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## EXCEPTIONAL SUDDEN CHANGES OF EARTH TEMPERATURE

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It is so well established as to be considered axiomatic that the earth temperature at depths below 2 ft is not subject to sudden changes. Even at the 1 ft depth the diurnal range of temperature in this country is rarely more than 5°F; at the 2 ft depth and below the daily change is so small that measurements are made only once a day. However, during exceptional weather it is possible for sudden changes to occur, and scrutiny of earth-temperature records since 1921 has revealed one or two large changes that are deserving of special mention.

The most important method of transmitting heat through the soil is by means of conduction, and most changes of temperature at depth can be explained very approximately by heat conduction. It can easily be shown that changes of temperature at the surface, when transmitted downwards by conduction, are progressively damped out exponentially with depth, the less persistent temperature changes being more easily damped out. Thus we should expect only small changes of temperature in the earth, and the greater the depth the smaller the changes. But other methods of heat transmission may, on occasion, be important. Radiation between soil particles in contact or very close together must be negligible. Convection of air trapped within the soil can only be slow and, because of the small heat capacity of the air, the effect on soil temperature must also be negligible.

The presence of ice or water within the soil can have several effects. The effect of latent heat released or absorbed by a change of state of the water or ice can only be to decrease the flow of temperature; in fact, with both water and ice present together in the soil the temperature remains constant at 32°F, whilst the proportions of ice and water vary so that the release or absorption of latent heat can compensate for any loss or gain of heat by other means. Water can help the soil particles make better contact with each other so that heat conduction through the soil is improved. However, the mass (and therefore the heat capacity) of matter through which the heat is to be conducted is also increased so that when once the thermal contact has been sufficiently established (only a comparatively small quantity of water is required for this) the rate of propagation of temperature change through the soil is decreased. In any case, the main agent of heat transfer is still conduction and so changes of temperature are progressively less with increased depth. There remains only the effect of drainage of water through the soil to transmit any temperature changes quickly from one depth to another.

Figure 1 shows diagrammatically the weather and consequent 1 ft earth temperature occurring at Hesketh Park, Southport, during March 1947. The air temperature was measured three times a day, at 9h, 13h and 17h GMT. The earth temperature was measured twice a day, at 9h and 17h, and it is therefore possible to draw a smooth curve through these plotted temperatures since all minor temperature fluctuations are damped out at that depth. Rainfall (measured once a day at 9h) is plotted at the top of the diagram in histogram form, and occasions when the ground was recorded as covered with snow are marked by a snow symbol within a square.

Until the 7th what precipitation occurred was in the form of snow; there was plenty of sunshine, and clear skies at night allowed the surface temperature to fall to quite low values (13°F grass-minimum temperature was recorded on the 3rd and 4th). The subsoil appears to have been fairly dry (although possibly containing ice), and the temperature at the 1 ft depth exhibited a diurnal oscillation with the lowest recorded temperature of 27·6°F at 9h on the 4th. After midnight on the 7th snow, which had been falling since midday, turned to cold rain. Although 0·46 in. of precipitation occurred the snow depth only increased by $1\frac{1}{2}$ in.; some of the snow must have thawed and, with the rain, have percolated through the soil to the 1 ft depth, where it formed a freezing mixture with the ice already present at that level, for the 1 ft earth temperature rose to 32°F and remained at or about that temperature from the 9th to the morning of the 20th. Even the prolonged snow, sleet and rain of the 12th and 13th (almost 2 in. of rainfall; duration of precipitation $28\frac{1}{2}$ hours out of a possible 48 hours) had little effect on the temperature at the 1 ft depth. With air temperature near 32°F, the rain was cold and even if it did drain through the soil it could not raise the temperature much above 32°F. Nevertheless, the snow was thawing. At midnight on the 12th the snow was 4 in. deep; at 9h the following morning it was only 1 in. deep. The 0·1 in. of snow lying at 9h on the 14th was recorded as new snow. On the 15th, after falling for four hours, snow lay to a depth of $1\frac{1}{2}$ in. during the evening but ensuing rain washed it away by morning. During the remainder of the month, as Figure 1 shows, rain occurred every day and the air temperature was at least 10°F higher. But some ice seems to have remained in the soil at the 1 ft depth until the 20th, for not until then did the temperature at that level begin to rise.

The soil at Hesketh Park is sand; moreover, the observing site in use until 1955 was not far from the top of a slight hill so that drainage through the subsoil could be expected to be exceptionally good. During March 1947 the consequences of this drainage were most spectacular and instructive. The first rainfall on the 7th–8th seems to have percolated little deeper than the 1 ft depth where, as we have seen, it raised the temperature there to an almost steady 32°F. But the heavier rain on the 12th and 13th was sufficient in quantity to force its way through the semi-frozen soil; and cold water percolated much further, affecting the temperature down to at least the 10 ft depth. This is illustrated in Figure 2, which depicts the temperatures at all four depths at which it was measured at Hesketh Park.

The temperature at the 4 ft depth fell from 35·8°F on the 12th to 32·1°F on the 13th and then began to rise steadily with the return of heat conducted from

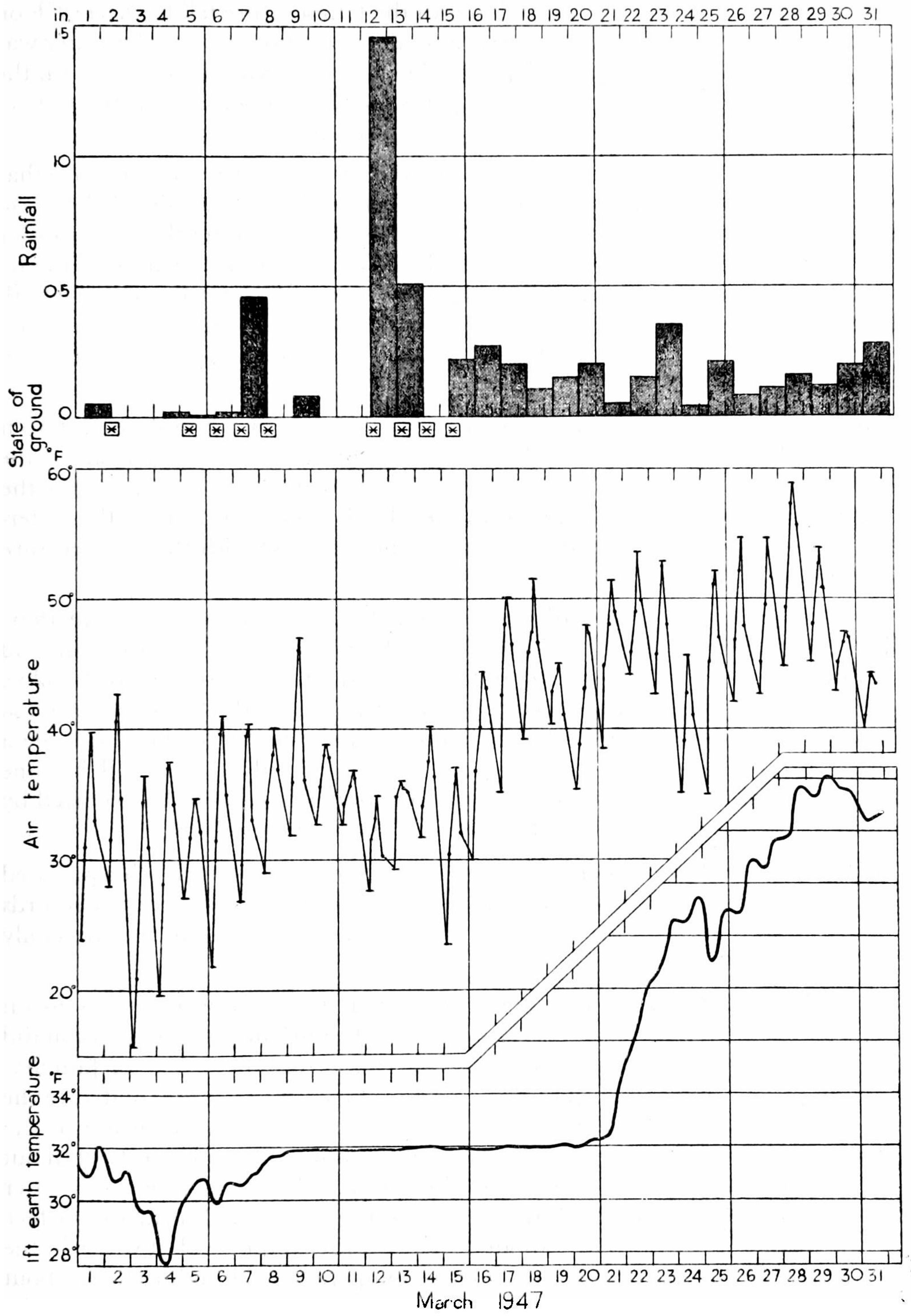


**FIGURE 1—RAINFALL, AIR TEMPERATURE AND 1 FT EARTH TEMPERATURE, HESKETH PARK, SOUTHPORT, MARCH 1947**

The state of ground was only recorded when snow was lying. The air temperature was measured at 9h, 13h and 17h and plots of these temperatures are joined by straight lines meeting plotted values of maximum and minimum air temperature as recorded every day at 9h. Earth temperature was measured at 9h and 17h; plots of these temperatures are joined by a smooth line.

the warmer layers below. At the 10 ft depth the temperature fell from 41·7°F on the 12th to 41·3°F on the 13th to 33·2°F on the 14th. Presumably the water was just beginning to reach the 10 ft depth at the daily observation hour (9h) on the 13th but was fully in evidence on the 14th when the temperature at the time of observation may even have been above its minimum.

