ARG100 – Rainfall Intensity Adjustments

1.0 Introduction

This document provides users of the ARG100 tipping bucket rain gauge (Figure 1) with a method of correcting for the error introduced by the finite time it takes a bucket to tip, which increases with rainfall intensity.

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)

The 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 the ARG100.

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Figure 2

3.0 Maximum Rainfall Intensity tests:

Due to the manufacture process of the ARG100 funnel section the maximum flow rate varies depending on the individual gauge. This is due to the size of the exit hole the water flows through. This tube is handmade for every gauge and can therefore differ from one gauge to the next. This difference is only slight, but can make a difference to the flow rate through the funnel. To show this, 10 ARG100 funnel sections were selected at random and tested. The 10 gauges were subjected to a constant increase of flow. All gauges continued to measure up to and above 500 mm/hr.
For rainfall intensity measurement we are only concerned with the 'maximum' rainfall intensity rate that the ARG100 gauge can cope with, and therefore we state that the ARG100 can measure up to a maximum flow of **500mm/hr**.

3.1 ARG100 Rainfall Intensity correction tests

For the tipping bucket section we used our calibration rig (Figure 3) with peristaltic pump to feed one litre of water through three randomly selected ARG100 gauges at known simulated rainfall rates.

Figure 3

Because we calibrate the ARG100 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 eight different rates up to a maximum of 120mm/hr. Above 120mm/hr we used a Mariotte bottle with an adjustable drain.

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Results of the 1-litre tests:

Rainfall Intensity (Ref) mm/hr	"Ideal" tips/min 0.200	Litre time secs	ARG 1 (Tips) 1 98.2	2 98.2	3 98.2	ARG 2 (Tips) 1 100.2	2 100.2	3 100.2	ARG 3 (Tips) 1 99.2	2 99.2	3 99.2
16.0	1.33	3750	98.2	98.2	98.2	100.1	100.3	100.2	99.2	99.2	99.2
20.6	1.72	2913	99.2	99.2	99.2	98.8	98.9	98.9	99.2	99.2	99.2
24.0	2.00	2500	98.3	98.1	98.5	99.7	99.6	99.8	98.3	98.3	98.4
28.8	2.40	2083	96.3	96.7	96.5	99.2	99.2	99.3	96.6	96.5	96.5
36.0	3.00	1667	98.0	98.0	98.1	99.8	99.4	99.4	98.0	98.1	98.0
48.0	4.00	1250	98.5	98.3	98.4	98.6	98.6	98.6	98.4	98.5	98.4
72.0	6.00	833	96.1	96.0	96.0	95.9	95.8	95.7	96.0	96.1	96.0
120.0	10.00	500	94.7	94.6	94.6	93.4	93.3	93.3	94.6	94.6	94.7
167.2	13.93	425	89.9	89.8	89.4	92.7	92.8	92.9	93.2	92.3	92.1
204.8	17.07	347	86.6	86.8	86.8	91.0	91.4	91.3	90.7	91.4	91.9
274.4	22.86	259	85.8	85.3	85.6	89.3	88.9	88.8	88.3	88.0	88.4
350.1	29.17	203	83.6	83.4	83.4	87.0	86.9	86.6	87.2	86.4	87.0
374.0	31.17	190	82.0	81.6	81.8	86.3	86.0	86.1	86.3	86.2	86.1
420.5	35.04	169	81.3	81.2	80.8	86.0	85.4	84.8	84.9	85.0	85.2

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. ARG1 = 98.2, ARG2 = 100.2, ARG3 = 99.2). This gives each ARG100 an accurate calibration factor (see Table 2).

No of Tips	C.F.
96.7 to 96.9	0.204 mm/Tip
97.0 to 97.4	0.203 mm/Tip
97.5 to 97.9	0.202 mm/Tip
98.0 to 98.4	0.201 mm/Tip
98.5 to 98.9	0.200 mm/Tip
99.0 to 99.4	0.199 mm/Tip
99.5 to 99.9	0.198 mm/Tip
100 to 100.4	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 ARG100 gauges (Table 3).

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Rainfall Intensity (Ref) mm/hr	ARG 1 (mm/hr)			ARG 2 (mm/hr)			ARG 3 (mm/hr)		
	1 98.2	2 98.2	3 98.2	1 100.2	2 100.2	3 100.2	1 99.2	2 99.2	3 99.2
16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
20.6	20.8	20.8	20.8	20.3	20.3	20.3	20.6	20.6	20.6
24.0	24.0	24.0	24.1	23.9	23.9	23.9	23.8	23.8	23.8
28.8	28.2	28.4	28.3	28.5	28.5	28.5	28.0	28.0	28.0
36.0	35.9	35.9	36.0	35.9	35.7	35.7	35.6	35.6	35.6
48.0	48.1	48.0	48.1	47.2	47.2	47.2	47.6	47.7	47.6
72.0	70.5	70.4	70.4	68.9	68.8	68.8	69.7	69.8	69.7
120.0	115.7	115.6	115.6	111.9	111.7	111.7	114.4	114.4	114.6
167.2	153.1	152.9	152.2	154.7	154.9	155.0	157.1	155.6	155.2
204.8	180.6	181.0	181.0	186.0	186.8	186.6	187.2	188.7	189.7
274.4	239.7	238.3	239.2	244.5	243.4	243.2	244.2	243.4	244.5
350.1	298.0	297.3	297.3	304.0	303.6	302.6	307.7	304.9	307.0
374.0	312.3	310.8	311.6	322.1	321.0	321.4	325.4	325.0	324.6
420.5	348.1	347.7	346.0	360.9	358.4	355.9	359.9	360.3	361.2

