CHAPTER 9

PRECIPITATION

9.1. GENERAL REQUIREMENTS

The total amount of precipitation which reaches the ground in a stated period at any place is expressed as the depth to which it would cover a horizontal surface at that place if there were no loss by evaporation, percolation or run-off. The precipitation may be liquid (rain or drizzle) or frozen (snow, snow pellets, snow grains, hail, small hail, ice pellets, diamond dust) or a mixture (rain and snow, drizzle and snow, rain and melting snow). Precipitation is described as freezing rain or freezing drizzle when the drops of rain or drizzle have temperatures below 0 °C and freeze on impact with the ground or with objects on the earth's surface. Surface condensation phenomena such as dew, wet fog, hoar frost and rime may contribute to the catch of a rain-gauge but are not classed as precipitation under the heading of 'present weather'.

The total precipitation recorded and reported is the sum of the amount of liquid precipitation and the liquid equivalent of any solid precipitation (that is if precipitation falling as snow or ice were melted). Somewhat different methods of measurement are required according to the nature of the precipitation. The standard unit of measurement nowadays is millimetres and tenths, with depths of snow measured in centimetres.

9.2. BASIC METHODS OF MEASUREMENT

Bearing in mind that falls of precipitation are rarely either uniform in intensity or duration, the chief aim of any method of measurement of precipitation should be to obtain a sample that is truly representative of the fall over the area to which the measurement refers. Therefore choice of site, the design and exposure of the rain-gauge, the prevention of loss by evaporation and the effects of wind and splashing are important points to be observed.

The method of obtaining a sample of precipitation is for it to be collected in a rain-gauge which is sited in a representative spot. In its simplest form a rain-gauge consists of a circular collector, of known area, which must be horizontal and with a sharp upper rim. The precipitation falling within this collector is channelled through a funnel, either to a receiver for measurement later or to automatic measuring equipment. The rim of the collector can either be exposed at a standard height above ground or set in the centre of a specially constructed, large-diameter pit with its rim flush with the surrounding ground. Both methods of exposure have their disadvantages. The amount of rainfall collected by the conventional types of rain-gauge protruding above otherwise open terrain is generally less than the actual rainfall at the site of the gauge; this effect is mainly due to the eddies set up by the gauge itself when the wind is strong. A gauge standing in a pit with the rim of the gauge flush with the surrounding ground and with the pit covered by a gridded (or

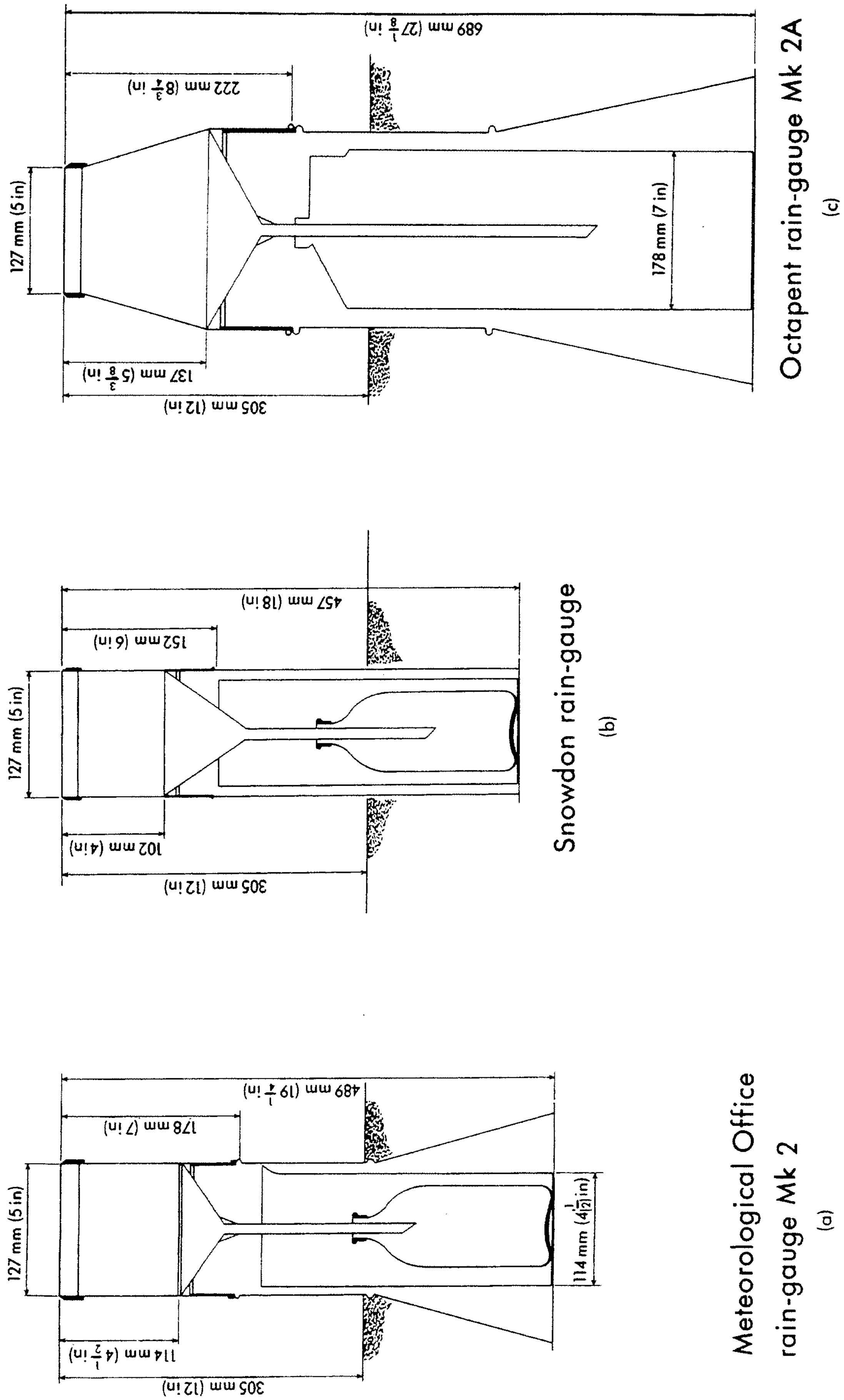

Figure 12. Approved types of rain-gauges

other suitable artificial) surface to minimize the effect of in-splash into the gauge itself may also be affected by wind eddies and can suffer drainage problems.

Comparability of readings within a rain-gauge network can best be achieved if the measurements are all made with an approved type of instrument in a standard exposure. The Meteorological Office has a strong preference for the gauges described in 9.3, that is for those in which the rim is 5 inches (127 mm) in diameter and sited at 30 centimetres (12 inches) above the ground (rather than flush with it). The exposure must also be standard, and determined by the rules given in I.9 of Appendix I (page 188).

The collection of rain and drizzle by a rain-gauge, and its subsequent measurement, is simple. Hail or sleet may be similarly sampled and collected within the rain-gauge and, after thawing by natural or artificial means, the liquid equivalent may be measured.