No sudden fall in temperature was observed at the 20 ft depth showing that the water-table was above that depth even before the heavy rain of the 12th. The normal rate of fall of temperature in March at the 20 ft depth is of the order of 1°F per month. The temperature actually fell about 2°F between the 13th and the 20th. This is consistent with the mixing of new cold water from above with water already present, together with increased loss of heat upwards by conduction; which was the more important method of transfer of heat on this occasion it is difficult to say.

That the main agent of heat transfer at depth between 1 ft and at least 10 ft was water drainage is confirmed by the top curve in Figure 2 which shows the depth of subsoil water as measured daily at Hesketh Park not far from the observing site but presumably at a lower level. The sudden raising of the water-table on the 13th and 14th is quite marked and in phase with the temperature variation at the 10 ft depth.

The last spell of wintry weather ended on the 15th, and a permanent thaw followed with further more persistent rain. The melted snow and the first cold rain draining through the soil is manifest on all the temperature records below the 1 ft depth as well as in the record of subsoil water depth. The effect is not so marked as on the 13th but, with precipitation not so heavy as then, so large a temperature change is not to be expected. Subsequently the subsoil became saturated and the changes of temperature were only what would be expected by normal heat conduction as modified by small latent-heat effects.

It is surprising that no such sudden temperature changes at depth associated with water drainage have been noticed before. A quick search through records of observation since 1921 at many likely stations in Great Britain revealed only three other occasions.

At Hesketh Park, in January and February 1940, there were occasions on which the phenomenon occurred at a depth of 4 ft, but only on one occasion did the water seep quickly to the 10 ft depth. There was rain on 23 and 24 January, and a temporary thaw on 26 January. Some of this melt water percolated to the 4 ft depth reducing the temperature by nearly 1°F. The height of water in the well rose by nearly 3 in. Further rain, turning to snow, fell on the 26th–28th but this had no effect on underground conditions until 3 February, when cold water appears to have broken through the block of semi-frozen earth near the surface (the 1 ft earth temperature was about 32°F) and raised the level of water in the well slightly. At the same time the 4 ft earth temperature fell suddenly by about 3°F and the 10 ft earth temperature by nearly 1°F. Later in the month, on the 18th–19th, associated with a thaw and a marked rise in the height of water in the well, the 4 ft earth temperature fell suddenly by more than 1°F.

Also in January 1940, heavy rain (2·12 in. in the 24 hours ending at 9 h on the 27th) at Swansea percolated very rapidly through the sandy soil reducing the 1 ft earth temperature to 32·8°F and the 4 ft earth temperature to 36·4°F (see Figure 3). Again the phenomenon was associated with a thaw. Although

