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# THE DIURNAL AND SEASONAL VARIATIONS OF FOG AT CERTAIN STATIONS IN ENGLAND,

BY

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# THE DIURNAL AND SEASONAL VARIATIONS OF FOG AT CERTAIN STATIONS IN ENGLAND.

By F. Entwistle, B.Sc.

The following investigation commenced with an examination of the relative frequencies of fog at Croydon at 7h. and 9h. during the period from April 1920 to March 1922. The examination, as will be seen from the discussion of the observations below, brought out clearly a result which had been observed in a general way in connection with the aerial route work of south-east England, viz., that visibility frequently deteriorates temporarily an hour or so after sunrise and then improves considerably during the day. This phenomenon had been associated, in the case of Croydon, with the proximity of the station to London, and it was with a view to examining whether this explanation held generally that the investigation was extended to include other stations free from local town influence. It was also thought worth while to extend the period to include all hours of the day at which observations were made in order to examine the diurnal variation in the frequency of fog. Observations from a coast station were included in order to compare the relative frequency of fog on the coast with that prevailing inland.

*Summaries of visibility frequencies according to the scale in general use were prepared for each month of the period April 1920 to March 1922 by the staffs of the local meteorological offices at Croydon, Lympne (summaries for Lympne and Dungeness) and Cranwell. From these summaries the figures referring to occasions of visibility less than 2,000 yards were extracted and the following groups were dealt with separately :—

(1) Occasions of visibility less than 2,000 yards (all fogs including slight fogs).

(2) Occasions of visibility less than 500 yards (fogs and thick fogs).

(3) Occasions of visibility less than 100 yards (thick fogs).

The observations were further grouped according to the seasons of the year, winter, summer and equinoctial periods being distinguished. The results are shown graphically in figures 1 to 3 of Plate I.

The following table gives the number of observations available for each hour of observation considered.

*See M.O. publication No. 252, p. 74.

NUMBER OF OBSERVATIONS AVAILABLE FOR EACH HOUR.

| | Hour of Observation. | 3h | 4h | 5h | 6h | 7h | 8h | 9h | 10h | 11h | 12h | 13h | 14h | 15h | 16h | 17h | 18h |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter. | Croydon | – | – | 90 | – | 240 | 240 | 240 | 240 | 240 | 240 | 240 | 240 | 240 | 240 | – | 240 |
| | Lympne | – | – | – | – | 240 | 207 | 239 | 240 | 240 | 240 | 240 | 240 | 240 | 240 | – | 240 |
| | Cranwell | – | – | – | – | 240 | – | 240 | 239 | 240 | 238 | 240 | 215 | 222 | 214 | 214 | 240 |
| | Dungeness | – | – | – | – | 120 | – | 205 | – | – | 208 | – | – | 194 | – | – | 120 |
| Summer. | Croydon | 88 | 119 | 210 | 179 | 246 | 215 | 246 | 246 | 246 | 246 | 246 | 246 | 246 | 215 | – | 246 |
| | Lympne | – | – | 42 | 77 | 246 | 229 | 226 | 246 | 246 | 233 | 246 | 246 | 246 | 246 | 112 | 246 |
| | Cranwell | – | – | – | – | 246 | – | 246 | 245 | 246 | 243 | 246 | 234 | 239 | 234 | 233 | 246 |
| | Dungeness | – | – | – | – | 123 | – | 194 | – | – | 201 | – | – | 195 | – | – | 123 |
| Equinox. | Croydon | – | 26 | 143 | 82 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | – | 244 |
| | Lympne | – | – | – | 20 | 244 | 218 | 226 | 244 | 244 | 229 | 244 | 232 | 242 | 233 | – | 244 |
| | Cranwell | – | – | – | – | 244 | – | 244 | 242 | 244 | 239 | 244 | 229 | 231 | 231 | 230 | 244 |
| | Dungeness | – | – | – | – | 121 | – | 181 | – | – | 186 | – | – | 167 | – | – | 122 |

**Variations Observed at all Seasons, including Diurnal Changes.**—A conspicuous feature of all the diagrams is a temporary increase in fog in the early morning, a maximum being reached between one and two hours after sunrise. This is seen most clearly in the case of Croydon and Lympne for which earlier observations are available, but the tendency is evident at all stations. The variation with sunrise of the time when the maximum frequency is reached in the different seasons is very clear, the summer maximum occurring about three hours earlier than the winter maximum.

