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ISO 4373

Third edition
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Hydrometry — Water level measuring devices

Hydrométrie — Appareils de mesure du niveau de l'eau

Reference number
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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.

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 4373 was prepared by Technical Committee ISO/TC 113, *Hydrometry*, Subcommittee SC 5, *Instruments, equipment and data management*.

This third edition cancels and replaces the second edition (ISO 4373:1995), which has been technically revised.

INTERNATIONAL STANDARD **ISO 4373:2008(E)**

Hydrometry — Water level measuring devices

1 Scope

This International Standard specifies the functional requirements of instrumentation for measuring the level of water surface (stage), primarily for the purpose of determining flow rates. This International Standard is supplemented by an annex providing guidance on the types of water level measurement devices currently available and the measurement uncertainty associated with them (see Annex A).

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, *Hydrometry — Vocabulary and symbols*

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

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

3 Terms and definitions

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

4 Instrument specification

4.1 Performance classifications

The parameters of performance of a water level measuring device shall be described by the classification categories of uncertainty, temperature range and relative humidity so that the overall performance of the equipment may be summarized in three digits.

4.2 General

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 ranges.

It should be made clear whether these levels of attainment can only be achieved by the use of special works, for example installation within stilling wells. It is also important to remember that in the measurement of stage, uncertainty expressed as a percentage of range gives rise to worst case uncertainty in the determination of stage at low values of stage. This is highly significant for the measurement of low flows and should be taken into account in the design of equipment for this purpose.

The manufacturer has to state the physical principle of the measuring device in order to allow the user to judge the device's suitability for the proposed environment.

Table 1 — Performance classes of water level measuring devices

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

4.3 Maximum rate of change

As water levels may rise and fall rapidly in some applications, in order to provide guidance on suitability, 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 a change in calibration;

c) the response time of the instrument.

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 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 % excluding 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 inherently more accurate than analogue timing.

4.5.2 Digital

The uncertainty of digital timing devices used in water level measuring devices shall be within ±150 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 ±15 min at the end of a period of 30 days, within the range of environmental conditions defined in 4.4.

5 Recording

5.1 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 devices. However, they are still used as back-up units or to provide rapid visual assessment of flow changes on site.

5.2 Data loggers

A data logger shall be able to store at least the equivalent of four digits per reading. 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 in contact with water are suitable for contact with potable water. It shall be stated whether or not the equipment may 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.

8 Estimation of measurement uncertainty

8.1 General

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

a) unsteadiness of the value being measured (waves on the water surface), or

b) resolution of the measurement process (the eye's resolution of submillimetre distance).

Two methods of estimation, Type A and Type B, are described in the *Guide to the expression of uncertainty in measurement* for relating the dispersion of values to the probability of "closeness" to mean value.

8.2 Type-A estimation

A Type-A estimation is determined directly from the standard deviation of a large number of measurements. (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.

8.3 Type-B estimation

A Type-B estimation is assigned to a measurement process for which 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 formula defining the relationship between the value and its primary measurements. Sensitivities are the partial derivatives of the value with respect to each primary measurement.

In the case of level, its relationship to primary measurement is generally linear. Sensitivity coefficients would then be equal to 1.

8.4 Level measurement datum

Level measurement is not absolute measurement; it is always relative to a datum, for example a local benchmark or the elevation of a weir crest. The uncertainty associated with the datum should be combined with the uncertainty of the derived value.

8.5 Combining primary measurement uncertainties

To determine the uncertainty of the derived value, U, it is necessary to combine the uncertainties of all primary measurements, u, thus,

$$U(\text{level}) = \sqrt{u(\text{level datum})^2 + u(\text{level measurement})^2}$$

This illustrates the method when combining the uncertainty of a reference level datum value. Other components of measurement uncertainty are added by inclusion of their squared value within the brackets.

