# Review: the CoCoRaHS raingauge

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This independent review compares the performance of an inexpensive CoCoRaHS plastic raingauge against UK and Ireland-standard instrumentation at a single site in central southern England over a period of several months.

*Important note: this review is entirely independent.* The CoCoRaHS gauge was supplied on a 'no strings' evaluation loan from Prodata Associates in Ely, Cambridgeshire. The unit was a standard 'off the shelf' package, without special modifications or calibrations. Neither the gauge manufacturer nor Prodata Associates have been involved in either the trial or the preparation of this review, and no incentives were offered or sought to influence this review in any way.

## What **is CoCoRaHS?**

CoCoRaHS www.cocorahs.org is a North American grassroots volunteer network of backyard weather observers of all ages and backgrounds working together to measure and map precipitation (rain, hail and snow) in their local communities. (CoCoRaHS is an abbreviation for 'Community Collaborative Rain, Hail and Snow Network'). By using low-cost measurement tools, stressing training and education, and utilising an interactive Web-site, the organisation aims to provide high-quality data for natural resource, education and research applications. The only requirements to join are an enthusiasm for watching and reporting weather conditions and a desire to learn more about how weather can affect and impact our lives (oh, and living in the United States or Canada ... !)

CoCoRaHS observers use an inexpensive plastic raingauge with a 100 mm diameter funnel (**Figure 1**); at the time of writing there were more than 15,000 observing sites equipped with this instrument in North America (mostly US, but some sites in Canada), outnumbering the 'official' NOAA/NWS climatological and rainfall observing network. The purpose of this review was to ascertain how rainfall records made with this type of raingauge compared to a UK and Ireland-standard 'five-inch' copper raingauge, and thereby whether or not to recommend the unit as an acceptable budget alternative to standard instrumentation, particularly for owners of automatic weather stations who do not otherwise have any means of checking the accuracy of the tipping bucket raingauge unit within their AWS system.

As at May 2013, the CoCoRaHS gauge price from Prodata was £45 including VAT, about a fifth of the price of a standard 'Mark II' copper splayed-base raingauge (**Figure 2**) with which comparisons were made.

## The CoCoRaHS raingauge

The CoCoRaHS raingauge was designed to provide an inexpensive and yet reasonably accurate means of measuring rainfall amounts. It is a traditional manual rain gauge (i.e. it needs to be read and emptied by a human observer, preferably daily).

The unit is made from heavy-duty, UV-resistant polycarbonate, and stands 350 mm tall. The funnel diameter is 102 mm / 4 in, and depth 40 mm (the UK standard 'five-inch' Snowdon or MkII raingauge funnel is 127 mm / 5 in diameter, and 114 mm deep). The gauge is supplied with an easy-to-install quick-connect bracket - this bracket can be screwed to, for example, a vertical wooden post (**Figure 1**) to secure the gauge. The main gauge body is then a slide-fit over the bracket making it quick and easy to remove the gauge for occasional cleaning. It is very important, however, to ensure that the rim is accurately level when installing the gauge, and that the structure on which it is mounted will not move in the wind.

Unlike a conventional UK standard 'five-inch' raingauge, the measuring cylinder is integral to the CoCoRaHS unit – rain falling into and through the funnel drops directly into the internal measuring cylinder for subsequent manual measurement. (This also makes it easy to read the instrument at a glance.) To measure the accumulated rainfall, the measuring cylinder is removed from the gauge by removing the funnel, and then read by eye in the normal manner. The cylinder is then emptied and reinstated within the body of the gauge, and the funnel replaced.

The capacity of the measuring cylinder is 25 mm of rainfall (both metric and imperial-inch calibration versions are available); larger amounts will overflow into the main gauge body. The gauge body can be detached from the mounting bracket, and any overflow can then be measured by - carefully - filling the measuring cylinder with the collected rainfall in 25 mm batches until the outer reservoir is emptied, and summing the individual increments. The total capacity of the unit is given as 275 mm rainfall (not verified), adequate for daily rainfall amounts anywhere within the UK and Ireland, and for occasional longer-period accumulations of a week or two. Note that significant evaporation of the contents may occur if the unit is not read daily, and longer periods of accumulation are therefore not recommended with this design of gauge.

