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INSTRUMENT TEST REPORT 660

Stability of five McVann Model 7499 TBRG

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9 Pages

1. AIM

To investigate the stability of the McVan Pty. Ltd. (MCVANN) tipping bucket rain gauge (TBRG) Model 7499 in controlled laboratory conditions.

2. BACKGROUND

Tests of several production runs during early 2001 of MCVANN Model 7499 TBRGs using Test Procedure A1980(3) suggested that the majority of gauges were showing a significant increase in sensitivity (that is, more tips per constant rainfall) at rainfall rates <250 mm/hr and the uncertainty of sensitivity at a rainfall rate of 100 mm/hr was significantly higher than for other rainfall rates (significant drift being defined as any step change in sensitivity that would cause the TBRG under test to fail the specification in A1980(3)).

Regional Instrument Centre (RIC) staff discussions with MCVANN during June 2001 determined that MCVANN:

- were aware of the some significant rates of change in TBRG sensitivity at rainfall rates of 100 mm/hr;
- used the 100 mm/hr as the rate for the adjustment of the gauges provided to the Bureau of Meteorology as per a request by the Bureau in the late 1980s;
- were aware of Bureau results suggesting that at least 5000 tips should be registered by a gauge prior to adjustment for calibration, but MCVANN found 2000 tips to be sufficient to stabilize the response of the gauge;
- felt any drifts in sensitivity of the gauges were a result of build up of contaminants on the buckets; MCVANN used distilled water for their adjustment procedures; and
- found that gauges returned to MCVANN, with significant drift in sensitivity, returned to their original calibration when distilled water was run through each gauge.

As a result of those discussions five Model 7499 gauges were prepared for the Bureau by MCVANN using their standard procedure but with the adjustment in sensitivity carried out at a rainfall rate of 200 mm/hr. The RIC found the 200mm/hr rate to exhibit less uncertainty in sensitivity than the 100mm/hr rainfall rate.

3. TEST PROCEDURE

The five Model 7499 TBRGs prepared at 200 mm/hr by MCVANN, were tested at least 4 times using the automated test rig Squiddly 1 using Test Procedure A1980(3), between 8 June 2001 and 7 August 2001. Squiddly 1 uses a Boyle bottle to deliver a fixed volume of rainfall equivalent to 20 mm, via a series of 6 nozzles that deliver the water at 6 approximate rainfall rates. The 95% uncertainty of water volume delivery is < 0.05 mm (equivalent to ¼ tips of a MCVANN 7499 TBRG). For a perfectly performing MCVANN 7499 gauge, after each completed procedure the TBRG would register 6060 tips, made up of 60 runs of 101 tips each, and 10 runs per nominal rainfall rate.

All tests were conducted using the standard water supply for the procedure, that is Bureau tap water passing through a Aqua Pure A1610 filtration unit.

One gauge S/N 81168 was tested 6 times using Test Procedure A1980(3). By the end of testing TBRG 81168 had recorded of the order of 36000 tips. After the 4th test, S/N 81168 was then subjected to flushing via approximately 40 litres of distilled and deionised water. The flushing procedure was used to clean the buckets of contaminant build up without disturbing the tipping mechanism. The measured sensitivities after flushing the TBRG would likely show a marked step or markedly decreased drift if contamination was responsible for any significant drift.

Gauges S/N 81149, 81165, 81167, and 81168 were put through the Test Procedure A1980(3) four times, without any flushing of the buckets with distilled or deionised water. Gauge S/N 81163 was put through the Test Procedure A1980(3) twice but a data collection failure of the automated system meant that this TBRG would have had more water through the gauge to complete 4 successful completions of A1980(3) so it's data were not included in the analysis below.

The data collected were then analysed by examining the derived responses for each rainfall rate. As 10 values (one for each run) are available for each rainfall rate on the completion of one A1980(3) procedure, 40 values were available for all four remaining gauges, and 60 values were available for each rainfall rate for S/N 81168 at the completion of testing.

Assuming contamination was not the reason for the drift, but rather the bedding in of the tipping mechanism, the apparent instability of the TBRGs at 100 mm/hr was examined by comparing the total tips measured with measured rainfall rate for each run using the 100 mm/hr nozzle.

