INSTRUCTION MANUAL

SBS500 Tipping Bucket Rain Gauge

April 2015

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Campbell Scientific (Canada) Corp.
14532 131 Avenue NW | Edmonton AB T5L 4X4
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SBS500 Rain Gauge

The SBS500 is a well-designed tipping bucket rain gauge which combines durable construction with reasonable cost. The gauge offers less resistance to air flow than most previous designs, which helps to reduce the sampling errors that inevitably occur during wind-driven rain, and the SBS series as a whole has less susceptibility to 'splash-out' errors. The gauge is manufactured for Campbell Scientific by Environmental Measurements Ltd. and, owing to its rugged aluminum construction, when correctly sites will provide many years of reliable operation in the most rigorous of environmental conditions.

1. Introduction

The main collector body of the rain gauge is constructed from 2mm thick powder coated aluminum, giving strength and rigidity. The base section is manufactured from LM6 marine grade aluminum. The base includes three adjustable mounting feet and a bubble level gauge for free-standing applications, or the feet can be removed and the unit bolted firmly to a suitable mounting plinth or concrete slab for more permanent applications.

Figure 1-1 SBS500 Series Rain gauge

2. Technical Specifications

Funnel rim height:	440mm
Collector area (SBS500):	$500cm^2$
Tip sensitivity:	0.2mm of rain per tip (SBS500)
Typical Accuracy:	98% @ 20 mm/hr 96% @ 50 mm/hr 95% @ 120 mm/hr
Output:	Contact closure – two reed switches allowing monitoring to be carried out on an additional channel. Reed contact rating: 50W (DC resistive) Reed supply voltage: 100V DC maximum
Weight (approx.):	6Kg

3. Operation

The tipping bucket arrangement is similar to most other gauges of this type; precipitation is collected by the funnel and flows through a stainless steel gauze filter which traps and removes any leaves, etc. Water then passes through a nozzle into one of the two buckets situated at either end of a short balance arm. See Figures 3-1 and 3-2 below.

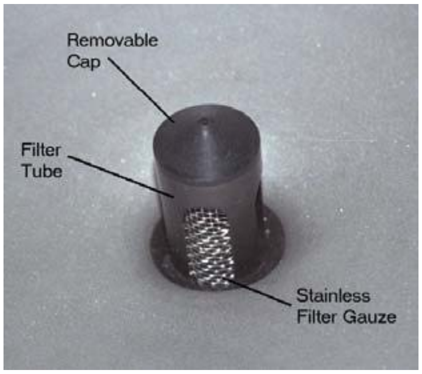

Figure 3-1 Filter Unit

Figure 3-2 Nozzle

The balance arm and bucket assembly rotates around precision rolling pivot bearings. The arm tips when the first bucket is full, emptying this bucket and positioning the second under the funnel. The tipping process repeats indefinitely as long as rain continues to fall, with each tip corresponding to a fixed quantity of rainfall. At each tip, the moving balance arm forces a magnet to pass a reed switch, causing contact to be made for a few milliseconds. A shielded two wire cable is used to connect the gauge to the datalogger where the switch closures are counted.

The SBS500 is adjusted at manufacture to tip once for each 0.2mm of rain. More information on gauge calibration is given in Section 8.

4. Installation and Siting

4.1 Choosing a Site

The site for a rain gauge is often a compromise between optimum exposure and operational constraints. The optimum site is level ground with a uniform scattering of objects in the surrounding area, thus reducing overall wind speeds. However, these objects should not be large enough to cause eddy currents or high gust speeds to occur near to the gauge, or so close to the gauge that rain is prevented from entering the funnel. Site the gauge carefully, and try to avoid obvious sources of error, such as nearby trees or buildings or other obstructions.

A useful ‘rule of thumb’ is that the distance between the gauge and any obstruction should be at least as great as twice the height of the obstruction above the ground. For standard meteorological sites the rain gauge should be above a short grass surface, and the SBS500 should be exposed similarly if measurements are required for comparison with those from agrometeorological or synoptic sites.

