of shelter without severe speed gradients (that is, variations of wind speed with distance) or eddying conditions in the boundary zone. A solid screen was known to cause a very disturbed eddy and to give only a relatively small extent of protected area. The experiments[6] in 1936 were therefore directed towards the development of a perforated barrier.

In the Manby (full-scale) experiments, flat slats were used instead of the gauze of the model tests. As the drag on flat plates is greater, this was compensated for by using a smaller wind-break density in the full-scale experiments. In spite of this, the full-scale experiments did not produce proportionally so large a sheltered area as the models.

Further model experiments[7] were carried out in 1938, using copper ribbon soldered to steel brackets and arranged to give the same density as in the full-scale experiments. The sheltered area was considerably less than in the earlier model tests but again greater than on the full scale. The differences between the two sets of wind-tunnel experiments were attributed to differences in screen design and to tunnel-boundary effects. The differences between the 1938 model tests and the full-scale experiments increased with distance from the barrier, and were accounted for partly by the constriction of the main stream by the tunnel walls and partly by the different methods of wind-speed measurement. On the full scale, the mean absolute speed regardless of direction was measured by a cup anemometer. In the model tests the air speed recorded by the pitot-static tube in approximately the mean wind direction would be lower than that shown by a cup anemometer in regions where frequent changes in wind direction occurred.

Concerning the effects of scale and aspect ratio, the available evidence[8] on the drag of plates of infinite aspect ratio shows no scale effect above a Reynolds number (based on width normal to wind) of about 4,000. Below this value the drag coefficient decreases to a minimum of 85 per cent. of its steady value with a Reynolds number of 1,500. The Reynolds number of the individual strip in the model tests was about 3,000 at full stream velocity. No evidence was known as to the scale effect on the dimensions of the wake of a flat plate or lattice girder, but it was assumed, on the basis of drag measurements[8], that the scale effect would be small and would not account for a larger sheltered area at the lower Reynolds number.

To examine end effects in the tunnel, it was found necessary and acceptable to use a much smaller aspect ratio of 11·9.

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EXAMPLE OF A DOUBLE WARM FRONTAL STRUCTURE OVER NORTH-WEST EUROPE

By W. J. BRUCE

In general forecasters are less ready to accept a double structure of warm fronts than of cold fronts, though it is thought that this is a measure of the difficulty of recognition rather than of frequency of occurrence. Matthewman[1] found that from 55 frontal cross-sections, 12 occasions of double structure were possible, whilst Chappaz[2] gave an interesting example of a double warm front observed from an aircraft over the Lake Constance area. However, in this latter paper it was considered that the double warm front was probably a result of the local topography, the high ground in the region having held back the surface front. It is considered worth while to add to these records some evidence for the existence of a double warm front over north-west Europe on September 3, 1952.

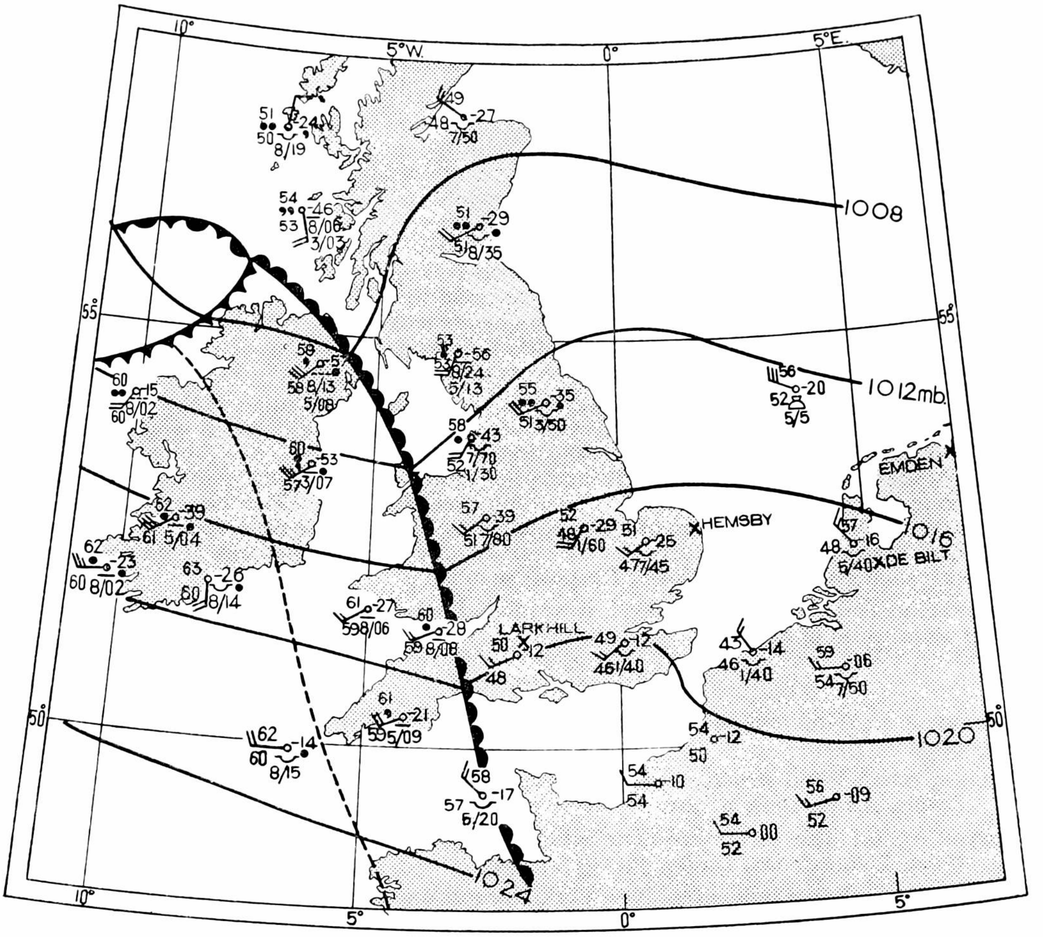

FIG. 1—SYNOPTIC CHART, 0300 G.M.T., SEPTEMBER 3, 1952

Synoptic situation.—Figs. 1 and 2 show the synoptic situation at 0300 and 1500 G.M.T. on September 3, 1952. A secondary depression moved eastwards in a strong thermal gradient and deepened somewhat. The rain area extended, and was more intense over Germany than in the same latitudes in England. The following gives some evidence for the existence of a second warm front intersecting the earth's surface at approximately the position of the pecked lines, though the surface front was not readily recognizable on the charts until 1500 G.M.T.

