Measurement of liquid flow in open channels —

Part 7: Specification of equipment for the measurement of water level

ICS 17.120.20

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee CPI/113, Hydrometry, to Subcommittee CPI/113/5, Flow measuring instruments and equipment, upon which the following bodies were represented:

British Hydrological Society
Chartered Institution of Water and Environmental Management
Environment Agency
GAMBICA

This British Standard, having been prepared under the direction of the Sector Committee for Materials and Chemicals, was published under the authority of the Standards Committee and comes into effect on 15 September 2000

First published October 1971
Second edition September 2000

The following BSI references relate to the work on this standard:
Committee reference CPI/113/5
Draft for comment 99/402485 DC

ISBN 0 580 33064 8

Amendments issued since publication

Amd. No.	Date	Comments

Contents

Foreword

This part of BS 3680 has been prepared by Technical Committee CPI/113/5. It forms a revision of BS 3680-7:1971, incorporating appropriate contents of BS 3680-9A:1971 and BS 3680-9B:1981, which have been combined in this part of BS 3680 to reflect the current level of technological development in equipment for the measurement of water level. This revision of BS 3680-7 supersedes BS 3680-7:1971, BS 3680-9A:1971 and BS 3680-9B:1981, which are withdrawn.

This standard is one of a series of parts of BS 3680 on measurement of liquid flow in open channels. The other parts are as follows:

— *Part 1: Glossary of terms*;
— *Part 2: Dilution methods*;
— *Part 3: Stream flow measurement*;
— *Part 4: Weirs and flumes*;
— *Part 5: Slope area method of estimation*;
— *Part 6: Guide to measurement of flow in tidal channels*;
— *Part 8: Measuring instruments and equipment*;
— *Part 9: Water level instruments*;
— *Part 10: Sediment transport*;
— *Part 11: Free surface flow in closed conduits*.

Annex A is informative.

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Summary of pages

This document comprises a front cover, an inside front cover, page i and ii, pages 1 to 14, an inside back cover and a back cover.

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Introduction

Determining the location of a water surface (stage) is a critical starting point for much of hydrometry. It is needed to define a threshold (flood level, tide level), depth (for navigation) or flow (in a stream, of a discharge, of a compensation flow), usually through a calibration process or derived formula, or to infer volume (of a reservoir). It is important to know that the method or equipment selected will be able to produce the level of accuracy and the resolution appropriate to the application, without over-specifying performance. The reading of stage may be required as a single instantaneous measurement, as a short series of instantaneous measurements or as a continuous or practically continuous record of the fluctuations of stage.

1 Scope

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

This British Standard is supplemented by an annex providing guidance on the types of water level measurement devices currently available (see annex A).

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 3680-1, *Measurement of liquid flow in open channels — Glossary of terms.*

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 purposes of this part of BS 3680, the terms and definitions given in BS 3680-1 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 uncertainty, temperature range and relative humidity so that the overall performance of the equipment may be summarized in three digits.

4.2 Uncertainty of water level measurement

4.2.1 *General*

Water level measuring devices shall be classified in accordance with the performance classes given in Table 1 in order to take into account the resolution to be achieved and the limits of uncertainty required over specified ranges.

NOTE 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.

4.2.2 *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.

Table 1 — Uncertainty classes of water level measuring devices

Class	Resolution	Range	Uncertainty
Uncertainty class 1	1 mm 2 mm 10 mm	1.0 m 5.0 m 20 m	≤ ±0.1 % of range
Uncertainty class 2	2 mm 5 mm 20 mm	1.0 m 5.0 m 20 m	≤ ±0.3 % of range
Uncertainty class 3	10 mm 50 mm 200 mm	1.0 m 5.0 m 20 m	≤ ±1 % of range
NOTE In each case the uncertainty is specified with respect to the range of environmental conditions defined in **4.3**.			

4.3 Environment

4.3.1 *General*

Water level measuring devices shall operate within the ranges of temperature in **4.3.2** and the ranges of relative humidity in **4.3.3**.

4.3.2 *Temperature*

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

- — temperature class 1: −25 °C to +55 °C;
- — temperature class 2: −10 °C to +50 °C;
- — temperature class 3: 0 °C to +50 °C.

4.3.3 *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.

