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Acquisition and management of meteorological precipitation data from a gauge network

Part 3: Code of practice for the design and manufacture of storage and automatic collecting raingauges

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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to ii, pages 1 to 26, an inside back cover and a back cover.

Foreword

Publishing information

This part of BS 7843 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 29 February 2012. It was prepared by Technical Committee CPI/113, *Hydrometry*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

Together with BS 7843-1:2012, BS 7843-3:2012 supersedes BS 7843-3.1:1999 and BS 7843-3.2:2005, which are withdrawn.

Relationship with other publications

BS 7843, *Acquisition and management of meteorological precipitation data from a raingauge network*, comprises four parts.

- *Part 1: Guide for design, development and review of a raingauge network.*
- *Part 2: Code of practice for operating raingauges and managing precipitation data.*
- *Part 3: Code of practice for the design and manufacture of storage and automatic collecting raingauges.*
- *Part 4: Guide for the estimation of areal rainfall.*

Information about this document

This is a full revision of the standard.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Introduction

Rainfall totals and intensity rates are measured at frequencies ranging from seconds to months, and the data are required by the user on timescales ranging from the immediate to several weeks in arrears. Measurements are made by many different organizations and individuals using various types of raingauges and techniques.

This British Standard covers instrumentation that measures rainfall by collecting the volume of water that falls on a fixed area. The collected volume of water is divided by the fixed area of the colleting device to give a value for volume per unit area, termed rainfall depth, and measured in millimetres. Raingauges may also be used to measure solid precipitation, although their performance for this purpose is generally poor and other measurement methods ought to be considered if accurate measurements are required. Unlike many other meteorological instruments, there is no absolute physical standard against which a raingauge can be compared [1]. It is important to recognize that different raingauge instruments and different technologies can yield a range of indicated measures of rainfall.

Many different types, shapes and sizes of raingauge are acceptable for the measurement of rainfall, each reflecting a specific requirement. Most consist of a circular collecting device, delineating the fixed area of the sample, and a funnel leading into a storage reservoir and/or measuring system. Some types of automatic gauge do not require a funnel.

The amount of rainfall collected in a raingauge is affected by the speed of the airflow over the gauge collecting device and the proximity of obstructions such as trees or buildings. In addition, the shape of the collecting device causes an obstruction to the wind flow pattern and the increase in air speed across the gauge orifice can result in the smallest raindrops being swept away from the collecting device and not being measured.

NOTE For the purposes of this standard the thermal expansion coefficient for water is not considered due to its negligible effect on rainfall measurement when all other uncertainties are considered.

1 Scope

This part of BS 7843 gives recommendations for the design and manufacture of storage and automatic collecting raingauges to be deployed at ground level, or close to the ground, for measuring the amount of rainfall in millimetres of water equivalent, either for a dedicated purpose at a specific location or as part of a network covering a large area. It is not applicable to remote sensing devices that detect the presence of precipitation particles or to weather radars.

BS 7843-1 provides information on the selection of raingauges depending on user requirements.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 7843-1, *Acquisition and management of meteorological precipitation data from a raingauge network – Part 1: Guide for design, development and review of a raingauge network*

BS 7843-2, *Acquisition and management of meteorological precipitation data from a raingauge network – Part 2: Code of practice for operating raingauges and managing precipitation data*

BS EN ISO 772:2001, *Hydrometric determinations – Vocabulary and symbols*

BS ISO 385, *Laboratory glassware – Burettes*

CEN/TC 318 N 320, *Hydrometry – Measurement of the rainfall intensity (liquid precipitation) requirements, calibration methods and field measurements*

OIML R111:2004, *Weights of classes E1, E2, F1, F2, M1, M1–2, M2, M2–3 and M3*

3 Terms and definitions

For the purposes of this part of BS 7843, the terms and definitions given in BS EN ISO 772:2001 and the following apply.

3.1 calibration
process which establishes, under specified conditions, the relationship between the values indicated by a raingauge and the corresponding known values indicated by a measurement standard with associated measurement uncertainties

3.2 dip rod
calibrated marked rod used to measure rainfall from the measurement of the depth of water in the collecting vessel

3.3 maintenance
process that ensures that the site and equipment continue to function correctly for the measurement of precipitation

3.4 manual reading
measurements of precipitation made by an observer using a storage raingauge and a rain measure

3.5 observer
person who makes a manual reading

3.6 precipitation
water or ice derived from the atmosphere and deposited at ground level

NOTE Measured in terms of the depth in mm of its liquid equivalent.

3.7 rainfall
total liquid component of precipitation, including condensation from the atmosphere collected and measured by a raingauge

3.8 rainfall collecting vessel
container that stores collected rainfall

3.9 rainfall intensity
accumulated precipitation in unit time

3.10 rain measure
graduated measuring cylinder made of clear glass or plastic, used by the observer for measuring the volume of collected liquid and melted solid precipitation

3.11 raingauge

3.11.1 automatic raingauge
collecting raingauge that measures rainfall by automatic means

NOTE This may include data processing and logging capability.

3.11.2 collecting raingauge
instrument that collects precipitation falling through an orifice of known cross-sectional area for the measurement of its water equivalent volume, mass or weight accumulated over a measured period

3.11.3 storage raingauge
collecting raingauge that accumulates rainfall and melted solid precipitation in a collecting vessel for manual measurement of its volume

3.12 real-time data
data obtained while the precipitation event to which it relates is occurring

3.13 site
area of ground where a raingauge is deployed for measurement or has been deployed in the past

NOTE Other instruments for measuring the environment may also be deployed at the site.

4 The UK reference storage raingauge

A storage raingauge should be constructed in accordance with Annex A, which gives recommendations for the UK reference gauge.

NOTE Over the last 100 years or so, storage rainfall measurements in the UK have been made using a basic design (or close variants) having a level circular collecting device 127 mm (5 in) in diameter, exposed at 305 mm (12 in) above the ground. The long record of rainfall data and extensive raingauge field trials have resulted in this type of storage gauge being established as the reference daily raingauge.

5 Main components of a collecting raingauge

Functionally, all collecting raingauges should comprise the following two component subsystems.

a) The collecting device (see Clause **6**), which acts to intercept and capture a portion of the incident precipitation.

b) The measurement device (see Clause **7**), which measures the collected rainfall.

Automatic raingauges may be optionally fitted with heaters (see Clause **8**).

An automatic raingauge should have an additional component sub-system comprising the following elements: signal processing, data logging and data transmission.

6 The collecting device

6.1 Design criteria for the collecting device: manually read and automatic raingauges

6.1.1 The rainfall capture component should be constructed such that the incident rainfall captured is independent of the direction of wind over the raingauge (a round orifice satisfies this recommendation).

6.1.2 The design of the gauge should minimize the vertical component of airflow over the raingauge orifice.

6.1.3 The upper part of the collecting device that delineates the collecting area should have a sharp edge, formed by an external bevel and with the inner face vertical. The material of which it is manufactured should be sufficiently robust to retain the sharp edge for the intended lifetime of the raingauge.

6.1.4 An automatic raingauge should be provided with a mechanism to allow the rim edge to be adjusted to be horizontal while in service or the design should maintain plane of rim level to within ±2° of the base plane. This mechanism should be designed and constructed to retain this setting for the intended duration of deployment.

NOTE Storage raingauges need to be installed in a level and stable manner. See BS 7843-2 for further information.

6.1.5 The diameter of the edge of the collecting device should not differ by more than 0.2% of the stated diameter in any direction. The gauge diameter should be greater than 100 mm to minimize unacceptable impacts due to the wind flow [2]. The selected cross-sectional area should be based on a consideration of the expected annual or seasonal precipitation and the requirements of the measurement mechanism.

6.1.6 The raingauge should be constructed in a material that is durable and can endure natural weathering without changes to its surface characteristics.

6.1.7 Sound watertight seams should be used throughout. If a gauge stores the rainfall then the storage volume should remain isolated from external flooding, up to a depth of 100 mm above ground level.

