CHAPTER 8

TEMPERATURE AND HUMIDITY

8.1. TEMPERATURE SCALES

The Celsius scale of temperature has been adopted by the World Meteorological Organization and it is now used by the Meteorological Office. It is replacing the Fahrenheit scale for everyday use in the United Kingdom.

Celsius temperature, t, is defined in terms of the Kelvin scale by:

$$t = T - T_0$$

where T is the temperature in kelvins (K) and $T_0 = 273{\cdot}15$ K. The kelvin is the International System (SI) unit of thermodynamic temperature and is defined as the fraction 1/273·16 of the temperature of the triple point of water.

The practical realization of any temperature scale depends on the acceptance of certain universally defined 'fixed points'. For the Celsius scale it has been internationally agreed that the triple point of water (0·01 °C) and the boiling point of water at a standard pressure of 1013·25 mb (100 °C) shall be two such 'fixed points'. On such a scale the freezing point of water is 0 °C.

8.2. THERMOMETRY

8.2.1. Thermometers. The most familiar form of thermometer is the ordinary sheathed pattern in which the temperature is indicated by the position of the end of the liquid column with reference to a scale of degrees engraved on the stem (see Figure 9A). In the United Kingdom mercury is generally used, except for minimum thermometers in which ethanol (ethyl alcohol) is used.

8.2.1.1. *Accuracy.* All thermometers used by the Meteorological Office for measuring dry-bulb and wet-bulb temperatures were at one time certified by the National Physical Laboratory (NPL) and the Meteorological Office certified the accuracy of all other thermometers. A certificate was issued by NPL giving the corrections to be applied at different points on the temperature scale. The Meteorological Office now exercises strict quality-control during the acceptance of thermometers which renders the application of individual scale corrections unnecessary for many meteorological purposes: for example, the measurement of air temperatures with ordinary sheathed thermometers in naturally ventilated screens, the measurement of maximum and minimum temperatures, and ground surface and soil temperatures. Scale corrections are still seen as necessary for inspectors' thermometers, for the thermometers used in aspirated psychrometers, and when more than usual accuracy is required; in these cases a certificate showing the scale correction is issued with each thermometer, as appropriate.

Ordinary sheathed thermometers, for which no Meteorological Office certificates are issued, are divided into two categories, A and B, by the Meteorological Office Test Laboratory. For easy identification, category A

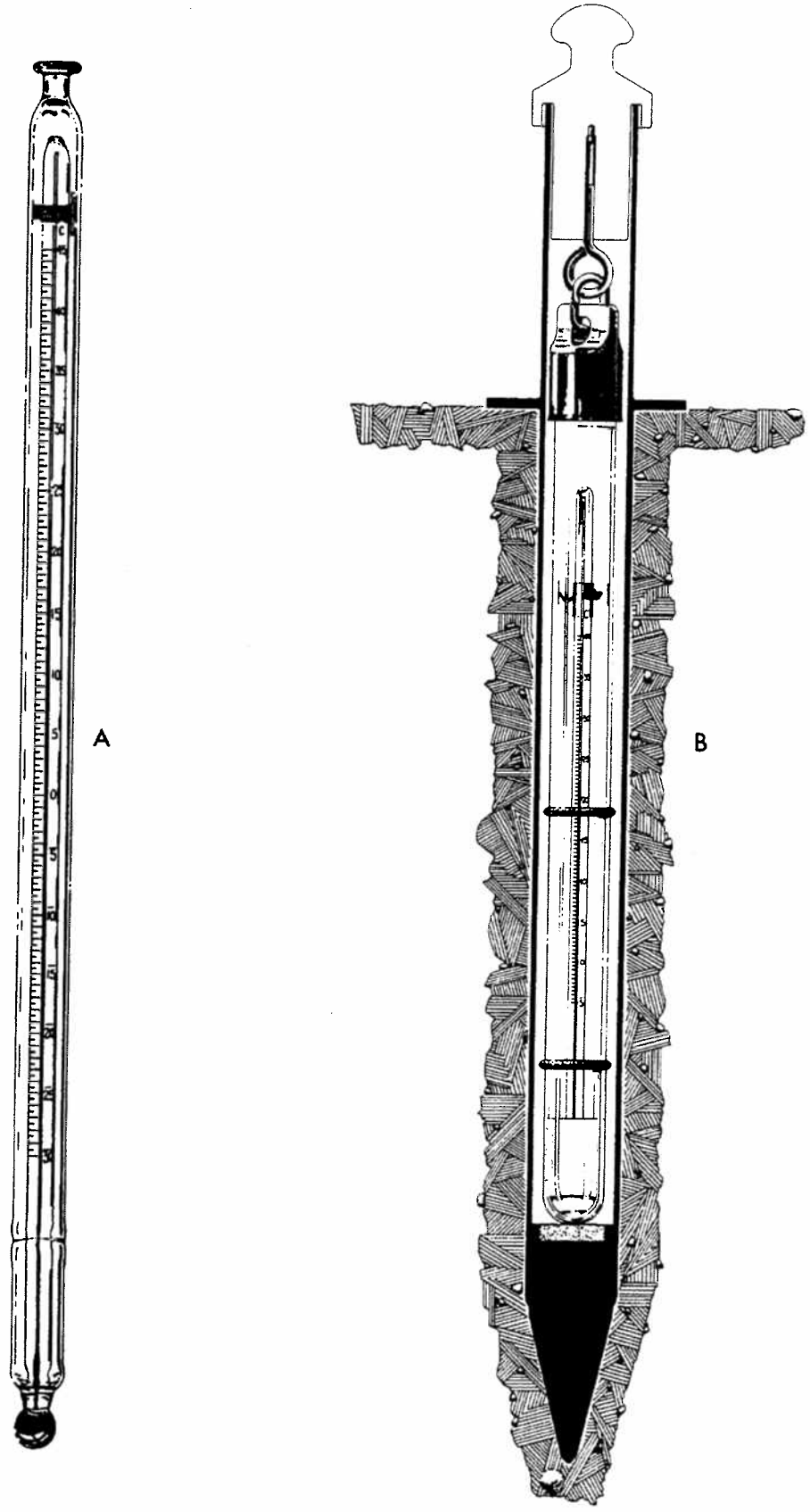

Figure 9. Standard types of thermometers

A Sheathed-pattern dry-bulb or wet-bulb thermometer

B 30 cm soil thermometer and steel tube, usually installed under a grass-covered surface