The fact that this phenomenon is common to stations which are very differently situated with regard to large towns is sufficient to show that the explanation cannot be connected entirely with town influence. This is confirmed by measurements, which have been made, of the amount of atmospheric impurity in London. Dr. J. S. Owens has found that on both foggy and non-foggy days the amount of impurity in the air of Westminster reaches a maximum in winter shortly after 10h.* If the increase in fog at Croydon in the early morning were due entirely to pollution by smoke, the maximum might reasonably be expected to occur later than 10h. whereas it actually occurs about 9h. That the proximity of a town does affect the visibility at a place in its vicinity is, of course, indisputable. In the case of Croydon, for example, the effect is very noticeable, particularly when light northerly or north-westerly winds prevail. Under these conditions the general visibility may be fair or good, but Croydon invariably reports slight fog, due to smoke haze, though as a rule it is not sufficient to interfere with the normal aerial traffic. It is interesting to note that if the wind persists in the same direction for a few days, and other conditions are favourable, the London smoke

*Advisory Committee on Atmospheric Pollution, *Report on observations for the year ending March 31st*, 1921, pp. 22 and 23.

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stream extends its influence further southwards. On occasions it has even been encountered by air pilots at sea a few miles from the Kentish coast.

The general increase in fog in the early morning is probably due to mixing in the layers of air near the surface. During the night turbulence practically ceases, the ground becomes cooled by the process of radiation, and the result is an inversion of the lapse rate of temperature within the first few hundred feet. We may thus regard the air near the surface as becoming arranged in layers of different temperatures which, on cooling, become nearly saturated. Any random mixing of these layers would then result in local supersaturation and fog formation. As an example we may consider the mixing of two masses of air at the surface and at a height of, say, 100 feet. Assuming that the surface air cools to 40°F. while the temperature at 100 feet is 50°F., it can be shown that if the former is nearly saturated, supersaturation cannot take place on mixing unless the relative humidity of the upper layer exceeds 94 per cent. On the other hand, if the upper layer is saturated, the relative humidity at the surface must be in excess of 90 per cent. before supersaturation can take place.* These figures do not take into account the relatively small adiabatic changes involved. Now at sunrise, on the average, there is already a certain amount of fog, which is evidence of high relative humidity. It seems reasonable to suppose, therefore, that any mixing due to eddy motion would produce an increase in the amount of fog and consequent deterioration in visibility. The slight warming of the lower layers after sunrise is sufficient to cause the limited amount of eddy motion most favourable to the production of fog, but at the same time it is insufficient to cause convection on an appreciable scale. Further warming gives rise to convection sufficiently vigorous to extend the mixing upwards, thus bringing drier air into the field, and also speeding up the surface layers; these effects and the general rise of temperature combine to disperse the fog.

Reverting to the diagrams it is noticeable that, with a few exceptions which are discussed below, there is less fog during the afternoon, between noon and 18h., than at any other time during the period of daylight. This is the natural result of a continuation of the processes referred to at the end of the preceding paragraph. The larger proportion of fog shown by Croydon as compared with Cranwell may certainly be ascribed to local town influence.

These results have an important application to civil aviation. In the case of regular early morning services, such as were in operation on the London-Continental air routes last summer, it would be advantageous to arrange the time-table, if practicable,

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* *See* Von Bezold "On the Thermo-dynamics of the Atmosphere (Third Communication)," pp. 258–272, *Smithsonian Miscellaneous Collections*. Vol. XXXIV, and G. I. Taylor, "The Formation of Fog and Mist," *Q.J.R. Met. Soc.*, Vol. XLIII, pp. 241–268, July, 1917.

so that the flight is completed before the maximum fog intensity is reached. For ordinary services the middle of the day is clearly the best time.

**Seasonal Variation.**—Taking first Fig. 1 (Plate 1), the diagrams for the *winter* period, the following outstanding features are evident :

(1) the larger proportion of slight fogs at Croydon as compared with other stations,
(2) the large proportion of thick fogs at Lympne,
(3) the almost complete absence of fog at Dungeness.

(1) has already been referred to as due to local town influence.

