INSTRUMENT TEST REPORT 652

Evaluation of a Tipping Bucket Rain Gauge Calibrator

Manufacturer: Hydrological Services

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Authorisation

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SRLR

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12 Pages

Tipping Bucket Rain Gauge Calibrator

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1. Project Brief.

- Assess instrumentation on the basis of operator repeatability and reproducibility.
- Test water flow rates of nozzles.
- Test a known Tipping Bucket Rain Gauge (TBRG) on the calibrator.
- Modify the calibrator for ergonomic and operational requirements.
- Develop standard test methods for Bureau Regions specific to climatic requirements.

2. Background.

There exists a requirement for the Regional offices of the Bureau to either calibrate or check the calibration of TBRGs that are deployed out in the field. Currently there exists a test method that delivers a volume of water at a fixed rate into a TBRG. However this is a field check and has limited accuracy and limited applicability for climatic regions with different rainfall rate requirements. The Hydrological Services Pty Ltd (HS) Calibrator provides the opportunity for a more comprehensive calibration and verification of TBRGs.

3. Description of the Instrument

The HS Calibrator is designed to calibrate one or two TBRGs. The instrument is symmetrically arranged with two dispensing containers each designed to dispense 653ml (nominally) into a siphon catch situated above a base plate. See Fig.1

Figure 1

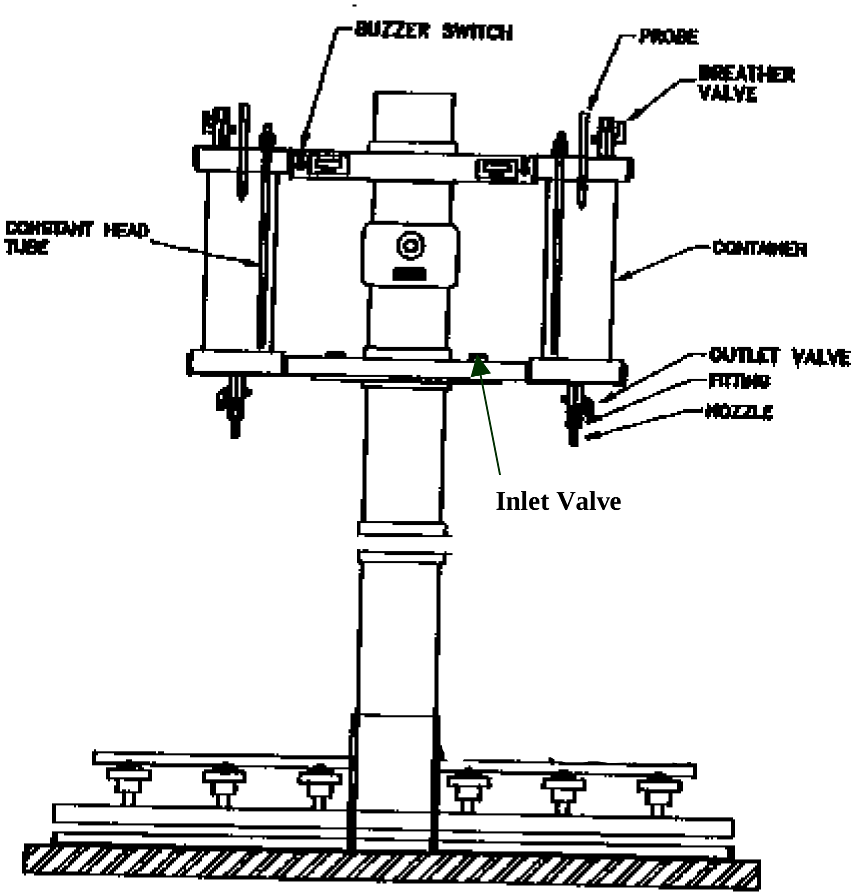

Image of an HS Calibrator

The containers are filled via an inlet valve that is operator controlled. The level of water is controlled by the operator, assisted by a probe at the top of the container. When the water level reaches the tip of the probe a circuit between the probe and the constant head tube is closed and a buzzer sounds. The operator closes the inlet valve. A switch located on the front panel disables the buzzer.