Annex A
(informative)

Types of water level measuring devices

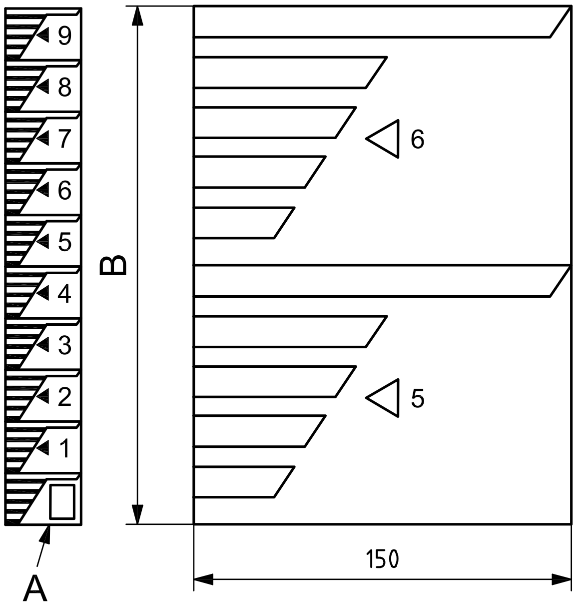
A.1 Reference gauges

A.1.1 Staff and ramp gauges

A.1.1.1 Description

A staff gauge (see Figure A.1) comprises a scale marked on, or securely attached to, a suitable vertical. Where the range of water levels exceeds the capacity of a single vertical gauge, other gauges may be installed in the line of a cross-section normal to the direction of flow. The scales on such a series of stepped staff gauges should overlap by not less than 15 cm.

Dimensions in millimetres



Key

A detachable plate for metre numeral, coloured red

B 10 mm divisions

Figure A.1 —Staff gauge

A ramp gauge (see Figure A.2) consists of a scale marked on, or securely attached to, a suitable inclined surface, which conforms closely to the contour of the riverbank. Throughout its length, the ramp gauge may lie on one continuous slope or may be a compound of two or more slopes. The ramp gauge should lie on the line of a cross-section normal to the direction of flow.

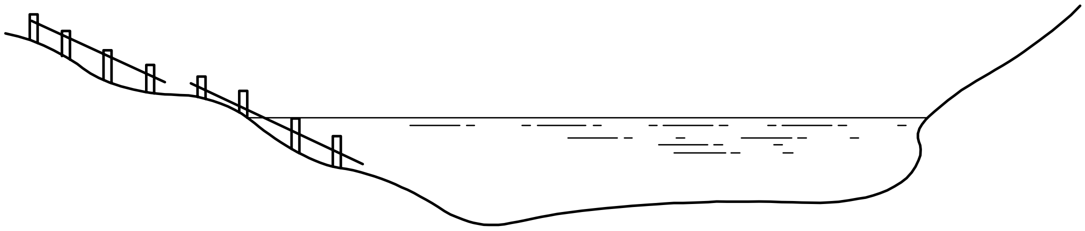


Figure A.2 — Ramp gauge installed in parallel sections

A.1.1.2 Materials

A staff or ramp gauge is constructed of durable material, able to cope with alternating wet and dry conditions. It resists the accretion of both vegetable and mineral matter. The markings should be resistant to wear or fading.

A.1.1.3 Strengths

A staff or ramp gauge is an inexpensive, simple, robust and absolute method of determining water level. It can be utilized by relatively unskilled staff. A ramp gauge provides, in addition, the opportunity to achieve a higher resolution.

A.1.1.4 Weaknesses

A staff gauge can only be used for spot measurements. It is difficult to obtain readings in the field with a true resolution higher than ±5 mm. Most staff gauge locations are such that the gauges require regular cleaning. Ramp gauges amplify surges and ripples. Whilst a stilling box may reduce this, it may also introduce a bias due to flow across the gauge.

A.1.1.5 Uncertainty

A triangular distribution applies to the uncertainty, u, associated with reading a staff or ramp gauge, x, so that

$$u\left(x_{\text{mean}}\right)=\frac{1}{\sqrt{16}}\frac{\left(x_{\text{max}}-x_{\text{min}}\right)}{2} \tag{A.1}$$

where

x_{max} is the discernible upper limit;

x_{min} is the discernible lower limit.

EXAMPLE If, from inspection, the discernible upper limit is 0,150 and the discernible lower limit is 0,145, then the best estimate is 0,147 5 with an uncertainty of 0,001.

A.1.2 Wire or tape weight gauge

A.1.2.1 Description

A wire or tape weight gauge consists of a weight that is manually lowered until the weight touches the surface of the water. The wire or tape may be wound on a drum attached to a winding mechanism or it may be a hand reel.

A.1.2.2 Materials

Corrosion-resistant materials.

A.1.2.3 Strengths

The equipment is robust.

A.1.2.4 Weaknesses

The equipment may be difficult to use in dark conditions or where the line of sight is difficult. It may be difficult to resolve to disturbed surfaces.

A.1.2.5 Uncertainty

A triangular distribution applies to the uncertainty associated with reading a wire/tape weight gauge, so that Equation (A.1) applies.