Weather.—The weather experienced at Wahn during the afternoon (see Table I) was consistent with the existence of a double warm front. Light to moderate rainfall occurred during the afternoon ceasing about 1600. The upper cloud then broke and became thinner whilst the low cloud tended to disperse temporarily. Later there was a general thickening and increase of cloud followed by moderate rainfall. The rain stopped at about 1900 which was approximately the time at which the second warm front should have passed the area. Subsequently there were typical warm-sector conditions with occasional light rain or drizzle. More detailed synoptic charts for 1500 G.M.T. covering northern Germany and the Low Countries showed two separate well defined belts of heavier rainfall, these belts being partially recognizable in Fig. 2.

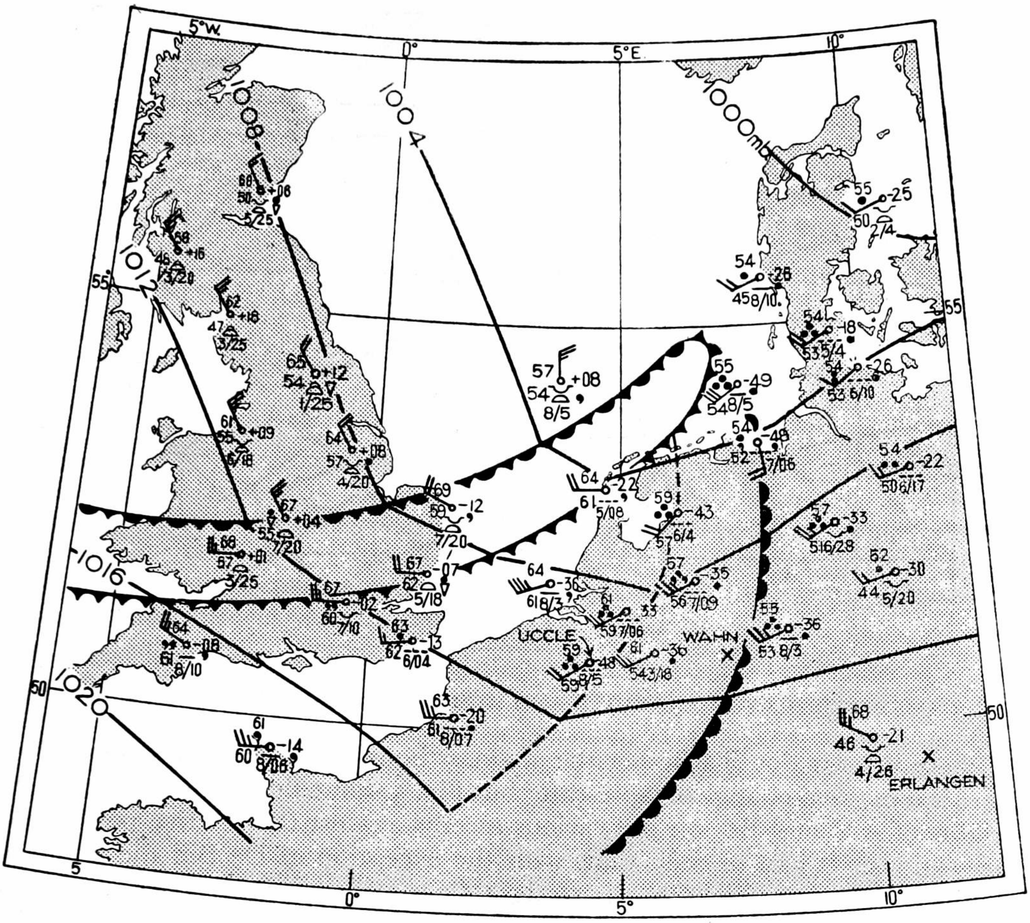

FIG. 2—SYNOPTIC CHART, 1500 G.M.T., SEPTEMBER 3, 1952

TABLE I—HOURLY WEATHER TAKEN FROM THE OBSERVATION BOOK AT WAHN, SEPTEMBER 3, 1952

	Dew point	Weather	Tendency	Surface wind		Cloud
G.M.T.	°F.		mb.	°	kt.	
1400	51	c	−3·1	250	9	8 oktas As at 8,000 ft., 5 oktas Sc at 2,000 ft.
1500	52	cr_0r_0	−3·0	250	7	8 oktas As at 8,000 ft., 5 oktas Sc at 2,000 ft.
1600	52	c/r	−3·0	270	9	7 oktas As at 9,000 ft., 4 oktas Sc at 2,600 ft.
			First warm front			
1700	55	cir_0	−2·6	250	11	7 oktas Sc at 2,000 ft., 1 okta St at 1,800 ft.
1800	56	crr	−2·6	250	8	8 oktas St at 900 ft.
1900	57	cir_0	−1·7	250	7	8 oktas St at 1,500 ft.
			Second warm front			
2000	59	c/r	−0·8	270	9	8 oktas Sc at 2,500 ft., 5 oktas Sc at 1,300 ft.
2100	59	c	−0·5	270	8	7 oktas Sc at 2,000 ft.
2200	59	cir_0	−0·6	270	7	8 oktas Sc at 2,000 ft., 5 oktas St at 1,500 ft.
2300	60	cir_0	−0·9	250	13	8 oktas Sc at 2,000 ft., 5 oktas St at 1,400 ft.
			Cold front or cold occlusion			
2400	55	c/r	−0·9	310	3	5 oktas Sc at 2,000 ft.

Upper air ascents.—Figs. 3 and 4 show the 0200 G.M.T. tephigrams for Larkhill, Hemsby, De Bilt and Emden, these stations lying approximately on a straight line normal to the warm front. The boundaries of both warm and cold air are shown in these diagrams at AA′ and BB′.