4.4 Timing

4.4.1 *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.

4.4.2 *Digital*

The uncertainty of digital timing devices used in water level measuring devices shall be within ±5 s a day measured over a period of 30 days within the range of environmental conditions defined in **4.3**.

4.4.3 *Analogue*

The uncertainty of analogue timing devices used in water level measuring devices shall be within ±30 s a day measured over a period of 30 days within the range of environmental conditions defined in **4.3**.

5 Recording

5.1 Chart recorders

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.

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.

5.2 Data loggers

A data logger shall be able to store at least the equivalent of 4 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.

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 comprises a scale marked on or securely attached to a suitable vertical surface (see Figure A.1). Where the range of water levels exceeds the capacity of a single vertical gauge other gauges may be installed on 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.

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

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 a cheap, 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 an accuracy higher than ±3 mm. Most staff gauge locations are such that the gauges require regular cleaning. Surges and ripples are amplified by ramp gauges. Whilst a stilling box may reduce this, it may also introduce a bias due to flow across the gauge.

A.1.2 *Peak level gauges*

A.1.2.1 *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. The tube is perforated at the bottom to permit the entry of water and at the top to permit the exit of air (see Figure A.3).

A.1.2.2 *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.1.2.3 *Weaknesses*

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

A.1.3 Hook and point gauges

A.1.3.1 *Description*

A hook or point gauge comprises a hook or point (see Figure A.4) 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**).