Note No two rain gauge designs are ever likely to produce identical results, and identical rain gauges can give slightly different catches even when sited within a metre of each other.

Research has shown that a rain gauge obstructs the flow of air and that the flow accelerates and turbulence increases over the top of the funnel. This can cause less rain to be collected in the funnel than otherwise would have fallen on the ground.

The body of the SBS500 has a profile which has been designed to reduce drag and turbulence using extensive practical data collected by Dr. Ian Strangeways (Strangeways, 1996) and it can therefore be sited conventionally on exposed sites with some confidence. Further details on the exposure of rain gauges are given in HMSO (1956, 1982) and by Rodda (1976). Another useful text on exposure and associated errors is Painter (1976).

Note If the gauge is sited in an area of livestock, then fencing will almost always be required to prevent damage from (and to) the animals.

4.2 Unpacking

Unpack the SBS500 carefully. The tipping bucket mechanism is immobilized before shipping to prevent damage in transit. To release the mechanism:

1. Remove the funnel of the gauge from its base by unscrewing the three screws and lifting the funnel.

2. Remove the piece of foam from under the bucket mechanism. Check the bucket mechanism for freedom of movement. The foam may be saved for use whenever the rain gauge is transported.

4.3 Mounting

The SBS500 weighs 6Kg, and so is heavy enough that is can, in many cases, be simply placed on an appropriate flat surface, ready for use.

However, three holes adjacent to the levelling feet are provided so that steel pegs (also provided) can be fitted for extra security in softer ground. In areas of high winds, or where additional security is required, these holes can be used to bolt the gauge (after correct levelling) to a solid surface, such as a concrete slab, using appropriate anchor bolts.

4.4 Levelling

If the rain gauge is tilted by more than a few degrees, the bucket mechanism may be thrown out of balance, significantly affecting its calibration. Furthermore, during wind-driven rain the gauge with a tilted funnel collector will vary with wind direction. It is therefore important to ensure that the rim of the rain gauge funnel is precisely levelled, using a spirit level.

Although a small circular bubble-type spirit level is incorporated into the base assembly of the rain gauge, this is provided only as a ‘quick check’ for initial setting up. Always level the rim precisely, using a separate spirit level (see Figure 4-1) and check regularly. Level the gauge by slackening the locking nuts on the adjustable feet, adjust the feet to achieve a perfectly level rim, and retighten the locknuts. If required, fit the pegs through the holes provided next to the adjusters.

Note Accurate and precise levelling of the rain gauge, as described above, using a spirit level, is the simplest and most effective way to ensure accurate rainfall measurements.

