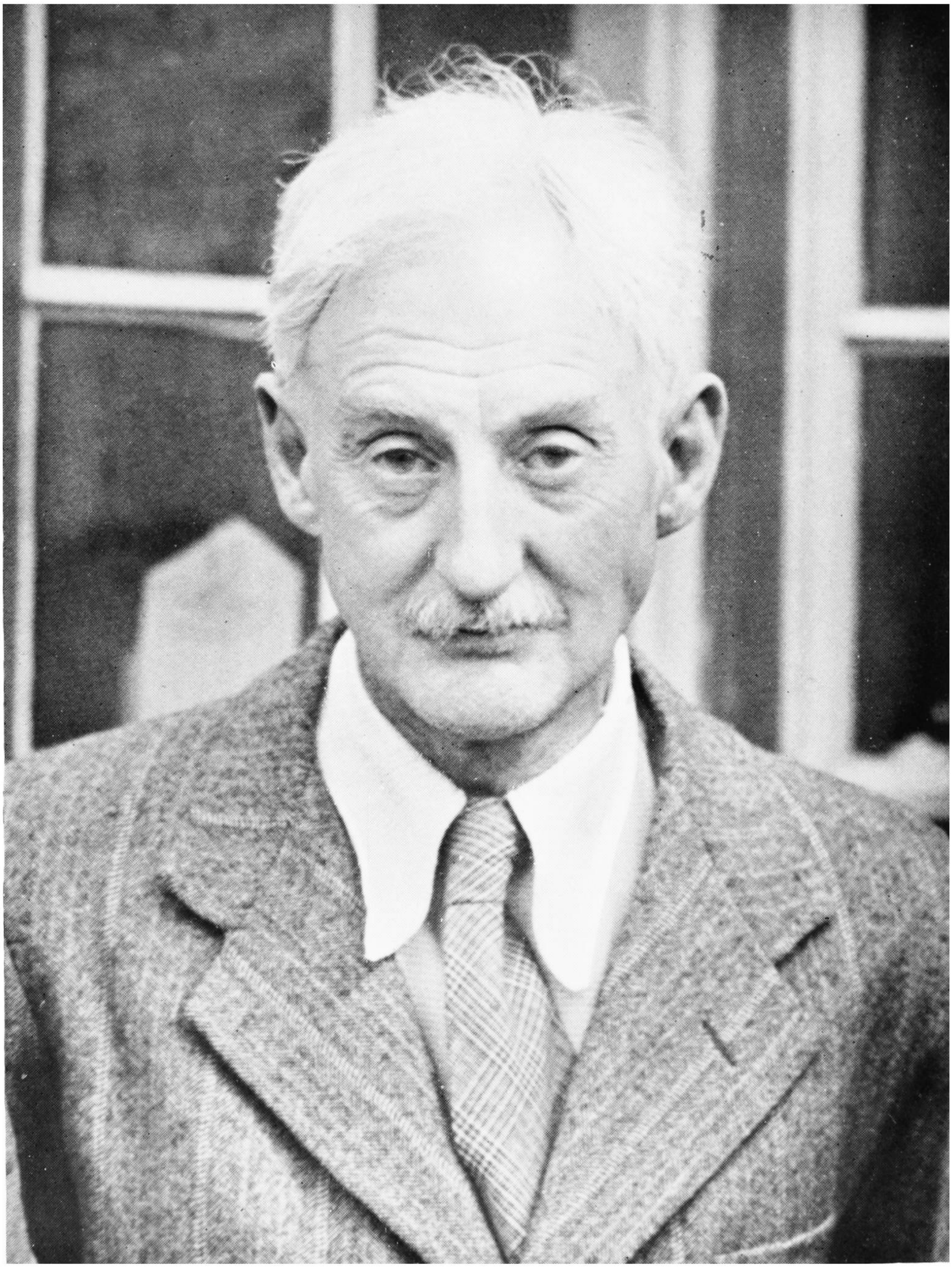
*Frontispiece*]



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MR. C. K. M. DOUGLAS, O.B.E., A.F.C., B.A.

M.O. 581 AIR MINISTRY

METEOROLOGICAL OFFICE

# THE METEOROLOGICAL MAGAZINE

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## MR. C. K. M. DOUGLAS, O.B.E., A.F.C., B.A.

Mr. C. K. M. Douglas, Assistant Director of the Meteorological Office (Central Forecasting) retired on May 28, 1954, after 35 years' service.

Mr. Douglas, born in 1893, was educated at Edinburgh Academy and at King's College, Cambridge. His interest in weather began about the age of 11 when one of his schoolmasters introduced him to the *Daily Weather Report*, to which he subscribed from 1912 to 1919. In January 1915 Mr. Douglas was commissioned in the Royal Scots but a few months later he transferred to the Royal Flying Corps in which he served as an operational pilot, reaching the rank of Captain. The urgencies of war did not interfere with his passionate devotion to meteorology, however. In 1916 he wrote his first meteorological paper, its subject being clouds as seen from the air, and this was published in the *Journal of the Scottish Meteorological Society* in 1917. Mr. Douglas joined the then recently formed Meteor flight in April 1918 and he remained with it till May 1919. His pioneering work in the upper air at this time became world renowned because of his cloud photographs taken from an aircraft, and his interest in instability phenomena was stimulated by being able to make his own upper air observations.

In August 1919, after demobilization, Mr. Douglas joined the Meteorological Office as a Senior Professional Assistant, and he served for two years in the Forecast Division. After a spell of training in observatory work at Eskdalemuir and Edinburgh from 1921 to 1923, he was posted as Senior Professional Assistant in charge of the forecasting office at South Farnborough, where he remained till 1925. In that year he was promoted Assistant Superintendent (Senior Forecaster) in the Forecast Division, and there he remained until his retirement except for a brief interlude from 1936 to 1938 when he held a post in the pool for training and special investigations.

In the second World War Mr. Douglas was a tower of strength to forecasters taking part in the daily operational conferences by telephone. When "Overlord" came along and the vital D-day decision had to be made the important contribution made by Mr. Douglas to the forecasts supplied to the Supreme Allied Commander was acknowledged by General Eisenhower in a personal letter of thanks. In 1941 he was appointed an Officer of the Order of the British Empire, a well deserved honour which all his colleagues applauded.

The voluminous output of meteorological papers and articles by Mr. Douglas since 1917 will be well known to contemporary students of synoptic meteorology, and later generations of such students will be familiar with his name in bibliographies and textbooks. His progress from an amateur to a professional meteorologist is reflected to some extent in his papers, beginning with the artistry of cloud studies and proceeding through such papers as "The modification of the strophic balance" (with Sir David Brunt) to forecasting monographs on "Prebaratics" and "Rainfall and thunderstorms"; the latter he finished a day before he retired.

The distinguished contributions of Mr. Douglas to the study of meteorology were acknowledged by the Royal Meteorological Society, first in 1927 when he was awarded the Buchan Prize, and second, this year, when he was awarded the Hugh Robert Mill Memorial Medal and Prize.

Mr. Douglas was widely known throughout the Meteorological Office as "Duggie", a name he disliked but tolerated, probably because he realized there was something of affection in it. None could know Mr. Douglas well or work under him without developing this affection. Having the highest scientific integrity himself he was forbearing to juniors. His complete disinterestedness gave colleagues the greatest confidence in his judgement, and they came to him time and again to test the validity of any proposals they might have affecting synoptic meteorology.

Colleagues throughout the Meteorological Office contributed to a present to Mr. Douglas on his retirement and this was handed over by Dr. J. M. Stagg, Principal Deputy Director, at a large gathering at Dunstable on May 28. Mr. S. P. Peters, Deputy Director (Forecasting), in asking Dr. Stagg to make the presentation referred to the notable contributions of Mr. Douglas to the science of meteorology. Dr. Stagg spoke of his achievements as an air observer and mountaineer. In a delightful reply Mr. Douglas made a pawky reference to the paper he had been disposing of in anticipation of his retirement. All his colleagues wish Mr. Douglas a long and happy retirement.

## FORECASTS FOR FARMERS

By R. T. ANDREWS

Each year, at certain seasons, forecasters at some main meteorological offices have to deal with large and increasing numbers of inquiries from the farming population. The effect of weather on farming operations is such that these forecasts are of prime importance to the individual farmer and ultimately to the national food-producing effort. It is therefore appropriate that in content and wording the forecasts issued to the farmer should be especially framed to meet his special requirements. This note is based on the experience of a forecaster working in the south-west of England, and is not a comprehensive article on forecasting for agriculture of all types.

**Some farming operations.**—The farmer has to reach decisions daily, sometimes more often, regarding employment of his labour and equipment and the weather enters into most operations. Notes on some of these are given below.

*Ploughing.*—This is carried out during autumn and winter, and the soil must not be flooded or excessively wet and it must not be frozen hard.

*Sowing.*—This is mainly an operation of early spring. Usually a field is prepared one day, when the soil is in a suitable condition, and sown the next day. Rainfall between these operations will mean wasted labour as the ground will have to be prepared again.

*Early potatoes.*—The Cornish crop is usually lifted in late May and the ground needs to be fairly dry for this. The importance of timing is illustrated by the fact that when price control operated, if the crop was on rail before June 1 the price obtained would be £35–40 per ton whereas a few days later this would have fallen to £18–20 per ton.

*Hay.*—Haymaking is carried out in June and July. Small farms may need only a few days dry weather whilst larger farms may spread the operation over a month or six weeks. A dry day is essential for cutting and two or three days are required to dry the grass. Early in this stage some rain will do no harm but at the end of the period the grass must be dry when turned in readiness for carrying or baling on the next day. Rain on hay which has been turned involves at least additional work and may be disastrous. The baler often belongs to a contractor and is only available according to a programme. Baling cannot be carried out when the hay is damped by a shower as the twine will break when the bale is dropped, and even heavy dew will sometimes delay the start of operations until the afternoon. The bales must be dry when stacked or the stack will heat up and burn or blacken. However for silage the grass is cut wet or dry and compressed in pits. Similarly for grass drying, the grass is cut wet or dry and heated with molasses, producing a solid form of fodder. An initial high moisture content increases the fuel costs.

*Corn.*—The season is from July to September and the operations take from 7 to 14 days or more. Dry weather is required for cutting and stooking. The stooks are left standing for several days to mature, and although occasional rain early in the period will not matter there must be several mainly dry days followed by a dry day for carrying. Appreciable rainfall may lead to the stooks becoming wet inside so that they have to be opened again and dried out. Very unsettled weather will cause growth of grass around the bases of the stooks, preventing them from drying, and it may also cause the grain to begin to sprout.

The combine harvester cuts, threshes and sacks the grain in one operation when the corn is dry. The grain has to have a lower moisture content than for cutting and stooking; the combine can sometimes be used efficiently for only 2–3 hr./day, even in fine weather, owing to excessive moisture.

*Root lifting.*—This usually occupies two or three weeks in late autumn when the ground must not be saturated and there must not be hard frost. Frosted mangolds may cause colic in animals.

*Livestock.*—Cattle must be moved from areas liable to flood, and be given cover and extra food during snow. At lambing time shelter from rain and wind is advisable since lambs born on a cold, wet and windy night are more likely to die than those born in dry, frosty weather.

**Some aspects of forecasting for farmers.**—The extent to which a farmer is dependent on the weather may be readily judged from the account of some of his operations given above. Many farmers have a sound knowledge of weather types and frequencies, coupled with signs of nature and the behaviour of birds and animals, which have been handed down from previous generations who have been similarly subject to the weather. From this background and experience they can often reach surprisingly correct conclusions about the future weather. Farmers have usually been regarded as a most conservative section of the community, inclined to distrust scientific method and language, but times have changed, and nowadays one finds that many of them can discuss at least the main features of a weather map, and are keen to do so. There is no doubt that the forecaster can be of great assistance to the farmer, and, from the farmer's point of view, the telephone discussion with the forecaster is of much greater value than the necessarily more generalized broadcast or press forecast. It is helpful to know in what details the inquirer is interested and his minimum requirements.

The incidence of wet and dry spells is of utmost importance to the farmer, and either of these at the wrong time may lead to great financial loss. Therefore "Spell warnings" are of great significance, especially where a change of type can be foreseen in advance so that the fullest use can be made of favourable conditions and losses due to unfavourable weather mitigated as far as possible. An outlook of unsettled weather should when possible be amplified in accordance with the general synoptic situation. If only comparatively short periods of mainly slight precipitation are likely, it is of great value to the farmer to know that is the general type expected.

It is in the detailed forecasting for the following 24 hr. that the meteorologist is in the best position to help the farmer, in the present state of forecasting knowledge. The first requirement of the forecaster is that he should possess a detailed knowledge of local variations, which may lead to quite appreciable differences over a short distance. In aviation forecasting the meteorologist has this knowledge in regard to airfields for which he is responsible, in matters like cloud base and visibility. To provide the best possible service to the farmer, however, he must, in particular, acquire a similar knowledge of the local variations in rainfall.