4. RESULTS

4.1 LONG TERM STABILITY DATA

Figures 1 through 6 display the total counts (with the expected value being 101 tips) for each rainfall rate verses the time sequence number of the run for the S/N 81168 gauge; the shape of these plots being representative of all five gauges regardless of water source. Time sequences for rainfall rates of the 25, 50, 200, 350, 500 and 100 mm/hr nozzles of the A1980(3) test rig are presented in figures 1 through 6 respectively.

Figure 1. Total measured tips over a sequence of 6 runs for gauge S/N 81168 at the rainfall rate of 25mm/hr on the A1980(3) test rig.

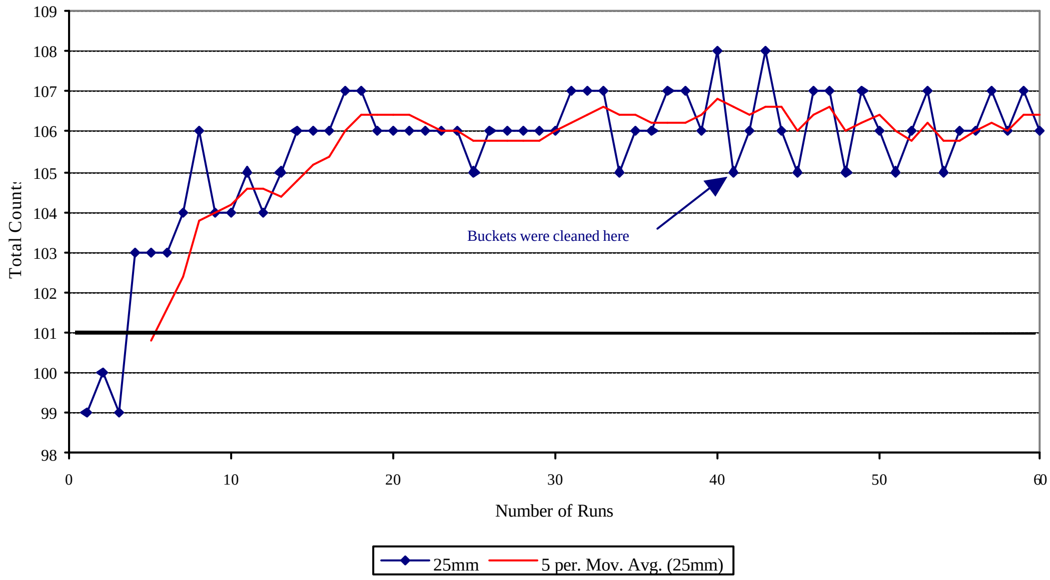


Figure 2. Total measured tips over a sequence of 6 runs for gauge S/N 81168 at the rainfall rate of 50mm/hr on the A1980(3) test rig.

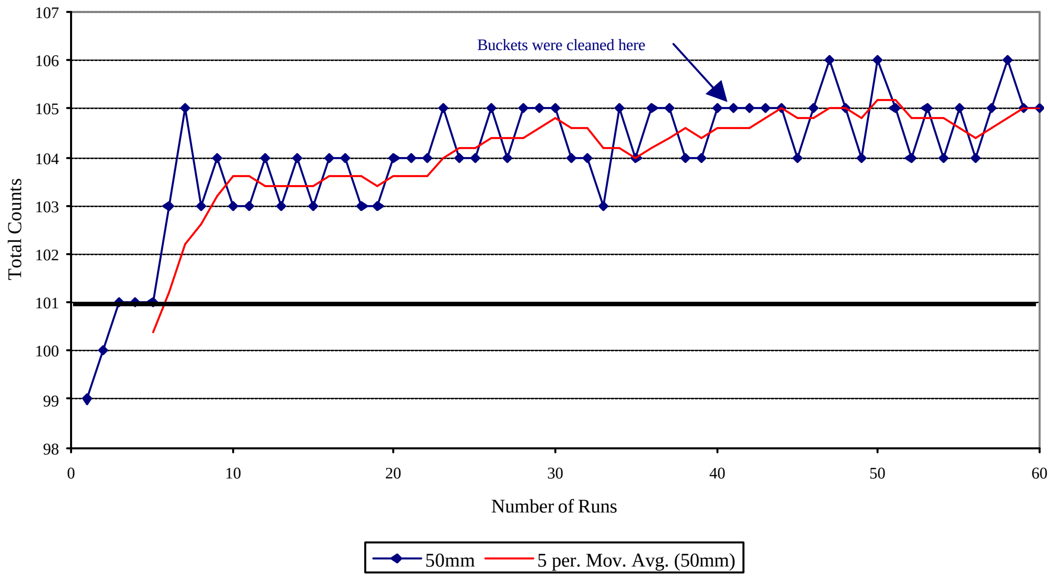


Figure 3. Total measured tips over a sequence of 6 runs for gauge S/N 81168 at the rainfall rate of 200mm/hr on the A1980(3) test rig.