EXAMPLE If, from inspection, the discernible upper limit is 0,225 and the discernible lower limit is 0,222, then the best estimate is 0,223 5 with an uncertainty of 0,000 6.

A.1.3 Hook and point gauges

A.1.3.1 Description

A hook or point gauge (see Figure A.3) comprises a hook or point and a means of determining its exact vertical position relative to a datum. The instrument may be portable in which case a datum plate or bracket is fixed at each site on which the instrument is to be used. The vertical position may be determined by, for example, a graduated scale with a vernier arrangement or a digital indicator. If the sensing head is suspended by a tape or wire, it is generally referred to as a dipper (see A.1.4).

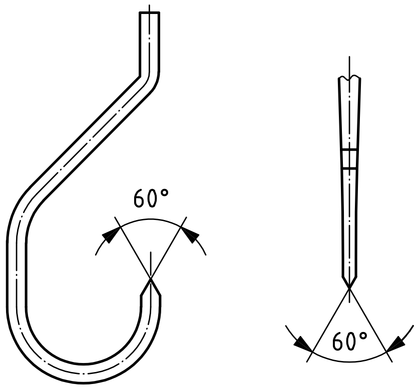


Figure A.3 — Hook gauge and point tips

A.1.3.2 Materials

A hook or point gauge and its ancillary parts are made throughout of durable, corrosion-resistant materials.

A.1.3.3 Strengths

A hook or point gauge is potentially the most accurate of the level determination devices and the preferred technique for use under laboratory conditions.

A.1.3.4 Weaknesses

Using a hook or point gauge is highly labour-intensive. A hook or point gauge cannot be used to maintain a continuous record.

A.1.3.5 Uncertainty

A triangular distribution applies to the uncertainty associated with reading a hook or point gauge, so that Equation (A.1) applies.

EXAMPLE If, from inspection, the discernible upper limit is 0,225 and the discernible lower limit is 0,222, then the best estimate is 0,223 5 with an uncertainty of 0,000 6.

A.1.4 Dippers

A.1.4.1 Description

A dipper is a portable or bench-mounted point gauge in which contact with the water surface is signalled by electrical means, normally by a light or buzzer, either singly or in combination. A typical configuration is shown in Figure A.4.

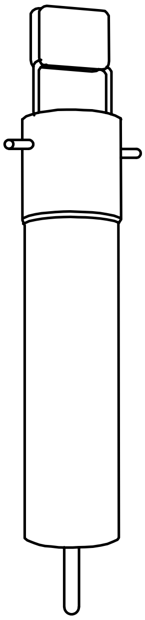


Figure A.4 — Typical dipper configuration

A.1.4.2 Materials

A dipper is made throughout of durable, non-corrodible materials. It is battery-powered.

A.1.4.3 Strengths

A dipper can provide an accurate indication of water level in situations where access and visibility are impaired, i.e. within a stilling well or a borehole. A dipper can provide acceptable accuracy when the distance to the water surface is of the order of tens of metres.

A.1.4.4 Weaknesses

A dipper may not work in waters of very low conductivity. It cannot normally provide a continuous record of stage.

A.1.4.5 Uncertainty

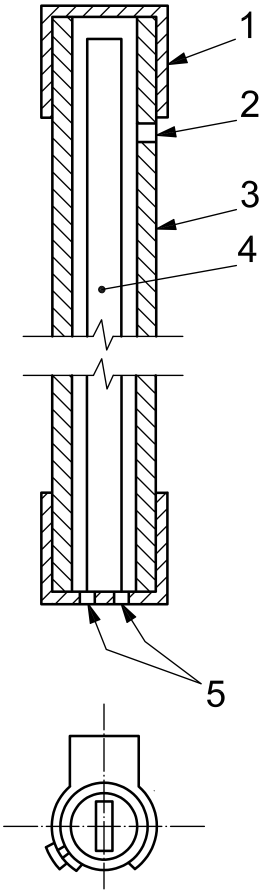
Taking a reading of the depth to a water surface with a dipper should always be made on making contact with the water surface and never on withdrawal. A triangular distribution applies to the uncertainty associated with reading a hand-held or bench-mounted dipper, so that Equation (A.1) applies.

EXAMPLE If, from inspection, the discernible upper limit is 5,536 and the discernible lower limit is 5,534, then the best estimate is 5,535 with an uncertainty of 0,000 2.