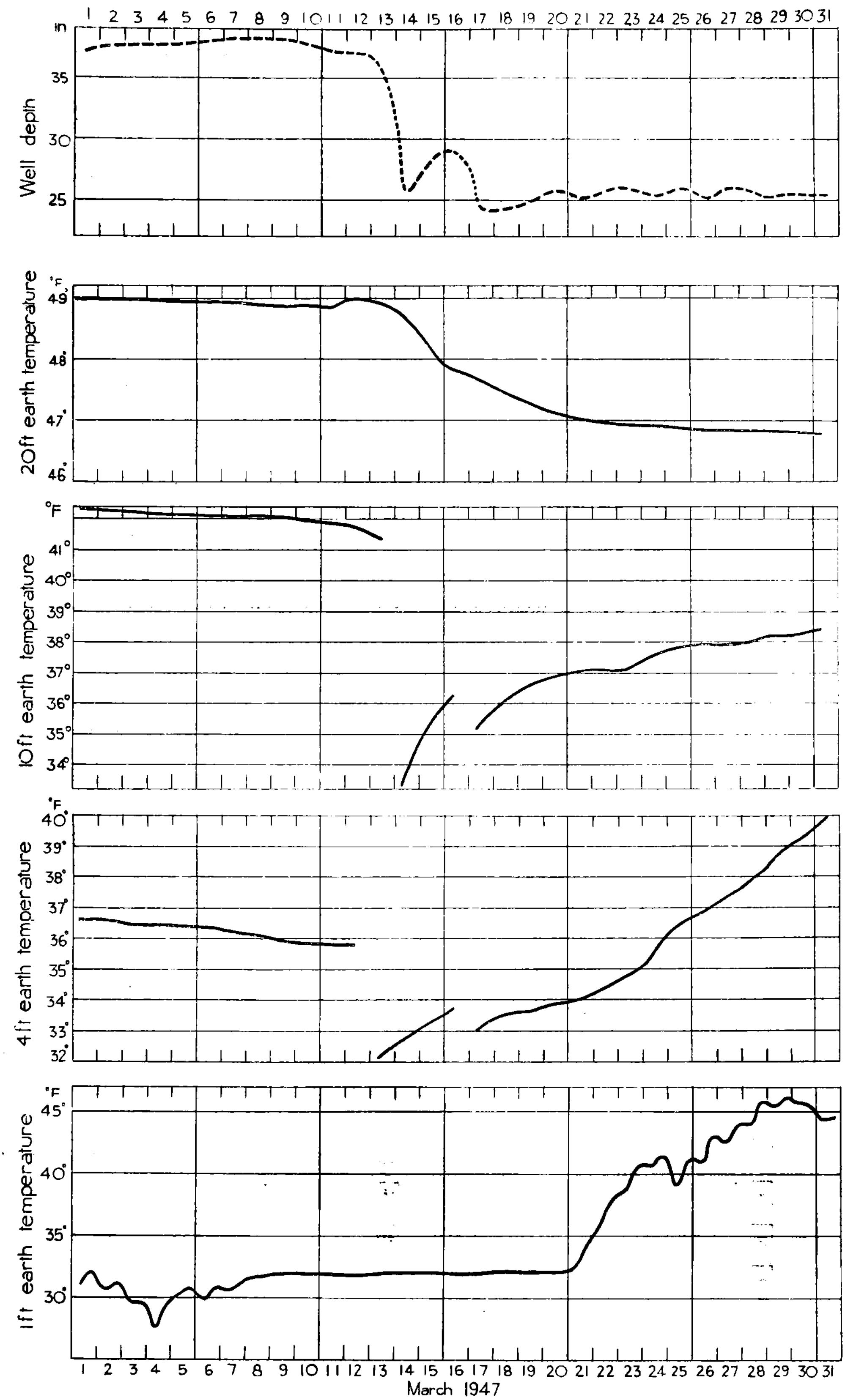


FIGURE 2—WELL DEPTH AND EARTH TEMPERATURES, HESKETH PARK, SOUTHPORT, MARCH 1947

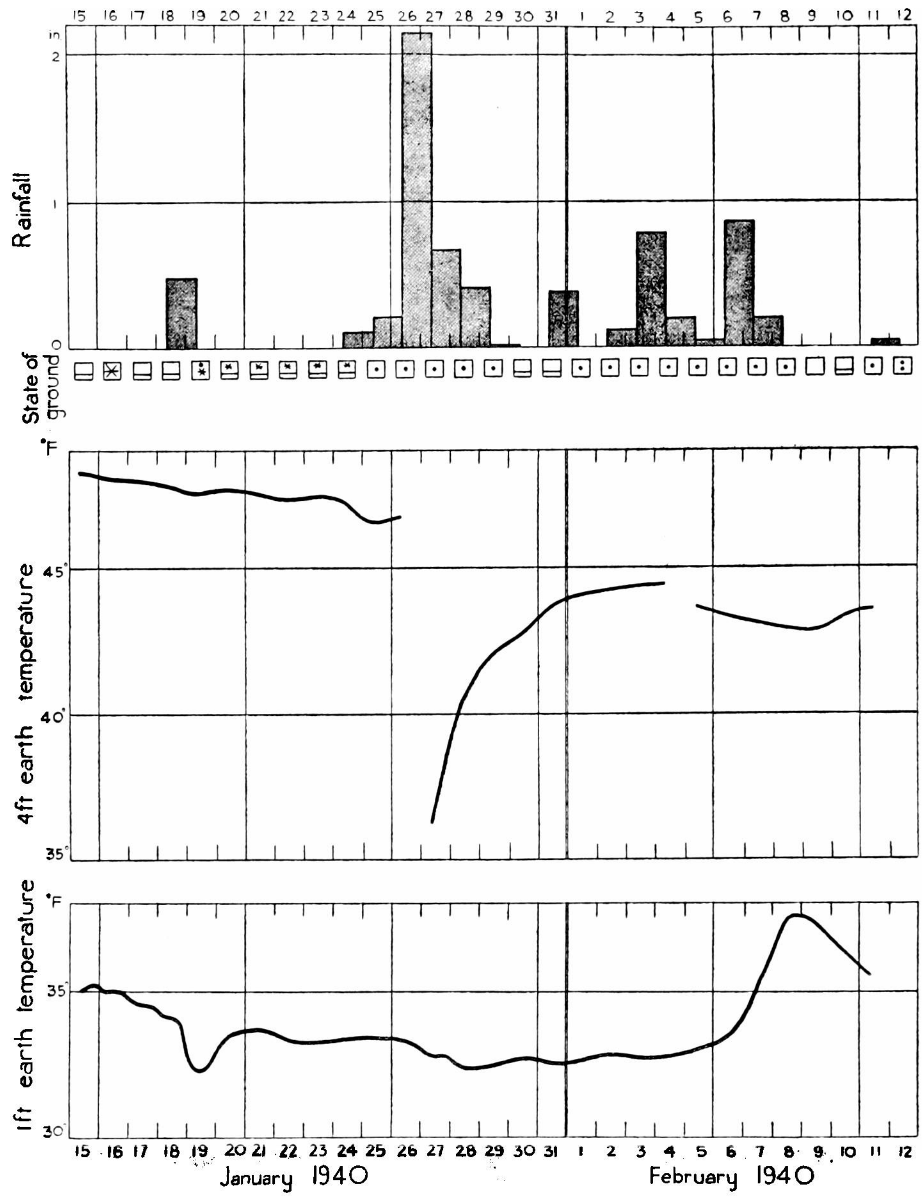


FIGURE 3—RAINFALL, STATE OF GROUND, AND EARTH TEMPERATURES, SWANSEA, JANUARY–FEBRUARY 1940

Meaning of symbols

| | | | |
|---|---|---|---|
| ☐ | Ground dry | | Ground partly covered with snow or hail |
| | Ground moist | | Ground completely covered with snow or hail |
| | Ground flooded | | Ground completely covered with snow or hail with ground frozen |
| | Ground frozen hard and dry | | Ground covered with thawing snow |

there is no water-table information as at Hesketh Park it is quite clear that the rain and melted snow must have broken through a layer of semi-frozen soil nearer the surface than the 1 ft depth. Another rapid minor temperature change at the 4 ft depth is associated with the rain of 3–4 February.

At West Linton, Peebles-shire, the changes in March 1940 were in different directions at depths of 1 ft and 4 ft (see Figure 4). On the morning of the 7th the ground was frozen hard and the 1 ft temperature was just less than 32°F. The first rain on the 7th–8th was cold and had little effect on the temperature at 1 ft and only lowered the 4 ft temperature by 1°F temporarily. But the rain on the 9th–10th had an initial temperature of about 40°F (the air temperature ranged from 39°F to 44°F), and soon percolated to the 1 ft and 4 ft depths. The 1 ft temperature was raised almost immediately to 39°F. However, by the time the water reached the 4 ft depth its temperature had fallen to 37°F. Consequently, in this case, the 1 ft temperature rose rapidly by 7°F and the 4 ft temperature dropped rapidly by 3°F. It seems that at West Linton drainage

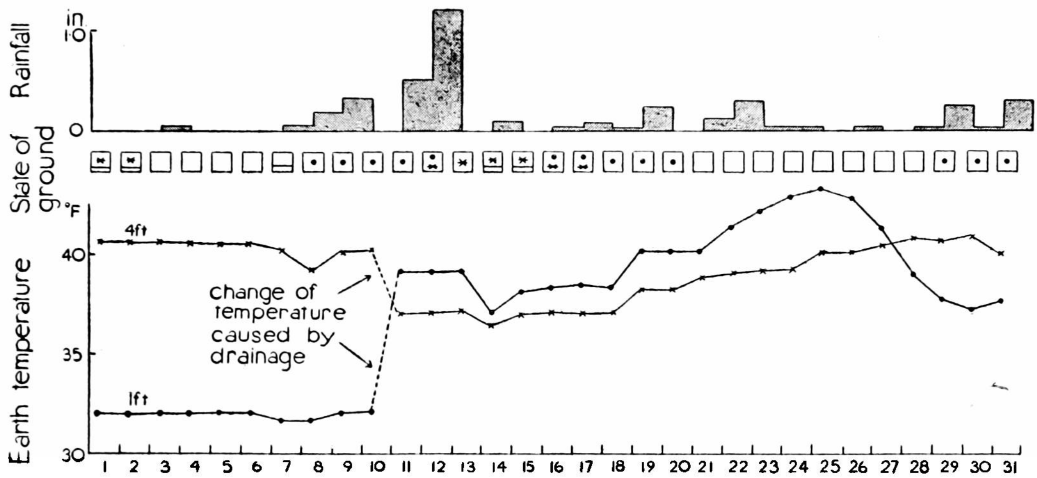


FIGURE 4—RAINFALL, STATE OF GROUND, AND EARTH TEMPERATURES, WEST LINTON, PEEBLES-SHIRE, MARCH 1940

The daily measurements of earth temperature are joined by straight lines.

through the soil was exceptionally rapid at all times, for cold rain and snow on the 12th–13th brought a temporary fall in temperature at both levels on the 14th, and warm rain on the 18th raised temperatures at both levels together on the 19th. The more usual time lag between 1 ft and 4 ft earth temperatures is shown towards the end of the month. The 1 ft earth temperature reached a peak on 25 March; the corresponding peak at a depth of 4 ft was not until 30 March, five days later, when the 1 ft earth temperature was actually at a minimum.

A recent example of a sudden change of earth temperature of over 5°F is shown in the thermogram from Wisley reproduced facing p. 208. Unlike the other examples this occurred in the summer (11 July 1959) and, being at the comparatively shallow depth of 1 ft, its occurrence was only observable by means of recording instruments. It is the only case so far recorded at Wisley since the thermograph was installed in 1956. The sudden drop in temperature was associated with a fall of 1·67 in. of rain during a heavy thunderstorm lasting from 2100 to 0430 G.M.T. during the night of 10–11 July. The observer described the rain as "torrential around 0200". The earth temperature at the 1 ft depth fell from 69·0°F to 63·8°F during a few minutes at about 0310 GMT, whilst the air temperature decreased by only 0·7°F from 62·2°F to 61·5°F between 0200 and 0400 GMT. It is clear therefore that the cooler rain (presumably at a temperature of about 62°F) was draining rapidly through the sandy soil which was previously dry—no measurable rain having fallen during the preceding eight days.