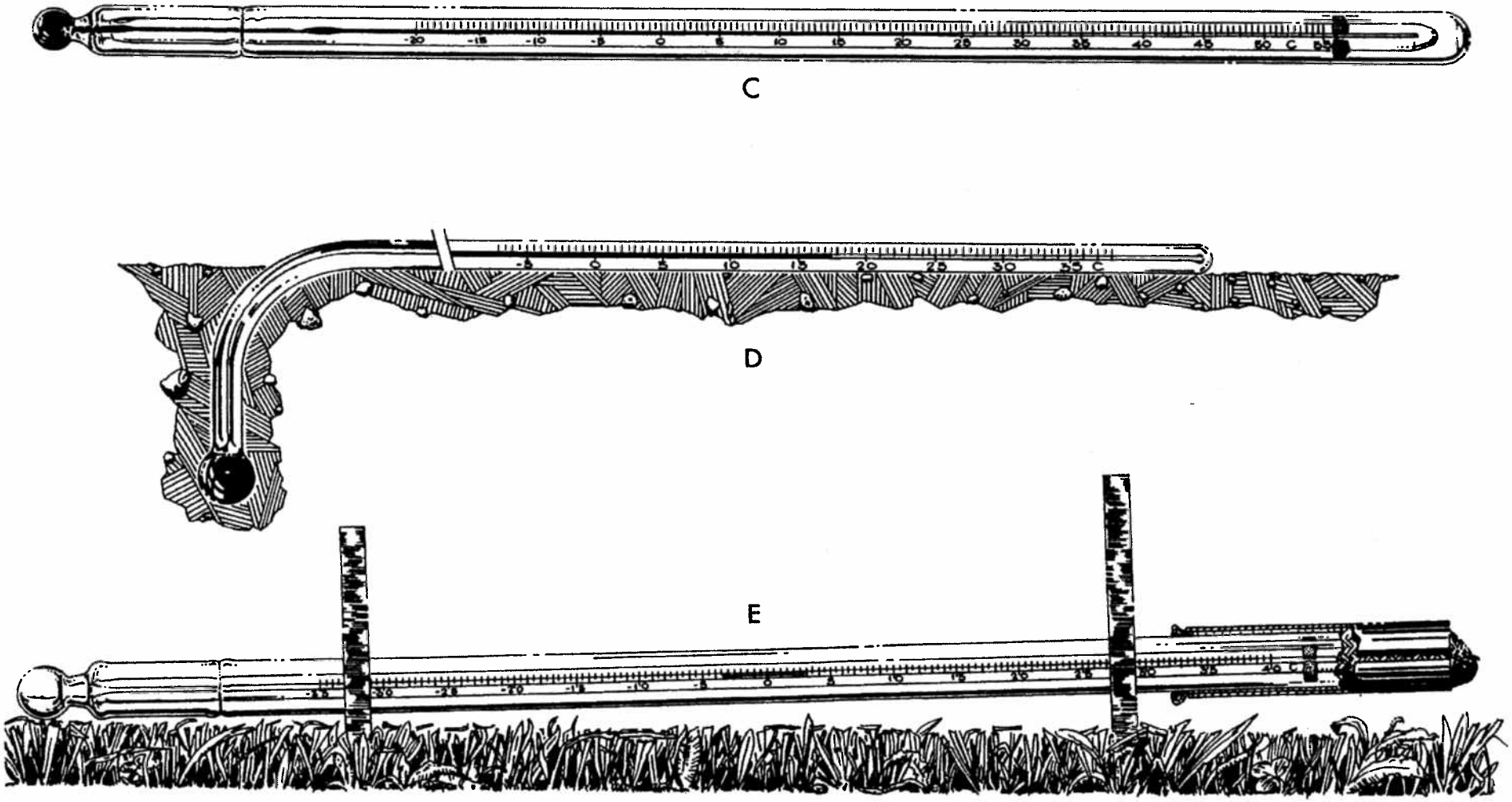

Figure 9. Standard types of thermometers (*continued*)

C Sheathed-pattern maximum thermometer

D Soil thermometer, installed in bare soil

E Sheathed-pattern minimum thermometer (illustrated as exposed over grass)

thermometers will be marked with a red paint on the top button and category B will be left unmarked. Any pair of these thermometers in the same category may be used for measuring dry-bulb and wet-bulb temperatures. Category A thermometers will normally be used at all Meteorological Office stations, all climatological stations and all auxiliary stations which render climatological returns and/or full synoptic reports. Category B thermometers will be used at all other auxiliary stations.

As part of the station inspection, the visiting inspector will check all thermometers, both those in use and those held as spares. Thermometers are compared with each other and with an inspector's thermometer in a bucket of water; the water should be at or near ambient temperature but not more than 20 °C and should be well stirred. Any thermometers whose readings differ from the inspector's thermometer by more than the specified tolerances will be reported to the appropriate authority for the necessary action to be taken; normally they will be withdrawn from use.

Maximum and minimum thermometers are difficult to check. Their readings should be noted before they are removed from the screen and the maximum thermometer should be reset. They may then be compared with an inspector's thermometer in a bucket of water (slightly warmer than the temperature to which the maximum thermometer was reset), as described in the preceding paragraph. The thermometers should be dried and reset to their original readings on being returned to the screen. As these types of thermometer are designed to be used in a near-horizontal position, this method of testing does not always give conclusive results. The observer should therefore check that the maximum and minimum thermometers agree with the dry-bulb thermometer when the former have been reset in the sahde and replaced in the screen.

8.2.1.2. *Application of corrections.* As indicated in 8.2.1.1, certificates are issued for certain thermometers, giving statements of the correction to be applied at different points on the scale.

A plus correction means that the stated correction is to be added to the observed reading; a minus correction means that the stated correction is to be subtracted from the observed reading. The errors arise mainly from variations in the bore of the tube, and it may be assumed that there are no sudden discontinuities. In order, therefore, to convert the given corrections (which are only given at a few well-spaced points) into a correction table for everyday use, the observer should first make a rough graph of the corrections given on the certificate and then read off the ranges over which the corrections apply.

Example: the certificate for thermometer No. Met.O. 12345/78 gives the following corrections:

at −30·0 °C	−0·2 °C	at 10·0 °C	0·0 °C
at −20·0 °C	−0·1 °C	at 20·0 °C	+0·1 °C
at −10·0 °C	0·0 °C	at 30·0 °C	0·0 °C
at 0·0 °C	0·0 °C		

These values were graphed and the following table was prepared:

−25·1 °C or below	subtract 0·2 °C
−25·0 °C to −15·1 °C	subtract 0·1 °C
−15·0 °C to 15·0 °C	no correction
15·1 °C to 25·0 °C	add 0·1 °C
25·1 °C to 30·0 °C	no correction.

On those occasions requiring the additional accuracy of a certified thermometer, the corrections should be applied before the readings are entered in Registers or other form of record.

8.2.1.3. *Precautions in reading thermometers.* The thermometers in the screen are to be read carefully, but quickly, so that the screen door is open for the shortest possible time and changes in temperature due to the presence of the observer are kept to a minimum. To avoid errors of parallax, the observer must read the thermometer in such a way that the straight line from his eye to the end of the liquid column (or index in the case of a minimum thermometer) is at right angles to the thermometer stem. When reading a thermometer the observer must first estimate the tenths of a degree, then note the whole degrees, and enter the temperature in the appropriate space on the observation pad. After all the necessary temperatures in the screen have been noted, a second look should be taken at the thermometers in turn in order to check that the tens and unit figures are correct.

It the thermometers are read at night a low-wattage lamp in waterproof housing may be provided well clear of the screen, perhaps fixed to the enclosure fencing. Alternatively a battery-operated torch may be used. Mains lamps must not be used inside the screen, neither must matches nor cigarette lighters be used as a source of illumination.

8.2.1.4. *Estimation to tenths of a degree.* The simplest case occurs when the end of the index or the column of liquid in the bore of the tube coincides exactly with a degree division such as 17, in which case the reading is recorded at 17·0. The decimal point and zero should always be inserted, to make it clear that the entry is not a 'rounded' value, and that the reading was in fact estimated in tenths of a degree. The next easiest case is that in which the reading is just half-way between two degree divisions giving the tenths figure as 5; thermometers calibrated in degrees Celsius have each half-degree division marked. The estimation of the intermediate tenths is a little more difficult, but four more values can be obtained from the following rules:

just over the exact degree	= ·1
just under the half degree	= ·4
just over the half degree	= ·6
just under the exact degree	= ·9

This leaves only ·2 and ·3, which are respectively a little under and a little over one-quarter, and ·7 and ·8 which are respectively a little under and a little over three-quarters. As a further aid, Figure 10 shows the exact appearance of each tenth of a degree from ·1 to ·9.

When the temperature falls below zero, the numerical value of the negative temperature increases towards the bulb end of the thermometer. With negative temperatures the diagram of tenths (Figure 10) needs to be figured in reverse: if the top graduation represents 0 °C, the readings shown in the diagram are (from left to right) −1·0, −·9, −·8 . . . −·1.

Nearly all observers have a personal bias in favour of certain particular numbers. One observer, for example, will hardly ever record ·1 or ·9, preferring ·0, ·2 or ·8; another will nearly always record ·7 in preference to ·6, or ·3 in preference to ·2. Each observer should be on his guard against such personal errors and should try to detect and correct them.