Special attention to wording should be given in forecasts of showery types. The effect of showers on farming operations is very variable, depending to some extent on the time of occurrence, frequency and intensity of the showers, as well as upon the state of the crop. The diurnal variation in cloud amount, as between coastal and inland areas, may also have an important bearing on the drying process. Forecasts should not be more definite than the situation warrants, but vagueness must be avoided. Suitable wording for forecasts of showery types is given in the following examples:—

Frequent showers will develop inland, mostly during the afternoon and early evening, with thunderstorms and squally winds in some places. Near coasts it will be bright and sunny and any showers will be only slight. It will become generally cloudless tonight and at first tomorrow.

Showers will develop in most places by the afternoon but will be slight everywhere, except perhaps near the highest parts of Dartmoor and Exmoor. Cloud will disperse during the night.

There will be showers at first this morning near coasts and hills exposed to the W. and NW. winds, but they will have died out by the afternoon when cloud will disperse and there will be a fresh, drying wind.

With regard to frontal rainfall, the annual and diurnal variations in rainfall amounts given by fronts and depressions moving eastwards across the British Isles should be noted particularly[1-5]. Often the rainfall decreases progressively from west to east, becoming much less east of the main hill barriers and almost negligible in some eastern and south-eastern counties. On the other hand, chiefly in summer, a front which causes only slight rain in the south-west, may give much heavier falls in the Midlands and east because of instability developing ahead of it.

The shelter afforded by high ground is especially a feature to remember in connexion with summer warm fronts and warm sectors. Warm frontal rain is much reduced in sheltered areas of east Devon and Somerset, and warm-sector drizzle is often negligible in these areas while quite appreciable further west. The general effect is illustrated by the fact that the average number of days a year with more than 10 mm. of rainfall is 30–35 in much of south-west England, but only 15 in East Anglia.

Again, many parts of the British Isles have rain on 200 or more days a year[6] and some have 225–250 rain-days. In August, at the peak of the harvesting season, there are, on the average, 17 rain-days in south-west England. Hence it is especially important for the farmer that all the dry days are in fact forecast as such. A special watch must be kept for ridge development or subsidence which may cut out showers very quickly.

The duration of rainfall is another important matter. On many occasions, particularly in summer, it could be stated with some assurance that rainfall would be of, say, 4–6 hr. duration near west coasts, but only of 1–2 hr. or less east of a line from Liverpool to Exeter.

Humidity also has an important bearing, and the forecaster can help by giving forecasts of wind strength, and some idea of the amount of moisture present in the air and the extent to which this will be reduced during the day. Early formation of dew on clear evenings may mean an early cessation of work in the fields. The forecaster can at present give only rough guidance on the amount of dew expected (e.g. heavy dew with initially wet grass, high humidity, low wind speed and clear sky), but he can indicate the approximate time of commencement. A heavy dew followed by a cloudy morning with little or no wind may delay the start of field work till after midday.

Finally, the forecaster should be completely frank in dealing with the farmer. It is helpful to explain any failure of an earlier forecast (e.g. the non-arrival of rain previously forecast). Confidence should be expressed when it is justified, and doubts should be introduced when there is good reason for doing so. Only thus can the farmer be helped to decide what chances he can take.

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# THE OCCURRENCE OF ICE CRYSTALS IN THE FREE ATMOSPHERE

By G. J. DAY, B.Sc.

At temperatures below freezing point the water in clouds may be either in the liquid or the solid phase, and the likelihood of either phase is initially a function of temperature. The supercooled state is an unstable condition and whenever ice begins to form the cloud tends to change quickly into the solid phase. The frequency with which supercooled droplets are found in clouds is important in studies of aircraft icing, precipitation mechanisms, and the role of nuclei in the ice-forming process.

If supercooled droplets are present in large quantities, then aircraft icing is probable.

If the cloud is wholly supercooled and remains so, the Bergeron process of precipitation cannot start as it requires ice crystals to grow at the expense of supercooled droplets. Similarly if the cloud is entirely ice crystals this process will not operate. Since, however, the probability that ice crystals will appear increases with decrease in temperature, clouds often exist in which the tops are composed of ice crystals and the remainder of a mixture of droplets and crystals, and these are those in which the Bergeron process can operate. A study of the relative frequency with which cloud tops are observed containing ice crystals or supercooled droplets will therefore provide data of the cloud-top temperature at which the Bergeron mechanism is usually initiated. It should be noted that any study of this type must be confined to cases with no cloud above, as seeding with ice crystals from the higher cloud may initiate the process in a cloud which might otherwise remain supercooled.

The probability of occurrence of ice crystals at various temperatures is of interest in studies of the role of nuclei in the ice-forming process. Many laboratory studies of this aspect have been made, for example that of Findeisen and Schulz[1] and more recently that of Bigg[2]. Apart from laboratory studies there is little published observational data available on this topic. In a study of occasions of precipitation from persisting sheets of stratocumulus in Northern Ireland, Mason and Howorth[3] suggested that such precipitation was unlikely with cloud-top temperatures higher than about − 12°C. (+ 10°F.), and it is commonly assumed that shower production commences in temperate latitudes at cloud-top temperatures between − 10° and − 15°C. (+ 15° and + 5°F.). Work by Peppler[4], Dessens[5], and Lafargue[6] confirms this result.

During the past two years a large number of cloud flights have been made by the Meteorological Research Flight, and during the preliminary analysis 37 flights have been examined in which it was improbable that the cloud level investigated was seeded from above by an ice-crystal cloud. The frequency of occurrence of water droplets and ice crystals at various temperatures in these flights is shown in histogram form in Fig. 1. It will be noted that the result is weighted in favour of the higher temperatures. This is a consequence of the limitation imposed by the effective ceiling of the aircraft for work of this type.

It does appear, however, that water droplets become much less probable at temperatures below about − 20°C. (− 5°F.), and this may be the level at which aircraft icing becomes infrequent save where there are unusually strong up-draughts as in convective clouds before maturity. This accords well with the observation of Pettit[7].

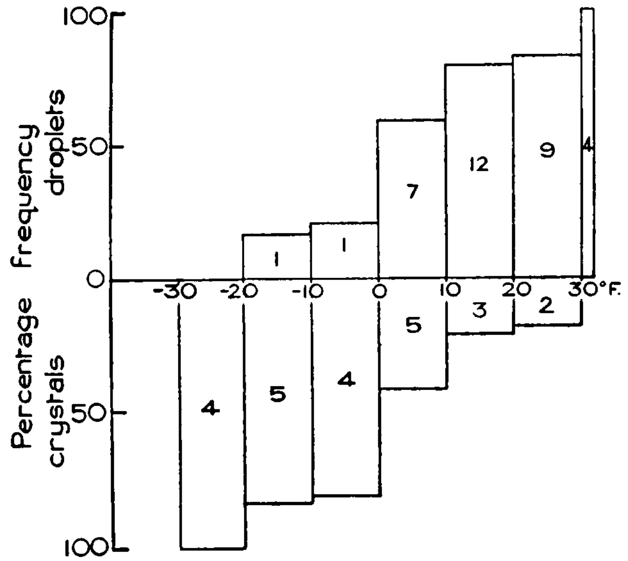


FIG. 1—FREQUENCY OF OCCURRENCE OF ICE CRYSTALS AND WATER DROPLETS IN NATURAL CLOUDS AS A FUNCTION OF TEMPERATURE

Figures in the blocks are the number of cases

It also appears that ice crystals have a small probability of occurrence at temperatures between freezing and − 12°C. (+ 10°F.).

Further, there is an approximately equal probability that cloud tops having temperatures between − 18° and − 12°C. (0° and + 10°F.) contain crystals or supercooled droplets. Thus, on about 50 per cent. of occasions a cloud which has a top at a temperature within this range and its lower portions at a higher temperature will be in a suitable condition for the Bergeron process to operate. As cloud-top temperature decreases the probability that the solid phase will appear increases.

The range − 18° to − 12°C. then is the highest cloud-top temperature range for which precipitation by the Bergeron process would normally be expected. For higher temperatures coalescence processes would have to predominate in the production of any rainfall. Similarly any initiation of the Bergeron process by artificial nucleation would normally only be worth-while when the cloud-top temperatures are above about − 12°C. (+10°F.), as below this temperature the change of phase occurs naturally on at least 50 per cent. of occasions.

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# AN INSTRUMENT FOR RECORDING THE FREQUENCY DISTRIBUTION OF MEAN HOURLY WIND SPEEDS

By B. G. COLLINS, B.Sc.

Programmes of ventilation research carried out in experimental houses at the Building Research Station, Garston, Hertfordshire, have shown that the air-change rate in a house is closely related to, amongst other factors, the external wind speed[1]. In order to use the information obtained from these experiments for prediction purposes in other locations, it is necessary to have a knowledge of the structure of wind-speed variations to be expected in various types of locality ranging from freely exposed sites to built-up areas. The most convenient form in which to obtain this is the frequency distribution of the mean hourly wind speed.

The wind-run analyser, described elsewhere[2], provides a record from which the desired information can be obtained, but to eliminate tedious arithmetic it was decided to develop an instrument from which the frequency distribution could be read directly. In view of the fact that the ventilation requirements for some particular types of building may be critical for only a limited period each day, it was thought that it would be desirable to break the frequency distribution down into smaller periods than the whole day. For example, offices have a definite ventilation requirement only during the period of day occupancy, say 9 a.m. to 5 p.m., whereas in a hospital ward ventilation is required at all times, and the critical period will probably be during the early hours of the morning when wind speed is normally at its lowest level. Accordingly an instrument was designed to register the distribution of the mean hourly wind speed in three separate 8-hr. periods of the day, namely midnight to 8 a.m., 8 a.m. to 4 p.m., and 4 p.m. to midnight. It is, of course, a simple matter to adjust the recorder to operate over any other desired 8-hr. period.

The wind-speed-frequency recorder described in this article, of which a circuit diagram is given in Fig. 1, works in conjunction with a standard Meteorological Office cup contact anemometer, and records the distribution of the mean hourly wind speed on Post Office message registers. With the exception of a time switch operating once an hour, all the parts used are standard Post Office components. They comprise telephone selector switches (known as uniselectors), and type 3,000 relays, in addition to the message registers. The operating details of the recorder are given below.

The making contact of the anemometer closes 20 times for every mile of wind run, and is used to operate relay A/1, thus closing contact A1 and energizing the operating coil of uniselector U. The latter is arranged as a scale-of-20 counting-down device, and its output, one pulse for every mile of wind run, is used to operate a second uniselector V, which therefore steps round with the increasing wind count. This selector is connected to a bank of Post Office message registers, one representing each wind-speed interval, so that, as it steps round, the register appropriate to the total counted is selected.

At the end of each hour the time switch operates, and relay D/4 is energized. This is a slugged relay and its operating time is considerably longer than that of the message registers. Hence a pulse from the time switch is passed to the message register which is then in circuit, via contact D2, increasing its count by one. Then relay D/4 operates, returning the second uniselector V to zero by contact D1, and at the same time breaking the anemometer and message-register circuits by contacts D4 and D2. Contact D3 is also closed and energizes uniselector W which thus steps round one contact. Three identical banks of message registers are provided, for use in the three 8-hr. periods of the day already mentioned. The operation of uniselector W is used to change to the next bank on every 8th, 16th and 24th hourly pulse received from the time switch.

It is found that ten message registers in each bank are sufficient to obtain the distribution, and these are arranged to count the number of hours with wind speeds of 0·5, 1, 2, 3–4, 5–7, 8–10, 11–15, 16–20, 21–30, and 31–50 m.p.h., these intervals being selected to permit the most accurate drawing of the curve of the distribution. It is thought improbable that a mean hourly wind speed greater than 50 m.p.h. will be encountered save in the most exposed coastal sites, with which the present investigation is not concerned.

