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Hidrometrija - Merjenje intenzivnosti padavin (tekoče padavine): zahteve, kalibracijske metode in terenske meritve

Hydrometry - Measurement of the rainfall intensity (liquid precipitation): requirements, calibration methods and field measurements

Hydrometrie - Messung der Regenintensität (flüssiger Niederschlag): Anforderungen, Kalibrierverfahren und Feldmessungen

Mesurage de l'intensité pluviométrique (précipitations liquides) : exigences, méthodes d'étalonnage et mesures de terrain

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Hydrometry - Measurement of the rainfall intensity (liquid precipitation): requirements, calibration methods and field measurements

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Foreword

This document (CEN/TR 16469:2013) has been prepared by Technical Committee CEN/TC 318 “Hydrometry”, the secretariat of which is held by BSI.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

The Executive Council of the WMO, noting the working arrangements between the ISO and WMO formally adopted on 16 September 2008, recognised the wide ranging benefits to National Meteorological and Hydrological Services and user communities resulting from the implementation of common Standards relevant for meteorology and hydrology and the need to established the benefit/cost implication to WMO Members of elevating an existing Technical Regulation/Manual/Guide to a common Standard. The EC finally approved procedures to be followed in proposing common technical standards (Resolution 8, Abridged Final Report of the sixty-first session of the WMO Executive Council).

This document is not a European Standard but a Technical Report. It is a document to describe recent findings in rainfall intensity (RI) measurements and related accuracy aspects, following the results and outcomes of the most recent international RI gauges intercomparison organised by the World Meteorological Organisation (WMO). The Technical Report also provides informative documentation (in annexes) containing methods for laboratory calibrations, field tests and reference field measurements.

In consideration of the requirement for general standardization and homogeneity of precipitation intensity measurements and the need for instruments development to promote worldwide instrument compatibility and interoperability, the WMO Lead Centre on Precipitation Intensity “B. Castelli” (Italy) has been designated by the WMO Commission of Instruments and Methods of Observation (CIMO General Summary of the fifteen Session, Helsinki, Finland, 2 - 8 September 2011). The Lead Centre is intended as a Centre of Excellence for instrument development and testing which would be established with the purpose of providing the scientific community with specific guidance and standard procedures about instrument calibration and their achievable uncertainty, performing laboratory and field tests and the intercomparison of instruments, and providing research advances and technical developments about the measurement of precipitation intensity and the related data analysis and interpretation.

Introduction

The need for, and the importance of accurate and reliable rainfall intensity (RI) measurements is ever increasing. This is the result of a number of factors, including the increased recognition of scientific and practical issues related to the assessment of possible climatic trends, the mitigation of natural disasters (e.g. storms and floods), the slowing down of desertification and the design of structures (buildings, construction works) and infrastructure (drainage). This has resulted in more rigorous and enhanced quality requirements for RI measurements.

The volume of rainfall received by a collector through an orifice of known surface area in a given period of time has traditionally been adopted as the reference variable, namely the rainfall depth. Under the restrictive hypothesis that rainfall is constant over the accumulation period, a derived variable, “the rainfall rate, or intensity (RI)”, can be calculated. The estimated RI should get closer to the actual flow of water ultimately reaching the ground as the recording time interval decreases. In view of the very high variability of RI, field measurements at short time scales (e.g. 1 min) are crucial to enable high quality measurement be taken to mitigate the impact of severe events and save lives, property and infrastructures. As the probability of heavy rainfall events is small, long-term records of RI are required to estimate the frequency of occurrence of very intense rainfall at a given location and time.

On completion of the most recent RI gauges intercomparison organised by the World Meteorological Organisation (WMO), it has been recommended that RI measurements should be covered by International Standards. These standards should be based on the knowledge obtained from those latest WMO intercomparison and other current research and good practice. The adoption of such an approach will assist rainfall data collection practitioners to obtain homogeneous and compatible data sets. The procedure adopted for performing calibration tests in the laboratory should become a standard method to be used for assessing the instruments’ performance. Acceptance tests could be based on the adopted laboratory procedures and standards. A classification of instrument performance should also be developed to help users in selecting the most appropriate instrument for their applications.

