COMMONWEALTH BUREAU OF METEOROLOGY

Regional Instrument Centre

Instrument Test Report - 669

EVALUATION OF THE HYDROLOGICAL SERVICES

PRECIPITATION GAUGE

TIPPING BUCKET TYPE TB-3

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Authorisation

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Aim

The aim of this technical note is to describe and discuss the testing of Hydrological Services Tipping Bucket Rain Gauge (TBRG) Model TB-3 against the Bureau specification for tipping bucket rain gauges [1]. To this end the structure of this document parallels that of the specification. This report contains references to sections of the Bureau TBRG specification considered relevant for RIC testing and does not include testing against all criteria outlined in the specification.

Experimental

The two testing rigs employed in this study are known within the RIC as Squiggly and Rex. Both systems are fully automated in terms of water delivery, tip counting and data logging. The two systems employ differing techniques to arrive at the same experimental value – *the number of tips for a fixed volume of water at a particular rainfall rate*.
Squiggly uses a Boyle bottle to deliver a fixed volume of water through fixed diameter nozzles under gravity. Hence the bottle volume determines the volume delivered and the 'rainfall rate' is determined by the nozzle diameter.
Rex employs a peristaltic pump to deliver water into the gauge, which is positioned on a weighing tray. A volume of water is delivered and then the tray is weighed allowing an accurate determination of both the volume delivered and the delivery rate. The 'rainfall rate' is determined by setting the RPM of the peristaltic pump.
The Squiggly system has been employed within the RIC for some time whilst the REX system has been recently developed based on overseas work [2] to achieve higher testing rates and greater flexibility of testing and is described separately [3]. The results of both testing systems were put into the same form, *corrections required per 100 tips* for each gauge at various rainfall rates producing graphs, which are employed to evaluate the gauges against the specification [1].
The water used in these tests was Melbourne tap water filtered through an Aquapure AP124 in-line water purification filter. Previous work has established that testing with filtered water does not significantly alter testing results when compared with distilled water [4].
20 gauges were received for testing. All were tested on either Squiddly or Rex or both. Throughout this document the term 'as received' is used to mean gauges that had not been bedded-in or previously tested by the RIC.
For these experiments 10 HS model TB-3 gauges were tested by Rex 'as received' and 10 were tested after they had been tested by Squiddly giving a total of 20 gauges.

Results

1. **Climatic Conditions** – Not evaluated in this study.

2. **Reliability**

   The rain gauge must be capable of resolving rainfall events of 0.6 mm and greater.
   Pass – that is, one or more tips were detected from a 'dry' gauge for an injection of 20ml of water into the gauge funnel.

3. **Tolerance** – See Section 9.

4. **Rainfall capability.**

For these tests Rex was employed, as Squiggly does not have the capability of programmed rainfall events. This test is designed to evaluate whether the gauge will overfill during expected short duration intense rain events.

4.1 *The gauge must accept water up to an equivalent rate of 350mm/hour without the collecting funnel starting to fill.* Pass

4.2 The gauge must accept volumes of water equivalent to the following extreme rainfalls without overflow of the collecting funnel:

a) 30mm of rain over 1 minute = 970 ml/min for one minute	Pass
b) 85mm of rain over 5 minutes = 550 ml/min for five minutes	Pass
c) 130mm of rain over 10 minutes = 420 ml/min for ten minutes	Pass
d) 250mm of rain over 30 minutes = 270 ml/min for 30 minutes	Pass

5. **Collector Details**

5.1 *Cross Section of rim between 200 and 205 mm in diameter* - Pass

5.2 *The overall height of the gauge must be between 250 and 360mm ±0.5 mm*- Pass

5.2 *The gauge must be suitable for installing on a flat metal plate or concrete slab. Three mounting holes of 8 to 10mm diameter shall be placed at 120° intervals on a 254mm pitch circle diameter at the bottom of the gauge. The holes may be in three separate legs or in a circular base.* - Fail - the 3 holes are on the wrong diameter circle and may not fit existing Bureau installations.

6. **Durability of materials** – Not evaluated in this study

7. **Measuring system details**

7.1 *The bucket mechanism must not retain more than 0.2 ml of water on the surface of the bucket side after its water has been discharged. A suitable coating such as Teflon may be used if necessary, in order to minimize the amount of water retained.* Pass.

