

SBS314 and SBS500 – Rainfall Intensity Adjustments

1.0 Introduction

This document provides users of the 0.2mm SBS Range (SBS314 or SBS500 (Figure 1), not the 0.1mm SBS1000) of tipping bucket rain gauges with a method of correcting for the error introduced by the finite time it takes a bucket to tip, which increases with rainfall rate.



Figure 1

2.0 WMO Intercomparisons

In September 2004 the WMO launched, simultaneously, the Intercomparison of Rainfall Intensity (RI) Gauges in the laboratories of the Royal Netherlands Meteorological Institute (The Netherlands), Meteo-France (France) and the Department of Environmental Engineering of University of Genoa (Italy) in collaboration with the Italian Meteorological Service. The main objective of the intercomparison was to test the performance of catchment rainfall intensity gauges of different measuring principles under documented conditions. Finally a comment on the need to proceed with a field intercomparison of catchment type RI gauges was required as well as to identify and recommend the most suitable method and equipment for reference purposes within the field intercomparison of catching and non-catching type gauges. This field intercomparison took place between October 2007 and October 2009 at Vigna di Valle in Italy.

The results of the intercomparison showed that the tipping-bucket rain gauges that were equipped with proper correction software provided good quality rainfall intensity measurements. The gauges where no correction was applied had larger errors. In some cases problems of water storage in the funnel occurred that could limit the usable range for rain intensity measurement. (Report of WMO Laboratory Intercomparison of Rainfall Intensity Gauges 2004-2005)

EML's ARG100 rain gauge took part in this intercomparison and has resulted in EML producing this document and algorithm to reduce errors in RI measurement using our SBS range of rain gauges.

3.0 Maximum Rainfall Intensity tests:

Unlike the ARG100 rain gauge the manufacture process of the SBS funnel and nozzle does not reduce the maximum flow rate. So for high rainfall intensity (over 500mm/hr) measurement we recommend our SBS314 or SBS500 and have tested them up to **1000mm/hr**.

3.1 SBS Rainfall Intensity correction tests

For the tipping bucket section we used our calibration rig (Figure 2) with peristaltic pump to feed the water through four randomly selected SBS tipping bucket bases at known flow rates.



Figure 2

Because we calibrate the SBS rain gauges at a rate of 16mm/hr we used this as our starting value. The pump has certain limitation for setting flow so we could only run at nine different rates up to a maximum of 120mm/hr. Above 120mm/hr we used a Mariotte bottle with an adjustable drain.

Rain Intensity (Ref) mm/hr	"Ideal" tips/min	- Litre time (secs)	SBS A (Tips)			SBS B (Tips)			SBS C (Tips)		
			1	2	3	1	2	3	1	2	3
			0.200								
16.0	1.33	3750	99.0	99.0	99.0	99.1	98.9	99.0	99.2	98.8	99.0
20.6	1.72	2913	98.9	99.0	99.0	98.8	98.9	99.0	99.2	99.3	99.1
24.0	2.00	2500	98.5	98.1	98.3	98.2	98.2	98.3	98.4	98.3	98.5
28.8	2.40	2083	98.1	98.1	98.2	98.3	98.3	98.4	98.2	98.3	98.1
36.0	3.00	1667	98.0	98.0	98.1	98.2	98.2	98.1	98.4	98.3	98.3
48.0	4.00	1250	97.9	97.8	97.7	97.7	97.9	97.8	98.1	98.2	98.2
72.0	6.00	833	95.8	95.8	95.9	96.4	96.2	96.2	96.2	96.0	96.1
120.0	10.00	500	94.1	94.3	94.2	94.2	94.0	93.8	94.4	94.3	94.3
167.2	13.93	425	91.8	91.3	91.7	91.9	91.5	91.4	92.1	91.8	91.9
205.4	17.12	346	90.7	90.6	90.9	90.8	90.4	90.3	90.9	91.1	91.0
271.2	22.60	262	87.6	88.0	87.6	87.6	87.5	87.4	88.4	88.0	87.9
350.1	29.17	203	86.0	85.6	86.0	85.6	85.8	85.7	86.0	85.9	85.9
370.1	30.84	192	86.0	86.0	86.0	85.2	85.0	85.0	85.2	85.0	85.1
420.5	35.04	169	82.9	82.7	82.2	83.0	83.4	82.8	83.6	83.4	83.6
670.4	55.87	106	77.6	77.6	78.1	77.4	77.8	78.2	78.4	76.2	77.4
789.6	65.80	90	74.0	73.9	73.8	74.1	75.6	74.7	74.9	72.8	74.7
911.1	75.92	78	69.6	70.7	69.9	71.4	73.3	68.2	71.0	70.9	70.9