Measurement of the liquid equivalent of snow presents the difficult problem of securing a representative sample, and no really satisfactory method is yet available. In light winds, falls of snow collected in the rain-gauge and not exceeding its retaining capacity should be thawed and then measured as liquid water. For heavier falls, and for falls in stronger winds, the method that offers the best guidance is the collection of samples of fresh snow of known horizontal cross-section that has accumulated upon the ground since the previous specified time of measurement. These samples are subsequently measured by weight or, when completely melted, by volume.

9.3. MEASURING PRECIPITATION BY COLLECTION

Many different types of rain-gauge have been designed and used. All consist of a circular collector, delineating the area of the sample, and a funnel leading into a reservoir. The precipitation collected is then measured directly in millimetres and tenths using a rain measure graduated for use with the particular type of gauge. The shape and size of gauges vary according to the storage capacity required in the reservoir, this being dependent on whether the precipitation is measured daily, weekly or monthly.

9.3.1. The Mk 2 rain-gauge. The standard rain-gauge used in the Meteorological Office for climatological observations is the Mk 2 (Figure 12(a)). This is a copper gauge with a 5-inch diameter (127 mm) collector which has a sharp brass rim. It is sited so that the rim is horizontal and 30 cm (12 inches) above the ground. The rainfall that is collected is led into a narrow-necked bottle placed in a removable copper can. The bottle is easy to handle when pouring the sample into the rain measure, and reduces loss by evaporation. The inner can ensures the retention, for measurement, of exceptionally heavy rainfall which may overflow from the bottle into the can. Both bottle and inner can are housed within the splayed base of the gauge which is sunk firmly into the ground. An additional 5-inch gauge may be provided at those stations which report rainfall for synoptic purposes.

9.3.2. The Mk 3 rain-gauge. This rain-gauge is of glass-fibre construction. It was originally designed as a ‘system’ which could act either as a recording rain-gauge (see 9.5.2) or as a collector. In its latter capacity it can be fitted with a circular collecting funnel of 127 mm diameter and, when exposed, the flared support tube must be buried so that the rim of the collector is 30 cm above ground level and horizontal. This gauge is not recommended for use as a manually read instrument because it is brittle and the collector is liable to chip and crack.

9.3.3. The Snowdon, Octapent and Bradford rain-gauges. Another pattern of rain-gauge which is used when daily readings are required is the Snowdon gauge, shown in Figure 12(b). However, this particular gauge does not have a splayed base and it is not so firm in the ground as the Mk 2 gauge.

The Octapent rain-gauge (Figure 12(c)) provides sufficient capacity for periods up to a month or more between measurements. A smaller capacity Octapent (680 mm) is used in the drier parts of the country and a larger capacity gauge (1270 mm) in areas of high rainfall. A special design feature of the Octapent rain-gauage is the frost protector. This is a piece of reinforced rubber tubing, closed and weighted at the lower end, which is inserted vertically in a hole set to one side of the top of the inner container. The protector operates by collapsing under the pressure due to expansion when the contents of the inner container freeze; when a frost protector is not used, the vacant hole should be sealed to reduce evaporation losses.

The Bradford rain-gauge (not illustrated) is an adaption of the Snowdon gauge with a deeper storage can to hold the rainfall. This gauge is capable of being read monthly in fairly dry localities but is more often used for weekly readings.

The measurement of the rainfall in the Octapent and Bradford gauges is done in two stages. As a crude check on the later accurate measurement, the rain is first roughly measured by inserting a graduated dip-rod which is lowered vertically until its metal foot touches the bottom. The rod, when withdrawn, is wet up to the mark indicating the amount of rain. This amount is noted and the rain is then measured accurately by means of a glass measure in the usual way. If fitted, the frost protector in the Octapent gauge should be removed before a measurement is made with the dip-rod.

9.3.4. Rain measures. The amount of precipitation collected by a gauge may be measured with the aid of glass vessels known as rain measures. Each measure is graduated to indicate, in millimetres, the amount of precipitation over the area of the collecting funnel of the rain-gauge; it is therefore essential that the rain measure should be one appropriate to, and calibrated for, the type of rain-gauge in use.

Meteorological Office rain measures (see Figure 13) for use with daily gauges are tapered at the base to facilitate accurate measurements of small amounts. There are two standard rain measures in use, the older one having a total capacity of 10·0 mm to the highest graduation and the newer having a graduated capacity of 10·5 mm. Amounts greater than the graduated capacity must therefore be measured in two or more stages. It is not necessary to fill the measure exactly to the highest graduation. For example, a rainfall of 30·8 mm might be summed in four stages:

$$9{\cdot}6 + 9{\cdot}4 + 9{\cdot}5 + 2{\cdot}3 = 30{\cdot}8 \text{ mm}$$

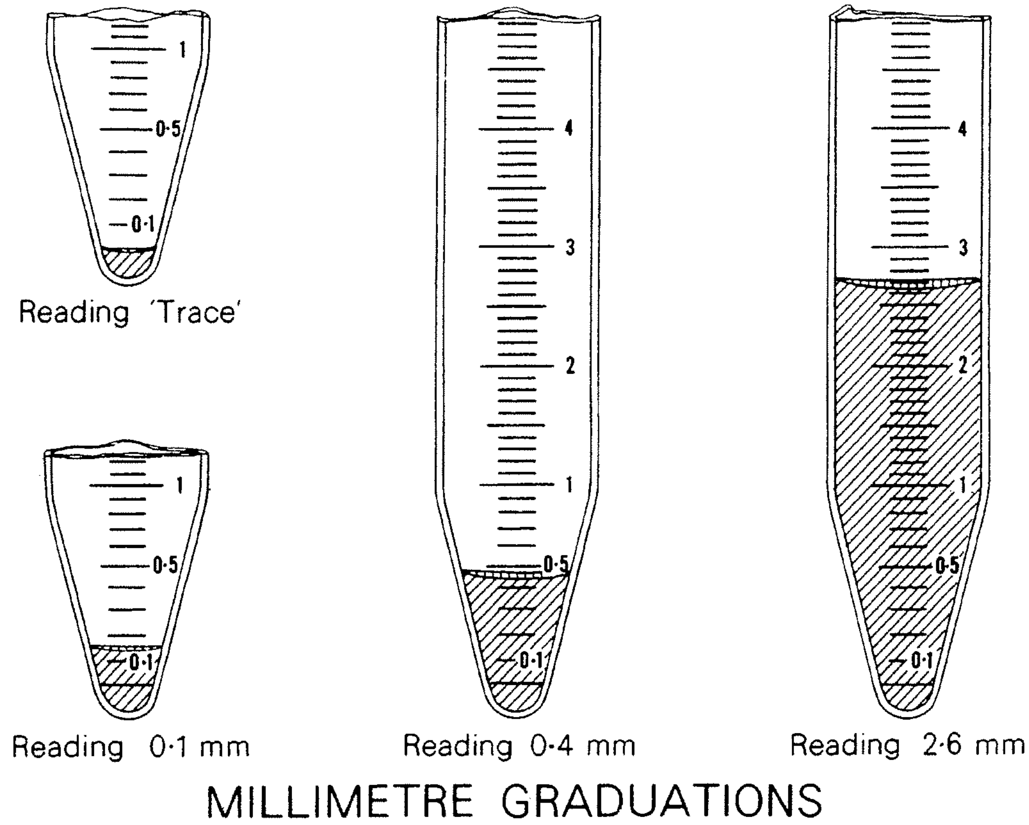

Figure 13. Reading the rain measure

The reading 'trace' is also applicable when rain is known to have fallen but the gauge is dry (see page 140)

