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Measurement of fluid flow in closed conduits — Methods of evaluating the performance of electromagnetic flow-meters for liquids

Mesure de débit des fluides dans les conduites fermées — Méthodes d'évaluation de la performance des débitmètres électromagnétiques utilisés pour les liquides

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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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.

International Standard ISO 9104 was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*.

Annex A of this International Standard is for information only.

Introduction

The methods of evaluation specified in this International Standard are intended for use by manufacturers to determine the performance of their products and by users or independent testing establishments to verify manufacturer's performance specifications and to demonstrate suitability of application.

The test conditions specified in this International Standard, for example the range of ambient temperatures and the power supply, represent those which commonly arise during use. Consequently, the values specified herein should be used where no other values are specified by the manufacturer.

The tests specified in this International Standard are not necessarily sufficient for instruments specifically designed for unusually arduous duties. Conversely, a restricted series of tests may be suitable for instruments designed to perform within a limited range of conditions.

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Measurement of fluid flow in closed conduits — Methods of evaluating the performance of electromagnetic flow-meters for liquids

1 Scope

1.1 This International Standard recommends methods of test for the evaluation of the performance of electromagnetic flow-meters for liquids flowing in closed conduits. It specifies a uniform procedure to verify the performance characteristics when the flow-meter is subjected to identified influence quantities and methods of representing the results of performance measurements.

NOTE 1 When a full evaluation in accordance with this International Standard is not required, those tests which are required should be performed and the results reported in accordance with those parts of this International Standard which are relevant.

1.2 This International Standard applies only to industrialized pipe-mounted electromagnetic flow-meters. It is not applicable to insertion-type flow-meters, liquid-metal flow-meters and medical flow-meters, although some of the tests described may be applied to such instruments if agreed to between the manufacturer and the user or evaluating body.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3966:1977, *Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes.*

ISO 4006:1991, *Measurement of fluid flow in closed conduits — Vocabulary and symbols.*

ISO 4185:1980, *Measurement of liquid flow in closed conduits — Weighing method.*

ISO 5168:—[1], *Measurement of fluid flow — Evaluation of uncertainties.*

ISO 6817:—[2], *Measurement of conductive liquid flow in closed conduits — Method using electromagnetic flow-meters.*

ISO 7066-1:1989, *Assessment of uncertainty in the calibration and use of flow measurement devices — Part 1: Linear calibration relationships.*

ISO 7066-2:1988, *Assessment of uncertainty in the calibration and use of flow measurement devices — Part 2: Non-linear calibration relationships.*

ISO 8316:1987, *Measurement of liquid flow in closed conduits — Method by collection of the liquid in a volumetric tank.*

IEC 68-2-3:1969, *Basic environmental testing procedures — Test Ca: Damp heat, steady state.*

IEC 68-2-4:1960, *Basic environmental testing procedures — Test D: Accelerated damp heat.*

IEC 68-2-6:1982, *Basic environmental testing procedures — Test Fc and guidance: Vibration (sinusoidal).*

1) To be published. (Revision of ISO 5168:1978)

2) To be published. (Revision of ISO 6817:1980)

IEC 68-2-27:1972, *Basic environmental testing procedures — Test Ea: Shock.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 4006 apply. The following definitions are given only for terms used with a special meaning or for terms the meaning of which might be usefully recalled.

3.1 electromagnetic flow-meter: Flow-meter which creates a magnetic field perpendicular to the flow, so enabling the flow-rate to be deduced from induced electromotive force (e.m.f) produced by the motion of a conducting fluid in the magnetic field. The electromagnetic flow-meter consists of a primary device and one or more secondary devices.

3.2 primary device: Device containing the following elements:

— an electrically insulating meter tube through which the conductive fluid to be metered flows,

— one or more pairs of electrodes, diametrically opposed, across which the signal generated in the fluid is measured, and

— an electromagnet for producing a magnetic field in the meter tube.