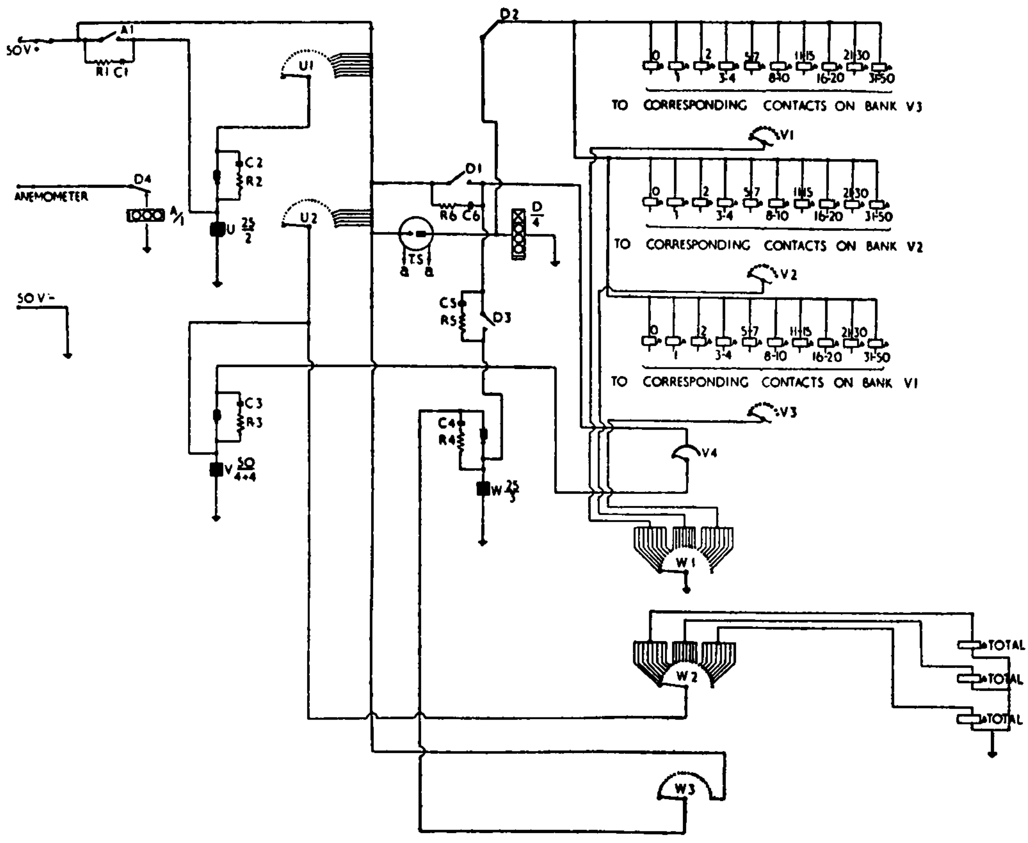


FIG. 1—CIRCUIT DIAGRAM, WIND-SPEED FREQUENCY RECORDER

In order to obtain also the value of the mean wind speed over each 8-hr. period, three additional message registers are provided which indicate the total number of miles of wind run occurring during the period. These registers are operated directly from uniselector U, receiving one pulse for every 20 pulses from the anemometer.

The uniselectors, message registers and relays used all operate from a 50-v. d.c. supply. A mains-operated unit delivering 50 v., 2 amp. d.c. is incorporated in the instrument, and since the time switch is also mains operated, a 230 v. 50 c. supply is all that is needed for the recorder. The equipment fits into a standard 19-in. Post Office rack for convenience of mounting, and all connexions are

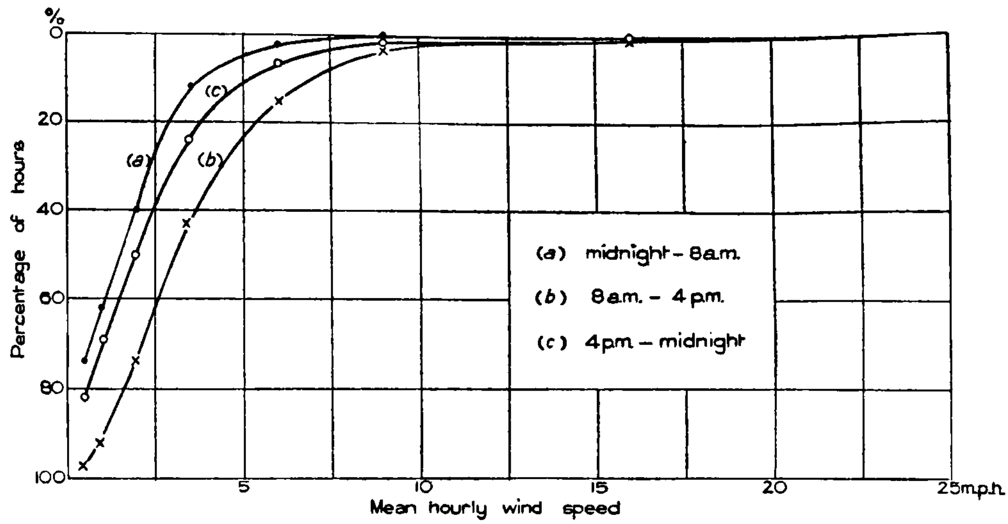


FIG. 2—CUMULATIVE PERCENTAGE FREQUENCY OF WIND SPEED EXCEEDING GIVEN VALUES

(one month's record)

brought into detachable plugs and sockets. The photograph (facing p. 256) shows a front view of the complete instrument.

Fig. 2 shows an example of the curves obtained for the cumulative-frequency distribution of the mean hourly wind speed on a fairly exposed site for the month of September 1952. If a ventilation system is required to be so designed that sufficient fresh air is admitted to maintain a given rate of air change for a certain minimum percentage of the hours, the graph will give the wind speed on which the design should be based for each of the three 8-hr. periods. For example, suppose that in a hospital it is essential that a stipulated rate of air change be maintained for at least 75 per cent. of the hours. The graph (*a*) shows that during the period midnight to 8 a.m., when the mean wind speeds are lowest, for 75 per cent. of the hours the mean hourly wind speed does not fall below 0·5 m.p.h., and hence, if the ventilation system admits sufficient fresh air to give the desired air-change rate with a wind speed of 0·5 m.p.h. it will be satisfactory. If, however, the ventilation rate needs to be maintained only during the period 8 a.m.–4 p.m., the graph (*b*) shows that for 75 per cent. of the hours the mean hourly wind speed does not fall below 2·0 m.p.h., and a ventilation system designed to admit enough fresh air at this speed will be satisfactory. These wind speeds of 0·5 m.p.h. and 2·0 m.p.h. are then known as the design wind speeds.

In a case where it is acceptable for the air-change rate to be maintained for only 50 per cent. of the hours, the design wind speeds for the two periods mentioned are seen from the graph to be 3 m.p.h. and 1·5 m.p.h. respectively.

This paper is published by permission of the Director of Building Research, and the work described forms part of the programme of the Building Research Board of the Department of Scientific and Industrial Research.

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# SINGULARITIES IN THE ANNUAL VARIATION OF AIR, GRASS AND SOIL TEMPERATURES

By E. N. LAWRENCE, B.Sc.

Before proceeding to the subject of air minimum, grass minimum and soil temperatures, and frost frequencies, it is helpful to bear in mind the main processes involved in the heat exchange at night near the surface of the ground. Heat is lost mainly in accordance with the Stefan-Boltzmann law of radiation, that every body radiates with an intensity proportional to the fourth power of its absolute temperature, and heat is lost also by evaporation. Heat is gained primarily by the counter radiation of the atmosphere and by conduction from the lower soil, but also by convection and to a smaller degree by radiative pseudo-conduction, by thermal conduction and in the formation of dew. Under clear night skies and generally calm conditions, evaporation and convection are restricted, and the main processes affecting the temperature near the ground are the radiation and counter radiation of the earth and atmosphere respectively (i.e. effective outgoing radiation) and the supply of heat from the lower soil. Now, the effective outgoing radiation ($R$ cal./cm.$^2$/min.), using Raman's values for the constants, is given by

$$R = 8{\cdot}26 \times 10^{-11} \left[T^4 \left(0{\cdot}23 + 0{\cdot}28 \times 10^{-0{\cdot}074e}\right)\right] \quad \ldots . (1)$$

where $T$ is the absolute temperature of the ground surface and $e$ is the vapour pressure measured near the ground in millimetres of mercury. According to Ångström[1], $R$ may be replaced by $R/(1 - c)$ on cloudy nights, $c$ being a constant depending on the height of base and type of cloud and the temperature at this height. Also, it has been shown[2] that, to a high degree of approximation, the fall of surface temperature $\delta T$ is given by

$$\delta T = 2R \, (t/\pi ks)^{\frac{1}{2}} \quad \ldots . (2)$$

where $t$ is the number of hours after sunset, $k$ is the coefficient of conductivity and $s$ the thermal capacity of the soil. Combining equations (1) and (2) and using Ångström's relationship for cloud,

$$\delta T = 16{\cdot}52 \times 10^{-11} \left[T^4 (0{\cdot}23 + 0{\cdot}28 \times 10^{-0{\cdot}074e})(t/\pi ks)^{\frac{1}{2}} (1 - c)\right] \ldots . (3)$$

Variations in absolute temperature and vapour pressure are often insufficient to explain nocturnal minimum temperatures on clear calm nights and a satisfactory explanation must include a consideration of the properties of the soil. The values of conductivity and thermal capacity can be greatly altered by changes in soil moisture. Increased moisture content (percentage of water in wet weight) causes increased heat conductivity because the water film between the grains leads to better "thermal" contact. Another effect of increased soil moisture is increased specific heat. Both these factors may help to check the fall of temperature at or near the ground surface, though, with air movement, loss of heat by evaporation may neutralize this. However, the net result of all operating factors is shown by the following presentation of data from Rothamsted (height 420 ft.), a site on clay soil (with flints) over chalk, near the top of a rise on slightly sloping ground with a north-eastern aspect. The data used applies to the period 1921–50 inclusive and mainly to the season January 1 to June 3, stated in terms of Shaw weeks, which are measured from November 6, week 1 being November 6–12 (inclusive). Thus January 1–7 is Shaw week 9. In leap years, week 17 is February 26–March 3 (instead of February 26–March 4) and the year ends on November 3 (instead of November 4).

The graph (Fig. 1) of the frequency of the number of occasions when the grass minimum temperature $T_g$ is at or below freezing point shows a rapid decrease during March, but during early April there is an increase, and not until the end of April is the rapid decrease resumed. The corresponding curve (not shown) for screen minima $T_n$, shows a similar though less marked singularity. The curves for other examined meteorological sites in the northern part of eastern England show similar singularities.

The graph of the mean daily minimum grass temperature for each week (right-hand scale of Fig. 1) shows a sharp rise during late March, but during April there is a slight decrease until late in the month when minimum temperatures continue to increase rapidly. The corresponding curve (not shown) for screen temperatures shows a similar form, though the singularities are less marked.

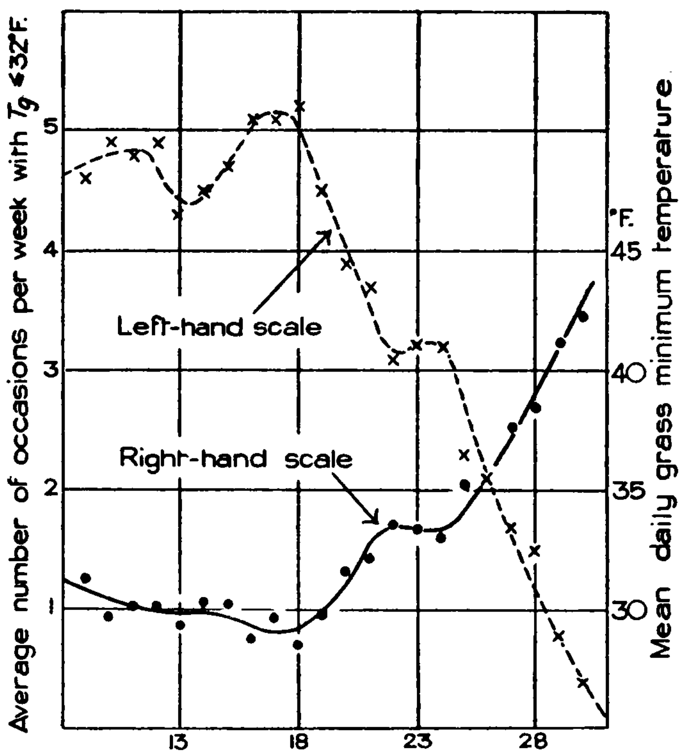


FIG. 1—AVERAGE WEEKLY FREQUENCY OF GRASS MINIMUM TEMPERATURES AT OR BELOW FREEZING POINT AND MEAN DAILY GRASS MINIMUM TEMPERATURE AT ROTHAMSTED

The graph in Fig. 2 of weekly mean values of soil temperature at 0900 at a depth of 4 in., $T_4$, shows little or no change during January, February and early March, but thenceforth temperature rises steadily. The corresponding curve for a depth of 8 in. shows a similar discontinuity.

The graph of monthly moisture deficit, as calculated at Rothamsted, is roughly as shown in Fig. 3 (right-hand scale). This curve suggests that after about the middle of March, the rate of loss of soil moisture begins to increase rapidly.