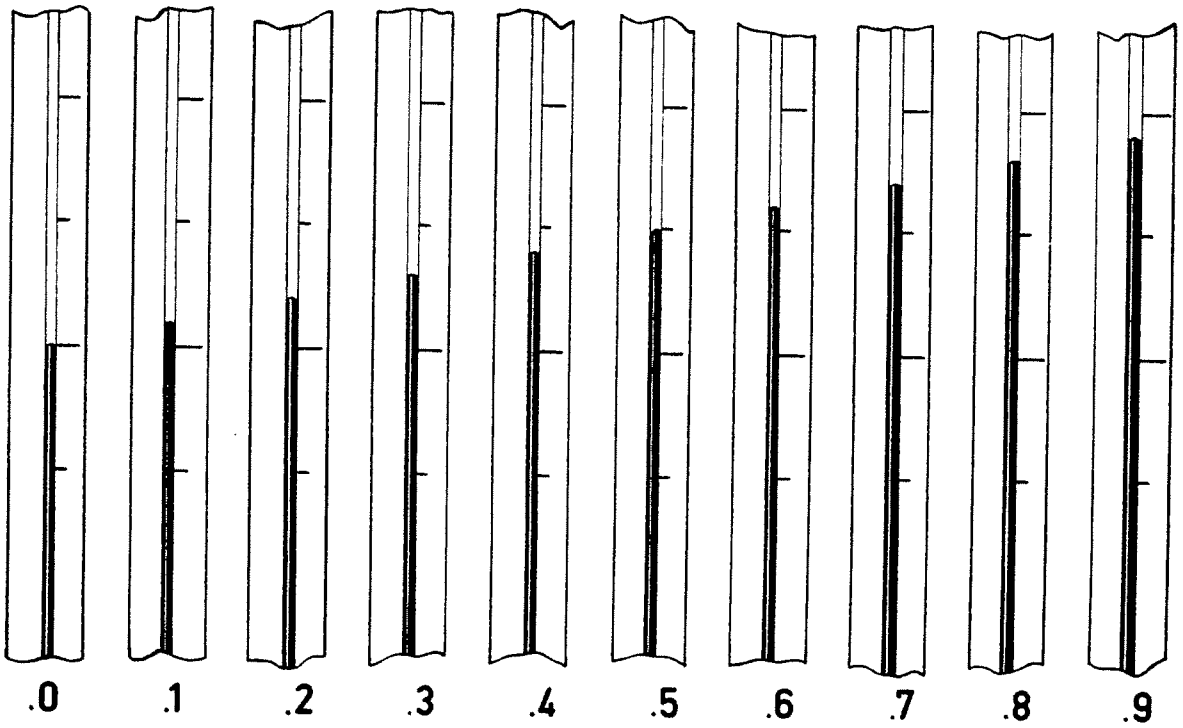

Figure 10. Estimating tenths of a degree

8.2.2. Electrical resistance thermometers. The principal advantage of electrical resistance thermometers is that they can be connected to an indicator or recorder up to 1 km away, thus enabling temperatures to be displayed from a remote site whose accessibility is limited or where the observer's other duties limit the frequency with which the screen may be visited. The thermometers contain a small coil of platinum wire whose resistance varies with temperature. In practice, over the relatively narrow band of surface meteorological temperatures, the relationship is approximately linear and no corrections for non-linearity are made. The resistance element is placed in a stainless-steel sheath, near to the tip, to form a robust thermometer with sensing characteristics similar to those of the ordinary thermometers.

Electrical resistance thermometers should be installed at the same height and location as the ordinary thermometers, care being taken to ensure that the steel sheath is not in accidental contact with the screen frame. Where both ordinary and resistance thermometers are in use in the same screen the resistance themometers are mounted behind the ordinary thermometers. A wet bulb is obtained by using a suitable tubular cotton wick. Procedures for use and care of electrical resistance thermometers to obtain wet- and dry-bulb temperatures are closely similar to those for ordinary thermometers and sections 8.4.1, 8.4.1.1. and 8.4.1.2 will provide adequate guidance.

8.2.2.1. *The Mk 5 temperature indicator.* In this temperature indicator (Plate XXIII) the thermometer inputs are switched by means of a rotary switch to a low-frequency a.c. bridge circuit which is balanced manually by the operator. The balance point is found by using a potentiometer linked to the dial and indicated by the simultaneous glowing of two neon indicator lamps. The dial has two pointers, in a similar fashion to a clock, with the smaller one pointing to tens of degrees and the larger to whole degrees. The dial is scaled with black (outer circle) figures for positive temperatures and

red (inner circle) figures in a mirror image for the negative temperatures. The scale divisions are three times more open than those on ordinary mercury-in-glass thermometers.

The letters shown on Plate XXIII indicate (A) the on/off switch, and (B) the thermometer selector switch (up to eight thermometers can be fitted). The electrical bridge is balanced by adjusting knob C, with the point of balance indicated by the neon lamps (D). The temperature is read directly in degrees Celsius from the dial integral with C. The switch E is used for calibration purposes. Up to eight sensors can be accepted.

8.2.2.2. *The Mk 1A digital temperature indicator.* The two parts, channel selector and display units, of a digital temperature indicator are shown in Plate XXIV. Up to eight sensors (described in 8.2.2) can be connected at any time, and readings from each one can be obtained by pressing the appropriate button on the selector unit. The temperature of the selected sensor, with either a positive or negative sign, is presented as an electronic digital display in degrees and tenths. In the event that all eight positions are not required to be connected to sensors, then a fixed resistance fitted to one of the spare channels can provide a ready form of calibration check in the form of a constant temperature reading.

8.2.2.3. *Routine thermometer checking.* When electrical resistance thermometers are used it is advisable to take a daily check reading against the mercury thermometers, preferably at a time when the temperature is changing slowly. If possible, one observer should read the electrical thermometers at a predetermined time just before another observer opens the screen to read the mercury-in-glass thermometers. If only one observer is available, he should read the glass thermometers as quickly as possible after reading the electrical thermometers. The equipment should be considered suspect if the mean difference between the two dry bulbs or the two wet bulbs exceeds 0·15 °C. If any individual dry-bulb readings differ by more than 0·5 °C, or wet-bulb readings by 0·8 °C, then more frequent comparisons should be made to determine if the mean differences have moved outside the limits. If the wet-bulb readings do not agree, and wick lengths are correct, the wicks should be removed and the thermometers rechecked as dry bulbs.

8.2.2.4. *Field calibration of electrical resistance thermometers.* The Meteorological Office issues detailed instructions concerning the calibration of electrical resistance thermometers when first installed and on routine inspections.

8.2.3. Rounding temperatures to the nearest whole degree. When any instructions specify that a temperature reading is to be reported or recorded only to the nearest whole degree the procedure is as follows:

(*a*) Read the thermometer by estimation to the nearest tenth.

(*b*) Add or subtract any necessary correction (see 8.2.1.2).

(*c*) If the number of tenths in the corrected value is 4 or less, disregard the tenths figure; for example:

corrected values: 12·0, 5·1, 15·3, 26·4,
rounded values: 12, 5, 15, 26.

(*d*) If the number of tenths in the corrected value is 6, 7, 8 or 9, add 1 to the number of whole degrees; for example:

corrected values: 2·6, 5·7, 11·8, 18·9,
rounded vlaues: 3, 6, 12, 19.

(*e*) If the number of tenths in a corrected value is 5, 'throw to the odd', i.e. round off to the nearest odd whole number; for example:

corrected values: 6·5, 7·5, 8·5,
rounded values: 7, 7, 9.

The above conventions also apply when rounding negative temperatures, and to the readings from electrical resistance thermometers although, in this case, no estimation of the value of the tenths of a degree is required since this is either displayed or read directly and corrections to the readings are not required.

8.3. THERMOMETER SCREENS

Every effort must be made to ensure that all thermometers used for meteorological purposes are exposed in as near standard conditions as possible. Only when this has been achieved can any real comparison between temperatures be made. This extends to readings made either at the same place or at widely differing geographical locations.

8.3.1. Approved screens. The thermometers used to determine the air temperature, the humidity and the maximum and minimum air temperatures are exposed in an approved type of screen. These screens are designed to shield the thermometers from precipitation and radiation while, at the same time, allowing the free passage of air. This is achieved by constructing the screens with louvered sides and door, a double roof with an air space between the inner and outer components, and a floor consisting of three partially overlapping boards separated by an air space. The screen is mounted on a stand so that the bulbs of the dry- and wet-bulb thermometers (which are mounted vertically) are 1·25 m above ground which ideally should be covered by short grass. As a further measure of standardization all such screens are painted in white gloss so that as much radiation is reflected as possible. This paintwork should be maintained in good condition. Daily familiarity with a screen makes it comparatively easy to accept a slow deterioration in the condition of the paintwork but, if allowed to continue unchecked, such deterioration can eventually lead to doubts as to the validity of any temperature readings made in the screen, and rot in the woodwork.

There are two sizes of thermometer screen. The large one (Plate XXV) can hold two ordinary thermometers and maximum and minimum thermometers (also, where necessary, electrical resistance thermometers) and a bimetallic thermograph and a hair hygrograph (see Plate XXIV). The ordinary screen will not hold any autographic instruments.

Where siting difficulties do not permit the installation of either of these screens it may be possible to use a marine screen fixed so as to have an unimpeded circulation of air through it. Stands are not available for this type

of screen. Dry- and wet-bulb mercury thermometers and electrical resistance thermometers only can be used. The screen's notice 'Hang to windward' is a reminder when the screen is used aboard ship.

At mountain stations subject to heavy snowfall an arctic screen may be necessary.

8.3.2. Care of the screen. Thermometer screens should be brushed out frequently, special care being devoted to the spaces between the louvers where dirt is apt to accumulate. About once a month, or more often in industrial localities or at coastal stations after onshore winds, the screen should be given a good wash with soap and water, or detergent and water.