7.2 *A surge suppression device of the Metal Oxide Varistor (MOV) type must be connected across each contact set. The MOV should have a voltage rating of not less than 25 volts but no more than 50 volts.* - Pass.

8. **Data Logger Cradle** - Pass

9. **Calibration and performance**

For these procedures the volume delivered, the diameter of collection area and other characteristics of the mechanism were used to calculate the expected number of tips. Only data from ‘as-received’ gauges were used in the determination of a pass or fail with respect to the Bureau specification. The criterion is the difference between the gauge under test and the ensemble mean, that is, the average correction for all gauges of that type for the set rainfall rates of 25, 52, 125, 250 and 300 mm/hr. The average of all corrections, for all gauges, at all applied rainfall rates was calculated and the

Bureau specification of ± 3 tips up to a rainfall rate of 250 mm/hr and ± 4 tips up to 350 mm/hr applied to that mean. This is illustrated in Figure 1.

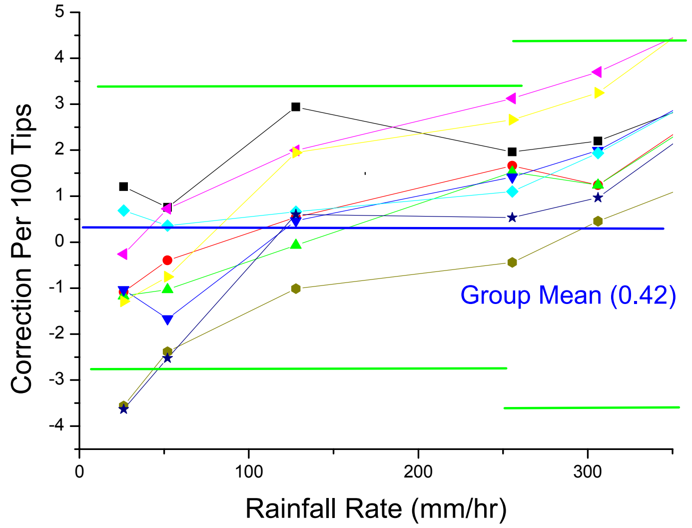

Figure 1. 'As-received' test of ten HS gauges. The blue horizontal line is the ensemble mean. The horizontal green lines are the Bureau specification [1].

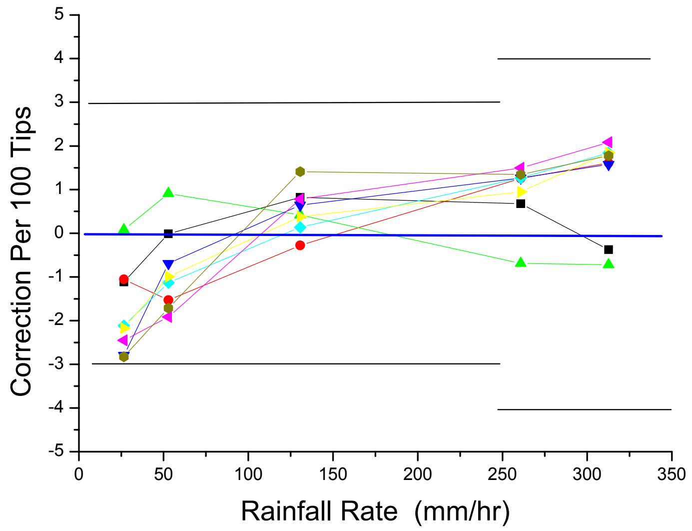

Figure 2. The 'as received' HS gauges shown in Figure 1 after their offsets have been adjusted to agree with the ensemble mean.

In figure 1 it can be seen that two out of the ten HS gauges tested fail the Bureau specification at 25 mm/hr. Figure 2 demonstrates that if the mean for each gauge were adjusted so that they coincided then the gauges would have passed the Bureau specification. This demonstrates that the largest contributor to gauge variability is sensitivity setting within a batch of gauges. Some gauges were selected for extended testing to determine if the characteristics of the gauge altered as a result. The results of this testing for HS gauges are shown in Figures 3 and 4. Of considerable interest is the increasing divergence of the correction at lower rainfall rates as more water is passed through the gauge. The impact of this 'bedding-in' process can be seen in both figures 3 and 4.