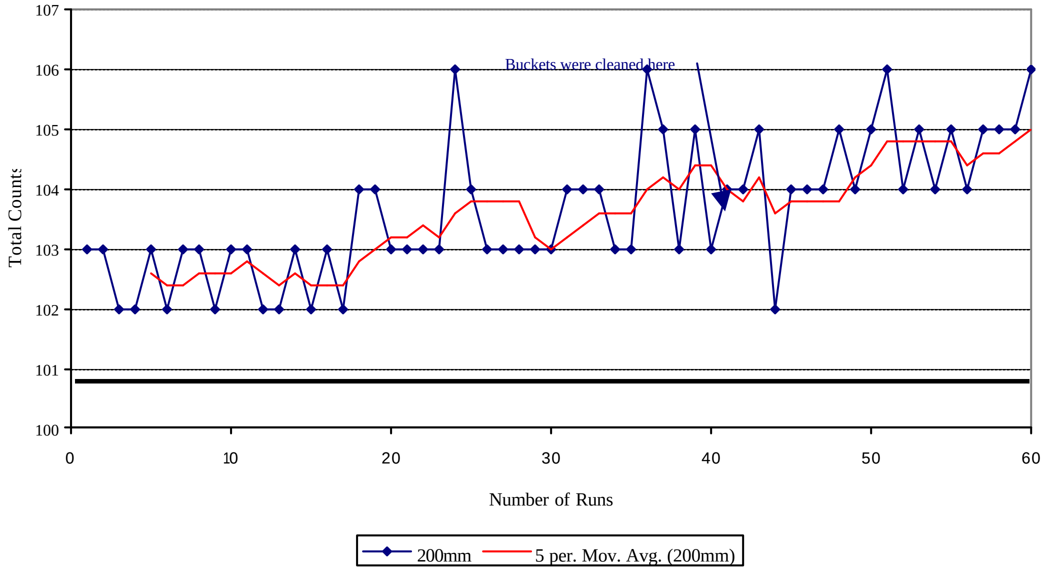


Figure 4. Total measured tips over a sequence of 6 runs for gauge S/N 81168 at the rainfall rate of 350mm/hr on the A1980(3) test rig.

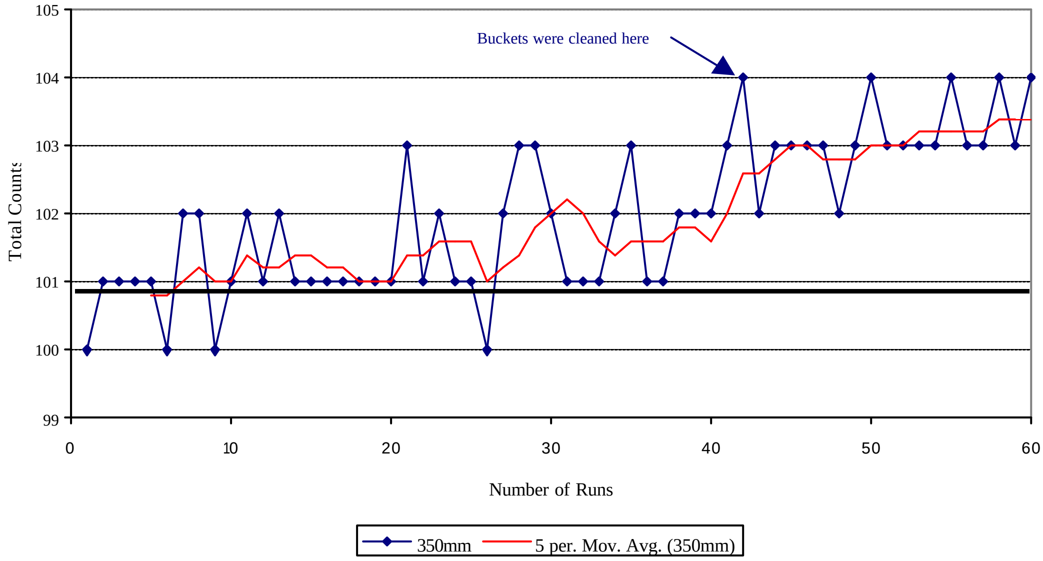


Figure 5. Total measured tips over a sequence of 6 runs for gauge S/N 81168 at the rainfall rate of 500mm/hr on the A1980(3) test rig.

