METEOROLOGICAL OFFICE Met.O.751

THE METEOROLOGICAL MAGAZINE

Vol. 93, No. 1105, August 1964

551.571.2(412):551.571.36

VERY LOW HUMIDITY IN THE EAST OF SCOTLAND IN DECEMBER 1962

By F. H. W. GREEN, A. WATSON and N. PICCOZI
The Nature Conservancy

One glance at the thermograph and hygrograph charts for early December 1962 at the Climatological Station maintained by the Nature Conservancy at Moss-side, Strachan (400 ft above mean sea level), Kincardineshire, indicated that air humidity must have been phenomenally low on 3 December and again on 5 December. Closer examination of the records at this, and various neighbouring stations, showed that relative humidities must have fallen at least down to 7 per cent, slightly below those reported for Moor House,[1] Westmorland, Achnagoichan,[2] Strathspey, and others.[3,4] Since the low humidities in December 1962 coincided with some low temperatures, phenomenally low dew-points must have occurred. The occurrences were discussed with Mr. R. Cranna, Superintendent of the Meteorological Office, Edinburgh, and the following account has been compiled with his help.

At Moss-side, the hygrograph trace shows that relative humidity (measured as a percentage) began to fall from about 80 at 0800 GMT on 3 December to about 10 at 1000 GMT and to 7 or below at 1400 GMT, remaining below 20 until 1800 GMT. It rose to about 60 by midnight, remained high (85 to 100) all next day, but fell rapidly after 0800 GMT on 5 December, and then fluctuated violently between 18 and 70 up to 2200 GMT. It tended downwards after this, to about 22 by midnight, and became about 16 between 0200 and 0500 GMT on 6 December, after which it rose to about 70 by 1000 GMT. The sky was largely clear on 3 and 5 December, but was cloudy during the intervening day (see Figure 1).

That the hygrograph was reasonably accurate was checked as carefully as possible from all the wet-bulb and dry-bulb thermometer readings available. Sources of error in the hygrograph are discussed in the *Handbook of meteorological instruments*, *Part I*[5] but the general shape of the graphs would not be in doubt. Roughly five hours after the observation time at 0900 GMT on 3 December the dew-point must have fallen to about −15°F since the thermogram indicated 47°F and the humidity reading was about 7 per cent. There is the possibility of error in the exact timing of the clocks on the thermograph and hygrograph, but it is clear enough that very low humidities and dew-points were attained, and this is borne out by the records at other stations, notably at Whitehillocks (845 ft),

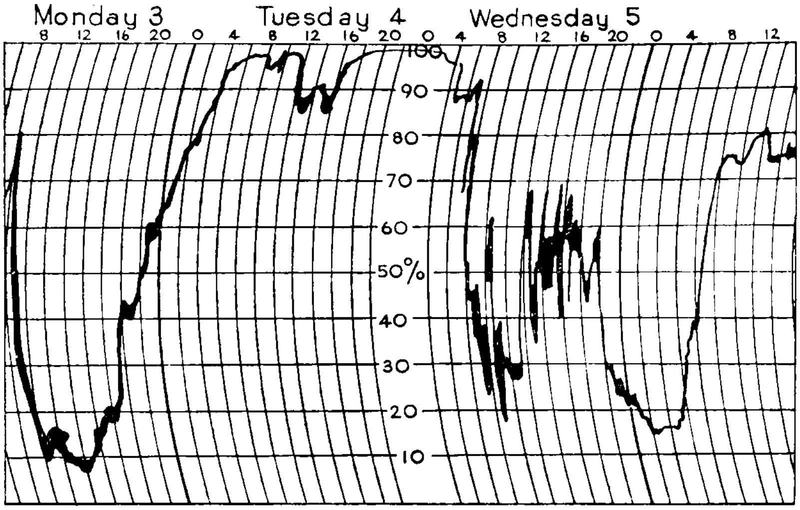

FIGURE 1—HYGROGRAM FOR MOSS-SIDE, STRACHAN, FOR 3–5 DECEMBER 1962

Tarfside (Angus), which lies in Glen Esk about 18 miles across the hills, as the crow flies, from Moss-side. Here there are no autographic instruments, but at 0900 GMT the dry-bulb thermometer reading was 46.5°F and the wet bulb 33.5°F, giving a relative humidity of 7 per cent and a dew-point of −16°F, one degree lower than at Moss-side; it may well have fallen even lower after 0900.

Some low humidities, and consequently low dew-points, also occurred during this period at the following stations (all heights above M.S.L.): Dinnet (580 ft), Dyce (190 ft), Craibstone (300 ft), Aberdeen (Mannofield) (171 ft) and Balmoral (927 ft) all in Aberdeenshire; Fettercairn (Glensaugh) (560 ft) in Kincardineshire; Achnagoichan (1000 ft) and Glenmore Lodge (1120 ft) in Inverness-shire. Although there were no records of relative humidities below 40 per cent or dew-points below 20°F at any of these stations at 0900 GMT, such low figures were surpassed, at other times, at Dyce, as shown by the following data from the Dyce instrumental records:

3 December at 1800 GMT—temperature 45.3°F, dew-point 17.6°F, giving a relative humidity of about 32 per cent.

6 December at 0600 GMT—temperature 41.5°F, dew-point 8.6°F, giving a relative humidity of about 27 per cent.

Autographic records corrected as carefully as possible by reference to fixed-time instrumental observations, give approximate periods with relative humidity below 40 per cent as shown in Table I.

TABLE I—PERIODS OF RELATIVE HUMIDITY BELOW 40 PER CENT IN EARLY DECEMBER 1962

Station	Periods of relative humidity below 40 per cent			
	3 December GMT	5 December GMT	5–6 December GMT	6 December GMT
Moss-side	0900–2000	0900–1300 1500–1600	2200–0800	
Glenmore Lodge	1200–1300 1600–1700	0900–2100	2300–0600	
Achnagoichan	0800–1700	1300–2100		
Dyce	1100–1600 1700–1800			0600–0700

The chief feature of the synoptic situation on 3 December was an anticyclone over central Europe, and the cold air coming over eastern Scotland had had a trajectory mainly over land. It had warmed slightly over the southern part of Britain, and subsidence may have occurred further north. It appears that the low humidities were not entirely confined to north-east Scotland, for, although no very low humidities were noted elsewhere in Scotland, they occurred sporadically in England and in Wales. It was noticed that the 0900 GMT observations at the Nature Conservancy's Moor House Field Station (1830 ft) in Westmorland were:

3 December—temperature 43°F, dew-point -5°F, relative humidity 9 per cent.

5 December—temperature 40.5°F, dew-point 3°F, relative humidity 21 per cent.

A mercury-in-steel thermograph (dry-bulb and wet-bulb)was in operation at Moor House at this time. Readings, corrected from the autographic traces between 1100 and 1130 GMT on 3 December according to careful comparison checks, were: dry-bulb 48°F, wet-bulb 35°F so that the dew-point was -3°F and the relative humidity was 10 per cent.

Strangely, also, another Conservancy Station, Swyddffynnon (540 ft) in Cardiganshire had at 0900 GMT on 5 December, a temperature of 44°F, a dew-point of 13°F and relative humidity of 26 per cent. Mr. E. H. I. Rogers of the Meteorological Office Headquarters, Bracknell, looked up the records for 0900 GMT from other high-level stations south of the Border. Among Spadeadam (900 ft), Malham Tarn (1297 ft), Onecote (1350 ft), Alwen (1100 ft), Bwlchgwyn (1267 ft) and Tredegar (1028 ft), only two stations recorded relative humidities below 40 per cent and these were Spadeadam on the 3rd and 5th and Malham Tarn on the 5th. From the observations published in the *Daily Weather Reports* it was noticed that some fairly low humidities occurred at a number of widespread places, but only the following showed relative humidities of less than 40 per cent, and only at the times stated: Aberporth at 0000 and 1800 GMT on 5 December and Manchester at 1200 GMT on the 5th.

On 4 December the influence of a front, parallel to the isobars, lying to the west, was felt at all the stations investigated, and it became cloudy. On 5 December conditions reverted to a situation similar to two days before; the return of the dry air at Strachan would seem to have been very unsteady, for the thermograph and hygrograph traces on 5 December show remarkable fluctuations; it was indeed blowing hot and cold. Later that day air seems to have been arriving from further west, as it became milder and more humid, and the remarkably dry air did not return again.

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WEATHER NOTE: A NOVEMBER RAIN ON THE GREENLAND INLAND ICE

By J. M. HAVENS, M.Sc.

U.S. Army Natick Laboratories

In the course of a field investigation undertaken by the U.S. Army Natick Laboratories, Massachusetts, U.S.A., for the purpose of relating meteorological parameters to snow surface conditions at DYE 2 (66°29′N, 46°22′W), a DEW-line station, an unusual occurrence of rain was experienced on 1 November 1963 at an elevation of 2330 metres (7650 feet) above M.S.L. on the the southern part of the Greenland inland ice.

Weather observations.—The surface weather observations at the station are taken on a routine synoptic schedule by Federal Electric Corporation employees on the station's 'weather deck', about 22 metres (71 feet) above the snow surface. During the period of special three-hourly observations by the U.S. Army an instrument screen was set up at standard height over the surface. The temperatures recorded at these two heights showed marked differences, sometimes as great as 10°–15°C, during inversion conditions that developed

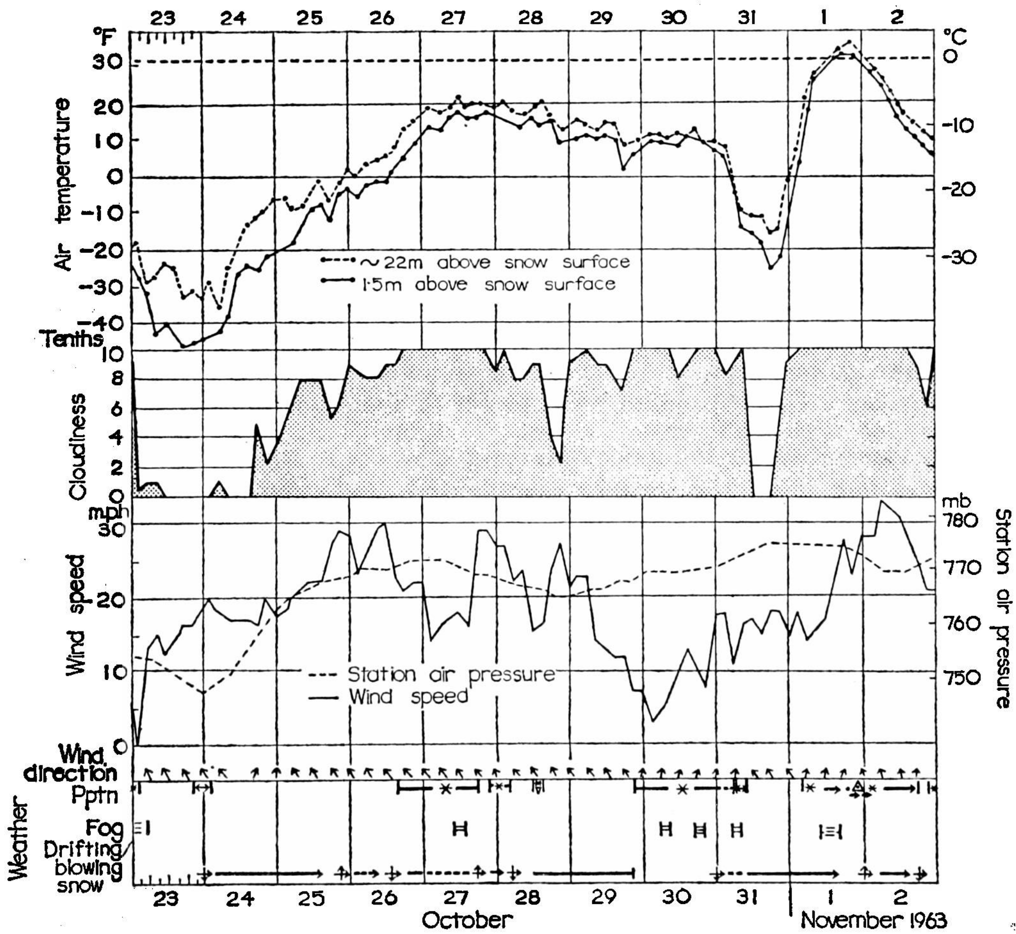

FIGURE 1—COURSE OF THE WEATHER AT DYE 2, GREENLAND, FROM 23 OCTOBER TO 2 NOVEMBER 1963

under clear skies and light or gentle winds. A Bendix-Friez aerovane, sited about 6 metres (20 feet) above the surface, indicated wind speed and direction on dials located in the station building.

