International Standard 4373

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Measurement of liquid flow in open channels — Water level measuring devices

Mesure de débit des liquides dans les canaux découverts — Appareils de mesure du niveau d'eau

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4373 was developed by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels*, and was circulated to the member bodies in July 1977.

It has been approved by the member bodies of the following countries :

Australia	India	Spain
Canada	Ireland	Switzerland
Chile	Italy	United Kingdom
Czechoslovakia	Mexico	USA
Egypt, Arab Rep. of	Netherlands	USSR
Finland	Norway	Yugoslavia
France	Romania	
Germany, F. R.	South Africa, Rep. of	

No member body expressed disapproval of the document.

Measurement of liquid flow in open channels — Water level measuring devices

Section one : General

0 Introduction

In order to obtain a systematic record of river flow in terms of instantaneous or mean daily discharge, it is usual to collect primarily a continuous record of water level with respect to time which can be converted into a record of discharge by one or more of several methods (see ISO 1100). The accuracy of the record of discharge is governed principally by the accuracy of the record of water level and it is essential that this can be sensed and recorded efficiently and with an accuracy sufficient for the purposes for which the measurements are required.

The record of water level is commonly produced by a recorder actuated by a float and counterweight or tensioning spring system, the movement of the float being used to operate a recording mechanism such as a pen or a punching head which can produce either an analogue record on a chart or a digital record on punched tape. Water level records can also be produced by sensing the hydrostatic pressure above a fixed point in the stream.

To protect the float and to eliminate, or at least reduce, the effect of surface waves and short period surging in the natural channel it is customary to provide a stilling well, usually set back in the bank of the river and connected to it by one or more intake pipes but sometimes placed directly in the stream. The accuracy of the recorded water level will then depend partly on the sensitivity of the instrument and partly on any difference between the water level inside the stilling well and that in the river.

1 Scope and field of application

This International Standard specifies the functional requirements of

a) a stilling well with intake pipes for float-operated water level recorders;

b) stage sensing devices and

c) recording devices.

2 Terminology

For the purpose of this International Standard, the terms and definitions used are in accordance with ISO 772, *Liquid flow measurement in open channels — Vocabulary and symbols.*

3 Units of measurement

For the purpose of this International Standard, the units of measurement used are SI units in accordance with ISO 31 and ISO 1000.

Section two : Stilling well and intakes

4 Stilling well

4.1 Functional requirements of stilling wells

4.1.1 General

The function of the stilling well is :

a) to accommodate the instrument and protect the float system;

b) to provide within the well an accurate representation of the water level in the river (see the annex);

c) to damp out oscillations of the water surface.

4.1.2 Specific

4.1.2.1 The well may be circular, oval, square or rectangular in plan and may be made of any suitable material.

4.1.2.2 The well may be placed in the bank of a stream or directly in the stream when attached to a bridge pier or abutment. It should not, however, be located directly in the stream where flow conditions would lead to separation and stagnation effects. When placed in the bank the well shall be connected to the stream by intake pipe(s). When placed directly in the stream, the intakes may take the form of holes or slots cut in the well itself.

4.1.2.3 The well shall not interfere with the flow pattern in the approach channel and if set in relation to a control, it shall be located far enough upstream or downstream to be outside the area affected by the control.

4.1.2.4 The well shall be firmly founded when placed in the bank and firmly anchored when standing in the stream so that it shall remain stable at all times.

4.1.2.5 The well and all construction joints of well and intake pipes shall be watertight so that water can enter or leave only by the intake itself.

4.1.2.6 The well shall be vertical within acceptable limits and have sufficient height and depth to allow the float to travel freely the full range of water levels.

4.1.2.7 The dimensions of the well shall be such as to allow unrestricted operation of all equipment installed in it. Clearance between walls and float shall be at least 75 mm and where two or more floats are used within the well, clearance between them shall be at least 150 mm. In silt-laden rivers it is an advantage to have the well large enough to be entered and cleaned.

4.1.2.8 When placed in the bank of the stream the stilling well shall have a sealed bottom to prevent seepage into or leakage out of the chamber.

