TECHNICAL SPECIFICATION

ISO/TS 15768

First edition
2000-07-01

Measurement of liquid velocity in open channels — Design, selection and use of electromagnetic current meters

Mesurage de la vitesse des liquides dans les canaux découverts — Conception, choix et utilisation des débitmètres électromagnétiques

Reference number
ISO/TS 15768:2000(E)

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Printed in Switzerland

Contents

Page

Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed every three years with a view to deciding whether it can be transformed into an International Standard.

Attention is drawn to the possibility that some of the elements of this Technical Specification ISO/TS 15768 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 15768 was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 1, *Velocity area methods*.

Introduction

The purpose of this Technical Specification is to highlight the particular characteristics of the typical electromagnetic current meter that distinguish it from the typical rotating element current meter, and to provide guidance to users of the electromagnetic device that will allow informed judgements to be made regarding its likely performance attributes and limitations in operational situations.

Measurement of liquid velocity in open channels — Design, selection and use of electromagnetic current meters

1 Scope

This Technical Specification gives guidelines for the design, selection and use of electromagnetic current meters used to determine point velocity for the purpose of measuring flow in an open channel using the velocity area method.

NOTE The electromagnetic current meter is acceptable as a device for making point determinations of velocity for the purposes of open channel flow determination by the velocity area method, using the multiple point velocity sampling technique described in ISO 748 (see reference [1] in the Bibliography).

2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this Technical Specification. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this Technical Specification are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 772, *Hydrometric determinations — Vocabulary and symbols.*

3 Terms and definitions

For the purposes of this Technical Specification, the terms and definitions given in ISO 772 apply.

4 Units of measurement

The units of measurement used in this Technical Specification are SI units.

5 Physical characteristics of the electromagnetic current meter

5.1 General

5.1.1 An electromagnetic current meter will normally comprise the following components:

a) a sensing head (sometimes referred to as a "probe");

b) a means of suspension;

c) a control unit;

d) a signal cable (between the sensing head and the control unit);

e) a source of electrical energy.

5.1.2 The source of electrical energy will normally be a battery pack, contained within the control unit. The signal cable will generally contain separate conductors to convey the electrical signal output from the sensing head to the control unit and the subsequent electrical response from the control unit back to the sensing head.

5.1.3 The signal cable may or may not be detachable from the sensing head or from the control unit. This feature may vary between devices made by different manufacturers. Sensing heads may vary significantly in size and shape.

5.1.4 Most devices are capable of distinguishing and indicating flow polarity, i.e. whether the direction of flow is forward or backwards with respect to the reference axis of the sensing head itself. Some manufacturers offer variants that are able to determine and indicate flow direction with respect to absolute directional references in either or both of the horizontal or vertical planes.

5.2 Sensing head

5.2.1 The sensing head generally consists of a streamlined solid body, within which is located an electromagnetic coil (for generating a local electromagnetic field). It also contains one or more pairs of sensing electrodes capable of detecting the electrical potential generated by the movement of water (the electrical conductor) through the local electromagnetic field.

5.2.2 The sensing head may also contain one or more of the following:

a) signal conditioning and/or amplification electronics;

b) communications electronics.

5.2.3 The sensing head may be expected to be constructed in such a manner, and of such materials, as to prevent the ingress of moisture, under all conditions of use for which the device is intended, to any extent that would interfere with the device's reliable and accurate operation, and for the duration of the device's intended working lifetime.

5.2.4 Each pair of sensing electrodes present, generally appears at the surface of the head, at a given distance apart in function to the detailed design of the device. Movement of water (the conductor) through the electromagnetic field, generated by the device's internal coil, causes an electrical potential to be generated. This potential may be detected by the electrodes, and is proportional to

a) the strength of the field,

b) the size of the conductor, and

c) the speed of the conductor through the field.

5.2.5 The size of the conductor (the body of water whose mean speed is detected by the device) is a function of the shape and extent of the field generated by electrical stimulation of the coil and the orientation of that field with respect to the mean direction of flow. The maximum potential is normally generated when the straight line intercepting a pair of sensing electrodes is normal to the mean direction of flow. Different proprietary devices may create differently-sized electromagnetic fields and, hence, sample the speed of differently-sized bodies of water.

5.2.6 The strength and extent of the generated electromagnetic field may be of particular relevance when sensing heads are deployed in close proximity to the air/water interface or to the water/channel-bed interface. Device calibration may be affected if the electromagnetic field produced is interrupted by one or other (or both) of the mechanisms described. Where the question is relevant, guidance should be sought from the manufacturer or supplier of the device that is to be used.