6.1.8 If a funnel forms part of the design, it should be constructed of durable stable materials, such that water droplets are not retained by surface tension but run freely towards the orifice and pass into the measurement mechanism. The surface of the funnel should remain in this state for the expected lifetime of the raingauge.

NOTE Experience has shown that painted surfaces are unlikely to meet this recommendation.

6.1.9 The collecting device should fit firmly over the top of the outer but should be removable without undue force.

6.1.10 If a funnel forms part of the design, the funnel spout internal diameter should be large enough to allow free flow into the measurement device at the maximum specified rainfall intensity.

6.1.11 The collecting device should be designed to prevent rain from splashing out. This can be achieved by designing the internal surfaces of the collecting device such that a line drawn perpendicular to any point on any surface intercepts the internal face of the gauge below the rim [2].

6.2 Additional design criteria for automatic raingauge collecting device

6.2.1 Tipping bucket raingauge (TBR) collecting device

The collecting device should have a funnel spout entering the measurement device. A filter may be provided to prevent small particles entering the bucket mechanism. If a filter is provided then the mesh size should be such that it does not cause undue blockage.

It is desirable that the mass of water accumulated in the bucket, prior to the tip should be significant in comparison with the tare weight of the bucket itself. The dimensions of the gauge should be such that a volume of 8 mL or greater is collected in each bucket before the mechanism tips. This requires the diameter of the collecting device to be greater than 225 mm (Figure 1).

Figure 1 **Tip volume corresponding to 0.2 mm increment of rainfall**

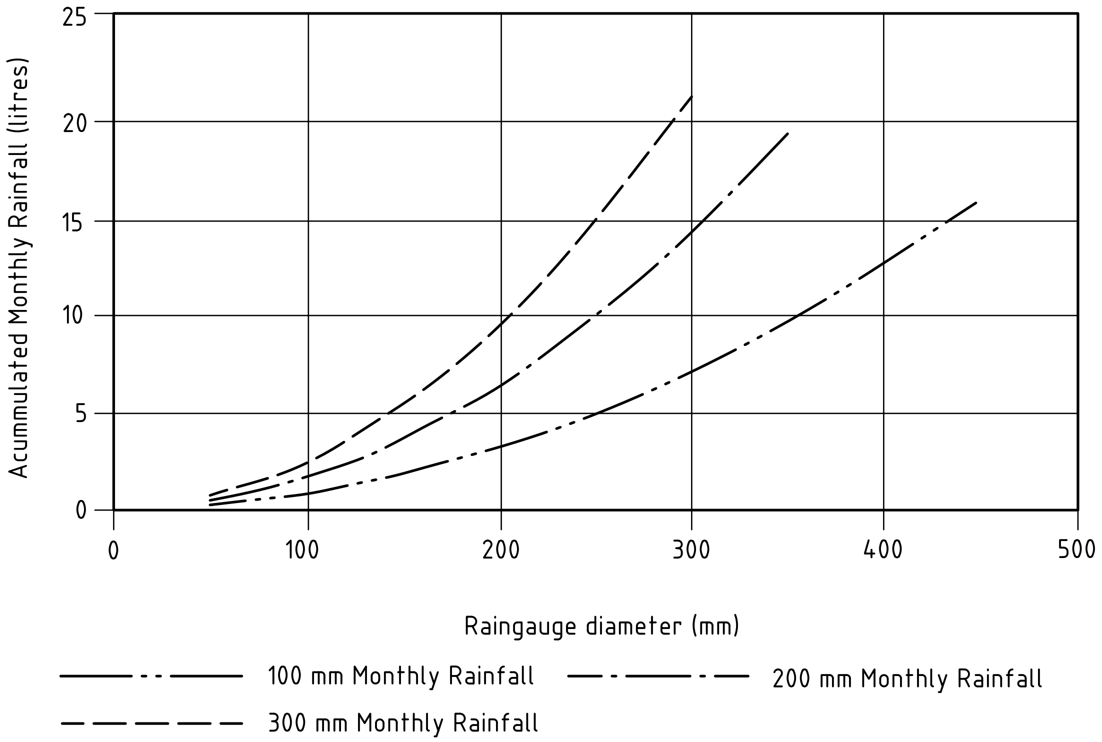
6.2.2 Weighing raingauge collecting device

The diameter of the collecting device should be determined by reference to the expected monthly rainfall totals and intended maintenance regime. Weighing raingauges are designed such that they only need to be visited when they need to be emptied. This can permit long periods between site visits, dependent on the storage capacity of the gauge and amount of rainfall. Weighing raingauges may be provided with an automatic emptying mechanism. Where these are provided then there are no constraints on their capacity.

The rainfall collecting vessel should have handles to assist removal and pouring. A siphon device may be provided for this purpose.

NOTE Figure 2 indicates that such a raingauge requires a large volume of water to be held in the gauge.

Figure 2 **Accumulated monthly collected rainfall as a function of raingauge diameter**



7 The measurement device

7.1 Manually read raingauge measurement device

7.1.1 General

The collecting device should have a funnel spout entering the measurement device. The measurement device should consist of a rainfall collecting vessel and rain measure. The storage volume should be appropriate to the intended measurement interval.

Dip rods may be used to measure rainfall amounts in large capacity raingauges. Their use is described in BS 7843-2. Two different rain measures (see **7.1.3**) should be provided depending on the storage capacity of the raingauge.

7.1.2 The rainfall storage vessel

The base of the raingauge should contain an inner removable can made from a durable material such as copper, stainless steel or plastic resistant to ultraviolet radiation from sunlight, for example 0.6 mm thick copper sheet.

The inner can of a small volume raingauge read on a daily basis should contain a narrow necked bottle. This bottle should be resistant to degradation due to ultraviolet radiation from sunlight and be made from a material that is resistant to shattering. The collecting device spout should enter into the bottle.

The funnel spout should contain a means of minimizing evaporation loss from the collecting vessel. The funnel spout from the collecting device should pass into the collecting vessel with a minimum of space between the spout and the container, the container itself having a narrow necked aperture. In addition, a retained sliding washer on the spout or a non-absorbent compressible material between the spout and the bottle rim or similar device should be fitted to reduce evaporative loss of collected precipitation. If a raingauge has an aperture for a frost protector then the frost protector should either be inserted or a plug provided to seal the gap. Large capacity raingauges read monthly or more infrequently may be constructed from a material with low thermal conductivity to reduce evaporative loss.

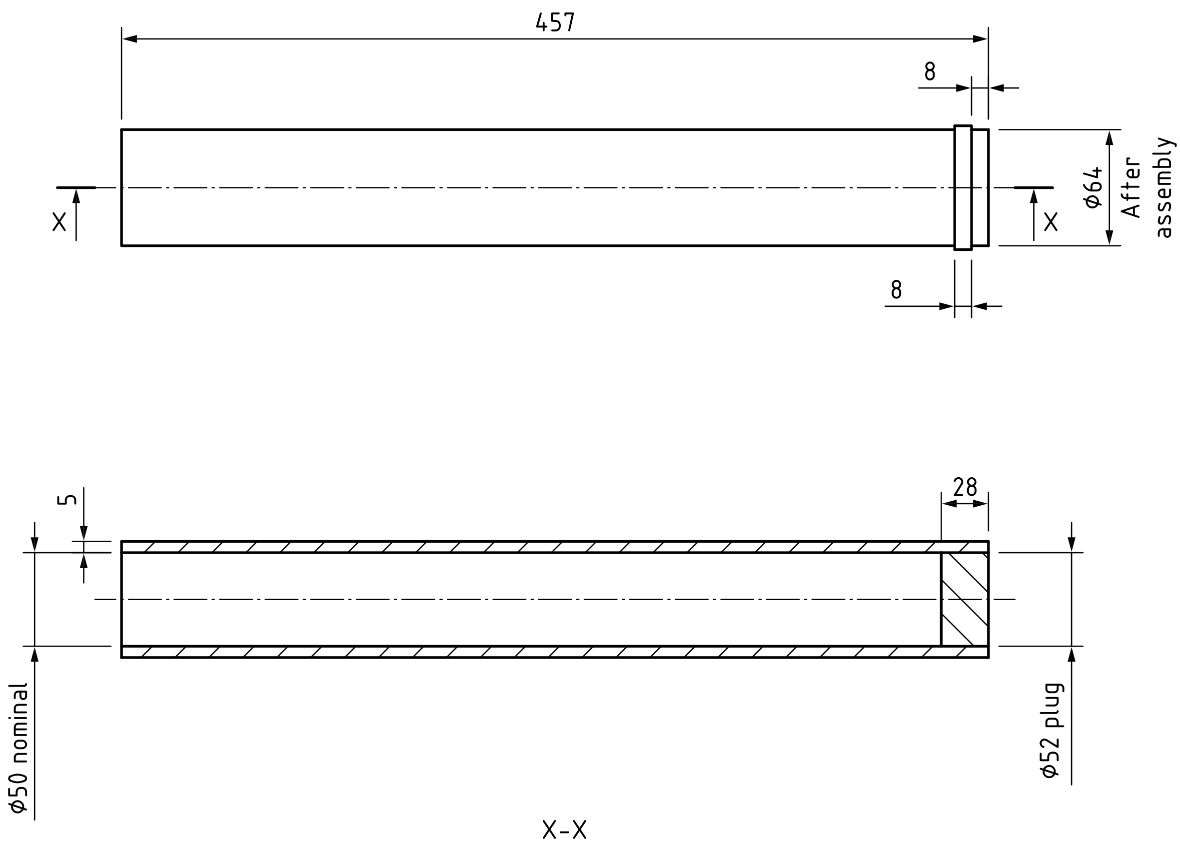
The inner storage vessel for large capacity raingauges should be fitted with handles to assist removal and pouring.

