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Hydrometry — Rotating-element current-meters

Hydrométrie — Moulinets à élément rotatif

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 2537 was prepared by Technical Committee ISO/TC 113, *Hydrometry*, Subcommittee SC 5, *Instruments, equipment and data management*.

This fourth edition cancels and replaces the third edition (ISO 2537:1988), which has been technically revised.

Hydrometry — Rotating-element current-meters

1 Scope

This International Standard specifies the operational requirements, construction, calibration, and maintenance of rotating-element devices for the measurement of flow velocities in open channels.

ISO 748 gives information on the use of these devices.

2 Normative references

The following referenced documents are indispensable for the application 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 772, *Hydrometric determinations — Vocabulary and symbols*

ISO 3454, *Hydrometry — Direct depth sounding and suspension equipment*

ISO 3455, *Hydrometry — Calibration of current-meters in straight open tanks*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 772 and the following apply.

3.1
propeller pitch
distance the propeller current-meter relatively moves through the water during one revolution

4 Principle of operation

4.1 Proportionality

The rotating element of a current-meter is driven by the fluid at an angular velocity that is proportional to the local velocity of the fluid at the point of immersion when that velocity exceeds a critical value.

4.2 Flow velocity

In order to determine the velocity of the fluid, a current-meter is placed at a point in a stream and the number of revolutions of the rotor during a specified time interval is counted or the time required by the rotor to turn a given number of revolutions is observed. The velocity is obtained from the current-meter calibration table or calibration equation(s), established experimentally during its calibration (Clause 9). The number of current-meter revolutions (rotations) may be determined by sensing the signals emitted (such as electrical pulses) through the rotation of the rotor by using a suitable counting device. The velocity can be determined from a direct reading of the speed of rotation of the rotating element by means of equipment designed for this purpose.

5 Types of current-meters

5.1 General

The current-meters are generally classified depending upon the type of rotating element used, i.e. vertical axis cup-type and horizontal axis propeller-type.

5.2 Cup-type current-meter

The rotor of the cup-type current-meter is constructed out of conical cups, or curved vanes attached at equal intervals around the perimeter of a hub, which rotates when placed in a fluid flow. Usually, the rotor is mounted with the axis vertical.

5.3 Propeller-type current-meter

The propeller-type current-meter is an assembly consisting of a number of straight or angled vanes attached at equal intervals around the perimeter of a hub, or two or more helical screw blades formed around a hub that rotates about a horizontal axis when placed in a fluid flow.

6 Operational requirements

6.1 Positioning

The current-meter shall maintain alignment with the flow in such a way that the rotating element responds to flow movement as intended. It shall balance in the stream with its longitudinal axis parallel to the water surface. If a pivoted suspension is incorporated within the current-meter, it shall permit freedom in the vertical plane to ensure correct alignment with the stream flow. Alignment in the horizontal plane may be affected by the correct choice of suspension equipment (see ISO 3454).

Current-meters of conventional construction are intended to operate in a horizontal or near-horizontal position. Current-meters designed to operate in other positions are not covered by this International Standard.

6.2 Resistance to flow

The current-meter shall offer minimum resistance to the force of the flow.

6.3 Limits of use

The rotating element of the current-meter shall be such that, when driven by the fluid, it rotates at an angular velocity, which has a known relation to the velocity of the flow within the calibrated velocity range stated by the manufacturer or rating laboratory. The suspension system shall be used as specified by the manufacturer.

The current-meter shall respond rapidly and consistently to the changes in velocity. The manufacturer shall state the expected response rates.

The current-meter shall be used only in liquids with properties similar to those in which it was calibrated. If the liquid properties are significantly different, the current-meter shall be recalibrated in a liquid with properties similar to that in which the current-meter is to be used.

Unless otherwise indicated, the current-meter shall be capable of being used in waters containing suspended sediment and in saline waters.

The manufacturer shall state the maximum hydrostatic pressure to which the instrument may be subjected.

The manufacturer shall also furnish information on the temperature limits as applicable to the use of current-meter with oil-lubricated bearings.