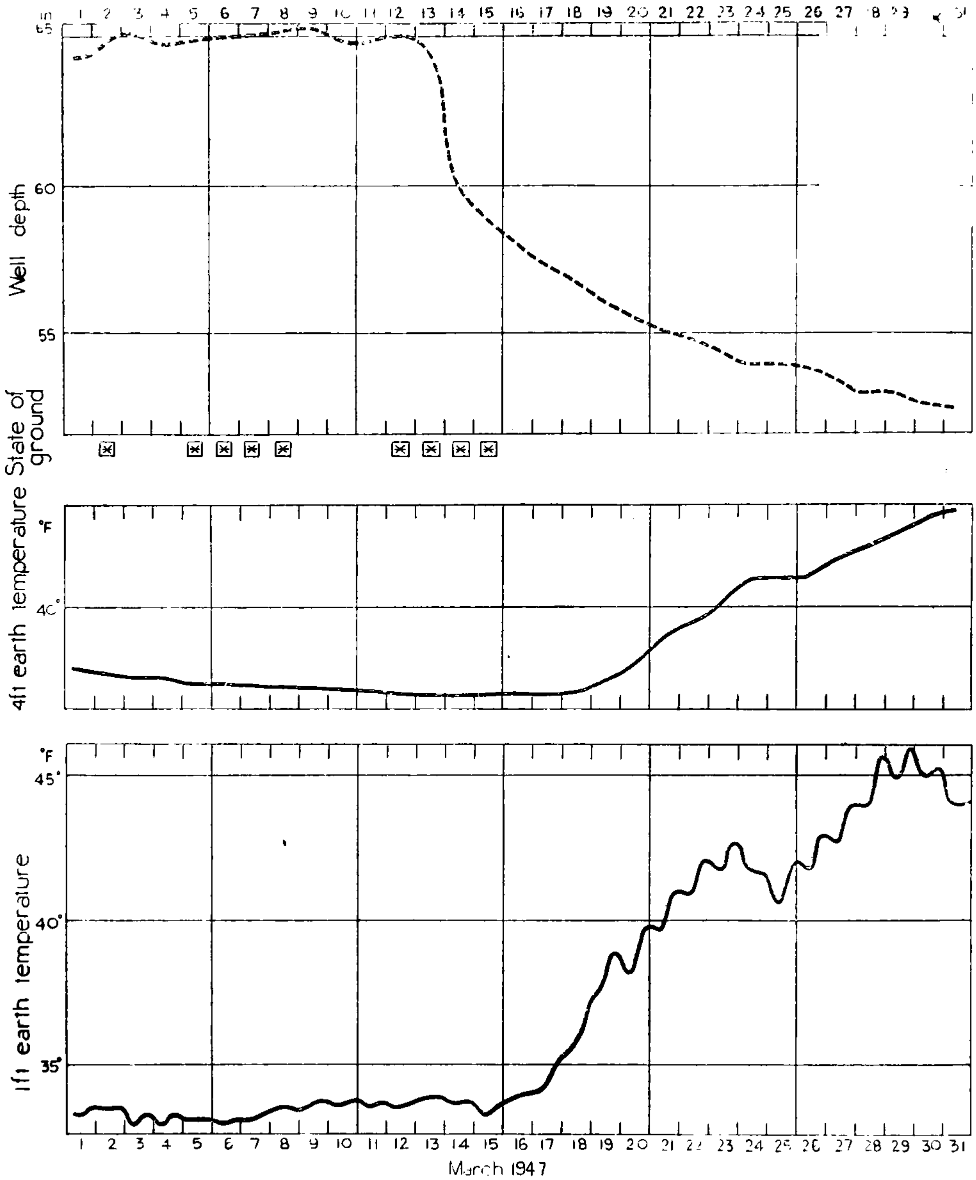


FIGURE 5—WELL DEPTH AND EARTH TEMPERATURES, BEDFORD ROAD PARK, SOUTHPORT, MARCH 1947

The state of ground was only recorded when snow was lying.

Necessary conditions for these sudden changes in earth temperature seem to be a light sandy soil (that is, large grains, well drained) and a large quantity of water from a thunderstorm, or a sudden thaw, usually caused by heavy rains, after a prolonged cold spell. It must be possible for the water to drain away from the lower soils beforehand and, in cold weather, the upper soil must be frozen so as to retain on the surface a sufficient quantity of snow or frozen water ready for release when the thaw comes.

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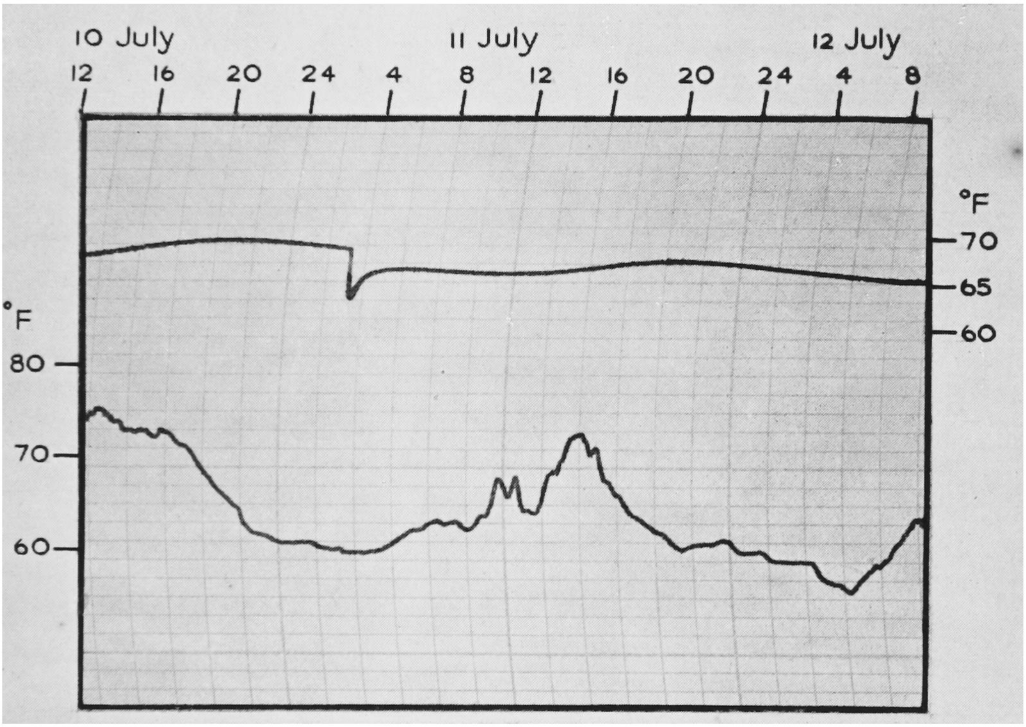


THERMOGRAM FROM WISLEY, 10–12 JULY 1959

The upper curve records the earth temperature at a depth of 1 ft; the lower curve records the air temperature at a height of 4 ft.

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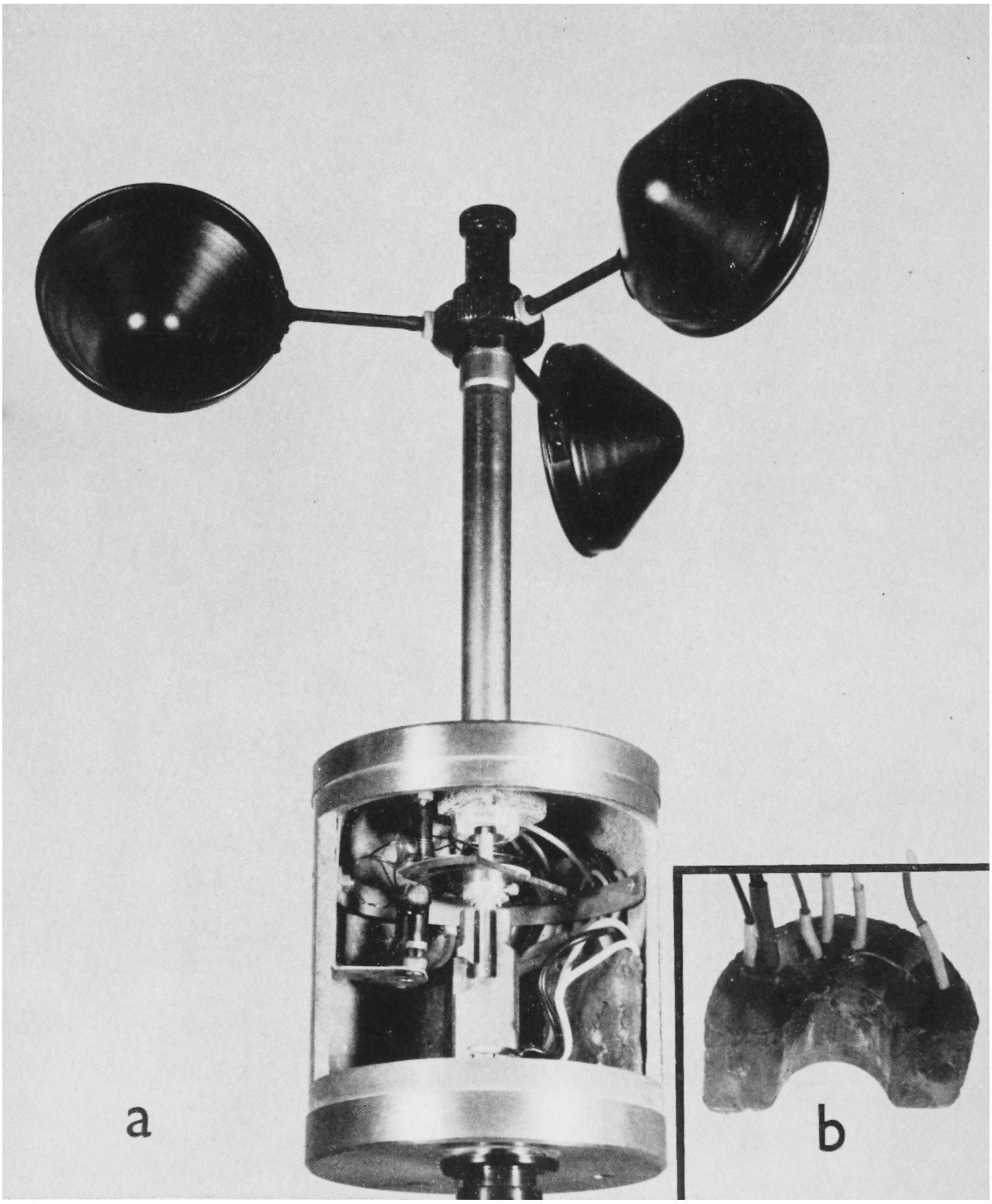


*CSIRO*

PLATE I—THE REDESIGNED ANEMOMETER WITH OUTER CASE REMOVED (*a*), WHICH USES THE POTTED TRANSISTOR CIRCUIT (*b*)

The anemometer is symmetrical about the axis of the cup rotor and its calibration is not influenced by its orientation with respect to the prevailing wind direction.

(see p. 213)

The necessity for previous drainage of water from the lower levels is shown by the record in Figure 5 from Bedford Road Park, Southport, during March 1947. The soil at Bedford Road Park is also sandy but the ground is level, and the drainage cannot be good; there was no sudden fall of temperature at 4 ft even though there was also a rise in the water-table, similar to that at Hesketh Park.