5.2.7 In device variants equipped with two or more pairs of sensing electrodes, pairs are normally disposed in lines that are mutually perpendicular. Thus, in a two-pair device, the straight lines intercepting each separate pair of electrodes (or planes containing those straight lines) would themselves intersect at right angles. The two pairs would normally be deployed in the horizontal plane, and the device as a whole would thereby be rendered capable of determining and indicating true flow direction relative to an absolute directional datum also in the horizontal plane.

5.2.8 In a three-pair device, the third pair of electrodes are normally oriented at right angles to the plane of the other two pairs, and the overall device can determine and indicate the absolute direction with respect to the vertical as well as the horizontal.

5.2.9 In device designs that allow disconnection of the sensing head from the signal cable, the connector is normally fully water-resistant, capable of withstanding submergence to a depth indicated by the device manufacturer's product specification. However, it may be a prohibited to disconnect the head while the device is under power from its control unit. Furthermore, threaded connectors may be made of very fine thread pitch, requiring careful attention when disconnecting or re-connecting to avoid accidental damage to the thread (i.e. “stripping”) that might render the connector insecure or no longer water-resistant. It is also important to keep such connectors scrupulously clean.

5.2.10 For any electromagnetic current meter to perform satisfactorily, the water in which it is deployed needs to be adequately conductive. The minimum water conductivity at which a meter performs to its specification may vary between devices made by different manufacturers, or between different generic variants of the same manufacturer. Typical minimum values of water conductivity at which electromagnetic current meters may reasonably be expected to perform to specification, range between 30 μS and 100 μS, depending upon device manufacture and, also, upon water velocity. As a generalization, low velocity and low conductivity may not combine well to deliver adequate measurement performance in a specific meter.

5.2.11 Surface contamination of the sensing head may have an effect upon a device's calibration by altering the electrical conducting properties of its electrodes. Sensing heads should be handled as little as possible, and it is sound operational practice to wash them clean of silt or other waterborne contamination immediately after every use, and to clean them free of grease (with a soft cloth and a mild non-abrasive detergent) immediately before use. If an oil film is located on the water surface, a method should be provided for protecting the sensing head from being coated with oil during insertion into the water. For example, a plastic bag can be placed over the sensing head and then removed under water and under the oil film. It is recommended to follow the manufacturer's operating instructions or advice, when provided, on the subject of probe or head contamination.

5.2.12 The specific calibration of a device is also likely to be a function of the hydrodynamic characteristics of its sensing head, as determined by its specific shape, and by the state of surface roughness. Sensing heads are normally constructed from material that is appropriately resistant to damage by impact, abrasion or chemical attack. Nevertheless, care should be taken in the handling and deployment of the sensing head of an electromagnetic current meter to prevent accidental damage that alters its shape or smoothness of its surface finish to any significant degree. Where there is doubt as to the significance of an observable alteration of this nature, re-calibration or comparison of performance against a reference device may be appropriate.

5.3 Means of suspension

5.3.1 The sensing head of an electromagnetic current meter is normally constructed to make it deployable by easy attachment to gauging rods as a basic method of suspension. It may also be possible to suspend such a device by cable, and to attach a tail fin and a sinker weight to allow deployment in circumstances where rods are not appropriate.

5.3.2 Depending upon the specific design of a metering system, the length of the signal cable that connects the sensing head with the control unit may be limited. The calibration of a specific individual meter may be unique to the specific length and type of signal cable used in the course of calibration (see also 5.5.3).

5.3.3 Some meter designs (but not necessarily all), may allow meter deployment by means of a cableway system.

5.4 Control unit

5.4.1 Depending upon the specific design, the control unit of an electromagnetic current meter should have or be able to perform some or all of the following features or functions:

a) switch the device on and off;

b) contain the required battery power supply;

c) interface with an external source of continuously-available electrical energy;

d) re-charge internally-contained re-chargeable cells;

e) apply appropriately regulated electrical stimulation to the sensing head;

f) detect a response signal from the sensing head that is representative of the electrical potential being generated at any time across an individual pair of sensing head electrodes;

g) quantify the returning signal in appropriate electrical units, and with an appropriate degree of accuracy, sensitivity and repeatability;

h) mathematically transform measured electrical units into velocity units (e.g. calibration);

i) integrate or average the instantaneously sensed signal from the device's sensing head (or its velocity transform), over one of a number of operator-selectable time periods;

j) display instantaneous or averaged values of velocity in digital form;

k) refresh the display at a frequency different from the selected measurement integration period (i.e. by giving a rolling average value integrated over x seconds which is updated and displayed every y seconds).

l) allow an operator to select from among the available set of operational modes or functions of the device;

m) provide an output signal of predetermined electrical form for transfer of data to an external recording medium.