Large capacity gauges may have additional specific design features to prevent frost damage (see Figure 3).

NOTE Raingauges need to endure cold conditions which can cause the stored rain to freeze. In many cases, heat conduction from the surrounding soil occurs. If a manually read raingauge is provided with a glass bottle the heat conduction usually prevents it from splitting or shattering.

Figure 3 **Raingauge: Example frost protector**

Dimensions in mm



Tolerances (unless otherwise stated): Linear ±1.0

7.1.3 Rain measures

Rain measures should be manufactured from good quality clear glass or plastic, free from striations and other visible defects. Plastic measures should only be provided where the user has requested them due to health and safety considerations associated with the use of glass. Graduation marks should be fine, clearly etched and permanent lines of uniform thickness. When the measure is held in a vertical position with the lip to the left, the centres of the graduation marks should lie in a vertical line down the front of the measure and all lines should be horizontal and evenly spaced. (Details are provided in Figures 4 and 5.) There should be graduation marks on the back of the rain measure to reduce parallax errors on taking readings.

A 10 mm capacity measure should be used for small capacity raingauges readable on a daily basis. Figure 4 provides an example measure.

A 50 mm capacity measure should be used for large capacity raingauges readable infrequently. Figure 5 provides an example measure.

7.1.4 Dip rods

Measurement dip rods may be used with large capacity raingauges that can be read infrequently, for example monthly. A measurement dip rod should be made from a robust material that clearly shows the wetted limit and that does not warp or change dimensions in use. Each full division should represent 20 mm of rain. The engravings should be 0.4 mm wide, filled in a colour to assist reading. The length of a dip rod should be sufficient to measure the contents of a full raingauge (see Figure 6).

7.2 Automatic raingauge measurement device

7.2.1 General

Materials should be selected such that corrosion does not disrupt proper operation. The raingauge should be designed to minimize ingress by small animals and insects. The measurement device of an automatic raingauge should be fitted to a base that is constructed such that a stable and secure mounting can be achieved.

Electrical connections for power supplies and outgoing signals should be provided using water-resistant plugs or terminals, suitable for the environmental conditions in which the raingauge is deployed.

NOTE IP67, as described in BS EN 60529, is suitable.

Any marking identifying connectors should be weather-resistant and remain legible for the expected lifetime of the raingauge.

7.2.2 Tipping bucket raingauge measurement device

a) Principle of operation: Two identical, small collecting buckets are connected to a rigid beam, the centre of gravity of which is above the pivot point. This mechanism oscillates between two adjustable end stops. The tipping action is initiated when sufficient water has accumulated in the uppermost bucket to unbalance the mechanism, leading to a rapid tilting of the beam which brings the empty bucket under the funnel and simultaneously allows the collected water to drain away. Precise measurement should be achieved by adjusting the height of the calibration adjuster, a post that the bucket assembly sits on when it is at rest. Increasing the height allows the respective bucket to hold a smaller volume of water before the point of balance weight is exceeded. Similarly, reducing the height of an adjuster allows the relevant bucket to hold a greater volume of water before the point of balance weight is exceeded (see Figure 7).

Electronic sensors such as magnet and magnetic switches, optical interruption sensors or other non-intrusive devices should be used to detect the action of the "tipping" event.

b) A tipping bucket raingauge should be capable of measuring rainfall intensities in the range 2 mm/h to 500 mm/h.

c) The measurement device should have, attached to the base or to a suitable part of the raingauge, a circular bubble level, or two orthogonal linear levels, mounted to ensure that the raingauge is correctly levelled when the bubbles are centred. The accuracy with which the raingauge can be levelled using such gauges should be stated in the instruction handbook.

d) The resolution of the gauge should be such that the rate of rainfall can be determined for an increment not exceeding 0.2 mm.

e) The tipping bucket mechanism should be designed and manufactured to permit adjustment of the volume or mass of rainfall that initiates a tipping event. This should be further designed and manufactured so that the adjustment, once made, is retained during operation of the gauge in the interval between calibrations.

f) The shape, material and surface finish of the bucket should be designed such that, ideally, all water that has been collected is drained from the bucket once it has tipped.

g) The raingauge bucket assembly should be designed and manufactured to minimize friction in the moving part of the mechanism, which can cause under-recording.

NOTE 1 Frictional forces in the pivot, around which the bucket mechanism moves, also leads to errors, as the centre of gravity might need to be displaced by a greater distance than intended before the friction is overcome.

h) The intercepting component of the tipping bucket raingauge should direct the collected rainfall to a small diameter aperture, positioned above the centre of the mechanism, such that water can only collect in the active bucket.

NOTE 2 A source of error is introduced if incident rainfall is preferentially directed towards one bucket, or if rainfall is allowed to enter the opposing bucket.

i) The design should ensure that incident rainfall enters one of the two buckets and that loss by splashing from the wall separating the buckets is minimized. This factor is cumulative and should be evaluated by comparison with a storage gauge if the intended purpose is to measure cumulative rainfall over a period.

NOTE 3 During the process of tipping, rainfall could pass from the collecting device and not be captured by either of the buckets in the mechanism.

j) The supplier should provide a description of the performance of the raingauge at varying rainfall intensities throughout its design rainfall intensity range.