The primary device produces a signal proportional to the flow-rate and in some cases a reference signal.

3.3 secondary device: Equipment which contains the circuitry which extracts the flow signal from the electrode signal and converts it to a standard output signal directly proportional to the flow-rate. This equipment may be mounted on the primary device.

3.4 meter tube: Pipe section of the primary device through which the fluid to be measured flows; its inner surface is usually electrically insulating.

3.5 meter electrodes: One or more pairs of contacts or capacitor plates by means of which the induced voltage is detected.

3.6 lower range value: Lowest value of the measured variable that a device is adjusted to measure.

3.7 upper range value: Highest value of the measured variable that a device is adjusted to measure.

3.8 span: Algebraic difference between the upper and lower range values. For example, the span is equal to 16 mA when the range is 4 mA to 20 mA.

3.9 common mode voltage: Voltage which exists equally between each electrode and a reference potential.

3.10 reference signal: Signal which is proportional to the magnetic flux created in the primary device and which is compared in the secondary device with the flow signal.

3.11 output signal: Output from the secondary device which is a function of the flow-rate.

3.12 full-scale flow-rate: Flow-rate corresponding to the maximum output signal.

3.13 referee measurements: Measurements repeated under closely controlled atmospheric conditions when the correction factors to adjust parameters, sensitive to atmospheric conditions, to their standard atmosphere values are unknown and when measurements under the recommended range of ambient atmospheric conditions are unsatisfactory.

4 General testing procedure

Most evaluation tests for electromagnetic flow-meters are carried out with the liquid flowing through both the flow-meter and the standard calibration facility or reference flow-meter. Care shall be taken to ensure a mean steady flow in the test circuit, independently of the rapid fluctuations in local velocities due to turbulence which always occurs in the range of Reynolds numbers peculiar to industrial flow conditions. Furthermore, the measurement uncertainty of the reference flow-meter or calibration facility should be taken into account when estimating the measurement uncertainty of the electromagnetic flow-meter under test.

It will be appreciated that the closest communication should be maintained between the evaluating body and the manufacturer. Note shall be taken of the manufacturer's specifications for the instrument when the test programme is being decided, and the manufacturer should be invited to comment on both the test programmes and the results.

4.1 General requirements

4.1.1 The flow shall be steady.

4.1.2 At the inlet of the upstream straight pipe the flow should be axisymmetric and free from significant pulsation and swirl.

4.1.3 The reference flow-meter or calibration standard for the measurement of flow-rate or quantity shall conform to the requirements of ISO 4185 or ISO 8316, or any subsequent International Standards covering reference standards for the measurement of liquid flow.

NOTE 2 It is recognized that the reference standards used for flow measurement are of various types. Those devices which measure directly in terms of the fundamental units of mass, length and time are more commonly referred to as primary standards. Other devices, including some flow-meters which are calibrated against primary standards, can be used to measure flow-rate for calibration purposes if they display high reproducibility. These devices are commonly referred to as secondary standards.

Future developments in liquid flow measurement may produce reference standards displaying a high degree of accuracy. These developments are recognized provided that the accuracy of these devices is traceable to fundamental measurements and the devices have been thoroughly investigated as to their uncertainty and the influence that they have on the calibration of the device under test.

4.1.4 The reference flow-meter or calibration standard shall be of suitable range to cover the range of flow for the flow-meter under test. Should the flow-meter be required to be installed in more than one test apparatus, then both (all) installations shall be described.

The accuracy rating of the reference standards system should preferably be at least three times better than that of the equipment under test.

4.1.5 The installation and reference standards shall be described in detail, including the traceability of the reference standards and the extent of the uncertainty in their indication and that of any other devices which may be part of the reference standards system. The assessment of the uncertainty in the flow measurement shall be in accordance with ISO 5168 and ISO 7066-1 and ISO 7066-2.

4.1.6 The conduit containing the liquid shall be full at all times. The liquid shall comply with the parameters defined in 4.3.