7 Characteristics of cup-type and propeller-type current-meter

7.1 General

There is no significant difference between the accuracies of the velocities registered by cup-type and propeller-type current-meters. Their characteristics can be summarized as follows.

7.2 Cup-type current-meter

a) This is a robust instrument requiring less maintenance; the rotor is replaceable in the field without affecting the calibration.

b) It operates at lower velocities than the propeller-type current-meter.

c) The bearings are well protected from silty water.

d) A single rotor serves for the entire range of velocities.

e) When held rigidly by rod suspension and pointing upstream at right angles to the measuring section, the current-meter may over- and under-register oblique flows with error generally increasing as the velocity and angle of the flow increases.

f) Vertical components of velocity may cause rotation of a hollow cup-type current-meter. When there is considerable turbulence in a stream or where there are otherwise significant vertical components of velocity, hollow cup-type current-meters may over-register. Usually, the over-registration will be small unless large vertical components of velocity relative to the horizontal components are encountered.

7.3 Propeller-type current-meter

a) This current-meter disturbs flow less than the cup-type current-meter.

b) The propeller is less likely to become entangled with debris than the cup-type current-meter.

c) Bearing friction is less than for vertical shaft rotors because any bending moment on the rotor is eliminated.

d) The commonly used propeller-type current-meter may give correct registration of velocity in oblique flow for incidence angle less than 5° with an error about 1 %. For precise measurement of flow in oblique or convergent flow, a special type of component (self-compensating) propeller-type current-meter is used which measures directly the axial component of velocity with an error less than 1 % for greater angle of incidence up to 45°.

e) Propeller-type current-meters are not as susceptible to vertical currents as cup-type current-meters and therefore give better results when used for stream flow measurement in large rivers by moving boat method (ISO 4369) to minimize errors created by the pitching or vertical motion of the boat.

8 Construction features

See Annex A.

9 Calibration (rating)

9.1 General

In order to determine the velocity of the stream from the revolution of the rotor of the conventional current-meter, a relation between the angular velocity of the rotor and the velocity of the water that spins the rotor has to be established experimentally. The relation so established experimentally is known as calibration (rating) of the

current-meter. The results of the calibration are provided in the form of a calibration table. In addition, a calibration curve with calibration equation(s) may be provided.

The calibration of the current-meter shall normally be valid only for that range of velocities for which it has been manufactured and calibrated, and for use with a similar liquid to that which was used in its calibration. Extrapolation is permissible to higher velocities provided that sufficient calibration data exist for current-meters of a similar type at these higher velocities and that a greater uncertainty is accepted.

Attention shall be paid to possible variation in the calibration due to liquid density and viscosity.

9.2 Conformity of calibration

Calibration of new current-meter and recalibration of old current-meter in use shall be carried out at the recognized rating laboratory in accordance with the ISO 3455.

9.3 Minimum speed of response

The minimum speed of response (also called the threshold, or stall velocity) of a rotating-element current-meter is defined as the minimum speed at which the rotor of the current-meter attains continuous and uniform angular motion during calibration. This speed shall be determined in the rating laboratories. The lower the speed of response of a current-meter, the lower the speed of flow that is measurable with confidence. However, the uncertainties of measurement at the minimum speed of response are high. It is therefore desirable that the current-meter shall be used in the field for stream velocities greater than twice its minimum speed of response.

9.4 Calibration table

For the new current-meter, the manufacturer shall supply the calibration table based on the calibration tests conducted at the rating laboratory. The calibration table shall be in the form suitable to the gauging technique in use. It shall also specify the calibration equation(s) and the following information:

a) the name and address of the rating laboratory;

b) the date of calibration;

c) the calibration job number;

d) the make and type of current-meter;

e) the serial number of the current-meter and each rotor;

f) spin time of cup-type current-meter;

g) type of suspension of current-meter on carriage (cable or rod suspension);

h) the details of sinker weight if used during calibration;

i) the position of the current-meter in the cross-section of the tank;

j) a statement indicating the minimum speed of response;

k) the limits of calibration;

l) any remarks regarding modifications made to the current-meter;

m) the water temperature during calibration;

n) the viscosity of the bearing oil;

o) standard deviation and percentage deviation indicating accuracy of calibration equation(s);

p) the signature of a responsible member of the staff at the rating laboratory.