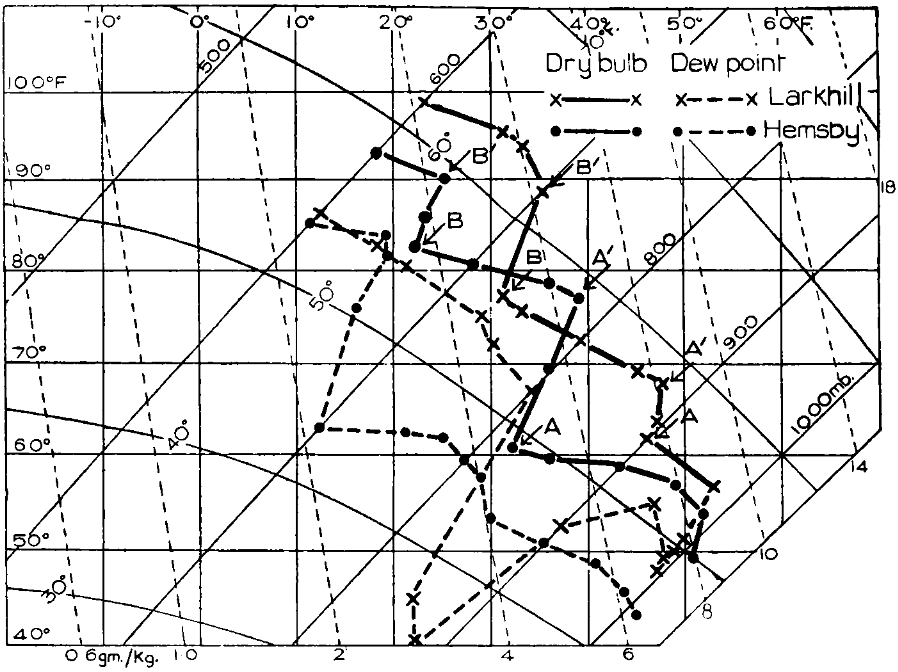

FIG. 3—TEPHIGRAMS FOR LARKHILL AND HEMSBY 0200 G.M.T., SEPTEMBER 3, 1952

There is some doubt whether the air-mass boundaries occur precisely where there is a marked change of lapse-rate[3] but Fig. 5 shows the result of plotting the heights of AA′ and BB′ on the various ascents against the relative positions of the stations. It can be seen that, with the exception of De Bilt the points so obtained lay approximately on straight lines, these being indicated by the pecked lines on the diagram. The poor fit of De Bilt may be explained by this station being almost 100 miles out of line to the south. It can be seen that the

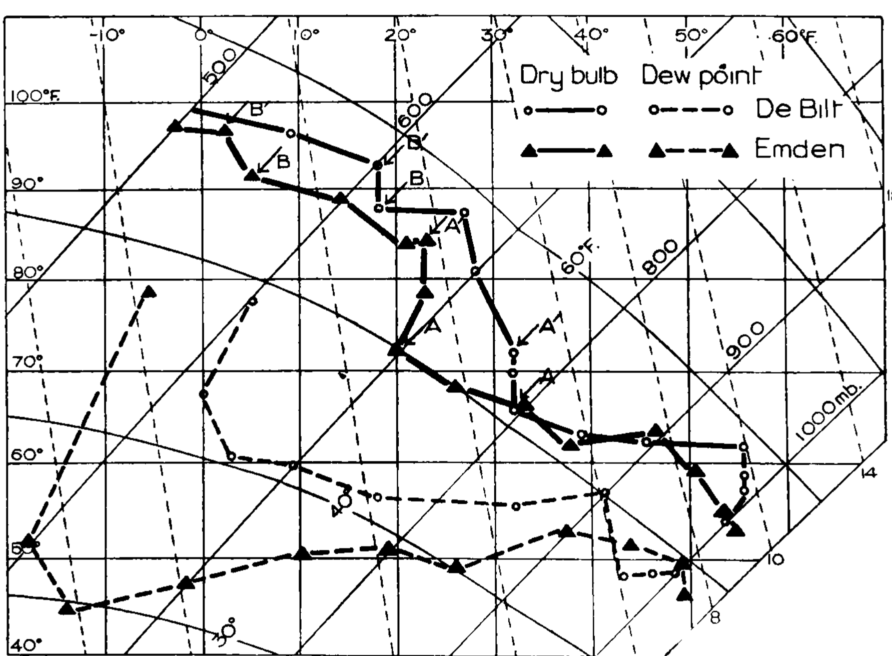

FIG. 4—TEPHIGRAMS FOR EMDEN AND DE BILT 0200 G.M.T., SEPTEMBER 3, 1952

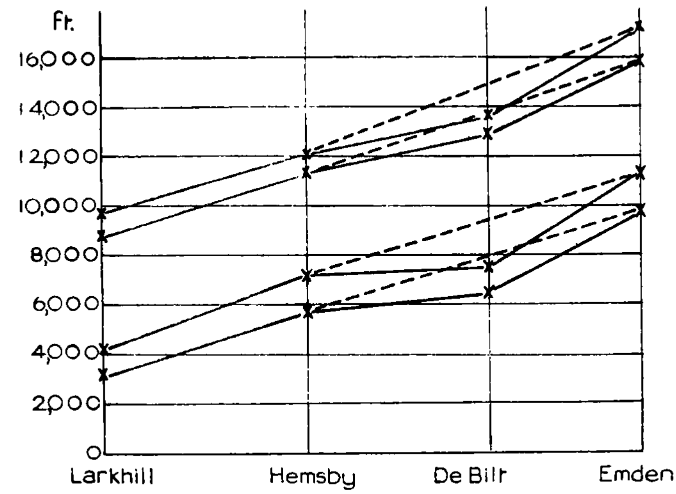

FIG. 5—HEIGHTS OF BASES AND TOPS OF INVERSIONS SHOWN ON TEPHIGRAMS

mixing zones were remarkably constant in depth on all the ascents. The slopes of the frontal surfaces were calculated to be 1 : 120 to 1 : 180.

In order to discount the possibility that one of the changes of lapse-rate might be due to subsidence, Table II shows the wet-bulb potential temperature taken from the various ascents on the day in question. The figures show that there were more than two air masses involved, the boundaries being indicated by dotted lines.

TABLE II—WET-BULB POTENTIAL-TEMPERATURE DISCONTINUITIES

Larkhill 0200 Pressure	Larkhill 0200 Wet-bulb potential temperature	Hemsby 0200 Pressure	Hemsby 0200 Wet-bulb potential temperature	De Bilt 0200 Pressure	De Bilt 0200 Wet-bulb potential temperature	Uccle 0800 Pressure	Uccle 0800 Wet-bulb potential temperature	Erlangen 1400 Pressure	Erlangen 1400 Wet-bulb potential temperature
mb.	°F.	mb.	°F.	mb.	°F.	mb.	°F.	mb.	°F.
500	58	500	57	500	54			500	60
550	57½	550	56					550	59
600	58	600	56½	605	53½	610	57		
650	58	640	54	620	52	650	57	630	57½
670	58								
700	58	670	54½	670	49	675	56	700	57
730	55	700	51	700	50	720	55	720	57
750	55	750	52½	760	48	770	54	770	55
800	54½	800	50½	795	51	820	50½	780	54
850	47½	820	47	850	49½	850	50½	850	57
870	47	850	47						
900	49	900	48	920	51				
910	49½								
950	52½	950	49½						
980	52	980	49	985	52				

As regards later ascents, the only relevant one at 0800 G.M.T. was that of Uccle (Fig. 6). The positions of the mixing zones were found to be consistent with the probable positions of the warm fronts and the slope of the frontal surface agreed with that found on the 0200 G.M.T. ascents. By 1400 G.M.T. the