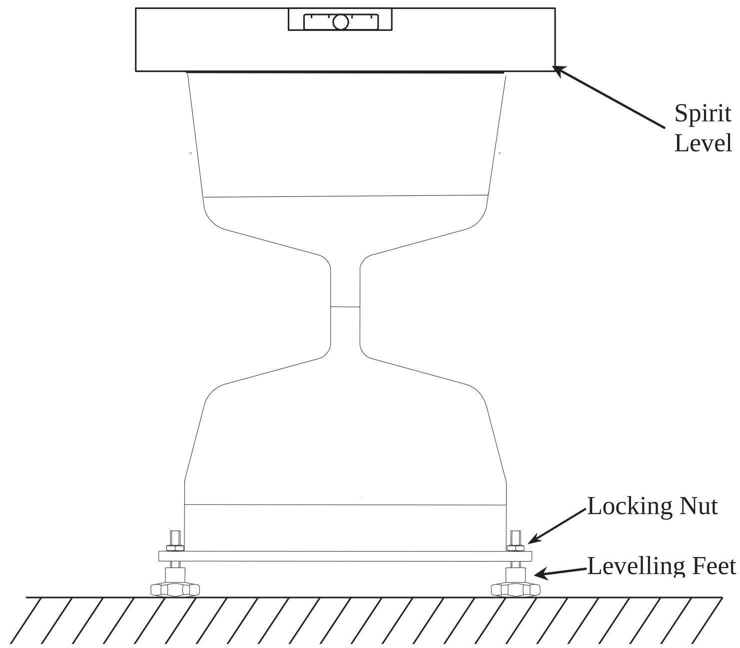

Figure 4-1 Levelling the SBS500 using a spirit level

5. Wiring

The rain gauge is supplied with a custom length cable at the time of order. For most applications the SBS500 may be connected directly to a pulse counting input on the datalogger as shown in Figure (5-1). For a long cable, a significant capacitance can exist between the conductors, which discharges across the reed switch as it closes. As well as shortening the life of the switch, a voltage transient may be induced in any other wires which run close to the rain gauge cable each time the gauge tips. A 100Ω resistor is fitted inside the gauge to protect the switch from arcing and prevent transients.

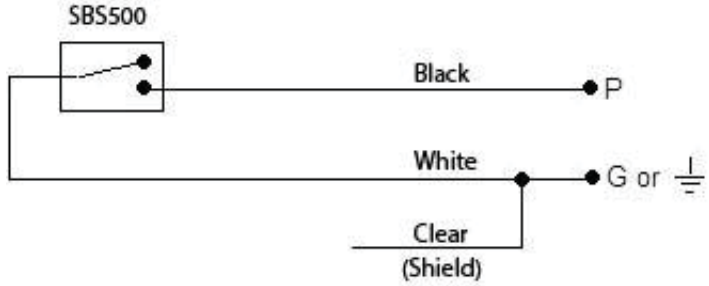

Figure 5-1 Wiring Diagram for SBS500

6. Datalogger Programming

Note This section is for users who write their own programs. A datalogger program to measure this sensor can be generated using Campbell Scientific's Short Cut Program Builder software. You do not need to read this section to use Short Cut.

Precipitation is measured using a Pulse Count with a switch closure configuration code. The multiplier used in the Pulse Count instruction determines the units in which rainfall is reported.

The sensitivity of the SBS500 is set at manufacture to a nominal figure of 0.2mm/tip and each gauge is subsequently calibrated as described in Section 8.1. For precise measurements, use this calibration value in your program instead of the nominal 0.2mm multiplier.

6.1 Pulse Channel Example Programs

The following example programs use a pulse channel to read the output from the precipitation gauge. The CR1000 example will also work with the CR800, CR850, CR3000, and CR5000. CR9000(X) programming is similar to the CR1000 except it has an additional parameter in the PulseCount instruction to specify the pulse module's slot.

The CR10X program will also work with the CR500, CR510, CR10, 21X or CR23X. CR7 programming is similar to the CR10X but has an additional parameter in the PulseCount instruction to specify the slot the Pulse Card is in.

6.1.1 CR1000 Example Program

```
'CR1000

'SBS500 Tipping
'Declare Variables and Units

Public Rain_mm
Units Rain_mm=mm
DataTable(Rain,True,-1)
	DataInterval(0,60,Min,0)
	Totalize(1,Rain_mm,FP2,0)
EndTable

BeginProg
	Scan(1,Sec,1,0)
		PulseCount(Rain_mm,1,1,2,0,0.2,0)
		CallTable(Rain)
	NextScan
EndProg
```

6.1.2 CR200(X) Series Example Program

```
'CR200(X) Series

'SBS500 Tipping

'Declare Variables and Units

Public Rain_mm

Units Rain_mm=mm

'Define Data Tables
DataTable(Rain,True,-1)
    DataInterval(0,60,Min)
    Totalize(1,Rain_mm,0)
EndTable

'Main Program
BeginProg
    Scan(1,Sec)

        'SBS500 Rain Gauge measurement Rain_mm:
        PulseCount(Rain_mm,P_SW,2,0,0.2,0)

        'Call Data Tables and Store Data
        CallTable(Rain)
    NextScan
EndProg
```