Figure 4 **10 mm rain measure**

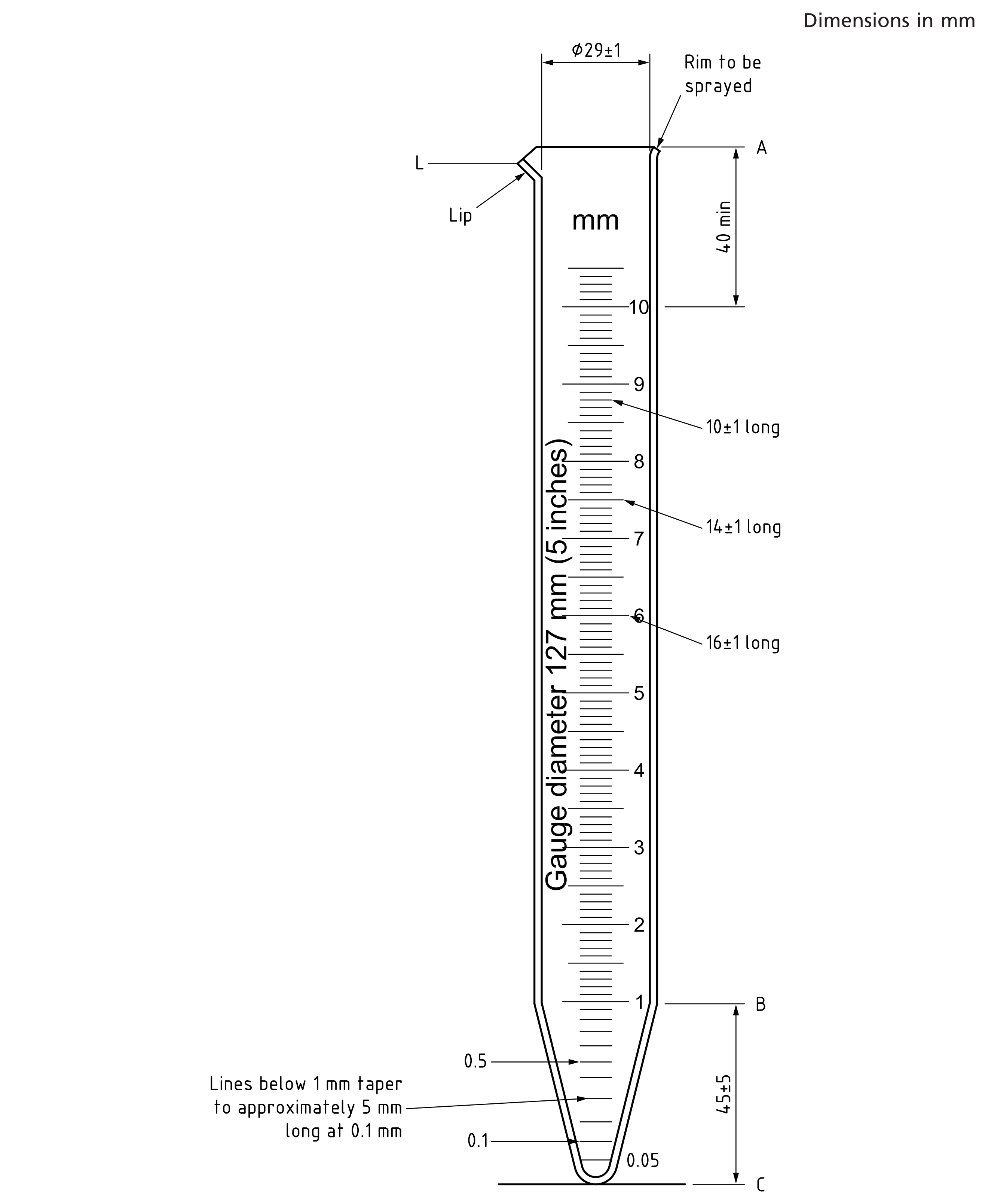


Figure 5 **50 mm rain measure**

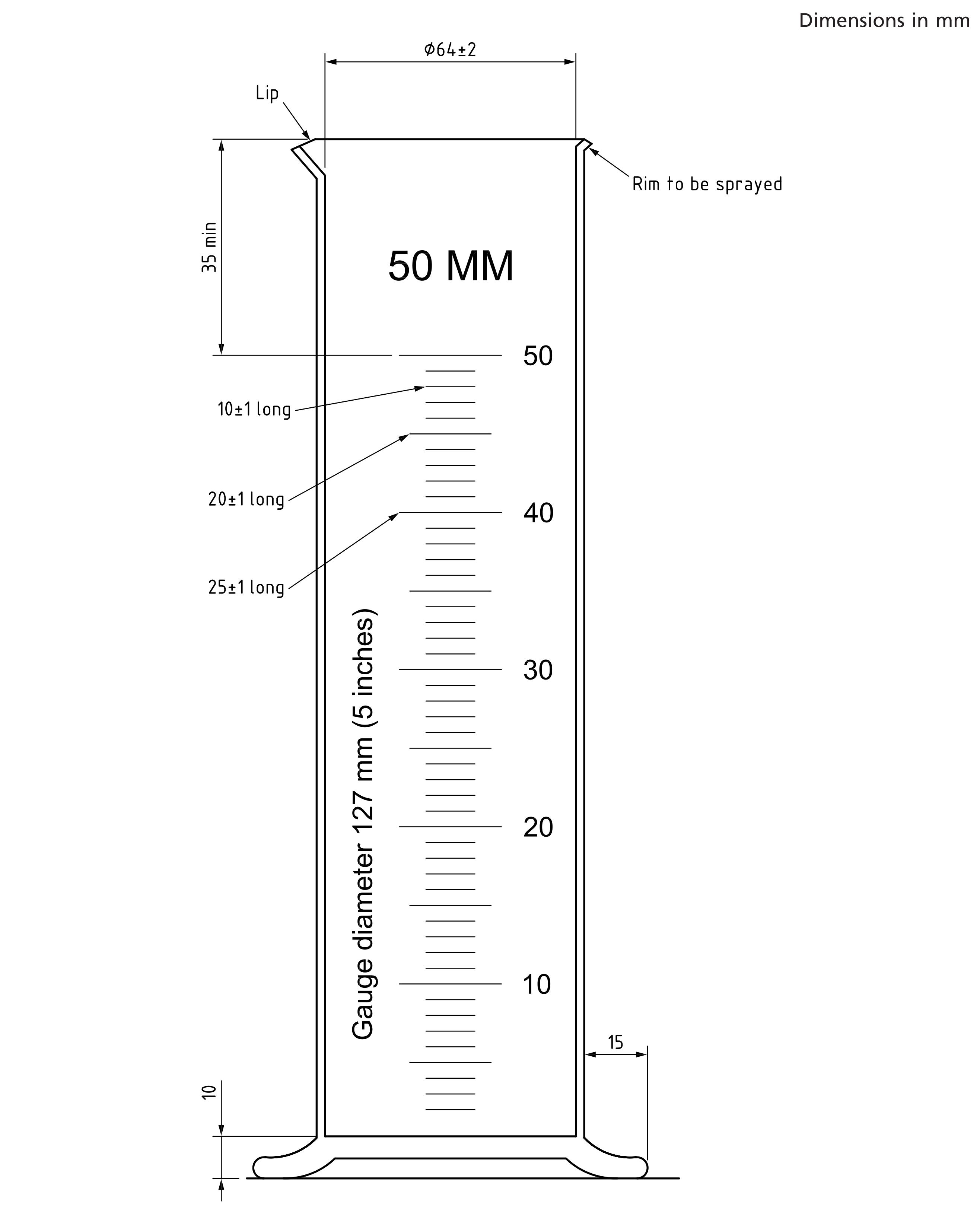
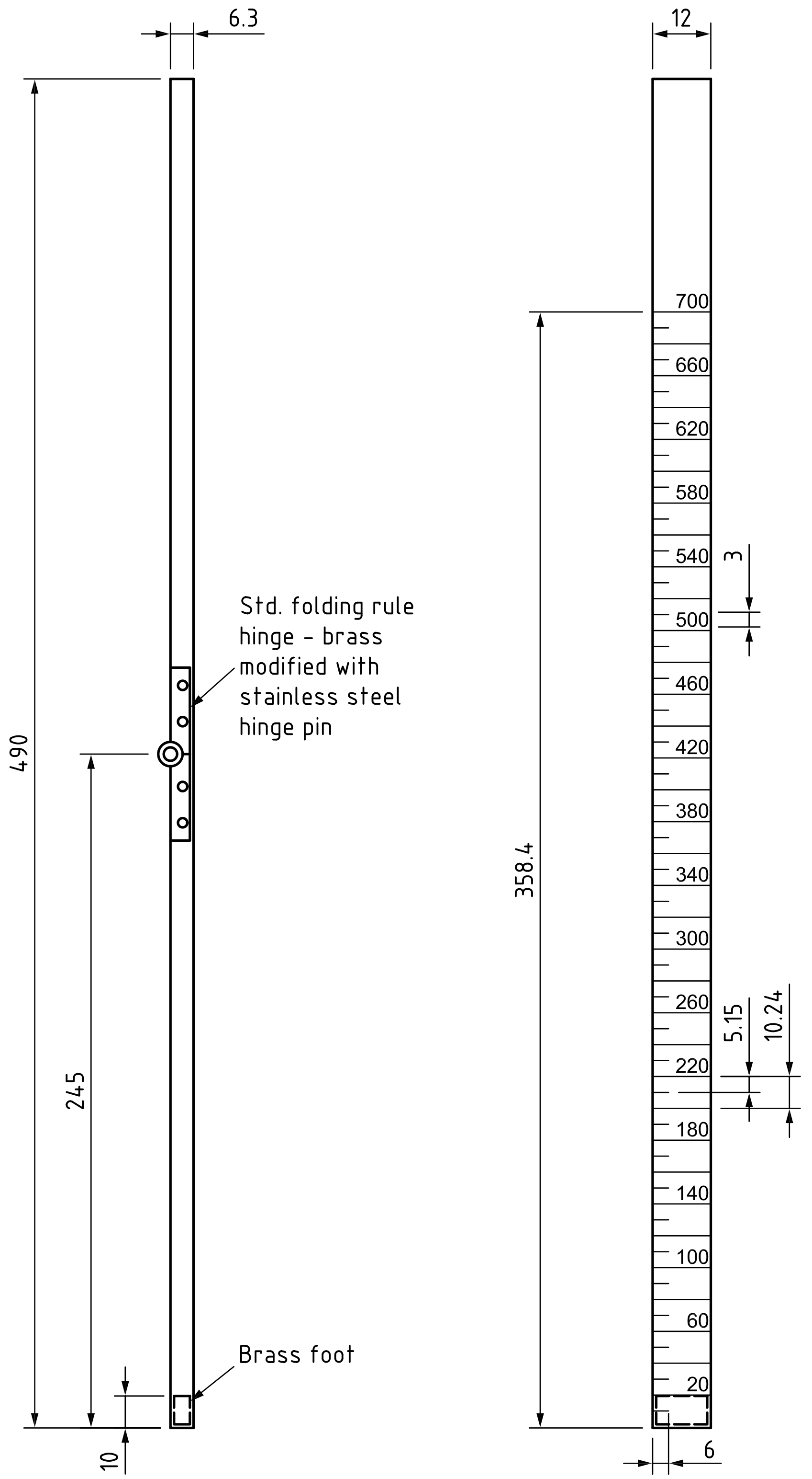


