Dynamic calibration of two catching type drop-counting rain gauges

M. Stagnaro[1,2], A. Cauteruccio[1,2], M. Colli[2], L.G. Lanza[1,2], P.W. Chan[3]

[1] University of Genova, Dep. of Civil, Chemical and Environmental Engineering, Via Montallegro 1, 16145 Genoa, Italy, mattia.stagnaro@unige.it, tel: (+39) 010 353 2089, fax: (+39) 010 353 2481
[2] WMO/CIMO Lead Centre "B. Castelli" on Precipitation Intensity, Italy
[3]Hong Kong Observatory, 134A Nathan Road, Hong Kong, China

Abstract:

This study reports the results of laboratory tests performed to assess the performance of two drop counting rain gauges of the catching type, and to propose suitable correction to make them compliant with the specifications of the World Meteorological Organization (WMO) at one-minute time resolution for Rainfall Intensity (RI) measurements. The tests were limited to the steady state conditions, with known and constant flow rates provided to the instrument at various reference intensities for a sufficient period of time, in order to compare the measures provided by the gauge with the reference figures (which is known as dynamic calibration).
The instruments investigated are manufactured by Ogawa Seiki Co. Ltd (Japan) and the Chilbolton RAL (UK). They are designed as high-sensitivity drop counter type rain gauges.
The dynamic calibration adopting a constant volume of the droplets declared by manufacturers reveals that these instruments do not fulfil the WMO requirements. A calibration curve of the drop volume with respect to the measured drop frequency has been derived for each instrument. Using a suitable correction algorithm, based on calibration curves as obtained from the tests performed in the laboratory, the precision of the instruments is improved and the results are fully compatible with the WMO required maximum admissible error (WMO, Pub. No 8).
Laboratory tests also reveal the operational limit of this kind of instrument that is given by the rainfall intensity at which the water flux from the nozzle start to be continuous, therefore a stand-alone installation is discouraged.

Introduction

For this study two Drop Counter instruments are considered, respectively manufactured by Ogawa Seiki Co. Ltd (Japan) and the Chilbolton RAL (UK) (see Figure 1).

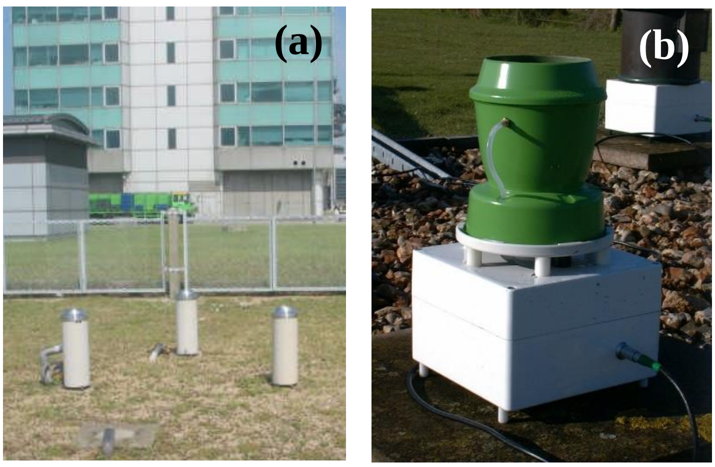

Figure 1 – The Drop Counter rain gauges manufactured by the Ogawa Seiki Co. Ltd (Japan) (a) and the Chilbolton RAL (UK) (b)

The Drop Counter is a catching type rain gauge, provided with a funnel that conveys the collected rain water towards a calibrated nozzle, which starts to drip. An optical sensor, placed under the nozzle, detects the drop passage, and allows to calculate the drop frequency measuring the time between two consecutive drops. The drop frequency is related to the rainfall intensity, and the total rainfall volume measured by the sensor is calculated assuming a constant volume of the droplets dispensed by the nozzle. The dimension of the funnel, the measuring range and the drop volume of each instrument are summarized in Table 1.