6.1.3 CR10X Example Program

```
;{CR10X}
*Table 1 Program
  01:  1.0000        Execution Interval (seconds)

1: Pulse (P3)
  1:   1             Reps
  2:   1             Pulse Channel 1
  3:   2             Switch Closure, All Counts
  4:   3             Loc [ Rain_mm ]
  5:   0.2           Multiplier
  6:   0             Offset

2: If time is (P92)
  1:   0             Minutes (Seconds --) into a
  2:   60            Interval (same units as above)
  3:   10            Set Output Flag High (Flag 0)

3: Set Active Storage Area (P80)
  1:   1             Final Storage Area 1
  2:   101           Array ID

4: Real Time (P77)
  1:   1220          Year,Day,Hour/Minute (midnight = 2400)
```

```
5: Totalize (P72)
   1:   1             Reps
   2:   3             Loc [ Rain_mm ]

*Table 2 Program
   01:  0             Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

6.2 Control Port Example

The following example programs use a control port to read the output from the precipitation gauge. The CR1000 example will also work with the CR800, CR850, and CR3000. The CR10X program will also work with the CR500, CR510, or CR23X.

6.2.1 CR1000 Example Program

```
'CR1000

'SBS500

'Declare Variables and Units
Public BattV
Public Rain_mm

Units BattV = Volts
Units Rain_mm =mm

DataTable(OneMin,True,-1)
      DataInterval(0,1,Min,10)
      Totalize (1,Rain_mm,FP2,False)
EndTable

'Define Data Tables
DataTable(OneDay,True,-1)
DataInterval(0,1440,Min,10)
      Minimum(1,BattV,FP2,False,False)
      Totalize (1,Rain_mm,FP2,False)                'SBS500 tipping bucket
EndTable

'Main Program
BeginProg
      Scan(5,Sec,1,0)
            'Default Datalogger Battery Voltage measurement BattV
            PanelTemp (PTemp,_50Hz)
            Battery(BattV)

            'SBS500 Rain Gauge measurement Rain_mm
            PulseCount(Rain_mm,1,14,2,0,0.2,0)
```

```
        'Call Data Tables and Store Data
        CallTable(OneMin)
        CallTable(OneDay)
    NextScan
EndProg
```

6.2.2 CR10X Example Program

```
;{CR10X}
;
*Table 1 Program
  01:  1            Execution Interval (seconds)

1: Pulse (P3)
  1:   1            Reps
  2:   8            Control Port 8 (switch closure only)   ;Black wire connect to C8
  3:   2            Switch Closure, All Counts
  4:   1            Loc [ Rain_mm ]
  5.   0.2          Multiplier
  6:   0            Offset

2: If time is (P92)
  1:   0            Minutes (Seconds --) into a
  2:   60           Interval (same units as above)
  3:   10           Set Output Flag High (Flag 0)

3: Set Active Storage Area (P80)
  1:   1            Final Storage Area 1
  2:   101          Array ID

4: Real Time (P77)
  1:   1220         Year,Day,Hour/Minute (midnight = 2400)

5: Totalize (P72)
  1:   1            Reps
  2:   1            Loc [ Rain_mm ]

*Table 2 Program
  02:  0.0000       Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

Output Instruction 72, Totalize, is used in the output section of the program to output the total rainfall over the output interval. This section should be executed every scan and not placed in a subroutine or conditional statement.

7. Maintenance

To ensure reliable and accurate measurements, we recommend that the following checks be carried out every month if possible.

Note If the gauge is connected to an operating datalogger you should try to avoid manually tipping the buckets during maintenance unless doing the balance check described in Item 5a, below.

1. Inspect the funnel for any damage or blockage and check the integrity of the connecting cable. At certain times of the year, leaves may accumulate in the bottom of the funnel, clogging the filter and preventing water flow to the buckets beneath, or reducing the flow rate to a slow drip. Remove the funnel from the base and clear any leaves or debris.

2. Clean the filter as follows:
   a) Unscrew the end cap from the filter tube.
   b) Carefully remove the stainless steel filter gauze and clean.
   c) Replace the filter and re-fit and replace the filter cap.