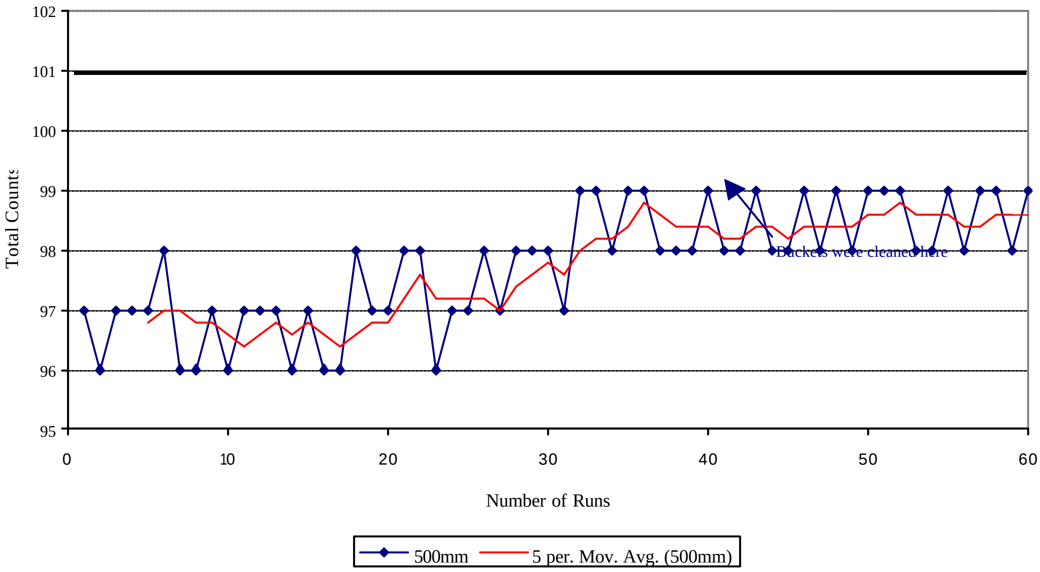
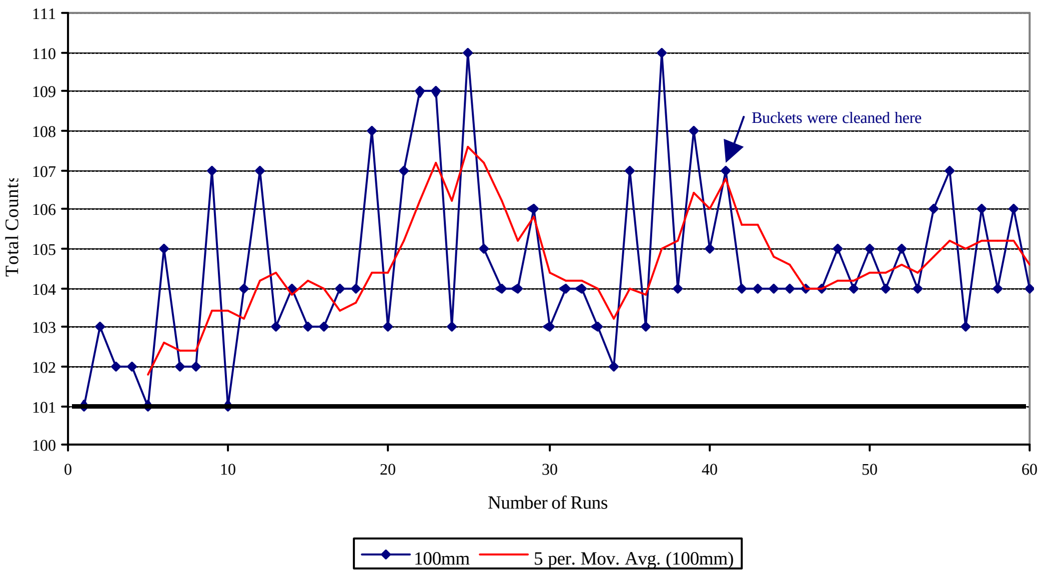


Figure 6. Total measured tips over a sequence of 6 runs for gauge S/N 81168 at the rainfall rate of 100mm/hr on the A1980(3) test rig.