The thick fogs at Lympne are due almost entirely to low cloud. In unsettled weather with winds between south and south-west, the cloud is frequently so low that the high ground of the North and South Downs is enveloped, thus producing the effect of thick fog at Lympne, while at Croydon and Dungeness, the ground visibility may be fair or good. The high ground skirting the coast experiences fog of this nature more frequently than inland uplands, a probable cause being the excessive turbulence produced by the relatively warm sea together with the increase of water-vapour by evaporation. Thus it frequently occurs in a south-westerly type that Lympne and St. Inglevert, situated on high ground on either side of the Channel, are enveloped in cloud, while inland districts are comparatively unaffected. The small amount of fog experienced at this season of the year at Dungeness is noteworthy. It would seem to indicate that, from the point of view of visibility, the best position for an aerodrome in winter is *on the coast near sea-level.*

The diagrams for the *summer* months in figure 2, show that fog is less prevalent at this season of the year, being confined at inland stations to early morning mists. The conspicuous feature of these months is the frequency of thick fog at Lympne and Dungeness, the fog persisting throughout the day. In the case of Dungeness, the bad visibility is chiefly due to sea fog. The air, which is rapidly warming over land areas at this time of year, becomes cooled in its surface layers on passing over the relatively cold water; the shallow inversions favourable to fog production are thus almost always present. Eddy-motion with the contiguous layers results in a supersaturated mixture which on further cooling produces a layer of fog. These fogs are rarely deep enough to affect high level stations such as Lympne, where the thick fog is chiefly due to low cloud, as in winter.

The diagrams for the *equinoctial* period, figure 3, show the smallest differences between individual stations. Dungeness again stands out as being relatively free from fog. The observations for this period were originally grouped according to the Spring and Autumn seasons, but the differences were so small that it was decided to combine the two periods. The only outstanding feature was a larger proportion of morning fogs in autumn, which is to be expected at this season when the air is relatively warm compared with the ground.

**Summary.**—The foregoing results may be summed up as follows :—

(1) Except in the summer months, coast stations at sea level experience less fog than any others.

(2) After coast stations, inland stations uninfluenced by the proximity of large towns are the most free from fogs.

(3) As regards diurnal variation during the period of daylight, there is least fog during the afternoon, the worst time occurring between one and two hours after sunrise.*

* Observations are not available between 1h. and dawn, so that it is not possible to state whether visibility is worse during this period than it is after sunrise.