A.2 Peak level gauges

A.2.1 Description

A peak level gauge is used to record the peak stage occurring at a given location during a given time period. Typically, the gauge consists of a vertical tube containing a float, a floating substance (such as cork dust) or a tape which permanently changes colour on exposure to water. This is shown diagrammatically in Figure A.5. The tube is perforated at the bottom to permit the entry of water and at the top to permit the exit of air.



Key

1 screw-on access cap or cap with locking facility

2 air release hole

3 barrel in metal or plastic (opaque or transparent)

4 plastic strip (or wood) carrying colour change tape or paint which may be scaled or plain and either rests on the base or is suspended from the top cap

5 one or more water inlet holes in base, or side holes if set on a diameter at right angles to the flow

Figure A.5 — Peak level gauge

A.2.2 Strengths

A peak level gauge is capable of operating unattended for long periods, only requiring attention and resetting after the occurrence of an event of interest.

A.2.3 Weaknesses

Recording data using a peak level gauge and resetting the instrument are labour-intensive.

A.2.4 Uncertainty

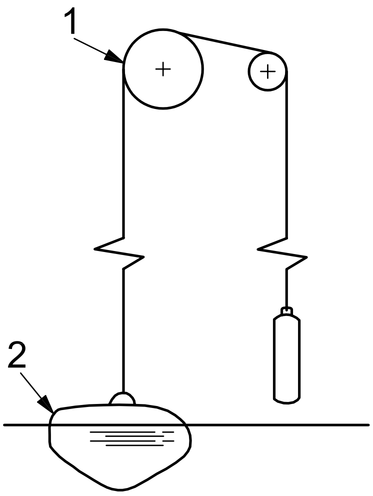
A triangular distribution applies to the uncertainty associated with reading a peak level gauge, so that Equation (A.1) applies.

EXAMPLE If, from inspection, the discernible upper limit is 4,150 and the discernible lower limit is 4,100, then the best estimate is 4,125 with an uncertainty of 0,01.

A.3 Mechanical float and counterweight gauges

A.3.1 Description

A float gauge consists of a float, usually operating in a stilling well, a graduated tape or wire, a counterweight or spring, a pulley and a pointer. The tape or wire runs over the pulley, which is engineered to inhibit slippage. The tape or wire is kept taut by the action of the counterweight or spring. In this way, the float that positions the tape with respect to the pointer senses the stage fluctuations. A float gauge is normally used in conjunction with a chart recorder (see 5.1) to maintain a continuous record, or a shaft encoder connected to a data logger (5.2). Figure A.6 shows a typical arrangement.



Key

1 driven pulley

2 float

Figure A.6 — Float and counterweight

A.3.2 Strengths

Used on its own, a float gauge can provide a direct readout of stage without requiring an external energy source. As a prime mover for recording equipment, it provides almost uniform resolution throughout the range and good accuracy at low stages.

A.3.3 Weaknesses

A float gauge is a mechanical device and therefore subject to errors from changes in temperature, hysteresis and friction. A float gauge usually requires a stilling well, which can be expensive to construct and maintain.

A.3.4 Uncertainty

Because hysteresis is present in a float and counterweight system, the uncertainty distribution is bimodal so that

$$U\left(x_{\text{mean}}\right)=\frac{\left(x_{\max}-x_{\min}\right)}{2} \tag{A.2}$$

If the value returned for a given stage is 0,150 during a falling stage and 0,145 during a rising stage, then the best estimate is 0,147 5 with an uncertainty of 0,002 5.

A.4 Air reaction gauges

A.4.1 Principle of operation

A small quantity of air or an inert gas is allowed to bleed into a pipe, supplying a nozzle fixed below the water surface so that a steady stream of bubbles emerges from the nozzle. The pressure in the pipe feeding the nozzle is equal to the head of liquid above the nozzle. The tube supplying the nozzle is also connected to a pressure-sensing system to provide an output.