Figure 1 describes the three-hourly weather observations at DYE 2 for the period 23 October through 2 November 1963. As cloudiness and wind speeds increased and snowfall began on 1 November the temperature in the surface screen rose by 32.8°C (59°F) in a 24-hour period to a maximum of +0.6°C (33°F). This cyclonic activity was associated with an occluded low near Frobisher Bay, Baffin Island, (Figure 2(*a*)) and strong warm air advection aloft. Twenty-four-hourly positions of the low show its approximate trajectory from 29 October when an advancing cold front became incorporated into hurricane GINNY then located off the east coast of the United States, changing the hurricane into an extratropical disturbance. The synoptic situations in Figure 2 have been copied from operational fascimile charts prepared by the National Meteorological Analysis Center, Washington, D.C., with the exception that the 0°C isotherm on the 700 mb chart has been redrawn, in view of the surface observations at DYE 2, to include a larger area of southern Greenland, Figure 2(*b*).

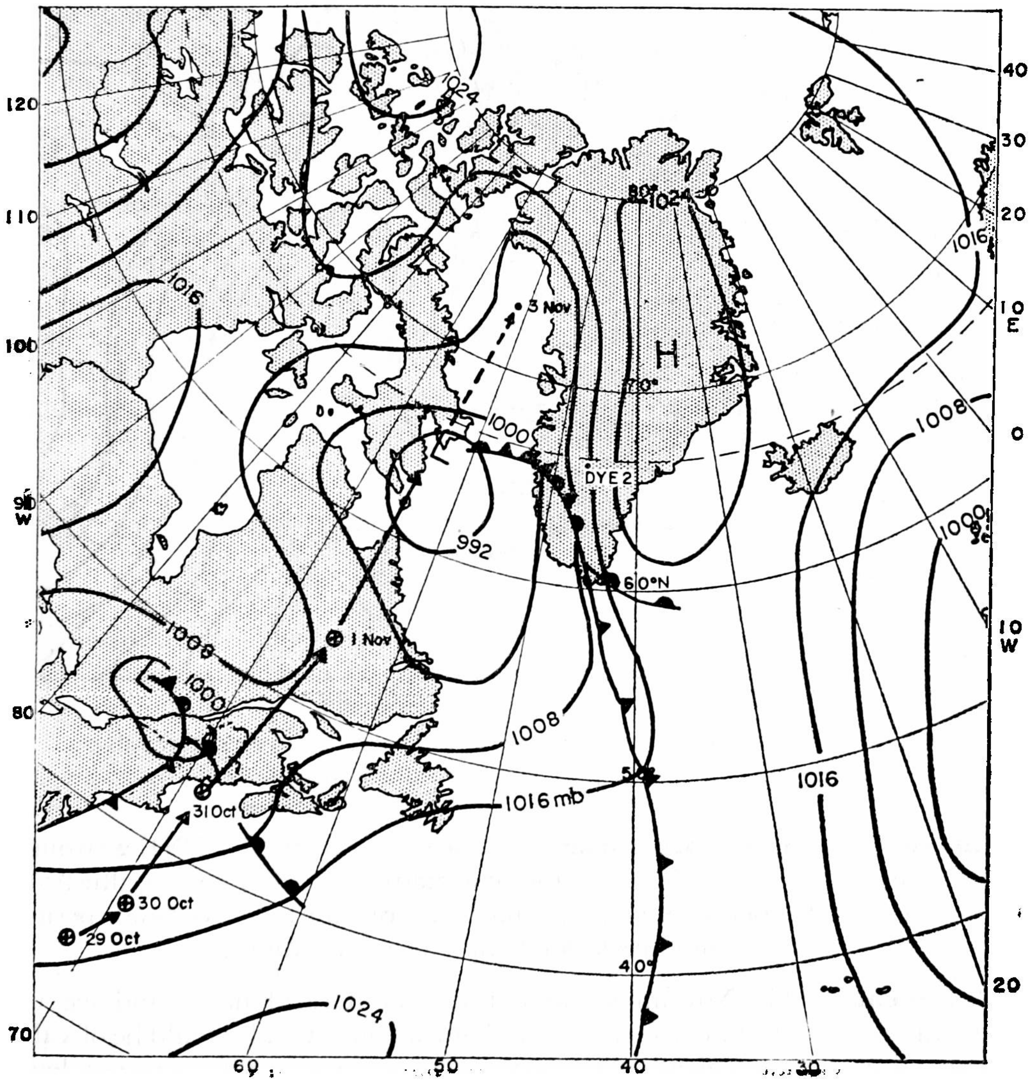

FIGURE 2(*a*)—SURFACE CHART FOR 0000 GMT, 2 NOVEMBER 1963
Arrows show the track of the depression and crosses the 24-hour positions.

Figure 1 also includes the precipitation sequence during the evening hours of 1 November: snow to rain to sleet, and then back to snow. Although the rain, which was light in intensity, did not freeze onto the station building, it may have frozen onto the snow surface, at least for a time. The rain, and associated melting, resulted in an ice crust about 1 cm thick that probably can be identified in snow pits in future years.

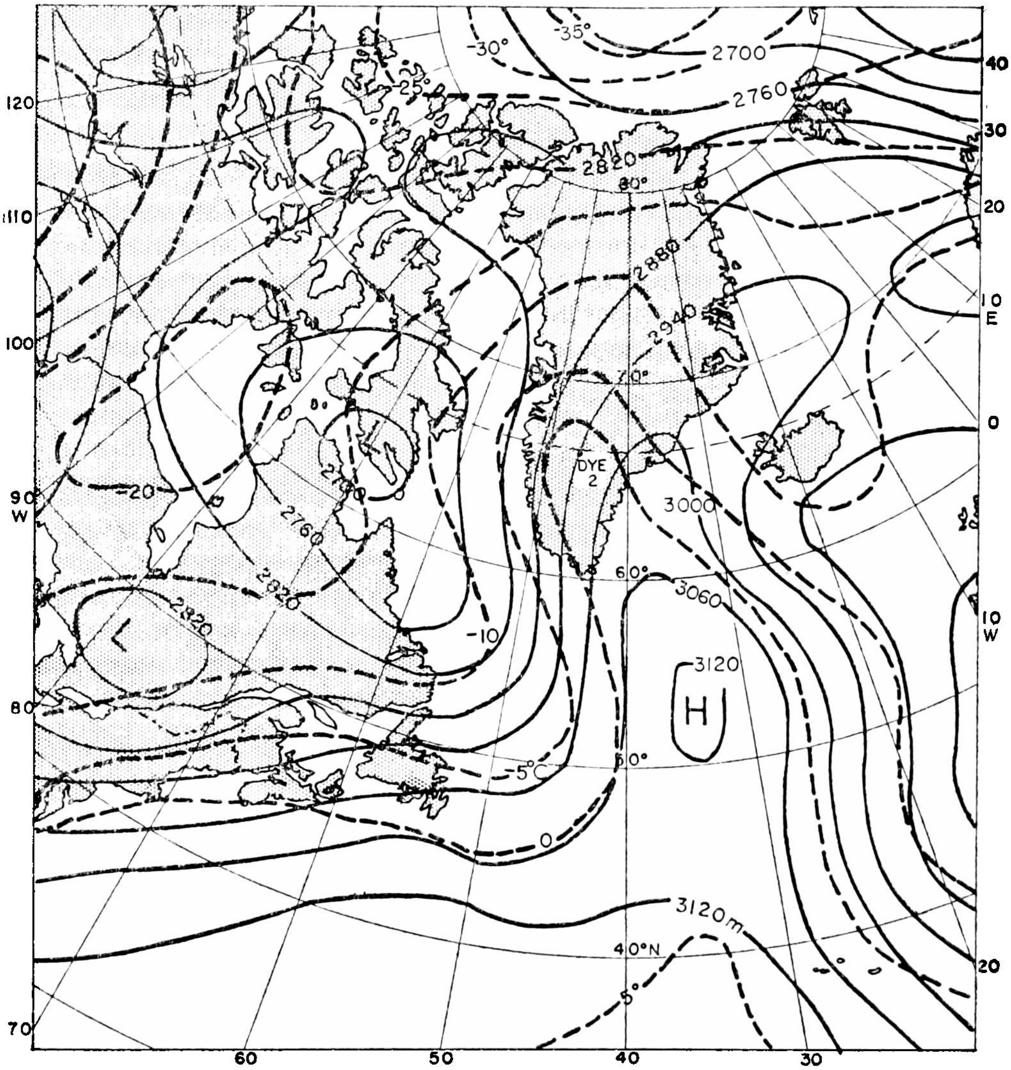

FIGURE 2(*b*)—700 MB CHART FOR 0000 GMT, 2 NOVEMBER 1963

——— Contours — — — Isotherms

Sub-surface snow temperatures.—The warm weather at DYE 2 strongly affected the temperature régime in the first metre of snow. Figure 3 illustrates the sub-surface temperature changes that occurred during two 5-day periods that include the period of marked air temperature variations.

Comment.—This November rainfall on the Greenland inland ice undoubtedly represents an extreme meteorological condition. It would be of value to learn of its climatological expectancy, perhaps through the correspondence column of this magazine.

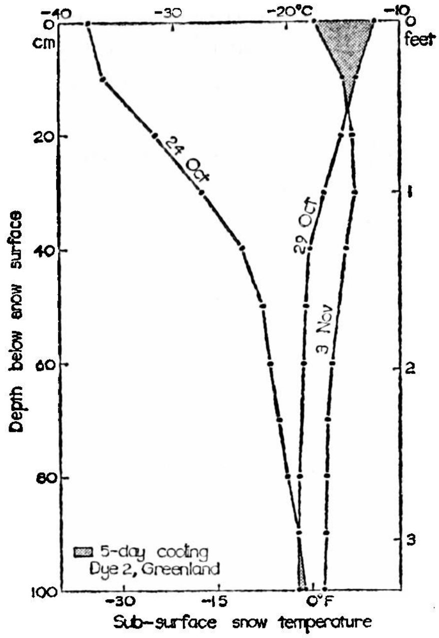

FIGURE 3—SUB-SURFACE SNOW TEMPERATURES AT DYE 2, GREENLAND, ON 23 AND 24 OCTOBER AND 3 NOVEMBER 1963

Shaded areas show the 5-day cooling at Dye 2.

Acknowledgements.—I greatly appreciate the helpfulness and hospitality extended to me by the American and Danish personnel at DYE 2. Sgt. L. E. Holden, U.S. Army, assisted with the weather observations at the station. Suggestions and comments for this note were made by Mr. Donald W. Hogue who also spent several weeks at DYE 2 during 1963. The figures were prepared by Miss Gertrude B. Barry.

Editor's note.—It is of some interest that at 0000 GMT on 2 November 1963, the total thickness (1000–500 mb) in this Greenland area reached the maximum recorded in the 1949–53 period.

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DRY SPELLS OF THREE DAYS OR MORE AT LONDON FROM NOVEMBER TO APRIL

By C. A. S. LOWNDES

Introduction.—This work provides a statistical background to the problem of forecasting dry spells at London in the winter months. A dry spell was defined as a period of three or more consecutive days at Kew with no precipitation other than a trace of dew. Tabulations of the total daily rainfall from midnight to midnight GMT at Kew Observatory were used to extract the dates of the beginning and end of periods when not more than a trace was recorded. The weather records for Kew in the *Daily Weather Report** were then examined and any day during these periods with precipitation other than dew recorded in the Beaufort letters was discarded and the dry-spell periods amended accordingly. The spells were extracted for the periods 1931 to 1939 and 1943 to 1958, a total of 25 years. The spells for each month were listed separately. Where a spell extended from one month to another, it was included in the month which contained the greater part of it.

*London, Meteorological Office. *Daily Weather Report.*

A similar report on dry spells at London during the summer half of the year has been published earlier,[1] the same definition of a dry spell being used. Where possible, the statistics relating to the summer months are included in this paper for comparison.

The frequency of dry spells of three days or more.—There were 190 spells during the whole period, giving an average of 1.3 spells per month. For the 6 summer months the average was 1.6 spells per month.

Table I shows the average number of spells for each individual month, ranging from 1.0 in December, January and February to 1.9 in March.

TABLE I—AVERAGE NUMBER OF SPELLS FOR EACH MONTH

Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
1.1	1.0	1.0	1.0	1.9	1.6	1.9	1.6	1.8	1.8	1.3	1.4

Each of the 6 months, however, was without dry spells in a number of years. Table II shows the number of months with no dry spells ranging from 2 for March and April to 11 for December. Roughly one in two Decembers, one in three Februarys and one in four Januarys and Novembers had no dry spell of 3 days or more.

TABLE II—NUMBER OF MONTHS WITH NO DRY SPELLS (IN 25 YEARS)

Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
7	11	7	8	2	2	3	3	3	2	7	5

Considering all months of the year, the number of months with no dry spell in individual years ranged from 1 in 1933, 1943, 1947, 1948 and 1955 to 5 in 1946. There were 3 consecutive months with no dry spell on only two occasions, November, December, January 1938 to 1939 and October, November, December, 1939. About half of the 25 years had 2 consecutive months with no dry spell. Only one year had two such periods, February–March and September–October 1954. Most of the periods occurred in the winter half of the year and none were associated with the months March–April, July–August and August–September. Apart from this, the periods were distributed in a random manner throughout the years. However, there were no such periods in the four consecutive years 1947 to 1950.