# PREVALENCE OF FOG AT VARIOUS STATIONS.

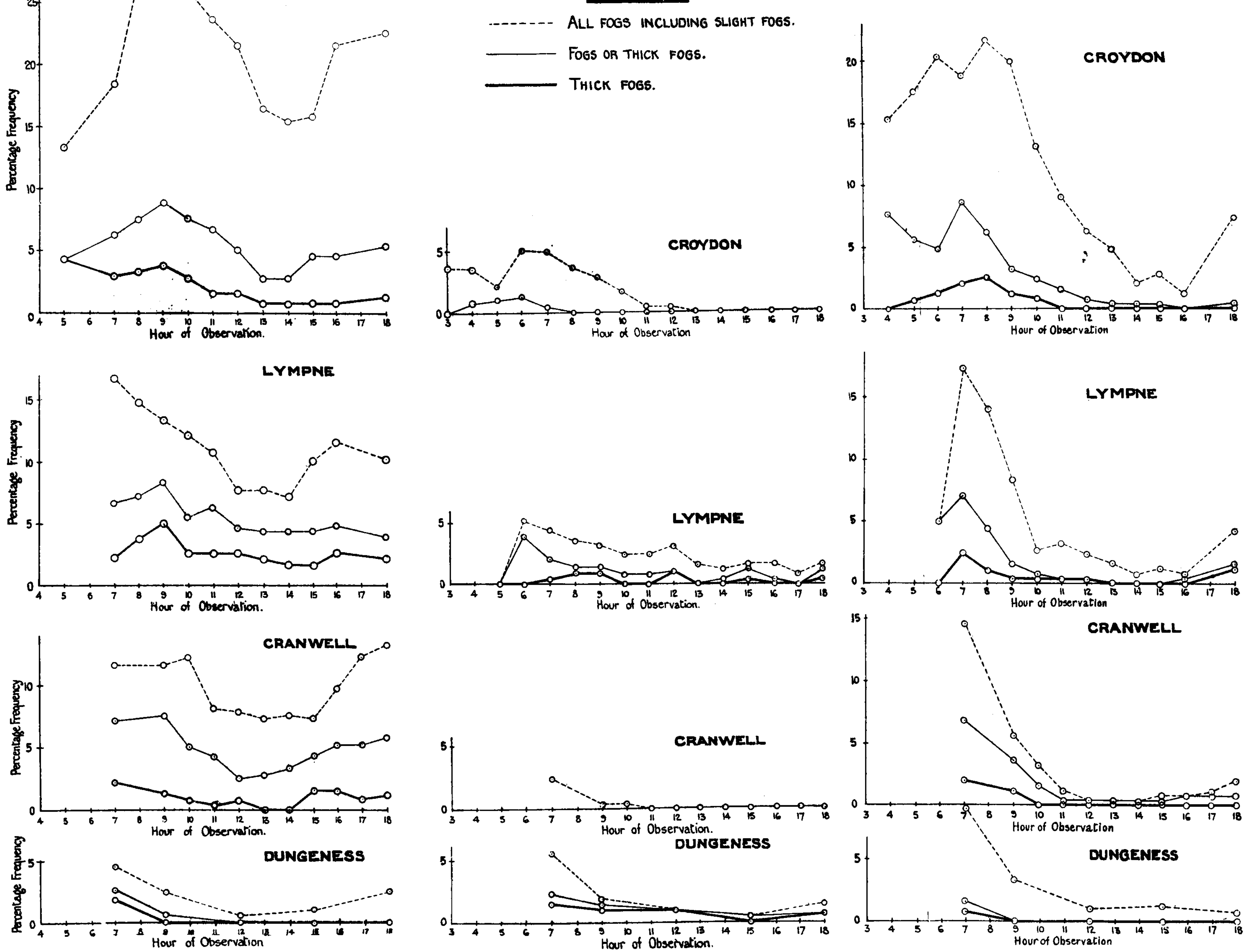


**FIG. 1. WINTER.**
(NOVEMBER - FEBRUARY)

**FIG. 2. SUMMER.**
(MAY - AUGUST)

**FIG. 3. EQUINOX.**
(MARCH-APRIL AND SEPTEMBER-OCTOBER)

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## PREVALENCE OF FOG AT VARIOUS STATIONS.