9.3.4.1. *Reading the measure.* Owing to the surface tension, the surface of the water in a rain measure is never quite flat but is slightly curved, the water being drawn up at the sides as illustrated in Figure 13. The rule is always to read the lowest point, which is the centre of the meniscus, because measures are graduated on this basis. To avoid errors of parallax the observer must hold the measure vertical with the meniscus exactly at eye-level when making a reading. The tapered measure is provided with duplicate engravings of the main graduation marks at the back of the glass to facilitate accurate reading.

The larger labelled divisions on the glass represent whole millimetres and the intermediate divisions represent tenths. The lowest division, the marking of which is carried completely round the glass, is figured 05 on some measures and represents half a tenth of a millimetre (0·05 mm). It is there for a special purpose, namely to distinguish between a reading to be logged as 0·1 mm and a reading to be logged as a 'trace'. If the bottom of the meniscus is below this special graduation the entry is trace (abbreviated in the Register to 'tr'). If the bottom of the meniscus is exactly on the special graduation, or between it and the next division, the reading is logged as 0·1 mm.

Higher readings are expressed to the nearest tenth of a millimetre, thus 0·7, 1·0, 2·3, etc. The figure '0' must be entered before the decimal point when the amount is below one whole millimetre. In other instances the whole millimetres are given by the number against the figured main division next below the meniscus, and the tenths are obtained by counting upwards from this division to the intermediate division nearest in line with the bottom of the meniscus. When the bottom of the meniscus is half-way between two graduation lines the reading is thrown to the odd value. Readings of whole millimetres must be logged with a zero following the decimal point, thus 2·0 etc.

Every drop of rain must be poured from the bottle into the measure and, after reading, the measure should be stored inverted to drain. It may be preferable to take a clean bottle to the rain-gauge at every reading, and take the used bottle indoors. The rainfall can then be measured, especially on a wet and windy day, with greater accuracy and at no discomfort to the observer. If the catch of more than one gauge has to be measured the bottle must be labelled. If the measurement has to be made at the site of the rain-gauge, care must be taken to avoid loss by spillage when the wind is strong; the lee side of the thermometer screen may provide some shelter. When precipitation is occurring at the time of measurement, the whole operation should be carried out as quickly as possible because some precipitation will be lost while the rain-gauge is dismantled. Bottles used for hourly readings should not be artificially dried out.

The entry 'tr' for a trace is to be made in the following two instances. Firstly, when there is less than 0·05 mm of water in the gauge, and the observer knows that this is not the result of a drop or two draining from the sides of the bottle after emptying the rain-water at an earlier observation time, and he can be reasonably certain that there has been precipitation since the preceding measurement. If the observer knows that the deposit in the gauge results from dew, wet fog, hoar frost or rime, an appropriate note should be made in the remarks column of the register (for example, tr(w), tr(fe), tr(x)). (The entry tr(w) is not made just because the observer sees dew on the grass.) Such deposits are sometimes more than 0·05 mm, in which case the measured amount is recorded. Secondly, the entry is to be made when the observer knows definitely from his own observation that precipitation (other than dew, wet fog, hoar frost or rime) has fallen since the preceding observation and yet finds no water in the gauge. This happens sometimes, especially in warm dry weather; the gauge may not even be damp, the small amount of rain having evaporated before it could run into the bottle. In such circumstances, particularly when no scheduled observation is made at a time which would include note of the precipitation, the observer should enter an appropriate note such as 'slight shower of rain' (or the appropriate Beaufort letters) and the time, if known, in the remarks column of the Register.

When the amount of rainfall is nil, the entry in the Register should be '—' not '0·0', but for certain data sheets different instructions may be given.

9.3.5. Care of the rain-gauge and rain measure. The gauge should be inspected from time to time to ensure that it is in sound condition and free from leaks. Such inspections are specially important for copper gauges which may become distorted or develop leaks. If a Mk 3 gauge is being used it should be noted that this type, made of glass fibre, is liable to chipping of the rim and cracking of the collector.

The best method of testing the funnel is to close the outlet tube with the thumb and plunge the funnel, rim downwards, into a bucket of water; any leak will immediately be revealed by air bubbles. Water should never be found in the outer case unless the bottle and inner can of the copper gauge have overflowed after quite exceptional rainfall. If water is found in the outer case under any other circumstances the case must be removed from the ground, tested for leaks, and any leaks repaired before it is set properly back into the ground.

The height and level of the rim of the gauge should be checked from time to time and corrected if necessary.

The gauge must be kept clear of fallen leaves or other debris which might block the opening and thus prevent the collected water from flowing into the receiver.

Bottles used with gauges should be kept clean; cracked bottles should be replaced at once. Beside being narrow-necked, the bottle should be sufficiently tall to permit the delivery tube to enter it, yet not too tall to foul the underside of the funnel. The delivery tube must be guided gently into the neck of the bottle. If the tube is banged hard against the bottle it will cause ridging and denting at the base of the funnel. The measure should also be kept clean and should be stored, preferably inverted, in a safe place when not in use.

Care must be taken to avoid damage to the rain-gauge when the grass is being cut around it. To reduce the risk of the gauge being damaged by grass-cutting equipment the turf should be removed for a few centimetres around the gauge and replaced by small stones or granite chippings; never surround the gauge with concrete, tarmac or other solid surface as this may cause insplashing.

9.3.6. Hours of reading. All types of station equipped with rain-gauges should take readings at 0900 GMT. Additional readings are taken at certain types of station in the United Kingdom as follows:

(*a*) Meteorological Office and auxiliary stations which make observations at 2100 GMT should take additional measurements at that time.

(*b*) Stations which contribute observations to the Health Resort Bulletin should take additional measurements at 6 p.m. clock time.

(*c*) All Meteorological Office stations, and those auxiliary stations making full synoptic observations and are able to, should take additional measurements at 0000, 0600, 1200 and 1800 GMT for synoptic purposes.

To ensure as far as possible the accuracy of rainfall measurements for climatological purposes, the standard rain-gauge should be used only for measurements at 0900 and 2100 GMT; stations as in (*b*) above may also use the gauge for their special readings at 6 p.m. clock time, pouring the water back into the collector when the measurement has been made. Rainfall totals should be carefully checked to ensure that they refer to the correct overall period when intermediate measurements are taken. Meteorological Office and auxiliary stations which make additional readings at other times should use a second rain-gauge for this purpose; this second gauge will be either a tipping-bucket or a 5-inch gauge or both (the latter acting as a back-up to the former where both are provided). This second gauge (or gauges) should be sited in the most convenient position which satisfies the rules for rain-gauge exposure (see I.9 of Appendix I, page 188).