If we consider the number of months with no dry spell of 4 days or more we obtain Table III. About half the Novembers, Decembers and Januarys had no dry spell of 4 days or more.

TABLE III—NUMBER OF MONTHS WITH NO DRY SPELLS OF 4 DAYS OR MORE (IN 25 YEARS)

Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
14	15	13	10	5	4	3	3	5	5	10	10

The frequency of each length of spell is shown in Figure 1. Of the spells 33 per cent were of 3 days and 17 per cent of 4 days, so that half the spells were of 3 or 4 days duration. Spells of 3 to 7 days made up 83 per cent of the total. Of the remainder 14 per cent were of 8 to 11 days and 3 per cent were 12 days or more in length; the longest spell lasted 18 days. In the summer months there were 5 per cent less spells of 3 days and 5 per cent more of 4 days. Otherwise the percentages were almost the same. The longest spell in the summer months lasted 19 days.

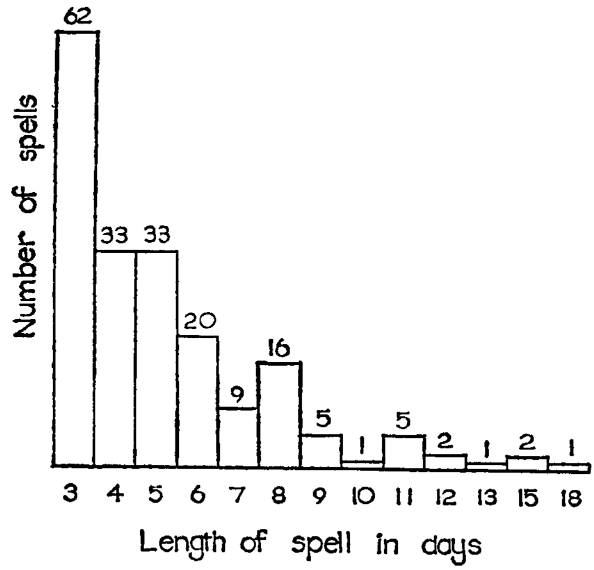

FIGURE 1—FREQUENCY OF EACH LENGTH OF SPELL, NOVEMBER TO APRIL

Total number of spells = 190.

The probability of a dry spell continuing.—The frequency of each length of spell was plotted against the length of spell, a best fitting curve drawn through the points and the frequency corresponding to each length of spell read off from the curve. Table IV shows the probability values calculated from the frequencies obtained in this way. The probability of a dry day after spells of from 3 to 12 days is roughly constant at about 0.7 for both the winter and the summer months, although the values are mainly slightly lower for the winter period.

TABLE IV—THE PROBABILITY OF A DRY DAY AFTER DIFFERENT NUMBERS OF SUCCESSIVE DRY DAYS

	Length of dry spell in days									
	3	4	5	6	7	8	9	10	11	12
	probability									
November to April	0.67	0.69	0.69	0.67	0.66	0.65	0.65	0.65	0.68	0.70
May to October	0.72	0.69	0.68	0.69	0.72	0.73	0.73	0.73	0.75	0.75

The synoptic types associated with dry spells at London.—A short description of the synoptic type in the region of the British Isles was written for each spell. On nearly all occasions this involved a description of the position, movement or formation of the anticyclone or ridge with which the dry spell was associated. The types were then classified according to the region from which the high or ridge moved towards the British Isles or in which the high was situated, often with a ridge extending to the British Isles. The regions are shown in Figure 2. For example, highs moving from the south-west or ridges extending from highs situated to the south-west were classed as Type V; highs as Type VH and ridges as Type VR. A type which began with a ridge extending from the south-west from which a high then developed or broke away was classed as Type VRH. There were only two occasions when a dry spell was not associated with a high-pressure system and these were classed as Type

IX. On these occasions a shallow depression extended over the Continent and the British Isles. Both were very localized dry spells and rain occurred in parts of south-east England.

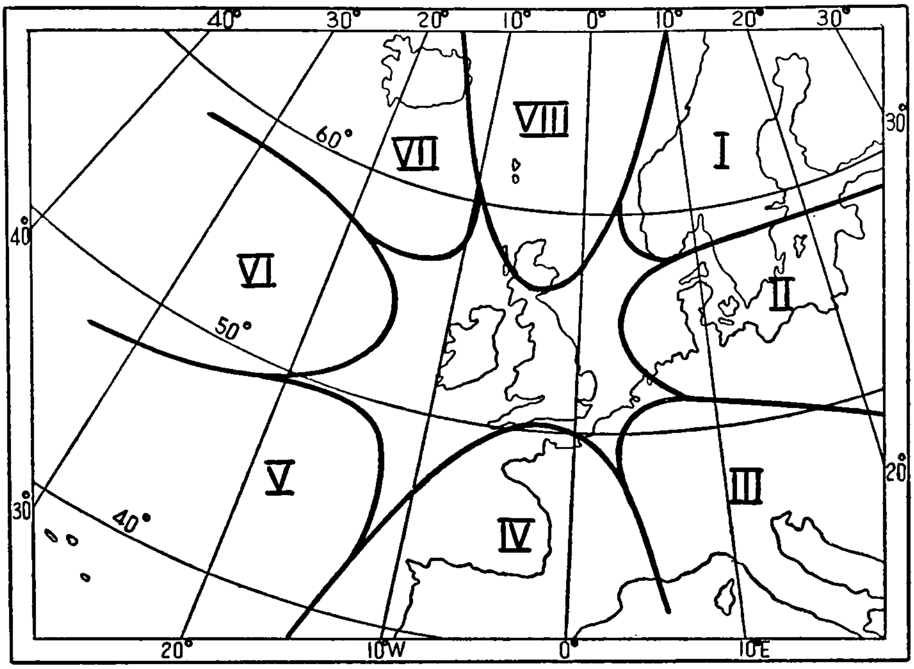

FIGURE 2—THE REGIONS USED IN THE CLASSIFICATION OF SYNOPTIC TYPES

The types were sub-classified by a suffix figure according to the track taken by the high or the orientation of the ridge with respect to the British Isles. Exactly the same classification was used as for the summer months, with additions as necessary. The complete classification is shown in Table V together with the number of spells associated with each type. For the purpose of this Table, if a spell was made up of more than one type, it was grouped under the type which predominated.

TABLE V—CLASSIFICATION OF SYNOPTIC TYPES (NOVEMBER TO APRIL)

Total number of spells = 190

Synoptic type	Class	Number of spells	
Ridge from Scandinavia extended over British Isles	IR_1		2
High over Scandinavia	IH	8	16
High moved from Scandinavia—over British Isles to Continent	IH_1	2	
—east of British Isles to Continent	IH_2	6	
Ridge from east extended—over British Isles	IIR_1	5	8
—over southern British Isles	IIR_2	2	
—to south of British Isles	IIR_3	1	
Ridge from east extended over British Isles, then high formed over British Isles and persisted	$IIRH_1$	2	3
Ridge from east extended to south of British Isles, then high formed to south of British Isles and persisted	$IIRH_2$	1	
High to east of British Isles	IIH	10	11
High moved from east to British Isles	IIH_1	1	
High over Continent	IIIH		13

High to south of British Isles	IVH	6	
High moved from south to Norwegian Sea—across British Isles	IVH_1	–	
—east of British Isles	IVH_2	1	
High moved from region of Spain, south of British Isles, to eastern Europe	IVH_3	9	18
High moved from south across British Isles to Continent	IVH_4	2	
Ridge from SW extended—to west of British Isles	VR_1	–	
—over British Isles	VR_2	2	7
—over southern British Isles	VR_3	2	
—to south of British Isles	VR_4	3	
Ridge from SW extended over British Isles, then high formed over British Isles and moved to—Norwegian Sea	VRH_1	–	
—Scandinavia	VRH_2	2	
—North Sea	VRH_3	–	
—Continent	VRH_4	3	9
—west	VRH_5	–	
Ridge from SW extended to south of British Isles, then high formed to south or SE of British Isles and persisted or moved east	VRH_6	4	
High to SW	VH	3	
High moved from SW—to a position west or NW of British Isles	VH_1	1	
—west of British Isles to Norwegian Sea	VH_2	–	
High moved from SW over British Isles—to Norwegian Sea	VH_3	–	
—to Scandinavia	VH_4	1	39
—to North Sea	VH_5	3	
—to Continent	VH_6	13	
—then to west	VH_7	3	
High moved from SW, south of British Isles, to Continent	VH_8	15	
Mobile ridge moved from west across British Isles	VIR_1	–	
Blocking ridge, or col, associated with high to south, moved from west across British Isles	VIR_2	3	7
Ridge from west extended over British Isles	VIR_3	4	
High to west of British Isles	VIH	3	
High moved from west, north of British Isles or over N. Scotland —to Norwegian Sea	VIH_1	–	
—to Scandinavia	VIH_2	–	
High moved from west over British Isles—to Scandinavia	VIH_3	–	
—to North Sea	VIH_4	–	21
—to Continent	VIH_5	10	
—to SW approaches	VIH_6	2	
—then to west	VIH_7	3	
High moved from west, south of British Isles, to Continent	VIH_8	3	
Ridge from NW extended over British Isles	VIIR		2
High to NW	VIIH	2	
High moved from NW—west of British Isles to SW approaches	$VIIH_1$	1	
—west of British Isles to Continent	$VIIH_2$	–	
—to British Isles	$VIIH_3$	4	17
—across British Isles to Continent	$VIIH_4$	6	
—across British Isles to SW	$VIIH_5$	1	
—east of British Isles to Continent	$VIIH_6$	3	
Ridge from north extended—over British Isles	$VIIIR_1$	1	
—east of British Isles	$VIIIR_2$	1	2
High to north of British Isles or over Scotland (low to south of British Isles)	VIIIH	3	
High moved from Norwegian Sea—east of British Isles to Continent	$VIIIH_1$	5	
—to east of British Isles	$VIIIH_2$	2	13
—across British Isles to Continent	$VIIH_3$	1	
—to west of British Isles	$VIIIH_4$	2	
Shallow depression over Continent and British Isles	IX		2

The highest proportion of spells (29 per cent) was associated with high pressure to the south-west of the British Isles (Type V). Of these, about half were associated with highs which moved from the south-west across the British Isles to the Continent or south of the British Isles to the Continent. Some 15 per cent of the spells were associated with high pressure to the west of the British Isles (Type VI). Of these, nearly half were associated with highs which moved from the west across the British Isles to the Continent or south of the British Isles to the Continent. Of the remaining spells, about 10 per cent were associated with high pressure to the north-east (Type I), to the east (Type II), to the south-east (Type III), to the south (Type IV), to the north-west (Type VII) and to the north (Type VIII).

Table VI shows the percentage of spells which were associated with each class of synoptic type together with the corresponding percentages for the summer months. The proportion of spells associated with Type V was only about half that for the summer months. For all the remaining types (excluding Type IX) the proportion was above that for the summer months and for all except Types VI and VIII about two to three times higher.

TABLE VI—THE PERCENTAGE OF SPELLS ASSOCIATED WITH EACH CLASS OF SYNOPTIC TYPE

	I(NE)	II(E)	III(SE)	IV(S)	V(SW)	VI(W)	VII(NW)	VIII(N)	IX
					percentage number of spells				
November to April	9	12	7	9	29	15	10	8	1
May to October	5	5	2	3	62	11	5	6	1

Table VII shows the number of spells in each month which were associated with each class of synoptic type, expressed as a percentage of the total number of spells in each month. The percentage of Type V varies between 16 per cent in February and 50 per cent in April, but there is no evidence of a systematic variation from month to month as is apparent in the period May to October when the percentage rises to a maximum of about 80 per cent in July and August. The only suggestion of systematic variation occurs with Type IV which reaches a maximum of 16 per cent in January and February.

TABLE VII—THE PERCENTAGE OF SPELLS IN EACH MONTH ASSOCIATED WITH EACH CLASS OF SYNOPTIC TYPE

Synoptic type	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
						percentage number of spells						
I(NE)	4	17	8	4	21	0	4	5	2	2	3	14
II(E)	25	8	16	12	10	2	4	0	2	2	9	14
III(SE)	7	13	4	8	6	5	0	8	2	0	0	5
IV(S)	7	8	16	16	8	5	9	0	2	0	3	3
V(SW)	18	25	40	16	21	50	55	64	80	78	50	39
VI(W)	28	8	8	16	15	13	9	10	10	11	16	11
VII(NW)	7	4	0	20	15	10	9	5	0	2	6	11
VIII(N)	4	17	4	8	4	13	10	8	0	5	13	3
IX	0	0	4	0	0	2	0	0	2	0	0	0
						total number of spells						
	28	24	25	25	48	40	47	39	45	45	32	36

The make-up of the longer spells.—As in the summer months the highest proportion (26 per cent) of spells of 7 days or more was predominantly associated with Type V but in the summer months the proportion was 66 per cent. However, over half of the spells of 7 days or more which were associated with Type V in the winter months occurred in April. For the other 5 winter months November to March, the highest proportion of the spells (19 per cent) was associated with Type II and a further 16 per cent with Types I, V andVI.