3. Check that the gauge is still level.

4. Remove any dirt, from, and clean, the bucket, being careful not to tip the bucket if the gauge is still transmitting to the datalogger. If you want to check that the balance arm/bucket assembly is free to move, see Items 5a and 5b, below.

Checking the Balance Arm Assembly with an Active Datalogger Link

5a. If the datalogger is still active and logging data, you can still check that the balance arm is free to move. This can be done by slowly pouring a measured quantity of water (say 250cm^3) through the gauge and counting the tips. It is worthwhile carrying this out at regular weekly intervals (for example, every Monday at 0900) while leaving the gauge connected to the datalogger. Providing a significant volume of water is used, these weekly checks can easily be identified in the logged measurements. This simple procedure confirms that the gauge is functioning, detects any marked change in the calibration and (if carried out punctually) introduces an independent time check into the records.

Checking the Balance Arm Assembly with an Inactive Datalogger Link

5b. If the datalogger is disconnected or not logging data, it is a good idea to check the balance arm for stiffness. The simplest way to do this in the field is to attempt to balance the bucket in its centre position. It should be very difficult (if not impossible) to do this. If the bucket balances easily, then examine the assembly for any dirt or wear on the pivot pin and bucket tubes.

A spares kit is available, comprising filter, filter cap etc. Please contact Campbell Scientific for spare parts requirements.

8. Calibration

The sensitivity of the SBS500 is set at manufacture to a nominal figure of 0.2mm/tip and each gauge is subsequently calibrated as described in Section 8.1. The calibration factor is given on a label inside the rain gauge. For precise measurements use this calibration value in your program instead of the nominal value of 0.2 shown in the program fragment in Section 6. Update this figure if the value changes on recalibration.

Before any recalibration is undertaken, take the opportunity to check and carry out any maintenance that may be required.

8.1 Static Adjustment and Calibration

The following procedure is carried out during manufacture and may be repeated if the calibration appears to have shifted.

1. Install the gauge over a sink unit as illustrated in Figure 8-1, ensuring that it is correctly labelled.

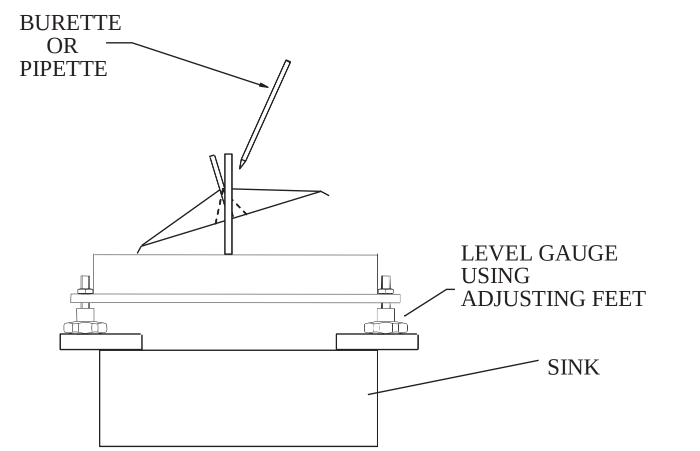

Figure 8-1 Setup for Static Calibration

2. Using a burette or pipette, slowly drip 10 10cm^3 of water (for the 0.2mm/tip gauge) into one side of the bucket. The bucket should tip on the last drip of water. Adjust the relevant calibration screw, situated under the tipping bucket, until this condition is met. Repeat for the other side of the bucket.

It may not be possible to set the screws very precisely using this method, but it should be done with as much care as possible. It is obviously very important to ensure that both buckets tip in response to the same amount of water. Many manufacturers and users of tipping bucket gauges aim to adjust the bucket settings until exactly the correct calibration is achieved. However, a dynamic test (see below) is required to check this calibration precisely after each readjustment and the process becomes very time-consuming. In any case, it is virtually impossible to get the adjustments absolutely correct, and it is generally preferable to adjust the settings as closely as is reasonably practical, and then to derive a calibration factor for each gauge individually after a dynamic calibration.