9.5 Types of calibration

9.5.1 General

The current-meters are calibrated individually or a group (standard) calibration is established from a group of current-meters of uniform manufacture.

9.5.2 Individual calibration

In the case of individual calibration, the relationship of velocity and rate of rotor revolutions is established for a particular current-meter. Individual calibration is necessary when a very high standard in manufacture is not guaranteed.

9.5.3 Group (standard) calibration

Group calibration shall be based on the calibration of a group of current-meters of uniform manufacture. The sample of current-meters calibrated shall be adequate in number and shall comprise, if possible, both new current-meters and well-maintained used current-meters. The manufacturer shall make available a description of the original calibration and of the current-meters used in the calibration. In addition, they shall check the validity of the standard calibration on a sample comprising at least 10 % of newly manufactured meters selected at random, and again shall give similar details of the check calibration. The cost saving in adopting a group calibration is significant but the confidence levels are lower than for an individual calibration. Strict control of manufacture's tolerances is an essential requirement for the implementation of a group calibration and careful vigilance by the user is necessary.

9.6 Recalibration

The current-meter shall be recalibrated whenever its performance is doubtful. In practice, recalibration for individually rated current-meters shall be carried out at yearly intervals or after 300 h of use, whichever is the shorter. Before undertaking recalibration of any used current-meter, it shall be ensured that the current-meter is properly repaired, its worn out parts are replaced and the shape of rotor is in order.

9.7 Type of suspension

The performance of a current-meter may be affected by its mode of suspension and the sinker (sounding) weight used (see ISO 3454). For individual calibration, it is advisable that the calibration be carried out using the same means of suspension and the sinker weight intended to be used during the subsequent field measurement. The distance from the bottom of the sinker weight to the current-meter, for the calibrated configuration, shall be specified by the rating laboratory or the manufacturer.

The differences between calibrations made on rod and cable suspensions depend on the dimensions and shape of section of rod and on the size and type of sinker (sounding) weight used.

For a given velocity, the rotor of a cup-type current-meter may rotate faster with rod suspension than with cable suspension, whereas in the case of a propeller-type current-meter, the propeller of the rod suspended meter may rotate slower than that of a cable suspended current-meter.

In order to correct for the effects of different sinker weights and different means, size and shape of suspension, the coefficients derived in the rating laboratories shall be used. Such coefficients are applicable only to the specific combination for which data have been experimentally obtained. However, when high precision in gauging is required, the same suspension method as proposed to be used in field measurements shall be used during calibration.

9.8 Uncertainty in calibration

As a check for goodness of fit of the calibration curve, the manufacturer or the rating laboratories shall state the standard error of the data for the lower and upper limits of calibration, and for at least two intermediate points. The standard error shall be stated as a percentage of the mean velocity class and shall be related to a level of confidence of 95 %.

The scatter of the points about the calibration curve for each velocity class shall be approximately normal so that the errors will be compensating.

10 Maintenance of current-meter

See Annex B.

11 Operational and servicing manual

A comprehensive operational and servicing manual shall be supplied with each current-meter. It shall present full instructions, illustrated where necessary, and include appropriate circuit diagrams with component values. The manual shall contain sections on the following:

a) normal maintenance, servicing on site, checking procedures including recommended screw torques;

b) list of recommended spare parts essential for maintenance of the current-meter during field use for a period of at least two years including list of contributing manufacturers;

c) list of accessories necessary for use of the current-meter in the field;

d) lubricant and sealant details, including lubricant and compound specifications;

e) preparations necessary for transport and storage;

f) details of the power source, if any, and appropriate ratings and duration of recharge;

g) details of electrical and (or) electronic circuitry (including component values) with circuit diagrams and test procedures.