During early March, a period of maximum anticyclonic activity[3], the value of $(T_4 - T_g)$ commences to increase rapidly (Fig. 3, left-hand scale), for soil temperature is increasing while grass minimum temperature is decreasing. After early March, the value of $(T_4 - T_g)$ continues to increase steadily, for on the relaxation of anticyclonic conditions it appears that the rise in $T_g$ is checked while $T_4$ increases steadily.

It may at first seem surprising that frost frequencies increase, or decrease less rapidly, and that mean daily air minimum and grass minimum temperatures decrease, or increase less rapidly, in spite of the high and steadily increasing soil temperature at 4 in. and 8 in. below the surface. The warming of the surface-soil layer during afternoons following "dry-out" is considerably greater than before, and this heat is transferred downwards to the 4-in. and 8-in. levels. At night, some heat is conducted upwards but this does not appear to counteract

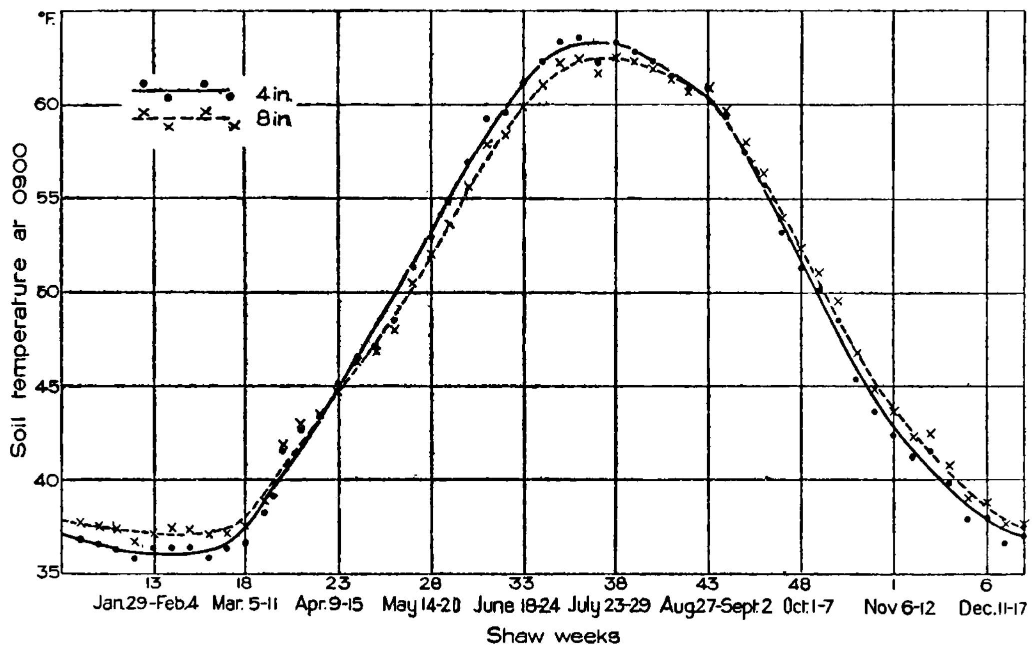


FIG. 2—WEEKLY SOIL TEMPERATURES AT DEPTHS OF 4 IN. AND 8 IN. AT 0900 G.M.T. AT ROTHAMSTED

the rapid loss of heat by radiation from the dry surface layer. If heat can be transferred downwards by day, it might be expected to be conducted upwards sufficiently by night to check the increased frost frequency. It is suggested that the explanation lies in the fact that both the change in frost liability and the increase in soil temperature are associated with the drying-out of the soil; that, after drying-out, heat is transferred downwards to a large extent by water percolation and that this process must more than compensate for the reduced soil conductivity. Whatever the mechanism, it is clear that soil drainage must be considered as an important means of influencing soil temperature in the zone of plant growth.

Thus, the graphs described above show the following:—

(i) Well marked discontinuities associated with the anticyclonic maximum during early March. These take the form of:—

a gradual decrease followed by a sharp rise in mean air minimum and grass minimum temperatures;

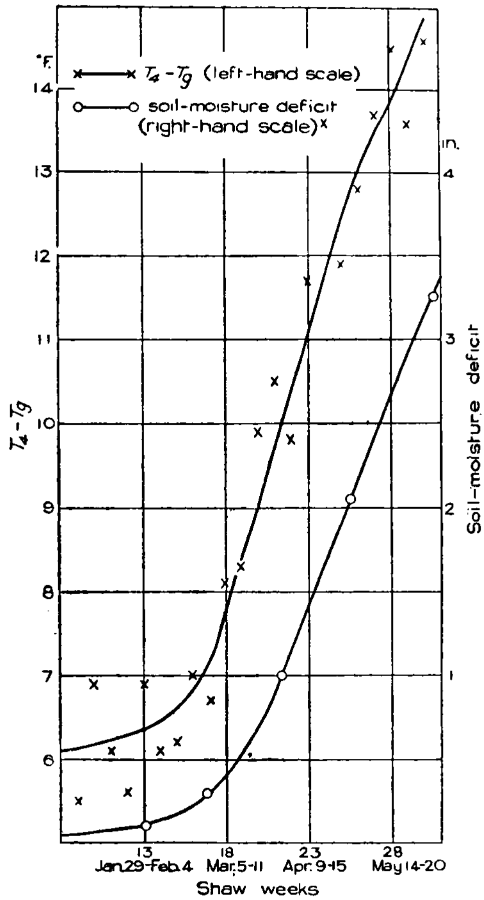


FIG. 3—DIFFERENCE BETWEEN WEEKLY MEAN TEMPERATURE AT A DEPTH OF 4 IN. AT 0900 AND GRASS MINIMUM TEMPERATURE $(T_4 - T_g)$, AND MONTHLY SOIL MOISTURE DEFICIT AT ROTHAMSTED

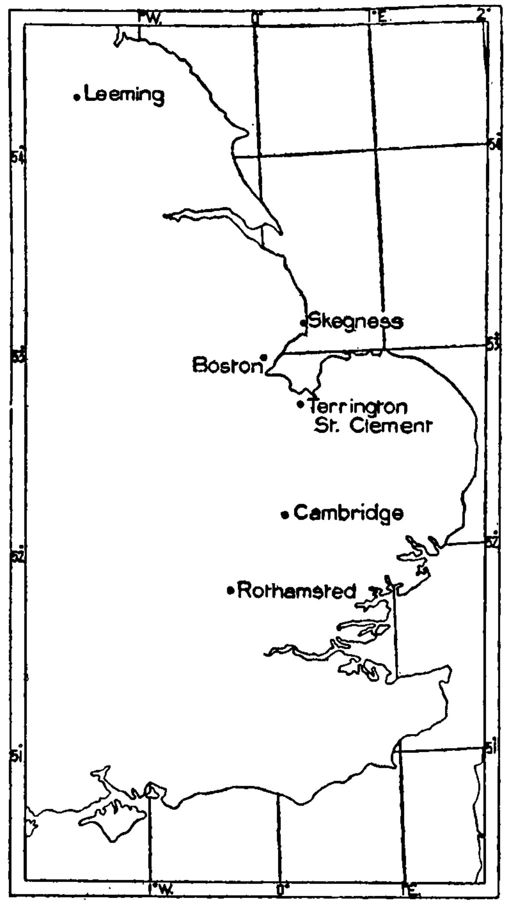


FIG. 4—POSITIONS OF STATIONS

a corresponding increase followed by a sharp decrease in frost frequencies;

almost constant soil temperatures at 0900 at depths of 4 in. and 8 in. followed by a sharp rise.

(ii) Lesser marked singularities associated with the drying out of the top soil in the early spring. These take the form of:—

a decrease or check in the rate of increase of air minimum and grass minimum temperatures;

a corresponding increase or check in the rate of decrease of frost frequencies;

a maximum rate of increase in soil temperatures around the beginning of spring.

**Mean maximum nocturnal inversion of temperature gradient near the ground.**—As an application of the relationship between air minimum and grass minimum temperatures and soil moisture and to obtain further evidence of their connexion, an investigation was made into the relationship between types of soil of various water-holding capacities and the mean maximum nocturnal inversion $l$ in the surface air layer between the ground and a height of 4 ft., as defined by $l = \overline{T_n - T_g}$ or $l = \overline{T_n} - \overline{T_g}$.

The data used applied to the period January 1 to June 3, for the years 1921–50 where these were available. Cases of snow-covered ground (more than half-covered at 0900) were excluded. The places examined together with the details of the sites are given in Table I and their positions shown in Fig. 4. All the sites are in flat terrain, except that of Skegness, which is situated in a slight depression, and Rothamsted.

TABLE I

| | Period | Number of years | Distance from sea | Type of soil |
|---|---|---|---|---|
| | | | *miles* | |
| Rothamsted | 1921–50 | 30 | 53 | Clay with flints over chalk |
| Cambridge | 1921–50 | 30 | 42 | Chalk and sand |
| Leeming | 1945–52 | 8 | 28 | Clay |
| Terrington St. Clement | 1935–46, 1951–53 | 15 | 3 | Silt and loam |
| Boston | 1939–53 | 15 | 3 | Alluvial loam |
| Skegness | 1933–41 | 9 | 0 | Sand |

In calculating the value of $l$, a slight error was introduced by the fact that normally $T_n$ refers to a 24-hr. period (0900 to 0900) while $T_g$ (except at Leeming) applies to the night period only. Normally, both screen and grass temperatures will reach minimum values around dawn, and when this happens, the error will not exist. A further small error is produced by the fact that readings are made at 0900 and a single large value of $l$ on one night may give rise to a further large value for the subsequent day if the former value for $l$ persists to some extent after 0900.

The results are shown in the graphs in Fig. 5 and may be summarized briefly as follows:—

With one exception (Boston) the curves have a characteristic form. In January and early February, the value of $l$ is low and decreasing slightly. In March and April, $l$ is high but gradually decreasing until by the end of May, the values are comparable with those for January. The high values of March and April are presumably caused by the drying-out of the top soil and initially aided by the effect of the "anticyclonic-calm" period. The subsequent gradual decrease may be a result of the increase in atmospheric water vapour or of shortening nights.

Apart from orography, the main factors influencing the value of $l$ appear to be soil type and distance from sea. Cambridge and Rothamsted (places furthest from the sea) have the highest values of $l$ but the value at Rothamsted is less than at Cambridge although further from the sea. This is probably because at Rothamsted, cold air is able to drain off so that a strong inversion is not built up, but soil differences may be partly responsible in that the water-holding Rothamsted clay is less conducive to the build-up of inversions than the Cambridge soil.

The value of $l$ at Leeming is far below those at Terrington St. Clement and Boston, probably owing to soil differences, moisture-retaining clays tending to give much lower values than the lighter sandy soils or loams, especially in winter, when a light soil may often develop a dry top layer. Skegness, on the coast, has, as might have been expected, a low value of $l$ but soil type and orography help to produce a value which, in spring, exceeds that at Leeming.

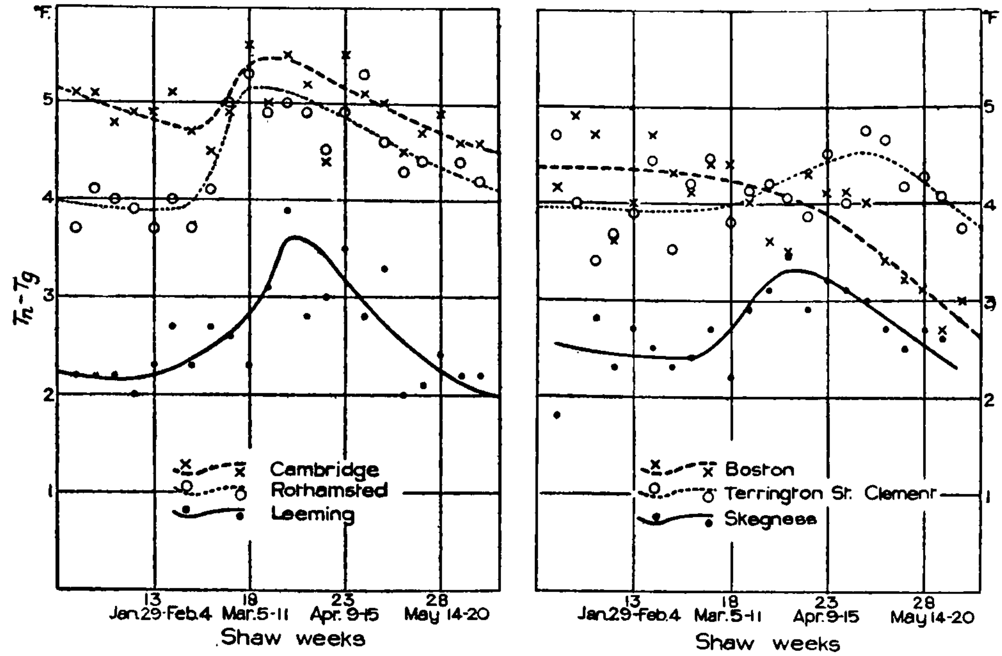


FIG. 5—DIFFERENCE BETWEEN WEEKLY MEAN DAILY MINIMUM SCREEN TEMPERATURE AND GRASS MINIMUM TEMPERATURE

**Further singularities.**—It has been shown[4] that during the autumns of 1948 and 1949 there occurred in early October, a sudden change in the time of the evening discontinuity in the rate of cooling under clear skies; it is suggested that this phenomenon is associated with very humid top-soil after this date. It may be expected that at about this date there will be other singularities. That the early October phenomenon just mentioned occurred well before the main autumn rain suggests that other discontinuities, associated with soil moisture, occur before the main autumn rain and are determined primarily by solar intensity rather than weather changes. This would mean that the "critical" dates for, say, frost frequency are less variable from year to year than the dates of the main weather changes.