Table 1 – Principal characteristics of the two Drop Counters

		Ogawa S.	Chilbolton
Funnel Area	*(cm^2)*	126.7	150
Measuring range	*(mm/h)*	0.25 - 200	0 – 300
Drop Volume	*(cm^3)*	0.0625	0.06

Due to the small volume of the dispensed droplets, this kind of instruments have an high sensitivity, and are particularly useful to measure low rainfall events.

Performance assessment and dynamic calibration

Following the Italian UNI 11452:2012 standard, the two rain gauges were tested in order to assess their performance for different rainfall intensities in the measuring range of each instrument. The relative error has been evaluated as:

$$e_{rel} = \frac{RI_{meas} - RI_{ref}}{RI_{ref}} \times 100$$

The measured rainfall intensities (RI_{meas}) provided by each instrument are calculated adopting a constant volume of the droplets, and the reference rainfall intensities (RI_{ref}) were provided by the Calibration system, using a balance to measure the total amount of water per each test.
The results of the dynamic calibration (Figure 2) show that these instruments do not fulfil the WMO requirements (± 5%) for the whole operational range. However, both instruments have a high accuracy for each RI tested except for the Chilbolton rain gauge in the field of very low intensity (~2 *mm/h*).

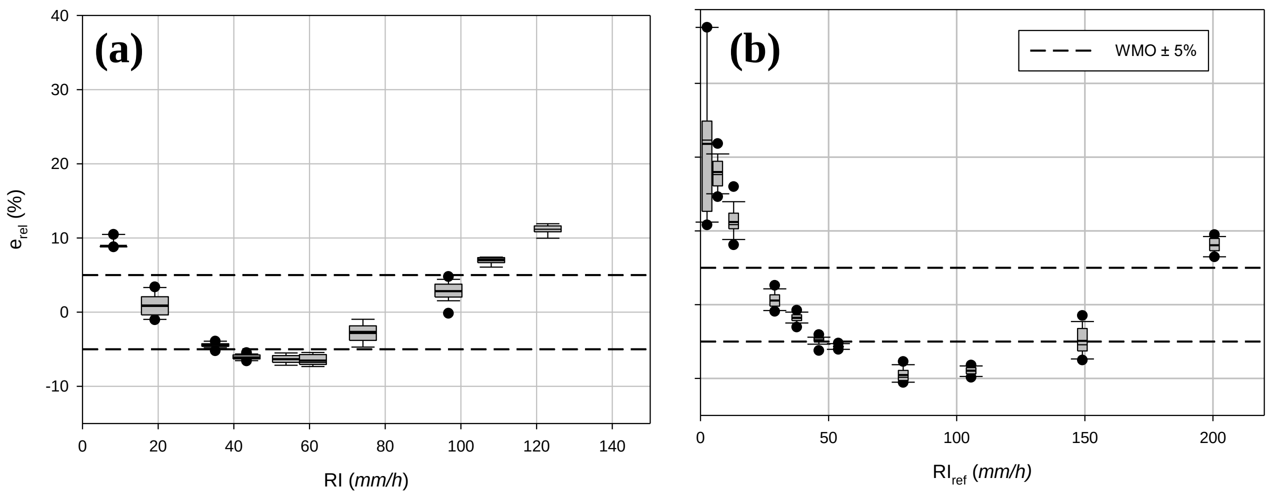

Figure 2 – Performance assessment of the Ogawa Seiki Co. Ltd (a) and the Chilbolton RAL (b) Drop Counter gauges assuming a constant volume for the generated droplets.

Laboratory tests performed under known and constant flow rates allow to estimate the drop volume for different rainfall intensities and the drop dispensing frequencies measured by the two rain gauges. A calibration curve (Figure 3) for the drop volume as a function of the measured drop frequency has been derived for each instrument using a third order polynomial law.