## Trials site and observing protocol

The CoCoRaHS raingauge was mounted using the supplied bracket on a fencepost such that its rim was 125 cm above ground level (**Figure 1**), as recommended by the CoCoRaHS organisation. It was exposed within the enclosure of the author's existing climatological observatory located in Berkshire, in central southern England, 3 m south of the standard MkII 'five-inch' raingauge, which is fixed in the ground with its rim 30 cm above ground level. The rural site (at 51.4°N, 1.0°W, altitude 60 m AMSL - **Figure 2**) is well-exposed, particularly between east and west through south, the direction of the prevailing and main rain-bearing winds, and is a UK Met Office approved rainfall site. The two gauges thus differ only in their construction and exposure (height of rim above ground level).

Most of the equipment on site is automated, (cabled) sensors being connected to two independent Campbell Scientific dataloggers, which sample most of the sensors (including the two tipping bucket raingauges) every second, logging data every minute, every 5 minutes and every hour. Daily summary totals, means and extremes are also generated at midnight UTC. All major meteorological parameters are measured, including solar radiation. The datalogging system and sensors are a superset of the Met Office Climate Data Logger system in use at many Met Office and co-operating authority climatological sites throughout the UK.

Both the CoCoRaHS and the five-inch gauge were read manually at every morning observation, normally 0900 UTC. Where an observation at 0900 UTC was not possible, both totals over the observed period were adjusted to 0900-0900 UTC (the standard UK 'rain day' period) using records from the co-located tipping bucket raingauges within the enclosure. All records therefore refer to the period of 24 hours commencing at 0900 UTC on the date shown. When precipitation fell as snow, snowfall remaining in the funnel of the five-inch gauge was melted and measured as water equivalent wherever possible, following standard UK precipitation measurement practices (for details, see Strangeways 2007 and Burt 2012). This was not always possible with the CoCoRaHS gauge, as described further below.

## Results

Records from the CoCoRaHS raingauge commenced on 22 June 2012 and continued until early July 2013, thus completing a full 12 months comparative records and sampling a typical range of temperate-zone weather and precipitation regimes in both summer and winter periods. Daily totals were available for the entire trial period from the five-inch standard checkgauge; totals from the CoCoRaHS gauge were lost during a nine day snowy period in January 2013 (see below) and were estimated using five-inch gauge records. **Table 1** shows the monthly totals and greatest fall in a rainday from both gauges over the trial period to date, while **Figure 3** shows a scatter plot of the daily totals covering the period 1 July 2012 to 30 June 2013 (365 days). Traces (< 0.05 mm) have been ignored.

The agreement between the two gauges is excellent, with little scatter. For the period of data shown in the scatter plot, the ratio of the two gauges is within 2%, the CoCoRaHS gauge slightly under-reading when compared with the standard checkgauge. **Table 1** shows that there is a slight seasonal variation in the ratio, the CoCoRaHS gauge reading slightly higher during the summer half-year and rather lower, by up to 5 per cent, during the winter months. This slight loss of catch in the winter half-year is most likely to due to additional turbulence in windy conditions, and this point is discussed further below.

## Differences in daily catch

During the 12 months July 2012 to June 2013, daily totals differed by 0.5 mm or more on only 14 days (4% of occasions). The largest differences in daily totals were +0.9 mm (CoCoRaHS wetter than checkgauge) on 13 December 2012, and -0.9 mm (CoCoRaHS drier than checkgauge) on 15 March 2013.

The CoCoRaHS gauge was significantly wetter (>= 0.5 mm) than the checkgauge on only one day in the comparison period, namely 13 December 2012, +0.9 mm (1.3 mm vs 0.4 mm). Moderate to heavy rain was falling at the time of the observation measurement, and some of the difference may be due to the slight difference in time of reading of the two instruments. On 12 days during the comparison period the CoCoRaHS gauge under-read the checkgauge by 0.5 mm or more, the greatest difference being -0.9 mm on 15 March 2013 (11.1 mm vs 10.2 mm).

Daily weather diary records were examined for common factors for these 12 days. All included spells of heavy rain and/or rainfall accompanied by strong winds. The largest discrepancy on 15 March 2013 occurred on a day with heavy hail showers.