September or early October is a period of maximum anticyclonic activity[3,5,6] and this phenomenon is normally followed by the very wet period of late October. This probably makes it difficult to distinguish the various autumn singularities. The September anticyclonic period occurs with much drier soil than the February–March anticyclone so that any water percolation aided by declining insolation produces a rapid decrease in soil temperatures at depths of 4 in. and 8 in. This decrease follows a very slow decrease from the mid-July maximum and the average soil-temperature curves present an unsymmetrical appearance. In late October, with the relaxation of anticyclonic conditions, the frequent onset of wet weather and decrease in insolation, the top soil becomes permanently moist, and it may be expected that changes in temperature (of screen minima, grass minima, soil temperature, etc.) caused by declining insolation would be checked. The Rothamsted soil-temperature curves do not show any discontinuity until the beginning of November, and then only a weak one. This may be because the Rothamsted site is well drained. A "flat" clay site would presumably show an earlier (latter part of October) and more marked discontinuity.

The mean dates of the spring and autumn temperature discontinuities would provide important demarcations in any division of the year into natural seasons of soil climate or microclimate. Lamb[3] gives March 30 as a seasonal demarcation based on pressure patterns, and although there is not a one-to-one correspondence between pressure pattern and weather, the change after March 30 to a period when "long spells . . . are clearly at their rarest" and therefore to a decrease in prolonged wet weather, may lead to better drying-out conditions. Similarly, during October, the change from anticyclonic to a wetter cyclonic type of weather helps to maintain a moist top-soil layer. Thus in both early spring and early autumn soil climate, microclimate and macro-climate show a seasonal demarcation, though it is probable that at both times the soil climate and microclimatic discontinuities are primarily controlled by solar intensity rather than by weather changes, and consequently less variable from year to year but with considerable local variation due to topography.

The close relationship between frost frequency and past weather has been demonstrated in an analysis[7] which used the long-term records for Greenwich and Kew, contained in "A century of London weather"[8]. It is concluded that the odds against May frosts increase if the weather has been wet during the previous March and April and decrease if the previous March and April have been dry.

**Conclusions.**—Soil moisture is a factor of paramount importance in the determination of frost frequency, screen-minimum, grass-minimum and soil temperatures. In particular, soil type and drainage have a considerable influence on soil temperatures.

As a result of a decrease in soil moisture in the spring, data from Rothamsted, supported by data from other stations, indicate that, at this time,

Frost frequency either increases or its rate of decrease is sharply checked;

Mean daily minimum temperatures either decrease or their rate of rise is sharply checked;

Soil temperatures rise considerably.

The mean maximum inversion of temperature gradient at night $l$ is dependent on the type of soil, distance from sea and orography. The influence of soil type is due to its water-holding capacity, the better drained lighter soils giving rise to higher values of $l$. This type of data could be used as a guide to estimate or forecast grass minimum temperatures. Maps may be drawn for flat terrain, showing, for a particular date, the variation of $l$ with location (distance from sea) and soil. Similar maps could probably be drawn for the mean dates of the various singularities.

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## METEOROLOGICAL RESEARCH COMMITTEE

The 29th meeting of the Physical Sub-Committee of the Meteorological Research Committee was held on April 2 to discuss the problem of the artificial production of rainfall. After a keen and stimulating discussion it was agreed that whilst at present there was no reliable evidence to show that rainfall had ever been increased on an economically useful scale by any methods, nevertheless, in view of the potential economic value of artificial production, trials to obtain a knowledge of large-scale diffusion of airborne particles should be initiated, analyses of natural nuclei concentrations should be extended, and the design of large-scale field trials to test the effectiveness of any suggested methods of seeding for increasing rainfall on an economic scale should be fully explored.

## OFFICIAL PUBLICATIONS

The following publications have recently been issued:

PROFESSIONAL NOTES

*No. 110—On the accuracy of contour charts in forecasting upper winds.* By R. Murray, M.A.

The practical importance of the various errors associated with forecasting winds by means of contour and forecast contour charts is assessed for the 700-, 500-, 300-, and 200-mb. levels.

Isobaric charts contain errors in terms of wind arising from the following factors:

(i) errors caused by inaccuracy of contour height observations,
(ii) errors caused by inaccurate estimation of geostrophic wind,
(iii) errors owing to the personal element in chart construction,
(iv) wind-measurement errors,
(v) small-scale wind fluctuations,
(vi) geostrophic departures.

Most of these errors are acceptably small, but (i) increases in importance with height and becomes the largest individual error at 200 mb. These errors are inherent in the contour method of wind representation and cannot be substantially reduced except at high levels where an increase in the accuracy of contour height observations is required.

In forecasts there is an additional error because of erroneous forecasting of contour patterns. In 24-hr. forecasts of wind at a point this is the main cause of forecast errors up to 300 mb., but at 200 mb. it is about equal to the combined effect of errors inherent in the contour method.

*No. 111—Nocturnal winds.* By E. N. Lawrence, B.Sc.

The relationship of katabatic winds and land-breezes to topography, soil and ground cover is examined, and the speed, depth, frequency, temperature, conditions of flow and other characteristics of these winds are discussed in the light of results of the present investigation and in relation to the results of other surveys and experiments. An empirical formula for the speed of the katabatic wind in terms of the slope and distance from the sea is obtained for extensive flat slopes. The magnitude of the land-breeze (and hence the nocturnal wind) over England is assessed.

## ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society on April 28, 1954, the main event was the delivery of Dr. O. G. Sutton's presidential address.

*Presidential Address—Development of meteorology as an exact science*

Dr. Sutton stated that his aim was to attempt a critical examination of the part played by mathematics in meteorology. One of the main uses of mathematics in applied science was to provide an objective method of summarizing experience and another was to make predictions. However only certain ideal problems, which had affinities with the real problem, could be solved. In meteorology the gap between the real situation and the ideal problem was much greater than in laboratory physics, and we were usually well satisfied with a meteorological "theory" in which the difference between the observed and calculated values was not more than, say, 10 per cent.

*Nature of the meteorological problem.*—The picture of the atmosphere as a shallow gaseous fluid, heated from below, was complicated by the fact that the system was based on a spinning earth and that the water vapour in the atmosphere was an effective means of taking up and releasing heat in enormous quantities. The system could not be isolated from the universe as a whole, and the state of the lower boundary influenced, and was also influenced by, the condition of the gaseous fluid resting upon it; almost every element of the system reacted significantly with every other. There was a strong temptation to propound soluble problems in physics which had some relation to atmospheric processes, but the essential step lay in discovering the framework of the real problem.

Two classes of problems could be distinguished. Problems like evaporation had nearly everything in common with laboratory problems except the possibility of complete control, but in the second class were problems which had little or nothing in common with laboratory experience such as those which appertained to the development and movements of large-scale pressure systems. Mathematics could be applied with profit in both classes but with different criteria of success.

*Evaporation.*—Evaporation was a typical problem of the first class, which could be approached in two ways, (i) by an examination of the mechanics of the process disregarding the economics, and (ii) by evaluating the energy balance disregarding the mechanics.

The earliest treatment was that of Jeffreys, in which the total evaporation from an area extending a known finite distance down wind was given by an expression involving the wind speed, dimension of the area and the eddy conductivity $K$; this solution could not be used to make numerical predictions because of the uncertainty regarding the value of $K$. Dr. Sutton in 1934 published an extended treatment of the semi-infinite area problem, taking into account the variability of wind speed with height and expressing the effect of turbulence in terms of measurable quantities; Dr. F. Pasquill used this solution and showed that the measured total of evaporation from small saturated surfaces agreed with the mathematical forecast to within 10 per cent. Subsequently there had been an attempt, in America, to extend the investigation to the meteorological scale at Lake Hefner; it was concluded that two of the theoretical formulae tested "gave good results" in predicting the rate of evaporation from measurements of wind, temperature and humidity.

As more was discovered about the mechanics of turbulence we should get better agreement. All observations of physical quantities contained random fluctuations which limited the precision with which the result could be stated. Meteorologists must accept, as satisfactory, agreement between quantities which were, to the laboratory physicist, rather crude averages.

The energy-balance method of attacking the problem consisted in estimating all the terms in the transformation of energy, except the one which represented the heat used up in evaporation, which was finally determined as a difference. This method gave good results.

Evaporation was typical of a large class of meteorological problems in which one might look forward to ultimate success. It was otherwise with problems arising in the phenomenon of weather.

*Mathematics in the synoptic problem.*—The central problem of meteorology was that of forecasting weather. Attempts to solve this mathematically had been mainly by the study of "model" atmospheric disturbances, by statistics and by the equations of hydrodynamics.

The three-dimensional character of the middle-latitude disturbance began to emerge in the Norwegian concept of the evolution of a depression, but we know now that the true Bjerknes depression was somewhat rare, and that the events described in the earlier papers represented on over-idealization of what actually occurred; nevertheless, we had reason to be grateful to the Bergen school for showing the value of air-mass analysis in routine forecasting.

The results obtained by the statistical approach were not commensurate with the effort expended. The search for empirical periodicities and correlations was unsound, because it tended to create a state of mind of the "true believer" who saw examples to support his creed in every case he examined. The application of statistical theory to pressure-time series for forecasting weather was considered to be a misuse of a mathematical tool. The main purpose of statistical theory was to examine data for internal consistency and weigh the evidence for a previously formulated hypothesis. In meteorology it was essential that the research had a sound physical basis before a statistical approach was attempted.

The direct attack on the problem by means of the equations of hydrodynamics held out considerable hope but the limitations were very serious. It seemed at times that the initial conditions might be insufficient to determine a unique solution. Disturbances, which were below the threshold of observation at one time, could grow exponentially and affect the distribution significantly at some later time. Also it was not yet known how far unpredictable astronomical events might affect the macro-processes of the atmosphere.

In routine forecasting the weather prognosis was built around the time extrapolation of the existing pressure fields, a process which was highly subjective. Whatever method was adopted by the forecaster, it was evident that good judgement and long practice were essentials in this difficult art. The mathematical method should be regarded as a means of indicating the most probable line of development.

In practice for a 24-hr. forecast, calculations were restricted to the movements of air masses over a rectangle covering part of the eastern Atlantic and part of western Europe. The distribution of air pressure at the surface and at some considerable height in the troposphere was known tolerably well within this rectangle at any one time. With a conventional "lid" at the tropopause and the assumption that conditions did not change (or changed according to some prescribed law) at the boundaries, the problem amounted to tracing the movements of the air inside the box formed by the rectangle, the vertical walls and the "lid" in a period of, say, 24 hr. We set up a model atmosphere which obeyed certain simplified forms of the laws of nature but we were not restricted to a rigid model of an anticyclone or depression.

This model was a compromise. Meteorologists must be prepared to accept models which were not strictly logical, in that there was an arbitrary selection of certain features to be retained, while others were rejected, not necessarily because they were small but because their retention would make the model unworkable. Such models were idealizations not easily justified on mathematical grounds. Attention was limited to an examination of the pressure and motion fields over a relatively small part of one hemisphere in the middle latitudes. The services of the meteorologist, as distinct from the mathematician, would still be required to "put in the weather", which might well be the most difficult part of the whole process of forecasting. The forecaster must recognize that the subjective element had not been eliminated by the mathematics but removed a stage further back, to the initial postulates of the model.

The results of the numerical method, tried by the Meteorological Office on a few occasions only, were encouraging. The charts produced by the machine have reproduced the main kinematical features of the real situation and were about as good as those which were drawn by experienced forecasters on the date in question. Though it was far too early to claim that the value of the method was established there were good grounds for continuing the research.

*Conclusion.*—The fact that a weather forecast was essentially a statement of chances, was not fully appreciated by the non-meteorologist, and some of the distrust with which the forecasts were regarded could be attributed to this misunderstanding.

The task of the meteorologist did not finish with the composition of the forecast—there was still the important problem of conveying the results of the analysis to the public in simple and straightforward terms; this part of the problem was almost as important as the examination of the physical processes at work.