A digital indicator is placed on the front panel next to each container. The digital indicator leads are attached to the TBRG under test.

4. Tests Performed:

All tests were performed on HS Calibrator containers 3&4, (see Figure 1 for container).

4.1.Volume Delivery

The repeatability of the volume of water delivered by one operator was determined. An operator filled and emptied each container six consecutive times into a beaker. The mass of the water was determined by weighing the beaker before and after the fill. The same operator repeated this procedure on three different days at different times of the day to establish a reproducibility value. The same test was repeated with a different operator. The variation between two operators filling the containers was assessed. An uncertainty value for the volume of water delivered for a standard operator was determined from these measurements.

4.2.Nominal and Actual Flow Rate

The flow rate of the instrument's flow rate nozzles was measured. The time taken to empty the container volume using the nozzles marked for the containers was measured six times for each nozzle.

A comparison of performance of one nozzle on the different containers was made. The time taken to empty the container volumes through the 3-500 nozzle was measured six times on each container.

4.3.Test Method Comparison

The performance of a known rain gauge was assessed. The rain gauge was tested under each container with each flow rate nozzle. The number of tips was recorded for each run. The variance of the tests was compared to equivalent historical tests on the same rain gauge using the volumetric bottle method.

4.4.General Assessment

A general assessment of the instrument was performed and a series of modifications and recommendations are detailed in this report.

4.5.Generic Testing Method

A generic testing method was developed for TBRGs that differs slightly from the procedure recommended by HS.

4.6.Regional Testing Procedures

Rainfall rate distributions across the country were consulted to develop testing procedures relevant for each climatic region.

5. Results and Discussion

5.1.Volume Delivery

The uncertainty of the volume of water delivered by each container on an HS Calibrator was determined. The difference of volumes delivered by one operator between two independent test runs was insignificant. The difference of the mean and uncertainty of the volume delivered between two different operators was also insignificant. The uncertainties quoted below are derived from a pooled variance between operators and different test runs.

The mean volume delivered from the containers was found and the uncertainty of filling the containers was found. The results can be found in the Table 1 below.

Table 1 Container Volumes

	Container #3	k=2.1 ν=12	Container #4	k=2.1 ν=11
	Mean	Uncertainty [1] 95% (mean)	Mean	Uncertainty 95% (mean)
Average Filling Volume	653.12ml	0.40ml	653.64ml	0.50ml
Rainfall in mm for RIMCO 203mm diameter	20.18mm	0.01mm	20.20mm	0.02mm
Rainfall in mm for HS 200mm diameter	20.79mm	0.01mm	20.81mm	0.02mm

5.2. Nominal and Actual Flow rates

The average flow rates for the nozzles were found and the uncertainty in delivery rate was calculated. The results are given in the Table 2 below in seconds taken to empty the container.

Table 2 Flow Rate Analysis

Nozzle Number	Container #3		Container #4		
	Average time to dispense container 3 (s)	Uncertainty Percentage (95%) (mean) k=2.6 ν=5	Nozzle Number	Average time to dispense container 4 (s)	Uncertainty Percentage (95%) (mean) k=2.6 ν=5
3-500	149.7	1.7	4-500	153	1.0
3-300	290.4	1.3	4-300	278.7	2.5
3-200	363.7	1.8	4-200	372.8	1.6
3-100	682.3	0.9	4-100	722.8	2.6
3-50	1412.5	1.9	4-50	1285.7	5.7
3-25	4100.4	8.2	4-25	4196.2	4.5

[1] Where 95% uncertainty is defined as k×ESDM in accordance with the ISO Guide to Expression of Uncertainty in Measurement. Where k is the coverage factor.