Cleaning operations are best carried out immediately after an observation hour (preferably 0900 GMT) so that the mercury thermometers, which should be dismounted and put in a safe place while cleaning is in progress, may have time to recover from the disturbance before the next observation is due. The readings of the maximum and minimum thermometers should be noted before dismounting.

Screens must be repainted if washing does not restore a clean white surface, or if the paint has started to peel or crack. There is no fixed period but normally the screen will require repainting about every two years. Rub down well with glass-paper and then apply an undercoating followed by a finishing coat of white hard-gloss paint of exterior quality. Any necessary repairs to the woodwork should be attended to before painting. In intermediate years a single coat of white hard-gloss paint may be applied after light sanding. The instruments should be removed whilst the inside of the screen is painted, but thermometers should be replaced as soon as possible to avoid the loss of any readings. Where it is necessary to leave electrical resistance thermometers in the screen, paint must be kept clear of the sensors.

As the metal stands supplied and recommended by the Meteorological Office are heavily galvanized they need no painting for many years. If the screen is mounted on a wooden stand, the stand should be painted at the same time as the screen.

The screws holding the screen to the stand should be 1¾ inches long to ensure that the screen is secure. In severe gales some screens have been blown off their stands through the use of screws of inadequate length.

8.4. STANDARD THERMOMETERS IN THE SCREEN

Four thermometers are normally exposed in an approved screen: two similar ordinary thermometers and a maximum and minimum. All these thermometers are discussed in the following sections and their arrangement in the screen is shown in Plate XXIV (in which two electrical resistance thermometers are also included). Other thermometers are exposed outside the screen to give further specialist readings (see 8.5).

8.4.1. Dry-bulb and wet-bulb thermometers. It was recommended earlier (8.2.1.1) that these thermometers should be selected from among those marked with red paint for nearly all stations. The dry-bulb thermometer is

exposed 'as it stands' and indicates the temperature of the air at the time of observation. The wet bulb is kept constantly moist by a cotton covering, the end of which dips into a reservoir of purified water. The wet-bulb thermometer indicates the 'temperature of evaporation' which is, in normal circumstances, lower than the air temperature (see 8.4.1.2). The difference between the dry-bulb and wet-bulb temperatures is known as the 'wet-bulb depression'. From the dry- and wet-bulb readings, relative humidity and vapour pressure can be obtained by reference to *Hygrometric tables* (Part II) or by the use of a humidity slide-rule. The combination of dry- and wet-bulb thermometers in a screen is known as a non-aspirated psychrometer (or non-aspirated hygrometer). For synoptic reports dew-point can be obtained from the slide-rule or from the booklet *Dew-point tables for screen readings, degrees Celsius*.

8.4.1.1. *Care of the wet-bulb thermometer.* In the calculation of dew-point the important element is the wet-bulb depression. It is necessary for the wet bulb to function correctly if this depression is to be accurately determined. The observer must give attention to the following points.

(*a*) *Use of purified water.* The water used for maintaining a wet bulb should be purified water. Water obtained when defrosting a refrigerator may be used. Clean rain-water is also permissible in an emergency, but tap-water and sea-water must not be used. Purified water obtained from a garage is liable to be contaminated with sulphuric acid when taken from a bulk source. 'Hard' tap-water will cause a deposit to build up over the bulb of the thermometer. This will cause false readings and any attempt to remove the deposit may lead to a broken thermometer.

(*b*) *Covering of wet bulb.* When either ordinary thermometers or electrical resistance thermometers are used as wet bulbs, a tubular cotton wick is used. The wick must either, in the case of an ordinary thermometer, cover the bulb and extend up the stem, or cover the resistance thermometer sensor, and in both cases for a specified length. The length of the wick actually covering the thermometers is important, not only to accord with the physical factors affecting the derivation of humidity, but also to obtain readings which are consistent between each of these two types of thermometer. In both cases the wick should be tied just below either the bulb or the tip of the sensor and again, for an ordinary thermometer, immediately above the bulb. The wick is then continued up the stem for 50 mm for the ordinary thermometer and tied again, 68 mm for Mk 2 electrical resistance thermometers (as shown for both in Figure 11) and 42 mm for Mk 4A electrical resistance thermometers.

Unbleached tubular wick should be given two short boils of 15 minutes in water and a little liquid detergent, with a tap-water rinse between, and then rinsed thoroughly in purified water before use. It may be convenient to keep one length of boiled wick in a sealed container of purified water prior to use, otherwise the wick should be stored dry in a clean plastic bag. The wick must be handled as little as possible, and then only with clean grease-free fingers. Tubular wick issued by Meteorological Office stores is usually bleached before dispatch.

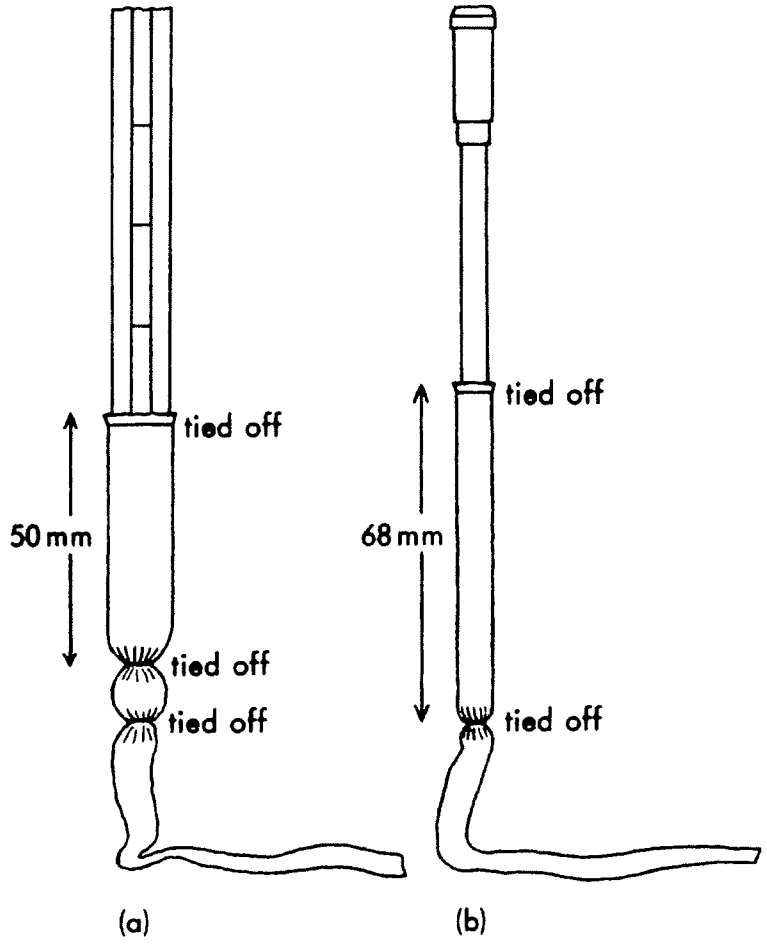

Figure 11. Wet-bulb coverings for (a) ordinary and (b) electrical resistance thermometers Mk 2

(*c*) *Changing the wick.* The wick should normally be changed once a week, but it should also be changed immediately after a period during which even slight dust has been raised. In addition, at coastal stations, the possibility of the wet bulb being affected by salt spray must be remembered, and immediately after a storm with onshore winds both water and wick must always be changed.

The changing should be carried out at least 15 minutes before a scheduled observation is due. The fact that the wick has been changed should be recorded in the remarks column of the Register.

(*d*) *Water container.* The water container should have a narrow neck or be fitted with a perforated cap to allow the passage of the wick; it should be placed near the wet bulb so that the distance which the water has to travel along the wick exposed to the air is not excessive. There should be no slack or dip in the wick, otherwise water may tend to drip from the lowest point and empty the container. The container should be replenished daily, or at shorter intervals in hot dry climates, to avoid any risk of its running dry. Non-breakable plastic containers held to the base of the screen are preferred.

(*e*) *Wet-bulb temperature below freezing.* When the wet-bulb temperature is below freezing-point it is necessary that the wet bulb should have a thin coating of ice instead of a coating of water. All derivations of

humidity are based on the assumption that the wet bulb is frozen once the temperature of it has fallen below the freezing-point. Ice evaporates in the same manner as water and once an ice bulb has been established it will need to be renewed at intervals. The maintenance of a properly functioning ice bulb is no easy matter. The application of too much water will result in an excessive build-up of ice which will invalidate any readings. If this occurs the excess ice must be cleared by applying lukewarm water, melting the ice and re-establishing a thin ice bulb in sufficient time before an observation for a true ice bulb to be formed. In very dry conditions an ice bulb will need renewing for every observation. Even when a covering appears frozen, a careful application of ice-cold water with a camel-hair brush to moisten the wick completely will be necessary in order to ensure a thin uniform covering of ice over the whole bulb. If the water applied to the wick does not freeze readily, induce it to do so by touching it with a little hoar frost, snow or fragments of ice collected on the end of the camel-hair brush. The same procedure should be adopted on those occasions when the dry-bulb temperature is below freezing but (owing to supercooling) the wet bulb is still liquid. Preparation of the ice bulb may have to be started up to 30 minutes before the observation is due.