## LETTERS TO THE EDITOR

### Monthly temperature characteristics at Kew Observatory

When I looked at Table IV of Mr. Marshall's interesting article about temperatures at Kew Observatory* I was struck by the large number of 9's in May and the small number in September. In 25 yr. there were 12 changeable Mays and only 3 changeable Septembers. This led me to make a table of frequency of occurrence of the ten different categories in each of the twelve months. The three groupings of the categories correspond broadly with "changeable", "above average" and "below average". Several points of interest emerge from it.

It is, I think, surprising that October should be the month most frequently "average". The preponderance of 7's in the autumn and of 8's in the spring

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* MARSHALL, W. A. L.; Mean maximum and mean minimum temperatures as criteria of temperature characteristics of a month. *Met. Mag., London*, **83**, 1954, p. 100.

| Index number | Description | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number of occasions in 25 yr. | | | | | | | | | | | |
| 0 | Average ... ... | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 6 | 3 | 0 |
| 1 | Rather warm ... | 4 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 2 |
| 2 | Rather cold ... | 0 | 2 | 0 | 0 | 1 | 2 | 3 | 3 | 1 | 4 | 1 | 1 |
| 3 | Warm ... ... | 0 | 4 | 5 | 4 | 0 | 2 | 3 | 4 | 3 | 0 | 1 | 1 |
| 4 | Cold ... ... | 5 | 2 | 0 | 0 | 2 | 0 | 0 | 2 | 1 | 0 | 0 | 2 |
| 5 | Brief cold periods | 3 | 2 | 1 | 4 | 2 | 4 | 3 | 2 | 2 | 1 | 4 | 4 |
| 6 | Brief warm periods | 1 | 4 | 2 | 7 | 4 | 3 | 5 | 2 | 3 | 1 | 5 | 8 |
| 7 | Warm then colder | 3 | 4 | 1 | 0 | 0 | 2 | 1 | 1 | 8 | 7 | 3 | 2 |
| 8 | Cold then warmer | 3 | 3 | 8 | 3 | 3 | 3 | 3 | 3 | 1 | 1 | 0 | 1 |
| 9 | Changeable ... | 6 | 4 | 6 | 6 | 12 | 9 | 7 | 7 | 3 | 4 | 7 | 4 |
| Total of 5, 6, 9, ... ... | | 10 | 10 | 9 | 17 | 18 | 16 | 15 | 11 | 8 | 6 | 16 | 16 |
| Total of 1, 3, 5 ... ... | | 7 | 6 | 7 | 9 | 3 | 6 | 6 | 6 | 6 | 2 | 6 | 7 |
| Total of 2, 4, 6 ... ... | | 6 | 8 | 2 | 7 | 7 | 5 | 8 | 7 | 5 | 5 | 6 | 11 |

might have been expected as these are the seasons of falling and rising temperatures, but there is no such obvious reason for the lop-sidedness disclosed by the totals for 3 and 4—27 warm months and only 14 cold months. Another unexpected result is that while May has the greatest and October the least number of changeable months, they both stand out as having the least number of months above average.

The period July–September 1953 was exceptional in having a mean maximum temperature well below the average in spite of the fact that it had 111 hr. of sunshine more than the average. There is a substantial positive correlation in summer between duration of sunshine and mean temperature (+0·76 for Oxford) and one would expect a higher correlation with mean maximum temperature. It was the very unusual character of July as shown by the graph of maximum temperature in the *Monthly Supplement to the Daily Weather Report* which led to my letter last August* suggesting the investigation so effectively completed by Mr. Marshall. It now leads me to suggest a computation of the correlation between duration of sunshine and maximum temperature, and, if the horticultural data exist, the correlation between the keeping properties of the apple crop and the sunshine and mean maximum temperature in the months July, August and September†. My apples have had a greater proportion than usual of bad ones in the past four months.

E. GOLD

*8, Hurst Close, London, N.W.11, May 2, 1954.*

[From my previous studies of the weather in London it was no surprise to me to see in Mr. Gold's most informative table and groupings of my index numbers that day-time temperature at Kew Observatory was about average more frequently in October than in any other month of the year. On the contrary, they confirm Figs. 6 and 7 of "A century of London weather" ‡ which show that October has been the month with fewest warm spells from 1841 onwards, and, for the first half of the month, fairly free from cold spells also, except during the late 1880's and early 1890's, which were very cold years generally.

The much larger number of consistently warm months than consistently cold months is due mainly to the warm springs which have been so noticeable in London's weather from 1933 onwards. If the original investigation had been carried out over the same period as that on which the average temperature value was based, i.e. 1906–35, the lop-sidedness in this respect would not have

* GOLD, E.; Unusual temperatures recorded during fog. *Met. Mag., London*, **82**, 1953, p. 246.

† The Food Investigation Laboratory, Ditton, of the Department of Scientific and Industrial Research is understood to be examining this problem.—Ed., *M.M.*

‡ MARSHALL, W. A. L.; A century of London weather. London, 1952.

been expected to occur. When the figures for March (5 warm, none cold) and April (4 to 0) are taken out of lines 3 and 4 of Mr. Gold's table there are 18 warm months compared with 14 cold months; an unexceptionable proportion. It is interesting to note that if the months with index number 5 are added to those with index number 3, i.e. the consistently warm and mostly warm months, the total is the same as the combination of consistently cold and mostly cold months given by index numbers 4 and 6, but this is probably accidental.

As Mr. Gold points out, May was the most changeable and October the least changeable month, yet these two otherwise contrasting months had one feature in common: they rarely came into the "above average" temperature grouping. The majority of Mays and Octobers classified in Table IV as changeable—index number 9—had mean maxima below average. This would, I think, hold good for typically changeable spring and autumn months in any 25-yr. period, when experience suggests and records confirm that the cold periods are usually longer and/or more pronounced than the warmer periods. But the small number of Mays and Octobers with temperature above average to which Mr. Gold draws attention is doubtless related to the period covered by the investigation.—W. A. L. MARSHALL]

## "Very rare" rainfall at Wyton, Huntingdonshire

On June 5, 1954, 3·32 in. of rainfall occurred in $2\frac{1}{4}$ hr., of which 3·15 in. is estimated to have fallen in 105 min. The rainfall during this spell was extremely heavy, and the intensity can only be described as tropical. The rate of fall was approximately 1·80 in./hr., and during the hour and three quarters, 14 per cent. of the annual average rainfall was experienced. Damage done on the station was extensive. The R.A.F. Station headquarters building, which lies centrally in the camp in a slight depression, became an island with water nearly 2 ft. above floor level. The boiler houses of both the Officers' and Airmens' Messes and several of the old-type married quarters were flooded to depths of up to 5 ft.; the sewage ejector pump was also flooded and the mass of water flowing through the drain-pipes was such that sewage was being forced out of the manholes in places. The meteorological office itself, on the first floor of a hangar building, was under a few inches of water as the verandah outside was filling from the hangar roof more quickly than the drains out could clear, with the consequence that the water made its way through the communicating door from the office. With the flooding of the headquarters, land-line connexions were disrupted, and both the teleprinter and telephone lines became unserviceable before the end of the storm.

Other damage in the district was extensive; notable was that at Broughton, a low-lying village in a rather narrow valley about two miles north of Wyton, where part of one street was under 5 ft. of water for about 8 hr., and there was a report from a chicken farm to the south of Ramsey of the drowning of 90 birds. The area of torrential rainfall appears from reports to be approximately that defined by Abbots Ripton and Somersham to the west and east (about 9 miles) and by Bury (just south of Ramsey) and Houghton to the north and south (about 7 miles); probably falls of 3 in. were confined to a considerably smaller area. Wyton appeared to be near the southern limit of heavy rain, and a report by Mr. J. S. Smith who happened to be in Hemingford two miles to the south of Wyton was of heavy but in no way exceptional rain.

At 1200 G.M.T. there was a shallow depression centred south of Newbury; the 0300 G.M.T. radio-sonde ascents for both Crawley and Hemsby had suggested a thundery prospect if surface temperatures reached about 70°F. (as seemed likely) though neither ascent appeared outstandingly unstable. At 1500 G.M.T. the depression was centred about 20 miles south of Wyton (having moved north-east at 15–20 kt.). Temperatures at this time were about 70°F. to the west and south of the area with fairly high dew points (Mildenhall air temperature 72°F. dew point 53°F., and Stansted air temperature 69°F. dew point 56°F.) whilst the Wyton air temperature rose between 1200 and 1500 from 59° to 67°F. and the dew point from 54° to 60°F.

Upper winds between 5,000 and 15,000 ft. were generally 140–180°, 10–15 kt. over the Midlands and south-east England, but the wind at 2,000 ft. above Hemsby at 1500 G.M.T. was easterly 15–20 kt. At just before 1500 conditions were quite clear to the west, but an extremely threatening cumulonimbus was observed to the east of the station, and the lower cloud which was visible was moving towards the west; the storm, as a body of course, travelled north-westwards with the medium-level winds. The surface wind was 360° 16 kt.; the wind over the previous hour or two had been 30° 10 kt. At 1500 moderate rain began, and within 5 min. it had become extremely heavy and remained so until 1645; much lighter rain continued until 1715. The temperature fell abruptly by 12°F. between 1500 and 1520, and the barometer which had been falling fairly rapidly (2·4 mb. in 3 hr.) slackened off to little change at 1500. At 1553 there was a sudden kick up of about 1 mb. and there was a gust of 30 kt. from 210°. The wind remained over 20 kt. from 210–230° until 1700, but by 1800 the speed fell to 10 kt., and by 1900 it had backed again to 10°. Thunder was heard intermittently during the whole period of the storm, and distant lightning was still being reported at 1800. Raindrop size was very large, and there was heavy hail mixed with the rain at times; the hailstones were large enough to bruise a cyclist's hands at Somersham. The character of the rain was such that at 1600 the visibility was reduced to 350 yd., and no assessment of the cloud base was possible. Cars in the roads nearby were either parked, or were proceeding with lights switched on. The rainfall was specially measured at 1800, and the total of 3·32 in. must be credited to the period 1500–1715 as no rain was observed outside these hours. It is worth noting that the rainfall for the conventional 24-hr. period ending 0900 G.M.T. on the 6th was 3 .56 in., which represents just over 16 per cent. of the annual rainfall for the district.

G. W. HURST

*Wyton, June 11, 1954*

## NOTES AND NEWS

### Voyage of the O.W.S. *Weather Recorder*

The following is an extract from the report of the Master, *Weather Recorder*, for Voyage 52, May 5–30, 1954:

"A voyage that started off with a violent westerly gale which was of short duration and henceforth a voyage which was the best that we have had for several years. The men were in swimming and the Mark D rubber dinghies were used for recreational purposes. The weather was so good that it was even reflected in the quality of the cooking; the cook excelled himself. Model makers, amateur landscape painters and rug makers were able to further their hobbies under ideal conditions. The films which were of good quality were very much enjoyed whilst the midweek shows of films from the Central Office of Information, mostly travelogues, were very acceptable. The Naval film documentary of the war in north Africa was enlightening and duly appreciated. Altogether a rare trip after what we have suffered in the past couple of years.

"The voyage commenced rather dramatically with an 'Urgent' message from the British steamer *Sir James* who was being blown ashore off the Ayrshire coast. We went to her assistance along with the *Lairds Ben*, and, after the *Lairds Ben* had failed to pass a line in the very full gale, we closed the *Sir James* ready to take the crew of four men and a boy off or pass the towing wire; however, it was found that the *Sir James* was slowly clawing off the shore and we got to windward of her and tried to provide a lee. We escorted the *Sir James* over to the coast of Arran accompanied by the Troon lifeboat; close to Arran we left the *Sir James* in the hands of the lifeboat."

The Meteorological Officer, *Weather Recorder*, reports as follows:—

"The wind veered to north-westerly and increased to 50–55 kt., a short steep sea rose in a matter of minutes and the flying spume gave the effect of low-lying fog on the sea surface, this occurred even when we were more-or-less sheltered by the shore. The ship was diverted to stand by a vessel which found itself in difficulties being caught in the extraordinary weather conditions."

C. E. N. FRANKCOM

## Loan of rain-gauges

The Council of the Royal Meteorological Society recently agreed that up to six rain-gauges could be purchased annually for loan to suitable observers in remote districts, who would be prepared to send their daily readings to the Meteorological Office on forms which would be supplied. The object of the loan is to secure records from areas at present unrepresented by rainfall observers. With the growing demand for water for domestic purposes, industry, agriculture and hydroelectric schemes it is becoming increasingly important to have more complete details of the amount of rainfall in all parts of the country. Moreover, observations from a closer network of stations are needed to define more precisely the distribution of rain in intense and widespread heavy rains which often cause extensive flooding.