Special instructions are issued to stations abroad.

9.4. MEASUREMENT OF SOLID PRECIPITATION

Special methods of measurement are required when the rain-gauge contains solid precipitation, whether originating from snow, snow pellets, snow grains, hail, small hail, ice pellets, diamond dust, or a mixture of rain and snow (sleet), or from rain-water which has frozen after falling.

The World Meteorological Organization has laid down that 'the amount of precipitation shall be the sum of the amounts of liquid precipitation and the liquid equivalent of solid precipitation'. With slight snowfalls, in little or no wind, no especial difficulty is encountered and the procedure in 9.4.1 should be followed. Reliable measurements of snowfall in stronger winds are very difficult and depend much on the zeal and skill of the observer in following the guidance given in 9.4.2.

The rainfall equivalent of any snowfall is determined in two ways, depending on the circumstances at the time of the snowfall. These are either the measurement of the liquid equivalent of any snow which has accumulated in the gauge funnel and receiver since the previous specified time of measurement or by obtaining an estimate of the equivalent rainfall by sampling level undrifted fresh snow. A quite separate climatological observation of the total depth of snow lying is made at 0900 GMT (see 9.7). There are a number of important reasons for requiring these measurements; not least is their use in the assessment of the amount of water which would be released in a sudden thaw, and the possibilities of river flooding.

In discussing the two measurements required when snow has fallen, namely the liquid equivalent and total depth of snow lying, reference is made to level undrifted snow. It is important, particularly during any prolonged cold spell when there may be further falls of fresh snow, that the area where measurements are made is as free from disturbance as is practicable. Random trampling of the snow surface may make it difficult to obtain representative samples. The path to and from the area should be chosen with care and maintained on subsequent visits, extending for further sampling only as necessity dictates.

9.4.1. Measurement of solid precipitation using the rain-gauge: liquid equivalent. When there have been no more than light winds during the period since the previous scheduled observation and there has been a comparatively slight fall of solid precipitation, the amount (liquid equivalent) may be measured by one of the following three methods; the first method should be used only when precipitation is not occurring at the time of observation.

(*a*) The rain-gauge funnel and receiver are brought indoors, the contents melted and the water measured in the normal way. The top of the funnel should be covered by a flat plate to minimize the loss by evaporation. Excessive heat should not be applied because, in addition to the possible loss of precipitation by evaporation even if the funnel is covered, there is a risk of melting the solder on a copper funnel.

(*b*) A cloth dipped in hot water is applied to the outside of the funnel and receiver to melt the snow or ice. Ensure that no water from the cloth enters the gauge.

(*c*) Some warm water is accurately measured in the appropriate rain measure and then poured into the gauge. Only sufficient warm water to melt the snow or ice should be used. The amount of water added is subtracted from the total measured. About two rain measures full of water at about 40 °C will be required if the funnel is full of snow. This method is to be preferred for glass-fibre gauges.

When rain collected in the bottle turns to ice, the bottle must be warmed gently to thaw the ice without cracking the bottle. If the bottle is found to be cracked the ice must be thawed in such a way that no part of the càtch is lost. The observer must take care to avoid being cut by broken glass.

9.4.2. Measurement of solid precipitation: other methods. Moderate or heavy falls of snow, particularly if accompanied by other than light winds, will probably make the methods described in 9.4.1 inappropriate. Wind eddies may carry snow clear of the gauge or even out of the collector. If the wind is strong, lying snow may be raised into the air and be blown into the gauge. In extreme cases the entire gauge may be buried in snow. In those circumstances the rain-gauge is unusable and special methods of measurement are required. The procedures which should be adopted are detailed below.

9.4.2.1. *When all the precipitation has occurred as snow and no snow was on the ground prior to the period of snowfall to be measured.* Obtain a sample by pressing the inverted funnel of the rain-gauge (not a glass-fibre gauge) vertically downwards through level undrifted snow until it reaches the ground. Melt the sample indoors and measure the liquid in the rain measure appropriate to the rain-gauge (to the nearest 0·1 mm).

It can be extremely difficult to judge from an extensive stretch of apparently level and uniform snow where a representative sample should be taken. For this reason it is advisable to take three samples several metres apart. Each of the three samples should be melted separately and the average reported. The maximum and minimum values of the liquid equivalents should be noted so that, in the event of the rainfall equivalent being queried, some indication can be given of the possible spread of the readings upon which the final reported figure will have been based.

When depths greater than about 15 cm occur, each sample should be taken by dividing the total depth into two or more layers by inserting a piece of sheet metal or hardboard into the snow at the appropriate depth, after clearing some snow adjacent to one side of the sampling area.

An alternative method is available for those observers who have accurate weighing facilities. A tube of about 5 to 8 cm diameter and with a sharp edge is used to obtain a core of snow by pressing the tube vertically downwards through level undrifted snow until it touches the ground. Weigh the tube and the sample and, after deducting the weight of the tube, convert the weight of the snow to an equivalent depth of rainfall, as in the following example.

	Weight of tube + snow	= 55·1 grams
	Weight of tube	= 35·0 grams
Thus	weight of sample collected	= 20·1 grams.

The 20·1 grams of snow equates to 20·1 grams of water which has a volume of 20·1 cm^3. The rainfall equivalent of the snowfall collected is given by

$$\frac{20{\cdot}1}{\text{Cross-sectional area of the tube}} \text{ cm.}$$

If the internal diameter of the tube is 5·0 cm, its cross-section area is $\frac{\pi \times 5 \times 5}{4}$ cm², i.e. 19·6 cm².

Thus the rainfall equivalent becomes $\frac{20 \cdot 1}{19 \cdot 6}$ cm = 1·03 cm = 10·3 mm.

The tube method does not work with wet snow.

9.4.2.2. *When snow has fallen or been blown on to the ground prior to the period of snowfall to be measured*, a clean surface must first be prepared to receive any further snowfalls. This can be provided by a wooden board (with a slightly rough surface, painted white) placed level on the top of the snow with its upper surface flush with the snow surface. The board should be swept clean of snow immediately after each snowfall measurement and replaced on the level snow as before.

The selected site should avoid places where drifting is likely or over-exposed places where snow is unlikely to accumulate in strong winds. The position of the board should be indicated by a thin cane so that it can be located under the snow.

When such a board is used, samples of snow taken from it can be treated by either of the methods in 9.4.2.1 to obtain the liquid equivalent.

9.4.3. When precipitation changes from snow to rain or drizzle between scheduled hours of observation. No special action is required when conditions described in 9.4.1 hold. In other conditions the observer should, as soon as possible, carry out the procedure detailed in 9.4.2.1 or 9.4.2.2, as appropriate, and set the rain-gauge ready to receive the liquid precipitation then falling. A note should be made in the Register of the time and the liquid equivalent of the sample taken. This liquid equivalent should be added to the amount of precipitation subsequently caught in the normal way by the rain-gauge to give the total amount of precipitation at the next scheduled hour of observation.