8.2 Dynamic Calibration

The SBS500 can be calibrated dynamically in two ways – by using a measured quantity of water or, preferably, by using the 'constant head' method. These two methodologies are described below.

1. Set up the gauge as illustrated in Figures 8-2 and 8-3, carefully levelled and connected to the datalogger.

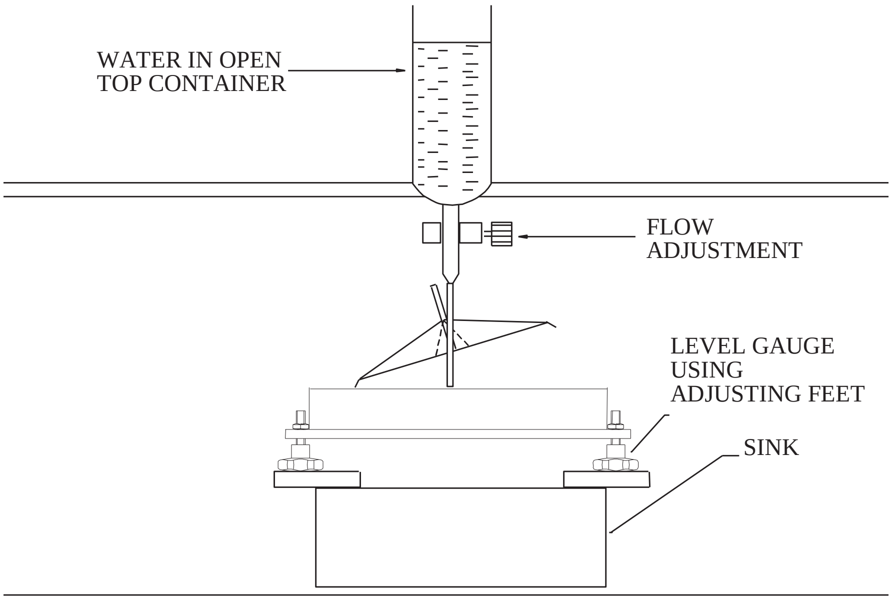

Figure 8-2 Dynamic Calibration using a Measured Quantity of Water

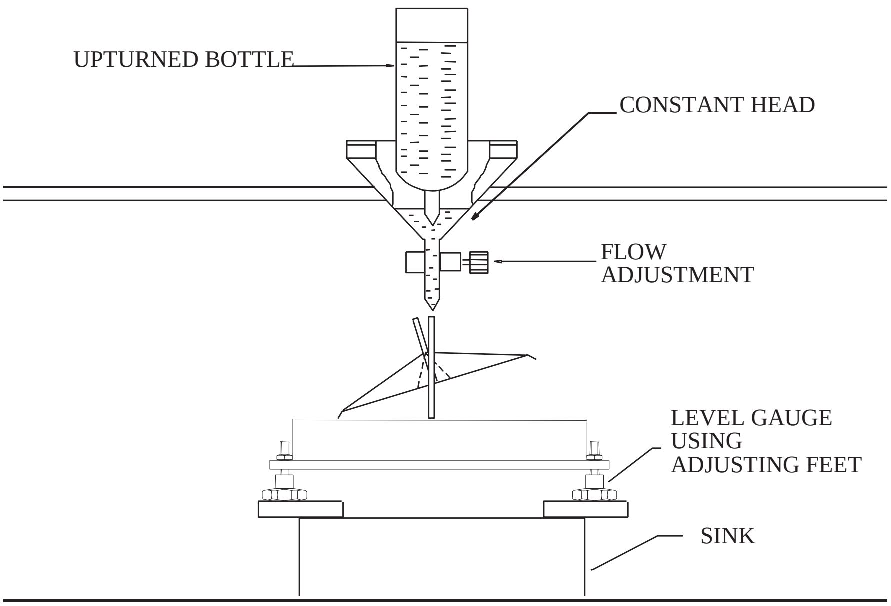

Figure 8-3 Dynamic Calibration using the Constant Head Method

2. Fill the water container with $1000cm^3$ of water for a 0.2mm calibration. This is usually achieved most precisely and consistently by weighing the water on a balance capable of measuring to 0.1g ($0.1cm^3$). An alternative is to use a good quality graduated measuring cylinder.