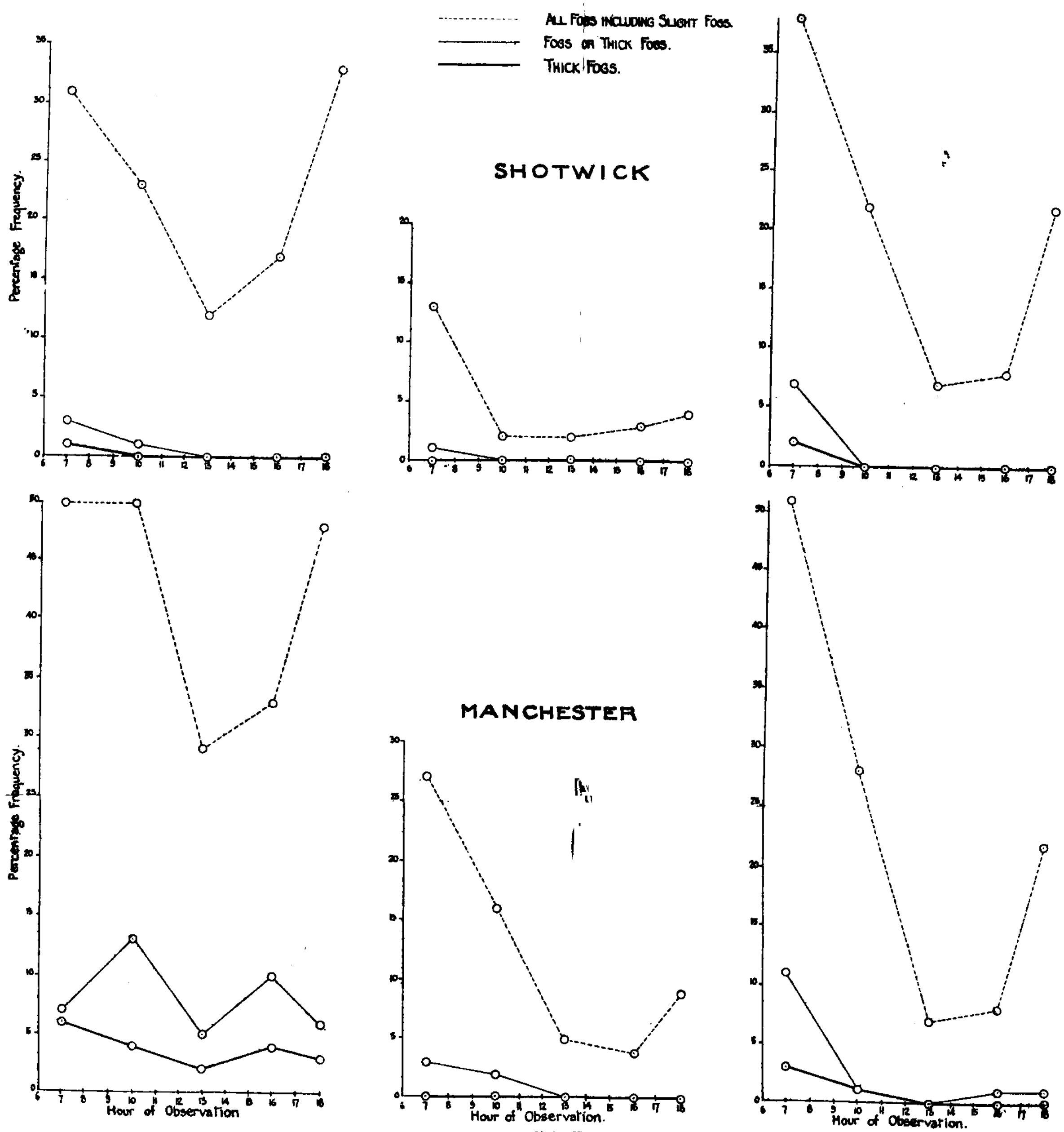


Fig. 4. WINTER. (NOVEMBER - FEBRUARY)

Fig. 5. SUMMER. (MAY - AUGUST)

Fig. 6. EQUINOX (MARCH - APRIL AND SEPTEMBER - OCTOBER)

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# Appendix.

**Relative Frequencies of Fog at Shotwick and Manchester Aerodromes.**—With a view to making the foregoing investigation more complete, the diagrams in Plate II., prepared by Captain H. F. Jackson, Meteorological Officer at Shotwick Aerodrome, have been included.

Summaries of visibility frequencies for Shotwick during the period November, 1921 to February, 1923 and for Manchester Aerodrome during the periods March, 1920 to October, 1921 and October, 1922 to February, 1923, were made as in the case of Croydon, Lympne, &c., and the frequencies of the same fog intensities plotted for the same seasons, so that the diagrams might be comparable with those in Plate I. It must be borne in mind, however, that in the case of Shotwick and Manchester, data for 7h., 10h., 13h., 16h. and 18h. only are dealt with, and that the shape of the curves between these hours is not known. A strict comparison of the two sets of diagrams cannot, therefore, be made. Plate II. is interesting, however, as showing the relatively large amount of fog at a station near an industrial area compared with a place in a neighbouring district which is free from smoke pollution. In comparing the curves, allowance must be made for the effect of the coal strike of 1921 on the Manchester visibility during the summer period.

Captain Jackson has made the following observations on the local conditions at the two stations:

" *Shotwick.*—The Aerodrome (16 feet above mean sea level) is situated on partially reclaimed land to the north of the present course of the river Dee. The surface is sandy, and although water lies within a few feet of the surface, the top layer dries rapidly owing to natural drainage. Early morning radiation mists are frequent, but these seldom persist with sufficient intensity to prevent flying for more than 1 to 2 hours after sunrise.

The few factories in the vicinity are so widely separated that the smoke factor is of little importance locally. The Shotton factory (about 2 miles to the south-west) occasionally produces a slight smoke haze during light south-westerly winds. During periods of prolonged light east to north-east winds the smoke from the manufacturing districts drifts towards this area rendering the visibility consistently poor.

When the easterly drift does not exceed about 10 m.p.h. and the sky between Shotwick and the coast is not completely overcast, the coastal breeze (north-westerly) flowing along the Dee estuary causes a local improvement of visibility during the Spring, Summer and Autumn periods, towards mid-day and early afternoon.

Observations made at this station to date suggest that coastal fog rarely extends for more than a few miles up the Dee estuary.

*Manchester.*—In the case of this aerodrome the smoke and general fumes from the numerous works appear to be the chief causes of low visibility, and during periods of very light gradient, the natural north-easterly flow of air from the high ground drifts this smoke over the comparatively low-lying districts in the vicinity.

The conditions most favourable for moderate to good visibility at Alexandra Park Aerodrome are of the southerly to westerly type, with moderate to fresh winds."

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