Conclusions.—As in the summer months, the highest proportion of the dry spells of 3 days or more at London was associated with high pressure to the south-west of the British Isles (Type V) but the proportion of 29 per cent was only about half that for the summer months. The second highest proportion of the spells, as in the summer months, was associated with high pressure to the west (Type VI) and the proportion of 15 per cent was similar to that for the summer months. However, for the 5 months November to March, the highest proportion of the spells of 7 days or more was associated with high pressure to the east (Type II) and the second highest proportion with high pressure to the north-east (Type I), to the south-west (Type V) and to the west (Type VI).

For the summer months, rules for forecasting dry spells associated with a spread of high pressure from the south-west or west of the British Isles (Types V and VI) have been obtained.[2] About half the dry spells which actually occur are forecast. In order to forecast a similar proportion of the dry spells which occur in the winter months it will be also necessary to forecast dry spells associated with a spread of high pressure from other directions, for the longer spells in particular from the north-east or east (Types I and II). A further paper will be published shortly giving rules for forecasting dry spells in the winter months.

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551.5:06:629.13

RESEARCH IN AIRCRAFT: TWENTY-ONE YEARS OF THE METEOROLOGICAL RESEARCH FLIGHT

By R. F. ZOBEL, O.B.E.

Introduction.—The Meteorological Research Flight (MRF) was formed at Farnborough in August 1946. This however was in the nature of a change of name and location, rather than the original creation. The true beginning of the Flight may be regarded as having occurred at Boscombe Down in the second half of 1942. It was then that special facilities were made available for meteorological investigations to be carried out by aircraft of the High Altitude Flight and a meteorologist was posted in to take charge of the investigations. Thus the Meteorological Research Flight had its beginnings a little over 21 years ago. It is therefore 'of age' and this may be an appropriate moment briefly to review its history and achievements, to compare them with earlier work and to take a glimpse into the future.

Early aerological work using aircraft at Farnborough.—The early investigators of the atmosphere, naturally enough, used the tools at their disposal, i.e. kites and balloons. This was pioneering work and was done largely by the inspiration, enthusiasm and endeavour of individuals. The days of institutional, organized research had not yet arrived and the rate of progress was slow.

The invention of the aeroplane in the early years of the century had led to the Royal Balloon Factory at Farnborough becoming the Royal Aircraft Establishment (RAE) and this further led, after rather protracted negotations, to the opening at Farnborough of the first Branch Office of the Meteorological Office, or outstation as we would now call it, in 1913. It is appropriate therefore to note in passing the jubilee of the first aviation outstation—the office at Farnborough. British aviation has had its home at Farnborough from the days of ballooning in the 1870's, so it was but natural that the meteorological demands of aviation should first arise there. In meeting them it is clear that the Director of the Office (Dr. W. N. Shaw, as he then was) also had well in mind the dividends that might accrue to the science of meteorology by the use of aircraft to carry meteorological instruments aloft.

A memorandum concerning the use of aircraft written by him in 1913 included the following items:

(*a*) the relative vertical motion of the air and the machine;
(*b*) the absolute vertical motion of the machine;
(*c*) the construction of a light vane to show deflections of the relative wind from the horizontal, recording on an open time-scale chart with a gyroscope or other steadying device to show changes of inclination of the aeroplane;
(*d*) a method of indicating 'bumps' by vertical accelerometer or other means;
(*e*) temperature and other meteorological elements including electrical elements.

These concepts have a distinctly modern note, but progress has been made, as will appear later. However, little immediate headway was made with this programme. The outbreak of World War I may have been the cause of little or no attempt being made, the demands of gas warfare and gunnery receiving higher priority. Prior to 1920, the only aerological work undertaken at Farnborough appears to have been an attempt in 1916 to relate visual range from an aircraft to horizontal visibility. That problem is still unsolved.

Early in 1921 however the meteorologist-in-charge (later to become famous for his discoveries in radar—Sir Robert Watson-Watt) wrote: "Full weight should be given to the fact that the association.......with the Royal Aircraft Establishment would, if fully utilized, provide an invaluable aid to meteorological research." Just prior to this an aeroplane psychrometer had been fitted to a DH9 machine and some observations were obtained up to a height corresponding to 550 mb. The tempo was now beginning to increase, but a great deal of effort was spent on a rather curious attempt during 1922 to release a balloon from an aircraft at 15,000 feet. The aim was to follow it some distance into the stratosphere by theodolites on the ground. It is not until this same year that reports of work indicate any investigations into 'bumps' being carried out. This was directed mainly to problems relating to the control of aircraft in polar air.

Somewhat sporadic measurements of accelerations were made during the mid-1920's, but the main effort was put into developing strut psychrometers of various kinds. Various types were used from time to time—the Marvin, the Jaumotte, the Barothermograph—and these were fitted to a variety of aircraft—DH9, Plover, Siskin, Bristol Fighter.

Plate I is a photograph taken about 1926 and depicts a considerably modified Bristol Fighter. The pipe under the upper mainplane was for the purpose of ducting air, undisturbed by propeller or engine exhaust, into the observer's cockpit where the temperature and humidity were measured. This method was later tried out operationally by the Duxford 'Met. Flight' and found to be impracticable. Regular vertical ascents by that flight were commenced in 1927.

The establishment of the Duxford flight naturally meant that some at least of the experimental flying was arranged to be done on aircraft of that flight. Nevertheless a certain amount of activity continued at Farnborough. By the outbreak of World War II the main undertaking was the investigation of icing on aircraft.[1] The tempo, which had never been fast, was again very slow. At no time between the wars was there any staff specially assigned to research using aircraft. Perhaps not very surprisingly the results obtained were rather modest for a lapse of time of 20 years. One thing that is very evident is the co-operation and assistance of the RAE, just as it is today. What was lacking were men and resources. The Annual Report of the Director of the Meteorological Office for 1927–28 shows the state of affairs clearly. It states: "Owing to the large amount of routine work, the opportunities for doing original research are very limited, but in all departments of the Office more or less purely scientific work is undertaken. The greater part of this work, however, is done out of office hours by the staff purely from the interest they have in the work....... More original work would be undertaken if the staff of the Office were larger. At present there is no special provision for pure research, every post in the Office carrying with it a definite amount of fixed work."

It was this state of affairs which was brought to an end in 1942. One of the first steps in this direction was the commencement of organized research using aircraft at Boscombe Down.

The Boscombe Down era.—It is an ill wind that blows no good and World War II was no exception. Scientific and technological advancement occurred in many fields at a much greater rate than hitherto. War in the air demanded that meteorology should be one of those fields.

The urgency with which the Meteorological Research Committee, itself only formed in November 1941, viewed the necessity for aircraft to be specifically allocated to meteorological research, may be judged by the fact that by the following August the necessary arrangements had been made and Dr. Brewer was in post. At that time the High Altitude Flight had two Spitfire and one Boston aircraft, but additional aircraft were allocated and these later included Fortress, Mosquito and Hudson aircraft.

The original concept was that the Flight should have two main aims, firstly to develop instrumentation and techniques for the several meteorological reconnaissance flights which then existed and secondly, to conduct investigations into the physics of the atmosphere. Early effort was much concerned with the development of instruments to measure temperature and humidity using the faster aircraft then in service. The outcome was two instruments still in regular use; the flat-plate resistance thermometer and the Dobson-Brewer frost-point hygrometer. The latter was the first instrument capable of providing reliable values of humidity in the stratosphere. It was indeed so outstanding at the time that offers to lend hygrometers were made to the U.S.S.R., the U.S.A., Canada and Australia in 1945, but the first successful ascent was actually made in December 1943. The results are reproduced by Frith[2] in his account of the MRF in 1948.

The information in those days was not easily obtained. The Fortress aircraft in which the early stratospheric flights were made had a ceiling of 37,000 feet, but it was unpressurized and the cabin heating was far from adequate. There was considerable difficulty in finding a crew, all of whom could withstand the physical strain of the climbs. The climb to ceiling took about an hour and observations were made on descent. It was not possible to observe on the ascent because by the time a high altitude was reached the crew became too cold and exhausted to persist in the climb to the ceiling.

Work at Farnborough.—The field of activity widened rapidly. By the time the MRF was formed under that title at Farnborough in 1946 the rather out-of-balance combination of two scientific officers and four aircraft (two Mosquito PR 34's and two Halifax Mk. VI's) were tackling a formidable list of problems. The following four were of high priority:

(*a*) investigation of water content of the troposphere and lower stratosphere under various conditions;
(*b*) observation and investigation of temperature, humidity and wind in the stratosphere in low and high latitudes;
(*c*) exploration of rain-producing clouds;
(*d*) investigation of size distribution of water particles in clouds.

The first of these problems had come into prominence earlier owing to the tell-tale appearance of condensation trails in the wake of high-flying bombing and reconnaissance aircraft. However it transpired later that atmospheric water vapour content was not the primary factor. MRF observations settled the matter beyond doubt.

As the years went by the list of problems became even longer. New ones were added, but old ones seldom removed. It is true of so many facets of nature that substantial progress to its understanding only serves to reveal further complexities demanding solution. This is perhaps outstandingly true of atomic physics, but it is true too of atmospheric physics. Progress has been made and MRF has made its contribution, often considerable, but some aspects, at least, of the problems enunciated by Sir Napier Shaw in 1913 are still not completely solved.

It would be quite impossible in this short article to review or even to quote the long list of scientific papers which has been published by MRF staff, neither is it its purpose. Nevertheless, it would be inappropriate not to mention an example of the work of Murgatroyd,[3] who played a leading part in the exploration of the stratosphere by aircraft and who was Head of the Flight for 12 years. The topics discussed by MRF writers are many: development of instruments, atmospheric temperature and humidity, cloud physics, condensation and sublimation nuclei, water content and drop sizes in cloud and precipitation, the structure of fronts, tracers of atmospheric circulations (ozone, water vapour, radio-activity), radiation and albedo, jet streams, and others. One of the few branches of meteorology in which there has been no participation is atmospheric electricity—strangely enough, the meteorological element singled out by Shaw in 1913, and in spite of the fact that the Varsity aircraft has twice been damaged by lightning.

The current programme of research.—So much for the past. What of the present? The Flight is now equipped with one Hastings, one Varsity and one Canberra aircraft. These are shown in Plate II. The Canberra has only just come into service as the replacement for a similar aircraft unfortunately lost in an accident. The loss caused a considerable break in stratopheric investigations. The instrumentation of the Hastings aircraft has recently been described by

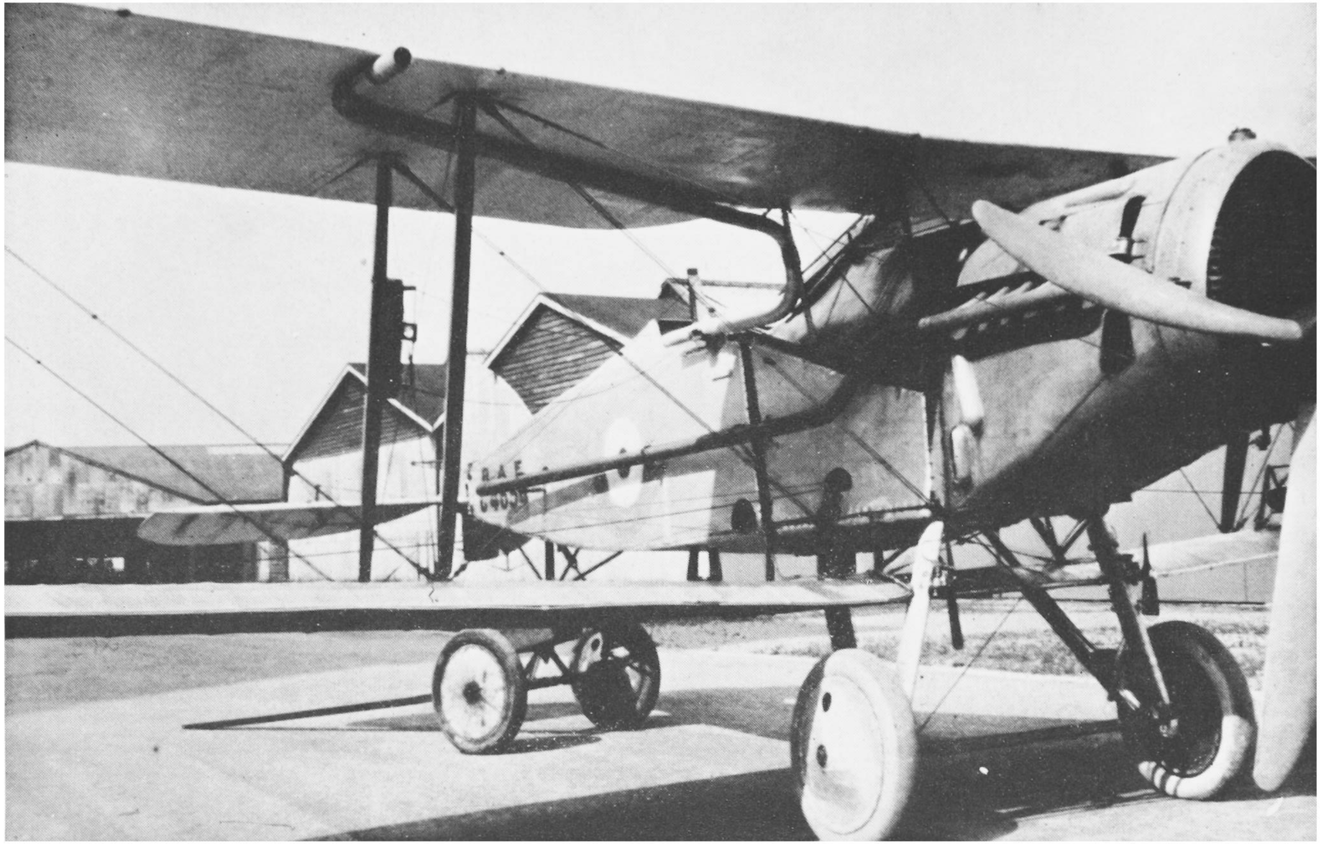

PLATE I—MODIFIED BRISTOL FIGHTER, ABOUT 1926, SHOWING AIR DUCT TO COCKPIT AND PSYCHROMETER WITH LENS CONTROL WIRES

(See p. 238)