## ON THE PERFORMANCE OF SENSITIVE CUP ANEMOMETERS

By N. E. RIDER, B.Sc.

**Summary.**—Certain difficulties and possible sources of error associated with the use of sensitive cup anemometers (stores ref. met. 639) and more particularly with the electric contact variant of the same external configuration are outlined. Suggestions are made for a method of exposing these instruments, particularly in profile work, which will minimize error. A new method of anemometer construction which overcomes at least one of the sources of error and has other worthwhile advantages is described.

**Introduction.**—The sensitive cup anemometer which is a development of the original instrument described by Sheppard[1] is in widespread use, particularly when vertical profiles of mean wind speed are required. In the latter instance it is usual to mount the instruments on short horizontal side arms attached to a vertical mast. When only a few determinations are needed at relatively large height intervals it is possible to mount all the instruments on one side of the vertical mast. If wind speeds at height intervals of much less than 40 centimetres are sought this is no longer possible as the overall height of the instruments is about 25 centimetres. Close mounting of one above the other causes disturbance to the air flow. On such occasions it is normal practice to mount instruments at alternate levels 180° apart on each side of the mast. Examination of profile data obtained in this way suggested that more scatter was being obtained in the measurements than the likely errors in calibration of the instruments would lead us to expect. Field and wind-tunnel trials were then conducted to examine the cause of this scatter. A very brief description of these trials is given and this is followed by a suggested mode of exposure for an improved instrument which leads to better results.

**Field experiments.**—Six anemometers were mounted at heights up to two metres above a short grass surface. The vertical mast used was of steel having a circular cross-section of 2·5 centimetres diameter and a height of 4·5 metres. It was stayed by three thin wires from its top to points well removed from its base. Minimum interference from the mast supports was thus ensured. Figure 1(*a*) shows the height of exposure of instruments and their positions with respect to the wind direction and mast. Figure 1(*b*) shows the profile obtained from a 10-minute run. During this and the subsequent run shown in Figure 2 the anemometers were held in standard-length (about 25 centimetres) side arms so that the plastic cases containing the electric contact mechanisms which are offset with respect to the rotor spindles and their outer tubes were all facing the observer who was downwind of the mast. It is evident (Figure 1(*b*) ) that there was a systematic difference in the measured wind speeds according to the side of the mast on which the corresponding instruments were mounted. For the second run, illustrated in Figure 2 (*a*) and (*b*), the mast complete with side arms and anemometers was rotated through 180° without any interchange of the instruments. However, individual anemometers were rotated through 180° to maintain the orientation of the cases with respect to the wind direction. Instruments which read "low" in the first run read "high" in the second and vice versa. The two profiles show that with a reasonably constant wind direction there was again a systematic difference of the measurements according to the side of the mast on which the anemometers were exposed. The difference amounted to about three per cent. Such variations are not acceptable in profile work in which the vertical gradients of mean wind speed are usually required.

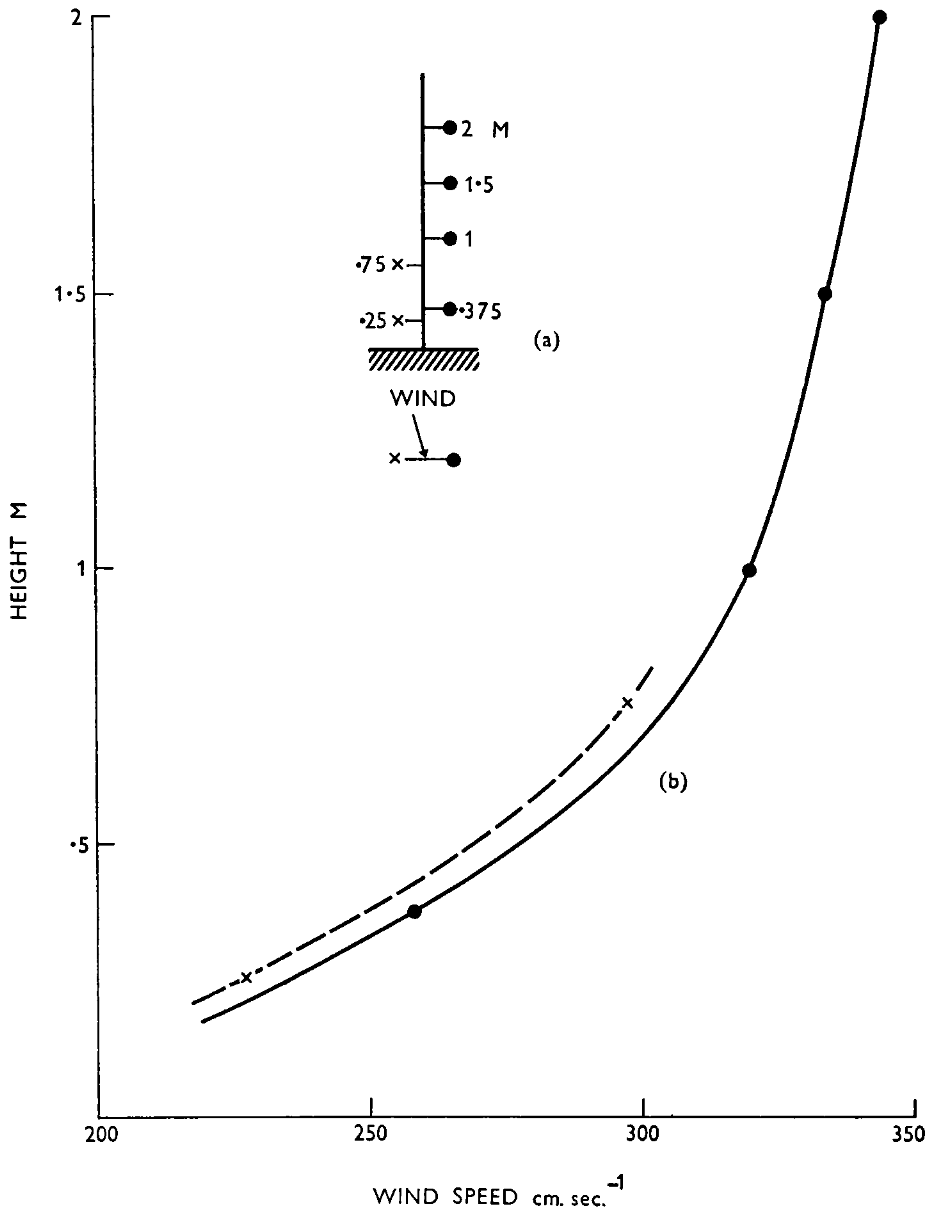


FIGURE I—ARRANGEMENT OF ANEMOMETERS (*a*), DURING 10 MIN. PROFILE DETERMINATION (*b*)

A further simple field experiment confirmed that the method of anemometer exposure exerts an appreciable influence on the results. An anemometer, A, was exposed at one metre above the ground on a standard side arm while a