A.4.2 Description

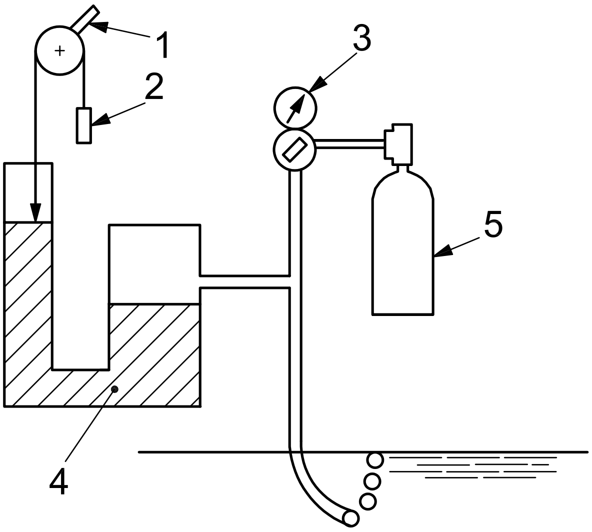
A.4.2.1 General

An air reaction gauge consists of a pressure regulator, a gas-flow-regulating valve and a pressure-sensing system. This type of gauge is often referred to as a “bubbler gauge”. The most common devices of this type use either a mercury manometer (A.4.2.2) or a servo beam balance (A.4.2.3) to detect pressure change. However, other pressure-sensing devices, e.g. load cells or pressure transducers, may also be used. An air reaction gauge requires a source of compressed gas, usually nitrogen or compressed air.

A.4.2.2 Mercury manometer bubbler gauges

In a servo manometer bubbler gauge, the pressure in the tube feeding the submerged nozzle is also connected to a mercury manometer, where a servo point gauge or similar device tracks the changes in mercury level. An output shaft may be connected to recording equipment. This is shown schematically in Figure A.7.

WARNING — The mercury within a mercury manometer is hazardous to health if exposed to the atmosphere outside the manometer. Users should therefore take appropriate care in the use of such a manometer, and under no circumstances should the mercury be handled. In many countries the use of mercury in such circumstances is not allowed. Where possible, such systems should be avoided.



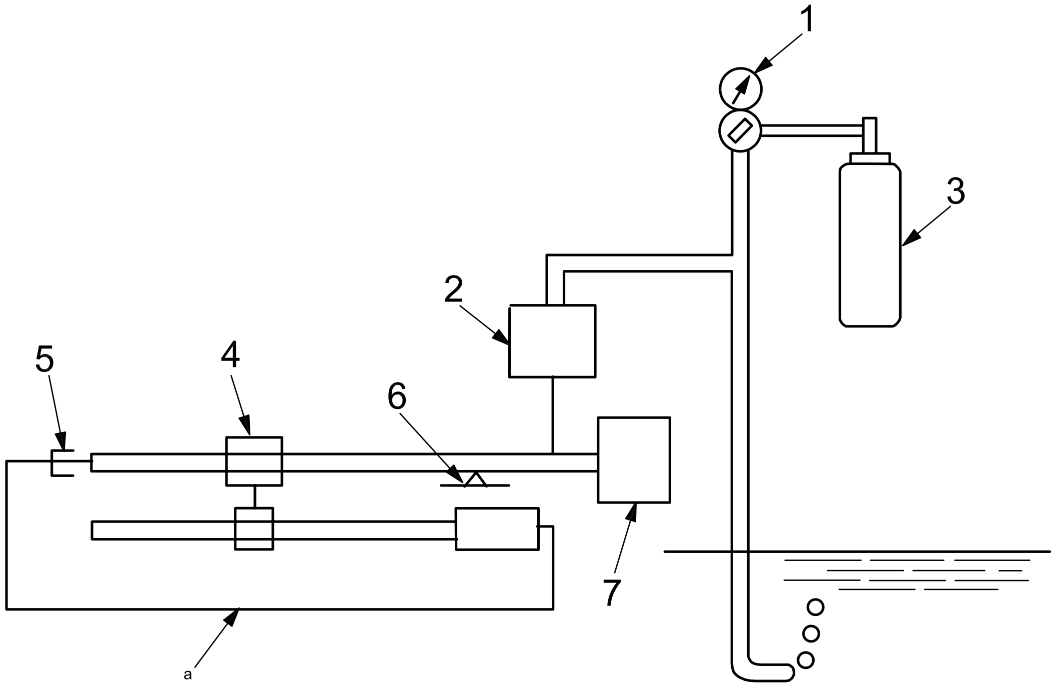
Key

1 output shaft
2 servo-driven surface follower
3 regulator
4 mercury
5 compressed gas

Figure A.7 — Mercury manometer bubbler gauge

A.4.2.3 Servo beam balance bubbler gauges

In the pressure-sensing system of a servo beam balance bubbler gauge, a servo beam balance is used to convert pressure into rotational movement. The servo beam balance has a pressure bellows acting on one side of the beam and a servo-driven sliding weight on the other. The servo system positions the weight to maintain the beam in balance. The movement of the weight is indicative of changes in pressure in the bellows caused by changes in water level. The servo mechanism that drives the weight may provide an output shaft for connection to recording equipment. This is shown schematically in Figure A.8.