PLATE II—HASTINGS (FARTHEST), VARSITY AND CANBERRA (NEAREST) AIRCRAFT OF THE METEOROLOGICAL RESEARCH FLIGHT

(See p. 240)

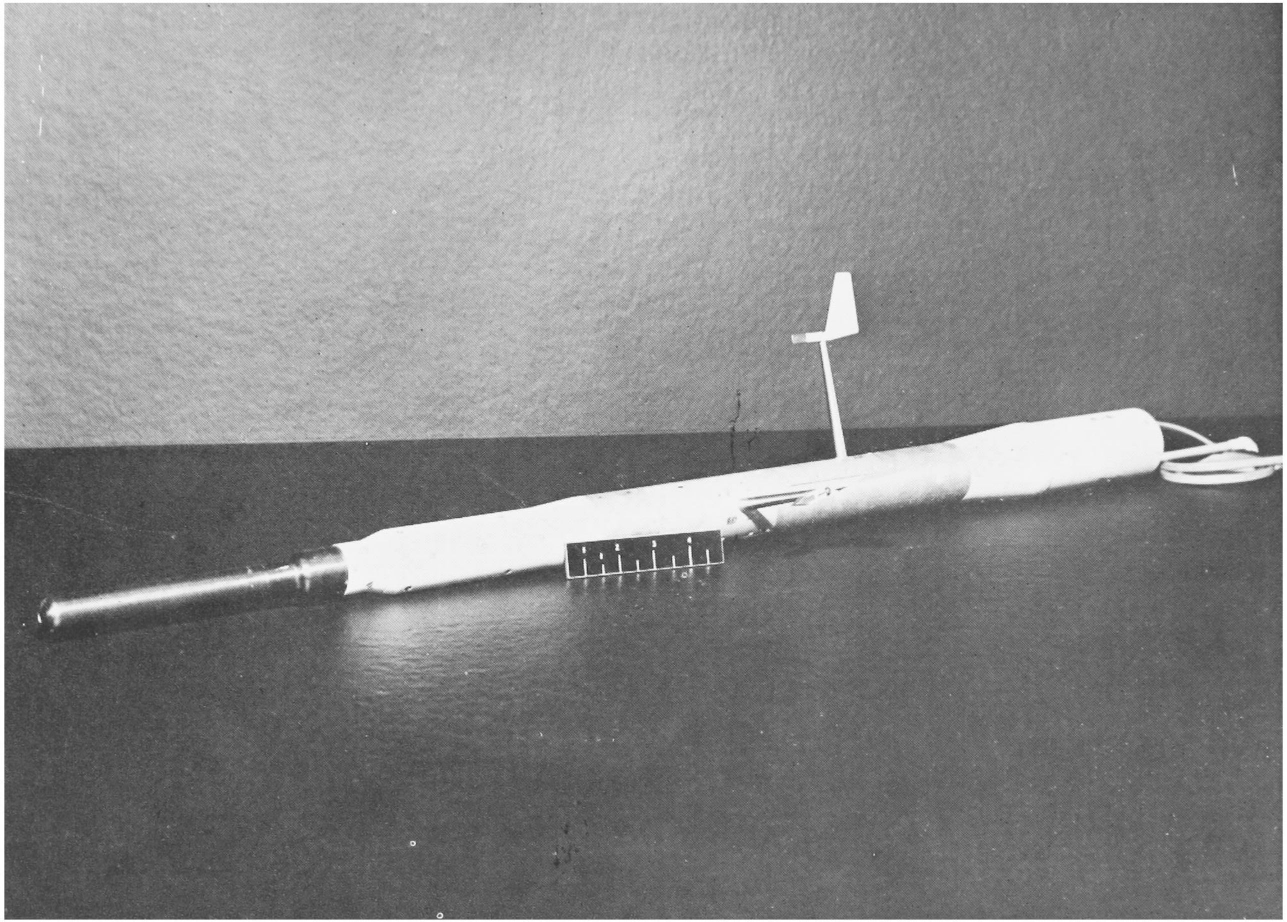

PLATE III—CANBERRA NOSE PROBE INCORPORATING TWO PERPENDICULARLY MOUNTED WIND VANES AND PITOT TUBE. (SCALE SHOWS INCHES)

(See p. 241)

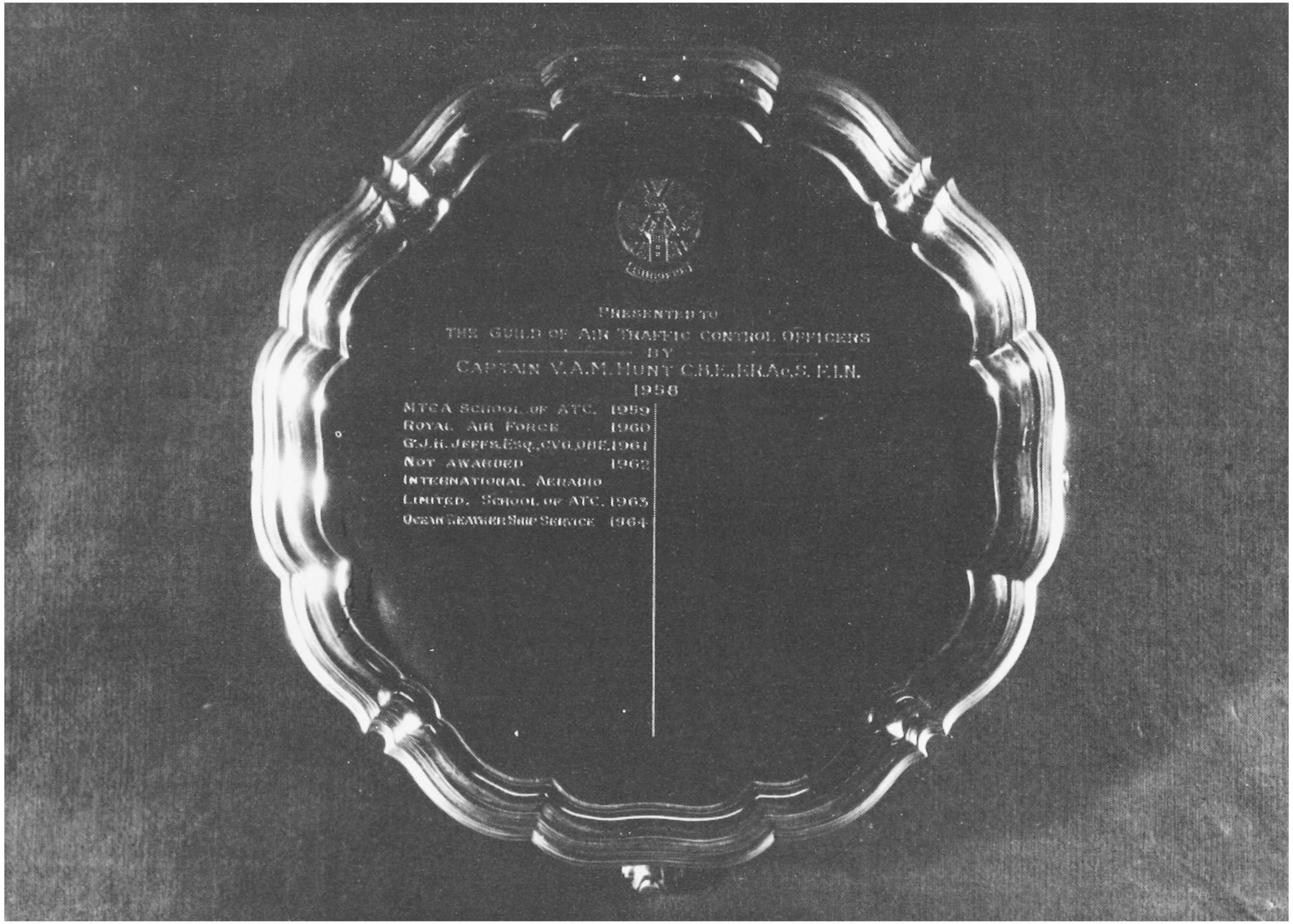

PLATE IV—HUNT TROPHY

Awarded to the British Ocean Weather Ships in 1964 (see page 254).

Grant.[4] The Varsity aircraft has rather similar, but less elaborate, instrumentation. It serves as an independent research vehicle for a number of purposes and also as a test-bed for new instruments and techniques.

The opportunity has been taken to equip the new Canberra aircraft with rather sophisticated instrumentation for the measurement of the vertical gust velocity of the air, a parameter of importance in studies, for example, of convection, jet streams and cloud dynamics.

It may be shown that the vertical gust component W_g acting on an aircraft is given by:

$$W_g = V_a\,(\,\alpha \cos r - \beta \sin r - \theta\,) + W_a + l\frac{d\theta}{dt}, \qquad \ldots (1)$$

where α and β are the angles of attack about the transverse and vertical axes respectively, θ is pitch angle, r is roll angle, V_a and W_a are the forward and vertical speeds of the aircraft and l is a simple dimension of the installation. The angles of attack, α and β, are measured by wind vanes mounted on a probe as shown in Plate III. The probe can also be seen mounted on the modified nose of the Canberra in Plate II. The angles θ and r are measured with gyroscopes. Forward speed V_a is obtained in the usual manner, whilst W_a is obtained by electronic integration of the vertical accelerations of the aircraft which are given by a sensitive accelerometer mounted on a gyroscopically controlled platform. The derivative $d\theta/dt$ is obtained directly from a further gyroscope.

At present the records consist of photographic traces produced by the deflections of galvanometers. At an airspeed of 150 metres per second a great deal of information requiring a great deal of processing (e.g. equation (1) above) may be accumulated in a very short time. For this reason it is hoped to develop, in the near future, a digital system for producing a record on magnetic tape compatible with a *Mercury*-type computer. This should very greatly accelerate the output of results, not only for air motion parameters, but for most or all of the 20 or so parameters normally recorded in the air. At the present time these measurements are mainly directed to studies of convection, radiation, cloud physics and dynamics, structure of fronts, clear air turbulence and ozone content.

Recently Cornford[5] has made an interesting, but so far not completely confirmed, discovery of a rainy layer near the main base of nimbostratus cloud in winter warm fronts. He has analysed the results of flights in such fronts. The rate of rainfall was calculated from the indentations by the raindrops on a continuously running foil of aluminium. He finds the somewhat surprising result that on some occasions the rate of rainfall near the cloud base (usually about 2000 feet) is several times that at the ground. A short account of the Monday Discussion of this topic is to be found in an earlier issue of this Magazine.[6]

Enough has been said of present activities to show that the Flight has plenty of interesting work to do.

The future.—One of the great difficulties of aerological work lies in finding a suitable observational platform in the free atmosphere. We have already mentioned earlier work in which instruments were raised on kites and free or tethered balloons. Indeed the two latter are still in use. More recently radar has allowed some measurements to be made without the need to raise any instruments. All these however have a common fault in that they lack mobility. The aeroplane has much to commend it from this point of view as it does not have to wait for the weather to come to it. Nevertheless it is far from an ideal platform. Its very mobility means that corrections which are related to airspeed become large, the motion of the aircraft disturbs the properties of the atmosphere which it is desired to measure and the high rate of sampling means that very sensitive, quick-response instruments are required if a knowledge of small-scale, local variations is required.