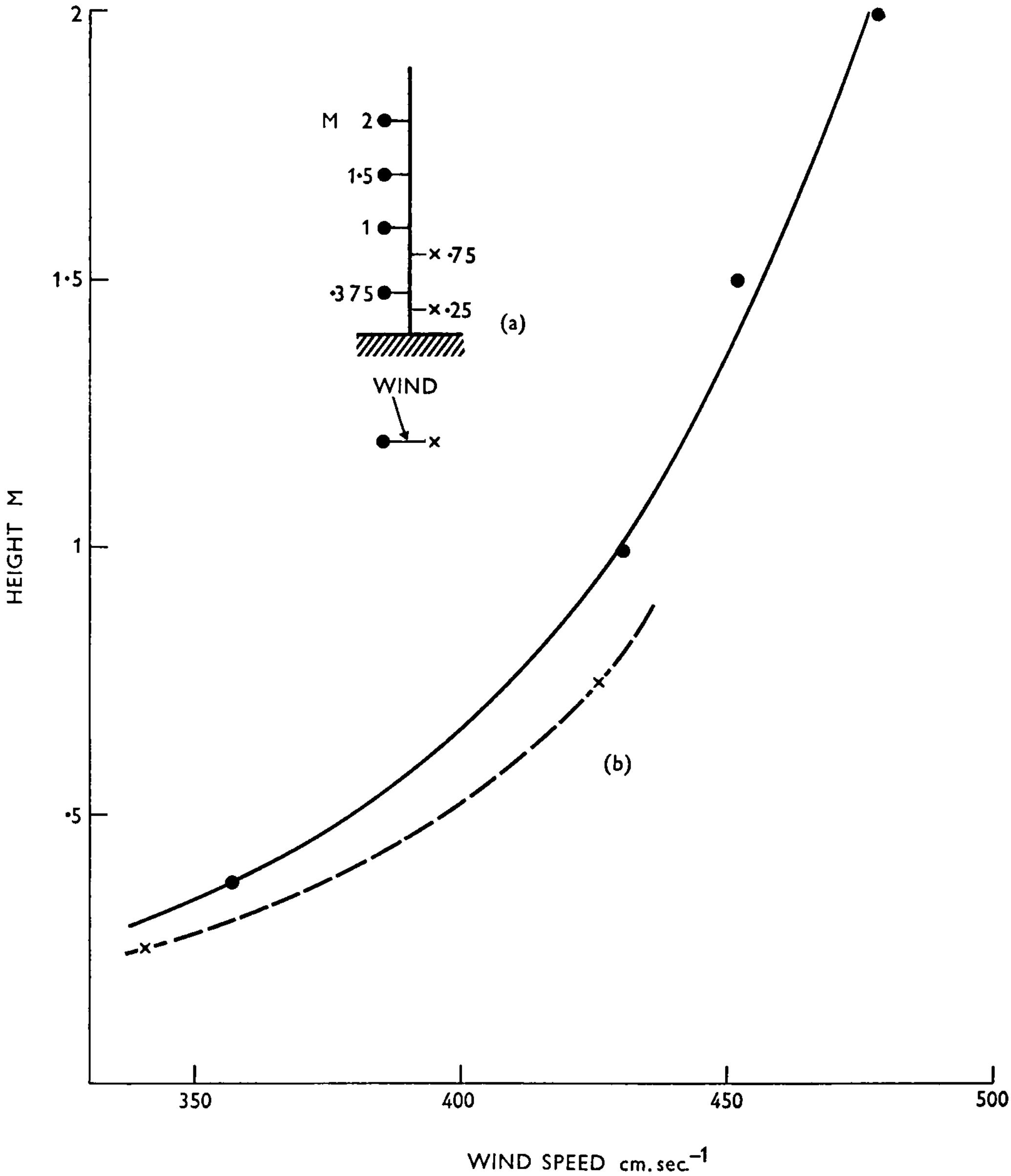


FIGURE 2—ARRANGEMENT OF ANEMOMETERS (*a*), DURING 10 MIN. PROFILE DETERMINATION (*b*)

second anemometer, B, was given a "free" exposure at the same height by mounting it on the top of a short mast about three metres across wind from the position occupied by A. Three 10-minute runs were then carried out in which the position of A with respect to its support was changed. In the first run A was to the right of its main supporting mast looking into the wind, in the second run it was directly in front of the mast, and in the third it was moved back to its original position. The results are set out in Table I. Here again we see the influence of mounting position on the indications of the anemometer. To sum up we can say that an anemometer exposed so that its cups are rotating in the direction of the wind at their closest point to the vertical supporting mast will give a higher indication than one exposed so that its cups are rotating against the wind at this point.

TABLE I—INFLUENCE OF ANEMOMETER INDICATION ON MOUNTING POSITION IN THREE 10-MINUTE RUNS

| Anemometer | Indicated wind speed ($cm\ sec^{-1}$) Run 1 | Run 2 | Run 3 |
|---|---|---|---|
| A ... ... ... ... ... | 473 | 403 | 416 |
| B ... ... ... ... ... | 467 | 422 | 407 |
| Difference ... ... ... ... | + 6 | −19 | + 9 |

**Wind tunnel experiments.**—To confirm the field results and to get a more precise evaluation of the effects of instrument exposure an anemometer was mounted in a wind tunnel on a standard-length side arm. The side arm could be rotated about a section of the mast as used in the field. The tunnel had a large working section. Its speed was known to be constant to one per cent across

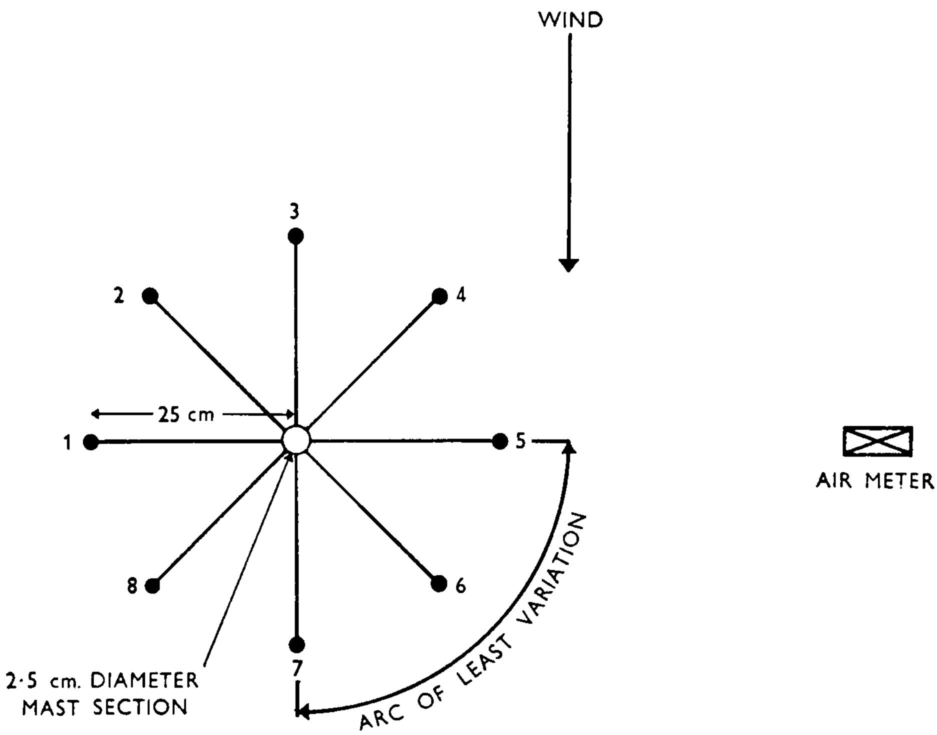


FIGURE 3—SEQUENCE OF POSITIONS OCCUPIED BY AN ANEMOMETER IN THE WIND TUNNEL DURING A SERIES OF 10 MIN. RUNS

The arc over which the anemometer indication showed the least variation is indicated.

this section and during the work was held as constant as possible around eight metres per second. An air meter (stores ref. met. 1) was employed in a fixed position to measure the actual speed during a series of 10-minute runs. Figure 3 shows the positions of the equipment and the various situations occupied by the anemometer and the results are given in Table II.

TABLE II—VARIATION OF ANEMOMETER INDICATION ACCORDING TO MOUNTING POSITION IN A WIND TUNNEL

| Position ... ... ... | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Air meter ($cm\ sec^{-1}$) per anemometer ($cm\ sec^{-1}$) | 1·028 | 1·009 | 1·008 | 1·026 | 1·000 | 0·996 | 1·002 | 0·995 |

*Photograph by A. Honeyman*

HOLE AND FURROWS PRODUCED BY A LIGHTNING STRIKE

(see p. 215)

*To face p.* 213]

*Photograph by A. Honeyman*

HOLE PRODUCED BY A LIGHTNING STRIKE

(see p. 215)

Here again we see the approximate three per cent overall variation as previously found in the field investigation. The 90° arc over which the variation in indication is smallest is shown in the figure. As any natural wind is not constant in direction these results show that it would be advisable to mount an anemometer to the right of the mast trailing 45° behind the normal to the expected wind direction. In this way the calibration would be least influenced by wind direction changes during the course of a run.

A further error of three per cent can arise in the use of these anemometers. When describing the field experiments it was stated that the orientation of the anemometer cases which contain the contacts or counting mechanisms were kept constant throughout. This was done as earlier it had been suspected that the calibration varied with this orientation. Confirmation was obtained in the wind tunnel. When the face of the instrument is upwind of the rotor shaft the indicated wind speed is three per cent higher than when it is facing downwind. The anemometers must therefore be used with the same orientation as that employed in their calibration.

**Reduction of error.**—There are two errors to eliminate. The first we will call the mounting error and the second the case orientation error. The first may be reduced and the second eliminated as will become apparent. The mounting error may be minimized by employing much longer side arms. This is not convenient as it is difficult to get a firm mounting when the length of these exceed about 40 centimetres. A firm mounting is essential since if the anemometer rotor shaft is allowed to wander from the vertical this in itself introduces calibration changes. A better solution is to calibrate the anemometer mounted in a side arm attached to a section of the mast with which it will be used. The side arm should be fixed so that it is in a position corresponding to position 6 of Figure 3. The direction of rotation of the anemometer rotor can be changed by rotating the individual cups through 180° in the vertical, and those anemometers to be used on alternate sides of the mast should be rotating in opposite directions. Two anemometers having opposite directions of rotation mounted in trailing positions (positions 6 and 8, Figure 3) and calibrated with these directions of rotations in these positions can be expected to yield good results in a natural wind. Complete elimination of the mounting error could be achieved by arranging the anemometer rotors at the desired height intervals so that they rotated about the axis of the main supporting mast. This would eliminate the use of side arms but unfortunately there are serious constructional difficulties associated with this scheme. The orientation error arises from the lack of symmetry of the plastic case about the rotor shaft. This can only be eliminated by a redesign of the complete instrument which has been satisfactorily achieved.