Actual flow rate data in mm/hr for flow rate nozzles calculated for 200mm and 203mm diameter TBRG's are presented in Table 3.

Table 3 Container Comparisons

	Container No 3				Container No 4			
	Nozzle No	Flow Rate	Percentile		Nozzle No	Flow Rate	Percentile	
			2.5%	97.5%			2.5%	97.5%
203mm TBRG	3-500	485.4	477.3	493.8	4-500	476.7	471.8	481.8
	3-300	250.1	247.0	253.4	4-300	260.9	254.5	267.7
	3-200	199.8	196.2	203.5	4-200	195.0	192.0	198.1
	3-100	106.5	105.6	107.4	4-100	100.6	98.0	103.3
	3-50	51.4	50.5	52.4	4-50	56.5	53.5	59.9
	3-25	17.7	16.4	19.3	4-25	17.3	16.6	18.1
200mm TBRG	3-500	500.1	491.7	508.7	4-500	491.2	486.1	496.3
	3-300	257.7	254.5	261.0	4-300	268.8	262.2	275.8
	3-200	205.8	202.1	209.7	4-200	200.9	197.8	204.1
	3-100	109.7	108.7	110.6	4-100	103.6	101.0	106.4
	3-50	53.0	52.0	54.0	4-50	58.3	55.1	61.8
	3-25	18.3	16.9	19.9	4-25	17.9	17.1	18.7

A comparison of the flow rate from one nozzle on both container 3 and 4 of the HS Calibrator was made to determine if the flow rate was dependent on the container. This was not expected to be the case. However the nozzles are marked according to container number and a nominal flow rate. The test was performed to confirm the assumption that the performance of the nozzle under both containers is the same. The use of different flow rate nozzles under a different container is not recommended however the accidental use of different flow rate nozzles with different containers is not expected to significantly change the result of a TBRG calibration.

Analysis of the variance of the measurements made on both containers showed there was no significant difference between the uncertainties in the measurements. However container 4 exhibited more variability than container 3.

The HS Calibrator was not used for three days prior to making the measurements on container no 4. The 'dry' state of the instrument after three days without use may have contributed to the large uncertainty value. The first few measurements made were discarded and the flow rate values recalculated. There seemed to be a numerical improvement in the uncertainty. Since the original uncertainty values were not statistically different no significant conclusion can be made about the difference of flow rates if the instrument is wet. These results are shown in Table 4.

It is recommended that a quantity of water be run through an HS Calibrator before any calibrations are made.

Based on the results of Table 4, the nozzle flow rate is independent of the container to which it is attached.

Table 4 Nozzle-Container Dependence Analysis

Nozzle 3-500									
	Container 3			Container 4			Container 4 Modified Data Set		
Average time to deliver volume (s)	148.5			147.7			150.5		
Uncertainty (s)	0.5			4.2			2.0		
No. of measurements	13			9			6		
Flow rate mm/hr @ 203 mm	489.3	Percentile		492.4	Percentile		483.1	Percentile	
		2.5%	97.5%		2.5%	97.5%		2.5%	97.5%
		487.6	491.1		478.8	506.7		476.9	489.5
Flow rate mm/hr @ 200 mm	504.1	502.3	505.9	507.2	493.3	522.0	497.7	491.3	504.3

5.3.Test Method Comparison

A TBRG was tested with the HS Calibrator and the results were compared with historical data. Because of the new to historical data comparison the mean number of tips compared to the expected number of tips for the volume of water delivered was not compared. However the variance of the rain gauge in both tests was compared to determine if both methods of testing would give reproducible results. An F-test was used to determine of there was a significant difference in variance between the test methods. For most flow rates the variance of the number of tests were the same with 95% confidence. Four of the HS Calibrator test runs produced a significantly smaller variance than the equivalent nozzle using the volumetric bottle method. Only one of the HS Calibrator test runs produced a significantly greater variance than the equivalent volumetric bottle method. On average there is no significant difference between standard deviation of the two test methods. These results are summarised in Table 5 below.

