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Hydrometry — Calibration of current-meters in straight open tanks

Hydrométrie — Étalonnage des moulinets en bassins découverts rectilignes

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 113, *Hydrometry*, Subcommittee SC 5, *Instruments, equipment and data management*.

This third edition cancels and replaces the second edition (ISO 3455:2007), which has been technically revised.

Hydrometry — Calibration of current-meters in straight open tanks

1 Scope

This International Standard specifies a calibration method for mechanical type, electromagnetic current-meters and acoustic type hydrometric current-meters used for point velocity measurement of flowing water. The method requires towing the instrument through still water in a straight open tank. It deals in particular with the measuring apparatus, the calibration procedure, the method of presenting the results and the uncertainties associated with the method.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 748, *Hydrometry — Measurement of liquid flow in open channels using current-meters or floats*

ISO 2537, *Hydrometry — Rotating-element current-meters*

JCGM 100:2008, *Evaluation of measurement data — Guide to the expression of uncertainty in measurement (GUM)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 772 apply. Units of measure are based on the International System of Units (SI). ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

4 Principle of calibration

4.1 Statement of the principle

Calibration of a current-meter means experimental determination of the relationship between water velocity and either the rate of revolution of the rotating element or the velocity directly indicated by the current-meter. For this purpose, the current-meter is mounted on a towing cart and drawn through still water contained in a straight tank with a uniform cross section at a number of steady speeds of the towing cart. Simultaneous measurements of the speed of the towing cart and the rate of revolution of the rotating element or the velocity indicated by the current-meter are made. In the case of rotating-element current-meters, the two parameters are related by one or more equations, the limits of validity of which are stated. In the case of stationary-sensor type current-meters, containing no rotating elements, the velocity indicated by its display unit is compared with the corresponding cart speed to know the error in measurement.

4.2 Accuracy of the method

4.2.1 Overall uncertainty on the velocity measurement

The towing method gives an absolute measurement of water speed which in principle only requires positions and time measurements. Provided that the precautions listed in 4.2.2 are taken, this method may be considered as very accurate.

4.2.2 Requirements for accurate measurements

The towing method gives an accurate measurement of water speed provided that:

a) the position, the timing and means for starting and stopping it achieve the necessary accuracy;

b) residual currents in the water are small.

5 Infrastructure

5.1 Dimensions of the towing tank

5.1.1 General

The dimensions of the tank and the number and relative position of current-meters in the tank cross section shall be chosen so that their effects on the test result are minimized.

5.1.2 Length

The length of a rating tank can be considered as comprising accelerating, stabilizing, measuring and braking sections.

The length of the accelerating and braking sections depends on the design of the cart, the maximum acceleration and deceleration achievable at maximum payload and the maximum speed at which the payload is to be towed along the tank. Safety requirements of the cart need to be taken into account while working out the length of the braking section. The length of the measuring section shall be such that the calibration error, which is composed of inaccuracies in the measurement of time, distance covered and rate of revolution, does not exceed the desired tolerance at any velocity. The required length will, therefore, depend on the type of current-meter being calibrated, type of cart and the way the signals are produced and transmitted.

5.1.3 Depth and width

The depth of the tank can have an influence on the test results which cannot be regarded as negligible, more particularly when the towing speed coincides with the velocity of propagation of the surface wave. The dependence of this critical velocity, v_c, on tank depth is given by the Equation (1):

$$v_{\mathrm{c}} = \sqrt{gd} \tag{1}$$

where

g is the acceleration due to gravity;

d is the depth of water.

Depending on the size of the current meter(s) and the cross section of the suspension equipment relative to the cross-sectional area of the tank, the wave crest produced by the current-meter and its means of suspension may cause an error in calibration within a narrow band in the velocity range from 0,5 v_c to 1,5 v_c. It is a systematic and not a random error.

The depth and width of the tank shall therefore be chosen to suit the size and the maximum velocity limits of the current-meters to be calibrated. Care shall be taken to ensure that either the calibration velocities in higher range are attained before the interference or that they exceed it sufficiently for the critical zone to be bridged without extrapolation.

5.2 Towing cart

5.2.1 General

During calibration, the current-meter is suspended below the cart and immersed in the water at specified depth and the cart travels along the length of the tank at known and accurate speeds in the measuring section.

5.2.2 Cart track system

The cart may run on two parallel rails which must be accurately aligned with both the length of the tank and the surface of the water in the tank. It is essential that the rails are straight and that the rails and the wheels of the cart are free of irregularities in order to avoid irregular motions of the cart. The material and hardness of the rails and the driving wheels should be chosen so that there shall not be undue wear and tear of the wheels. In the case of rubber tire wheels, provision shall be made to lift the wheels above the rail surface when not in use for a long time.

5.2.3 Types of towing carts

The following types of towing carts are in common usage.

a) The towed cart which is moved along the track by a cable driven from a constant speed motor standing apart from the moving cart. The towed cart may be lighter in construction with the consequent advantage of high acceleration and quick braking, but the elasticity of the towing cable can cause irregularities in the running of the cart thereby affecting the accuracy of current-meter calibration.

b) The self-propelled cart which is moved along the track by internally mounted electric motor(s). The power to the cart may be fed by a trailing wire track system or by an overhead conductor system or other systems specially designed for the purpose. The self-propelled cart will be heavier in construction as it has to carry the driving motors. This results in greater inertia of the cart and assists in smoothing out the running irregularities of the cart.