Dimensions in millimetres

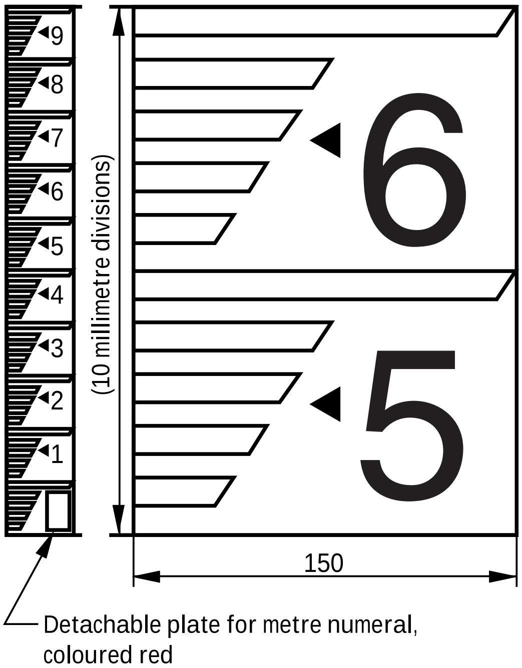


Figure A.1 — Staff gauge

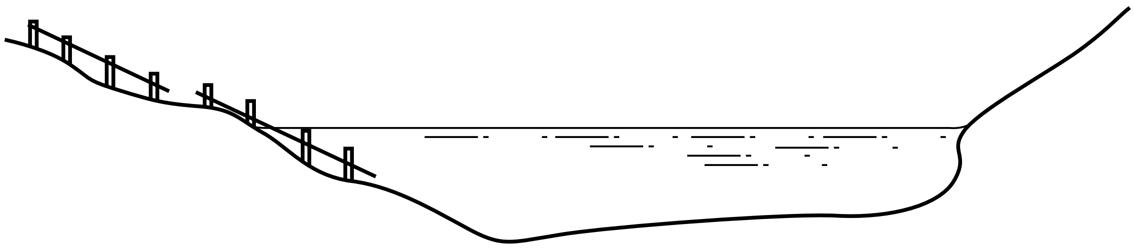
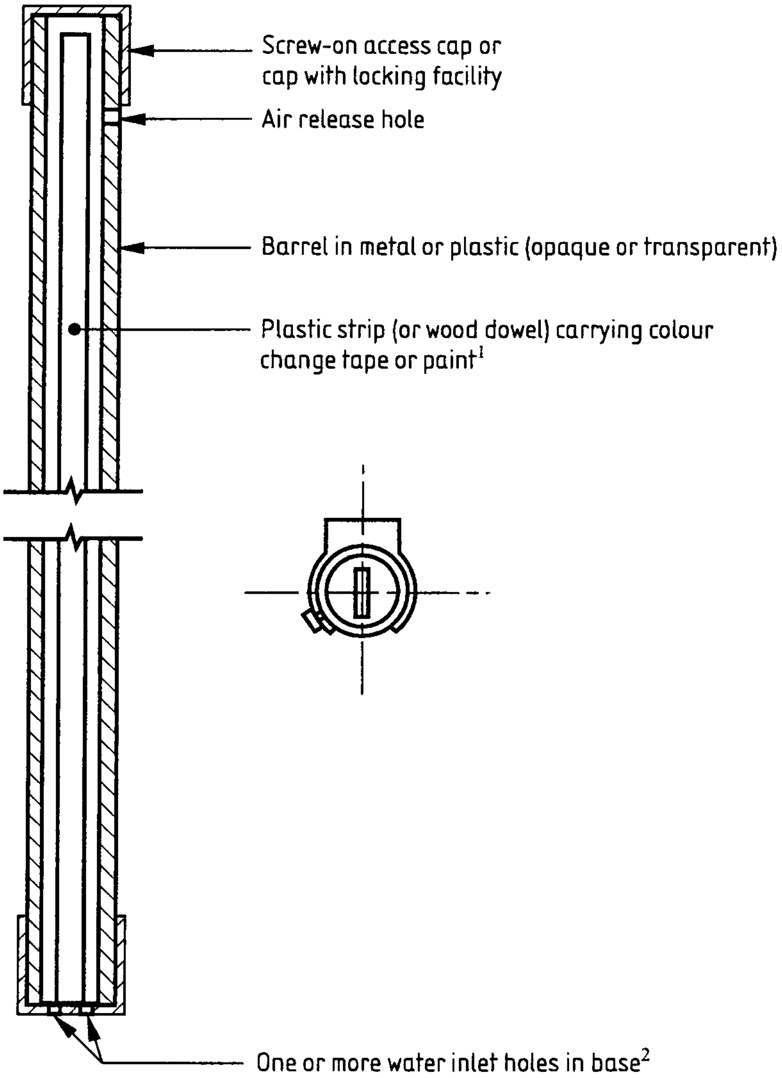


Figure A.2 — Ramp gauge installed in parallel sections



[1] The plastic strip (or wood dowel) may be scaled or plain and either rests on the base or is suspended from the top cap.

[2] Side holes may be used if set on a diameter at right angles to the flow.

Figure A.3 — Peak level gauge

A.1.3.2 *Materials*

A hook or point gauge and its ancillary parts is 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.

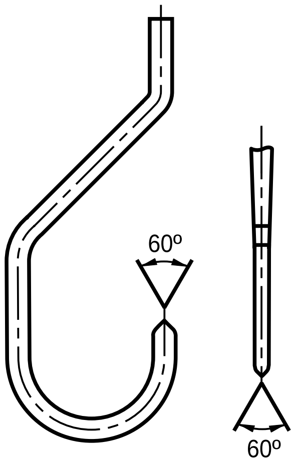


Figure A.4 — Hook gauge and point tips

A.1.4 ***Dippers***

A.1.4.1 *Description*

A dipper is a portable 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 (see Figure A.5).

A.1.4.2 *Materials*

A dipper is made throughout of durable non-corrodable 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 cannot normally provide a continuous record of stage.

A.2 Mechanical float and counterweight gauges

A.2.1 ***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 in such a way as to not allow any slippage. The tape or wire is kept taut by the action of the counterweight or spring. In this way the stage fluctuations are sensed by the float which positions the tape with respect to the pointer. 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 (see Figure A.6).

A.2.2 ***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.2.3 ***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.