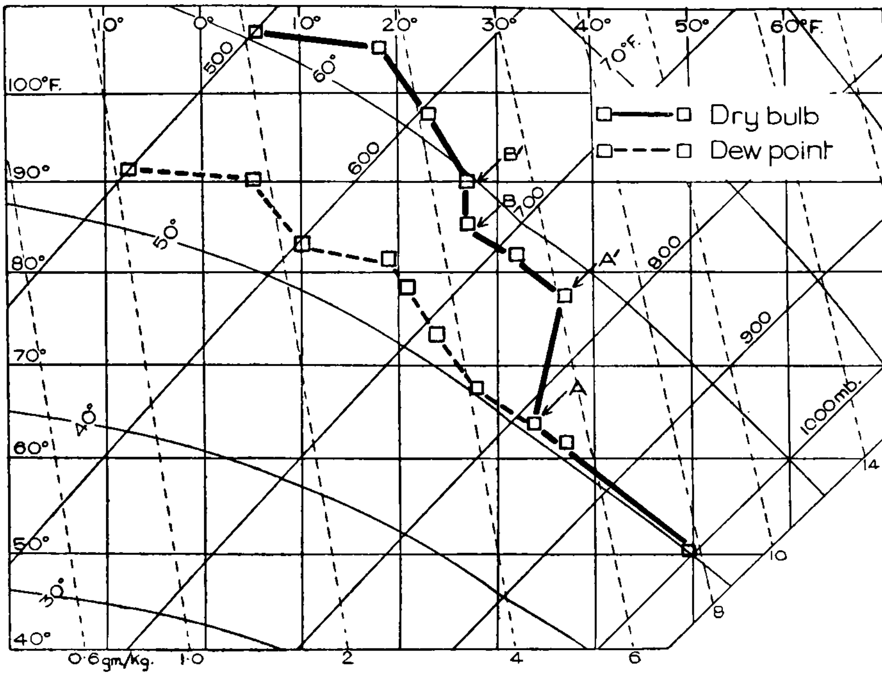

FIG. 6—TEPHIGRAM FOR UCCLE, 0800 G.M.T., SEPTEMBER 3, 1952

Erlangen ascent (Fig. 7) was showing both mixing zones at heights in reasonable agreement with the positions of the warm fronts on the surface chart.

Conclusion.—It appears probable that there were two warm fronts involved in the situation on September 3, 1952, the second one becoming more active and more readily recognizable at the surface as time progressed. The early recognition of such double structures through upper air ascents might be of some importance in the framing of accurate short-range forecasts for some localities.

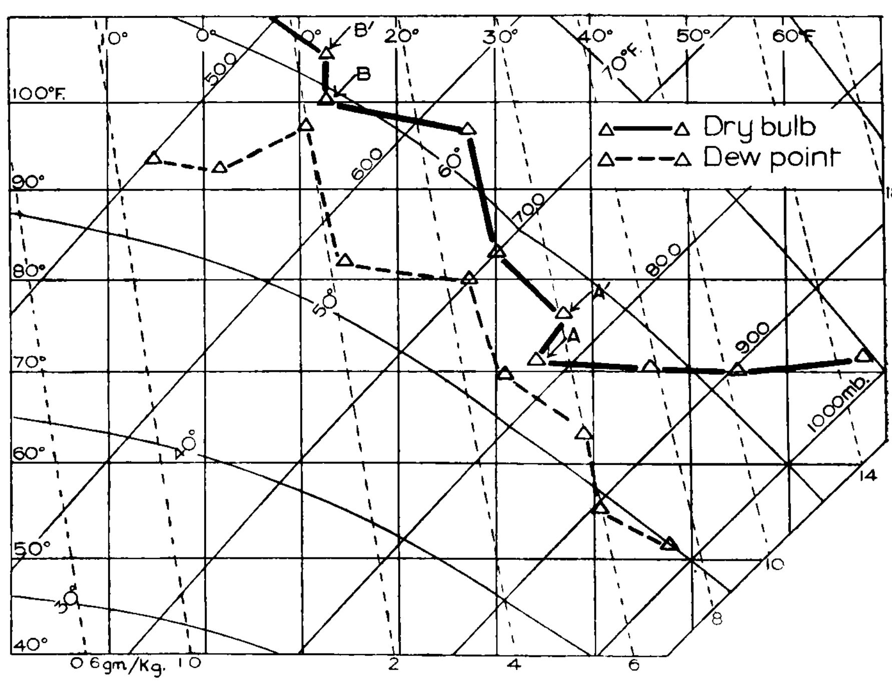

FIG. 7—TEPHIGRAM FOR ERLANGEN, 1400 G.M.T., SEPTEMBER 3, 1952

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OFFICIAL PUBLICATION

The following publication has recently been issued:—

PROFESSIONAL NOTES

No. 113—Depressions crossing Labrador and the St. Lawrence Basin. By A. G. Forsdyke, Ph.D.

Depressions which traverse the eastern part of North America may be divided into two main classes according to their subsequent behaviour; they may either move out into the Atlantic or become slow moving somewhere to the west of Greenland. The relation between the behaviour of these depressions and the synoptic situation over western Europe is examined with a view to its possible use in extended forecasting for the British Isles. The corresponding hemispherical 500-mb. contour patterns are studied but they appear to afford little indication of the subsequent surface developments.

The development and movement of individual depressions is examined in relation to the 1000–500-mb. thickness pattern, but no simple connexion which would be useful in forecasting is found.

ROYAL METEOROLOGICAL SOCIETY

Symons Memorial Lecture

The 1955 Symons Memorial Lecture was delivered in the Royal Meteorological Society's rooms by Prof. A. C. B. Lovell, Director of the Jodrell Bank Experimental Station, University of Manchester, on April 27, 1955. The title of the lecture was "Radio astronomy and the fringe of the atmosphere". This was the first time for many years that the outer atmosphere had been the topic of one of these lectures, and the hope was expressed that this would lead to more attention being paid to the outer layers by meteorologists in this country.

The ignorance of the subject on the part of many of those present was matched by the very small amount of observational knowledge of atmospheric flow at very great heights so far available. By intricate processes of deduction, however, the Jodrell Bank workers, and others, have now obtained an interesting collection of self-consistent evidence on air movements at very great heights which require interpretation.

Prof. Lovell's lucid account was largely taken up with various techniques evolved by the radio astronomers, such as measuring the drift of meteorites and interstellar dust within the earth's atmosphere, to deduce the motion of the atmosphere at the 80–100-Km. level and around 300 Km. The winds at 300 Km. over England included speeds of 100–200 m./sec. and twice daily reversals of direction. Other observing techniques yielded information about pressure and air density at various heights, which were in very fair agreement with the V2 rocket observations over Nevada.