9.5. RECORDING RAIN-GAUGES

Recording rain-gauges are used to keep a continuous record of rainfall amount against time. The type principally used by the Meteorological Office is the tilting-siphon rain recorder (see 9.5.1). A tipping-bucket rain-gauge (see 9.5.2) can be converted to a rain recorder by the addition of a recording unit (see 9.5.3.).

Rain recorders are usually installed in conjunction with a standard collecting rain-gauge. It is the measurement of the rain in the standard rain-gauge which is reported for climatological purposes. At those selected stations which are issued with a tilting-siphon rain recorder the total rainfall from the standard gauge is supplemented by the analysis of the permanent record chart to provide details of times of onset and cessation of rainfall and any variations of intensity. A tipping-bucket gauge is usually used when rainfall is reported for synoptic purposes (although manually read gauges are also used), and the rainfall derived from the number of tips over a period (hourly or six-hourly) is the amount reported in this particular case. With the introduction of the magnetic-tape event recorder (see 9.5.3), subsequent interpretation of the magnetic tape can provide similar information to that from the tilting-siphon rain recorder.

Details of several types of recording rain-gauges are given in the *Handbook of meteorological instruments*.

9.5.1. Tilting-siphon rain recorder. The mechanism of the Meteorological Office tilting-siphon rain recorder, Mk 2, is illustrated diagrammatically in Figure 14. The water collected by a large funnel 287 mm (11·30 inches) in diameter falls into a chamber A and raises a plastic float B which is provided with a vertical rod to which the recording pen is attached. The chamber A is mounted on knife-edges C and is so arranged that it overbalances when full of water, sending a surge of water through the double siphon tubes D which empty the chamber and allow the pen to return to the zero of the chart. The overbalancing is controlled by a trigger E which is released by the rising float at a predetermined point. As the float chamber empties, the centre of gravity shifts to the left and under the action of the counterweight F the system resets itself to the normal working position. A rain trap G reduces the loss of precipitation during the siphoning period which should be completed within 8 seconds. By means of an upright rod H, the pen is automatically lifted clear of the chart as soon as the chamber starts to overbalance.

The earlier version of this recorder, the Mk 1 (Plate XXVIII), has only one siphoning tube and in consequence the siphoning takes a minimum of 15 seconds. The float, being of metal, is liable to sustain damage if the water in the chamber becomes frozen. There is no rain trap to reduce the loss of precipitation during the siphoning period.

The metal float cannot be interchanged with the plastic float but the whole of the float-chamber assembly can be replaced by the Mk 2 float-chamber assembly. This assembly not only includes the plastic float but also the two siphoning tubes and the rain trap. Full details and instructions are given in the instructions which are available from the Operational Instrumentation Branch of the Meteorological Office.

9.5.1.1. *Method of use.* The chart should be changed daily at about 0900 GMT and as nearly as possible at the time of reading the standard rain-gauge; at the same time the clock should be wound. The pen reservoir should be topped up if a fibre-tipped pen is not in use. When fitting the new chart on the drum, corresponding graduations on the overlapping portions should be coincident and the chart should be as close as possible to the flange on the bottom of the drum. The end of the chart should overlap the beginning. When adjusting the drum so that the pen is at the correct time on the chart, the drum should be turned counter-clockwise (when viewed from above) to avoid backlash, but every effort should be made to set the time correctly at the first attempt. Only daily clocks may be used.

A time mark should be made on the chart within two hours of the commencement of the record (but not within the first half hour) by gently depressing the float-chamber centre spindle enough to make a small mark. If possible another time mark should be made when the record is about half completed. Care should be taken that the pen does not 'bounce' above the rainfall trace. No time mark should be made when precipitation is occurring.

Full station details, the times of the time marks, the time the record commenced and ended, should be entered on the old chart. The times should be noted to the nearest minute. The serial number should be taken from Met. O. Leaflet No. 11, The Meteorological Office Calendar.

The readings of the total rainfall each day should always be compared with the readings of a standard rain-gauge exposed nearby. Any errors in the readings of the recording instrument, apart from small discrepancies caused by slight under-recording of the value of total precipitation, should be investigated immediately.

9.5.1.2. *Testing the tilting-siphon rain recorder.* The instrument should be tested regularly, especially when no precipitation has occurred for some time, by pouring successively into the funnel equal quantities of water corresponding to some specific interval on the chart. This quantity is best measured out in a rain measure, but the equivalent rainfall has to be calculated by taking into account the relative diameters of the apertures of the tilting-siphon gauge and the gauge for which the measure was graduated. For example, if a rain measure graduated for a 5-inch rain-gauge is used, the amount in the measure needed to obtain a reading of one millimetre on the tilting-siphon would be $(11{\cdot}31/5)^2 = 5{\cdot}1$ mm.

9.5.1.3. *Care of the tilting-siphon rain recorder.* The inside of the funnel should be kept clean by being rubbed with a damp rag; polish must not be used. The hinge should be oiled occasionally.

The time taken to siphon should be checked occasionally to establish that the outlet tubes are not partially blocked; the correct siphoning period should be about 8 seconds for a Mk 2 recorder and 15 seconds for the Mk 1. The drain-filter through which water from the siphon tube passes to the base of the instrument should occasionally be inspected and cleaned if possible, although access to this part is very difficult. Methylated spirit may be used if necessary.

The rain trap fitted above the float chamber should periodically be taken off and inspected and cleaned. The filter should be cleaned with methylated spirit. If the small hole in the rain trap leading to the drain becomes blocked, the small rubber cap on the end of the tube should be removed and the hole cleaned out with a piece of wire. A light smear of silicone grease applied very occasionally to the inside of the rain trap will improve the run-off, but care should be taken that the grease does not block the hole.

9.5.1.4. *Frost protection.* In temperatures below freezing, if no form of heating has been installed, the water in the float chamber will freeze, thus causing the recorder to become inoperative. The plastic float in the Mk 2 recorder will not be affected by the ice in the float chamber but the metal float in the Mk 1 will be liable to damage. To ensure continuous efficient operation of the recorder in frosty weather some form of heating is required. This heat is not intended to melt frozen precipitation but purely to prevent freezing of the rain-water already inside the chamber of the gauge.