5.4.2 The operating components of a control unit are normally housed in a protective container of a design appropriate to the operational conditions under which the device is intended for use. Its design should include an adequate degree of protection for use outdoors in rain and within a specified range of ambient temperature.

5.4.3 In device designs that allow disconnection of the control unit from the signal cable, the connector normally is water-resistant and suitable for use in rain, but not necessarily proof against submergence. However, it may be prohibited to disconnect the head while the device is submerged. Furthermore, threaded connectors may be made of very fine thread pitch, requiring careful attention when disconnecting or re-connecting to avoid accidental damage to the thread (i.e. "stripping") that might render the connector insecure or no longer water-resistant. It is also important to keep such connectors scrupulously clean.

5.5 Signal cable

5.5.1 This is normally of a design and type appropriate to the electrical requirements of the device as a whole, and depending upon the individual manufacturer, may be permanently connected or disconnectable from either or both the sensing head or control unit.

5.5.2 In devices that allow disconnection, the design of connectors normally precludes incorrect connection. If this is not the case, the device manufacturer's advice should be sought and followed regarding the possible consequences of incorrect cable connection.

5.5.3 In individual designs of the device, there may be practical limitations to the length of the signal cable that may be specified. This limited length is normally indicated in the manufacturer's specification. Furthermore, if the signal cable length is changed to a length different than that used during the calibration of the meter, the meter may have to be recalibrated with the new signal cable length.

5.6 Energy source

5.6.1 The energy source is normally a battery pack housed within the device's control unit and consists of a specified number of individual cells of a commonly available specification.

5.6.2 Individual designs of the device may allow the use of re-chargeable cells and may have provision for them to be recharged while installed within the control unit.

5.6.3 Devices that have provision for battery-cell recharge may also allow the use of non-rechargeable cells. Operators should take care not to enable a device's battery recharge function without being certain that rechargeable cells have been installed, as damage to the device and danger to the operator may result if the recharge process is applied to non-rechargeable cells.

6 Use of electromagnetic current meters

6.1 General

6.1.1 In general terms, an electromagnetic current meter may be regarded as suitable for use in any operational situation in which a rotating element meter would be appropriate, other than places where strong outside ambient electromagnetic fields or ambient electrical noise occur that may adversely affect meter performance.

6.1.2 An electromagnetic type of current meter is functionally similar to a rotating element meter in that it is essentially a calibrated device. Subsequent to its manufacture, each device should have been subjected to a calibration process. In this process, the relationship between the characteristic electrical signal that the device produces when subject to relevant stimulation and the speed and direction of a body of water with which it is in contact at the time is established against a known standard over a range of speeds appropriate for the intended use of the device.

6.1.3 An electromagnetic current meter is functionally different from a rotating element meter in mechanical and electrical construction. These functional differences may make the electromagnetic current meter suitable for use in operational situations where rotating element meters are unsuitable. Such situations may include:

a) water velocities lower than the starting velocity of an otherwise comparable rotating element meter (though measurement uncertainty may be great at such low velocities);

b) water subject to weed infestation;

c) water with high concentrations of suspended solids.

6.1.4 An electromagnetic current meter is a device containing no moving parts. This results in a device which is inherently resistant to physical changes during normal operational use, thus making it more operationally robust and in less need of periodic recalibration than a rotating element meter. Electromagnetic meters should nevertheless be checked periodically for performance and electronic drift in the control unit against a reference standard (which may be another electromagnetic meter of identical capability) and subjected to a full recalibration process if performance is observed to have been altered to an unacceptable degree.

6.1.5 Deployed in water that is electrically conductive but absolutely free of movement, an electromagnetic current meter should display a measured velocity of zero, plus or minus a reasonable tolerance that is a function of the device's design, and which should be stated in its performance specification. This zero stability should be checked frequently, ideally before and after each operational deployment, and the manufacturer's advice sought if there is significant departure, either in terms of frequency or magnitude, from specification. If there is an evident or known source of electrical noise or electromagnetic interference in the vicinity of a site at which an individual electromagnetic meter is observed to suffer from significant zero instability, it may not be necessary to suspect device performance overall if, at other locations, acceptable zero stability is demonstrable.