Many present must have been groping for a connexion between this realm of radio-astronomical exploration and the layers to which our attention as meteorologists has been usually confined. Bowen's proposed association between meteor showers and rainfall 30 days later in Australia came in for mention. Unfortunately the proposed rainfall responses to the Bielid and Giacobinid showers also occur in epochs when these meteor groups are, or were, far from the earth and undetectable by astronomical observation. Perhaps the lesson here is twofold: first that calendar-bound weather singularities may have more elusive origins within the system earth–atmosphere; secondly that any linkages between the circulations in the inner and outer atmospheric layers may be altogether more subtle and perhaps limited to occasional trigger effects.

The meeting of the Society held on June 15, 1955, with Prof. P. A. Sheppard, Vice-President, in the Chair, opened with the election of Dr. R. C. Sutcliffe as President for the next session and the election of the other members of the new Council.

The technical part of the meeting was a joint discussion with the Challenger Society on "Wind and waves". The papers read were mainly concerned with the interaction between the wind and the sea.

*Longuet-Higgins, M. S.—On the statistical distribution of the heights of sea waves**

The author began by reviewing several simple ways in which wave heights could be defined, such as the mean height of all waves, the mean height of the highest one-third waves, etc., and explaining the relation between them after pointing out how difficult it is to describe the state of the sea because the heights of waves vary so greatly. From a consideration of all the wave-generating areas off a coast, each of which contributes to the wave height at a point, he deduced that the probability-distribution of such a sum of contributions resembled the "random-walk" distribution found by Rayleigh, and thence arrived at a theoretical frequency distribution of the maximum wave height and the highest 30 per cent. of the waves. In conclusion the author showed that comparisons of the ratios of the mean values of these quantities to the mean height of all the waves as derived from the theory given in this paper, gave satisfactory agreement with the values found for these quantities in practice by Munk, Putz and other workers.

Darlington, C. R.—The distribution of wave heights and periods in ocean waves†

In this paper, which was also presented by Mr. Longuet-Higgins, the first experimental records of waves in the deep ocean have been analysed. These records were obtained from a new wave recorder, due to Tucker, which has been installed in a British ocean weather ship. The profiles of the waves are recorded automatically by this instrument, which eliminates the effect of the ship's own vertical motion and responds to waves of all periods between 5 and 25 sec. The results show a close agreement with the theoretically deduced results of Longuet-Higgins, just described.

Mr. D. E. Cartwright was next asked to present some work of his extending that of Longuet-Higgins. Assuming a frequency distribution for the height of sea waves the same as that found by Rice in a mathematical investigation in acoustic theory, and using a rather different measure for wave height, he found a method of correlating mean wave-crest height above mean sea level with the statistical properties of the wave sample used.

Hay, J. S.—Air flow over the sea‡

Mr. Hay measured wind velocity profiles from a large platform moored about 800 m. east of a coastline of the United Kingdom, by using sensitive electric contact anemometers at heights of 0·5, 1, 2, 4 and 8 m. above the windward edge of the platform. He found that the flow was aerodynamically rough at all mean wind speeds ranging from 5 to 10 m./sec. used in his experiments. The profiles showed a wind increasing with the logarithm of the height above the sea and from them the stresses were inferred. He also concluded from the scanty data available that in inversion conditions the variation of wind speed with height departed from the logarithmic a few metres above the surface. Gustiness measurements were made but were considered to have been affected by the presence of the coastline and cliff 60–90 m. high on the up-wind shore.

In his invited contribution Dr. H. U. Roll (Hamburg) discussed Mr. Hay's values of the shear-stress coefficient and drew attention to the similar results of other workers some of which showed a minimum value of the shear-stress coefficient with a wind speed between 4 and 6 m./sec. He considered this result was real, and that a search should be made for a physical cause. Wave steepness might well be an important factor. Dr. Roll then described work he had carried out on the relation between wind speed at various heights and air-sea temperature difference.

Dr. H. Arakawa, who was also invited to contribute, then gave an interesting account of his investigations into interference between complicated wave patterns at sea. As examples he cited tidal waves on the inland Sea of Japan, and an occasion when pyramidal waves seriously damaged the Japanese fleet while a fast-moving typhoon passed through the area where it was carrying out manoeuvres. Finally, Mr. Darbyshire presented some wind-stress measurements made on Lough Neagh in conditions of low-level stability and instability. The level of the water surface was measured by water-level gauges at four stations located in representative positions and winds taken from an anemometer at Aldergrove. A surprising result found from this work was that the stress coefficient increased with the fetch or distance down wind under all conditions.

In the discussion which followed Mr. Gold wanted more information about the shape of the nearby coast and its influence on the wind profiles described by Mr. Hay. He also found the small value of the roughness parameter rather surprising and wanted to hear more from Dr. Roll about the relation between the Beaufort scale and wind near the sea surface. Dr. Roll said his measurements of Beaufort force were made by anemometer at the top of the ship's mast. Finally, Mr. Francis thought Mr. Hay's values of the stress coefficient were on the high side, and that a possible reason for this might be the formation of "standing waves" in the sea by reflection from the sides of the floating platform.

J. Mar. Res., New Haven Conn.*, **11, 1952, p. 245.
†*Quart. J. R. met. Soc., London*, **86**, 1954, p. 619.
‡*Quart. J. R. met. Soc., London*, **81**, 1955, p. 307.

LETTER TO THE EDITOR

Glazed frost

The occurrence of glazed frost is quite an uncommon phenomenon anywhere in this country and yet I have had the opportunity of witnessing it on four occasions in three successive years—three times at my station at Habergham Eaves near Burnley, and once in Burnley, 1½ miles away. The occurrences were all in January: January 5, 1953, January 6 and 8, 1954, and January 15, 1955.

On January 5, 1953, there was snow in the morning, freezing rain in the afternoon, and dense fog at night. When the rain was falling in the afternoon, the temperature was about 29°F. All objects exposed to the wind and rain were coated with layers of ice, and on the steep Manchester Road in Burnley a long line of vehicles could not move owing to the glassy surface.

Thick fog occurred on January 6, 1954 at 0900 G.M.T., and at 0930 it began to rain with the temperature at 32°F. Everything was instantly coated with ice, but the rain gradually turned into snow later in the morning as it became colder, with a cold N. wind blowing at night. I was astonished to find only two days later, glazed frost occurring again, but this time only in Burnley. It came just before noon, when the temperature was 31°F., and motorists complained of their windscreens being completely "iced up". There was keen frost in the early morning but it became milder during the day.