Table 1

Table 1 shows the data from the 1-litre water tests. Each gauge was tested three times to test repeatability. The value at the top of the data columns is the original calibration value of each gauge (i.e. SBS1 = 99.0, SBS2 = 99.0, SBS3 = 99.0). This gives each SBS an accurate calibration factor (see Table 2).

No of Tips	B.C.F.
97.8 to 98.2	0.204 mm/Tip
98.3 to 98.7	0.203 mm/Tip
98.8 to 99.2	0.202 mm/Tip
99.3 to 99.7	0.201 mm/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

Table 2

From Table 1 we can produce a table of data showing applied rainfall intensity (reference) against the rainfall intensity measured by the SBS gauges (Table 3).

<u>Rain Intensity</u> (Ref) mm/hr	<u>SBS A (mm/hr)</u>			<u>SBS B (mm/hr)</u>			<u>SBS C (mm/hr)</u>		
	<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>3</u>
	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0
16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.7	20.6
24.0	23.9	23.8	23.8	23.8	23.8	23.8	23.9	23.8	23.9
28.8	28.5	28.5	28.6	28.6	28.6	28.6	28.6	28.6	28.5
36.0	35.6	35.6	35.7	35.7	35.7	35.7	35.8	35.7	35.7
48.0	47.5	47.4	47.4	47.4	47.5	47.4	47.6	47.6	47.6
72.0	69.7	69.7	69.7	70.1	70.0	70.0	70.0	69.8	69.9
120.0	114.1	114.3	114.2	114.2	113.9	113.7	114.4	114.3	114.3
167.2	155.0	154.2	154.9	155.2	154.5	154.4	155.6	155.0	155.2
205.4	188.2	188.0	188.6	188.4	187.5	187.3	188.6	189.0	188.8
271.2	240.0	241.1	240.0	240.0	239.7	239.5	242.2	241.1	240.8
350.1	304.1	302.7	304.1	302.7	303.4	303.0	304.1	303.7	303.7
370.1	321.5	321.5	321.5	318.5	317.8	317.8	318.5	317.8	318.2
420.5	352.1	351.3	349.1	352.5	354.2	351.7	355.1	354.2	355.1
670.4	525.5	525.5	528.9	524.1	526.9	529.6	530.9	516.0	524.1
789.6	590.2	589.4	588.6	591.0	603.0	595.8	597.4	580.6	595.8
911.1	640.5	650.6	643.3	657.1	674.6	627.6	653.4	652.5	652.5

Table 3

For the purpose of creating an adjustment equation and graph we then produced a table of data showing the mean of the tests and the standard error (2X) – Table 4.

<u>Rain Intensity</u> (Ref) mm/hr	<u>Measured</u> <u>Rainfall Intensity</u> <u>(Mean)</u> (mm/hr)	<u>Std Dev</u>	<u>Std Err</u>	<u>Std Err</u> (2X)	<u>Std Err</u> (2X) +	<u>Std Err</u> (2X) -
16.0	16.0	0.02	0.01	0.02	16.0	16.0
20.6	20.6	0.03	0.02	0.04	20.6	20.6
24.0	23.8	0.03	0.02	0.04	24.0	24.0
28.8	28.6	0.03	0.02	0.04	28.8	28.8
36.0	35.7	0.05	0.03	0.06	36.1	35.9
48.0	47.5	0.10	0.06	0.11	48.1	47.9
72.0	69.9	0.15	0.09	0.17	72.2	71.8
120.0	114.2	0.22	0.13	0.26	120.3	119.7
167.2	154.9	0.44	0.26	0.51	167.7	166.7
205.4	188.3	0.56	0.32	0.65	206.0	204.7
271.2	240.5	0.87	0.51	1.01	272.2	270.2
350.1	303.5	0.59	0.34	0.68	350.7	349.4
370.1	319.2	1.74	1.00	2.01	372.1	368.1
420.5	352.8	2.00	1.16	2.31	422.8	418.2
670.4	525.7	4.36	2.52	5.04	675.5	665.4
789.6	592.4	6.40	3.70	7.39	797.0	782.2
911.1	650.2	12.81	7.40	14.79	925.9	896.3

From the above data we can calculate the second order polynomial equation that will allow us to adjust the mean measured rainfall intensity to the reference or ideal value. The following graph (figure 3) shows this adjustment and an estimate of the 95% confidence limits. The red line represents the average of the measured data and the black line is the ideal or adjusted data.

