Applicable measuring technologies for rain/precipitation measurements, observation and monitoring

KISTERS AG

Authors:

Kurt Nemeth, Leading Solution Manager, Meteorology
Peter Ward, Senior Product Specialist, HydroMet

The collection of highly accurate data for liquid and solid precipitation is required for climatic and synoptic applications across the world.

This data is critical in developing an understanding of the earth's climate on a regional, national and global basis. It is fundamental to analyzing trends and developing solutions for problems that impact our planet, including agriculture and the world's food supply, the water resource needs of our biosphere with our existing and ever-expanding population, and the protection of life and property from extreme events such as flooding. Just as importantly, the collection of this data over the course of years helps in the study of climate change, global warming, and a host of other issues.

Experience has shown that many existing networks using a traditional type 'uncorrected' tipping bucket rain gauge (TBRG) will struggle to meet the requirement for highly accurate data, particularly during high-intensity rain events, or as a result of errors when frozen precipitation is melted. In contrast, for the measurement of combined liquid and solid precipitation, weighing type precipitation gauges can be an excellent solution, meeting and exceeding the updated requirements of the WMO/CIMO guideline No 8, with an overall field accuracy of ±5%.

However, in regions where only liquid precipitation will be measured, the cost to deploy a network of weighing type gauges is approximately 5 times higher than deploying standard TBRG's. For these areas the challenge becomes finding a 'cost effective' TBRG that can; deliver highly accurate rainfall data in both low and high intensities; maintain accuracy over time with long term stable calibration; be manufactured from high quality materials for extended field life, and provide a low cost of ownership through reduced operational support & unscheduled site visits.

Sir Christopher Wren was a 17th century English designer, astronomer, geometer, and one of the greatest architects of his time. However, one of his lesser known achievements was the creation in 1662 of a rain-gauge, that did not require daily visits – the world's first tipping bucket rain gauge. The real advantage of this technique was that it enabled a clockwork chart to record rainfall so that Sir Christopher did not need to read and record every single day's data. Astonishingly, the same basic principle survives to this day in rain gauges currently operating in many countries worldwide; the tipping bucket rain gauge. The TBRG consists of a funnel, which is mounted in the top of a cylinder set into the ground or standing upon it. The funnel collects precipitation and passes it on to one of two small buckets, which are balanced on a pivot. After a specific amount of precipitation (typically 0.1mm, 0.2mm or 0.01in) falls, the bucket tips and an electrical signal is sent to a recorder or datalogger. This process, tips (almost all of) the water from the bucket so that it is ready to repeat the process.

Anyone who has been responsible for the collection of data from typical TBRG's will be aware of their shortcomings. TBRG measurements only take place every time there is a bucket tip, which does not necessarily correspond with the timing of very light precipitation; although for many agencies and organizations this fine amount of rainfall does not represent a significant issue. Dirt accumulation, surface tension and evaporation can cause accuracy errors by affecting the volume of each bucket tip, while blocked or partially blocked filters will cause a complete loss of rainfall data or render collected data virtually useless. In some cases, these issues have been significantly mitigated through innovative rain gauge design as well as the type and quality of the materials used in construction. Routine field visits to inspect and clean gauges will improve overall performance of all TBRG's.

A more significant issue and one that is less understood is the ***underreporting*** by TBRG's during periods of intense rainfall. This problem occurs for several reasons. The most significant of these is referred to as ***'loss'***. This loss occurs when precipitation continues to enter the bucket after it has begun tipping and is a fundamental reason for inaccuracy in all uncorrected tipping bucket rain gauges. In addition, rain entering the gauge may also be splashed away by the rapid movement of the pivoting bucket. Precipitation from a TBRG may also be lost in locations where freezing occurs unless fitted with a heating system. These heating systems will typically require a substantial power supply.