The Meteorological Office uses a standard rain-gauge heater in which a low-voltage, low-wattage, flexible heating element is used in conjunction with a thermostat. The heating element operates from a 24-volt d.c. or a.c. supply, and either heavy-duty accumulators, or a mains supply through a suitable

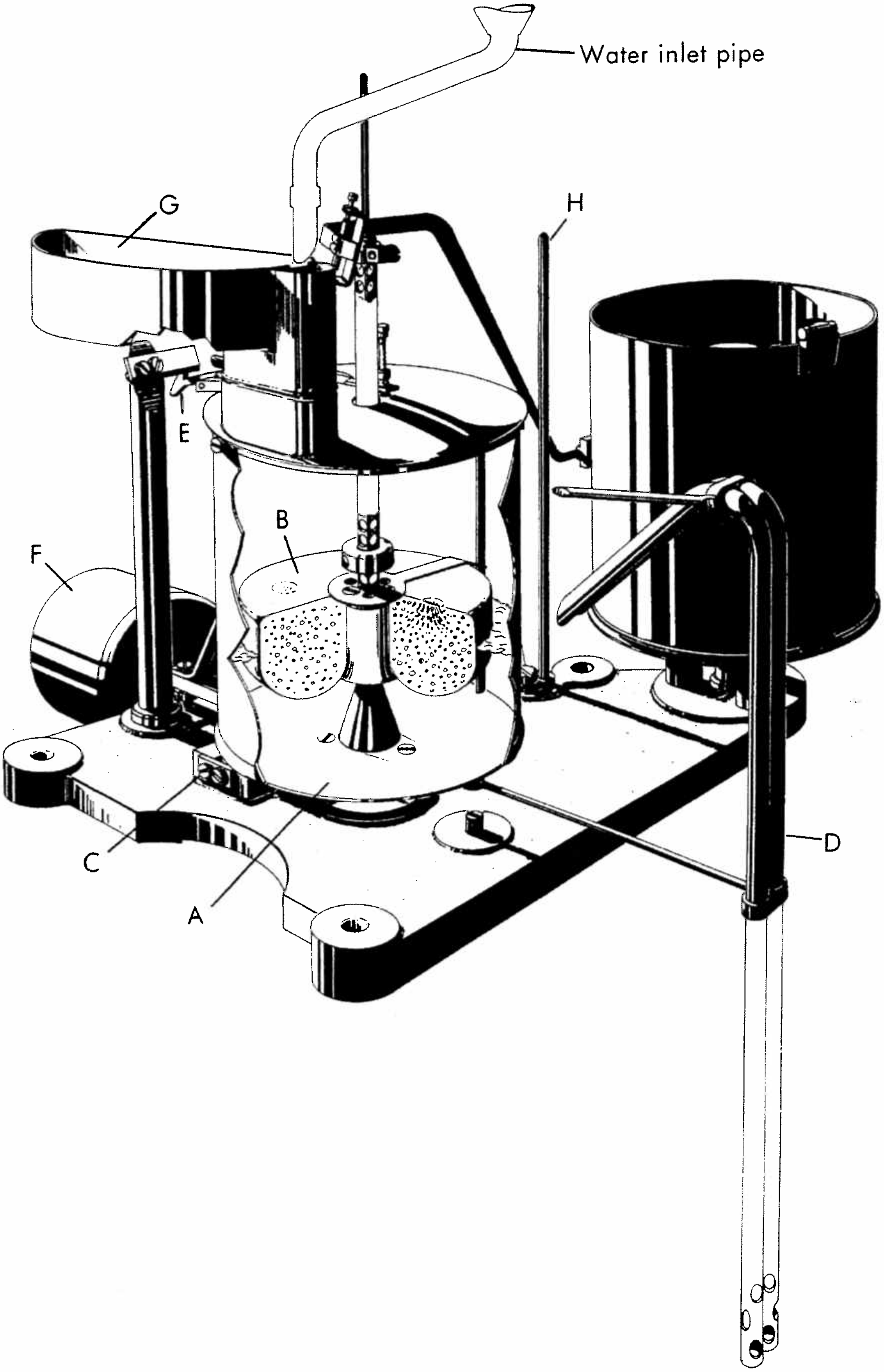

Figure 14. Meteorological Office tilting-siphon rain recorder

A	Collecting chamber	E	Trigger
B	Plastic float	F	Counterweight
C	Knife-edges	G	Rain trap
D	Double siphon tubes	H	Pen-lifting rod

transformer, may be used. The heat is spread around the circumference of the gauge while the thermostat, set to operate at a few degrees above freezing, ensures both freedom from overheating and the minimum use of power. To reduce power consumption a tailored kit of insulation material is available that will prevent freezing down to approximately −10 °C.

An alternative method is to heat the gauge by using a 12-volt supply from a suitable transformer or a battery to supply a low-voltage bulb, with its lamp-holder fitted to the base at the side of the float chamber opposite the chart drum. A 25-watt lamp will prevent freezing down to approximately −10 °C. *Under no circumstances must a high-voltage mains supply be connected direct to the recorder; the maximum voltage which may be connected to a rain-gauge is 30 volts a.c. or 50 volts d.c.*

9.5.2. Tipping-bucket rain-gauges. The Meteorological Office tipping-bucket rain-gauge (Figure 15(a)) is a version of the glass-fibre Mk 3 system (see 9.3.2) which is used to provide a remote indication of rainfall in increments of 0·2 mm. The collecting funnel has a sampling area of 750 cm² and the rim must be 450 mm above the surrounding ground level. From Figure 15(a) it will be seen that for such a requirement very little of the flared support tube is buried. To give the gauge the necessary stability it is bolted down on to a concrete slab.

During the next few years the Mk 3 will be replaced by the Mk 5 tipping-bucket rain-gauge (Figure 15(b)). In principle the system is the same as the Mk 3. Improvements to the design include the use of jewel bearings in the bucket assembly and in general accessibility. The 750 cm² collector can be removed as a whole without disturbing the tipping-bucket mechanism which sits on a large base plate.

The principle of operation of a tipping bucket is that a stainless-steel bucket, divided into two equal compartments, is pivoted at its base so that only one of the compartments will collect the water from the gauge funnel at any one time. When one compartment has collected 15 cc (equivalent to 0·2 mm of rainfall) the bucket overbalances, tips and empties, bringing the second compartment under the collecting funnel. Stops are fitted to prevent the bucket from completely overturning. Each tip of the bucket activates a reed switch which in turn operates an electromagnetic counter.

9.5.2.1. *Operational procedure.* Those meteorological offices and auxiliary stations which are required to make additional rainfall readings for synoptic purposes should be equipped with a second rain-gauge for this purpose, which is often a tipping-bucket gauge with an electromagnetic counter.

At the hour of observation the observer should note the counter reading. To obtain the amount in millimetres of rain which has fallen during the preceding 1, 6 or 12 hours as required, the observer should subtract from the current reading the counter reading he noted 1, 6 or 12 hours before; he can then either multiply the result (the difference in the number of tips) by 0·2 mm or divide the difference by five to obtain the rainfall in millimetres; for example, 21 tips = 21 × 0·2 mm = 4·2 mm, or 21 ÷ 5 = 4·2 mm. If a small amount of precipitation is known to have occurred but there is no change shown on the counter, the observer is to record 'tr'; on certain data sheets an encoded entry representing 'trace' is made.