When, in exceptional circumstances, it is not possible to induce an ice bulb, the supercooled wet-bulb reading should not be used in computing relative humidity. At those stations with hair hygrographs, the relative humidity should be taken from the record at the time of observation. An appropriate correction should be applied to the hygrograph reading, the correction being based on recent comparisons between the hair-hygrograph record and the corresponding value of humidity computed from dry- and wet-bulb temperatures when the wet-bulb reading exceeded 0·0 °C. Where no hygrograph is available, observers should note the reading of the unfrozen wet bulb without attempting any derivation of humidity.

8.4.1.2. *Exceptional ice- or wet-bulb readings.* Correct functioning of the wet-bulb (or ice-bulb) thermometer is normally indicated by the reading being lower than that of the dry bulb, though the two readings will be the same when the air is completely saturated and the temperature is above freezing-point. With air temperatures below freezing-point it is physically possible, when no water fog is present, for the ice bulb to read up to about 0·3 °C higher than the dry bulb. Such occasions are of great interest, and the observer should check that the ice bulb is functioning correctly before recording the observations as genuine, and make an appropriate note in the remarks column of the Register.

An authentic reading exceeding the dry-bulb reading can occur only with an ice bulb, never with a wet bulb in the ordinary sense of the term. If the wet-bulb temperature is above 0 °C and is higher than the dry-bulb temperature, either the wick on the wet bulb is very dirty and should be changed immediately, or one or other of the thermometers is defective.

Very occasionally, during rapid fluctuations of temperature, the wet bulb may read fractionally higher than the dry bulb owing to the difference in the speed or response. On such occasions, if there is no doubt that the wick is

clean and that the thermometers are not defective, the wet bulb should be taken as correct and the dry-bulb reading adjusted to conform with the wet bulb.

8.4.2. Maximum thermometer. This thermometer (Figure 9C) depends for its action on the presence of a small restriction in the bore of the tube below the lowest graduation near the bulb end. The constriction offers considerable resistance to the flow of mercury. The pressure created by the expansion of the mercury with rising temperature is sufficient, however, to force mercury past the constriction. When the temperature falls, provided that the stem of the thermometer is approximately horizontal, no reverse force comes into play, the mercury column breaks at the constriction, and the mercury in the tube beyond the constriction is left behind. If after such a fall in temperature there is a rise to a temperature higher than that existing before the fall, additional mercury will be forced past the constriction. Thus the reading of the far end of the mercury column in the tube indicates the highest temperature reached since the thermometer was last set.

The thermometer is installed in the thermometer screen upon the metal clips on the thermometer support, inclined at an angle of about 2° to the horizontal with the bulb slightly below the stem. This arrangement ensures that the mercury thread does not run up the stem away from the constriction.

After reading the maximum thermometer at the specified time it should be reset, except at the reading for 6 p.m. Press reports during the period of British Summer Time when the thermometer is not reset. The method of setting involves forcing the mercury back through the constriction until the mercury forms a continuous thread from the bulb to the meniscus. In order to do this, the thermometer should be gripped firmly by the centre of the stem and swung vigorously up and down in a semicircle, taking care that it does not slip out of the hand; (do not hold the thermometer in a gloved hand). Care should also be taken to avoid striking an obstacle, including the observer's own person or clothing.

When set, the maximum thermometer should show a reading agreeing with the dry bulb; any difference between the readings of the two thermometers should not exceed the following figures:

±0·2 °C when checked with a Category A ordinary thermometer ±0·4 °C when checked with a Category B ordinary thermometer	with dry-bulb temperature above 0 °C
±0·3 °C when checked with a Category A ordinary thermometer ±0·5 °C when checked with a Category B ordinary thermometer	with dry-bulb temperature below 0 °C.

The thermometer is then replaced on its supports. The bulb end is replaced first and the stem is then carefully lowered until the other end rests on its support.

Maximum thermometers occasionally develop a tendency to act as ordinary thermometers; that is to say, with falling temperature, the mercury tends to move back against the resistance of the constriction. This fault cannot be cured by the observer and the instrument should therefore be replaced.

8.4.3. Minimum thermometer. The minimum thermometer is a sheathed thermometer of the spirit-in-glass type with a small dumb-bell shaped index of

dark glass in the bore. This index is prevented from breaking through the meniscus of the spirit column by surface tension. As the temperature falls, the index is drawn towards the bulb, but it remains stationary as the temperature rises. The end of the index furthest from the bulb therefore indicates the minimum temperature reached since the last setting.

The thermometer is installed in the thermometer screen upon the metal clips on the thermometer support, inclined at an angle of about 2° to the horizontal with the bulb slightly below the stem. With this arrangement the movement of the index towards the bulb is slightly assisted by gravity.

The reading of the minimum is taken by noting the position of the extreme end of the index nearest to the meniscus. Setting is carried out by lifting the thermometer off the clips and tilting the thermometer bulb upwards so that the index slides along the tube and makes contact with the meniscus. When replacing the thermometer in the screen, incline the instrument with the bulb upwards and place the other end on its support first.

After the thermometer has been reset and replaced in the screen it should be read again and the reading compared with that of the dry-bulb thermometer. The difference between the readings of the two thermometers should not exceed the values given in 8.4.2.

8.4.3.1. *Errors in minimum thermometers.* If the comparison of temperatures mentioned above shows that the minimum thermometer reads consistently lower than the given limits, the cause is probably due to detached spirit. Unlike mercury, spirit wets the glass and consequently, if the temperature falls rapidly, a thin film of spirit may be left on the walls of the bore, or the same effect may be caused in hot weather by distillation of spirit from the liquid column to the upper walls and even to the safety chamber at the top of the bore. Bubbles may also form in the spirit column during transit.

The spirit column can usually be reunited by bouncing the bulb end of the thermometer on a thick telephone directory or pile of newspapers laid flat on a table. The thermometer should be held vertically, with the bulb end downwards and about 12 cm above the directory, and then let slip through the fingers so that the bulb end bounces on the directory. This process should be continued until all the bubbles have gone and the spirit column shows no breaks. This treatment may not always be sufficient, especially if spirit is present in the safety chamber; in that case the thermometer should be placed vertically, bulb downwards, in a vessel filled with water sufficiently hot to cause the liquid column to expand to the safety chamber, *but not so hot that the chamber is filled with liquid* (a convenient criterion is that the water should be just too hot to keep one's finger in) and the vessel with the thermometer allowed to cool slowly for 24 hours. Whichever method is used it is most important that the thermometer should be left standing upright, bulb end downwards, for 24 hours immediately after the treatment, otherwise bubbles are likely to reappear. A spare rain-gauge bottle or similar narrow-necked bottle makes a good holder.

Bubbles may occasionally develop in the stem of the minimum thermometer in the screen, even though the instrument has not been disturbed in any way and has been inspected and found in order on the previous evening. This is especially so on cold nights when the minimum temperature recorded is well below freezing-point. The correct procedure for such occasions is:

(*a*) Discard the reading.

(*b*) Take the recommended steps to remove the bubbles before resetting.

(*c*) Make a note of the reading, the condition of the thermometer and the action taken, in the Register and the monthly return.

8.4.4. Procedure for reading the thermometers. At most synoptic stations and all climatological stations, the dry-bulb and wet-bulb thermometers are read at every hour for which an observation is made. At stations which are also required to make special reports for aviation purposes, additional readings of these temperatures are required for the half-hourly reports. In addition, the maximum and minimum thermometers are read at the hours specified in Chapter 1 for different types of station, and are reset immediately after they have been read. See, however, the special instructions in 1.5.2 (page 8) applicable to those stations making special observations at 6 p.m. clock time. Special procedures are arranged at some auxiliary reporting stations.

When all four thermometers have to be read, the order of reading should be dry bulb, wet bulb, maximum, minimum.