Key

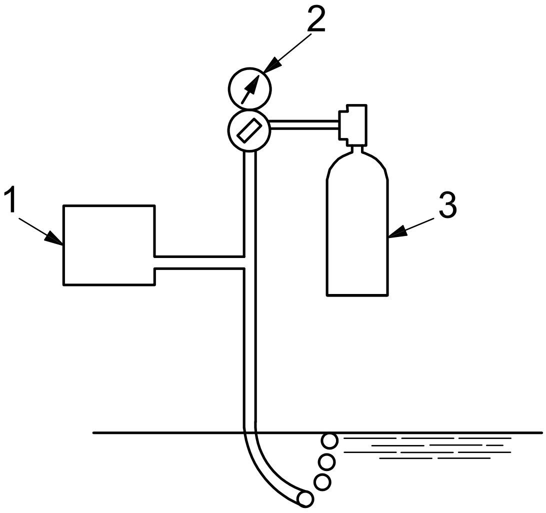
1	regulator	5	limit switches
2	bellows	6	pivot
3	compressed gas	7	balance weight
4	sliding counterweight		

[a] Servo drives shaft, moves weight and provides output.

Figure A.8 — Servo beam balance bubbler gauge

A.4.2.4 Pressure transducer

A pressure transducer instead of the mercury manometer system or beam balance may determine the pressure in the dip tube (see Figure A.9). Performance is then dependent on the quality and accuracy of the pressure transducer (see Clause A.5).



Key

1 pressure sensor
2 regulator
3 compressed gas

Figure A.9 — Pressure transducer bubbler gauge

A.4.3 Strengths

An air reaction bubbler-type gauge is particularly well suited for the measurement of liquids carrying suspended solids. It can also maintain an acceptable level of accuracy without requiring a stilling well.

A.4.4 Weaknesses

An air reaction bubbler-type gauge of acceptable accuracy is a complex device needing skilled maintenance. An air reaction gauge is affected by changes in specific gravity of the water column, e.g. due to suspended solids. It may also be affected by siltation. In a mercury manometer, the mercury poses a potential health and safety risk. This is a toxic substance and may require a specific risk assessment under national or regional legislation before deployment.

A.4.5 Uncertainty

The uncertainty model depends on the method used to sense the pressure within the system. If hysteresis is present because a float and counterweight or mechanical balance is incorporated into the system, the uncertainty distribution is bimodal so that Equation (A.2) applies. If a pressure transducer is used, then the uncertainty distribution is likely to be rectangular so that

$$U\left(x_{\text{mean}}\right)=\frac{1}{\sqrt{3}}\frac{\left(x_{\text{max}}-x_{\text{min}}\right)}{2} \tag{A.3}$$

A.5 Electrical pressure transducers

A.5.1 Description

An electrical pressure transducer operates by converting fluid pressures into electrical signals. A typical sensor comprises:

a) a mechanical force summing device (e.g. diaphragm, capsule, bellows or bourdon tube) which responds by displacement to the change in pressure;

b) an electrical component producing signals proportional to the mechanical displacement;

c) a tube venting to atmosphere to remove atmospheric pressure variations; or

d) two absolute pressure devices with one measuring atmospheric pressure.

A.5.2 Strengths

An electrical pressure transducer does not require a stilling well to smooth out water level fluctuations. Electronic or software smoothing may be carried out. It is ideally suited to interfacing with electronic data recording and transmission systems.

A.5.3 Weaknesses

The levels of uncertainty of an electrical pressure transducer are typically ±(0,1 to 0,5) % of full scale. Because the range defines the resolution, the uncertainty increases with reducing stage. An electrical pressure transducer is susceptible to changes in its environment (the manufacturer's stated accuracy is often at a constant reference temperature). An electrical pressure transducer is also affected by changes in density of the water column. It is liable to drift over even short time scales (< 1 year).

A.5.4 Uncertainty

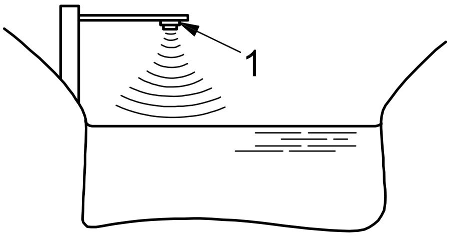
A pressure transducer has a rectangular uncertainty distribution so that Equation (A.3) applies. This probability distribution is usually applied to the resolution limit of the equipment.

