FINAL DRAFT

INTERNATIONAL STANDARD

ISO/FDIS 4373

ISO/TC **113**/SC **5**

Secretariat: **ANSI**

Voting begins on:
2021-12-02

Voting terminates on:
2022-01-27

Hydrometry — Water level measuring devices

Hydrométrie — Appareils de mesure du niveau de l'eau

ISO/CEN PARALLEL PROCESSING

Reference number
ISO/FDIS 4373:2021(E)

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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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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 113 *Hydrometry*, Subcommittee SC 5, *Instruments, equipment and data management*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 318, *Hydrometry*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 4373:2008), which has been technically revised. The main changes are as follows:

— improvements in water level measuring devices have been incorporated;

— the use of mercury has been removed;

— the old Annex A has been divided into three new separate Annexes A, B and C;

— in the new Annex A, the electronic techniques that are currently more commonly used have been brought to the front in order to give them a greater emphasis.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Measuring the level of water surface is very important in hydrometry for the purpose of, among other things, determining flow rates. Information about water levels is also used in operational water management, including for the design of dikes, storm surge warning services and guidance of shipping.

Hydrometry — Water level measuring devices

1 Scope

This document specifies the functional requirements of instrumentation for measuring the level of water surface (stage), primarily for the purpose of determining flow rates.

This document is supplemented by Annex A, which provides guidance on the types of automatic water level measurement devices currently available and the measurement uncertainty associated with them. The manually operated measuring devices are described in Annex B.

This document is applicable to both contact and non-contact methods of measurement. The non-contact methods are not in direct material contact with the water surface but measure the height of the water level with ultrasonic or electromagnetic waves.

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 772, *Hydrometry — Vocabulary and symbols*

IEC 60079-10, *Electrical apparatus for explosive gas atmospheres — Part 10: Classification of hazardous areas*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

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

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

4 Instrument specification

4.1 Performance parameters

The performance parameters of a water level measuring device are uncertainty, measurement range, temperature range and relative humidity range. Thus, the overall performance of the equipment can be summarized by a few characterizing parameters.

4.2 Performance classification

Water level measuring devices shall be classified in accordance with the performance classes given in Table 1 that account for the resolution to be achieved and the limits of uncertainty required over specified measurement ranges. Measurement range is to be understood as the difference between the highest and the lowest water level that can be measured. When measuring short ranges with class 1 and 2 devices, the uncertainty is a few millimetres, and this is difficult to achieve.

It should be made clear whether these levels of attainment can only be achieved using special works, e.g. installation within a stilling well, also referred to as a "gauge well".

Table 1 — Performance classes of water level measuring devices

Class	Resolution	Range	Nominal uncertainty
Performance class 1	≤ 1 mm ≤ 2 mm ≤ 10 mm	≤ 1,0 m ≤ 5,0 m ≤ 20 m	< ± 0,1 % of range
Performance class 2	≤ 2 mm ≤ 5 mm ≤ 20 mm	≤ 1,0 m ≤ 5,0 m ≤ 20 m	< ± 0,3 % of range
Performance class 3	≤ 10 mm ≤ 50 mm ≤ 200 mm	≤ 1,0 m ≤ 5,0 m ≤ 20 m	< ± 1 % of range

The manufacturer shall state the physical principle of the measuring device to allow the user to judge the device's suitability for the proposed environment. Table 2 lists the various physical principles of operational water level measuring devices being used in the field against their characteristics. These different techniques are described in more detail in Annex A.

Table 2 — Characteristics of operational water level measuring devices

Device	Type	Suitable for continuous measurement	Typical measurement range	Typical uncertainty
Mechanical devices	Float and counterweight in a stilling well	Yes	20 m	5 mm to 10 mm
	Wire weight gauge	No	20 m	5 mm to 10 mm
	Peak level	No	15 m	10 mm to 20 mm
	Staff and ramp gauge	Yes	10 m	10 mm to 20 mm
Electrical devices	Bubbler	Yes	30 m	10 mm to 20 mm
	Pressure transducer	Yes	20 m	10 mm to 20 mm
	Capacitance	Yes	15 m	10 mm to 20 mm
	Resistance	Yes	15 m	10 mm to 20 mm
Non-contact devices	Radar/laser	Yes	10 m to 50 m	5 mm to 10 mm
	Ultrasonic (through air)	Yes	3 m to 30 m	10 mm to 20 mm
	Ultrasonic (through water)	Yes	3 m to 30 m	10 mm to 20 mm

4.3 Maximum rate of change

As water levels can rise and fall rapidly in some applications, to provide guidance on suitability, for mechanical devices the manufacturer shall state on the equipment specification sheet and in the instruction manual:

a) the maximum rate of change which the instrument can follow without damage;

b) the maximum rate of change which the instrument can tolerate without suffering in change in calibration;

c) the response time of the instrument.