It seems most likely that the most likely causes of the CoCoRaHS gauge under-reading are (i) additional turbulence over the gauge mouth during windy conditions, exacerbated by the greater height of the gauge rim when compared with the UK standard (125 cm vs 30 cm), and (ii) the loss of catch in heavy rain or hail owing to outsplash from the relatively shallow funnel. Raingauge losses from wind turbulence would be expected to be greater in the winter months as a result of higher wind speeds during the winter half-year, and this is borne out by the monthly catches compared in **Table 1**.

It is certainly possible to mount the CoCoRaHS gauge at a lower rim height than the 125 cm North American standard (the rim would stand at only 35 cm if the gauge base was mounted at ground level). Doing so would almost certainly reduce losses arising from wind turbulence, but may increase evaporation (loss) and insplash (gain). The contents would also be more likely to freeze (see below) and perhaps be affected by drifting snow. Having the gauge at or close to eye height also makes it easier to read.

For more on how raingauge catch is affected by turbulence, and other factors influencing raingauge catch, see Burt (2012) and the references in Chapter 6 thereof, or Strangeways (2007), Part 3.

## Performance in heavy rainfall

The average discrepancy of the ten heaviest daily falls during the 12 month period was 0.3 mm or 2% (17.4 mm CoCoRaHS vs 17.7 mm checkgauge). Losses were greater in shorter spells of intense rainfall, however (see below).

During the comparison period, no daily fall exceeded 25 mm, and accordingly the ease or otherwise of measuring the overflow into the outer container could not be verified.

## Performance in light rainfall

For all falls of 1.0 mm or less the average discrepancy was 0.02 mm or 8% (0.30 mm vs 0.32 mm), suggesting increased losses with small amounts owing probably to wetting or evaporation (see below).

## Observational notes and comments

The 12 month observational period provided a sufficient period with which to evaluate the not only the performance but the usability of the CoCoRaHS gauge. The following comments summarise findings.

*Losses through funnel wetting*

The hard, shiny plastic surface of the funnel encourages the formation of hemispherical droplets. Above a certain size these will drain down into the funnel outlet tube by gravity, but experience shows that droplets usually remain on the surface of the funnel (rather than draining into the gauge) at the cessation of rainfall – this can be seen in **Figure 1**. If droplets are present at the time of the observation, these can easily be encouraged to drain using the index finger in a downward spiralling motion within the funnel, but often these droplets will evaporate before the next measurement, resulting in a typical loss of 0.1 or 0.2 mm rainfall – more significant for small falls. It is possible that longer exposure to the weather may result in the funnel surface 'weathering' and so becoming more suited to draining, rather than retaining, raindrops which fall on it.

In addition, the short funnel outlet pipe leading into the measuring cylinder is moulded horizontally. A conical section would encourage the release of droplets held by surface tension on the base of the funnel. (This can easily be rectified with careful application of a Stanley knife or a file.)

*Splashing in the measuring cylinder*

Water dripping through the funnel into the measuring cylinder has a long fall (250 mm from the base of the funnel to the bottom of the measuring cylinder when empty). Once a little water has accumulated in the measuring cylinder, subsequent drops falling into it cause splashes up the walls of the measuring cylinder which remain in place once the rain has stopped (see **Figure 1**). If conditions are suitable, these small splashes evaporate, resulting in the loss of the (small) amount of rainwater they represent. Even if they do not evaporate, it is well-nigh impossible to 'swirl' the water in the measuring cylinder to 'capture' them in the main body when making the daily measurements. The loss is probably negligible in the winter months, but during the summer months may amount to 0.1 or 0.2 mm daily.

*Tapered measuring cylinder*

Standard designs of raingauge measuring cylinder used in the UK and Ireland have for more than a century featured a tapered base (**Figure 4**), which greatly facilitates the measurement of small amounts of rain. This is particularly useful in distinguishing between falls of 'trace', 0.1 or 0.2 mm – 0.2 mm being the UK and Ireland standard threshold for a 'rain day'. Unfortunately the CoCoRaHS measuring cylinder has a flat rather than tapered base, and it is very difficult reliably to distinguish falls of < 0.1, 0.1, 0.2 or 0.3 mm, making the accurate determination of 'rain days' somewhat subjective. Inclusion of a tapered base into future designs of the measuring cylinder would greatly improve the design, usability and repeatability of measurement of small amounts of rainfall.

*Cleaning*

The bottom of the measuring cylinder becomes dirty surprisingly quickly, even at a rural site, and a regular clean with a long-handled bottle brush certainly makes for easier reading of small amounts. During the summer months, the outer container can quickly become home to all manner of insects and insect detritus, and a regular clean is again advisable to maintain transparency and ease of reading.