4.1.7 Any adjustments to the flow-meter during the test shall be reported and the effects of these adjustments on the performance under reference conditions should be determined and be stated as percentages of the output span.

4.1.8 There are several parameters which may affect the performance of an electromagnetic flow-meter, and in general the tests should be carried out by changing these one at a time, while ensuring that the remainder do not vary. It may be necessary to restrict the variation in interacting parameters by suitable means.

4.2 Installation

4.2.1 Pipe installation

The primary and secondary devices of the electromagnetic flow-meter should be installed in accordance with the manufacturer's instructions and ISO 6817.

The meter tube shall be full of liquid during all tests. To achieve this, the pipework circuit in which the primary device is mounted shall include adequate provision for the removal of gases collecting in it.

If the manufacturer's instruction recommends the use of grounding rings, this should be complied with and reported.

Where there is no manufacturer's recommendation for connecting pipe material, it will be necessary to establish the effects on performance of using different pipe materials.

Examples of materials are

— plastic pipe (which is electrically non-conducting and non-magnetic),

— steel pipe (which is electrically conducting and magnetic),

— stainless steel pipe (which is electrically conducting and non-magnetic).

The effects shall be stated as percentages of the output span.

In all cases, the manufacturer's mounting instructions for the measuring equipment shall be observed.

In the absence of manufacturer's recommendations, the flow-meter shall be installed in piping having a nominal size and nominal internal diameter in accordance with that of its upstream and dowstream connections. The internal diameter of the pipe which is connected with the flow-meter shall not be smaller than the internal diameter of the flow-meter and should not exceed the internal diameter of the flow-meter by more than 3 %.

The primary device shall be installed in a straight pipe, at a distance of at least 10 times the nominal diameter (10 DN) from any upstream disturbance and 5 DN from any downstream disturbance. If required, a flow straightener should be used to eliminate swirl. Tests should never be conducted downstream of throttling points (e.g. valves or partially opened gate) (see the note to 5.2.3.2).

The connection between the pipe and the flow-meter shall be such that the sealing device does not protrude into the flow stream.

In the case of a primary device without flanges, and which is therefore connected between two flanges, care should be taken to mount it as concentrically as possible.

If there is a possibility of surrounding materials influencing the meter's magnetic field, the advice of the manufacturer should be sought.

4.2.2 Electrical installation

The potential of the metered liquid and the primary device should be at the same level, preferably ground potential. The connection between the liquid and the primary device housing may be made by direct contact with the adjacent conducting piping or by means of an earthing ring at both ends of the primary device.

The manufacturer's instructions shall be carefully followed for interconnections between the primary device and the secondary device. Instructions for connections to the power supply shall be followed.

4.3 Test liquid

Since the properties of the test liquid may affect the flow-meter characteristics, it is common practice to use water at conditions which have negligible effect. Water at a temperature between 4 °C and 35 °C, free from entrained air and magnetic particles, and reasonably clear of visible particles is acceptable. For other liquids, their type (including their tradename), viscosity, density and conductivity shall be known or determined immediately before and after the test.

4.3.1 Air entrainment

The test liquid shall be free from entrained air and the test pressure shall be sufficiently high to maintain the liquid above its vapour pressure and to prevent any dissolved gases in the liquid coming out of solution at any point in the piping system.

4.3.2 Conductivity range

The conductivity of the test liquid should be within the range of 5 mS/m (50 µS/cm) to 500 mS/m (5 000 µS/cm) or as otherwise specified by the manufacturer.

4.4 Environmental test conditions

The test conditions specified in this International Standard are in accordance with IEC 160.

Tests and calibrations should be carried out at the reference conditions specified unless otherwise stated; all specifications given in this International Standard refer to these reference conditions.