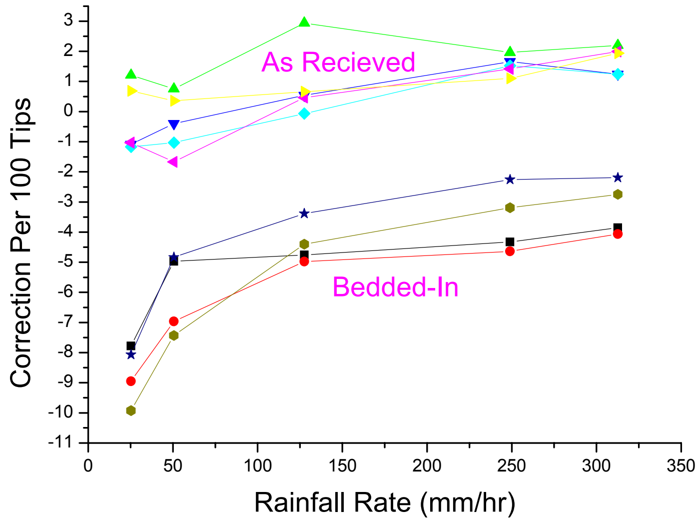

Figure 3. Before and after bedding in test – not the same gauges as used in Figure 1.

The upper group of curves in figure 3 is the corrections for 5 'as received' gauges. The lower set of curves is the corrections for 4 gauges after approximately 40 litres of water had passed through them.

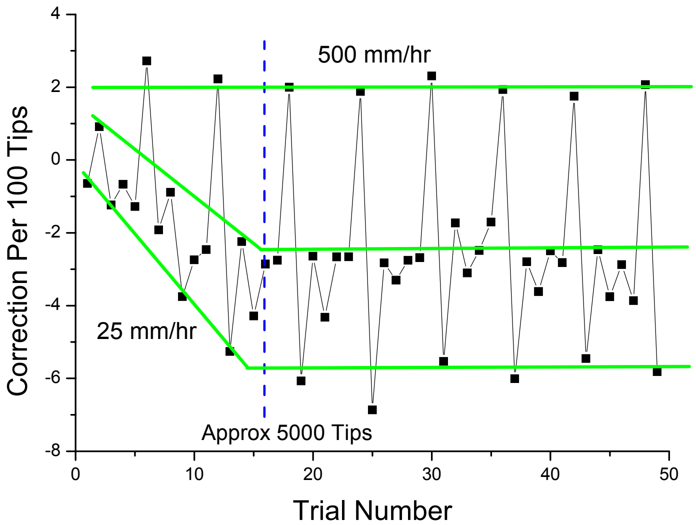

Figure 4. Correction versus trial number (HS 02-07) showing drift in correction versus total number of tips. 25 and 500 mm/hr data points marked. Centre green line is around the 52-mm/hr data points.

Figure 4 shows the drift in corrections during the 'bedding-in' of a HS gauge. The plot consists of the corrections calculated for successive test as the gauge is repeatedly cycled for 300 tips runs at 25, 52, 125, 250, 300 and 500 mm/hr. It can be seen that for 25 and 52 mm/hr the gauge correction moves significantly during early testing. This 'bedding-in' process is sufficient to move a gauge well out of specification at lower rainfall rates. More problematically the correction at 500 mm/hr drifts down by approximately 1 tip whilst at 300-mm/hr-rainfall rate drifts down by approximately 3 tips and at 25 mm/hr drifts downward by approximately 6 tips. This rate dependent change of the correction implies that a gauge initially adjusted to meet the specification will tend to fall outside the specification at lower rainfall rates after more water has passed through the gauge. It should be noted that the gauge

shown in figure 4 had already been tested once so it had already had approximately 2000 tips through it in addition to whatever amount HS had put through whilst adjusting the gauge. The Bureau specification also includes a test of the reproducibility of the gauge type. After a large amount of water has passed through the HS gauges (5000 tips) the behavior of the gauges was seen to alter as illustrated in figure 4 and the results indicate that the HS gauges will fail the reproducibility test if they are not bedded in.
Table 1 summarizes the group statistics for the 10 HS gauges 'as received'. The standard deviations calculated were then employed to calculate the 95% confidence levels for the expected mean at each rainfall rate for the group of 'as received' gauges [5] shown as vertical bars in figure 5. The data points are the mean corrections for the 10 gauges tested whilst the error bars are the 95% confidence levels calculated from the group corrections at each rainfall rate. These show that there is an expectation that more than 5 % of HS gauges will fall outside the Bureau specifications (shown in green) at the two lowest rainfall rates tested and 300 mm/hr.