On January 15, this year, there had been steady snow falling during the afternoon with an easterly wind blowing, but later on at 1600 G.M.T. it turned to drizzle and rain with the temperature at 30°F. These conditions persisted for about two hours, and in that period everything exposed to the rain was covered with ice. It was peculiar to hear the "swish-swish" of the rain and drizzle as it made contact with objects. Branches of trees were bending under the heavy weight of accumulated ice, and the whole sides of houses were like sheets of glass. As sub-freezing temperatures prevailed for a time after this, the ice on trees, houses and telephone wires persisted for five days.

The latter glazed frost was most probably due to supercooled rain falling from the warmer moist air of the depression which was passing over southern England at the time, overriding the colder surface air that had prevailed for a fortnight.

I do not know if glazed frosts occurred anywhere else on the given dates, but it does seem noteworthy that this district should be particularly subject to this supposedly "uncommon" phenomenon on so many occasions in such a short time!

R. MICHAEL SMITH

87 Glen View Road, Habergham Eaves, near Burnley, Lancashire. April 23, 1955

REVIEWS

Further outlook. By F. H. Ludlam and R. S. Scorer. 8¾ in. × 5½ in., pp. 174, *Illus.*, Allan Wingate (Publishers) Ltd, London, 1954. Price: 15*s.* 6*d.*

The term "further outlook" has been absorbed in the vocabulary of the weather forecaster, and in its more general meaning is tending to disappear from common usage. In choosing a title for their book, Mr. Ludlam and Dr. Scorer have disregarded any restriction, for among the interesting aspects of meteorology they deal with, the subject of forecasting occupies less than a quarter of their pages. They apparently set out to write about what interests them most, for many meteorologists in this country could identify the authors from the contents of this book. The picture on the jacket is appropriate; it depicts a stratospheric glider of the future above mother-of-pearl clouds over Norway. The pilot, one feels sure, is a somewhat older Dr. Scorer checking that the air goes up and down in the right places while, in the passenger's seat behind him, Mr. Ludlam engages in a little surreptitious cloud seeding.

The first two chapters are a rather ordinary account of necessary fundamentals such as sequences of observed weather, the formation of the main cloud types, and permanent and transient circulations. If these pages were written with enthusiasm it is not imparted to the reader. Indeed he is likely to be discouraged by the inadequacy of the explanations. He is repeatedly told, for example, that cloud forms by the cooling of rising air, but the process must remain obscure to him.

The writers warm to their task in Chapter III where atmospheric turbulence is introduced in homely and effective language. Beginning with a chimney emitting smoke with "lumps all over its outside", this chapter develops a stimulating picture of eddies up to the scale of those constituting the general circulation. The reader may be left in some doubt as to what he has learnt, for the treatment is free and discursive, but he should have no difficulty in keeping in step with the writer. The next chapter, "Exploiting the atmosphere", deals with thermals and the pastime of soaring, with fascinating examples from the behaviour of locusts, which we are told fly "for the fun of it" and gravitate to regions where thermals produce the surface moisture needed to maintain life; and we learn of the habits of the vulture and the albatross.

Chapter V brings us back to earth with eight pages allotted—somewhat grudgingly, one feels—to "The art of forecasting", and a dismal art it appears, consisting largely of extrapolation based on the experience of years and guided by "some scientific knowledge". On the dictionary definition of art as "the practical application of any science" we cannot cavil at this title, but it is quite another thing to accept that there is such a chasm between the science of meteorology and the practice of forecasting. This chapter is in contrast to the next, on "The science of forecasting", which presents a somewhat optimistic picture of the machine age of forecasting. While rightly giving prominence to the greatest forecasting development of today, the writers recognize that the machine cannot replace the forecaster but will result in still greater demands being made on his skill. Greater emphasis might indeed have been given to the inability of a machine to handle any problem which cannot be solved by a meteorologist with unlimited time and labour at his disposal.

The pages on "Weather control" are bound to appeal to the general reader because human interference with the course of nature provides the most impressive demonstration that nature's secrets have been revealed. The authors are to be commended, however, on concluding with a strong reminder that the effects of cloud seeding are difficult to establish with certainty, particularly in a country where this activity is commercialized and unco-ordinated. The final chapter, "Uncertainties", is written in a philosophical vein, and discusses the pitfalls in assessing the significance of observations or the degree of success attained in forecasts. It constitutes an unusual and interesting addition to a book on meteorology.

C. J. BOYDEN

Plant climate and irrigation. Edited by S. A. Searle. $8\frac{1}{2}$ in. × $5\frac{1}{2}$ in., pp. xii + 155, *Illus.*, Chichester Press Ltd., Chichester, 1954. Price: 20*s*. 0*d*.

This book consists of a series of articles by four contributors on plant climate, the term plant climate being used in its broadest sense to cover the climate from the lower limit of the root zone to the top of the vegetation and thus including the soil. Its aim is essentially practical, to provide growers with sufficient background knowledge to enable them to modify the plant climate to their own advantage by controlling the temperature, light and water supply of the plants. It does, incidentally, provide a great deal of interesting information to meteorologists.

Mr. Searle has contributed the first two chapters on "Plant climate" and "Environmental factors in the glasshouse". The second chapter gives a generally sound account of a difficult subject, but there is one statement which will cause surprise to climatologists; on p. 14 it is stated that tomato plants need a difference of 10°F. between day and night temperatures during the early stages of growth, and that the range between average day and night temperatures in the British Isles is less than half this value in the winter months. This statement arises from the faulty interpretation of hourly means of temperature which have apparently been used to give the range. This chapter ends with a most clear and concise account of photoperiodism. Chapter III by F. R. Frampton has the rather surprising title "Growing in a microclimate" and is an essentially practical account of a system of heat distribution in glasshouses. Chapter IV by Eastwell and Searle deals with the measurement of soil moisture and concludes that above *pF* 2·8 (a moisture tension of about 50 cm. of mercury) soil moisture is best measured by electrical methods, and below *pF* 2·8 by a tensiometer. The following chapter gives a summary of the "balance-sheet" method of calculating the water needs of a crop.

Chapter VI is by P. J. Salter and is entitled "The effects of different water régimes on the growth and yield of tomatoes". It occupies almost half the book and is part of a thesis. It is an account of a valuable piece of horticultural research but, to the reviewer's mind, it is quite out of place in this publication. Naturally, the chapter deals with such topics as experimental details and significance of results which can hardly interest most growers. A short summary of the work could have been more valuable and would have resulted in a more balanced publication. The last chapter by Mr. Searle reverts to practice, particularly in relation to the tomato crop.

The appendices include a short account of Penman's work on the physics of irrigation control and some useful conversion tables. The book is well documented and illustrated and has good author and subject indexes.