**The redesigned anemometer.**—Plate I shows the new instrument. The usual plastic case is replaced by a cylindrical brass casting which occupies the same vertical height as the former. The rotor shaft and its outer casing now passes co-axially through the casting so that the instrument has the same appearance from all sides. The rotor shaft outer casing is a tight push fit in the casting, to which it is fitted and pinned at the top and bottom bosses provided in the casting. After the shaft outer casing has been fitted to the casting it is removed and cut in two at the level occupied by the small pinion wheel normally fitted to the rotor shaft. About two centimetres of the outer casing at this level is removed and the pinion wheel discarded and replaced by a light tufnol plate which is attached to the rotor and rotates with it. This tufnol plate carries a small strip of Stolloy metal and a piece of copper at opposite ends of a diameter. The copper is provided to balance the rotating section of the instrument. The shaft outer casing is now refitted to the casting in its two sections. It is now obvious that the mechanical strength of the instrument is in the casting as the shaft casing is no longer continuous. In a recent paper McGregor[2] described the design of a transistor circuit, a slightly modified form of which is used in this instrument. Briefly, it consists of a transistor oscillator which is controlled by the inductance between two small coils, the inductance being determined by passing a Stolloy strip between the coils. The circuit controls the current passing through a relay coil and the relay contacts make every time the Stolloy strip passes between the coils. In the present instrument the circuit which contains three transistors and seven other small components (excluding the relay) is potted in resin so that it fits in the casting to which it is secured with screws. A circuit is shown in Plate I. The coils together with their formers and cores are attached to the casting so that the tufnol plate passes between them. The casting is closed with a thin brass cover plate and the whole is polished and lacquered on the outside. A light three-conductor cable leaves the casting via a small plug and socket. This connects an 18-volt d.c. supply and the relay. With a Siemens type H.96 E. relay the current drain in the "on" state is 12 milliamps and in the "off" state 2 milliamps, so that operation from one set of dry cells over several months is possible. Twelve of these instruments have been constructed and have given satisfactory operation over several weeks of continuous exposure. They have the following advantages over previous types:

(*a*) Calibration is not influenced by instrument orientation with respect to wind direction.

(*b*) Wind speed for stopping and starting is below 20 centimetres per second whereas 35 centimetres per second is a more typical figure for the usual electric contact type.

(*c*) There are no contacts to wear and possibly fail after long use.

(*d*) Variation in frictional drag such as occurs as a result of changes in contact spring pressure and in the degree of gear wheel meshing cannot take place and therefore the calibration should be very constant in time.

(*e*) Calibration of the twelve anemometers so far produced shows that all are well matched. The calibration is also rather more linear than is the case for previous types.

In addition to this the new instruments have another characteristic which can be an advantage in some applications and a disadvantage in others. Since each revolution of the rotor provides an operation of the relay the count rate in a wind speed of 10 metres per second is in the region of 400 counts per minute. This is the limit for simple electromagnetic counters so that high-speed counters would be required for wind speeds in excess of the figure quoted. However, it would be a simple matter to incorporate a scale-of-two circuit in the instrument. On the other hand the high speed of counting for a given wind speed has the advantages in certain uses that one count represents a small run of wind.

**Conclusion.**—It has been shown that the use of sensitive cup anemometers for the accurate determination of mean wind speeds needs care in instrument calibration and in subsequent use in the field. A new design of anemometer has been described which compares very favourably in performance with previous types. It has given good service over lengthy exposures and has the great merit that its calibration is not affected by changes in wind direction.

The field and wind tunnel experiments described here were carried out at the Meteorological Offices at Cambridge and Harrow respectively. The new anemometer was designed and constructed in the Division of Plant Industry, Commonwealth Scientific and Industrial Research Organization, Canberra, A.C.T., Australia.

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## NOTES AND NEWS

### Lightning strike furrows

We are indebted to Dr. A. Honeyman, voluntary climatological observer at Fort William, for the photographs between pp. 212–213 of the hole and furrows produced by a lightning strike and for the information in this note.

The flash struck the ground above Auchnadaul Farm, about midway between Fort William and Spear Bridge, Inverness-shire, during a violent thunderstorm on the afternoon of 28 April 1959. The strike was on rough moorland near a boundary fence of vertical wooden posts 3 ft. 9 in. high, supporting six horizontal wires. In the first photograph two deep furrows are seen to extend from a post, which had been split, to a hole. This hole was 7 ft by 4 ft across and 4 to 5 ft deep. Smaller furrow marks ran further on from the hole for several feet to some bushes on the edge of a burn. Muddy turfs and stones from the hole were hurled to distances of 10 yards uphill and 15 yards downhill. The staples holding the wires into the split post had disappeared and the wood was deeply charred both where the staples had been and at the base of the post. Where the hole had been made, a 2-in. metal water-pipe carrying water from the burn had been severed and an underground drain-pipe smashed. There were no witnesses of the flash.

## OFFICIAL PUBLICATION

The following publication has recently been issued:

SCIENTIFIC PAPER

No. 1—*Airborne measurements of the latitudinal variation of frost-point, temperature and wind.* By N. C. Helliwell, B.Sc.

The results of six flights in July and August 1956 and three flights in March 1957 between 40°N and 68°N are presented together with diagrams showing the variation of frost-point, temperature and wind. Little latitudinal variation of frost-point at 46,000 feet (140 millibars) was found, and generally frost-points in the lower stratosphere showed little variation except in the region of upper fronts or jet streams. Some of the flights showed evidence of frontal zones in the lower stratosphere. Some aspects of the clear-air turbulence associated with jet streams are discussed and the location of turbulence with respect to the jet-stream maximum and the tropopause is presented in a diagram using the data obtained on these flights.

*Air pollution control*, by W. Faith. 9½ in. × 6 in., pp. vii + 259, *illus.*, Chapman & Hall Ltd., 37 Essex Street, London, W.C.2, 1959. Price: £3 8*s*.

The author of this book, Dr. Faith, is a well known authority on air pollution matters and one must commend his initiative in providing an elementary and mainly descriptive account of the causes and effects of air pollution, of its cure and control and of the principles leading to protective legislation. Such a book, written for non-specialist and indeed non-technical people, has long been needed because air pollution is a subject in which progress depends on a vast co-operative effort not only from a wide variety of professional interests but also from groups of workers who, though lacking specialized knowledge, are giving valuable help in a hundred and one different ways.

The introductory chapter is a survey of air pollution problems with details of the more tragic episodes such as occurred in London, in Donora and in the Meuse Valley, and contains also interesting accounts of the damage that can be caused by air pollution to health, vegetation and buildings. The nuisance factor, which can be of major importance even when actual damage cannot readily be proved, is well covered.

Useful chapters then follow on meteorology, on various fuels and their contributions to smoke, on dusts, fumes and mists, on gaseous pollutants from domestic and industrial sources, on vehicle exhausts, and on the complex and not easily defined problem of offensive smells. In these chapters, which are by no means long, the author has managed to include a wealth of detail supported by figures, diagrams and tables. Finally, there are chapters on the organization of air pollution surveys and on the legal aspects. To each chapter is appended a fairly comprehensive bibliography.

Judged on its main objective—a simple, explanatory presentation of air pollution—the book is a valuable and necessary addition to the literature. The specialist will also find much that is useful, not least the exhaustive set of conversion factors in the Appendix, but he will also raise his eyebrows at some statements in the text. Where the author has gone outside his own field the treatment is less assured and brevity has not been gained without some loss of strict accuracy. However, the book can be well recommended as a general introduction to air pollution and its control, and as preparatory reading to more authoritative books such as the *Air pollution handbook* and the standard work by Meetham.

P. J. MEADE

*Scientific papers, Vol. 2: Meteorology, oceanography and turbulent flow*, by G. I. Taylor. Edited by G. K. Batchelor, 10 in. × 7 in., pp. x + 515, *illus.*, Cambridge University Press, 1960. Price: £3 15*s*.

This is the second part to be published of Sir Geoffrey Taylor's contributions to science; it deals with his work in meteorology, oceanography and the basic concepts of turbulent motion. On glancing through this large volume, two impressions are immediate: first, how much of Taylor's early work in meteorology has now become an accepted part of the science of the atmosphere and second, how little the contributions have "dated", despite the vast amount of new information that has become available in the last thirty or forty years.

The volume begins, appropriately, with the great memoir of 1915, "Eddy motion in the atmosphere". Written when "G. I." was still in his twenties, this paper, which in many ways began the modern study of atmospheric diffusion, is still a delight to read. It is an astonishingly mature work for a young man, and displays the cunning blend of physical insight and mathematical skill which today everyone recognizes as characteristic of the writer.

This is a treacherous volume to have lying on a desk cumbered with official files, for it tempts one to browse. In these pages it is easy to recapture the excitement of reading meteorology for the first time. Here, for instance, is the 1917 paper on the formation of mist and fog with the first fog-prediction diagram, followed by two equally celebrated studies on atmospheric turbulence, the first of which introduced the bi-directional vane and revealed much about the structure of eddies near the ground, while the second contains the well known analysis of the diurnal variations of temperature and wind. A few pages on is another fundamental contribution, the paper of 1921 entitled "Diffusion by continuous movements" in which Taylor, by generalizing the problem of the drunkard's walk, introduced into fluid mechanics the concept of Lagrangian correlation. At the time of publication this study excited little interest among theoretical physicists, possibly because it was published in a journal devoted to pure mathematics, but more probably because the ideas were so novel. Today, it is recognized as one of the foundation stones of statistical hydrodynamics. The progress of gravity waves around the world (a study suggested by observations following the Krakatoa explosion), the behaviour of tides in the Irish Sea, the distribution of salinity and momentum at Schultz' Grund and in Randers Fjord —all are grist for the mill of this remarkable man who, in versatility and insight, recalls Kelvin and Rayleigh and other giants of bygone days.