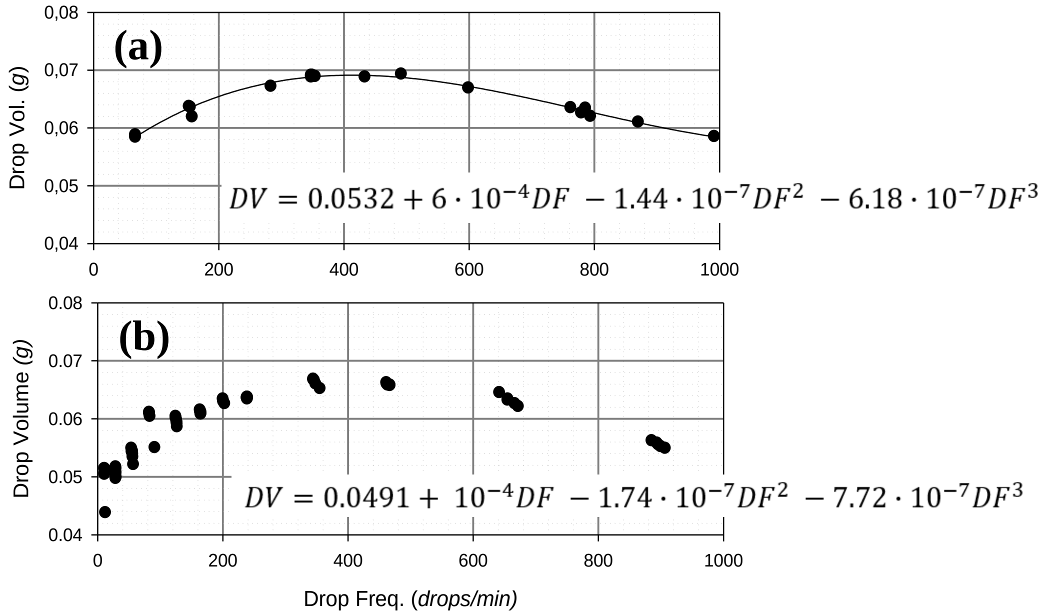

Figure 3 – Calibration curves for the Ogawa Seiki Co. Ltd (a) and the Chilbolton RAL (b) Drop Counters.

If the drop volume of the droplets is varied according to the calibration curves, as a function of the measured drop frequency, the performance of the two instruments falls within the WMO limits of ±5% for most of the operational range, except for very low rainfall intensity less than 2 *mm/h*.

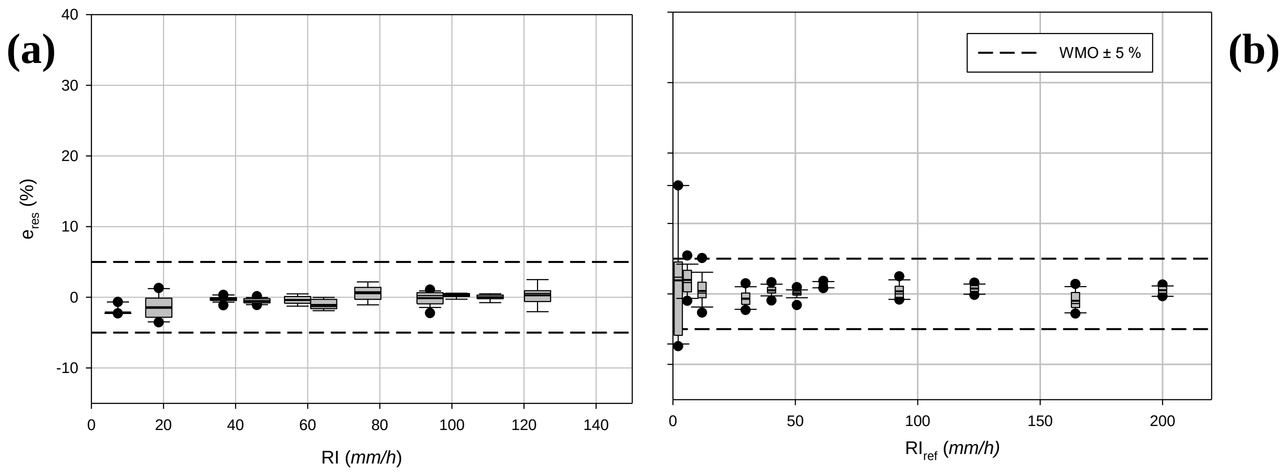

Figure 4 - Performance assessment of the Ogawa Seiki Co. Ltd (a) and the Chilbolton RAL (b) Drop Counters after varying the volume of droplets according to the calibration curves obtained from dynamic calibration.