A.6 Echo-location, acoustic instruments

A.6.1 Instruments with sound path in air

A.6.1.1 Description

An instrument with its sound path in air (see Figure A.10) consists of an acoustic transducer/receiver, a means of measuring the time elapsed between transmission of the pulse and reception of the echo from the water/air interface and a means of converting this time to distance. The instrument is mounted above the maximum water level. The velocity of sound in air is strongly proportional to temperature, and a technique for compensating for this effect is required. Either the air temperature is measured directly, or a reference bar is located at a known distance below the transducer.



Key

1 transceiver

Figure A.10 — Air path ultrasonic level sensing

A.6.1.2 Strengths

Because an instrument with sound path in air is mounted above the water surface, it may be more easily accessed for maintenance. It is not in direct contact with the medium.

A.6.1.3 Weaknesses

It is difficult to focus the acoustic beam tightly and thus transducer heads cannot be mounted flush with the side of channels but need to be offset to some extent. The temperature sensor only measures temperature in one place. Temperature gradients over the length of the ultrasonic beam give rise to errors. These may be large at low heads.

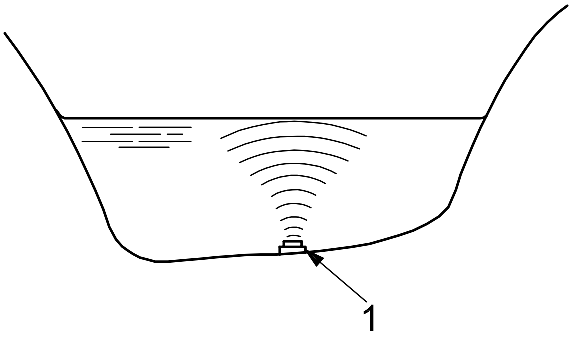
A.6.1.4 Uncertainty

Acoustic devices have a rectangular uncertainty distribution so that Equation (A.3) applies.

A.6.2 Instruments with sound path in water

A.6.2.1 Description

An instrument with sound path in water (see Figure A.11) consists of an acoustic transducer/receiver, a means of measuring the time elapsed between transmission of the pulse and reception of the echo from the water/air interface and a way of converting this time to distance. The instrument is mounted below the minimum water level. The velocity of sound in water is strongly proportional to temperature and a technique for compensating for this effect is required. Either the water temperature is measured directly, or a reference bar is located at a known distance above the transducer.



Key

1 transceiver

Figure A.11 — Water path ultrasonic level sensing

A.6.2.2 Strengths

Because an instrument with sound path in water is wholly beneath the water surface, it does not intrude visually, is less susceptible to vandalism and experiences less temperature variation.

A.6.2.3 Weaknesses

The unit is wholly beneath the water, making maintenance more difficult. Care should be taken to ensure that there is no risk of reflection from channel edges at higher water levels. If the same transducer is used as transmitter and receiver, there is usually a minimum time after transmitting before receiving is possible. This results in a requirement for a minimum depth of water. The upwards-facing transducer is prone to sediment settling on it, particularly if it is placed on or near the bed in an attempt to overcome the minimum depth limitation.

A.6.2.4 Uncertainty

Acoustic devices have a rectangular uncertainty distribution so that Equation (A.3) applies.

A.7 Echo-location, radar instruments

A.7.1 Description

A downward-looking radar unit is able to determine the relative position of a water surface. The value returned relates to the area covered by the beam.

A.7.2 Strengths

An echo-location instrument is mounted in air and is accessible for maintenance. The temperature of the air column through which the signal passes does not affect it. An echo-location instrument operates without a stilling well and has an accuracy of 0,1 % of range.

A.7.3 Weaknesses

An echo-location instrument usually needs to be mounted on an arm extending over the flow to ensure that the conical beam does not strike channel walls. This equipment tends to have a high-energy requirement and may need to be connected to a mains power supply. However, it can be operated by batteries or solar panels. It is potentially vulnerable to vandalism.

A.7.4 Uncertainty

Echo-location devices using radar have a rectangular uncertainty distribution so that Equation (A.3) applies.

A.8 Systems using electrical properties

A.8.1 Systems measuring capacitance

A.8.1.1 Description

A system measuring capacitance consists of a probe with a measurable capacitance, which changes as the depth of submersion changes. This is often a tubular system where the dielectric is air. The air is displaced by water as the level rises causing a change in capacitance.