6.1.6 Certain designs of the electromagnetic current meter may be capable of indicating water velocity over very short measurement periods. Set to operate in a mode that allows the measurement of instantaneous velocity, a device may display data that is subject to very rapid change, possibly over an apparently wide range of values. These variations may not necessarily indicate device malfunction and may normally be eliminated as an effect by setting the device to display only values that have been averaged over longer time periods.

6.2 Measurement procedures using electromagnetic current meters

6.2.1 Other than as specifically indicated elsewhere in this Technical Specification, electromagnetic current meters should be deployed and used in like manner to the rotating element meter.

6.2.2 There may be operational circumstances under which it may be advantageous to make use of the electromagnetic current meter's capability to indicate velocity integrated over a very short time interval (for example, where water velocity is changing rapidly). Instantaneous velocity indication may be possible but, as discussed in 6.1.6, may result in too volatile a display of varying velocity data to be operationally useful. An indicated value that has been integrated over as short a period as 5 s may, on the other hand, be sufficiently stable to be considered to be an acceptable determination.

6.2.3 Operator judgement may have to be exercised to allow optimum use of a meter's capability to make short-period determinations of velocity. In reality, the minimum period over which a given velocity sample should be integrated is dependent upon the unsteady characteristics of the flow being measured. For typical stream gauging applications, a minimum sample integration time of 50 s is likely to be required to achieve adequate representation of the mean velocity at the measurement point in question.

6.2.4 Individual designs of electromagnetic current meter may exhibit specific performance characteristics regarding such considerations as:

a) time to achieve electrical stability following switch on;

b) time to respond to change in water velocity (as when being moved from one point to another in a channel cross-section, and in the operational context of a long measurement integration period having been set);

c) control unit performance under extremes of ambient temperature;

d) minimum electrical conductivity of water;

e) effects of incorrect sensing head orientation with respect to

  1) the horizontal, and

  2) the true mean direction of flow at the point of deployment;

f) minimum water depth in which deployable, and also

  1) minimum distance below water surface, and

  2) minimum distance above channel bed, at which deployable;

g) effect on performance of ambient electromagnetic fields other than that created by the sensing head itself, and of ambient electrical noise in general. Site proximity to such physical phenomena as overhead and buried high tension power lines, electric railways, and radio and television transmitters may be a determining factor in successful device deployment;

Where there is operator concern regarding any of these (or other) factors, the device manufacturer's advice should be sought and followed, or experimentation undertaken to resolve the uncertainty.

6.2.5 Device manufacturer's instructions regarding deployment and use should be followed carefully and scrupulously.

6.2.6 In principle, no calibrated device should be used to make determinations outside the measurement range over which it has been calibrated. An electromagnetic current meter differs from its rotating element counterpart in that it may not be physically possible to use the rotating element device outside its minimum calibrated range (because the device's impeller will not turn), whereas an electromagnetic device may be electrically capable of indicating velocity over a continuum that extends to zero. There may be operational situations in which this feature is of value, but care should be taken to make it clear to subsequent data users that related velocity determinations may be subject to an unknown degree of uncertainty. Near-zero velocity measurement performance by electromagnetic meters may be subject to wide uncertainty, and manufacturer's formal claims in this regard should be studied carefully.

6.3 Use of an electromagnetic current meter in preference to a rotating element meter

6.3.1 An electromagnetic meter can be used at sites or in circumstances where a properly maintained rotating element meter cannot deliver the required performance in velocity measurement. This is normally limited to situations such as:

a) weed-infested water;

b) water with high incidence of entrained material;

EXAMPLES Raw or screened sewage, water with high sediment concentrations.

c) water velocities close to or below the stall speed of the most sensitive mechanical meter available.

6.3.2 Although electromagnetic meters can deliver velocity measurement performance that, in appropriate circumstances, is as good as that of mechanical meters operating within their known calibrated range, they can be susceptible to electrical interference effects which may not be immediately obvious to a field user.