*Losses through evaporation*

The construction of the standard UK checkgauge limits evaporation losses through its multi-shell structure, a small gap between the funnel inlet pipe and the collecting bottle, and the partial burying of the gauge body within the ground. In contrast, the CoCoRaHS gauge is mounted at height and in the open air and is thus exposed to drying winds and the warming effects of sunshine, leading to partial evaporation of any accumulated rainwater within the measuring cylinder or on the funnel surfaces. Evaporation from the CoCoRaHS gauge body is limited by the close fit of the funnel into the gauge body, and effects on daily measurements are probably small (at least within the climate of the British Isles), but period accumulations are likely to be affected to a greater degree, particularly in the summer half-year.

*Frost impacts*

Self-evidently, liquid rainwater collected in the measuring cylinder of the CoCoRaHS gauge will freeze if the air temperature falls low enough. (This rarely occurs in the five-inch checkgauge as the collecting bottle is well-protected within the body of the gauge itself, and located slightly below ground level to reduce the risk of sub-zero temperatures: usually a very severe frost is required to freeze the contents of a Snowdon or MkII raingauge.) If the temperature is still below or close to 0 °C at the time of measurement (as will often be the case with a morning measurement time in the winter half-year in the British Isles), then the accumulated precipitation will be partially or completely frozen within the CoCoRaHS measuring cylinder, and will require thawing for the measurement to be made. If no precipitation is falling, or imminent, at the time of the observation, then this can be done by removing the measuring cylinder to a warm room for 30 minutes or so, taking care to avoid possible loss from evaporation by stoppering the open end. If however precipitation is occurring at the time, or is imminent, then the measurement must be delayed. When observations are made only once per day this leads to multi-day accumulations in the record, although if the record of a tipping bucket raingauge or other autographic rainfall recorder is available the daily amounts may be successfully apportioned from the period accumulation to maintain an unbroken daily precipitation record.

It would seem unlikely that sufficient liquid water would accumulate in the measuring cylinder to almost fill it, and then the entire unit freeze solid, but if this did happen the expansion of the ice may result in the cylinder being split. This is another reason for using the instrument for daily records, rather than leaving longer accumulations.

*Snowfall*

The CoCoRaHS gauge is arguably better at coping with snowfall than the standard Snowdon or MkII gauge. The recommended procedure in snowfall is to remove both the funnel and the measuring cylinder and leave the open top of the outer plastic case open to snowfall. At the observation time the outer gauge is then removed from its bracket, the contents carefully melted and then measured in the measuring cylinder in the normal manner.

This procedure probably works best for fine snowfall (of the type that occurs with the air temperature well below 0 °C). In the British Isles, snowfall is often wet and heavy (falling at or a little above 0 °C) and/or with a high water content, perhaps as rain and sleet mixed, or following a period of rain turning to snow. Under these circumstances removing the funnel is likely to hinder, rather than help, the gauge's collection efficiency, and may of course greatly increase the evaporation risk.

During the 12 month trial, snow or sleet was observed to fall on 32 days, with snow lying on the ground on 11 mornings. The funnel of the CoCoRaHS gauge was *not* removed during snowfalls, and snow was observed to build up rapidly within the shallow funnel of the CoCoRaHS gauge during heavier snowfall, quite quickly drifting over and thus being lost to measurement. (In contrast, the deeper funnel of the five-inch checkgauge retained most of the snowfall.) The water equivalents of even fairly slight snowfalls were quite difficult to measure with the CoCoRaHS gauge, partly because of this factor and partly because most if not all of the gauge needed to be dismantled to melt accumulated snow – not very practical when snow is falling at the time of the observation, of course.

For this comparison trial, frozen snowfall was left in place in or on the CoCoRaHS gauge until natural melting took place, and measurements made at the next scheduled morning observation. For the daily values, such as those shown in **Figure 3**, the period accumulations were apportioned into daily values using the ratios obtained from the (melted snowfall equivalent) checkgauge value. Most were acceptably close to the daily checkgauge values, although as the shallow CoCoRaHS gauge funnel filled with snow during a longer spell of snowy conditions 15-24 January 2013 records were lost. Estimates based upon the checkgauge values were substituted to complete the monthly totals in **Table 1**.