The current-meter shall also be supplied with a calibration certificate from a recognized rating laboratory.

Annex A
(normative)

Construction features of current-meters

A.1 General construction

A.1.1 A cup-type current-meter shall generally consist of

a) a rotor revolving about a vertical shaft;

b) a hub assembly;

c) upper shaft bearing and lower pivot bearing;

d) a main frame or yoke;

e) a chamber containing the signal generating mechanism;

f) tail fins;

g) a means of attaching the instrument to the suspension equipment;

h) a means of locking the rotor when not in use.

A.1.2 A propeller-type current-meter shall consist of

a) a rotor in the form of a screw or propeller revolving about a fixed horizontal shaft;

b) ball bearings in oil chamber or water-lubricated bearings;

c) a streamlined body containing a device giving electrical signal to indicate movement of the rotor;

d) a tailpiece with or without a vane;

e) a means of attaching the instrument to the suspension equipment.

A means of providing directional control to the current-meter in the current shall be provided. This may be either a part of the suspension equipment or an integral part of the current-meter.

Each newly manufactured current-meter shall be engraved with the source of manufacture, trademark, year of manufacture and the serial number for its identification.

Both cup-type and propeller-type current-meters are available in miniature forms for use in very small depths of flow. The miniature cup-type current-meter with rotor diameter of about 50 mm is also known as pygmy current-meter. It has no tailfin and it is used only with rod suspension. The rotational speed of a pygmy current-meter is more than twice of the standard cup-type meter.

A.2 Cup-type current-meter

The rotor shall be constructed of six hollow or solid conical cups, fixed in the same horizontal plane at equally spaced intervals (equal angles) to a frame mounted on a vertical shaft. This assembly shall be retained in the main frame (yoke) by means of the upper shaft bearing and a lower pivot bearing consisting of a central pivot and a bearing cup fixed in the bottom end of the shaft.

A.3 Propeller-type current-meter

The current-meter may be provided with a single propeller or with several interchangeable propellers each having a different pitch and/or diameter. Each propeller shall consist of two or more vanes or helical screw blades that generally rotate about a horizontal axis. The propellers shall be made from a material that will not

allow them to be easily distorted. The propellers of different screw pitches are used for different ranges of stream velocity. The manufacturer shall specify the velocity range for each propeller size.

A.4 Bearings

The resisting torque of the bearings shall be as small as possible and shall be constant during use. The pivots and the bearing of the cup-type current-meter shall be made out of rustproof, hardened and tempered steel with adequate hardness for longer life. Bearings shall be lubricated as stated by the manufacturer. Provision shall be made to ensure that silt and water do not enter the bearings except as required for water-lubricated bearings.

A.5 Means of counting rotor revolutions

A.5.1 Signals

The revolutions of the rotor shall, by means of mechanical contacts or by means of magnetic, optical or other devices, generate a clear and positive signal at all velocities within the effective range of the current-meter. If electrical connections are used, they should be appropriately waterproofed.

Manufacturers should stipulate the maximum conductivity of water in which the current-meter can be used.

A.5.2 Signal generating mechanism

In the case of a cup-type current-meter with a reed switch type contact, the signal generating system shall be a permanent magnet with balancing counterweight or a diametrically opposite pair of small permanent magnets mounted on the cup wheel (rotor) shaft in the contact chamber. The reed switch sealed in a brass enclosure shall be suitably mounted on the chamber. The magnet(s) shall actuate the reed switch and complete the circuit once per revolution or twice per revolution depending on design. From the switch, a twin conductor cable shall carry the electric pulses generated by each revolution of the cup wheel to the counting device. A wading rod or suspension cable can be used as one of the conductors.

In the case of a propeller current-meter with a reed switch contact, a small permanent magnet or a diametrically opposite pair of small permanent magnets shall be inserted at the rear of the impeller boss and the reed switch enclosed in a glass envelope located in the current-meter body. In all types of design, the electrical impulses produce either a signal which registers a unit of a counting device or an audible signal in a headphone.