4.4.1 Standard reference ambient conditions

For the purposes of this International Standard, the standard reference atmosphere shall comply with the following specifications:

temperature: 20 °C

relative humidity: 65 %

atmospheric pressure: 1 013 mbar (101,3 kPa)

This standard reference atmosphere is that atmosphere to which values measured under any other ambient conditions are corrected by calculation. It is recognized that in many cases a correction factor for humidity is not possible. In such cases the standard reference atmosphere takes account of temperature and pressure only.

This atmosphere is equivalent to the normal reference operating conditions usually identified by the manufacturer.

4.4.2 Admissible range of ambient conditions for test measurements

The admissible range of ambient conditions for test measurements are given in table 1.

Table 1

Condition	Admissible range
Temperature	4 °C to 35 °C
Relative humidity	35 % to 75 %
Atmospheric pressure	860 mbar (86 kPa) to 1 060 mbar (106 kPa)
Electromagnetic fields	Value to be stated if relevant

The maximum rate of change in temperature permissible during any test shall be 5 °C in 1 h.

4.4.3 Standard ambient conditions for referee measurements

When correction factors to adjust parameters sensitive to ambient conditions to their standard atmosphere values are unknown, and measurements under the admissible range of ambient conditions defined in 4.4.2 are unsatisfactory, repeated measurements under closely controlled ambient conditions should be conducted.

For the purposes of this International Standard, the ambient conditions shown in table 2 are specified for referee measurements.

Table 2

Condition	Nominal value	Tolerance
Temperature	20 °C	± 2 °C
Relative humidity	65 %	± 5 %
Atmospheric pressure	860 mbar (86 kPa) to 1 060 mbar (106 kPa)	

For tropical, sub-tropical, or other special requirements, alternative referee atmospheres are given in IEC 160.

4.5 Nominal calibration conditions during tests

4.5.1 Reference values

The reference values shall be those specified by the manufacturer.

4.5.2 Tolerances

The tolerances on the electrical supply given in table 3 shall apply unless closer tolerances are agreed between the user and the manufacturer.

Table 3

Variable	Tolerance
Rated voltage	± 1 %
Rated frequency	± 1 %
Harmonic distortion	less than 5 % [alternating current (a.c.) supply]
Ripple	less than 0,1 % [direct current (d.c.) supply]

4.5.3 Reference conditions for the connecting cable

The cable connecting the primary device to the secondary device shall be no longer than necessary and in accordance with the manufacturer's requirements.

4.6 Signal output

4.6.1 Analog

The load impedance shall be the arithmetic mean of the allowable maximum and minimum values, or the reference value specified by the manufacturer.

4.6.2 Frequency

The load impedance shall be the minimum allowable.

4.7 Zero checking

In order to check the flow-meter zero, means should be provided to stop the flow through the primary device, leaving it filled with stationary liquid.

4.8 Other conditions

Pressure fluctuations or pulsations which affect the measurement shall not be present.

4.9 Flow-meter calibration — Requirements and methods

The flow-meter under test and the associated test equipment shall be allowed to stabilize (i.e. a warm-up period of at least 15 min under steady-state environmental conditions should be allowed before any test is commenced). During this warm-up period the output should be approximately in the middle of its range. Environmental conditions which may influence test results shall be observed and recorded.

Unless otherwise specified, the flow-meter shall be adjusted for minimum error at the lower and upper range values before the test.

In order to evaluate the performance of the flow-meter system on a specified flow range, test points should be taken at flow-rate settings which are approximately 10 %, 25 %, 50 %, 75 % and 100 % of the span (see figure 1). It is recommended that at least three measurements be taken at each test point.

From the readings at each flow-rate, an average output reading shall be computed. The difference between this value and the corresponding value of the reference standard system is an error relative to this standard. This deviation shall be expressed as a percentage of either the output span or the measured flow.

The uncertainty in the flow measurement shall be assessed in accordance with ISO 5168 and ISO 7066.

Where range-changing provision is incorporated in the equipment, the test procedure above shall be applied independently for each flow range but the compatibility of readings in appropriate regions of each range shall be cross-checked by changing ranges.