1 Scope

This Technical Report describes a method for calibrating rainfall intensity (RI) gauges and the measurement requirements to obtain accurate and compatible data sets from hydro-meteorological networks, as a forerunner to the development of full hydro-meteorological data collection standards.

This Technical Report deals exclusively with catching-type RI gauges (see Clause 3). It concentrates on the generic calibration, performance checking and estimation of uncertainties for RI gauges. It does not cover specific gauge measurement principles, technical characteristics and technology adopted in the design of RI gauges

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 13798, *Hydrometry – Specification for a reference raingauge pit*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
catching raingauge
a raingauge which collects precipitation through an orifice, often a funnel, of well-defined size and measure its water equivalent, volume, mass or weight that has been accumulated in a certain amount of time

Note 1 to entry: This type of gauge includes storage, level monitoring, tipping bucket and weighing raingauges. This is the most common type of recording raingauge in use in operational networks at the time of preparing this Technical Report.

3.2
delay time of the output of a RI measuring gauge
delay of the output message of some RI measuring raingauges

Note 1 to entry: The internal calculation of the rainfall intensity in some raingauges can cause a delay of the output data message (e.g. 1 minute) which can easily be shifted automatically to the correct time without any degradation in measurement accuracy. This is typical of software corrected tipping bucket raingauges through embedded electronic chips or interfaces. The delay time should not be confused with the time constant. If real-time output is not needed, software induced delay times are less critical than longer time constants or any other effects, because delay times can easily be corrected to retrieve the original RI information.

[SOURCE: Adapted from WMO – IOM 2009]

3.3
measurand
quantity intended to be measured

[SOURCE: VIM:2008]

3.4
measurement uncertainty

non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

[SOURCE: VIM:2008]

Note 1 to entry: The parameter may be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

Note 2 to entry: Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterised by standard deviations. The other components, which may be evaluated by Type B evaluation of measurement uncertainty, can also be characterised by standard deviations, evaluated from probability density functions based on experience or other information:

a) Instrumental measurement uncertainty (VIM 2008): component of measurement uncertainty arising from a measuring instrument or measuring system in use.

   Instrumental measurement uncertainty is obtained through calibration of a measuring instrument or measuring system, except for a primary measurement standard for which other means are used.

   Instrumental uncertainty is used in a Type B evaluation of measurement uncertainty.

   Information relevant to instrumental measurement uncertainty may be given in the instrument specifications.

b) Achievable measurement uncertainty (WMO no. 8, Part I Annex 1.B): it is intended as the measurement uncertainty achievable in field and/or operational conditions.

3.5
non-catching raingauge

raingauge where the rain is not collected in a container/vessel

Note 1 to entry: The rainfall intensity or amount is either determined by a contact-less measurement using optical or radar techniques or by an impact measurement. This type of gauge includes optical disdrometers, impact disdrometers, microwave radar disdrometers, optical/capacitive sensors.

3.6
resolution

smallest change in a quantity being measured that causes a perceptible change in the corresponding indication

[SOURCE: VIM:2008]

3.7
step function / heaviside function or unit step function

an input signal that switches on at a specified time and stays switched on indefinitely for determining the response (output) of a dynamic instrument system

3.8
step response

the time-varying response of an instrument system to a step function (heaviside function)

3.9
step response time

duration between the instant when an input quantity value of a measuring instrument or measuring system is subjected to an abrupt change between two specified constant quantity values and the instant when a corresponding indication settles within specified limits around its final steady value

[SOURCE: VIM:2008]

3.10

time constant

risetime characterizing the response of a instrument classified as a system of first order response (the way the system responds is approximated by a first order differential equation)

Note 1 to entry: It represents the time that the step response of an instrument system takes to reach the (1-1/e)•100[%] ≈ 63 % of the final or asymptotic value.