## Conclusions and recommendations

When benchmarked against an adjacent UK and Ireland-standard 'five-inch' copper raingauge, the CoCoRaHS gauge performed very well – indeed, much better than expected. The height of the gauge rim – 125 cm versus 30 cm for the standard checkgauge – was almost certainly to blame for some losses owing to the effects of increased wind turbulence: these occasionally exceeded 10 per cent on windy days (most frequent during the winter half-year). The shallow funnel also increased outsplash in heavy precipitation (particularly hail) and resulted in similar losses, while even 2-3 cm of snow quickly filled the shallow funnel resulting in the loss to measurement of subsequent snowfall, particularly in strong winds.

In conclusion, on the basis of the comparison trial described here the CoCoRaHS gauge can be strongly recommended for UK/Ireland observers where budget considerations do not permit consideration of a standard 'five-inch' copper raingauge. Although the results from the CoCoRaHS gauge cannot be accepted as fully comparable with the official standard, this analysis has shown that differences over a lengthy comparison period, measured daily, were small - a very acceptable 2 per cent at the comparison site, although it is likely that losses would be greater in areas with a higher frequency of strong winds and wind-driven rain than central southern England.

**This gauge is particularly recommended for owners of automatic weather stations whose only precipitation measurements come from the built-in tipping-bucket raingauge within such systems.** Experience has shown (see, for example, Burt 2009 and Burt 2012, Chapters 2 and 3) that the 'out-of-the-box' calibration on such units can be 20 per cent or more in error, while simple blockages may quickly destroy the reliability and continuity of rainfall records. A fixed manual raingauge installed on the same site will invariably provide both more accurate and more reliable measurement of absolute precipitation totals, help pinpoint any shortcomings in instrument calibration and identify any periods of instrumental failure or funnel blockages.

## Suggested improvements

In any future design alterations, the following changes would greatly increase the usability and accuracy of the CoCoRaHS raingauge:

- A *tapered measuring cylinder*, to facilitate the accurate delineation of small amounts of precipitation;
- A *chamfered funnel spout*, to aid the draining of the last drops of water from the funnel; and
- A *deeper funnel* would likely reduce wind-induced precipitation losses.

REFERENCES

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**Strangeways, Ian** (2007) *Precipitation: Theory, measurement and distribution.* Cambridge University Press, London and New York

 

*Table 1. Monthly totals and highest daily fall (0900-0900 UTC) for both gauges over the comparison period. Central Berkshire, southern England (51.4°N, 1.0°W), 2012-13. January 2013 CoCoRaHS data includes some estimates during a period of snowfall.*

| | | **Monthly totals (mm)** | | | | **Wettest day of each month (mm)** | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Year* | *Month* | *CoCoRaHS gauge* | *Standard five-inch gauge* | *CoCoRaHS as % five-inch* | | *CoCoRaHS gauge* | *Standard five-inch gauge* | *Date in month* | *CoCoRaHS as % five-inch* |
| **2012** | July | 75.6 | 74.8 | 101.1 | | 13.3 | 13.0 | 6 | 102 |
| | Aug | 42.9 | 43.5 | 98.6 | | 16.1 | 16.1 | 13 | 100 |
| | September | 47.3 | 47.1 | 100.4 | | 19.1 | 18.8 | 23 | 102 |
| | October | 119.3 | 120.8 | 98.8 | | 20.2 | 20.7 | 31 | 98 |
| | November | 84.8 | 85.9 | 98.7 | | 16.2 | 16.5 | 24 | 98 |
| | December | 112.7 | 117.1 | 96.2 | | 22.7 | 23.2 | 19 | 98 |
| **2013** | January | 62.5 | 65.5 | 95.4 | | 7.9 | 8.0 | 31 | 99 |
| | February | 37.3 | 37.3 | 100.0 | | 14.5 | 14.6 | 10 | 99 |
| | March | 90.7 | 91.2 | 99.5 | | 15.7 | 16.0 | 19 | 98 |
| | April | 43.7 | 45.7 | 95.6 | | 14.8 | 15.1 | 10 | 98 |
| | May | 53.5 | 54.4 | 98.3 | | 10.3 | 9.8 | 14 | 105 |
| | June | 19.0 | 19.2 | 99.0 | | 4.2 | 4.2 | 15 | 100 |
| | **12 month TOTAL** | **789.3** | **802.5** | **98.4** | | **22.7** | **23.2** | **19 Dec** | **98** |