The operational limit of this kind of instrument is given by the RI at which the water flux from the nozzle starts to be continuous or cannot be considered as a regular drop dispensing flux. Beyond this limit, the drop detector continues to detect the falling water, but the volume becomes irregular and significantly different until producing a continuous flux of water. In such conditions the sensor detects a low frequency of droplets and attributes it to a low rainfall intensity.

Since it is not possible to know a-priori the real RI, a co-located rain gauge is required to use this gauge operationally.

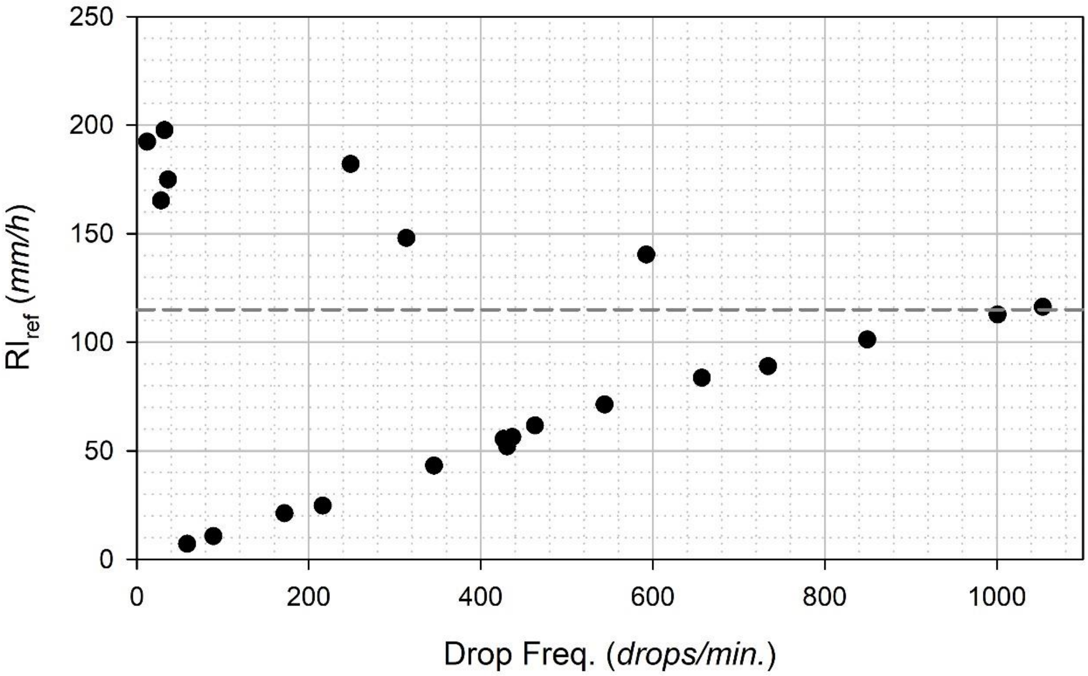

Figure 5 – Operational limit of the Drop Counter instrument - Ogawa Seiki Co. Ltd

Conclusions

Using a suitable correction algorithm, based on correction curves obtained from dynamic calibration in the laboratory, it is possible to improve the precision of the instruments and to obtain results that are fully compatible with the WMO required maximum admissible error (CIMO guide, Pub. No 8).
The performance in the field may be lower than those observed in the laboratory, due to errors induced by the atmospheric conditions, installation, status of maintenance, etc.
Although very suitable to measure low rain intensity rates, due to the operational limits of this kind of instrument, a stand-alone installation is discouraged. A co-located rain gauge is required to avoid large underestimation of severe rainfall events.

References

WMO: *Guide to Meteorological Instruments and Methods of Observation: (CIMO guide No. 8)*, (2014 edition, updated in 2017)

UNI: *Hydrometry - Measurement of rainfall intensity (liquid precipitation) – Metrological requirements and test methods for catching type gauges.*, UNI 11452:2012 (2012)