4 Standardization of RI raingauge calibration and field requirements

An RI international intercomparison organised by the WMO was conducted in a laboratory and in the field. The results have been published as IOM series (Instruments and Observing Methods), respectively the IOM 84 (RI laboratory intercomparison, 2004-2005) and IOM99 (RI Field intercomparison, 2007-2009). This concluded that a standardization of RI measurements is recommended, in terms of uncertainty evaluation for laboratory calibration and field measurements in order to improve the measurement accuracy of meteorological network instruments. This should be based on the achievable RI measurement performance (accuracy) rather than on the involved measuring principle or gauge design/technical solutions.

The following activities are recommended.

a) The WMO procedure, or similar, adopted for performing calibration tests in the laboratory should become a standard method to be used for assessing the instruments' performance.

b) A classification of instrument performance should be developed, possibly based on the results of laboratory tests and on user application requirements.

c) Field calibration procedures used, or similar to those, for the WMO field intercomparison of the catching type gauges should be adopted as a standard procedure for operational assessment of instrument's performance in the field.

d) Necessary steps should also be made towards common WMO – international standard(s).

5 Accuracy of rainfall intensity

5.1 Fundamentals and requirements

The performance of a raingauge should be assessed according to its accuracy in a given measurement range, in order to select the optimal raingauge for the required application. The accuracy of the RI instruments should be evaluated according to:

a) the measurement uncertainty in stationary conditions (laboratory calibration);

b) the step response to a step function/heaviside function (see Clause 3);

c) the achievable measurement uncertainty in dynamic/real conditions (field measurements).

The measurement uncertainty is obtained by means of calibration in a certificated laboratory under a constant flow regime (reference rainfall intensity). Water can be conveyed to the funnel of the instrument under test in order to simulate a constant rainfall intensity. The flow is measured by weighing the water over a given period of time. The output of the instrument under test is measured at regular periods of time or when a pulse occurs. The two measurements are compared in order to assess the difference between the actual flow of water conveyed through the instrument and the rainfall intensity measured by the instrument itself. The relative percentage difference between each measured and actual "rainfall intensity" figure is assumed as the relative percentage error (e_{rel}) of the instrument for the given reference flow rate. Within the RI output or averaging time (e.g. 1 min), the relative percentage error e_{rel} can be expressed as follows:

$$e_{\text{rel}} = \frac{I_{\text{mis}} - I_{\text{ref}}}{I_{\text{ref}}} \cdot 100$$

where

I_{mis} is the rainfall intensity measured by the instrument;

I_{ref} is the rainfall intensity produced by the reference constant flow.

By performing (or repeating) the test for a certain amount of time (minimum 30 min, 30 samples), it is possible to determinate the mean relative error for each level of reference rainfall intensity. The uncertainty can be finally determined in terms of expanded uncertainty calculated by the standard deviation of the relative error (estimated by the sample standard deviation, type A measurement uncertainty).

The step response (see Clause 3) is characterised by the determination of the raingauge time constant (if it can be treated as a first-order response instrument) by means of a variable water flow (unsteady conditions) such as a step-function input (see Clause 3). If the rainfall intensity is evaluated or calculated or reported over 1 min intervals, the time constant of the raingauge should be as short as possible compared to 1 min: It indicates the capability of the instrument to better represent the variability of precipitation over reduced time scales. The instrument response should be also negligibly affected by oscillations and/or overshooting and/or noise. A short time constant and lack of oscillations guarantee the best representation of the variability of the natural RI flow. The time constant should not to be confused with the data output delay that can be easily corrected through a time shift to retrieve the original RI information.

The achievable measurement uncertainty is determined in field comparisons of the RI gauges output to a reference RI instrument or a composite RI reference (consisting of more than 1 instrument) operated and maintained according to standards. Such reference systems are or will be established, e.g. at instrument centres that are recognised by WMO (such as a WMO-CIMO Lead Centre).

A more detailed description of the method applied for the evaluation of RI accuracy is provided in the following subclauses.