6.4 Practical aspects of using an electromagnetic current meter to determine flow in open channels using the velocity area method

An electromagnetic meter may be used in exactly the same manner as a rotating element meter, i.e. the same number and location of verticals, the same number of points in the vertical, the same exposure time (though see below), the same limitations on deployment in close proximity to channel bed or water surface. Specific operational points to bear in mind are:

a) be aware that interference effects are possible with electromagnetic meters, even where there may be no obvious indication of a potential source. Be aware that the close proximity of a radio transmitter is a possible source of interference, as may be an electric railway. Be vigilant for, and reject, any obviously "wild" velocity readings;

b) as a routine preliminary to the use of an electromagnetic meter at any site (and in addition to any still water zero stability test that a manufacturer may recommend), deploy the meter at approximately mid-depth and mid-distance in the cross-section to be gauged, and undertake a consecutive series of no less than twenty, 10 s measurements of indicated velocity, with the meter head oriented such that it is as nearly at right angles to the mean direction of flow as may be ascertained by a brief trial. Note the sequence of "near zero" readings that results, and preserve for subsequent detailed examination;

c) expect some variation in the sequence of "near-zero" velocity measurements, in the range ± 10 %, but note any obvious instances of extreme volatility in the meter output, especially instances of polarity reversal. If significant variations are noted from an otherwise reasonably steady, or modestly varying, meter output, or if no such steady state is apparent, reconsider whether or not there is value in proceeding any further. If proceeding in the face of a highly (or erratically) volatile "near zero" test, consider the use of extended sampling times;

d) take great care to orient the meter body horizontally, especially in the case of elongated body shapes and where electrodes are located on one face of the meter body only; some designs of electromagnetic meters may be particularly sensitive to non-horizontal deployment;

e) unless there is a good reason to do otherwise, do not integrate velocity samples over periods of less than 50 s. It is recommended to select an integration period of 100 s if the meter control electronics unit has this capacity and time is available to execute the specific flow determination. Alternatively, take pairs of 50 s measurements at each meter placement in the gauged cross-section and average the two results;

f) if electing for short-period velocity integration (less than 30 s), in order specifically to reduce overall gauging time, expect significant measurement volatility (up to ± 20 %), particularly in turbulent flow regimes;

g) if using a “continuously reading” form of device display, when moving the electromagnetic meter head from one point to another within a channel cross-section, allow no less than 10 s for the meter to stabilize before noting a velocity reading;

h) heed the advice (if any) contained in the manufacturer's specification regarding the deployment of an electromagnetic meter close to a channel bed, channel banks, or the water surface. In the absence of specific advice or performance statements, assume that the electromagnetic meter is subject to the same constraints in this regard as that of a rotating element meter.

6.5 Selection, care and maintenance of electromagnetic current meters

Being non-mechanical in nature, electromagnetic meters may reasonably be expected to be much less susceptible to accidental damage, or to operational wear and tear, than their rotating element counterparts. However, they should not be used or treated carelessly. Just like any mechanical meter, they are calibrated devices, but differ in that the calibration is embedded in the device's electronics. This does not mean that it is proof against variation with time, or that the embedded calibration is necessarily adequate for all possible uses. The following should be borne in mind and acted upon:

a) when purchasing an electromagnetic meter, define the specifics of the calibration that should be undertaken and recorded to the supplier. Ensure that sufficient calibration points are established to be sure that the device's performance will be satisfactory in any parts of the velocity range that are of especial interest, for example the ultra-low range;

b) ensure that the electromagnetic meter is calibrated in its entirety, as a matched set of sensing head, control electronics and signal cable. If any of these is changed, re-calibrate the new set;

c) keep the electromagnetic meter head scrupulously clean and, in particular, free of contamination by grease. Follow the supplier's instructions regarding the cleaning method. Note the possibility of contamination when introducing the electromagnetic meter head into water that has a surface film of oil or similar. If necessary, protect the head during entry by means of a clean plastic bag that can be removed once the meter body is adequately submerged. Be aware that an operator's own hands are a potential source of contamination by naturally-occurring body oils and/or grease;

d) undertake and keep a careful record of the outcome of periodic zero offset tests by deploying the meter in still water. If the characteristic result of these tests alters suddenly, or demonstrates a continuing trend away from the meter's original stable state, consider re-calibration;

e) be aware that the performance of electronic components in an electromagnetic current meter assemblage may alter with time as a result of an ageing effect; also be aware that extremes of ambient temperature can affect the performance of electronic componentry;

f) regardless of usage, have the calibration of electromagnetic meters checked at least once every three years.

Bibliography

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

[2] ISO/TR 11974, *Measurement of liquid flow in open channels — Electromagnetic current meters*.

ICS 17.120.20

Price based on 9 pages