The response time is the time interval between the instant when the level sensor is subjected to an abrupt change in liquid level and the instant when the readings cross the limits of (and remain inside) a band defined by the 90 % and the 110 % of the difference between the initial and final value of the abrupt change. The response time should be short enough for the instrument to follow even the fastest relevant changes in water level, e.g. tides and flood waves. The response time should not be too short. Therefore, in many electronic devices, it is possible to enlarge the response time through the setting of certain parameters within the instrument. This can be useful, for example, to damp out the rapid excursions caused by short waves. Such rapid disturbances are due to local hydraulic phenomena and are thus not representative for the water level over a large section of the water course. The locally excited disturbances are thus to be discarded as much as possible.

4.4 Environment

4.4.1 General

Water level measuring devices shall operate within the ranges of temperature in 4.4.2 and the ranges of relative humidity in 4.4.3.

4.4.2 Temperature

Water level measuring devices shall operate within the following ambient air temperature classes:

Temperature class 1:	–30 °C to +55 °C;
Temperature class 2:	–10 °C to +50 °C;
Temperature class 3:	0 °C to + 50 °C.

4.4.3 Relative humidity

Water level measuring devices shall operate within the following relative humidity classes:

Relative humidity class 1:	5 % to 95 % including condensation;
Relative humidity class 2:	10 % to 90 % including condensation;
Relative humidity class 3:	20 % to 80 % including condensation.

4.5 Timing

4.5.1 General

Where timing, either analogue or digital, is part of the instrument specification, the timing method used shall be clearly stated on the instrument and in the instruction manual.

NOTE It is recognized that digital timing is potentially more accurate than analogue timing.

Moreover, when several raw data samples are assembled together in order to arrive at a time averaged measurement value, it should clearly be stated to which moment in time the final result applies. It is preferred to have this time label at exactly the middle of the averaging time window, because this moment is the most representative. However, many commercially available loggers add time and data stamps at the beginning or at the end of the averaging time window.

4.5.2 Digital

The uncertainty of digital timing devices used in water level measuring devices shall be within ± 60 s at the end of a period of 30 days, within the range of environmental conditions defined in 4.4.

4.5.3 Analogue

The uncertainty of analogue timing devices used in water level measuring devices shall be within ± 5 min at the end of a period of 30 days, within the range of environmental conditions defined in 4.4.

5 Recording

5.1 General

Recording devices serve the purpose of storing the water level data for immediate or later use. Such devices can be divided into analogue chart recorders and digital data loggers. For more information about the strengths and weaknesses of these recording devices, see Annex C.

5.2 Chart recorders

Where a chart recorder is to be used as the primary source of data, the resolution and uncertainty parameters shall take account of changes in the dimensions of the recording medium due to atmospheric variables.

NOTE Chart recorders have been superseded to a large extent by data logging services. However, they are still used as back-up units or to provide rapid visual assessment of flow changes on site.

5.3 Data loggers

A data logger shall be able to store at least the measured value and a timestamp. The data logger shall be able to store at least the equivalent of four digits per measurement and at least the equivalent of nine digits for the timestamp. In practice, however, the minimum requirement of four digits per measurement does not always suffice. It is advised, therefore, that the data logger is capable of storing readings which are sufficiently resolute to record the full range of measured water level values including all increments possible at the level sensor’s resolution. This means that there shall be sufficient decimal places, or equivalent, to record all possible step changes in measured values across the sensor’s range. Consequently, for some high-resolution water level measurements, there is a need for more than four digits per measurement.

The nine digits for the timestamp are based on the format YYDDDHHMM (year, day, hour, minute). However, a more time resolute and practical date time stamp such as a DDMMYYYYHHMMSS (day, month, year, hour, minute, second), or similar, format is preferred. Furthermore, it is advised to properly mention the local time zone and its reference to coordinated universal time (UTC) as well as any applied daylight-saving time shifts.

Where a data logger includes the interface electronics, the resolution and uncertainty shall relate to the stored value.

6 Enclosure

The performance of the enclosure shall be stated in terms of the IP classification system in accordance with IEC 60529. It shall be stated whether or not any parts potentially in contact with water are suitable for contact with water. It shall be stated whether or not the equipment can be used in a potentially explosive environment in accordance with IEC 60079-10.

7 Installation

The manufacturer shall provide clear instructions for the installation of water level measuring devices.

The water level measuring device shall have a clearly visible reference mark, which can be used for tying the device to the local gauge datum.

If a float measuring system is equipped with a stilling well, the diameter of the horizontal inlet pipe or orifice to the stilling well should be about 10 times smaller than the diameter of the stilling well itself in order to sufficiently reduce any disturbances originating from waves on the water surface.