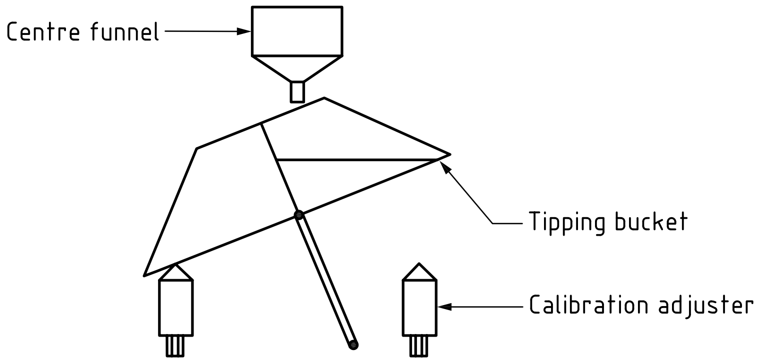
Figure 6 **Raingauge: Example dip rod**

Dimensions in mm

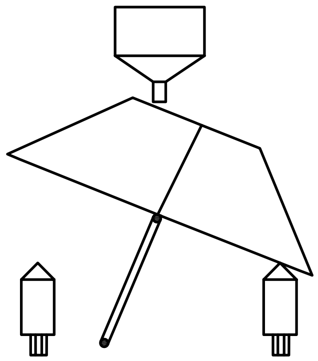


Tolerances (unless otherwise stated):
whole units (e.g. 245) ±1.0
units to one decimal place (e.g. 6.3) ±0.5
units to two decimal places (e.g. 10.24) ±0.1

Figure 7 **Tipping bucket operation**



a) Position "A" before tip event



b) Position "B" after tip event

7.2.3 Weighing and depth measurement raingauge measurement device

NOTE 1 Weighing raingauge principle of operation: A weighing raingauge converts the measured weight of collected water in the measurement device into rainfall depth.

NOTE 2 Depth measurement raingauge principle of operation: A depth measurement raingauge converts the measured depth of collected water in the measurement device into rainfall depth.

The measurement device should meet the following criteria.

a) Minimum resolution and accuracy of the scale 0.1 mm.

b) Rainfall intensities measurable from 0.1 mm/min to 1 000 mm/h or higher.

c) Mechanical overload protection for forces, e.g. during transportation or when emptying the collecting bucket.

A weighing raingauge should be designed to prevent errors due to oscillation caused by turbulent air currents over the interceptor aperture.

NOTE 3 This effect can cause short duration variance in the recorded output, which might require signal filtering or conditioning to counteract. This error can be either positive or negative in effect.

The raingauge may optionally be provided with a self-emptying mechanism.

The gauge should be designed, manufactured and operated to prevent freezing. This may be achieved by the use of heater elements to maintain the temperature of the stored water above freezing point, or by addition of a suitable anti-freeze solution. Anti-freeze solutions should be stable over the intended maintenance interval and resistant to evaporation through the expected operating temperature range.

8 Automatic raingauge heaters

Automatic raingauges may be optionally fitted with heaters if they are to be used to measure solid precipitation, or to maintain operation of the raingauge in freezing conditions. Raingauge heaters should conform to the following.

a) They should not provide such heating that might cause significant evaporation loss.

b) They should be thermostatically controlled so that heating is only provided when required.

c) The heater power consumption should be kept to a minimum so that ideally it can be powered from a locally generated renewable power source.

9 Data conditioning, data logging and data transmission

Automatic raingauges may have a means of processing, storing and transmitting data that are integral to the raingauge. Its functionality may include one or more of the following.

a) Signal processing and formatting.

b) Application of rainfall intensity calibration algorithms for Class A tipping bucket raingauges (see BS 7843-2:2012, **12.3**).

NOTE 1 The manufacturer ought to provide details of any rainfall intensity calibration algorithms.

c) Algorithms that correct for other known systematic errors in the measurement (e.g. evaporation loss).

d) Real-time quality control checks (see BS 7843-2:2012, **11.3**) and provision of data flags.

e) Corrections for any errors detected by real-time quality control (e.g. erroneous effects of debris entering the measurement mechanism of a weighing raingauge).

f) Data storage for the maximum likely period between data retrievals from the site.

NOTE 2 This ought to take into account possible data outages due to line failures.

g) Remote access facility for system interrogation by maintenance engineers.

h) Wireless transmission system.

10 Facilitating maintenance

The manufacturer of an automatic raingauge should provide their recommended maintenance intervals and identify parts of the gauge which require replacement during its operational lifetime. The gauge should be designed and manufactured to operate for extended periods without requiring maintenance, cleaning or inspection visits subject to site-specific considerations.

The raingauge should be designed and manufactured to facilitate cleaning and routine replacements of wear components. Where possible, the design and manufacture should permit these activities to be carried out without the calibration and adjustment of the raingauge being compromised.

11 Automatic raingauge environmental considerations

11.1 Operating

The automatic raingauge should function in its intended manner over the following range of environmental conditions.

Maximum temperature	+30 °C
Minimum temperature (TBR, without heating or weighing gauge without antifreeze)	0 °C
Minimum temperature (TBR, with heating or weighing gauge with antifreeze)	–20 °C
Maximum relative humidity	100% RH
Minimum relative humidity	80% RH

The mechanism of the raingauge should not suffer undue effects of freezing. Automatic raingauges may be provided with heating elements to assist operation in sub zero conditions (see Clause **8**).

11.2 Storage

The automatic raingauge should function in its intended manner over the following range of environmental conditions.