The aeroplane has other deficiencies. Not only is it a fast-moving platform but it is a very unsteady one too. It pitches, rolls, yaws, sideslips and flexes. As indicated above, the MRF employs gyroscopes to overcome some of these difficulties where they are important, but one cannot eliminate them completely. Costs are also high. For work of the highest accuracy very precise and very expensive gyroscopes are required. The aeroplane also has limited altitude. Whilst new aircraft, ever flying higher and higher, pose new meteorological problems there is a need for a platform at flying height before the production aircraft begins to operate there. But very seldom is a research aircraft of any kind available to provide such a platform. The tropical stratosphere is still largely unexplored by aircraft.

So the aeroplane is not an ideal vehicle from which to conduct meteorological research, but it is a very useful one and one to which meteorologists owe much. As the supply of problems is unlikely to run out and as a slower, steadier, yet highly mobile platform is not yet in sight the aeroplane is likely to remain our research vehicle for some time yet.

The Meteorological Research Flight has come of age with a good record of achievement behind it. Nowadays the Flight has its own scientific staff, its own aircraft, its own RAF aircrew and a new building with laboratories and excellently equipped workshop. It has the tools to enable it to continue its record of achievement. There is still plenty to be done.

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551.524.2(421):551.588.7

AN ACCUMULATED TEMPERATURE MAP OF THE LONDON AREA

By T. J. CHANDLER
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Heating engineers are frequently interested in accumulated temperatures below certain base temperatures. Manley[1] has argued the case for a datum of 14°C (57°F) mean temperature below which some form of artificial heating becomes necessary but for present purposes the more customary 15.6°C (60°F) will be taken. This is 2.7°C (5°F) below what in this country can be regarded as a desirable comfort temperature, the difference being accounted for by solar radiation through windows and incidental heat gains from lighting, cooking and persons within the building.

Knight and Cornell,[2] amongst others, have shown that for buildings maintained at an indoor temperature of 18.3°C (65°F), there is quite a close relationship between fuel consumption and accumulated temperature below 15.6°C (60°F) over corresponding periods of time. This suggests that the degree-day total below 15.6°C (60°F) measures a large part of the heating requirements of buildings, particularly where the incident wind speeds are low, as in the more densely settled parts of cities.

Sometimes, however, heating engineers have taken their climatological records from a nearby rural station, failing to realize the substantial differences between temperatures inside and outside cities. This is well illustrated in London.

Averages of accumulated temperature may be derived in a number of ways[3] but for present purposes the method described in Meteorological Office Form 3300[4] (designed for use with a 5.6°C (42°F) base) has been used to derive accumulated temperature below 15.6°C (60°F) by using suitably adjusted individual monthly values of mean daily maximum and minimum temperatures. A map was first prepared for 1959–62 using records from more than 50 stations established by the London Climatological Survey[5] as well as synoptic and climatological stations sending monthly returns to the Meteorological Office. This short-period analysis was then used as a guide for a longer-period study from 1951–60 based upon 15 stations. Figure 1 shows the annual pattern and Table I gives the individual monthly values.

Two main factors differentiate accumulated temperatures within Greater London: altitude and urban exposure. Totals of more than 4000 Fahrenheit degree-days occur in the elevated rural areas of south Hertfordshire, north of London, and on the North Downs to the south of the city. Similar values occur on Hampstead Heath and also, no doubt, in comparable areas such as Harrow Hill in north London. The lowest values occur in the inner north-east suburbs of Islington, Finsbury and Shoreditch. The urban influence accounts for a reduction of about 400 degree-days, or about 10 per cent of the values at comparable heights outside London. Elevation controls are more difficult to assess since they cannot be separated from associated changes in the urban morphology. Even so, the fall-off in degree-day totals from Upper Holloway, Tufnell Park and Kentish Town to Hampstead is outstanding. If Regent's Park and Hampstead are compared (both stations with a fairly open exposure and 2.5 miles (4 kilometres) apart in north London), the decrease in the annual total of degree-days amounts to 532 in 321 feet (98 metres), an average of about 1.7 degree-days per foot. This is considerably more than the average of 1.0 degree-days per foot in southern England[3] and emphasizes the position of Hampstead Heath and comparable areas above the majority of London's heat-islands.

Figure 1 makes a fair summary of London's heat-island as it affects regional temperatures. The obvious asymmetry is mainly owing to the character of the urban development, with some of the highest building densities in the City of London and in the compactly developed areas of inner north-east London. The character of the immediate urban environment is, in fact, highly

TABLE I—ACCUMULATED TEMPERATURE BELOW 60°F, LONDON, 1951–60, IN FAHRENHEIT DEGREE-DAYS

	Height above M.S.L. feet	Height above M.S.L. metres	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
					degree-days						*degree-days*				
Westminster	27	8.2	614	560	470	324	152	60	28	28	66	211	414	508	3435
Camden Square	110	33.5	620	566	500	318	152	60	31	28	66	205	414	508	3468
Kensington Palace	81	24.7	626	563	479	327	161	54	31	34	69	229	420	520	3513
Regent's Park	129	39.3	620	578	482	336	164	66	31	34	81	213	417	517	3539
Kew Observatory	18	5.5	620	578	491	351	173	66	31	34	84	235	423	514	3600
Hampton	39	11.9	638	590	485	297	173	66	34	40	84	229	441	529	3606
Greenwich*	24	7.3	623	569	491	339	179	72	31	40	90	245	429	523	3631
London (Heathrow) Airport	82	25.0	641	590	494	351	188	75	34	40	87	247	441	550	3738
Bromley	213	64.9	644	593	503	363	197	81	37	43	96	253	447	541	3798
Dartford	17	5.2	638	596	497	363	209	90	37	43	99	253	441	541	3807
Croydon	220	67.1	656	599	512	375	203	81	34	43	96	259	432	544	3834
Southgate	221	67.4	674	605	515	354	203	84	34	43	96	256	450	553	3867
Wisley	105	32.0	659	584	503	366	203	99	46	52	126	274	471	559	3942
Addington	474	144.5	680	626	533	393	212	96	43	46	108	247	474	565	4023
Hampstead	450	137.2	677	623	563	384	212	99	52	52	108	265	468	568	4071

*Greenwich Observatory, 149 feet (45.4 metres), 1951–52

Source of data: London. Meteorological Office. *Monthly weather report*, 1951–60.

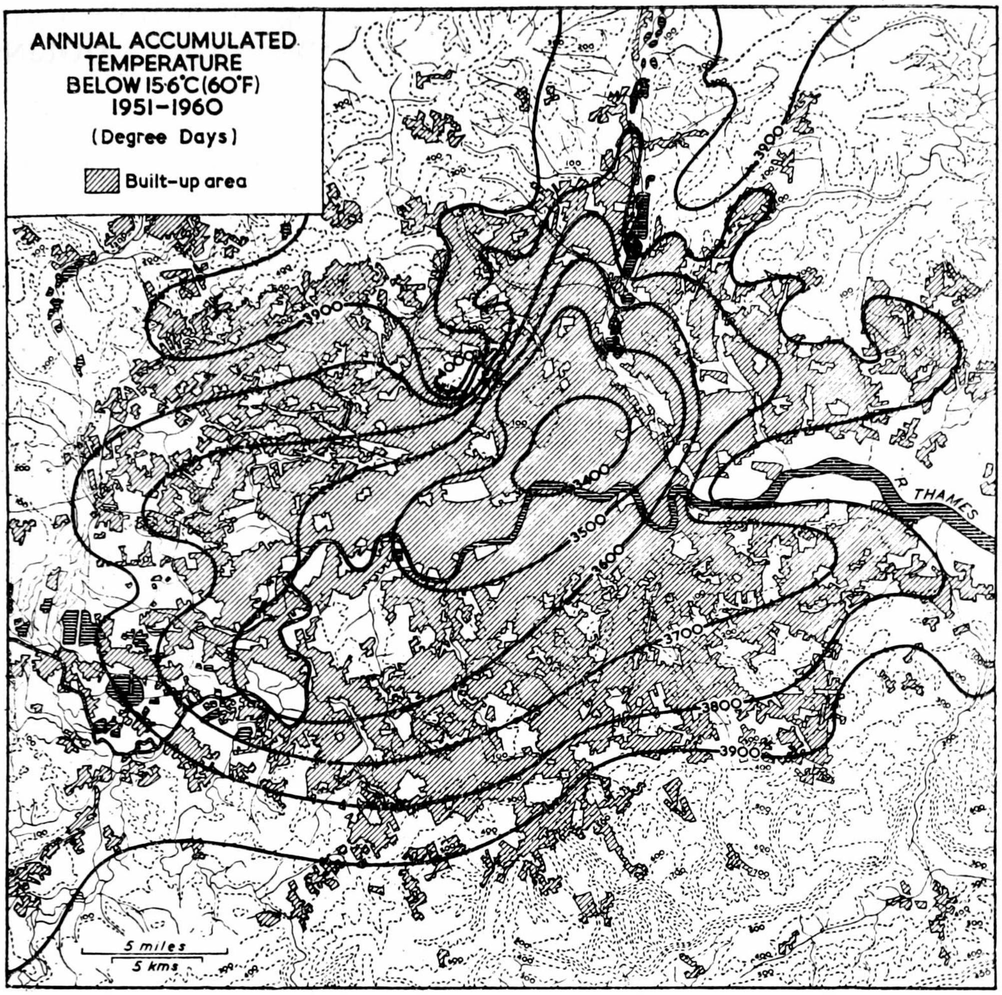

FIGURE 1—AN ACCUMULATED TEMPERATURE MAP OF THE LONDON AREA
Isopleths are numbered in Fahrenheit degree-days

critical in determining the degree of local warming and for detailed studies of heating requirements, account must be taken of site influences upon solar radiation, temperatures and winds close to the buildings in question. But the picture is also complicated by the style of architecture and in most studies more regional climatic values have to be used. Nevertheless, attention should always be paid to the effects of the buildings themselves upon the climate outside their walls.

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551.509.323:551.521.32:551.524.31

A METHOD OF FORECASTING A RADIATION NIGHT COOLING CURVE

By J. A. BARTHRAM

Introduction.—Articles, notably by Saunders,[1,2] have shown that the rate of decrease of temperature on radiation nights has a discontinuity during the evening, and that the subsequent fall of temperature is related to the strength of the geostrophic wind. This article describes a method of depicting these factors on a simple diagram, and with an assumption about the time of minimum temperature a cooling curve can be quickly drawn.

Factors used in determining the cooling curve.—

Temperature of discontinuity.—Articles by Saunders and others [3-6] show that at a time which varies from month to month there is a check in the rate of cooling, and the temperature of this discontinuity (T_R) is given by

$$T_R = \tfrac{1}{2}(T_{max} + T_d) - K$$

where T_{max} is the day maximum temperature, and T_d is the dew-point at the time of T_{max}. The factor K varies between cases when there was or was not an afternoon inversion with a base below the height of the 850 mb level and also varies with location of site.

The following figures are suggested mean values of K for low-lying inland airfields:

(*a*) with an inversion below 850 mb, $K = 2°C$
(*b*) with no inversion below 850 mb, $K = 1°C$

They are based on values published in the articles mentioned, and on the author's experience at airfields so situated. Figure 1 is a diagram from which the discontinuity equation can be solved for the values of K suggested. Each vertical line is given values for cases with and cases without an inversion, though individual stations may have to amend the values shown. For normal use a temperature range from, say −10°C to 25°C would be displayed.

Time of discontinuity.—This time is related to the time of sunset and will also vary with location, and possibly with whether the ground is wet or dry. Figure 2 is a suggested monthly curve for low-lying inland airfields in the southern half of England near the meridian, based again on values from the articles previously mentioned. The values of time (GMT) of T_R at the beginning of the month are:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1645	1745	1845	2015	2100	2130	2145	2130	2030	1900	1745	1700

Subsequent cooling: the minimum temperature.—The articles[1-5] also give details showing how the fall of temperature after T_R is related to the geostrophic wind speed and the value of T_R. It was found that acceptable means could be produced from the data given, and Figure 3 shows curves giving the night minimum temperature for a range of values of T_R and wind strength. Once again the graph is based on low-lying inland airfields, and significant amendments may be necessary for other locations.

Time of occurrence of minimum temperature.—Although there is generally a day-to-day variation in the time of occurrence of the minimum temperature (T_{min}), it has been found that the time of local sunrise gives a good approximation.