Furthermore, the vertical cylindrical pipes, in which the float can move up and down should be at least 10 cm wider than the float diameter and shall be erected exactly along the local vertical in order to ensure free movement of the float over the entire range.

Ensure that a non-contact sensor is set up with its beam perpendicular to the water surface. Non-contact sensors shall be installed on rigid and well secured brackets to prevent movement of the sensor that can introduce errors in the measurement. There should be a clear path from the sensor face to the water surface, free from obstacles that can give false reflections. Many non-contact instruments include signal diagnostics that help the user when commissioning the instrument.

Careful selection of the measurement technique is required when foam, bubbles or other disturbances are likely to be present on the water surface (see Annex A).

8 Maintenance

Clear instructions shall be given regarding the proper maintenance of the measuring device. This also includes regular inspections and possibly regular calibrations. It is important that measurements from installed devices are checked periodically and, when necessary, the instrument should be recalibrated. Reasons why recalibration is sometimes necessary vary with instrument type but can include: change in the datum, cable stretch, electronics drift, etc.

Maintenance needs to include the periodic check of the gauge reference mark(s) to the gauge datum. The frequency of the reference mark/datum checks depends on the stability of the gauge structure.

The level of maintenance required will vary depending on instrument type and site conditions. Annex A gives basic maintenance considerations against each instrument type.

NOTE The above-mentioned maintenance instructions do not only apply to the measuring device, but also to any ancillary equipment (e.g. inlet pipes and stilling wells) that can affect the proper operation of a water level measuring station.

9 Estimation of measurement uncertainty

9.1 General

The uncertainty of a value derived from primary measurements may be due to:

a) unsteadiness of the measured value (noisy fluctuations due to, for example, waves on the water surface or due to noise in electronic systems);

b) resolution of the measurement process (resolution of the sensor or of the human eye);

c) measurement errors due to changes in temperature, sediment content or salinity of the water or due to Bernoulli effects caused by the water velocity;

d) gradual drift from the original calibration due to sensitivity to, and variability in, environmental conditions, e.g. temperature, relative humidity, atmospheric pressure;

e) gradual drift from the original calibration due to sensitivity to, and variability in, electrical conditions, e.g. supply voltage, supply frequency;

f) gradual shift in vertical position of the gauge structure and consequent drift from the last datum check (this is elaborated upon in 9.5).

Under the GUM uncertainty framework (GUM stands for *Guide to the expression of uncertainty in measurement*[1]), measurement uncertainty is expressed in terms of "standard uncertainty" and "expanded uncertainty". Standard uncertainty is denoted by u. Expanded uncertainty is denoted by U and $U = ku$, where k is the coverage factor depending on the desired level of confidence. The GUM describes two methods for estimating uncertainties that are classified as Type A and Type B. These two estimation methods are used for relating the dispersion of values to the probability of "closeness" to the mean value.

9.2 Type A uncertainty estimation

A Type A uncertainty is estimated as the standard deviation of a large number of measurements under a steady-state condition. Note that the distribution of these results need not be Gaussian. Type A estimations can be readily computed from continuous measurements when the dispersion is not masked by hysteresis of the measurement process. Of course, the dispersion must exceed by a significant margin the resolution of the measurement process.

Another approach for a Type A estimation is to compare the readings from two water level measuring stations in the same water course within a very short distance of each other. When carefully examining the difference between the two neighbouring stations, a randomly fluctuating signal can be discerned that represents the combined effect of the two individual uncertainties at both water level measuring stations. When the two stations are of identical construction and their measurements are uncorrelated, the combined variance is twice the variance of each individual station. Thus, the standard deviation of each station can be calculated by dividing the standard deviation in the random part of the water level difference between both stations by the square root of two.

Yet another Type A estimation is the comparison of instrument water level measures and manual observations using reference gauges such as staffs, ramps and wire-weight gauges.

9.3 Type B uncertainty estimation

A Type B estimation is assigned to a measurement process for which sufficiently large numbers of measurements are not available or to a measurement with defined limits of resolution. To define a Type B uncertainty, the upper and lower limits of the dispersion or the upper and lower limits of resolution are used to define the limits of a probability diagram whose shape is selected to represent the dispersion, i.e. uniform dispersions would have a rectangular distribution, dispersions with most measurements congregated about the mean value would have a triangular distribution. Allocation of probability distributions is described in Annex A.

The relationship between the uncertainty of primary measurements and the value of the uncertainty of the result is derived from the relationship between the value of this result and its primary measurements. For instance, the primary measurement for a non-contact sensor can be the measured travelling time elapsed between transmission and reception of an echo from the water surface. Any uncertainty in measuring this travelling time will lead to a correlated uncertainty in the resulting water level.

In the case of level, this relationship to primary measurements is generally linear. Sensitivities that describe the dependencies of the uncertainty in the result to the uncertainty in the individual primary