Whilst the collection of reliable rainfall reports is one of the functions of the Meteorological Office the actual observations have always been obtained mainly from voluntary observers who provide their own rain-gauges and forward copies of their daily observations to the Meteorological Office at the end of every year, or at more frequent intervals where required. The number of such observers now exceeds 5,000. There is a great advantage in this system in that the records are maintained by observers who are interested in finding out the amount of rain falling in their gardens or farms, which results in the records attaining considerably reliability. Meteorologists from other countries often comment most favourably on the reliability of the data obtained here by the co-operation of interested observers.

The reading of the rain-gauge occupies but a few minutes each morning. It consists of pouring the collected rain-water into a glass measure and reading the amount on the graduated scale. Readings are required to be made regularly each morning usually at 0900 G.M.T., but regular readings at a fixed time between 0700 and 1000 G.M.T. are acceptable provided the time of measurement is noted on the register. The need for regularity usually entails that there should be a deputy observer available in the absence of the observer. The gauge has to be set up with the rim 1 ft. above ground in a site which is neither too sheltered nor too wind-swept. The ideal exposure to aim at is the centre of a lawn in a fairly large garden, but guidance on siting the gauge can be given if details of the available positions are provided. Detailed instructions are set out in "Rules for rainfall observers" obtainable on application from the Meteorological Office.

Most of the stations which report rainfall are situated in the towns and well populated parts of the country, but there are relatively few in the mountainous districts, which are generally the wettest parts. The offer to lend a rain-gauge and measure is therefore available to those living in remote districts, where there is no existing representative record and where there is a reasonable probability of measurements being maintained for at least five years. It may be that some readers of the *Meteorological Magazine* know of people living in such districts who would be willing to maintain a record if the necessary instruments were supplied. Additional rainfall reports are especially required in parts of the north and north-west of Scotland, Wales and in the north of England. These areas include, in Scotland, parts of the Outer and Inner Hebrides and large areas in the Highlands. The largest gaps in Wales are near St. David's (Pembrokeshire) and Aberayron (Cardiganshire). In England the largest remaining gaps are in northern Cumberland around Bewcastle; in the Cheviot Hills to the west of Wooler; the North Yorkshire Moors, e.g. Pickering Moor, Fylingdales Moor and the valley of the River Rye; in the Stainmore Forest area to the west of Barnard Castle; in Derbyshire between Tideswell, Matlock, Sudbury and Leek including Dovedale; in Lincolnshire a 15-mile band from the outskirts of Lincoln through Wragby and south to Mablethorpe and in the north-eastern quarter of Suffolk.

Applications for the loan of instruments under this scheme should be made to the Director, Meteorological Office, Headstone Drive, Harrow, Middlesex, in the case of places in England, Wales and Northern Ireland; and for places in Scotland to the Superintendent, Meteorological Office, 26 Palmerston Place, Edinburgh 12. The Meteorological Office will then advise the Royal Meteorological Society of those observers recommended for the loan.

J. GLASSPOOLE

## REVIEWS

*Mathematics in action.* By O. G. Sutton. 8½ in. × 5½ in., pp. viii+226, *Illus.*, G. Bell & Sons Ltd, London, 1954. Price: 16*s.*

The interpretation of physical science for non-physicists dates from the middle of the last century and received a tremendous impetus from the new ideas developed in physics after the turn of the century; indeed it would be difficult to list the popular books on modern physics. The exposition of mathematical ideas for non-mathematicians has never enjoyed such a vogue and it is only in comparatively recent times that popular books on mathematics have begun to appear. Most of these books have dealt with the pure mathematical aspect of the ideas of mathematics; in this book Dr. Sutton is concerned with how the applied mathematician uses these ideas in "solving" physical problems.

In the first chapter the author explains how the applied mathematician builds up a simply related skeleton world whose main features have something in common with the world in which a physical event occurs, and so is able to treat the more amenable problem of the mathematical world which is the abstraction of the real physical problem. He is very careful to point out that there is considerable idealization and simplification before the translation into mathematical language, and that the real problem is usually quite insoluble by mathematics. There has been a regrettable tendency in popular books, especially those on relativity, to identify the real and mathematical worlds but the author avoids the trap.

The second chapter is entitled "The tools of the trade" and perhaps it was the most difficult to write, since any account in a few pages must be a miracle of compression (the latest American book which might well have had the same title is advertised as in two volumes, each of 1,000 pages!). Dr. Sutton cannot achieve the impossible task of keeping the mathematics at the same level—all the tools are not equally sharp or of equal importance—so that there is a variation from the elements of the infinitesimal calculus to partial differential equations. The general reader may be alarmed at the number of definitions and equations in this chapter, but if read judiciously, skipping the actual equations as verifiable later (which is what mathematicians do in a first reading of a paper) there is a lot to be learned here about the general applied mathematical method, and the author is particularly happy in showing how the initial and boundary conditions determine the form of the solution of a differential equation. For some of the later work the reader will have to refer back to this chapter.

The five following chapters apply the methods to a very varied fare in mathematical physics. The short chapter on ballistics develops the notion of viscous drag and shows how this complicates the equations of motion so much that an analytical solution becomes impossible. Step-by-step integration leads naturally to a discussion of methods of calculation and so to analogue machines and digital calculators.

The chapter on waves (where a wave is the noun corresponding to the verb "to propagate" and not "to undulate") is very good indeed. There is a customary treatment of Fourier series and integrals, and the integrals are used to find a relation between a radio signal and its band-width, thus preparing the way for relationships of the type of the uncertainty principle. Waves and particles follow naturally and here the author is very clear in stating that they are the applied mathematicians' inventions designed to give a coherent theory which can be tested against experiment. Most experimental observations deal either with a length or an angle, not with a wave or a particle. This section is especially recommended as an antidote against metaphysical writings that are still widely read. The chapter ends with an account of the method of characteristics in the solution of partial differential equations—which is the mathematical high-water mark of the book—and the application to fluid flow round a corner and the formation of shock waves.

The chapter on the mathematics of flight gives a simple account of how an aircraft which is heavier than air can sustain flight, bringing home to the reader that what may be neglected in one aspect of a problem may well be the crux of another aspect. Simple hydrodynamical theory and conformal transformation are dealt with, without much mathematics. How Bernoulli's theorem enables the mathematician to deal quantitatively with the dynamics of flight is well brought out, and the schematic solution of the problem is given. The Joukowski transformation is introduced showing how a circle may be transformed into a shape similar to that of an aerofoil, and this together with the previous schematic solution for the lift on a long cylinder, completes in outline the calculation of the lift. The chapter ends with a short account of high-speed flight and more about shock waves, of interest to everyone today.

A very short account of the use to which statistics can be put is then given. The four typical problems—distribution, correlation, sampling and significance—are dealt with and examples of each given; what is more important, there are many warnings as to the free interpretation of statistical results as meaningful in the physical world, and the example on p. 183 should be especially noted as an awful warning of how not to interpret. The final conclusion—to call in the expert—will be agreed by all.

To meteorologists the last chapter will in many ways be the most interesting. Why is it not possible to produce a book of weather forecasts for a long time ahead? The answers are sketched here—the complexity of the problem, instability, the failure to find a reasonably simple abstraction and so on. Richardson's work is discussed and contrasted with present routine forecasting methods. Finally the author gives his views on the possibility of forecasting by mathematical methods and mentions some of the numerical work which is going on now.

Since the author cannot allow himself to use too much technical mathematics he has in many cases to illustrate by analogy. The analogies are simple and appealing and, what is more important, not pushed too far—a common failing of popular accounts. The book is very modern in content, very readable and with humour in the pages. The professional will enjoy this book as much as the amateur; it is a book to be recommended and a book to own.

The publisher's name guarantees good printing and I did not notice any errors in the mathematical display.

E. KNIGHTING

## Centenary of the Royal Netherlands Meteorological Institute

*Koninklijk Nederlands Meteorologisch Instituut 1854–1954.* 10¼ in. × 5¼ in., pp. 472, *Illus.*, Staatsdrukkerij-en Uitgeverijbedrijf, 's-Gravenhage, 1954.

The Royal Netherlands Meteorological Institute was founded on February 1, 1854, and the magnificent volume under review has been published in celebration of the centenary. The royal decree establishing the Institute, signed by King William III on January 31, 1854, is reproduced in the book.

The volume is in three main parts. The first part describes the history of the Institute, the second is a detailed description of the current work, and the third consists of a number of scientific papers written by members of the staff. The volume concludes with lists of past and present members of the governing body (College of Curators), of the Directors-in-Chief and other senior staff, and a list of publications.

The first Director-in-Chief was Prof. C. H. D. Buys Ballot known to all who have ever studied meteorology at all seriously for the law he enunciated in 1857.

Buys Ballot was a lecturer in chemistry and mineralogy, later Professor of Experimental Physics, at the University of Utrecht. He had established a meteorological observatory at the bulwark of Sonnenbergh on the town wall of Utrecht in 1848 and did much to stimulate and organize meteorological observing in Holland before 1854. Buys Ballot remained Director-in-Chief until his death in 1890 at the age of 72. A reproduction, in colours, of his portrait appropriately faces the title page.

The collection of weather reports by telegraph was soon organized and the issue of storm warnings began on June 1, 1860. Holland was the first country in Europe to have a storm-warning organization.

Since these early days the work of the Institute grew steadily until after the end of the Second World War when it became very rapid indeed. The Institute now provides the national service of meteorology, climatology, oceanography, terrestrial magnetism and the observation of the ionosphere. Maritime meteorology has naturally always been prominent in the Institute's work from the earliest days and port meteorological offices were opened at Rotterdam and Amsterdam in the 1880's.

The Dutch Institute has always played a large part in international meteorological work. Buys Ballot was one of the early instigators of international collaboration, and the first President, in 1874, of the International Committee. In 1928 the first permanent office of the International Meteorological Organization was established in the Institute building.

The Institute moved from Utrecht to De Bilt in 1897 and is now housed in an imposing building, of which several photographs are included, standing in large grounds. A high tower for anemometer development is a prominent feature.

The ten scientific papers deal with a wide variety of subjects from improved electrical methods of obtaining continuous records of wind speed and direction from Dines and contact anemometers, the theory of the general circulation, statistical methods in climatology, an apparatus for continuously recording sea temperature and salinity, to the application of microseismic observations in forecasting and the theory of the ionosphere.

All British meteorologists will wish the Royal Netherlands Meteorological Institute every success during its second hundred years of existence.

G. A. BULL

## ADDENDUM

To the article, in the March 1954 number of the *Meteorological Magazine*, "Estimation of meteorological averages for other months given average values for January, April, July and October" by A. F. Jenkinson, the following paragraphs should be added.

Dr. C. E. P. Brooks points out that by the omission of the sin $(60t)^\circ$ term in the expansion (1) the assumption is made that the maxima or minima of the semi-annual term occur at the mid-season months. It is, of course, not possible to complete the full four-term harmonic expansion from only four equally spaced values. The reasonableness of this assumption is shown by Tables III and V. It would not, however, apply generally for tropical regions.

"Nearly" with reference to the use of mid-month values in place of monthly means gives a difference of about 1 per cent.

## METEOROLOGICAL OFFICE NEWS

**Academic success.**—We congratulate Mr. C. E. Wallington, Experimental Officer, on passing the London M.Sc. examination in mathematics.

**Sports and athletics.**—The Harrow Meteorological Office Social and Sports Club held their fifth Annual Sports meeting at Headstone Manor Sports Ground on July 1, 1954. A full programme of events was held and there was a good entry for all. The following records were set up:—

I. McDonald ran the mile in 4 min. 50·4 sec.

Miss K. Newman ran the ladies' 100 yd. in 12·6 sec.

L. P. Farrant jumped 18 ft. 0¾ in. in the long jump.

R. Cowen set up a time of 24·4 sec. for the 220 yd., an event not previously held at Harrow.

There were several novelty races during the evening. Commander Frankcom won the veterans 80 yd. and Messrs. B. C. V. Oddie, J. K. Bannon and G. J. Evans won the Meeting Officials' four-legged race. During the evening there was an excellent display of archery by Dr. and Mrs. R. Frith and at the end of the evening Mrs. R. G. Veryard presented the prizes.

*Cricket.*—The annual match between the Central Forecasting Office cricket team and a team selected from the meteorological offices in the London area was played on the ground of the Dunstable Town Cricket Club at Bull Pond Lane on June 16. Winning the toss, the visitors elected to bat first and, by tea-time, were able to declare at 126 for 8 wickets. This total proved too difficult a target for the home side despite a forceful contribution of 29 from H. Snow and they were all out for a total of 58 runs. The outstanding performance of the afternoon was the batting and bowling of J. B. Shaw for the visitors, who scored an undefeated 81 and took six wickets for 18 runs. The inclusion of a lady player, Miss Audrey Winterbottom, in the Dunstable side appeared well justified by her very competent performance. The Dunstable ladies provided an excellent tea for the occasion.