A.5.3 Adjustable frequency signals

For the measurement of low velocities, it shall be possible to choose the frequency of signals transmitted to the counting mechanism in such a way as to reduce to a minimum the errors entailed in measurements of normal duration.

It is permissible to provide a means of multiplying or dividing the signal pulse rate to suit counting equipment with a limited range of operation. If electrical connections are used in the equipment, they shall be appropriately protected against short-circuiting.

A.5.4 Signal receiving devices

A.5.4.1 Counter

A counter is an essential component of the current-meter, which registers the signals received from the current-meter rotor. The counters shall be mechanical type or electronic type.

The mechanical type counter shall indicate the revolutions of current-meter rotor during the performance of point-to-point measurements over a selected measuring period. The counter shall be battery-operated, provided with either an on/off switch when used in combination with a stopwatch or an automatic timing device

that can be set for a selected period. A button shall be provided for resetting the counter to zero. The instrument case shall be made of impact resistance material, be waterproof and shall be suitable to carry on a shoulder strap.

The electronic counter shall be a solid state low power device preferably with LCD or LED display and provided with rugged field-worthy splashproof casing resistant to water entry. It shall be possible to easily read the LCD display even in sunlight. The counter shall be provided with filters for suppressing glitches and electrical noise that may be produced by the signal generating mechanism. The power supply shall be battery operated with either dry batteries or rechargeable batteries in-built in the same casing. Low battery indicator and easy access to replace batteries shall be provided.

A.5.4.2 Direct velocity indicator

This instrument shall be an electronic indicator which can transform the signals (pulses) received from the current-meter into a measuring voltage and indicate them on a scale as velocity in metre per second. The instrument shall work on DC supply, which can be obtained from standard rechargeable batteries. The front panel of the read out unit shall have a velocity indicator, push buttons for selecting velocity ranges, a low range velocity counter, a pair of binding posts for battery connection and a socket for connecting the current-meter cable. The unit shall have the facility of battery check. The unit shall be assembled in a robust light box and the assembly shall be made weatherproof. Adjustable straps shall be provided for convenient handling.

A.6 Mounting

The body of the current-meter shall provide means for mounting on a cable suspension or the slide support of a rod (see ISO 3454). If an adapter is necessary, the current-meter shall be calibrated for such conditions. When the current-meter is used on rod suspension, it is necessary to ensure that the current-meter is pointing at right angles to the measuring section.

A.7 Directional control

Directional control shall be provided by means of tail fins or suspension system or other devices to enable the current-meter to align itself with the stream flow and to remain stable in that position throughout the full range of calibrated velocities.

In some designs, the propeller-type current-meter is fixed to the nose of the sinker weight called a middle piece. The middle piece is generally equipped with an electrical ground feeler (contact device) which produces a signal when the weight touches the bed.

The sinker weight needs to be sufficient to reduce the vertical angle of trail of cable to about 6° so as to ensure that the current-meter is operating close to the chosen cross section and also to make certain that the horizontal swivel of both the current-meter and the weight will not be restricted.

A.8 Interchangeability of parts

Spare parts shall be fully interchangeable so as to have uniform functional characteristics, to cause less than a 2 % divergence from the normal calibration curve, and to facilitate easy replacement of worn or damaged elements.

A.9 Materials of construction

Current-meters shall be constructed of corrosion-resistant materials throughout or of materials that are effectively protected against conditions encountered in natural waters. The manufacturer shall provide information on the materials used in the construction of current-meters that may be used in fluids having properties different from those of most natural waters. In such cases, it is the responsibility of the user to determine whether the current-meter is suitable for the proposed use. The current-meter shall be of sufficiently

rugged construction to maintain calibration under conditions normally encountered at a gauging site. The use of the current-meter in silty or saline waters may reduce the life of the current-meter.

In the case of a reed switch contact type current-meter, the shaft material shall be non-magnetic and its electroplating shall also be non-magnetic chrome plating so as not to generate magnetic induction in the contact chamber affecting performance of the current-meter.