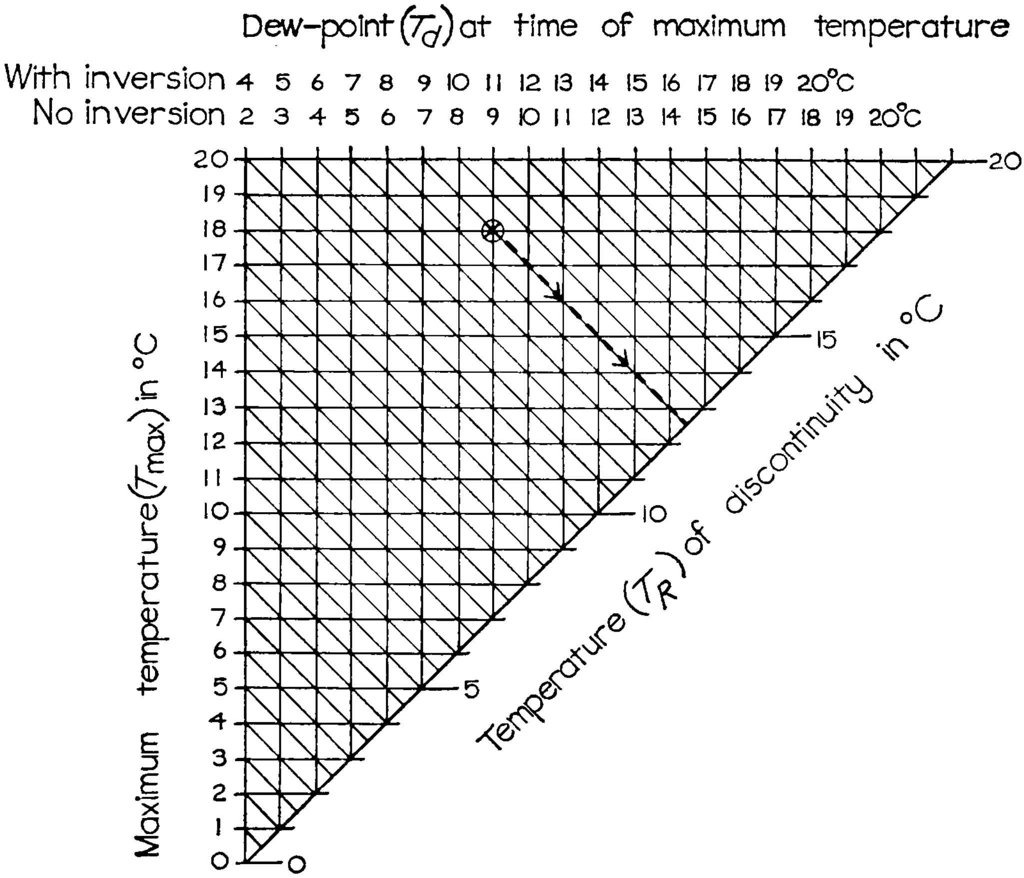

FIGURE 1—GRAPH FOR OBTAINING THE TEMPERATURE OF DISCONTINUITY FROM THE MAXIMUM TEMPERATURE AND THE DEW-POINT AT THE TIME OF MAXIMUM TEMPERATURE

Example: T_{max} = 18°C, T_d = 11°C with inversion give T_R = 12.5°C.

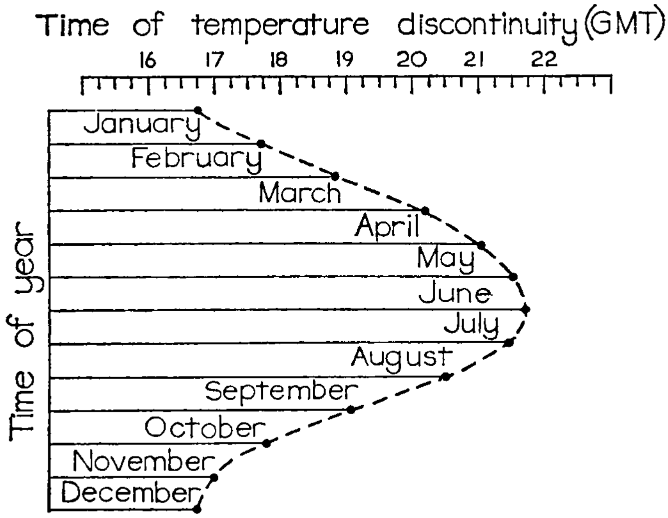

FIGURE 2—MONTHLY CURVE OF TIME OF TEMPERATURE DISCONTINUITY

The curve is based on data for low-lying airfields and is dependent on the time of sunset.

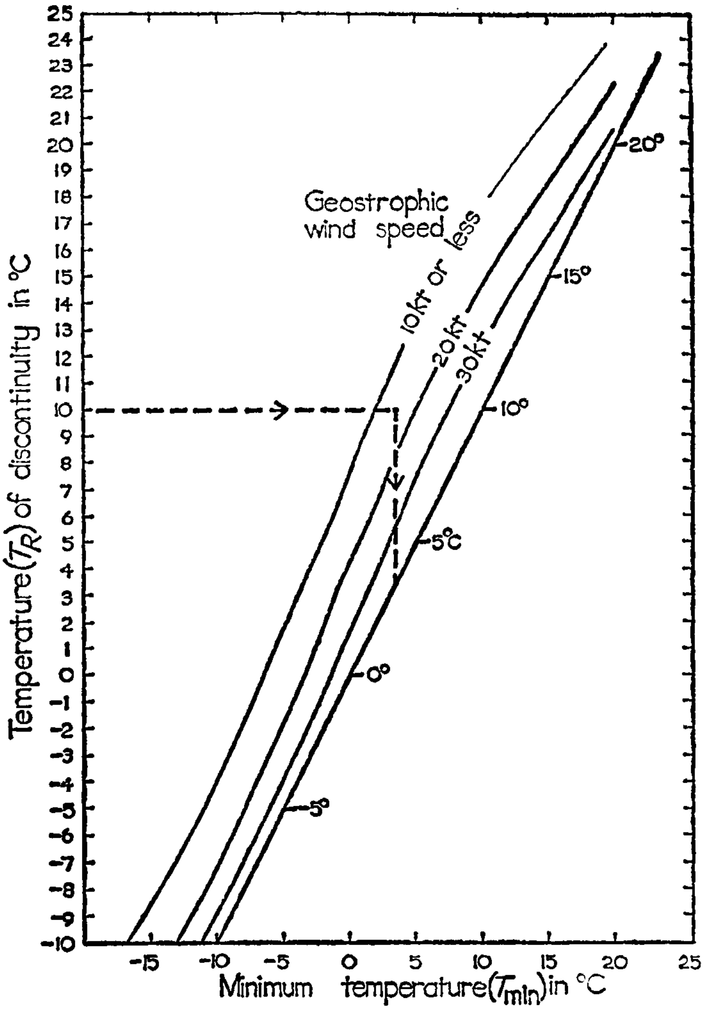

FIGURE 3—GRAPH FOR OBTAINING THE MINIMUM TEMPERATURE FROM THE TEMPERATURE OF DISCONTINUITY FOR VARYING GEOSTROPHIC WIND SPEEDS

Example: $T_R = 10°C$ and wind speed = 15 kt give $T_{min} = 3 \cdot 5°C$.

Forecasting a cooling curve.—

Features of the diagram in Figure 4.—Section 2, the central part of Figure 4, has a horizontal time-scale and a vertical temperature-scale. On this part the cooling curve is drawn. In the lower part of this section are drawn the curves of time of discontinuity and time of minimum temperature.

In section 1, on the left, is a reproduction of Figure 1—reduced in size and detail—for finding the temperature of discontinuity. Section 3, on the right, is the graph (shown in detail in Figure 3) for determining the minimum temperature from the temperature of discontinuity and the geostrophic wind speed.

Method of positioning T_R.—The method of positioning T_R is shown in Figure 4. Plot the maximum temperature at its time of occurrence in section 2, run back along the T_{max} isotherm to the appropriate dew-point in section 1, and then follow the sloping grid lines to the main diagonal. Take this value, T_R, horizontally across until it cuts the vertical from the time of discontinuity. Plot this point.

Method of positioning T_{min}.—To plot T_{min} the value of T_R already obtained is carried horizontally across the diagram in Figure 4 until it cuts the curve of the appropriate geostrophic wind speed in section 3. Follow a vertical line through

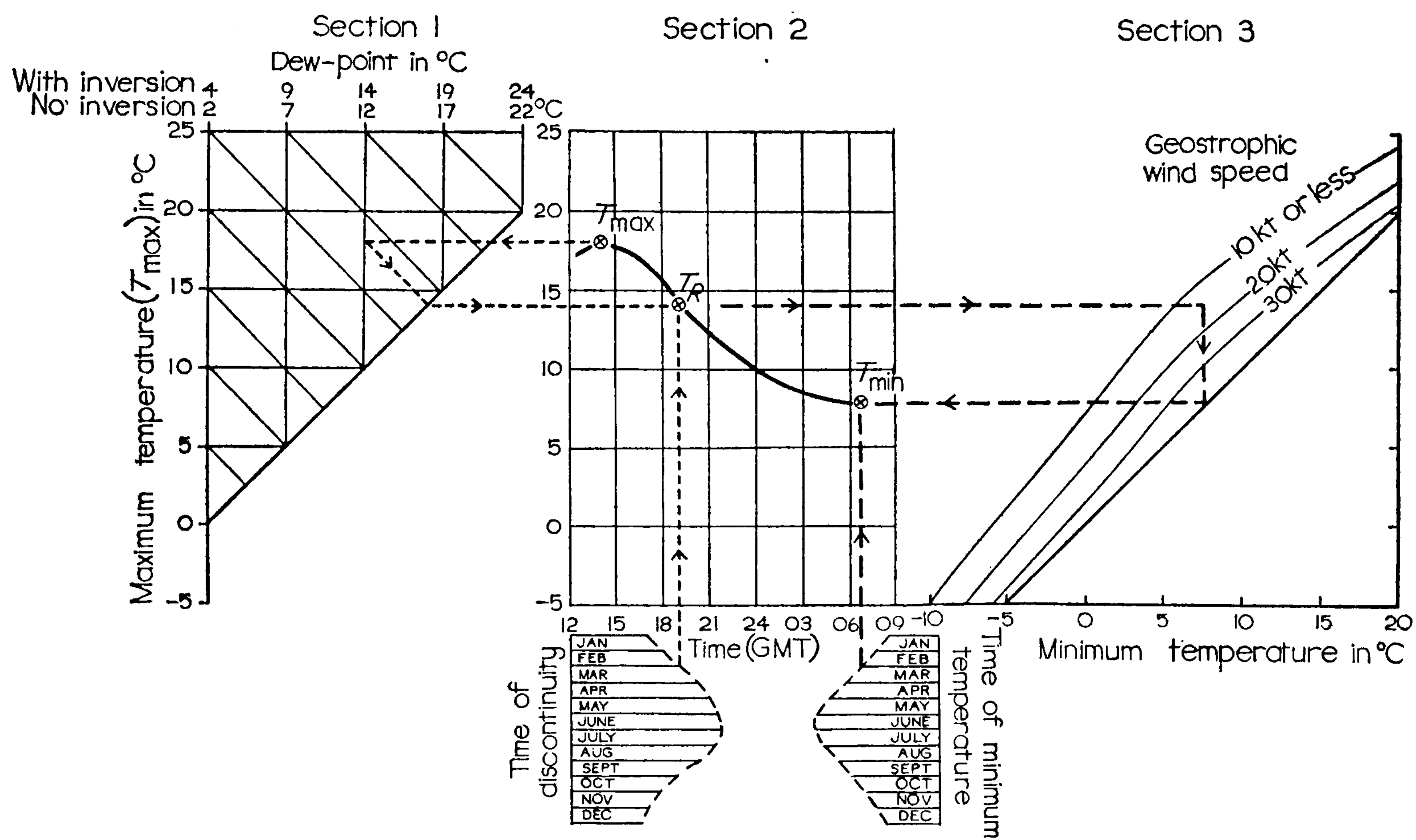

FIGURE 4—DIAGRAM FOR FORECASTING A COOLING CURVE ON RADIATION NIGHTS

Example: date = 3 March. T_{max} = 18°C at 1400 GMT, T_d = 12°C, no inversion, and wind speed = 15 kt.

here to the main diagonal. This is the minimum temperature. Run back along the horizontal isotherm of T_{min} until it meets the vertical from the time of minimum temperature, and this point is plotted.

The cooling curve.—The key points of T_{max}, T_R, and T_{min}, of the cooling curve on radiation nights are now plotted. By joining freehand with the usual 'opposing curves' a forecast of the night's temperatures is quickly obtained. The shape of the 'opposing curves' is soon assessed with experience in use.

An example of a forecast curve is shown on Figure 4. Here the maximum temperature was taken as 18°C, the dew-point as 12°C, on a day in early March without an inversion. The T_R is plotted as 14°C at 1900 GMT, and using a geostrophic wind speed of 15 knots the minimum temperature appears as 7.5°C plotted at 0630 GMT.

Discussion.—A statistical check on the accuracy and usefulness of the curve drawn is not easy. Almost every radiation night has its own irregularities, with the actual temperature fluctuating around the forecast profile.

At Laarbruch, Germany, a check over the past year showed that only about one in every eight forecast curves was considered misleading, the remainder being broadly classified as useful. The most likely cause of failure is the difficulty of assessing a representative dew-point in inhomogeneous air. The minimum temperatures forecast were within plus or minus 2°C on all occasions described as 'useful,' and on half of these occasions the forecast was within 1°C.