Marked on each of these figures is the point in the sequence when S/N 81168 was flushed with deionised water. The figures also show a 5-point moving average curve as an indication of the trend in the total counts.

A significant shift in sensitivity is assumed to be greater than a 2.5 tip difference from the mean of the first 5 runs of test 1 (sequence nos. 1 through 5) and last 5 runs of test 6 (sequence nos. 56 through 60) considering:

- The 95% uncertainty of the water delivery (~0.5 tips).
- The digitisation of the volume by the gauge (e.g. 1 tip).

- ✍ The well known double tip feature for siphoned TBRGs.
- ✍ The bias in the volume delivered and the expected volume for the capture area of the TBRG.

Table 1 presents the mean measured tips for sequence numbers 1-5 (T_{1-5}), 26-30 (T_{26-30}) and 56-60 (T_{56-60}), and their differences for all 6 rainfall rates for S/N 81168. The tabulated data show significant shifts in sensitivity at the 3 slowest rainfall rates of the order of 5 tips and smaller shifts at higher rainfall rates. All shifts are the equivalent of increases in sensitivity. The differences between T_{56-60} and T_{26-30} for all rates are less than 1 tip.

Table 1. Mean measured tips for sequence nos. 1-5 (T_{1-5}), 26-30 (T_{26-30}) and 56-60 (T_{56-60}), and the differences between the later groups of 5 runs and the initial 5 runs for S/N 81168. Significant shifts are indicated in bold italics.

Rate (mm/hr)	**Mean Tips T_{1-5}**	**Mean Tips T_{26-30}**	**Difference T_{26-30}-T_{1-5}**	**Mean Tips T_{56-60}**	**T_{56-60}-T_{1-5}**
25	100.8	106.2	***5.6***	106.6	***5.8***
50	100.4	104.2	***3.8***	105.0	***4.6***
100	101.8	104.9	***3.1***	104.8	***3.0***
200	103.8	103.6	-0.2	105.0	1.2
300	101.0	102.9	1.9	103.6	***2.6***
450	96.6	98.5	1.9	98.6	2.0

Table 2 presents a summary of the differences between the means tips of sequence numbers 26-30 (T_{26-30}) and sequence numbers 1-5 (T_{1-5}) for four gauges at rainfall rates of 25 and 50mm/hr.

Table 2. ($T_{26-30} – T_{1-5}$) at two rainfall rates for four gauges.

TBRG S/N	**25 mm/hr $T_{26-30} – T_{1-5}$**	**50 mm/hr $T_{26-30} – T_{1-5}$**
81149	5.5	3.6
81165	3.4	1.0
81167	6.4	4.4
81168	5.6	3.8

At all rainfall rates, except 100 mm/hr, the four gauges show no significant shift in the mean sensitivity after the 2nd test was conducted. Table 3 presents a summary of the differences between the mean tips of sequence numbers T_{36-40} and sequence numbers T_{26-30} for the four gauges. Out of the 24 differences in the table, for the absolute differences;

- ✍ 15 were <0.5 tips,
- ✍ 19 were < 1.0 tips,
- ✍ 21 were <1.5 tips,

- 23 out of the 24 were < 2.0 tips.
- The 100 mm/hr rate gave 3 out of 4 gauges as having absolute differences > 1.1 tips.

Table 3. ($T_{36\text{-}40} - T_{26\text{-}30}$) at all rainfall rates and all four gauges.