8.4.5. Care of thermometers in the screen. Moisture may be deposited on all surfaces inside and outside the thermometer screen by condensation of water vapour in wet fog or from some other cause. This deposit of moisture can cause significant errors in the readings of thermometers if the bulbs of those thermometers intended to be dry become moist; errors will continue until all the moisture has evaporated (which may not be for several hours after the conditions which led to the moisture has ended). The dry-bulb thermometer would act as a partial wet-bulb thermometer and would indicate a lower temperature than a true dry bulb. Consequently the derived dew-point using this reading in conjunction with the wet-bulb reading would also be in error. Similarly the maximum and minimum thermometers might indicate lower temperatures than the true values if their bulbs are moist at the time that the true maximum or minimum temperatures are reached.

If the dry-bulb, maximum or minimum thermometers are affected in this manner, the deposits of moisture should be removed with a clean tissue, blotting-paper or cloth, care being taken not to warm the thermometer in the process. A note of the time and action should be made in the remarks column of the Register.

8.4.7. Discrepancies in readings. If all four thermometers in the screen are working correctly it is clear that:

(*a*) The reading of the maximum should be higher than (or at least as high as) any reading of the dry bulb since the maximum was last set.

(*b*) The reading of the minimum should be lower than (or at least as low as) any reading of the dry bulb since the minimum was last set.

If the readings of the maximum and minimum have been checked at the time of observation and are then found to be inconsistent with the above rules, the cause of the discrepancy may be either an error in reading the dry bulb at one of the hours during the period covered, or a defect in one of the thermometers. The reading which, on examination, the observer considers to

be erroneous should be adjusted by him, and the adjusted value should be entered in the Register within brackets. A note of the actual reading should also be made in the remarks column, both in the Register and in the appropriate monthly return.

In winter the night minimum temperature often occurs around dawn. In these circumstances, especially at synoptic stations where the first reading of the minimum is taken at 0600 GMT, if the fall of temperature is rapid and is still in progress, the minimum thermometer may show a slightly higher reading than the dry bulb simply because the lag of the minimum thermometer is greater than that of the dry bulb. In this instance it is legitimate to adjust the minimum reading to agree with the dry-bulb reading.

At observing stations on or very near to aerodromes, errors in thermometer readings may be caused by the hot exhaust gases from jet aircraft, either standing with engines running near the meteorological enclosure or even taxiing past it. The gases may be projected towards the enclosure by the jets, or they may be carried to it by the wind after they have lost their original momentum.

With dry-bulb and wet-bulb thermometers the only precaution necessary is to avoid reading them during, or immediately after, exposure to exhaust gases. With a maximum thermometer, however, it is necessary to consider whether it may have been affected in this way at any time since it was last set. At observing stations where a thermograph is in use the question can usually be decided by an examination of the thermograph; sharp kicks in the trace, caused by the passage of a taxiing aircraft or by the running of an engine nearby, can be easily recognized. If there is no thermograph, the maximum temperature should be checked by comparison with the half-hourly or hourly temperatures, if available. There should be fairly close agreement between the highest of these and the readings of the maximum thermometer.

Any maximum thermometer reading which the observer considers erroneous should be adjusted and entered in the Register, as indicated above for other suspected temperature readings.

8.5. THERMOMETERS EXPOSED OUTSIDE SCREENS

Additional thermometers are required to be exposed outside the screen, usually on or near to the surface of the ground and, in special circumstances, below the ground (soil thermometers) at specified depths. Readings from these thermometers are required for particular purposes and care must be taken to ensure that, where necessary, they are set correctly and that no confusion arises when entering the recorded temperatures in the appropriate Register or return form.

8.5.1. Grass minimum thermometer. The grass minimum thermometer (see Figure 9E) is similar to the minimum thermometer used in the screen. It is used to record the lowest temperature reached during the night over short grass freely exposed to the sky. It is read at 0900 GMT daily, but full synoptic stations also read the thermometer at 0600 GMT without resetting.

The most open position available within the enclosure should be selected for the grass minimum, and the grass should be kept short so that its condition

resembles that of a lawn. The thermometer should be laid on two Y-shaped pegs or placed in the special grass minimum thermometer supports which are made of stiff black rubber. When the pegs are used they should support the thermometer at an inclination of at least 2° to the horizontal so that the bulb is lower than the stem and at a height of between 2·5 and 5 cm above the ground, with the bulb in contact with the tips of the grass. If the special rubber supports are used, the thermometer is pushed through the hole in the rubber squares, the large one adjusted to be about 29 cm from the bulb and the smaller square 11 cm from the bulb, thus ensuring that the thermometer will be at the required inclination to the horizontal. By choosing a particular side of the squares to rest on the ground, the thermometer bulb will be just touching the tips of the grass.

The thermometer is set by tilting the bulb above the stem so that the index runs down the bore until it comes into contact with the meniscus. The thermometer should be set and exposed at the last observation hour before sunset. For example, if sunset is at 1935 GMT, then a station making hourly observations throughout the 24 hours will set and expose the thermometer at 1900 GMT; a station observing only at main and intermediate synoptic hours will set and expose at 1800 GMT, and a station closing down at 1700 GMT will set and expose at that time. At stations where observations are only made at 0900 GMT and the thermometer is reset and exposed more than 2 hours before sunset, it is essential that an anti-condensation shield be fitted.

An anti-condensation shield is a black metal sheath fitted over the thermometer at the end remote from the bulb. The black sheath absorbs more heat from the sun than the exposed part of the thermometer so vapour is prevented from condensing in the upper part of the bore, and any vapour which has already condensed there evaporates and condenses lower down the stem at the top of the ethanol column. The shield should be repainted with black paint when necessary.

Except at the stations where the grass minimum is reset and left exposed during the day, the thermometer should be stored after the 0900 GMT reading, the most convenient place being the thermometer screen. A thermometer taken off wooden pegs should be stored in a near-vertical or sloping position with the bulb end lower. A thermometer with rubber supports attached may be stored in the well in the floor of the screen. If for any reason the thermometer cannot be stored in the screen, it should be brought indoors and stored in a position as near vertical as is practicable, with the bulb end downwards.

The grass minimum thermometer should be checked with the screen dry-bulb thermometer about every 3 months. If the grass minimum thermometer is stored in the screen on the special rubber supports (i.e. at the correct angle), the check may be carried out during the day.

As with all ethanol-type thermometers, bubbles or breaks in the liquid column are liable to occur, usually under conditions of great cold or when the thermometers are left out in the sunshine. The effects of this latter cause can be alleviated by the use of the anti-condensation shield described above. If such bubbles are seen when the thermometer is due to be read, no reading should be taken.

The methods for removing bubbles from minimum thermometers are described in 8.4.3.1 (page 123).

8.5.1.1. *Procedure with snow on the ground.* When snow covers the ground the thermometer should be supported immediately above the surface of the snow, as near to it as possible but not actually touching it, using the wooden pegs or the rubber supports. If, owing to a fall of snow overnight, the thermometer is found to be buried in the morning at the time of reading, the snow should be carefully removed and the thermometer read in the usual way. The reading should be entered in the Register and marked '?', and a note 'grass minimum buried in snow' entered in the remarks column. If the thermometer is to be left exposed it should be replaced at the snow surface as described above. Doubtful readings should not be included in synoptic messages.

At synoptic stations where the enclosure is visited during the night hours the thermometer should not be left buried in the snow until it is first due to be read. When the snowfall appears to have ceased the thermometer should be supported above the snow surface, care being taken not to displace the index, so that a reading of the temperature immediately above the snow surface may be available at the observation time. The time when the thermometer was placed above the snow should be noted in the remarks column of the Register. If, having carried out the above procedure, further falls of snow occur at intervals and may be doing so at the time of observation, the snow should be cleared and the temperature read from the undisturbed thermometer. A note on the extent to which the thermometer was covered should be made.

8.5.2. Ground minimum thermometers. The same type of thermometer as the grass minimum (described in 8.5.1) is also used at selected stations for measuring minimum temperatures on bare soil and/or on a concrete slab. Suitable sites for bare-soil and concrete-slab minimum thermometers are indicated in Figure 20 (page 179), and details of exposure are given in Appendix I in I.8.7 and I.8.8 respectively. The same sites, once selected, must always be used.

The time for setting and exposing both these thermometers is the same as for the grass minimum, i.e. the last observation hour before sunset, as detailed in 8.5.1. Each thermometer should be read at 0900 GMT daily, and they are then stored in the screen or indoors as advised in 1.10.3. When left exposed during the day or exposed more than two hours before sunset the thermometers must be fitted with an anti-condensation shield.

Concrete-slab and bare-soil minimum thermometers should be checked against the screen dry-bulb temperature at approximately 3-monthly intervals, using the same tolerances as given in 8.2.1.1. The possibility of this type of thermometer developing bubbles should be borne in mind and action taken, as described in 8.4.3.1, if it occurs.