W. H. HOGG

METEOROLOGICAL OFFICE NEWS

Retirement.—Mr. R. P. Batty, O.B.E., Senior Principal Scientific Officer, retired on June 27, 1955. After serving in the Royal Welch Fusiliers from 1915 to 1918 he was commissioned in the Meteorological Section, Royal Engineers. He joined the Office on demobilization in November 1919 and served at West Lavington, Calshot and Larkhill. In 1925 he was seconded for duty with the Royal Air Force in India. He returned to the Office in 1931 and after a short period at Headquarters in the Aviation Services Division he was posted to Iraq.

On his return in 1934 he served for two years at Cranwell. In 1936 Mr. Batty was posted to Heliopolis and during the Second World War 1939–45 was Chief Meteorological Officer at the Royal Air Force Headquarters in Cairo. On his return from the Middle East in 1946 he was appointed Head of the R.A.F. Overseas Branch and from 1948 until his retirement he was Assistant Director (Military Services). Mr. Batty was "Mentioned in Despatches" in 1943 and was awarded the O.B.E. in 1950.

At a ceremony in the Conference Room in Victory House on June 30 Dr. A. C. Best presented Mr. Batty with a cheque subscribed by his colleagues. In expressing his thanks Mr. Batty recounted some interesting recollections of his experiences in the Office and events with which he had been associated.

Mr. Batty has accepted a temporary appointment in the Meteorological Office.

Sports activities.—The Air Ministry Annual Sports were held at the White City Stadium on June 29 and marked the end of the year for the competition for the Bishop Shield. The Meteorological Office retained the Shield for the seventh successive year. The Office also won the W. S. Jones Memorial Cup for the aggregate of points gained on Sports Day and the Halahan Shield for the Tug of War. The Office won both the Men's and Ladies' Relay Championships and several other events. The Ladies' Relay team by finishing in 55·6 sec. broke the record for the event which had stood since 1939 and Mr. B. L. Woolcott with 5 ft. 6 in. broke the record for the High Jump in addition to winning the Quarter Mile Championship.

The Meteorological Office Centenary Sports Meeting was held on Wednesday, June 22, at the Headstone Manor Ground. The weather was appropriately ideal and several hundreds of present and past members of the staff including many from the Headquarters branches of the Office at Harrow, London and Dunstable were able to spend a most enjoyable afternoon. Among many former members of the staff who attended were Sir George Simpson, Mr. Gold and Mr. Lempfert, accompanied by Lady Simpson, Mrs. Gold and Miss Lempfert. There was a large programme of track and field events and a number of less serious items were also included. Some of the better performances, which were attained on a loose track, were:—

Mr. K. Garrard won the two miles in 10 min. 11·5 sec.
Mr. B. L. Woolcott won the 440 yards in 55·1 sec.
Mr. M. Bibb won the 100 yards in 11·0 sec.
Miss K. Newman won the ladies' 100 yards in 12·8 sec.

In the field events Mr. G. L. Whitworth jumped 19 ft. 2 in., a new record for the Sports organized by the Harrow Social and Sports Committee, and Mr. Woolcott won the high jump at 5 ft. 4 in. Lady Sutton presented the prizes, though unfortunately owing to illness Sir Graham Sutton himself was unable to be present. After the prize-giving the Chairman of the Meteorological Office Social and Sports Committee, Mr. N. H. Smith, thanked Lady Sutton, and, on behalf of the spectators, asked her to convey to Sir Graham the sincere wishes of all present for his speedy recovery to health. A considerable number of those present then moved on to a Social Gathering which was held at Kodak Hall by kind permission of the Factory Manager. Refreshments were available as well as facilities for dancing for those who wished, and a pleasant evening came to an end all too quickly.

WEATHER OF JUNE 1955

The weather was marked by below-normal pressure near Novaya Zemlya and the White Sea, thence in a zone across Siberia east-south-east to the Okhotsk Sea, and from there in another zone stretching north-east to the maximum anomaly of −5 to −6 mb. over extreme north-west Canada. This whole zone of lowered pressure was followed by travelling depressions. The disturbances continued south-east to southern Quebec and later combined with Atlantic depressions to give another region of pressure 5 mb. below normal in 50–55°N. over the eastern Atlantic. The depressional activity was farther north than usual over Alaska and north-west Canada and was displaced south-eastwards over the eastern Atlantic (lowest monthly mean pressure 1008 mb. near 55°N. 30°W.). The polar anticyclone was rather weaker than usual but displaced towards the Atlantic sector (centre 1019 mb. over north-west Greenland). Pressure was a little above normal over most of Europe.

Temperature was generally a little below normal over Europe, except over France, Spain and the Balkans. Most of the United States was also rather cool, but Canada was generally warmer than usual, culminating in an anomaly of +6°C. over northern Alberta.

Precipitation was above normal over north Spain, France, Germany, the Alps, England and Ireland, also in north Norway and along the Atlas Mountains. Stations round the Bay of Biscay, also in Alaska and in parts of the southern Rockies had over double the normal June rainfall.

In the British Isles a south-easterly type of weather prevailed during the first week, but on the 7th a colder air stream swept southward from the Greenland region and northerly winds were maintained over the country until the 10th. A period of milder south-westerlies followed as depressions moved eastward from the Atlantic, until an anticyclone became established over the North Sea from the 16th to the 19th, with a renewal over England of mainly south-easterly winds. During the remainder of the month the weather was of a generally westerly type.

The fine weather experienced at the end of May continued during the first two days of the month. On the 3rd, a secondary to the main Atlantic depression formed in the Bay of Biscay and moved northward, giving widespread and in places heavy rain, particularly in the west country, where nearly 2½ in. of rain fell at Abergavenny, Monmouthshire in 24 hr.; there were frequent thunderstorms the following day as the depression passed over Ireland. Thunderstorms and outbreaks of heavy rain also occurred on the 6th, 7th and 8th, especially in the southern half of England. The 6th was the warmest day of the year at many places so far; London Airport and Holyhead both recorded 76°F. The next day an anticyclone near Greenland increased in intensity; troughs in the north became retrograde, and were brought south again over the country by the cold north-easterly air stream flowing round the east side of the anticyclone; widespread rain accompanied their passage. Maximum temperatures at many places in the north were 20°F. below the previous day's highest temperatures. During the early hours of the 10th temperature at Kew Observatory fell to 40·2°F., the lowest screen temperature recorded there in June for 32 yr. The cold weather was short-lived, however, for the following evening a depression from the Atlantic moved eastward across northern England, giving nearly 1 in. of rain in many places and fairly widespread thunderstorms in eastern England. As pressure rose behind the depression an anticyclone developed over northern France, and the resulting circulation brought subtropical air from near the coast of Spain to our south-western districts with considerable drizzle, low cloud and sea fog. The high pressure over Greenland joined with that over France and settled as an anticyclone over the North Sea from the 16th to the 19th. During this period the weather was cool near the east coast and mainly dry, but there were thundery outbreaks in Cornwall on the 18th, and on the following day weak low-pressure systems moving north from France brought some rain to most of England and Wales, but thereafter a westerly type of weather set in, and persisted for the rest of the month. Weather was fairly dry and sunny over most of the country, but rain was more prolonged in the west and north, notably on the 23rd when nearly 1 in. of rain in 12 hr. was recorded at Benbecula in the Hebrides. More than twice the average amount of rain for the month was recorded over most of south and central Wales, the south-west Midlands and Exmoor; the duration of sunshine at several places was the lowest on record for June.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	79	24	−1·1	143	+1	81
Scotland	76	22	−0·3	87	−2	103
Northern Ireland ...	70	33	−1·0	154	+4	63