Maximum temperature	+40 °C
Minimum temperature	–20 °C
Maximum relative humidity	80% RH
Minimum relative humidity	50% RH

12 Calibration of automatic raingauges

*NOTE BS 7843-2:2012, **5.4**, describes the circumstances that trigger the need for calibration of automatic raingauges.*

12.1 Tipping bucket raingauges

12.1.1 Class A tipping bucket raingauge

Class A tipping bucket raingauges should be calibrated in accordance with CEN/TC 318 N 320 and typically demonstrate a laboratory uncertainty within 5% across the specified rainfall intensity range. The test system should have a target uncertainty of <1%.

12.1.2 Class B tipping bucket and depth measurement raingauge

The raingauge should be calibrated for performance at a single equivalent intensity of rainfall (termed a static calibration). This intensity should preferably be equivalent to a rainfall of 12 mm/h^{-1}, and not outside a range of 10-15 mm/h^{-1}. These raingauges may have a laboratory uncertainty of up to 20% at the extremes of the rainfall intensity range.

NOTE 1 This standard permits the use of alternative test methods which can demonstrate performance conformity with this standard.

a) The calibration procedure should be carried out in an enclosed, dry area, free of draughts. The raingauge under test should be mounted on a stable workbench and levelled in all horizontal directions prior to testing.

b) Prior to testing, the diameter of the interception component should be measured on a minimum of three evenly separated places. The average of the three measurements should be within 0.2% of the stated diameter for the raingauge. The interception area, calculated from the mean of these measurements should be recorded for determination of the amount of rainfall that is equivalent to the volume or mass recorded by the raingauge under test.

c) Tap water, between 10 °C and 30 °C, should be used for calibration testing. The raingauge under test should be prepared by passing a sufficient quantity of water through it, to ensure that all surfaces are wetted thoroughly. If the raingauge under test is of a non-storage type (such as a tipping bucket raingauge) the water used for this purpose should be drained from the measuring containers or cups, but the surfaces should not be allowed to dry.

d) If the raingauge under test is of non-storage type, arrangement should be made to collect all water that passes out of the raingauge, in suitable containers, so that the volume or mass of water can be measured at the end of the test and compared with the volume or mass used for the test. In raingauges of tipping bucket type, the volume or mass of water passed through each side should be collected separately.

e) A volume of tap water should be prepared and placed in a volumetric or weighing vessel, from which it can be passed at a fixed rate into the collecting mechanism of the raingauge under test. The required volume should be determined from the capacity of the measuring components within the raingauge. For a non-storage gauge of the tipping bucket type, the volume should be sufficient to obtain a minimum of 200 tip events.

f) The required flow-rate should be obtained by use of a metering pump, such as a peristaltic pump, in which the flow is dependent only on displacement of a known volume of liquid. Pumps of an impellor type might require use of a separate metering device. As an alternative, a constant-head tank may be used.

   NOTE 2 If a burette type of volumetric vessel is used, the head will vary over the range of the measured volume and can result in variation of the flow-rate.

   If a burette is used, it should conform to BS ISO 385, Class A, and the flow-rate should be determined at several points over the volume range. Constant head flow may be approximated if the burette is constantly refilled to a given volume and only small volumes are metered into the raingauge under test. The error implicit in estimation of the meniscus position will be accumulative in this case. Therefore, constant flow-rate pumps should be preferred over burettes for calibration.

g) The flow-rate of the calibration apparatus should be determined using a volumetric flask and a stopwatch. If a collecting funnel forms part of the raingauge under test and the design permits adjustments to be made with the funnel *in situ*, the water flow should be directed into the approximate centre of the funnel. In all other situations, the flow nozzle should be carefully centred over the recording mechanism.

h) A suitable data recording device should be connected to the raingauge under test and the flow initiated. The volume passed into the raingauge and the duration should be recorded. For a raingauge of tipping bucket type, the number of tipping events should be recorded. Additionally, for a tipping bucket raingauge the residual water in the active cup, following the last recorded tip, should be extracted using a pipette or syringe and accurately recorded. In non-storage raingauges, the volume or mass of the water collected from the drain outlets should be recorded and compared. In depth measurement raingauges, both the depth in the measurement component and the volume or mass of the water collected in the gauge should be recorded and compared.

i) For a non-storage raingauge of tipping bucket type:

1) overall the raingauge should measure within 2% of the water passed into or through it; and

2) the difference in the volumes collected from either side of the bucket mechanism should not differ by greater than 4% of the total volume passed through the raingauge.

If either of these criteria are not met, the mechanism should be adjusted and the calibration repeated.

NOTE 3 An example of the calculations for a tipping bucket raingauge Class B calibration is provided in Annex B.

12.2 Weighing raingauges

Weighing raingauges should be calibrated accurately by the manufacturer in accordance with CEN/TC 318N 320. It is unlikely that they will require further calibration unless damaged or a serious fault develops, but the supplier should provide information on how field calibration checks may be carried out using calibration weights or by adding known quantities of tap water. This process should be such that the gauge calibration can be checked from zero to its full capacity range. Where weights are used to check the calibration, these should conform to OIML R 111:2004, Class F2 or higher.

If a gauge calibration is found to be in error:

a) if the weighing mechanism is not designed for user adjustment, the raingauge should be returned to the supplier for adjustment and recalibration in accordance with CEN/TC 318; and

b) if the weighing mechanism is designed for user adjustment, the manufacturer should provide information on how this is done; a full calibration should be carried out in accordance with CEN/TC 318 following any adjustment.

13 Other technologies for the measurement component of automatic raingauges

Any other technologies developed or implemented to measure the rainfall received by the collecting device should undergo field trials of a least one year to compare performance against the UK reference storage raingauge recommended in Annex A.

The reference raingauge can be used as part of a raingauge network, but other raingauges of equivalent performance might be preferred in modern raingauge networks.

Annex A (normative) The UK reference storage raingauge

A.1 General construction items

Construction of the components of this type of gauge should be in accordance with the dimensions and materials given in Figures A.1, A.2, A.3, A.4 and A.5.

The general shapes of gauges that meet the UK reference storage raingauge design are provided in Figures A1 and A2.

The outer can (Figure A.3 provides an example for the meteorological office raingauge mk 2) should be made from 0.6 mm thick copper sheet. The finish on the inside of the outer can should be natural, grease-free and the finish on the outside of the outer can should be polished and lacquered.

For the inner can (Figure A.4) the body should be made from 0.6 mm thick copper sheet. The handle should be made from 2.5 mm diameter round brass bar, the rim from 1.5 mm diameter round brass bar and the handle eyes from 1.5 mm brass sheet. The finish should be natural, grease-free.

For the funnel (Figure A.5) the body should be made from 1.2 mm seamless or brazed updrawn tubing having an internal diameter of 130 mm. The top ring should be made from brass. The tube should be made from seamless brass. The funnel should be made from 0.6 mm copper. The finish inside should be natural, grease-free and on the outside it should be polished and lacquered.

The funnel should be checked for ease of fit and correct seating over the top of the outer can. It should be removable without undue force, but it should fit firmly to the outer can without rocking.

The inside of the funnel should be washed with dilute nitric acid by the manufacturer, to remove any grease or flux left behind after manufacture.

A.2 Identification of raingauges

Each raingauge funnel should be clearly marked with the manufacturer's name, mark, badge or label, together with an indication of the raingauge model or type.

A.3 Construction of joints

Particular attention should be given to all the joints. Soldered joints should be securely soldered, with no gaps to hold water and no roughness or any lumps of solder left on the joints.

Rolled or folded joints should be checked to ensure tightness and a correct fit between mating parts.

A.4 Tests for leakage

Tests for leakage should be conducted on each inner can, outer container and funnel as follows.

a) Each inner can should be filled with water and left to stand for 2 h. No leaks or seepage should be apparent.

b) Each outer can should be inverted and submerged under water. No bubbles of escaping air should be apparent.

c) Each funnel spout should be sealed by placing a finger over the end of it, and the funnel should then be inverted and submerged under water. No bubbles of escaping air should be apparent.