A.8.1.2 Strengths

A system measuring capacitance has no moving parts and can be easily interfaced with electronic data capture systems.

A.8.1.3 Weaknesses

A system measuring capacitance is not widely used for water level measurement.

A.8.1.4 Uncertainty

Capacitance devices have a rectangular uncertainty distribution so that Equation (A.3) applies.

A.8.2 Systems measuring resistance (direct)

A.8.2.1 Description

As wetting changes the resistance of certain materials, a conductor is installed so that the wetted length changes as water level changes. This change can be measured and is proportional to the wetted length of the conductor. A system measuring resistance may be installed vertically or inclined to improve resolution.

A.8.2.2 Strengths

A system measuring resistance can be easily interfaced with electronic data capture systems.

A.8.2.3 Weaknesses

The weaknesses of a system measuring resistance are contamination of the conductors, variable conductivity of water in direct contact with river water in open systems, and failure of the membrane in sealed systems.

A.8.2.4 Uncertainty

Devices using resistance in this way have a rectangular uncertainty distribution so that Equation (A.3) applies.

A.8.3 Systems measuring resistance (indirect)

A.8.3.1 Description

A system measuring resistance (non-contact) can be a flexible tube or hollow tape, which is crushed by the pressure of water. It is mounted vertically or at a known inclination to the water level, and the extent of the crushing is a function of the water level. This is measured by the change of resistance of an internal coil and wire, which are shorted together up to the water level.

A.8.3.2 Strengths

A system measuring resistance (non-contact) can be easily interfaced with electronic data capture systems. The water does not contact the measurement element and so the level measurement is independent of the properties of the water.

A.8.3.3 Weaknesses

In a system measuring resistance (non-contact), the tape is usually installed in a tube in which sediment can accumulate to crush the tape. Resolution is generally greater than 10 mm. A system measuring resistance (non-contact) offers no price/performance advantage over other measurement systems.

A.8.3.4 Uncertainty

Devices using resistance in this way have a rectangular uncertainty distribution so that Equation (A.3) applies.

A.9 Recording devices

A.9.1 Analogue devices

A.9.1.1 Description

The primary analogue device for recording stage is the chart recorder. Generally, a float and counterweight are used to move a pen or stylus in one plane while the chart moves at right angles, thus producing a continuous record.

A.9.1.2 Strengths

A chart recorder produces a continuous record which is immediately available for inspection on site and when retrieved.

A.9.1.3 Weaknesses

Restrictions of the recording media and the quality of the clock affect the accuracy of a chart recorder, both in timing and in resolution of stage values. If the data are to be converted to a digital format for subsequent analysis, the process is labour-insensitive and time-consuming. The translation process produces further inaccuracies.

A.9.1.4 Uncertainty

Because hysteresis is present in a float and counterweight system, and in the recording mechanism, the uncertainty distribution is bimodal so that Equation (A.2) applies.

A.9.2 Digital devices

A.9.2.1 General

The principal method of digital data recording on site in use today involves the data logger storing data directly into semiconductor memory. Punched paper tape systems or magnetic tape systems may still be in use, but the technology has been largely superseded and is not included in this annex.

A.9.2.2 Description

A microprocessor-controlled data logger usually offers a range of parameters, which may be set by the user to tailor the unit to the application. These parameters may include recording frequency, input range and signal type, covering the most common signal standards. An external interface may be necessary for sensing devices with non-standard outputs. The unit may incorporate a modem for telemetry access or provide a modem connection.

A.9.2.3 Strengths

Recording to a memory is directly computer-compatible. Once the data has been recorded, it is relatively unaffected by environmental influence. Data can be recorded at some distance from the prime sensor because it can be transmitted without further degradation. The equipment is usually constructed from very reliable commercial semiconductors. It is compact, has a low power requirement and is relatively inexpensive.

A.9.2.4 Weaknesses

The process of converting from a continuous signal to digital format invariably introduces errors. However, these errors are typically designed to be of an order of magnitude less than those in the generation of the primary signal. With digital devices, there is poor on-site access to the data without specialized equipment or software.

A.9.2.5 Uncertainty

Devices using analogue to digital conversion prior to storage have a rectangular uncertainty distribution so that Equation (A.3) applies. This relates to the limits of resolution of the device.

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[1] ISO/IEC Guide 98-3[1], *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

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[1] ISO/IEC Guide 98-3 is a reissue of the *Guide to the expression of uncertainty in measurement* (GUM), 1995.

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