8.5.2.1. *Bare-soil minimum thermometer.* The thermometer should be set, then laid on level bare soil with the stem having a slight slope downwards towards the bulb. Small pegs of wood should be placed in the ground at each side of the thermometer, but not near to the bulb, to prevent accidental movement.

When snow covers the ground the thermometer should rest on top of level snow. When the thermometer is buried by overnight snow it should be carefully extricated and then exposed on top of level undisturbed snow as close as

possible to the normal site. Appropriate notes should be made in the remarks column of the Register, and the procedures of 8.5.1.1 followed.

8.5.2.2. *Concrete-slab minimum thermometer.* The thermometer should be set and then placed in the PVC-coated phosphor-bronze spring clip with the end of the anti-condensation shield just touching the clip and with the thermometer stem parallel to the major axis of the slab. The thermometer bulb will then be in the centre of, and in contact with, the slab and the thermometer will have the correct downward slope of approximately 2° (see I.8.8 in Appendix I).

When snow covers the ground, the concrete slab should be swept clear of snow at the time of setting the thermometer. If there is a fall of snow overnight this should be removed carefully as soon as possible after the snow has ceased, and the free exposure of the thermometer restored as far as possible, care being taken not to displace the thermometer index. If the thermometer is, nevertheless, covered by snow at 0900 GMT, the snow should be removed carefully and the thermometer read in the usual way. Appropriate notes concerning the removal of snow from the concrete slab or about the thermometer being covered by snow at 0900 GMT should be entered in the remarks column of the Register and the procedures of 8.5.1.1 followed.

8.5.3. Soil thermometers. At certain selected stations the temperatures below the level of the earth's surface are measured at various depths. The depths used in the United Kingdom are 5, 10, 20, 30 and 100 cm, although measurements at all of these are not necessarily taken and, exceptionally, temperatures at other depths may be measured. To cope with these variations in depths, two special types of thermometer are used: one type for depths of 30 cm or more and the other for depths of less than 30 cm.

8.5.3.1. *Soil thermometers for depths of 30 cm or more.* The type of thermometer used for these depths is shown in Figure 9B. The thermometers are enclosed in glass tubes and their bulbs are embedded in wax to make them insensitive to sudden changes of temperature. This allows them to be drawn to the surface and read before their temperature has had time to change appreciably. As underground changes of temperature are very slow, the slow response resulting from the coating of wax does not lead to inaccuracies in the measurements.

At depths of 30 cm or more, the temperatures are measured under a grass surface. The thermometers are suspended in steel tubes sunk through the surface of the grass plot.

Water must not be allowed to collect in the steel tubes; to prevent this, the tubes are fitted with caps. The thermometer is suspended from the cap. If water is found to be present, it can be removed by means of a sponge or other absorbent material tied to the end of a stick. Leaking tubes should be repaired and faulty caps replaced.

Temperatures should be read to the nearest tenth of a degree; to avoid parallax errors the thermometer should be raised to eye-level (see 8.2.1.3). The instrument should be shielded from direct sunshine during the observation.

8.5.3.2. *Soil thermometers for depths of less than 30 cm.* These thermometers (pattern for use at 5 cm is shown in Figure 9D) are unmounted and

unsheathed with a bend in the stem between the bulb and the lowest graduation. The bend allows the bulb to be at 5, 10 or 20 cm, according to the particular pattern, when the vertical part of the stem is sunk into the ground with the horizontal (graduated) part of the stem in contact with the surface. Measurements at these depths are made under a bare soil surface. The thermometers are read without being disturbed from their position in the soil, the readings taken to the nearest tenth of a degree.

Instructions for installation under bare soil are given in I.8.5, page 187, and these should be carefully followed if it is necessary to move or replace the thermometers at any time.

In dry weather, cracks in the soil develop, especially in clay, and it sometimes happens that the vertical section of a soil thermometer is situated in a crack. The development of cracking should be delayed, when warm dry weather is expected, by light raking of the surface soil to prevent it becoming smooth and hard. This treatment must be carried out, with as little disturbance as possible, at any time after rain when the soil is partially dry and in a suitable condition. In this way cracks which have appeared may sometimes be got rid of, but in a prolonged dry spell nothing should be done; the readings should be accepted. The presence of the cracks is recorded in the observation of state of ground (see 6.2.1).

8.6. AUTOGRAPHIC INSTRUMENTS

8.6.1. The bimetallic thermograph (Plate XXVI) gives a continuous record of air temperature. For routine use the thermograph is accommodated in the large thermometer screen (Plate XXV), positioned to the left of the thermometer supports on the middle bottom board of the screen.

The temperature-sensitive element is a bimetallic helix formed by welding together strips of two metals which have widely different coefficients of expansion; changes of temperature cause the helix to coil or uncoil. In the thermograph this action is made to control the movement of a recording pen, the pen-arm spindle being attached directly to one end of the spiral, the other end of which is anchored to the framework of the instrument. The mechanism is thus very simple, and as the spiral exposes a large surface to the air the instrument has a lag about half that of the ordinary mercury thermometer and is capable of recording short-period as well as long-period variations of temperature. A weekly or daily clock can be fitted to drive the drum on which the chart is secured.

The procedure for changing the chart and putting time marks on the record is the same as for the barograph (see 7.7.3 and 7.7.4, pages 107 and 108, and also 1.1.4, page 4). Time marks should be made gently, displacing the pen by the equivalent of only one or two degrees of temperature on the chart.

Two chart ranges are in use in the British Isles: the winter chart has a range from −25 to +20 °C and the summer chart from −10 to +35 °C. A third chart range of +10 to +55 °C is used at certain overseas stations. The change from the winter to the summer chart should usually be made at 0900 GMT on the Monday nearest the middle of April, and the change from summer to the winter chart at 0900 GMT on the Monday nearest the middle of October, but

the observer should use his own discretion in the matter. Abroad, the best dates for changes will depend on the locality and the range of charts provided.

When changing from summer to winter charts, or vice versa, the position of the pen arm has to be adjusted to register the correct dry-bulb temperature. Coarse adjustment of the position of the pen on the new chart is effected by loosening the screw which attaches the pen arm to the pen-arm spindle, rotating the pen arm about the spindle until the pen records approximately the correct dry-bulb temperature, and then tightening the screw. The pen is brought to the correct dry-bulb temperature by use of the fine-adjustment screw, which is the milled-head screw at the fixed end of the helix.

This final adjustment to the pen is best done on a cloudy day when the temperature is steady. The thermograph should be left in the screen for half an hour and then compared with the reading of the dry bulb. Alternatively, a room with a constant temperature may be used. Place the thermograph away from direct sunlight and draughts, and set a thermometer with its bulb as close as possible to the bimetallic helix. Some instruments have a clip on the guard for holding a thermometer.

8.6.2. The hair hygrograph. This instrument (Plate XXVI) is used to obtain a continuous record of relative humidity. For routine use, the hygrograph is accommodated in the same large thermometer screen as the thermograph, positioned to the right of the thermometer supports.

The sensitive element is a bundle of human hair from which all oil has been extracted. The length of hair so prepared is affected by changes in the relative humidity of the air, but is practically unaffected by temperature. The length increases with increasing relative humidity but the rate of increase is not uniform throughout the range. For example, a change from 90 to 95 per cent gives a much smaller change in length than a change from 40 to 45 per cent. The hair is clamped between two rigid supports and kept taut by a loaded hook at the middle. The movement of the hook is transmitted through a lever and two quadrants to the pen arm, the quadrants acting as a lever of varying length; in this way the non-linear response of the hair is changed to a linear response on the chart. The pen arm is fitted with a gate suspension and the pen records on a chart wound on a clock-driven drum which may be daily or weekly as required.

The hygrograph should be tapped slightly with a finger before a reading is taken.

The procedure for changing the chart and making time marks is detailed in 7.7.3 and 7.7.4, pages 107 and 108). In making time marks it is important that the pen arm should be moved downwards about 3 mm; an upward movement strains the hair.