Figure A.1 **Reference daily raingauge: General assembly**

Dimensions in mm

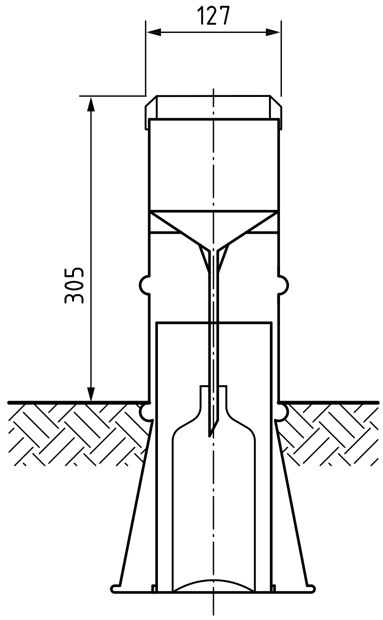


Figure A.2 **Reference daily raingauge: General assembly**

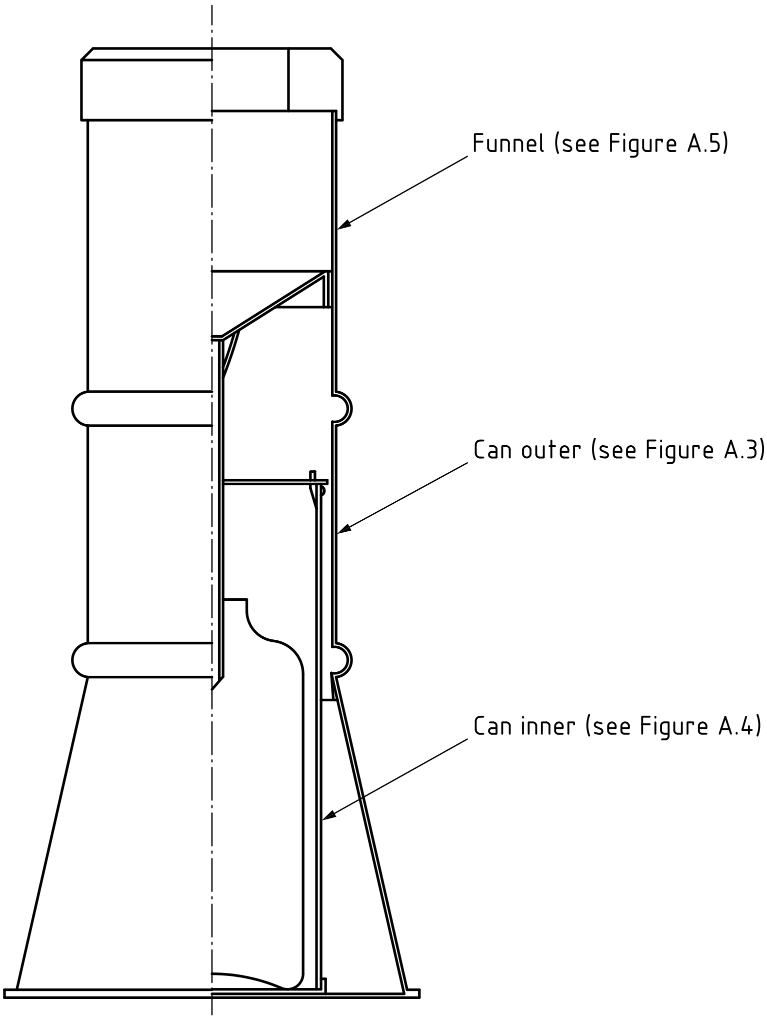
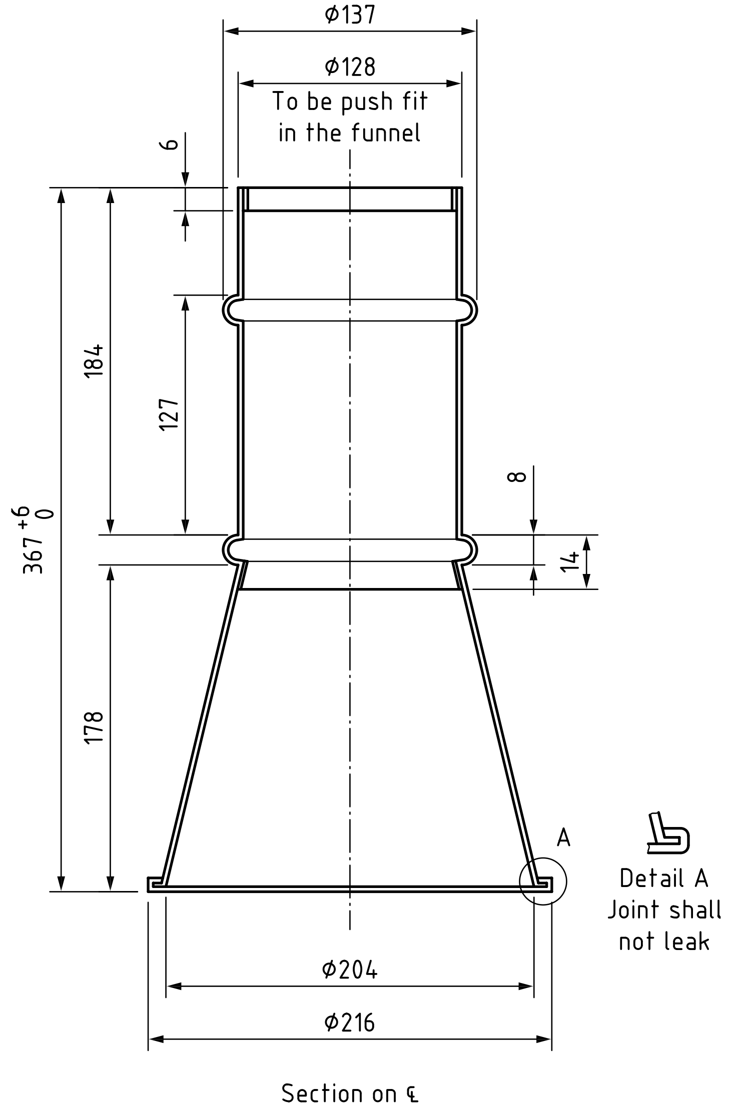