5.2.4 Cart operation

The cart shall travel smoothly and at constant speed in the measuring section of the towing tank ensuring that oscillatory motion is not transmitted to the current-meters under calibration.

The cart shall have smooth operational capability. Vibration of the tow cart should be avoided.

The cart shall remain stable during acceleration, deceleration and braking. There shall not be any forward/backward or sideways rocking, or slippage during peak acceleration/deceleration and during normal operation at any speed in specified range.

During calibration, the measuring equipment, sensors and other instruments shall not be affected by noise and spurious signals induced by the mains power supply or cart drive and control system or otherwise by electrical equipment installed in the rating tank building and vicinity.

In addition to normal braking, an alternate brake system shall also be provided on the cart which would automatically activate during an emergency.

5.2.5 Cart control

The cart may be manned or unmanned. In the case of a manned cart, an operator on-board controls various functions of the cart.

The unmanned cart is operated remotely without any operator on board.

5.3 Measuring equipment

5.3.1 General

The calibration of a current-meter calls for the simultaneous measurement of the following three parameters:

a) distance covered by the cart;

b) time; and

c) signal (pulses) delivered by the current-meter.

The towing speed is calculated from the simultaneous measurement of distance and time. In case of rotating-element current-meter, the rate of current-meter revolutions (rotations) is obtained by the simultaneous measurement of the number of signals (pulses) and the time.

5.3.2 Distance measurement

Different methods are available for measurement of distance to the specified measurement uncertainty (see 5.3.5). Two of the most common methods are as follows:

a) the establishment of light barriers (markers) at regular intervals along the length of the tank which actuate mechanical or optical pulse transmitters fitted to the cart;

b) the use of measuring wheels with mechanical or photoelectric pulse transmitters/optical encoders which are drawn along the track by the cart.

In the case of use of a measuring wheel, it shall be ensured that there is no slippage during travel. An additional method of precise speed measurement shall also be provided to check the accuracy of the measuring wheel on a regular basis.

5.3.3 Time measurement

The time of travel of the cart is normally measured by an electronic counter with an in-built accurate time reference, for example a quartz crystal. A period can thus be read to 1 ms or better. This equipment should be checked periodically against a reference device traceable to a national time standard.

5.3.4 Current-meter signal measurement

The cart shall be provided with a suitable recording device for the measurement of current-meter signals.

In the case of rotating-element current-meters, the sensor of the current-meter shall generate a clear and positive signal corresponding to the rotor revolutions. Normally, as per the design of the system, the signals are generated once per revolution, twice per revolution or in some cases once for five revolutions or even once for ten revolutions. The signals received from the current-meter(s) may be counted using the counting device of the current-meter. In measuring the number of current-meter revolutions in a given time, it is important to measure between identical points on the current-meter signal. It shall be ensured that none of the signals are missed.

In the case of an electromagnetic current-meter, the electrical signals from its sensor are processed by its control unit.

5.3.5 Sources of error related to infrastructure

Sources of error (sources of uncertainty) shall be treated according to GUM (Guide to the expression of uncertainty in measurement, JCGM 100:2008). Only the principal sources of systematic and random errors are considered below.

5.3.5.1 Error due to the distance measurement

The following influence factors can contribute to the measurement uncertainty of the distance measurement method:

- Systematic uncertainty of the reference distance measuring method
- Thermal expansion on measuring wheels
- Repeatability of the distance measurement method
- Detection/counting of impulses from pulse transmitter or encoders

5.3.5.2 Error due to timing measurement

The following influence factors can contribute to the measurement uncertainty of the timing measurement method:

- Systematic uncertainty of the reference timing measuring method
- Drift of the time reference

5.3.5.3 Error due to residual currents in the water

The water in the tank is never completely still and residual currents from various origins are always present. The following influence factors can contribute to the upper limit on residual currents

- Standing waves (surface gravity waves) linked to the dimensions of the tank and due to previous measurements or disturbances in the water
- Thermal convection currents due to temperature gradients

5.3.5.4 Error due to environmental conditions

The ambient temperature fluctuation should be as low as possible and direct sunlight should be avoided to minimize the influence on the tank's measurement system and to reduce the creation of thermal convection currents.

Electromagnetic interference generated by drive units and drive unit controls such as frequency converters and power rails, especially if these are located directly on the tow carts, may have an influence on the device under test and sensitive electronic devices.

Magnetic inductive flow meters may be affected by ferro magnetic structures like steel beams or reinforced concrete in the near surrounding.

5.3.5.5 Random errors

The repeatability with which the cart speed can be determined depends on the repeatability of the distance measurement method and on the timing accuracy. For any installation, this may be determined experimentally by setting the cart speed to a fixed value and perform a series of runs to provide a series of estimations of the cart speed.

This is repeated for several different cart speeds and from the standard deviation of each series of measurements, the 95% confidence limits may be evaluated.