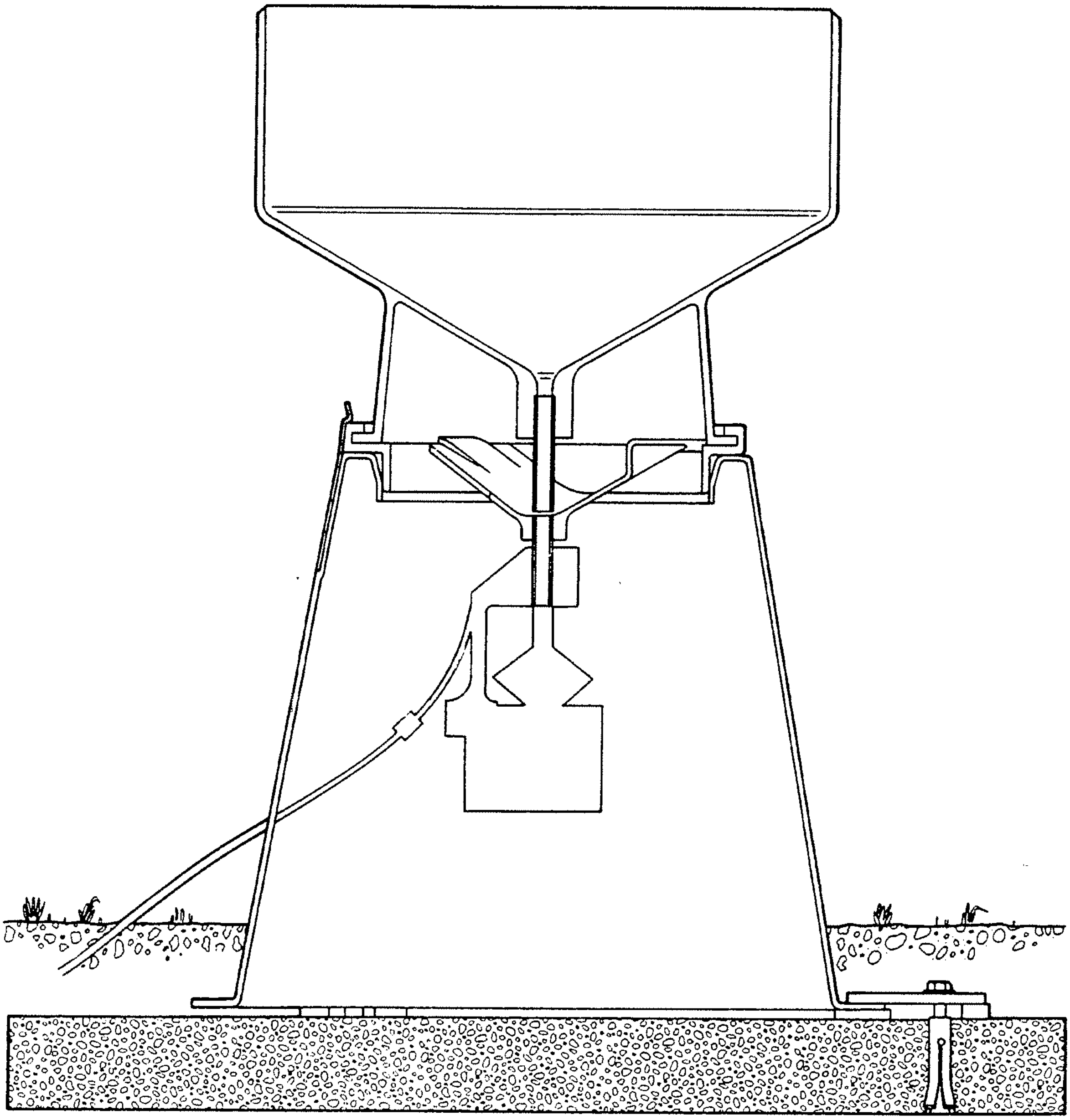

Figure 15(a). Tipping bucket rain-gauge Mk 3

The procedure for dealing with solid precipitation in a tipping-bucket gauge is detailed in 9.5.2.5.

9.5.2.2. *Care of the tipping-bucket gauge.* Once the rain-gauge is installed and calibrated, care should be taken not to disturb the system; for instance, a hard knock may alter the calibration or cause a nearly full bucket to tip.

The collector funnel must be kept free of obstructions such as fallen leaves, grass cuttings, etc., but any cleaning should be done gently without disturbing the tipping-bucket switch. Should it be necessary to detach the collector funnel of a Mk 3 gauge, it should be eased free of the retaining lugs without shaking the support tube and laid gently on its side to avoid chipping the rim. The funnel should be refitted to the support tube with equal care.

At six-monthly intervals the tipping-bucket switch should be carefully lifted just free of the gauge and the buckets examined to see if they contain silt. It is