Table 5 Test Method Comparison Results

HS Calibrator Method				Manual Volumetric Bottle Method				F-test
Container & Nozzle	Mean Tips	St Dev	No of Runs	Flow Rate	Mean Tips	St Dev	No. Runs	St Dev >, <, =
4-25	103.00	0.63	6	25.4	103.6	3.53	10	<
4-50	103.3	0.76	7	50.8	104.9	2.28	10	<
4-100	105.3	0.76	7	127	106.1	1.10	10	=
4-200	104.0	0.63	6	254	104.0	0.67	10	=
4-300	104.7	1.21	6	381	101.6	0.52	10	=
4-500	102.5	0.84	6	508	100.3	0.48	10	=
3-500	100.3	0.52	6	508	100.3	0.48	10	=
3-300	104.3	1.80	7	381	101.6	0.52	10	>
3-200	104.0	0.00	6	254	104	0.67	10	<
3-100	105.0	0.89	6	127	106.1	1.10	10	=
3-50	102.7	2.63	7	50.8	104.9	2.28	10	=
3-25	104.2	1.17	6	25.4	103.6	3.53	10	<

The HS Calibrator test results for 5 runs to 3 runs were compared to determine if there would be a significant difference between running a full test or an abbreviated test for the Regional sites. There was no significant shift in variance for 5 runs to 3 runs. Therefore an increase in the uncertainty commensurate with only a decrease in the number of degrees of freedom is appropriate for the HS Calibrator method.

5.4. Modifications to the instrument have been recommended and are listed here.

- Automation.

  It is recommended that the HS Calibrator be developed into an automated system. Advantages of automation of the HS Calibrator are increased reproducibility of the test method and decreased labour time required performing the test. Automation would improve the accuracy of the HS Calibrator; in particular the volume of water delivered from the containers. The uncertainty introduced into the test method by the operator controlled volume delivery was approximately a half tip.

- Siphon Coupling Units.

  The siphon coupling units were removed from the instrument for the purposes of this assessment. It is recommended that they be removed prior to shipping to the Regions. The siphon coupling can potentially introduce errors into the measurement and is not representative of the actual performance of the TBRG. This modification was made at the Physics Laboratory.

- Water Height – Buzzer Circuit.

  The probe and buzzer circuits are exposed at the top of the instrument. Heat shrink should be placed over cable connections at the top of the instrument to protect from water and human contact. It is also recommended that insulating material be placed around the height probe and constant head tube outside of the container to prevent short circuit occurring outside of the container in the occurrence of water overflow from the constant head tube. A removable cover over all valves at the top of the containers allowing for the appropriate outlets is recommended. This modification was made at the Physics Laboratory.

- Water Drainage and Base

  The HS Calibrator is attached to a plywood base. This base if continuously wet, it may swell and buckle causing the HS Calibrator to become unstable. It is recommended that the plywood base is removed and the HS Calibrator set up without this base.

The HS Calibrator has a flat base with a hole in the centre. The entire unit may either be placed over a sink or the hole can be connected to a hose leading to a drain. The current configuration of the base allows water to collect without draining. It is suggested that several other drainage ports be cut into the base of the instrument and hoses connected to these prior to shipping to the Regions.

- Plumbing

  Fittings to plumbing are required and are not supplied by the manufacturer of the calibrator. The fitting on the inlet port is SWAGELOK® fitting Part No B-400-1-4. However it is recommended that pneumatic fittings be used. This requires an adaptation of a SWAGELOK® adaptor to a ¼” NPT fitting. Alternatively by removing the water inlet manifold and unscrewing, the SWAGELOK® fitting can be removed. The inlet port is a ¼” NPT thread. The SWAGELOK® fitting is difficult to remove and requires dismantling of parts of the HS Calibrator - this is not recommended. It is recommended that an adaptor be used to connect the inlet valve to a pneumatic fitting. This modification was made at the Physics Laboratory.