*Swimming.*—Miss C. W. Fleming, Scientific Assistant at Renfrew, has been selected to swim for the Civil Service against the Royal Air Force on July 1, and against the Army and the Navy on September 1 and 2. Miss Fleming was third in this year's Scottish Ladies' Breaststroke Championship which was held recently.

## WEATHER OF JUNE 1954

Mean pressure was 2–4 mb. above normal from the Bay of Biscay south-westwards to the Azores and westwards to Newfoundland; and slightly below normal over northern Europe, the Mediterranean and the eastern United States.

Mean temperature was slightly above normal over most of Europe and the Mediterranean.

In the British Isles, generally speaking, the weather was dull and cool, with heavy rain and thunderstorms at times.

In the first few days of the month an anticyclone to northward of Scotland gave rise to dry weather almost everywhere; it was dull and cool in eastern districts with morning drizzle, but in the west it was sunny and warm. At

Prestwick Airport temperature reached 77°F. on the 4th and over 15 hr. of sunshine was recorded daily at some places in the Hebrides and west Scotland. Brighter weather occurred in parts of eastern England on the 3rd and 4th but on the latter day there were isolated thunderstorms in the south Midlands. On the 5th a trough of low pressure moved over the British Isles from the Atlantic and it was preceded by an extensive outbreak of thunderstorms, particularly in the Midlands and the south-east. A depression formed in this trough and became slow moving over England giving rise to widespread rain, heavy in places, over the Whitsun holiday (3·46 in. at Long Newnton, Gloucestershire and 3·56 in. at Wyton, Huntingdonshire, of which 3·15 in. fell in about 105 min., on the 5th, and 2·21 in. at Treherbert, Glamorgan and 2·06 in. at Swansea Waterworks, Brecknockshire on the 6th). During the ensuing week further depressions moved from the Atlantic into the south of the British Isles bringing much rain, particularly in southern and western England, but there were sunny periods especially in east England and north-west Scotland. Strong winds occurred in the English Channel on the 9th. From the 6th to the 12th London had its wettest June week since 1905. Following an outbreak of thunderstorms during the night of the 12th–13th (1·98 in. of rain in the 36 min. ending at 0130 on the 13th at Hertford Sewage Works) the 13th was a cold, rather wet day in east and south-east England and at Dunstable the temperature fell to 46°F. during the early afternoon. From the 14th to the 24th a sequence of small but active depressions moving east brought cloudy rainy weather with only brief intermissions to parts of Scotland and rain at times to northern England and Northern Ireland; on the 15th the rainfall was heavy in north-west England and west Scotland (4·37 in. at Grasmere, 4·33 in. at Langdale, Westmorland and 3·81 in. at Borrowdale, Cumberland. In the south the fronts associated with these depressions were very weak and in the intervening ridges of high pressure fine, rather warm weather occurred in many places especially from the 22nd to the 24th. A depression formed south of Iceland on the 25th and moved slowly to Scandinavia; cool northerly winds spread to all areas on the 26th and 27th and lasted until the 29th, with some rain or showers in places. Long sunny periods were recorded on the 26th and 27th, but it was mainly cloudy on the 28th and 29th though there were bright periods in the west. On the 29th a warm front moved into Scotland from the north-west and later moved south-east over England; winds backed to W. or SW. and temperature rose somewhat, particularly in eastern districts (maximum 72°F. at Dyce, near Aberdeen on the 30th). Rain fell in Scotland on the 29th and spread south but it did not reach the south-east until the night of the 30th.

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

| | AIR TEMPERATURE | | | RAINFALL | | SUNSHINE |
|---|---|---|---|---|---|---|
| | Highest | Lowest | Difference from average daily mean | Percentage of average | No. of days difference from average | Percentage of average |
| | °F. | °F. | °F. | % | | % |
| England and Wales ... | 77 | 30 | −1·4 | 142 | +3 | 70 |
| Scotland ... ... | 79 | 28 | −0·6 | 143 | +2 | 78 |
| Northern Ireland ... | 70 | 37 | −1·3 | 111 | +2 | 71 |

# RAINFALL OF JUNE 1954

## Great Britain and Northern Ireland

| County | Station | In. | Per cent. of Av. | County | Station | In. | Per cent. of Av. |
|---|---|---|---|---|---|---|---|
| *London* | Camden Square ... | 3·42 | 169 | *Glam.* | Cardiff, Penylan ... | 4·51 | 180 |
| *Kent* | Dover ... ... ... | 1·91 | 99 | *Pemb.* | Tenby, The Priory ... | 2·52 | 105 |
| „ | Edenbridge, Falconhurst | 3·94 | 179 | *Radnor* | Tyrmynydd ... ... | 6·43 | 197 |
| *Sussex* | Compton, Compton Ho. | 3·82 | 153 | *Mont.* | Lake Vyrnwy ... ... | 5·52 | 171 |
| „ | Worthing, Beach Ho. Pk. | 2·45 | 140 | *Mer.* | Blaenau Festiniog ... | 9·03 | 139 |
| *Hants.* | Ventnor Cemetery ... | 2·94 | 156 | „ | Aberdovey ... ... | 6·10 | 224 |
| „ | Southampton, East Pk. | 3·54 | 176 | *Carn.* | Llandudno ... ... | 2·75 | 145 |
| „ | South Farnborough ... | 2·87 | 149 | *Angl.* | Llanerchymedd ... | 3·41 | 144 |
| *Herts.* | Royston, Therfield Rec. | 1·91 | 85 | *I. Man* | Douglas, Borough Cem. | 2·22 | 92 |
| *Bucks.* | Slough, Upton... ... | 4·04 | 196 | *Wigtown* | Newton Stewart ... | 5·04 | 191 |
| *Oxford* | Oxford, Radcliffe ... | 3·63 | 162 | *Dumf.* | Dumfries, Crichton R.I. | 3·33 | 132 |
| *N'hants.* | Wellingboro' Swanspool | 2·60 | 124 | „ | Eskdalemuir Obsy. ... | 6·21 | 197 |
| *Essex* | Shoeburyness ... ... | 2·59 | 147 | *Roxb.* | Crailing ... ... | 1·72 | 78 |
| „ | Dovercourt ... ... | ... | ... | *Peebles* | Stobo Castle ... ... | 2·58 | 110 |
| *Suffolk* | Lowestoft Sec. School... | 2·13 | 118 | *Berwick* | Marchmont House ... | 2·48 | 107 |
| „ | Bury St. Ed., Westley H. | 2·22 | 106 | *E. Loth.* | North Berwick Res. ... | 2·72 | 164 |
| *Norfolk* | Sandringham Ho. Gdns. | 2·10 | 97 | *Midl'n.* | Edinburgh, Blackf'd. H. | 2·29 | 115 |
| *Wilts.* | Aldbourne ... ... | 5·52 | 238 | *Lanark* | Hamilton W. W., T'nhill | 2·45 | 111 |
| *Dorset* | Creech Grange... ... | 2·59 | 113 | *Ayr* | Colmonell, Knockdolian | 4·07 | 161 |
| „ | Beaminster, East St. ... | 2·94 | 130 | „ | Glen Afton, Ayr San. ... | 3·89 | 123 |
| *Devon* | Teignmouth, Den Gdns. | 2·76 | 144 | *Renfrew* | Greenock, Prospect Hill | 4·02 | 129 |
| „ | Ilfracombe ... ... | 3·77 | 174 | *Bute* | Rothesay, Ardencraig... | 4·52 | 147 |
| „ | Princetown ... ... | 8·17 | 203 | *Argyll* | Morven, Drimnin ... | 4·59 | 148 |
| *Cornwall* | Bude, School House ... | 2·73 | 136 | „ | Poltalloch ... ... | 5·19 | 170 |
| „ | Penzance, Morrab Gdns. | 3·22 | 145 | „ | Inveraray Castle ... | 6·15 | 155 |
| „ | St. Austell ... ... | 4·24 | 163 | „ | Islay, Eallabus... ... | 4·19 | 160 |
| „ | Scilly, Tresco Abbey ... | 2·87 | 166 | „ | Tiree ... ... ... | 3·48 | 136 |
| *Somerset* | Taunton ... ... | 2·59 | 147 | *Kinross* | Loch Leven Sluice ... | 2·97 | 136 |
| *Glos.* | Cirencester ... ... | 5·58 | 233 | *Fife* | Leuchars Airfield ... | 2·13 | 128 |
| *Salop* | Church Stretton ... | 3·76 | 148 | *Perth* | Loch Dhu ... ... | 4·16 | 100 |
| „ | Shrewsbury, Monkmore | 2·55 | 123 | „ | Crieff, Strathearn Hyd. | 2·57 | 97 |
| *Worcs.* | Malvern, Free Library... | 3·70 | 159 | „ | Pitlochry, Fincastle ... | 2·10 | 100 |
| *Warwick* | Birmingham, Edgbaston | 3·21 | 138 | *Angus* | Montrose, Sunnyside ... | 2·03 | 122 |
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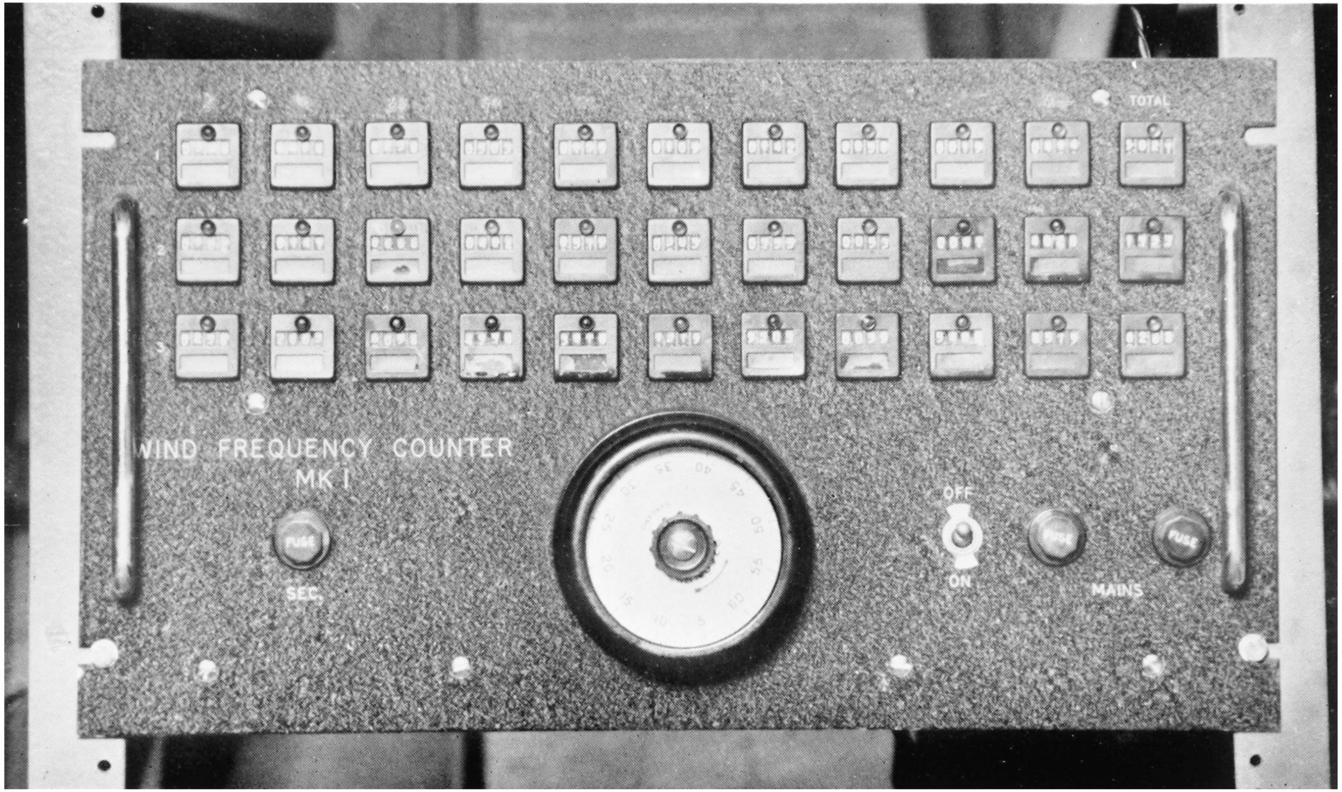


WIND-SPEED FREQUENCY RECORDER

(see p. 232)

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PHOTOGRAPHS OF LIGHTNING TAKEN AT ACTON, MIDDLESEX, DURING THE STORMS OF THE NIGHT OF JUNE 12–13, 1954