3. Allow the water to drip slowly into the gauge, allowing at least 60 minutes for the container to empty (approximately 40 seconds for each tip). This is a rate equivalent to a rainfall of 10mm/hour, as recommended in BS7843 Section 2.1 for calibration purposes. At the end of this period approximately 100 tips will have occurred. The exact number is obtained from the datalogger, together with an estimation of what fraction of a 'tip' is left in whichever bucket is still filling as the flow of water finishes. This fraction can either be assessed visually, or, for a more exact estimate, a graduated syringe can be used.

8.3 Calculating the Calibration Factor

Using the figures from the dynamic calibration tables, the calibration factor can be read from Table 8-1.

TABLE 8-1. Calibration Factors

Number of Tips	Calibration Factor
97.8 to 98.2	0.204mm/tip
98.3 to 98.7	0.203mm/tip
98.8 to 99.2	0.202mm/tip
99.3 to 99.7	0.201mm/tip
99.8 to 100.2	0.200 mm/tip
100.3 to 100.7	0.199 mm/tip
100.8 to 101.2	0.198 mm/tip
101.3 to 101.7	0.197 mm/tip

Alternatively, the calibration factor can be calculated using the formula shown below:

The nominal number of tips for a 0.2mm bucket is 100.

Let N equal the *actual* number of tips plus the fractional part left in the one bucket.

The calibration factor (CF) is then:

$$CF = 0.2 \text{ (optionally 0.25) } \times 80/N$$

For example, if N = 78.8, then:

$$CF = 0.2 \text{ (optionally 0.25) } \times 80/78.8$$

$$= 0.203 \text{ mm/tip}$$

In other words, each tip corresponds to 0.203 mm of rainfall. Provided that CF lies between 0.197 and 0.204mm, it will be acceptable for most purposes. If the CF lies outside these limits, repeat the static and dynamic calibration procedures.

The amount of rainfall in any particular interval is obtained by multiplying the number of recorded tips by the calibration factor.

As discussed above, the design of the gauge and its exposure are important factors. The aerodynamic design of the SBS series rain gauges should produce readings close to the true precipitation on the ground, in a wider range of weather conditions, than conventional rain gauges (even ‘standard’ designs such as the ‘Snowdon’ gauge). For sites with poor exposure characteristics, comparison of different types of gauges may vary with weather conditions.

9. Advantages and Limitations of a Tipping Bucket Gauge

Gauges which operate on the tipping bucket principle provide a digital output, which simplifies connection to a datalogger. The pulses returned during rainfall may be counted over any time interval desired allowing accurate determination of the rainfall rate (this variable, sometimes called ‘intensity’, is frequently used in soil erosion studies and it relevant to some aspects of crop pathology).

A tipping bucket gauge responds to discrete quanta of rainfall, and the accuracy and reproducibility of this quantum are determined not only by factors such as friction in the bearings, etc. but also by the rate of fill of the buckets. When the rainfall rate is high, a bucket may *start* to tip when the necessary volume of water has been collected, but while the bucket is moving away from the funnel outlet, an extra volume will have been collected and lost through spillage. The resulting degradation in accuracy is of the order of 4% at rainfall rates of 25mm/hr and 8% at 133mm/he for most gauges (Parkin et al, 1982). This is important when results from gauges of different designs are compared. These errors worsen when gauge sensitivity is increased. It follows that gauge design is always a compromise between the need for good resolution and good overall accuracy in rainfall totals.

References

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Rodda, J.C., (1967) *The rainfall measurement problem* Proc. IAHS Gen. Ass. Bern, IAHS Pub. No. 78, 215-231

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