RAINFALL OF JUNE 1955

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square	2·29	113	*Glam.*	Cardiff, Penylan	4·19	167
Kent	Dover	1·51	79	*Pemb.*	Tenby	4·64	193
„	Edenbridge, Falconhurst	2·43	110	*Radnor*	Tyrmynydd	6·89	211
Sussex	Compton, Compton Ho.	3·09	124	*Mont.*	Lake Vyrnwy	5·77	179
„	Worthing, Beach Ho. Pk.	2·33	133	*Mer.*	Blaenau Festiniog	12·81	197
Hants.	St. Catherine's L'thouse	3·22	181	„	Aberdovey	5·66	208
„	Southampton (East Pk.)	2·73	136	*Carn.*	Llandudno	3·21	169
„	South Farnborough	2·74	142	*Angl.*	Llanerchymedd	4·59	194
Herts.	Harpenden, Rothamsted	2·00	89	*I. Man*	Douglas, Borough Cem.	4·80	198
Bucks.	Slough, Upton	2·20	107	*Wigtown*	Newton Stewart	3·69	140
Oxford	Oxford, Radcliffe	4·22	188	*Dumf.*	Dumfries, Crichton R.I.	2·57	102
N'hants.	Wellingboro' Swanspool	2·15	102	„	Eskdalemuir Obsy.	3·07	97
Essex	Southend, W. W.	1·84	99	*Roxb.*	Crailing	0·89	40
Suffolk	Felixstowe	1·93	113	*Peebles*	Stobo Castle	1·42	61
„	Lowestoft Sec. School	2·08	115	*Berwick*	Marchmont House	1·34	58
„	Bury St. Ed., Westley H.	2·42	115	*E. Loth.*	North Berwick Gas Wks.	0·93	57
Norfolk	Sandringham Ho. Gdns.	2·29	106	*Midl'n.*	Edinburgh, Blackf'd. H.	0·74	37
Wilts.	Aldbourne	3·55	144	*Lanark*	Hamilton W. W., T'nhill	1·08	49
Dorset	Creech Grange	2·88	125	*Ayr*	Prestwick	2·81	146
„	Beaminster, East St.	2·86	124	„	Glen Afton, Ayr San.	3·09	103
Devon	Teignmouth, Den Gdns.	3·18	166	*Renfrew*	Greenock, Prospect Hill	3·25	104
„	Ilfracombe	4·66	215	*Bute*	Rothesay, Ardencraig	3·91	127
„	Princetown	4·88	121	*Argyll*	Morven, Drimnin	4·21	136
Cornwall	Bude, School House	2·46	122	„	Poltalloch	3·82	125
„	Penzance	3·73	168	„	Inveraray Castle	6·11	154
„	St. Austell	3·82	147	„	Islay, Eallabus	3·74	143
„	Scilly, Tresco Abbey	4·30	249	„	Tiree	3·39	133
Somerset	Taunton	2·72	155	*Kinross*	Loch Leven Sluice	1·73	79
Glos.	Cirencester	3·69	148	*Fife*	Leuchars Airfield	0·92	55
Salop	Church Stretton	4·04	159	*Perth*	Loch Dhu	3·82	92
„	Shrewsbury, Monkmore	2·38	114	„	Crieff, Strathearn Hyd.	1·39	53
Worcs.	Malvern, Free Library	5·15	222	„	Pitlochry, Fincastle	1·50	72
Warwick	Birmingham, Edgbaston	2·93	114	*Angus*	Montrose, Sunnyside	0·77	46
Leics.	Thornton Reservoir	2·86	132	*Aberd.*	Braemar	1·02	52
Lincs.	Boston, Skirbeck	2·77	152	„	Dyce, Craibstone	1·96	105
„	Skegness, Marine Gdns.	3·82	212	„	New Deer School House	1·19	60
Notts.	Mansfield, Carr Bank	3·28	145	*Moray*	Gordon Castle	1·53	75
Derby	Buxton, Terrace Slopes	3·76	117	*Nairn*	Nairn, Achareidh	1·03	88
Ches.	Bidston Observatory	3·09	140	*Inverness*	Loch Ness, Garthbeg	1·28	56
„	Manchester, Ringway	3·13	129	„	Glenquoich	4·89	100
Lancs.	Stonyhurst College	3·44	112	„	Fort William, Teviot	4·00	113
„	Squires Gate	3·54	170	„	Skye, Broadford	5·02	128
Yorks.	Wakefield, Clarence Pk.	1·60	74	„	Skye, Duntuilm	5·82	224
„	Hull, Pearson Park	2·09	101	*R. & C.*	Tain, Mayfield	0·98	53
„	Felixkirk, Mt. St. John	2·45	112	„	Inverbroom, Glackour	1·90	67
„	York Museum	2·37	114	„	Achnashellach	4·78	127
„	Scarborough	1·30	71	*Suth.*	Lochinver, Bank Ho.	2·46	115
„	Middlesbrough	2·46	130	*Caith.*	Wick Airfield	0·57	32
„	Baldersdale, Hury Res.	2·23	102	*Shetland*	Lerwick Observatory	1·85	103
Norl'd.	Newcastle, Leazes Pk.	3·00	142	*Ferm.*	Crom Castle	4·08	151
„	Bellingham, High Green	1·97	86	*Armagh*	Armagh Observatory	4·30	171
„	Lilburn Tower Gdns.	1·19	57	*Down*	Seaforde	5·13	186
Cumb.	Geltsdale	3·49	129	*Antrim*	Aldergrove Airfield	3·85	160
„	Keswick, High Hill	3·24	111	„	Ballymena, Harryville	3·95	136
„	Ravenglass, The Grove	4·11	157	*L'derry*	Garvagh, Moneydig	2·98	117
Mon.	A'gavenny, Plâs Derwen	5·93	221	„	Londonderry, Creggan	3·51	124
Glam.	Ystalyfera, Wern House	9·66	256	*Tyrone*	Omagh, Edenfel	5·35	190

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