 

**Figure 1** – The CoCoRaHS gauge used in this comparative trial. It is mounted on a fence post with its rim at 125 cm above ground level. Note the splashes from falling raindrops within the upper part of the measuring cylinder, and undrained droplets remaining within the funnel.
*Photograph taken on 14 August 2012.*

 

**Figure 2** – the trials site in central southern England, looking south-west. The CoCoRaHS raingauge (yellow circle) is located on a fence post at 125 cm above ground level, and 3 metres south of the standard 'five-inch' copper raingauge (white circle) used for benchmarking purposes. This photograph was taken on 23 June 2012, shortly after the start of the evaluation period.

 

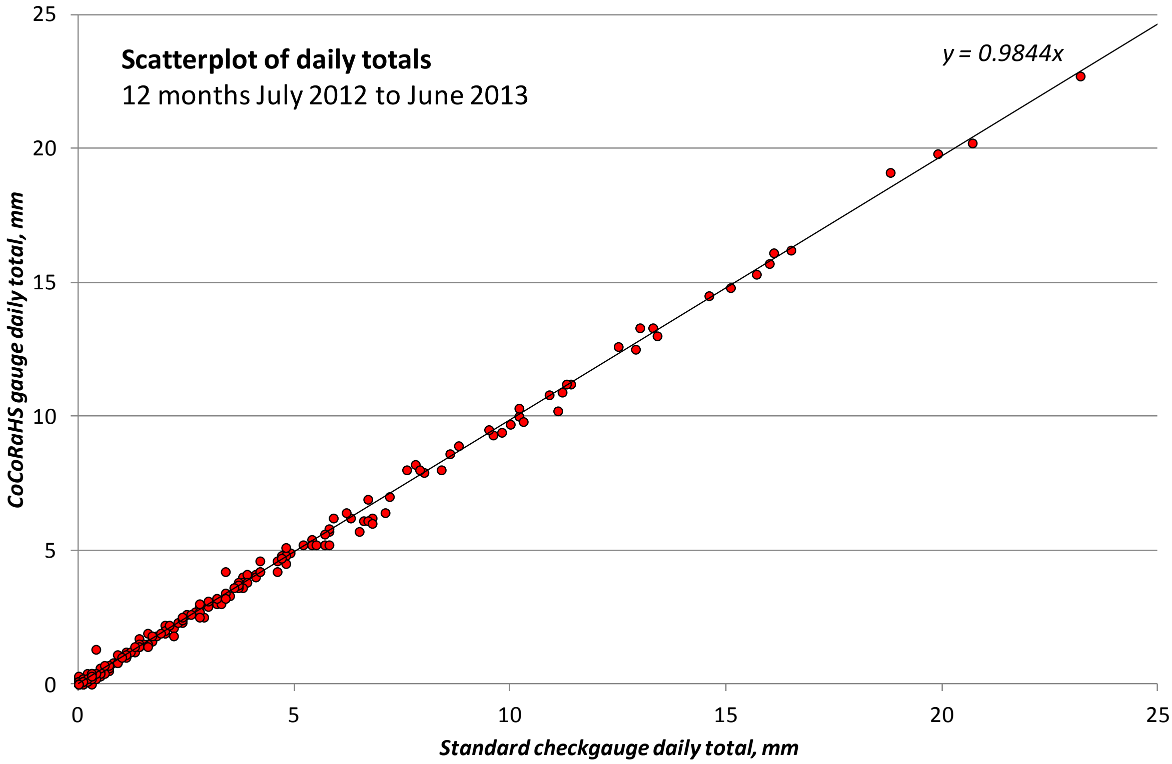


**Figure 3** – Scatterplot showing correspondence of daily totals from the standard 'five-inch' raingauge (*x* axis) and the CoCoRaHS gauge (*y* axis) for the 12 month comparison period commencing July 2012

**Figure 4** – Tapered measuring cylinder for UK/Ireland standard ‘five-inch’ raingauge, shown here with inch graduations (illustration taken from *British Rainfall* 1923). This design was introduced by George Symons, founder of the British Rainfall Organization, in the 1870s, and is known as the ‘Camden’ style, after the HQ of the British Rainfall Organization in Camden Square, north London.