Tipping Bucket Rain Gauges are still by far the most widely used instrument in global rain monitoring observation networks, having the benefit of ultra-low power requirements and a consumption close to zero. Weighing type gauges for the direct measurement of liquid and solid precipitation are widely used and deployed in countries in the northern hemisphere. Weighing type gauges eliminate the known underreporting of solid precipitation through the use of anti-freeze stored in a large collector. The use of anti-freeze lowers the freezing point of collected solid precipitation, eliminating the systemic underreporting of heated tipping bucket gauges which use a thermal melting process.

Technology developed by KISTERS offers a new global standard for Tipping Bucket Rain Gauges with increased accuracy, reduced maintenance, and increased operational field life.

Accuracy - TBRG underreporting of rainfall during high intensity events.

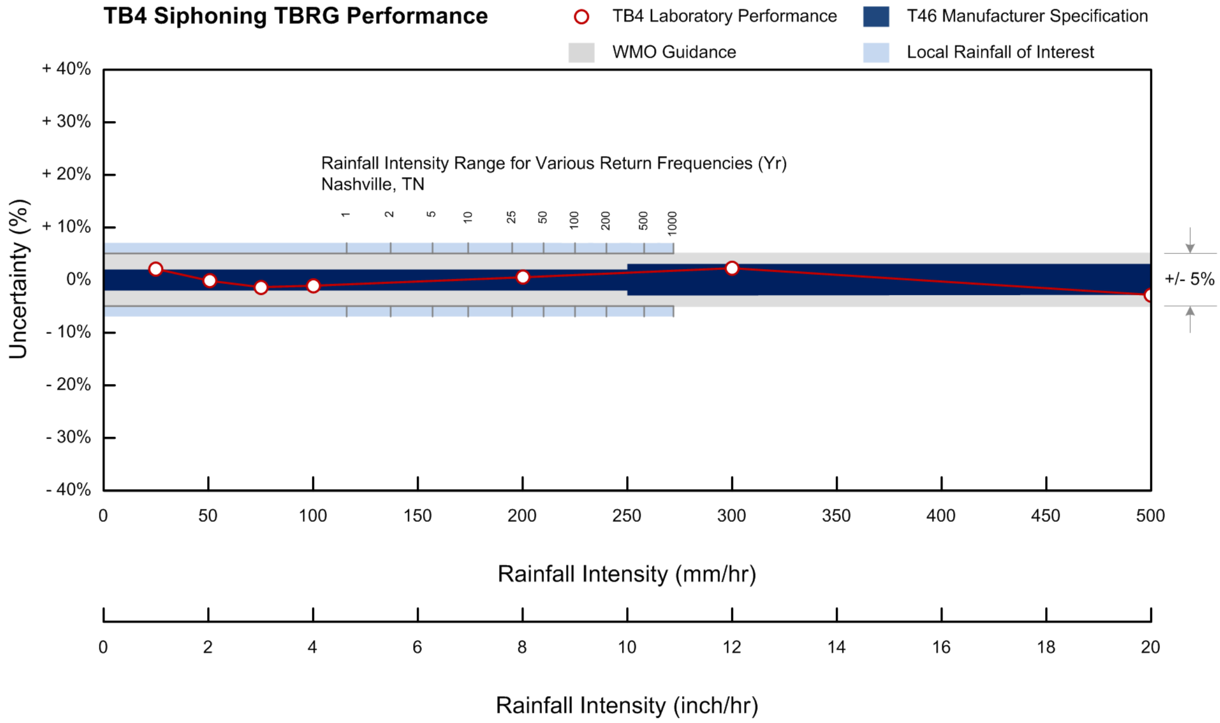
As stated, it is well documented that tipping bucket rain gauges under-register when collecting rainfall at high intensities. KISTERS has overcome this problem by incorporating a flow control device or ***'syphon'*** into the design of their TBRG. Rain falling passes through a finger filter at the base of the funnel into a small reservoir in the body of the syphon, where it collects until being discharged into one of the two tipping buckets. The syphon design ensures that precipitation always discharges into the presenting bucket at a constant rate, regardless of rainfall intensity. By controlling the discharge rate, we are able to calibrate the gauge taking account of the loss that occurs with each bucket tip. Further, the vertically oriented finger filter in the base of the funnel protects the gauge from blocking due to bird droppings, dust and leaves.