8.6.3. Checking, adjusting and maintenance of thermographs and hygrographs. Certain procedures are common to both types of autographic instruments. A check should be made on the setting of the pen whenever a chart is changed; this is to ensure that the pen starts recording on the chart at either the temperature of the dry bulb in the screen or, in the case of the hygrograph, at the humidity at that time, to values as close as adjustment will

allow. A further method of checking the setting of a hygrograph is outlined below in 8.6.3.2. When the charts are finally removed, the values of temperature and humidity obtained from the screen thermometers should be entered against the time marks on the charts and a comparison made between the actual values and those recorded on the chart. A small, near constant, difference between the two can usually be removed by using the fine adjustment. A non-constant difference over a week between actual and recorded values may be due to other causes: dirty hairs on the hygrograph, a distortion of the chart drum, or the drum may not rotate in the horizontal are possible reasons. The last two can be checked by manually rotating the drum once, at either a constant temperature or humidity, with a chart in position and the pen recording. The trace so obtained should be horizontal. Experience has shown that frequently this is not the case and, on thermograph traces, errors of up to 0·9 °C have been detected. If such cases are found, the fact should be noted in the instrument log (see 1.10, page 14) and reported to the appropriate authority for a decision as to whether the instrument should be exchanged. In the particular case of the hygrograph, unless the instrument is well maintained, errors due to drum distortion or the drum not rotating horizontally may be compounded by errors arising from the mechanical malfunctioning of the instrument movement or dirty hairs. Dirt on the clock and drum collars is often the cause of trouble.

The timing of the clocks should be checked by comparison between time marks. Alterations can be made to the clocks by removing them from the instrument and adjusting the regulator in the base. The daily clock allows a total adjustment of 15 minutes and the weekly clock a total adjustment of 1¾ hours.

If metal pens are used, they should be cleaned of sediment as necessary with Inhibisol or methylated spirit. The instructions (for barograph pens) in 7.7.6, page 109, should also be followed. The type of pen recommended for the thermograph consists of an ink reservoir fitted with a fibre nib; this type will produced a good clean trace. However, the fibre-nib pen is not recommended for a hygrograph as its weight introduces errors in the record which are difficult to assess. Particular care should therefore be taken to obtain a good record with a metal pen. Ensure that the pen rests as lightly as possible against the chart as is consistent with a good record.

8.6.3.1. *Thermograph.* Clean the instrument regularly, handling it carefully to avoid damage. Wipe the case and the base plate with a clean soft rag. Treat ink-stains promptly before they dry and harden. Clean any dirt from the bearings and apply, very sparingly, a little clock oil. Remove any surplus oil with blotting paper.

8.6.3.2. *Hygrograph.* Prior to any instrument maintenance on the hygrograph, the wire cage over the hairs should be removed and the hairs unhooked with a camel-hair brush. Clean the instrument and remove any ink-stains with methylated spirit or other suitable fluid. Clean the quadrants by rubbing the rolling surfaces with blotting paper which has previously been rubbed with a soft lead pencil. As with the thermograph, the bearings should be cleaned and very lightly oiled, any excess oil being removed with blotting paper. Great care must be taken to ensure that no oil gets on to the hairs. When replacing the hairs on to the hook the camel-hair brush must be used. This maintenance should be carried out once a month. At more frequent

intervals the hairs should be washed. This should be done at least once a fortnight in country air but more frequently where the hairs are exposed to sea spray or industrial fumes and dust. Apply purified water to the hairs with a soft camel-hair brush. The wire cage must, of course, be removed for this purpose and great care taken not to touch the hairs with the fingers. After the excess water has been removed with the brush, the weight of water remaining is still quite appreciable for a time and this is enough to cause sagging of the hairs to the extent that the chart record will indicate about 95 per cent and not 100 per cent. This fact can be used when resetting the instrument. If it needs adjustment, move the jaw holding one end of the hairs and use the fine adjustment screw for which a key is provided.

8.7. ASPIRATED PSYCHROMETER

The values of humidity deduced from dry-bulb and wet-bulb thermometers exposed in standard screens are subject to uncertainty on account of variations in the rate of movement of air past the wet bulb. This uncertainty is generally ignored for ordinary synoptic or climatological purposes. When more precise values of humidity are required, or if atmospheric temperature and humidity readings are a requirement where there is no screen available or the installation of one would not be feasible, these readings can be obtained by the use of an aspirated psychrometer (Plate XXVII), also known as an aspirated hygrometer. The method of aspiration is by a fan, operated either by an electric or clockwork motor, which produces a fast and regular flow of air over the bulbs of two thermometers mounted in a frame. Each bulb is protected from external radiation by highly polished double-walled radiation shields.

Normally observations should be made with the instrument suspended from a fixture so that the bulbs of the thermometers are 1·25 m above the ground. The rod issued with the instrument may be screwed into any convenient object, preferably a fairly thin post away from other objects. If the support is of appreciable size, the instrument should be mounted on the windward side. If no convenient supports are near, the instrument may be held to windward at arm's length and tilted slightly so that the air inlets face approximately into the wind but not directly towards the sun. If the wind speed is greater than 12 knots and the instrument is hanging vertically from the support rod, inaccuracies in the readings may occur as the wind blows horizontally past the bottom of the radiation shield and disturbs the airflow over the thermometers. In that case the instrument should be hand-held instead, as described above.

The most important single factor affecting the accuracy of the readings is the wick of the wet-bulb thermometer. It should be a close-fitting piece of tubular wick of correct length; a loose-fitting or too short a wick may give rise to serious errors. When a new wick is received it will almost invariably be ready for use. If not, it should be treated as described in 8.4.1.1(b), page 119. In order to fit the wick, one of the polished radiation shields must be removed by giving it a short turn to the left to release the bayonet fitting. The piece of wick must be of such a length that it extends at least 12 mm above the top shoulder of the thermometer bulb. The wick should be handled as little as possible, and then only with clean fingers. If an instrument is used at only

irregular intervals, a new wick should be fitted each time. If in regular use, the wick should be changed at least once a week; at sea or near large towns or in polluted areas it should be changed two or three times a week.

The following procedure should be followed when making an observation:

(*a*) The wick should be moistened by means of the injector provided. The injector is filled with purified water and the bulb pressed until the water rises to the top of the tube. The tube is then pushed over the wick and left there until it is completely saturated. The wick should never be moistened by using the injector as a squirt. If after saturation there is a residual drop of water on the bottom of the wick, this should be removed by touching the drop with the end of the tube. Care must be taken not to push the wick above the thermometer bulb when using the injector. If the wick becomes frayed at the bottom it should be changed.

The temperature of the purified water should be approximately the temperature of the wet bulb, otherwise a period of 1½ to 2 minutes may be required for the wet bulb to stabilize after each moistening. A wetting may only last about 5 minutes in conditions of low humidity. When the wet-bulb temperature is below freezing, ice-cold water should be used and, if necessary, the water should be induced to freeze on the wick by touching it with ice or hoar frost (as recommended in 8.4.1.1(e) for ice-bulb temperatures in screens.).

(*b*) Start the fan. One full winding of the clockwork motor should run the fan at the correct speed for at least 7 minutes. As soon as a slackening of the speed of the fan becomes noticeable through a lowering of the pitch of the note produced, the motor should be rewound. Readings taken at less than the full fan speed are liable to be in error.

(*c*) Two minutes after commencing aspiration, and again after a further half-minute, the thermometers should be read, wet bulb first and then the dry bulb. If these consecutive readings agree within ±0·1 °C, note the actual readings of the wet- and dry-bulb thermometers. Sometimes consecutive readings may differ by as much as 0·5 °C and in these circumstances the mean of readings at half-minute intervals from minute 2 to minute 5 should be taken.

As stated in 8.2.1.1, thermometers used in psychrometers with forced ventilation are issued with certificates giving the corrections at different points on the scale; these must be applied before using the readings. Special scales for computing humidities from aspirated psychrometer readings are provided on the Meteorological Office humidity slide-rules, Mk 6 and Mk 6A. Tables for use with aspirated psychrometers are given in *Hygrometric tables,* Part III. Dew-points in degrees Celsius and tenths can also be obtained from special tables used by the Observational Practices Branch of the Meteorological Office.

8.7.1. Routine maintenance. The chromium-plated parts of the instrument should be rubbed from time to time with a soft cloth which is clean and dry; no metal polish should be applied. Care must be taken not to scratch the plating.

The bearings of the clockwork motor should be oiled occasionally with a little clock oil. To gain access to the motor, the winding key must first be

removed by screwing counter-clockwise; if the six screws in the casing are then taken out, the casing will slide off, exposing the motor.

The thermometers should be cleaned periodically, especially when an instrument is used in a salt-laden atmosphere. Access can be gained by loosening the two locking nuts under the fan housing and detaching the frame from the fan. The thermometers can be released by turning the locking ring so that the recesses are over the thermometer apertures. The rubber spacing rings should be replaced as soon as they show sign of wear.

8.7.2. Safety precautions. Particular attention must be paid to safety precautions when using a psychrometer with an electrically driven fan.