- A Standard Test Procedure is recommended with suggested flow rate regimes for the different regions. See Section 5.6 for Standard Test Procedure recommendations for each Region. This has been completed in the Inspections Handbook, (see Annexe 27, Part 4.27 As at 31 Oct 1998).

- Installation recommendations.

When installing the HS Calibrator ensure the base, the water inlet and containers of the calibrator are level.

Piping recommended for installation is nylon tubing with 6mm inner diameter. Pneumatic fittings are recommended for the water inlet valves and as connection to the mains water taps. Recommended Pneumatic fittings are listed below. All can be found in RS Components catalogues under pneumatics accessories.

- 8mmO.D. 5 to 6mm I.D. nylon tubing
- 8mm × ¼” Straight Adaptor Parallel Thread or any pneumatic fitting required to attach 8mm tubing to mains.
- A SWAGELOK® Female adaptor – B-4-TA-4-7
- G¼” × 8mm Half-Union SMC Uni-Fit Component. RS stock no. 726-730 at1998.

5.5. Generic Testing Method

- Remove jacket from TBRG.

- Connect the TBRG switch to the digital counter on the HS Calibrator next to the container under which the gauge is being tested.

- Place TBRG on mounting table. Ensure the water outlets from the tipping bucket rain gauge are aligned over the drainage holes on the mounting plates. Adjust levelling knobs on mounting table to ensure that the base of the TBRG is level.

- Replace the jacket on the TBRG.

- Select the appropriate flow rate nozzle and attach it to the outlet valve fitting of the container under which the gauge is being tested.

- Switch the buzzer on. The switch is located next to the digital indicator. The switch is on when it is pointing toward the top of the HS Calibrator.

- Ensure the outlet valve is closed.

- Open the breather valve at the top of the container.

- Fill the container by slowly opening the inlet valve (see figure 1) for the container. Ensure that the height increase of water in the container is no faster than approximately 5mm per second to maintain adequate control over the filling of the container. Stop filling the container prior to the water level reaching the tip of the probe.

- Place a small cup or beaker beneath the nozzle and open the outlet valve. This removes air bubbles trapped in the nozzle and outlet valve. Trapped air bubbles will affect the volume of water delivered and the flow rate.

- Slowly fill the container. When the buzzer sounds, stop filling by turning the inlet valve all the way off. Switch the buzzer off.

- Close the breather valve at the top of the container.

- Ensure the digital indicator connected to the TBRG is reading zero initially. If it isn't, reset the indicator.

- Open the outlet valve and allow water to empty into TBRG.

- When the water has stopped flowing into the TBRG for at least three minutes, record the digital counter reading against the flow rate of the nozzle.

5.6. Recommended Standard Test Procedure

The distribution of rainfall rates in Australia was examined to determine the most appropriate calibration for each Region's latitude. Graphs displaying rainfall rate distributions can be found in Appendix A.

The rainfall rate distribution suggests that there should be two procedures for calibrating tipping bucket rain gauges depending on where they are situated. There are two distinct climatic types to which the two procedures apply. The first is the northern region and east coastal region. The second is South and Western Australia.

These regions are defined as follows

Area	**Latitude**		**Longitude**	**Regions Included**
Area 1	≤25°South	OR	≥ 140°	VIC, NSW, QLD, NT, WA, SA
Area 2	>25°South	AND	< 140°	WA, SA, NT

Procedures for the two areas are shown in the tables below

Area 1	
Nozzle Number	Number of Runs
(Container Number)-25	3
(Container Number)-50	3
(Container Number)-300	3

Area 2	
Nozzle No	Number of Runs
(Container Number)-25	3
(Container Number)-50	3
(Container Number)-200	3

It has been established that the uncertainty of the test is the same as the equivalent volumetric bottle test. Further analysis was completed to determine if decreasing the number of runs at each flow rate would cause a significant difference to the test results and uncertainty. There was no significant increase in the uncertainty of the test method.