Table 1. Combined average correction and standard deviation

Rate	Avg Corr.	Std Dev
26.122	-0.875	1.291
52.019	-0.537	1.006
127.786	0.747	1.217
255.488	1.268	1.236
306.052	1.507	1.412
497.522	4.799	2.662

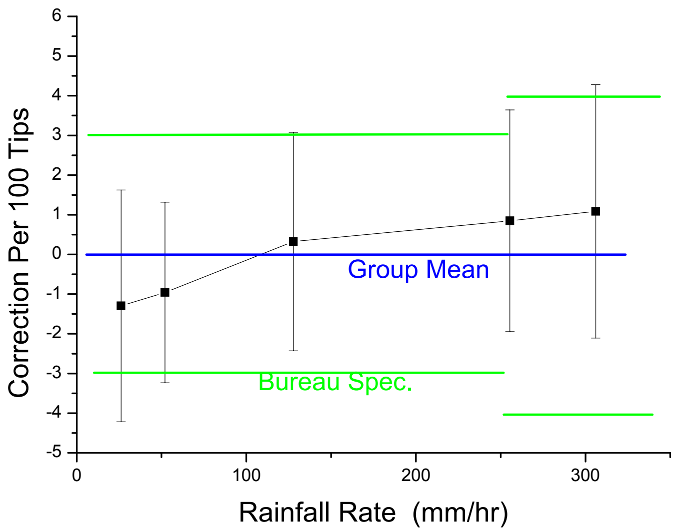

Figure 5. Plot of the mean corrections for the 10 'as received' HS gauges at testing rainfall rates. The error bars are the 95 % confidence levels derived from the test data.

As more than 5% of the 'as received' gauges failed the Bureau specification, and all gauges change their sensitivity by more than 3% at low rainfall rates after the equivalent of 5000 tips, the HS gauges fail the section 9 component of the specification.

Discussion

Figure 2 is important since it implies that if the gauges could be adjusted such that their means coincided the gauges would pass tolerance testing. However further testing would lead to the gauges moving out of tolerance, driven by the bedding-in process shown in figures 3 and 4. The gauges clearly increase in sensitivity, that is, the corrections become more negative after bedding-in. Figure 5 indicates that more than 5 % of HS gauges 'as received' will fall outside the Bureau specification.

10. Packing and Marking – Not relevant to this testing

11. Additional Comments

1. Manufacturing reproducibility for this gauge was poor. The variation in rim diameter for example was at the end of the acceptable range for a number of the gauges tested.
2. While not required by the specification, neither the siphon nor funnel was marked with a serial number thereby allowing mixing of different bases and siphons.
3. Variations in manufacturing meant that some funnels would not fit other bases, which has maintenance implications.
4. One gauge tested (s/n 02-01) had a leak in the rim seal, which allowed water that had entered the funnel to leak down the side of the gauge thereby bypassing the siphon and buckets (Specification Section 6.1e).

Conclusion

The Hydrological Services Model TB-3 TBRG fails to meet the Bureau specification [1]. While considerable manufacturing variation was noted, the calibration results at rainfall rates greater than 300 mm/hr are reasonable with the gauges having an ensemble mean of 0.42 for rainfall rates less than 350 mm/hr. The reason for the failure of the HS gauges was that at least two of the gauges were outside the Bureau spec at 25 mm/hr and the gauges were not 'bedded-in' before delivery resulting in a drift in characteristics with increasing total tips. It is difficult at this time to determine why bedding-in is necessary. However the effects of previous exposure to testing are significant and have been reported earlier [4] for other gauges. This drift impacts significantly on both the variability of the gauges and their offset errors.

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[1] *Precipitation Gauge Tipping Bucket Type*, Equipment Specification A 1980 Revision 3, Bureau of Meteorology 2002
[2] M. D. Humphrey and J.D. Istok*, A New Method for Automated Dynamic Calibration of Tipping-Bucket Rain Gauges,* , Vol. 14 Atmos and Oceanic Tech., Dec. 1997
[3] J.D. Gorman, *Evaluation of the RIC Designed Pumped Rain Gauge Tester*, Bureau of Meteorology 2003 ITR 670
[4] M.Berechree, *Stability of Five McVann Model 7499 TBRG*, Instrument Test Report 660, Aug. 2001
[5] *Uncertainty Measurement, The ISO Guide, Monograph 1.* NML Publication No. TIP P1337 2001