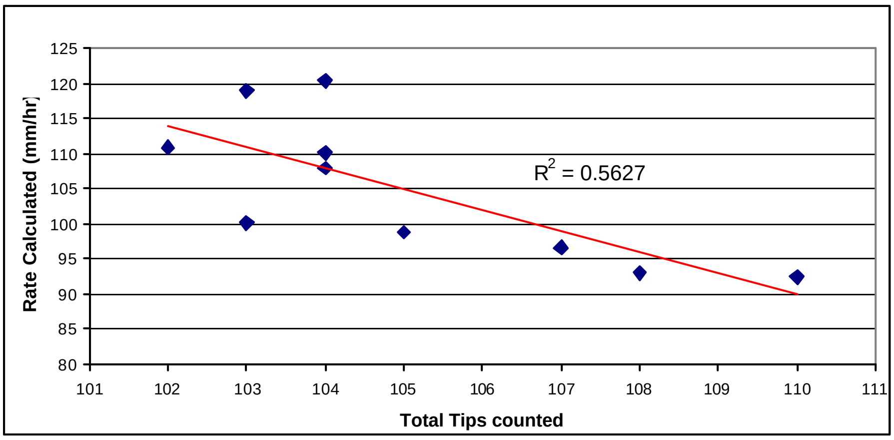
Nominal Rainfall Rate (mm/hr)	S/N 81149	S/N 81165	S/N 81167	S/N 81168
25	2.2	-0.2	0	0.8
50	-0.2	0.2	0.4	-0.2
100	-1.8	-1.2	0.2	1.6
200	-0.4	0.2	0	1.4
350	0.6	0.8	0	-0.4
450	0.4	0.2	0.4	0.6

All gauge results indicate that the lowest rainfall rates show the greatest change in the bedding in process. For rainfall rates above 250 mm/hr all except one gauge (S/N 81168) showed the least change in sensitivity from sequence 1 to sequence 30 (typically less than 1.5 counts) at rainfall rates of 350 mm/hr and 450 mm/hr; S/N 81168 showed changes of about 3 counts at these rates.

4.2 RAINFALL RATE 100 MM/HR

Figure 7 shows that the measured tips for S/N 81168 at the approximate 100mm/hr rainfall rate verse the actual rainfall rate. The coefficient of determination for the straight line of best fit for sequence numbers 21 through 60 indicates that only 56% of the variance is explained by a linear relationship, indicating that there is no simple linear relationship between measured tips and rainfall rate on or about 100 mm/hr.

Figure 7. Rainfall fall rate (mm/hr) verses measured tips for gauge S/N 81168.



5. DISCUSSION

For all rainfall rates except 100 mm/hr the data presented in figures 1 through 6 suggest that TBRG 81168 had stabilized for these nominal rates after test 2 was completed. Data from the other 3 TBRGs indicate a similar result. The range of the running means for these 5 rates after the completion of test 2 deviate from rate's mean value by less than 1 tip. On the flushing of the TBRG between test 5 and 6 shows no statistically significant change in the running mean. Hence it is likely that there is no trend in TBRG sensitivity through contamination of the buckets. Instead it appears that there is a bedding in process of the mechanism that stabilizes after about 12000 tips have gone through the TBRG on it's receipt from MCVANN.

For rainfall rate 100 mm/hr there is a significant periodic variation in the running mean, with amplitude of approximately 3 tips. The data in table 3 indicates that the 100mm/hr rate for 3 out of 4 of the TBRGs show larger absolute values for (T_{36-40} - T_{26-30}) when compared to other rainfall rates.

6. CONCLUSIONS

There is no apparent impact on the sensitivity of the MCVANN TBRGs when filtered tap water is used during the testing procedures.

The gauges show a significant monotonic increase in sensitivity between sequence number 1 and 20 for all rainfall rates tested, but the largest drift (of the order of +6 tips) is found at the 25mm/hr rate. The drift in tips per 101 at the two highest rates (350 and 450 mm/hr) is of the order of +1 tip. Any significant drift in the running average rate is removed after the gauges were subjected to 12000 tips.

The data at 100 mm/hr for each gauge shows a large amplitude variation in the sensitivity even after the bedding in process has been completed. The reason for this oscillation is unknown, but indicates that this rate should not be used for field calibrations or sensitivity adjustment.

The 50 mm/hr or 200 mm/hr rates seem the more appropriate for gauge adjustments. While the 50 mm/hr rate is the most stable and shows the least differences over a large number of sequences the time taken to complete one sequence is prohibitive (being double the time for the 100 mm/hr sequences). For field use the 200 mm/h would be a practical compromise.

7. REFERENCES

A1980(3) Specification for Tipping Bucket Rain Gauge, 1999, Bureau of Meteorology