Figure A.3 **Reference daily raingauge: Can outer**

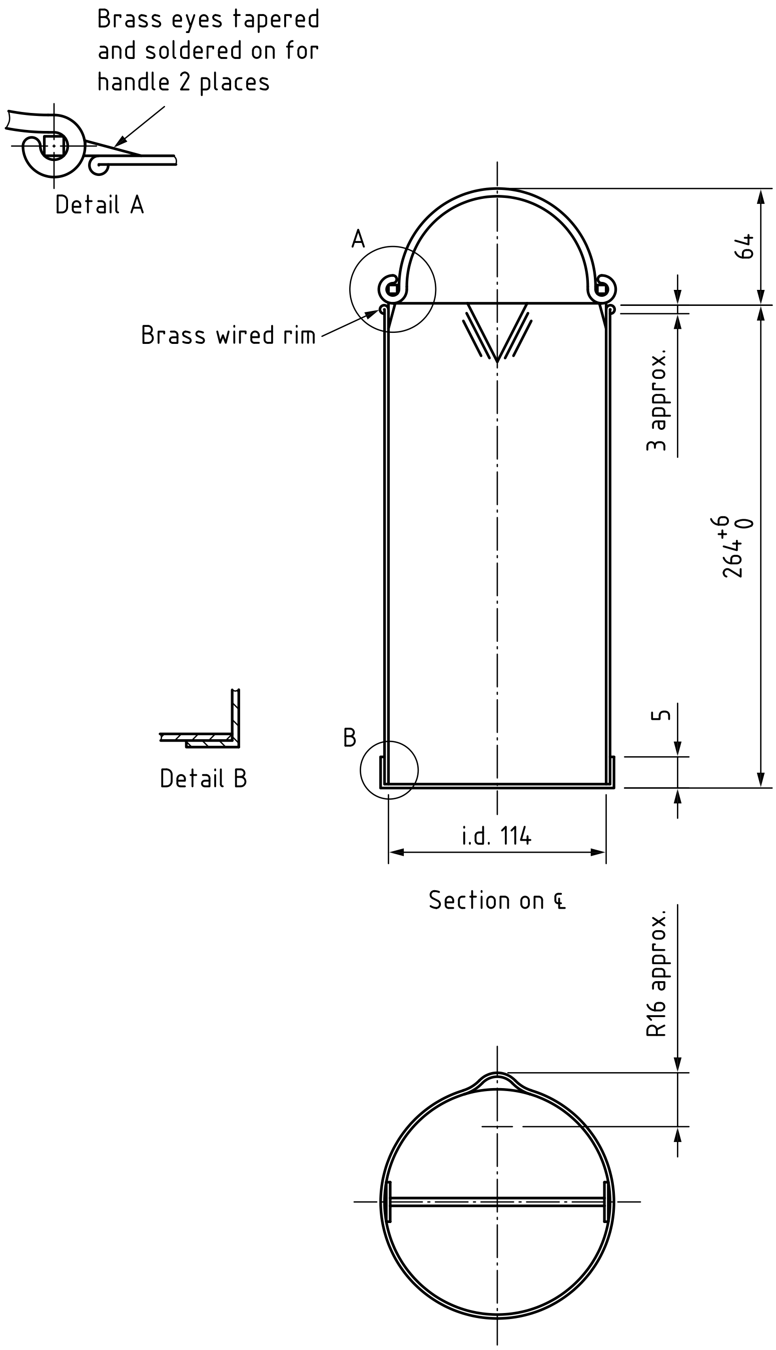
Dimensions in mm



Tolerances (unless otherwise stated): ±1.0

Figure A.4 **Reference daily raingauge: Can inner**

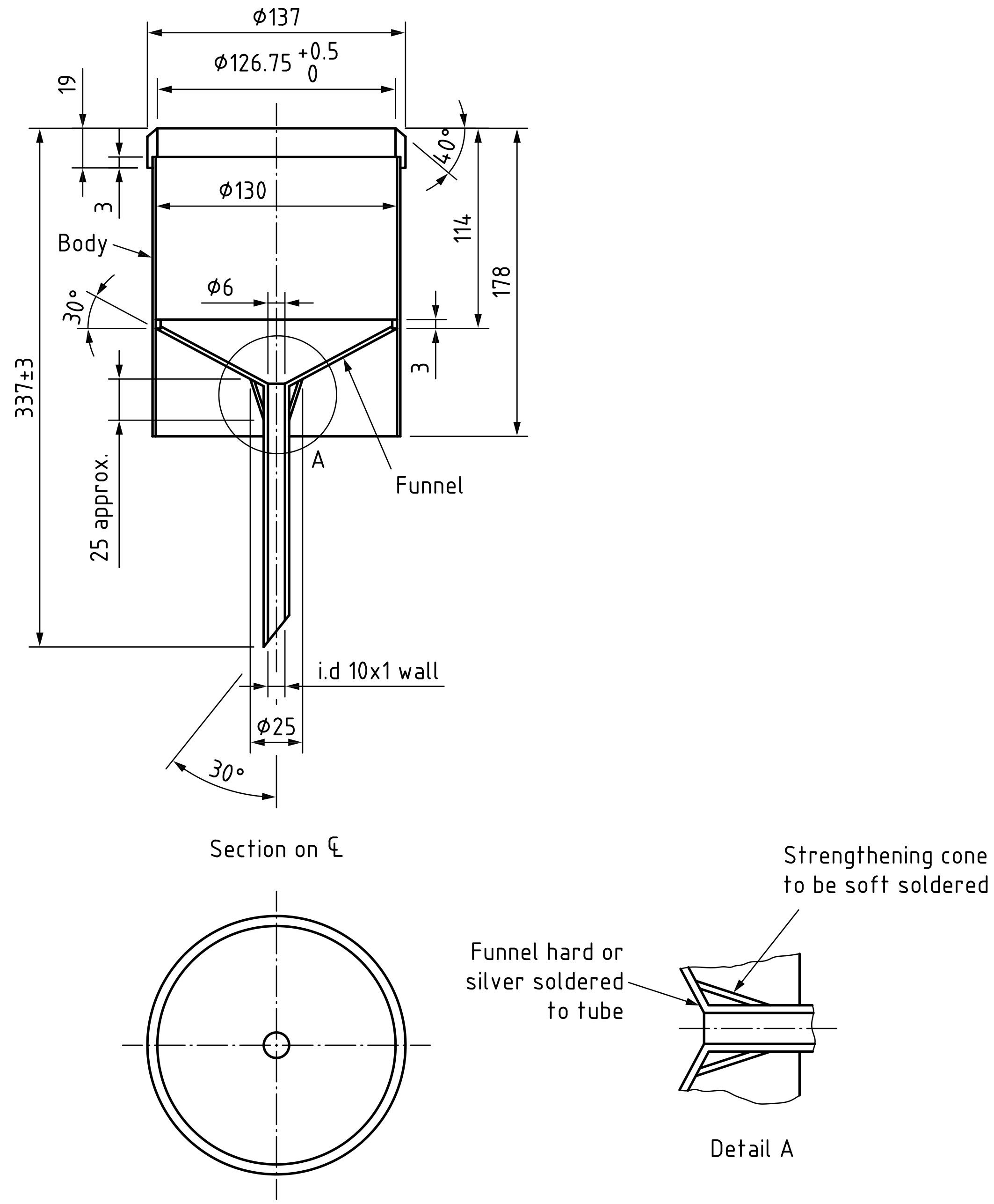
Dimensions in mm



Tolerances (unless otherwise stated): ±1.0

Figure A.5 **Reference daily raingauge: Funnel**

Dimensions in mm



Tolerances (unless otherwise stated):
- Linear ±1.0
- Angular ±1°

Annex B (informative) An example tipping bucket Class B calibration calculation

Let P = Expected total rainfall (mm) and P' = Indicated rainfall (mm)

Let A = Area of interception component (mm²)

Let v = Volume of cup (mL)

Let r = Volume remaining in cup at end of test (mL)

Let N = Expected number of tip events

Let N' = Recorded number of tips

Let $V1$ = Volume of water passed through the left bucket (mL)

Let $V2$ = Volume of water passed through the right bucket (mL)

Let V = Total volume of water passed through the raingauge, and $V1 + V2 = V$ (mL)

Then:

$$P = \frac{1000 \times V}{A} \text{ mm}$$

and:

$$P' = \frac{1000 \times ((N' \times v) + r)}{A} \text{ mm}$$

Calibration pass criteria are:

$$P \times 98\% \leq P \leq P' \times (102\%)$$

The difference in the volumes collected from either side of the bucket mechanism ought not to differ by greater than 4% of the total volume passed through the raingauge.

Worked example:

TBR of 400 cm² catchment: A = 40 000 mm²

0.2 mm bucket size:

$$\text{Bucket volume } v = \frac{0.2 \times 40000}{1000} = 8\text{mL}$$

The flow-rate through the raingauge, equivalent to a rainfall rate of 12 mm/hr is given by:

$$\frac{40000 \times 12}{1000 \times 60} = 8\text{mL/min}$$

Let V = 2 000 mL

Then:

$$P = \frac{2000 \times 1000}{40000} = 50\text{mm}$$

and:

$$N = \frac{50}{0.2} = 250$$

Example calibration results:

Number of recorded tips, N' = 248

v = 3 mL

So:

$$P' = \frac{1000 \times ((248 \times 8) + 3)}{40000} = 49.7\text{mm}$$

$V1$ = 980 mL

$V2$ = 1 020 mL

For the gauge to pass calibration: $49 \leq P' \leq 51$ and $245 \leq N' \leq 255$. Both criteria have been satisfied.

In addition, the difference in the volumes collected from either side of the bucket mechanism ought not to differ by greater than 4% of the total volume passed through the raingauge.

$V \times 4\% = 80$ mL

The difference in the volume collected between the buckets is:

$V2 - V1 = 1\,020 - 980 = 40$ mL

This criterion has been satisfied.

Biblography

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For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN 60529, *Degrees of protection provided by enclosures (IP code)*

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