The drawing of this cooling curve gives an early assessment of the time the fog-point is likely to be reached. Also hourly plots of actual temperature alongside the forecast profile draw attention to the occasions when this forecast time may require amendment. The probable time of air frost is also readily obtained.

Some places experience a continuing fall of temperature after fog has formed. Figure 5 gives the result of an investigation during 1957 and 1958 at Wyton, Huntingdonshire. An additional detail such as this may be included on the diagram Figure 4, and the forecast curve amended after the expected fog-point is reached. This perhaps rather unusual feature is important when, although the fog-point is significantly above 0°C, an air frost must still be considered.

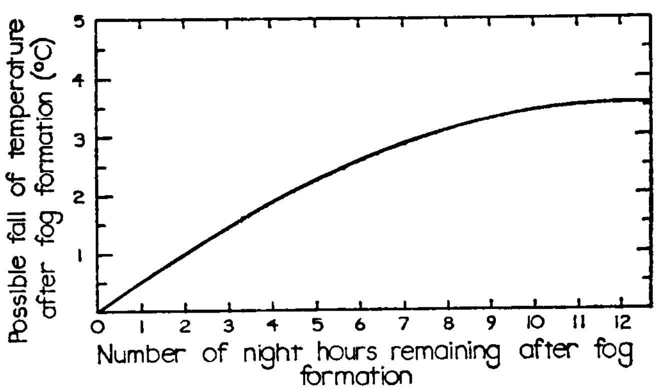

FIGURE 5—POSSIBLE FALL OF TEMPERATURE AFTER THE FORMATION OF RADIATION FOG

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REVIEW

Keoeeit—the story of the aurora borealis, by W. Petrie, 10 in × 7½ in, pp. xii + 134, *illus*, Pergamon Press Ltd., Headington Hill Hall, Oxford, 1963, Price: 35*s*.

For whom is this book intended? It is very difficult to decide. The style of writing seems to vary from section to section, even from paragraph to paragraph, which gives the impression that it has grown up from a set of notes which the author has enlarged. The prologue states that the book is aimed primarily at the non-scientist and the earlier chapters sound faintly like someone talking down to a 12-year old. Later on a much greater familiarity with Advanced Level Physics would be necessary for its full understanding.

The book starts off with an interesting account of the aurora in history, but we are told only what the ancients thought it looked like, and the reader has to wait until Chapter IV before his curiosity about its actual appearance can be satisfied. This is somewhat characteristic of the whole book; the author assumes that the reader has a passing acquaintance with all the topics discussed.

Despite the fact that the aurora "has long attracted the attention of man" Chapter II is an apology for its study. It is not, apparently, the fascination for the aurora which compels people to study it, as the author's prologue would imply, but the cold needs of telecommunications. In this chapter the reader is irritated by the needless digression on the ionized layers in the atmosphere. Chapter III is purely technical, and describes the instruments used to study the aurora. The human eye gets a mention but hardly in due proportion; a discussion of the response of the eye to different levels of intensity of light would have been much more useful to the layman than descriptions of radar installations.

At last in Chapter IV the reader is to be told what the aurora actually looks like. After saying that it defies description the author takes his own words to heart and makes a very poor attempt compared with the build-up in the earlier chapters. The so-called description seems to have been taken bodily from the *Atlas of Auroral Forms*, and amounts to no more than a technical classification of forms. The next chapter deals with "the Habitat of the Aurora", and gives details of the height and geographical extent of the aurora. The transatlantic origins of the book become obvious when one notices that although there is a map of North Amercia showing a highly idealized auroral zone, Europe is not so privileged, and the British reader would get no clear idea of where to go to see the aurora.

After dealing with temporal and spatial variations the writer goes on to discuss light and sound in Chapter VII. Here, it seems, he is more confident and his style more relaxed. He is now writing on a topic he understands, but unfortunately the lay reader will find the technicalities getting too involved; band spectra, Doppler-shifted hydrogen lines and the rest. Finally we go into deep waters discussing the relatives of the aurora and their causes.

The general impression given by this book is that the author has taken on more than he can manage. He wants to write for the layman, but cannot explain first ideas. For example, on page 15 he discusses the necessity for "fast" lenses when photographing the aurora. He seems unequal to the task of describing what this implies to all his readers; he abdicates by saying "those familiar with cameras will appreciate..... the camera has an f number of 0.71". Those who are unfamiliar with cameras are left behind. As the book progresses, more and more basic knowledge is assumed. On page 51 we get the first reference to "particle belts" to correct an impression given by an accompanying diagram, but with no explanation. The Van Allen belts are not properly introduced until the last chapter.

The book is well produced with diagrams and some good photographs in black and white. A novel feature is the collection of coloured paintings aimed at giving a more realistic impression of the aurora as seen. The diffuse nature of the forms comes over well, and this seems to be the best effort in this direction in any popular work on the aurora. Credit for the paintings, however, goes to the author's wife.

G. M. THOMAS

Behind the scenes at London Airport, by Norman Wymer, 8 in × 5½ in, pp. 82, *illus.*, Phoenix House Ltd., 10–13 Bedford Street, Strand, London, W.C.2, 1963. Price: 10*s.* 6*d.*

The link between meteorology and aviation is a very strong one. During the past 50 years, the needs of flying have led to many demands from the meteorological services, but this has been no onesided business relationship. Aviation has made a profound contribution to meteorology itself, not only in the form of direct observations, but more importantly in the stimulus that it has given both to the setting up of surface and upper air observation and networks and to the undertaking of theoretical studies. The association of meteorology and aviation is thus in a true sense a partnership and it has been a very profitable one to both sides.

Despite increasing applications of meteorology today to other fields, aviation still remains by far the biggest customer. It is therefore very much to the advantage of every meteorologist to see to it that he knows and understands something about the world of aviation, for any partnership will be more fruitful if each member of it is well informed about the needs and activities of the other.

The stated intention of this book (which is one of a series) is "to satisfy young people's curiosity about the inside working of everday enterprises." It is thus not aimed directly at adult readers, though it could certainly be read with profit by many who have had little personal contact with civil aviation. Moreover, there are few adults who are not involved from time to time with the curiosity of the younger generation, and in trying to provide answers find themselves singularly ill-equipped for the task. In these situations it is most useful to know a book that may be recommended to, and read by the inquirers themselves.

Having given a brief history of London (Heathrow) Airport and of civil aviation in England, the author continues with a survey of the functions of some of the main departments concerned with the running of the airport and then gives an account of the airlines who use it. This is followed by some information on modern civil aircraft, their development, equipment and maintenance. Succeeeding chapters are on Freight and Mail, Air Crews and Air Traffic Control, whilst to conclude there is a description of a flight followed through from pre-flight planning stage to the maintenance hangar after final touch-down.

References to the Meteorological Office are mostly brief, but following one of them it is pleasant to see recorded the opinion of the Vice-President of the American Air Line Pilot's Association that Heathrow is operationally "as close to Utopia as you can get from a pilot's viewpoint". Undoubtedly the operational side of the Airport, including its meteorological services, is high in international esteem, and the striking thing about this is that such a reputation should have been established in the short time that Heathrow has been open for civil air traffic. The photograph of the 1946 Passengers Waiting Room in a dilapidated marquee is a vivid reminder of the changes that have taken place in well under 20 years.

There are two major pitfalls for books of this kind that set out to provide information for the young; the style can be bad or irritating to the point where the reader loses interest, or the facts provided can be incorrect. On the whole this book has successfully avoided both those traps. The style has the merit of being simple and straightforward, and is completely devoid of any talking down to the reader, whilst the author has obviously gone to a good deal of trouble to inform himself about his subject. He has consulted not only a number of the Airlines and other organizations concerned with the running of the Airport, but also the Ministry of Aviation.

It is therefore a pity that errors have crept in, but a few must be recorded. It is very doubtful whether bonding the aircraft structure (p. 42) reduces the risk of the aircraft being struck by lightning; it would be better to refer to reducing the danger when the aircraft is struck. Icing (p. 42) may form in cloud *above*, not below, the freezing level, and in the same paragraph it would have been better to refer to ice 'on the hinges of control surfaces' rather than "on the hinges of wings". Although the intended contrast with turbulence in cloud is reasonably clear, to say that "above the clouds the weather is usually calm" is not a statement that any pilot or meteorologist can accept.

The description of basic aircraft instruments (p. 41) though simplified is probably adequate except that the periscopic sextant is for use in astronavigation and thus enables the pilot to determine his latitude not his altitude. The simplified version of the quadrantal altitude procedure (p. 61) is probably acceptable, but the example given of its working is quite incorrect; if North America were substituted for the Mediterranean all would be well. The description of Instrument Landing System (ILS) on pp. 68–69 is wrong. Two transmitters at the ends of the runway give the localizer beam and glide path and operate the cockpit instruments. The marker beacons have nothing to do with this, being used in conjunction with the radio compass to give distances from the end of the runway or as a joining facility.

In the description of meteorological pre-flight procedures (p. 72) there are a few turns of phrase which would grate on the ears of a professional meteorologist; similarly the aviation specialist would note the slip in the caption to one of the photographs in which Quantas are alleged to operate a Comet. However, these are quite minor points and could easily be rectified in a future edition along with the other errors noted.

The book is attractively produced, and is well illustrated with 6 line drawings and over 40 photographs. It should also fulfil its stated aim, and it is hoped that it will enjoy the success it deserves.

R. J. OGDEN

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LETTER TO THE EDITOR

Lightning strike 23 April 1964

During the afternoon of Thursday, 23 April 1964, a Varsity aircraft of the Meteorological Research Flight, Farnborough, was flying in a large cumulonimbus situated south of Bedford. The base of the cloud was at 2500–3100 feet with patches of stratus at 1200 feet. A thunderstorm was in progress with frequent lightning and heavy rain. At 1410 GMT, when the aircraft was at 3000 feet in heavy rain just below the cloud base, a brilliant flash of white light and a loud bang was observed. The inside of the aircraft was then illuminated with a shimmering whitish-blue light for a couple of seconds from the starboard side.

The pilot, on the other hand, reported that the loud bang momentarily preceded the flash. He then saw a ball of blue light about the size of a football on the starboard wing tip. This ball lasted for about two seconds before vanishing.

There were several more flashes of lightning, but none in the immediate vicinity of the aircraft.

After landing, a number of small burns were found on both the starboard and port wing tips and also on the underneath of the fuselage. The navigation light on the starboard wing tip had been smashed and the aircraft compass when tested indicated an error in reading of about 10 degrees.

G. T. VIDLER

Meteorological Research Flight, Farnborough.

AWARDS

The Council of the Royal Society of Arts has awarded a Silver Medal to Dr. R. C. Sutcliffe, C.B., O.B.E., F.R.S., for his paper on 'Advances in Weather Forecasting' which was read to the Society on 15 April 1964.

Hunt Trophy

The Hunt Trophy is awarded annually by the Guild of Air Traffic Control Officers to the individual or organization considered to have made the most outstanding contribution to Air Traffic Control in the preceding year. The trophy itself is a silver tray (about 10 inches in diameter) and is inscribed with the names of the recipients in the various years. It was originally presented to the Guild in 1958 by Captain V. A. M. Hunt, C.B.E., B.A., F.R.Ae.S., who is the Director of Control (Operations) in the National Air Traffic Control Service, and who at that time had the responsibilty for Air Traffic Control in the Ministry of Aviation.

The award in 1964 was made to the British Ocean Weather Ships and was accepted by the Director-General of the Meteorological Office on behalf of the Ocean Weather Ships on Friday, 17 April 1964 at the Annual Dinner of the Guild. The Master of the Guild made the presentation and read the following citation:

"While appreciating that the first function of the Ocean Weather Ship Service is to provide meteorological data which itself is of immense value to International Aviation, it has long been evident to Transatlantic aircrews, and to Control Officers at Oceanic Area Control Centres, that the services to Air Traffic Control in respect of communications relay, radar fixing of aircraft, and Alert of Search and Rescue action, often carried out under very difficult conditions and with equipment not specifically designed for the task have been outstanding.

A bond has grown up between Weather Ship Officers, typified by those of the United Kingdom Weather Ships, Oceanic Controllers and Air Pilots, which it is desired to perpetuate by the award this year of the "Hunt" Trophy to the U.K. Ocean Weather Ships Service."

Previous recipients have been:

1959 School of Air Traffic Control. (Ministry of Transport and Civil Aviation.)
1960 Royal Air Force. (In recognition of the setting up of the United Kingdom Air Traffic Service Branch in the RAF.)
1961 G. J. H. Jeffs, C.V.O., O.B.E. (One of the original Air Traffic Control Officers *circa* 1920, and lately Airport Commandant, London Airport.)
1962 (No award this year.)
1963 School of Air Traffic Control. (International Aeradio Ltd.)

The trophy will be exhibited at the Ocean Weather Ship Base at Greenock after a short period of display at the Meteorological Office Headquarters, Bracknell.