The advanced TBRG's developed by KISTERS provide highly accurate data in both low and high intensity rainfall events; including intensities up to 500mm/hr. With an accuracy of ±2% from 0-250mm/hr; ±3% from 250 to 500mm/hr; and a measuring range of 700mm/hr; the KISTERS gauges easily exceed the WMO/CIMO requirements for an overall field accuracy of ±5%.

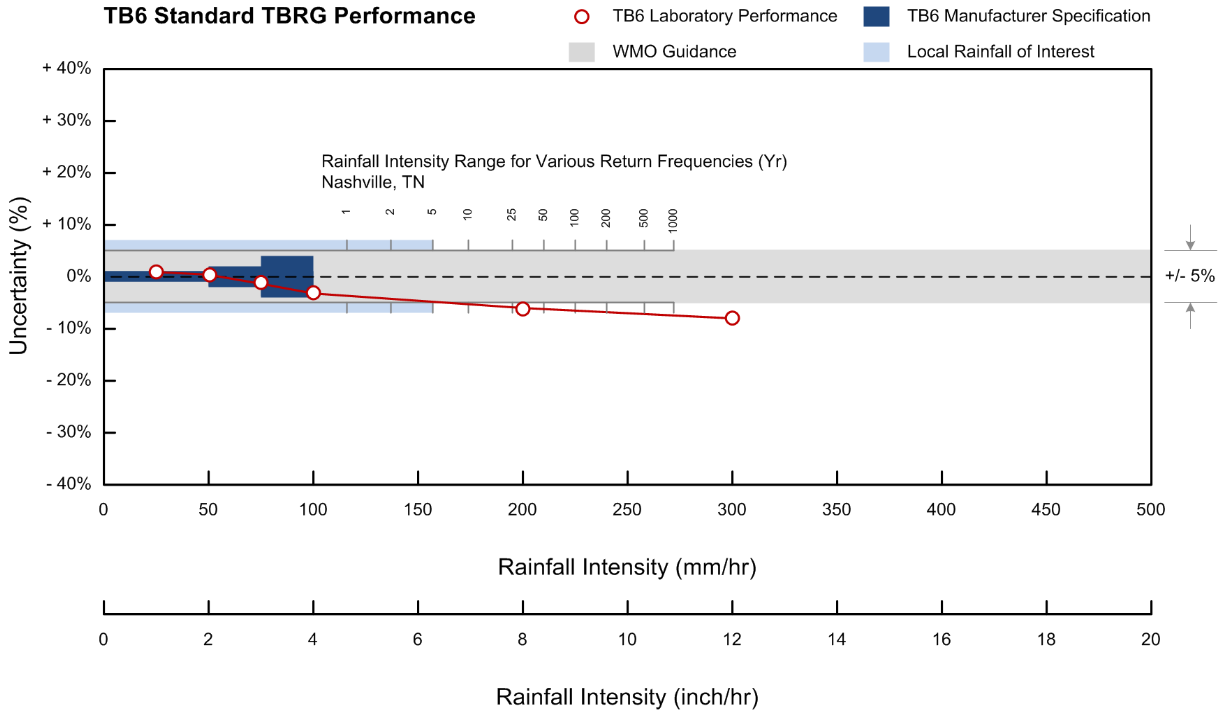
'All uncorrected tipping bucket rain gauges show their characteristic underestimation' (Source: WMO Laboratory Intercomparison of Rainfall Intensity Gauges, Wiel Wauben Instrumental Department, INSA-IO, KNMI April 18, 2006.)