The greater part of this volume is taken up with Taylor's basic contributions to the theory of turbulent motion. In 1935 and 1936 came the five great papers which continued the study of 1921 and created the statistical theory of turbulence. Other papers deal with flow in pipes and wind tunnels and the collection closes with the 1956 paper on the mechanics of the convectional jet, which has applications in many important problems of atmospheric pollution.

In this volume there are 45 separate papers. It is therefore impossible, in a short review, to deal with them adequately. Nearly every one represents, in differing degree, a contribution to science which has inspired others to follow and yet, according to the publishers' notice, this is but the first of three volumes to be devoted mostly to Taylor's work in the mechanics of fluids. Even in this limited field such an output is a tremendous achievement, almost without parallel in the history of the subject, and there are still the contributions to other branches of physics to be reckoned.

Throughout the whole of this work there glows the personality of one who is not only one of the greatest of applied mathematicians of all time but also a kindly approachable man, a great leader of research who has made Cambridge a Mecca for young men who aspire to follow his footsteps. Meteorology is especially fortunate in that Sir Geoffrey found in the atmosphere a source of inspiration in his early days.

It is perhaps unnecessary, but pleasant, to add that the printing and layout generally are a credit to the Cambridge University Press.

O. G. SUTTON

*Veröffentlichungen des Instituts für Agrarmeteorologie der Karl-Marx-Universität, Leipzig, Band 1, Heft 4. Untersuchungen über den Wärmehaushalt von Pflanzen in Verbindung mit phänometrischen Messungen*, by Fritz Pfeifer. 9 in. × 6 in., pp. 179–247, *illus.*, Akademische Verlagsgesellschaft Geest und Portig K.-G., Leipzig, 1959. Price: *D.M.* 6.30.

This publication deals with a subject which has not, to the reviewer's knowledge, been investigated in this country, namely, a detailed study of the relation between the heat balance of plants in relation to their growth and development. The author's opening paragraphs suggest that this topic has probably been neglected in Germany also, for he implies that previous work has been mainly limited to the search for statistical relationships between crop yields and one or more climatic elements. Undoubtedly the author breaks new ground in his approach to the problem, for he has used the methods of physics, biology, and meteorology in his attempt to unravel the complex relationship between weather and plant growth.

The section on the heat exchange of plants and plant parts gives details of the instruments used. Many measurements are given of temperatures in various parts of a leaf in relation to radiation and wind speed and direction. The futility of attempting to define the temperature of a leaf as a single numerical value is apparent in many of the diagrams.

Measurements of transpiration in relation to radiation intensity and wind speed suggest that when radiation is 1·2 gm cal $cm^{-2}$ $min^{-1}$, transpiration decreases by some 60 per cent as the wind speed increases from 0·5–3·0 m $sec^{-1}$, a result which appears surprising until it is realized that the increased ventilation no doubt leads to a reduction of leaf temperature. The author emphasizes that in questions of heat exchange, attention must be paid to parts of plants, whole plants and plant stands. Other sections of the paper describe the phenometric methods used, the morphology of growth curves and the influences of weather on plant growth.

The main impression gained from reading the paper is one of complexity without any clear results. This is probably inevitable. The author agrees that his work can be considered as only a limited contribution to the subject and that a large number of examples of such relationships must be studied to obtain a comprehensive picture.

There is unfortunately no summary in English and the German summary is not very informative, surprisingly, in view of its length. Anyone whose German is sufficient to translate the legends to the diagrams would be well repaid by a close look at this paper.

W. H. HOGG

## HONOUR

The following award was announced in the Birthday Honours' List on 11 June 1960:

O.B.E.

Mr. F. H. Dight, lately Chief Meteorological Officer, Headquarters, Coastal Command, Royal Air Force.

## OBITUARIES

*Mr. Herbert Donald Hoyle, B.Sc.*—It is with deep regret that we record the sudden death at Bari of Mr. H. D. Hoyle on 19 May 1960, whilst on his way back to the United Kingdom.

Mr. Hoyle or "Don" as he was usually called, was well known to and extremely popular with a large proportion of the Office staff. His pleasant easy manner and genial nature, together with his ability to be at ease in any society, made him many friends in all walks of life. He had many and varied interests, but derived his greatest pleasure from his love of music, for he was a first class pianist of both classical and popular music. He enjoyed life to the full.

Don Hoyle was born on 13 February 1920, and entered the Office as a Technical Assistant III in August 1939 just prior to the outbreak of war. He spent the first three years of his career gaining experience at stations co-operating with Army units, notably Aberporth and Shoeburyness. In April 1943 shortly after promotion to Assistant II he was mobilized in the Royal Air Force Volunteer Reserve with the rank of Pilot Officer. His work was now concerned with the briefing of crews for the Bomber offensive. At the conclusion of the European hostilities he was posted to the South-East Asia Command, where he was promoted to Flight Lieutenant. He remained in the Far East until his demobilization in 1947.

He was established as an Experimental Officer and in 1948 he was posted as an instructor to the Training School, where he was to remain, apart from short periods of temporary duty, for the next five years. During the Festival of Britain, Mr. Hoyle was attached to the Meteorological Office Unit in the Dome of Discovery, and did much to ensure the popularity of the exhibits with the public. Throughout this period he was studying hard in his spare time and in 1953 he obtained his B.Sc. in mathematics at London University. At the end of the same year he was promoted to Senior Scientific Officer and after a short period at Dunstable he was posted to Harrow in the Climatological Research Division.

In 1957 he was seconded to the World Meteorological Organization and appointed as a climatological expert to the Technical Assistance Mission in Iran. His high standard of technical knowledge as well as his fine personal qualities enabled him to accomplish a large amount of work in a relatively short time, and did much to make the Mission a success.

A career such as this is difficult to summarize adequately for each high-light seems to be eclipsed by the next. Don Hoyle's life held the promise of a very bright future, it seems very sad that this future was so suddenly denied him. All who worked with him, both in the Meteorological Office and World Meteorological Organization, will wish to join us in extending our deepest sympathy to his mother and brother in their great loss.

C.H.H.

*Mr. Percival Lancelot Seller.*—It is with deep regret that we learn of the death on 19 June of Mr. P. L. Seller, Experimental Officer, at the age of fifty-six. He joined the Office in July 1935 as an Observer and was posted to Shoeburyness where he remained for seven years. In 1942 he was posted to an aviation outstation and he served successively at a number of such stations until 1957 when he was transferred to the Assistant Directorate for Military Services in which he was serving at the time of his death. He is survived by a widow and two daughters to whom the sympathy of all who knew him is extended.

## METEOROLOGICAL OFFICE NEWS

**Retirement.**—The Director-General records his appreciation of the services of: *Mr. A. M. MacLeod*, Senior Experimental Officer, who retired on 30 June 1960. He joined the Office in April 1939 as an Assistant II after earlier service in the Department of Scientific Research of the Admiralty. Apart from a period of two years between 1947 and 1949 at Eskdalemuir Observatory, the whole of his service in the Office was spent at aviation outstations including tours of duty overseas in the Middle East, Iraq and India. At the time of his retirement he was serving at Mildenhall.

**Sports Activities.**—The Annual Sports Meeting organized by the Harrow Social and Sports Committee was held on the evening of 22 June at the Headstone Manor Ground. Events were open to all members of the Meteorological Office and there were many entries. Four new records were established for these sports. They were:

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| Long Jump, Men | Distance 19 ft 0 in. | B. W. Drummond, M.O.3, Harrow |
| 220 yd, Men | Time 25.0 sec | B. W. Drummond, M.O.3, Harrow |
| Long Jump, Ladies | Distance 13 ft 8 in. | Mrs. M. Lane, M.O.13, Harrow |
| 4 × 110 yd Relay, Men | Time 48.6 sec | M.O.3, Harrow |

The high jump record of 5 ft 3 in. was equalled by G. Gaye, M.O.16, Harrow.

The four cups donated last year by the Dunstable Social and Sports Committee were won by the following:

| | |
|---|---|
| Tug of War | London Airport |
| 4 × 110 yd Relay, Men | M.O.3, Harrow |
| 4 × 110 yd Relay, Ladies | M.O.13, Harrow |

Division with most first places in all events: M.O.3, Harrow.

Four events (100 yd, 440 yd, one mile and Ladies' 100 yd) were Meteorological Office Championships for which medals were awarded by the Meteorological Office Social and Sports Committee.

There was again a fine warm evening for the meeting which was attended by visitors from Dunstable, London Airport, Victory House and other nearby offices. The prizes were presented by Mrs. R. H. Clements.