SBS314 and SBS500 - Reference RI v Measured RI

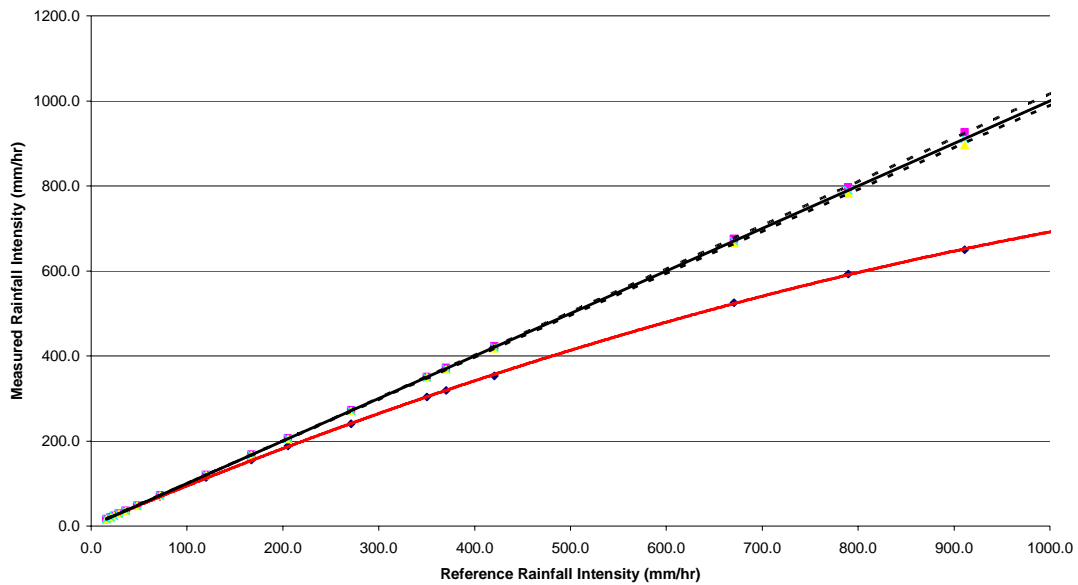


Figure 3

The adjustment equation is as follows:

$$\text{Rainfall Intensity (mm/hr)} = 6.5400\text{E-}04y^2 + 9.5616\text{E-}01y$$

Where *y* is the measured rainfall intensity (mm/hr) produced from the SBS rain gauge.

We recommend applying this equation to 1-minute samples. (See comments below).

4.0 Comments

The intercomparison tests (Vigna di Valle in Italy) on the EML ARG100 rain gauge showed that with the application of a mathematical adjustment our tipping buckets could produce good quality rain intensity data. Our mathematical adjustments differ from the WMO trials because we decided to determine the flow correction for the tipping bucket mechanism alone in a controlled calibration set-up. The WMO field trials had other uncontrolled variables, mainly wind that would likely be site dependant.

From our in-house tests we would limit the range of the SBS314 and SBS500 to a maximum measured value of rainfall intensity of 1000mm/hr and apply the above equation to either the final data produced or implement the adjustment in your logging system at the time of sampling. Because of the temporal variations in rainfall rate, the WMO recommended that rainfall intensity is corrected on a minute by minute basis. If rainfall intensities are corrected on a longer time basis there may be an underestimation of total rain, as the required corrections to short high intensity events will not be made.

References

- ARG100 – Environmental Measurements Ltd (Brazil/UK) datasheet (from the WMO field intercomparison (Vigna de Valle, Italy) report (October 2007 – April 2009)
- WMO Field Intercomparison of Rainfall Intensity Gauges ((Vigna de Valle, Italy) report (October 2007 – April 2009)
- WMO Laboratory Intercomparison of Rainfall Intensity Gauges 2004-2005