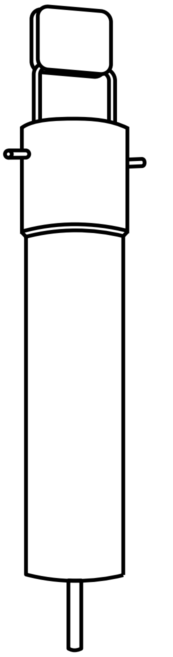


Figure A.5 — Dipper

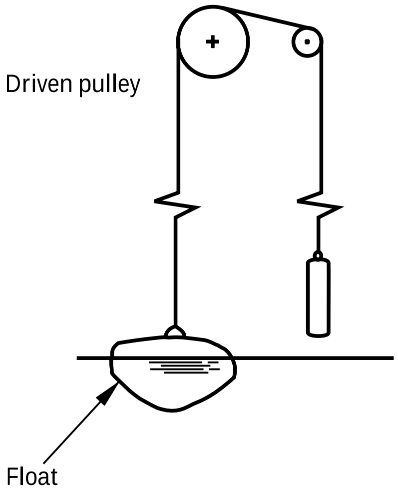


Figure A.6 — Float and counterweight

A.3 Air reaction gauges

A.3.1 ***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 which may use a mercury manometer or a servo beam balance to provide an output.

A.3.2 ***Description***

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.3.3**) or a servo beam balance (**A.3.4**) 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.

A.3.3 ***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 (see Figure A.7). An output shaft may be connected to recording equipment.

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.

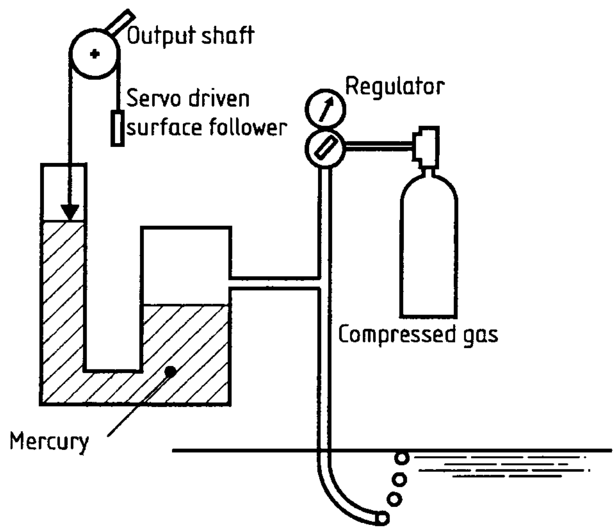


Figure A.7 — Servo manometer bubbler gauge

A.3.4 ***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 (see Figure A.8). The servo mechanism which drives the weight may provide an output shaft for connection to recording equipment.

A.3.5 ***Pressure sensor***

The pressure in the dip tube may be determined by a pressure transducer instead of the mercury manometer system or beam balance. Performance is then dependent on the quality and accuracy of the pressure transducer (see **A.4**).

A.3.6 ***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.3.7 ***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 density of the water column. In a mercury manometer, the mercury poses a potential health and safety risk. This is a toxic substance and will require a specific risk assessment under the Control of Substances Hazardous to Health (COSHH) regulations [1] before deployment.

A.4 Electrical pressure transducers

A.4.1 ***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. a 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.4.2 ***Strengths***

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

A.4.3 ***Weaknesses***

The levels of accuracy of an electrical pressure transducer are typically $\pm(0.1-0.5)$ % of full scale. However, to achieve a high range, poor accuracy may be the result at low levels, e.g. ±10 mm at 5 m range. 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 Echo-location, acoustic instruments

A.5.1 ***Instruments with sound path in air***

A.5.1.1 *Description*

An instrument with its sound path in air 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 [see Figure A.9b)]. 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.

A.5.1.2 *Strengths*

Because an instrument with sound path in air is mounted above the water surface access for maintenance is facilitated.

A.5.1.3 *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 at one place. Temperature gradients over the length of the ultrasonic beam give rise to errors.

A.5.2 ***Instruments with sound path in water***

A.5.2.1 *Description*

An instrument with sound path in water 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 [see Figure A.9b)]. 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.