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.

Rainfall Intensity (Ref) mm/hr	Measured Rainfall Intensity (Mean) (mm/hr)	Std Dev	Std Err	Std Err (2X)	Std Err (2X) +	Std Err (2X) -
16.0	16.0	0.01	0.00	0.01	16.0	16.0
20.6	20.6	0.21	0.12	0.24	20.8	20.4
24.0	23.9	0.11	0.06	0.12	24.1	23.9
28.8	28.3	0.22	0.13	0.25	29.1	28.5
36.0	35.8	0.16	0.09	0.19	36.2	35.8
48.0	47.7	0.38	0.22	0.43	48.4	47.6
72.0	69.7	0.68	0.39	0.79	72.8	71.2
120.0	114.0	1.72	0.99	1.98	122.0	118.0
167.2	154.5	1.53	0.88	1.76	169.0	165.4
204.8	185.3	3.50	2.02	4.04	208.8	200.8
274.4	242.3	2.47	1.43	2.85	277.2	271.5
350.1	302.5	4.04	2.33	4.67	354.7	345.4
374.0	319.4	6.07	3.50	7.00	381.0	367.0
420.5	355.4	6.30	3.64	7.27	427.8	413.2

Table 4

From the above data we can calculate the second order polynomial equation that will allows us to adjust the mean measured rainfall intensity to the reference or ideal value. The following graph (figure 4) 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.

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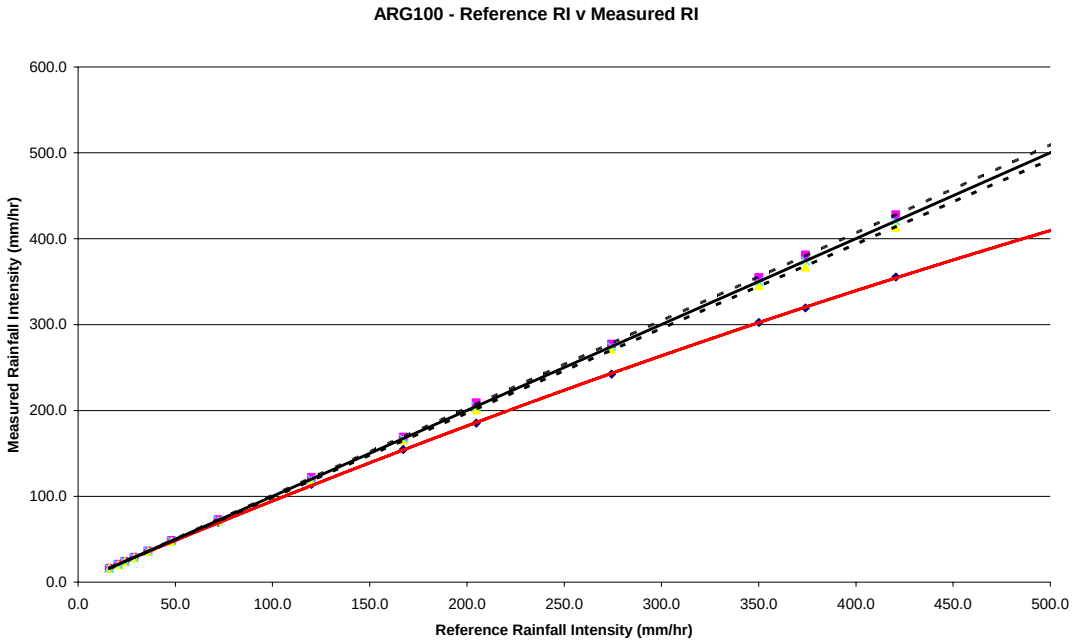

Figure 4

The adjustment equation is as follows:

$$\textbf{Rainfall Intensity (mm/hr)} = 5.1367E\text{-}04y^2 + 1.0038E+00y$$

Where y is the measured rainfall intensity (mm/hr) produced from the ARG100 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 ARG100 showed that with the application of a mathematical adjustment this tipping bucket 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 ARG100 to a maximum measured value of rainfall intensity of 500mm/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

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