5.2 Laboratory calibration method (constant flow and step response)

According to Annex 1 included in the Report of the 15th WMO CIMO Session, which recalled the Recommendation no. 2 of the Abridged Report of the 14th WMO CIMO Session (Geneva, 7-14 December 2006), namely WMO No. 1019 Part 1, a standardised procedure has been recommended for use by National Hydro-meteorological data collection organisations for laboratory calibration of operational, catching-type raingauges. In addition to a well designed calibration system, the calibration set-up and procedures should be documented in full detail and staff should be well prepared before starting any calibration activity.

RI raingauges should be calibrated using a calibration system that:

a) has the capability of generating a constant water flow at various flow rates corresponding to the entire operational range of measurement (recommended range: from 0,2 mm/hup to 2 000 mm/hor up to the gauge RI limit; Typical WMO reference flows for calibration: 2, 20, 50, 70, 90, 130, 170, 200, 300, 500, 800, 1 200, 2 000 mm/hor the upper gauge RI limit);

b) is able to measure the reference flow by weighing the amount of water, i.e. the fluid mass generated over a given period of time (measurement of weight and time);

c) is able to measure the output of the calibrated instrument at regular intervals (1 min as minimum) or when a pulse occurs, which is typical for the majority of raingauges with a tipping-bucket measuring principle.

To characterise the performance of an RI gauge the calibration procedure should be able to:

1) synchronise the raingauges and clearing of buffered (or stored) amounts of rain inside the gauge before the start of constant flow;

2) determine the response of the raingauge to the constant reference flow by a graphical or numeric representation of the difference between the measured RI values and the reference RI for the calibration range;

3) determine the response of the raingauge to a reference step input by a graphical or numeric representation for the calibration range (determination of the time constant and overshooting/oscillating behaviour).

Additional, specific calibration tests could also be performed to evaluate the balancing of the bucket element of tipping-bucket raingauges or to evaluate the stability of the weighing element of weighing raingauges in absence of incoming reference flow.

The calibration system should be designed to obtain uncertainties less than 1 % with respect to each generated RI, and such performance should be reported and detailed. The result of any calibration will be a calibration certificate presenting the results of the calibration (including corrections to be applied), allowing a compliance check with the relevant recommendations. This certificate should also contain the measurement uncertainty for RI; it should document the traceability of the RI reference, the environmental conditions (such as temperature, date and time, etc.) and the applied time averaging method to retrieve RI over a defined time base.

Further details of the laboratory calibration method are contained in Annex A.

5.3 Classification of gauges according to accuracy performances

A standard classification of raingauges performance should be developed. This classification should be based on the results of laboratory tests and on user application requirements. The different classes of instruments would help users in selecting the proper instrument for their applications. Different classes may also apply to different ranges of rainfall intensity. In particular, the required accuracy performance of an RI gauge for assigning a specific class should be determined according to the measurement uncertainty in constant flow conditions and to the time constant in step input conditions. Applying specific criteria to accuracy performance results should determine the instruments classification and the consequent user application.

5.4 Field calibration method (calibration verification)

The main purpose of this activity should be to verify the operational status of raingauges, to detect malfunctions, output anomalies and calibration drifts during the operational use. These calibrations also provide valuable insight into data analysis and interpretation. The field calibration should be performed by means of a portable field calibration based on the same principles as laboratory calibration using the generation of constant rainfall intensity within the range of operational use (stationary flow). From the operational viewpoint the portable field calibrator should permit rapid tests and it should not contain any sophisticated components in order to provide a cost effective solution for metrological verification of RI instruments. The repeatability of the field calibrator (and its accuracy) should be assessed in a laboratory before the operational use and its uncertainty (expanded uncertainty) should be suitable for the raingauge to be tested in field.

During the WMO Field Intercomparison of Rainfall Intensity Gauges (Vigna di Valle, Italy, 2007-2009) a dedicated portable calibrator was designed and successfully used for calibration verification. Performances and results are described in the Final Report of the intercomparison (WMO/TD no.1504 IOM no.99) for further information.

Further details of the field calibration method are contained in Annex B.