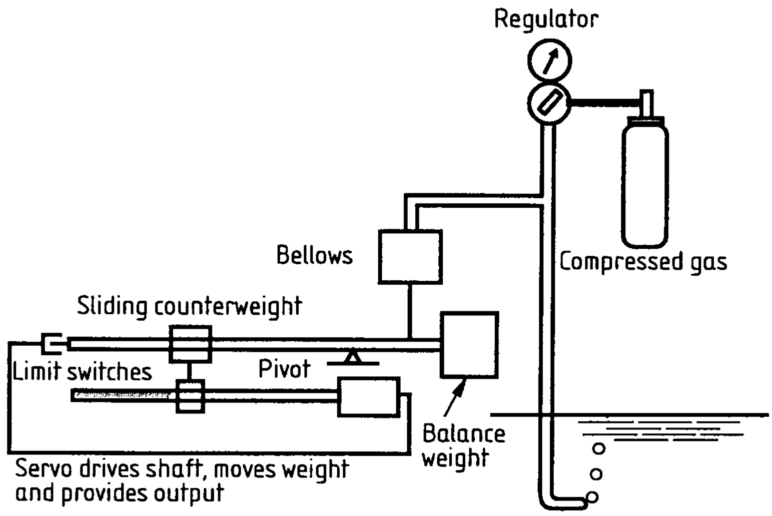


Figure A.8 — Servo beam balance bubbler gauge

A.5.2.2 *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.5.2.3 *Weaknesses*

The unit is wholly beneath the water which makes maintenance more difficult. Care should be taken to ensure that there is no risk of reflection from channel edges at higher water levels. Since the same transducer is usually 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 Echo-location, radar instruments

A.6.1 *Description*

A downward looking radar unit may be used to determine the water surface in much the same way as a downward looking acoustic system but it transmits microwave radiation rather than sound.

A.6.1.1 *Strengths*

An echo-location instrument is mounted in air and is accessible for maintenance. It is not affected by the temperature of the air column through which the signal passes. An echo-location instrument operates without a stilling well and has an accuracy of 0.1 % of range.

A.6.1.2 *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. The instrument needs to be connected to a mains power supply. It is possibly vulnerable to vandalism.

A.7 Systems using electrical properties

A.7.1 *Systems measuring capacitance*

A.7.1.1 *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.7.1.2 *Strengths*

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

A.7.1.3 *Weaknesses*

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

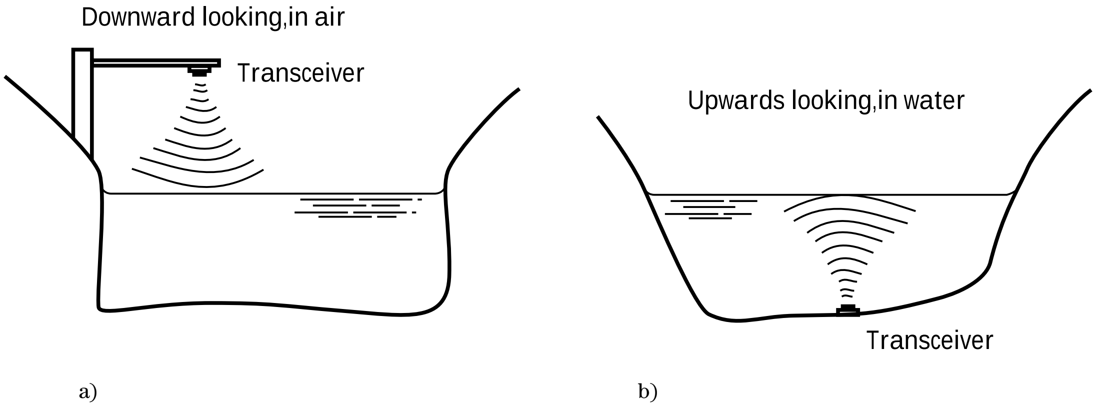


Figure A.9 — Ultrasonic level sensing

A.7.2 Systems measuring resistance

A.7.2.1 ***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.7.2.2 *Strengths*

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

A.7.2.3 *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.7.3 ***Systems measuring resistance (non-contact)***

A.7.3.1 *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.7.3.2 *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.7.3.3 *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 Recording devices

A.8.1 ***Analogue devices***

A.8.1.1 *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.8.1.2 *Strengths*

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

A.8.1.3 *Weaknesses*

The accuracy of a chart recorder, both in timing and in resolution of stage values, is affected by restrictions of the recording media. If the data is to be converted to a digital format for subsequent analysis, the process is labour insensitive and time consuming. Further inaccuracies are produced by the translation process.

A.8.2 ***Digital devices***

A.8.2.1 *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.8.2.2 *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.8.2.3 *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.8.2.4 *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 specialist equipment or software.

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Bibliography

[1] GREAT BRITAIN. Control of Substances Hazardous to Health (COSHH) regulations, SI 437, 1999, London: The Stationery Office.

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