Example - The Effects of the 'Syphon' Flow Control Device on Rainfall Accuracy

Corrected – with Syphon flow control device



Uncorrected – no flow control



Collecting orifices versus best catching efficiency, site versus instrument characteristics

Worldwide there are existing two major standard orifices and catching diameters for global rain monitoring, 200 cm² with its 161 mm diameter and 314 cm² with its 200 mm diameter. It is unclear how both catch sizes (diameter and orifice) became standards, but looking back to the beginning of rain monitoring in the 17th century, the reason may be the missing global communication between different national observation institutes (assumption by the author). A National Weather Institute that had collected many years of time series rainfall data would want to continue collecting data with the same orifice and diameter sizes. Considering the exchange of weather recorded data from all over the world, it is obvious and logical that both orifices are used for data exchange and therefore are considered interchangeable, compliant and equivalent.

Regarding historical time series precipitation data; it has been shown by the latest WMO Inter-Comparison Test 'SPICE' that windshields can significantly improve catching efficiency, especially when low rainfall intensities are combined with high wind, leading to underreporting of precipitation at monitoring sites. Alternative to the installation of an additional large mechanical device such as a windshield, it has been investigated that a special design of the rain gauge body and funnel can significantly improve catching efficiency of TBRG's. This design combines a standard rain gauge body with 200mm diameter with a proportionally larger funnel, with the result resembling a trumpet design. Horizontal wind components and proportions are deflected and directed underneath the instrument resulting in a site related under-pressure condition. This achieves the highest catching behavior in the funnel of the instrument, similar to a windshield design.

With catching efficiency, the highest measuring performance and accuracy matter, the KISTERS Models TB3 and TB4 with a larger catching area of 630 cm² and trumpet design, will satisfy the requirements of the highest resolution of 0.1mm and accuracy of ±2% from 0-250mm/hr; ±3% from 250 to 500mm/hr; and a measuring range of 700mm/hr; in conjunction with scheduled maintenance intervals.

TB3 with 630 cm² Collector

TB3 with 314 cm² Collector

Innovative Finger Filter reduces clogging in our Tipping Bucket Rain Gauge (TBRG) by 81%

81% reduction in the number of clogged rain gauges as a result of switching to our Tipping Bucket Rain Gauge (TBRG) that is fitted with a finger filter in the Catch Rim assembly.

Nashville Metro Water has achieved an 80+% reduction in clogged rain gauges that are located within their network - after switching to the Model TB6 TBRG. This dramatic improvement in performance reliability is due to the difference between the flat screen filter that is fitted on most brands of tipping bucket rain gauges and the finger filter that is supplied with the all of our Rain Gauges including the TB6. Over the 30 month period after upgrading to the our Rain Gauge the actual % reduction was 83% and over the course of the evaluation period, the cumulative reduction ranged from 81% to 84%. These statistics were observed from a 21 x rainfall monitoring network located in Nashville, Tennessee, that is owned by Nashville Metro Water Services and maintained by ADS Environmental Services.

*ADS observed a total of 8 clogged Finger Filters during 2014. Since our Rain Gauge was not implemented during 2013, the statistics from 2013 are not used in the graph below. For comparison with the previous gauges, the clogging statistics from 2010-2012 have been averaged. During this period, ADS maintained 12 inch Sierra Misco rain gauges at these same locations.

Finger Filter vs Flat Screen

Month	Clogs 2014	Clogs 2013	Clogs 2012	Clogs 2011	Clogs 2010	Average 2010-2012		
Jan	0	3	3	0	7	3.33		
Feb	0	1	0	1	0	0.33		
Mar	0	1	5	2	0	2.33		
Apr	3	7	3	12	12	9.00		
May	0	6	5	11	5	7.00		
Jun	1	6	1	8	3	4.00		
Jul	1	2	5	1	1	2.33		
Aug	1	2	2	1	2	1.67		
Sep	0	2	2	3	1	2.00		
Oct	1	2	6	2	4	4.00		
Nov	1	2	4	5	3	4.00		
Dec	0	0	5	1	1	2.33		% Reduction
Total	8	34	41	47	39	42.33		81%

References

The following customer references highlight and demonstrate the previously described features in actual field applications over extended time periods.

https://www.kisters.net/success-story/gauging-rain-in-era-of-atmospheric-rivers/