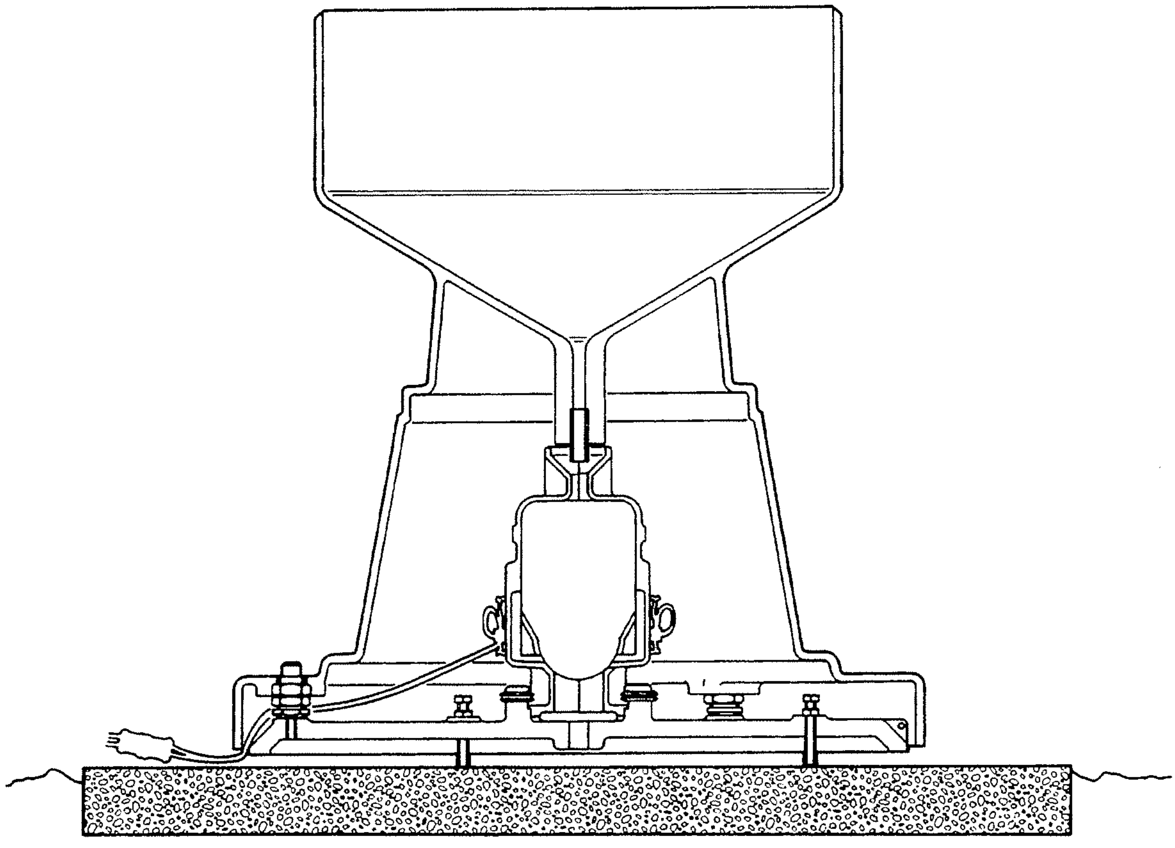

Figure 15(b). Tipping bucket rain-gauge Mk 5

advisable to disconnect any recording device from the gauge before inspection is carried out but the recording device should not be switched off. If a bucket contains more than a light deposit of silt it should be cleaned by using a small paintbrush. Care must be taken during this operation not to damage the reed relay or the light metal arm that holds the magnet. If possible, the funnel should be replaced in the same position that it occupied before cleaning. Meteorological Office recorders will be serviced by the Maintenance Organization.

9.5.2.3. *Routine performance checks.* At about monthly intervals, or when a cumulative rainfall total exceeding 10 mm has been reached, the total obtained from the standard check-gauge should be compared with the product of the calibration value and the number of tips obtained from the counter in the same period. Differences should not normally exceed 5 per cent. A discrepancy greater than 10 per cent indicates that the calibration has probably changed.

A simple test may be performed by slowly pouring water into the gauge and listening for the noise made when the bucket tips; the amount of water used must be noted and an appropriate correction made to the amount next reported. If no tips are heard, there may be excessive bearing friction or a leak between the buckets may allow the water to escape. If tips are heard but nothing is recorded a technician's services will be required.

9.5.2.4. *Calibration.* The tipping-bucket rain-gauge should be calibrated at six-monthly intervals and at Meteorological Office stations this is carried out by the Maintenance Organization. The Operational Instrumentation Branch may be able to supply instructions, on request, for privately owned gauges.

9.5.2.5. *Solid precipitation in a tipping-bucket rain-gauge.* If snow or hail has fallen and there is solid precipitation in the gauge, hourly measurements are to be discontinued. The hourly entries over this period will be 'snow (or hail) affecting rain-gauge'. At main synoptic hours the funnel should be cleared of snow or hail (measurement of the liquid equivalent being made). This liquid equivalent is poured carefully back into the tipping gauge so as to obtain a final reading on the counter; this reading should be entered in brackets in the Daily Register.

9.5.3. Magnetic-tape event recorder. The Meteorological Office magnetic-tape event recorder is designed for use in remote locations with the tipping-bucket rain-gauge to provide a record of rainfall over periods of up to three months.

The battery-powered recorder consists of an incremental tape deck which records on magnetic tape contained in a large cassette. The recorder places a magnetic pulse on two of the four tracks each time the bucket tips, and a similar pulse is written on the remaining tracks once per minute following a signal from the recorder's internal electronic clock. Connections to the recorder should only be by circuits which have been specifically approved.

The recorder is housed in a hermetically sealed glass-fibre box and may be installed indoors or outdoors. Installation, operation and maintenance instructions are given in the handbook issued with the equipment. At Meteorological Office stations installation and regular maintenance is carried out by staff of the Maintenance Organization.

Although designed to run for longer periods, the cassette is usually changed at monthly intervals. The procedure for removing the used cassette and replacing it with a new one are dealt with fully in the operating instructions. The used cassette is sent to Meteorological Office Headquarters at Bracknell where the tape is translated and the information processed by computer to give hourly, daily and monthly rainfall totals. If the recorder unit is located outside and is brought inside a building for the cassette to be changed, care should be taken to prevent condensation forming on the inside of the recorder unit when it is opened.

9.6. GRAVIMETRIC RAIN-GAUGE

It has long been appreciated that the amount of rainfall collected by a conventional type of rain-gauge is likely to be less than the actual rainfall at the site of the gauge. The defect can arise from various causes, but by far the most common is due to the effects of the turbulent air flow near the ground. Various methods have been employed to eliminate or reduce the effect of the wind on the catch of a gauge; one method is to mount the gauge with its rim level with the ground (flush gauge) and to surround it with an artificial surface to minimize the effect of in-splash. Gauges mounted like this, together with their surrounding surface, can however still cause wind eddies which affect the catch.

The Meteorological Office has developed a flush type of gauge called a gravimetric rain-gauge which collects the precipitation in a pan of diameter 1·21 m mounted on a weighing-machine placed in a concrete-lined pit in the ground. The rim of the pan is level with the surrounding ground. The whole pan is covered by a stainless-steel mesh; the mesh and a circular area extending 2 m from the rain-gauge pan are covered with granite chips to form a homogeneous surface (apart from the small gap between the pan and the pit lining). The water can flow readily through the layer of granite chips into the pan. This construction of the collecting area of the gauge, together with its surrounds, has been designed to affect the airflow over the instrument as little as possible, and also to minimize the net effect of splashing. The weight of the pan and its contents is converted to give a millivolt analogue output which is registered on a recorder. Experiments have shown that this gauge will measure precipitation more accurately than other gauges used by the Meteorological Office but it is still undergoing tests; it is not anticipated that their distribution will be widespread when eventually they are introduced operationally. They will act as reference gauges at a few selected sites in the British Isles.

9.7. MEASUREMENT OF SNOW DEPTH

At climatological stations the total depth of snow lying at 0900 GMT is to be noted in the remarks column of Metform 3100 (Pocket Register). The symbol [✳] may be used as an abbreviated indicator with the total depth shown at the right-hand side. The depth should be measured in centimetres, using a ruler* held vertically when more than half the ground representative of the station is covered in level snow, in a space free from drifting and not scoured by wind. The spot so described should be chosen to be as near as possible to the rain-gauge. If practicable, the mean of three such measurements at different spots should be taken.

At full synoptic stations the total depth of snow is reported at 0600 GMT in the coded synoptic message. In addition, the total depth of snow is reported in a special group at 0600, 0900, 1800 and 2100 GMT whenever snow is lying to an undrifted depth of 0·5 cm or more. If as a result of fresh snowfall, or the thawing of existing snow cover, the depth has changed by 2 cm or more since the last report, the new depth is reported at any main or intermediate synoptic hour. Most synoptic stations also report the total depth of snow and the depth of fresh snow at 0900 GMT in a separate message for climatological purposes. Instructions for observations of cover, character and regularity of snow at synoptic stations are given in the *Handbook of weather messages*, Parts II and III, and specific instructions are issued to certain stations.

*The ruler should either be adapted to read zero at ground level or alternatively a note should be made of the length of the short gap between the end of the ruler and the zero mark. A metre rule is preferable.