A Standard Test Procedure and the analysis of the final results can be found in the Inspection Handbook, Annexe 27, Part 4.27, As at 31 October 1998.

Appendix A: Rainfall Rate Distribution Across Australia

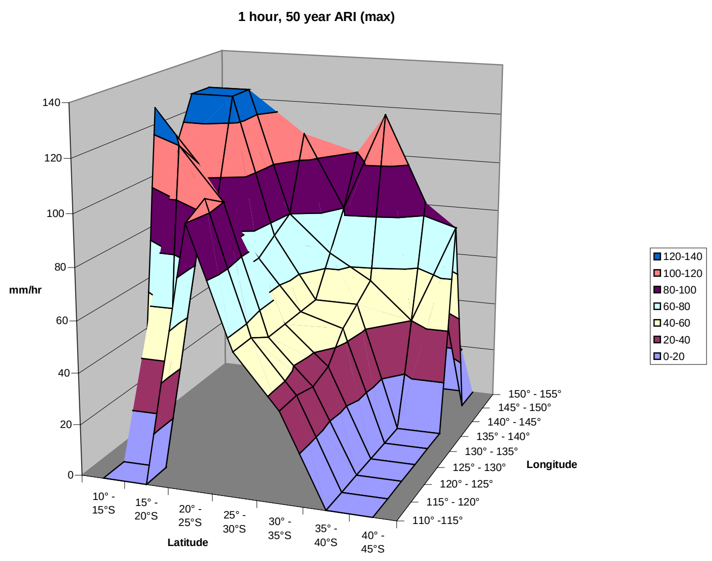

Figure A 1

The maximum rainfall rate over one hour with an average recurrence interval of 50 years is shown in Figure A1. There is clear difference between the North and East Coast compared to South and Western regions of Australia.

A distribution of the minimum rainfall in each latitude/longitude area is shown in Figure A 2 below.

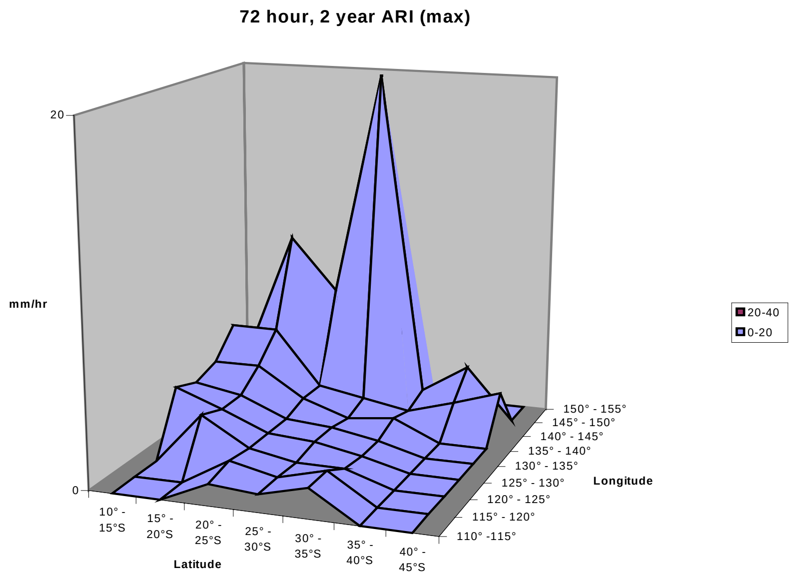

Figure A 2

The rainfall rate over a 72-hour period with and average recurrence interval of 2 years gives a good indication of the typical expected rainfall rate for the region. The slower flow rates of 25 and 50 mm/hr cover the typical expected rainfall rate across the country.