Propellers made of dense metals such as brass need to be more carefully balanced than those made of light material such as plastics. Some current-meters may have propellers made of polystyrene.

Current-meters having plastic propellers and water-lubricated bearings require little attention and adjustment. They are ideal for measurement of low speeds and for use at remote sites.

Annex B
(normative)

Maintenance of current-meter

B.1 General

The calibration of a current-meter will be valid only if it is properly handled and timely oiled, and if good care is taken for its cleanliness and maintenance. Training to the field personnel on care, maintenance and repair of current-meters shall be provided.

The user shall follow meticulously the recommended check procedures before and after each discharge measurement, as described in the manufacturer's operation and servicing manual. In the event of more comprehensive instructions not being provided, the procedures specified below shall be followed.

B.2 Examination

The current-meter shall be examined, before and after each discharge measurement, for damage and wear of the rotating parts, faulty alignment of the shaft, proper operation of contact points, and deformation of the yoke or cup wheel (in the case of a cup-type current-meter) or of the propeller (in the case of propeller-type current-meters). The pivot of a cup-type current-meter shall be periodically examined to make sure that the pivot point is not damaged and has not become magnetized. All moving parts shall be carefully inspected and checks shall be performed to ensure operation in accordance with specifications. Particular attention shall be paid to the current-meter that has been in storage for a long period of time.

B.3 Inspection

For inspection, it shall be possible to dismantle and reassemble the current-meter assembly in the field, without specialized workshop facilities and by personnel without specialist training. Tools required to carry out this operation shall be supplied as standard accessories.

On-site removal and replacement of the rotor on its shaft shall be possible with minimum disturbance to the bearing assembly, and preferably without removing the bearing assembly from the instrument.

B.4 Cleaning and lubrication

A current-meter shall be cleaned after each day of use or after each discharge measurement in water heavily laden with sediment. All bearing surfaces shall be thoroughly cleaned and, where appropriate, lubricated. The lubricant used shall have the same viscosity characteristics as the lubricant used at the time of calibration; this lubricant shall have the same or equivalent specifications as that recommended by the manufacturer.

B.5 Signal test

Before use, the current-meter shall be tested for proper operation. By turning the rotor slowly, the number of rotations shall be compared with the number of pulses received.

B.6 Spin test

B.6.1 Current-meters with ball bearings or a pivot bearing

If no special instructions are provided by the manufacturer, the test described below shall be carried out after the current-meter has been lubricated and assembled ready for use.

Place the current-meter in normal operating attitudes, with the rotor protected from air currents. Spin the rotor by hand. As it nears its stopping point, observe its motion carefully to see whether the stop is abrupt or gradual. If the stop is abrupt, the cause shall be found and corrected before the current-meter is used. A pre-specified minimum spin time should be observed for a current-meter in good condition.

B.6.2 Current-meter without ball bearings

The design of current-meter without ball bearings prevents the current-meter from working properly in air. The manufacturer shall recommend a simple check procedure to ensure proper operation.

B.7 History sheet (log book)

The user of the current-meter shall maintain a history sheet (log book) of the current-meter at site in which the following details shall be given:

— name of manufacturer;

— date of manufacture;

— serial number of current-meter;

— date of start and stoppage of use and reuse;

— date of calibration/recalibration;

— place of calibration;

— calibration equation;

— repairs carried out;

— any other relevant information.

B.8 Transport and storage

Damage to the current-meters normally occurs because of improper packing and careless handling in transportation. The current-meter must therefore be handled with extreme care during transportation. Provision shall be made for the storage and transportation of the current-meter and its components in such a manner that the bearings and other delicate parts of the current-meter can be protected from wear and from damage resulting from vibration or shock.

A suitable protective instrument case shall be provided by the manufacturer on request in which the current-meter may be stored when not in use. Suitable storage shall also be provided in the case for the tools required for instrument maintenance.

Bibliography

[1] ISO 748, *Measurement of liquid flow in open channels — Velocity-area methods*

[2] ISO 4369, *Measurement of liquid flow in open channels — Moving-boat method*

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