4.1.2.9 In wells with sealed bottoms the bottom of the well shall be at least 300 mm below the invert of the lowest intake to provide space for sediment storage and to avoid the danger of the float grounding at times of low flow.

5 Intakes

5.1 Functional requirements

5.1.1 General

The function of the intakes to the stilling well is :

a) to allow water to enter or leave the stilling well so that the water in the well is maintained at the same elevation as that in the stream under all conditions of flow;

b) to permit some form of control to limit lag and oscillating effects within the stilling well.

5.1.2 Specific

5.1.2.1 Intakes may take the form of one or more pipes connecting the well to the river when the well is set back into the bank or a series of holes or slots cut into the well itself when it is set directly into the river. In rivers with a permanent high silt content a well set in the stream may have a hopper shaped bottom to serve as an intake and also as a means of self cleansing.

5.1.2.2 The dimensions of the intakes shall be large enough to allow the water level in the well to follow the rise and fall of river stage without appreciable delay.

5.1.2.3 The dimensions of the intakes shall be small enough to damp oscillations caused by wave action or surges.

NOTE — These requirements are opposed and a suitable balance must be achieved. For example, to effectively eliminate surging it may be necessary to restrict the cross-sectional area of the intakes to 0,1 % of the cross-sectional area of the well whereas to reduce lag effect to acceptable limits the ratio may have to be at least 1 %. This will depend on site conditions, the type and length of intakes and the surface area of the well. Because of this, no firm rule can be laid down for determining the best size of intake but it is advisable to make the connection too large rather than too small as a restriction can be added if found necessary. As a general guide the total cross-sectional area of the intakes should not be less than 1 % of the cross-sectional area of the well.

5.1.2.4 Two or more intakes may be installed, at different levels, to ensure operation of the system if one intake becomes blocked.

5.1.2.5 For a stilling well set into a bank the invert of the lowest intake shall be at least 150 mm below the lowest anticipated stage and shall enter the stilling well at least 300 mm above the well bottom. In cold climates this intake shall be below the frost line.

5.1.2.6 Intake pipes shall be laid at a constant gradient to avoid low points and on a suitable foundation which will not subside.

5.1.2.7 The intake shall be so oriented in the stream that it will sense the true water level. When velocities in the stream at the point of measurement are sufficiently large, that the dynamic pressure is of sensible magnitude, the intake shall incorporate a static pressure device (wall piezometer, piezometer in a plate, surface parallel to flow, static tubes, etc.) to ensure that the dynamic pressure does not influence the level in the well.

5.1.2.8 It is desirable that intake pipes more than 20 m in length shall be provided with an intermediate manhole fitted with internal baffles to act as a silt trap and provide access for cleaning.

5.1.2.9 Means of cleaning the intakes shall be provided, either by a flushing system where water under several metres of head can be applied to the stilling well end of the intake, by pumping water through the intake or by hand cleaning with collapsible draining rods.

5.1.2.10 Where velocity past the river end of the intake is high, drawdown of the water level in the well may occur. This can be reduced by attaching a capped and perforated static tube to the river end of the intake and extending it horizontally downstream.

6 Protection from frost

In cold climates the well shall be protected from the formation of ice. This may be done by the use of well covers, sub-floors, heaters or oil on the water surface. When oil is used the oil surface will stand higher than the water level in the stream and a correction must be used when setting the recorder.

Section three : Stage sensing devices

7 Accuracy of stage measurement

For the measurement of stage, in certain installations an uncertainty of ± 10 mm may be satisfactory; in others an uncertainty of ± 3 mm or better may be required; however, in no case should the uncertainty be worse than ± 10 mm or 0,1 % of the range whichever is greater.

This clause applies in all cases except where specifically stated otherwise.

8 Gauge datum

The stage of a stream or lake is the height of the water surface above an established datum plane. The datum of the gauge may be a recognized datum, such as mean sea level, or an arbitrary datum plane selected for the convenience of using gauge readings of relatively low numbers. It is generally desirable to avoid negative values for these readings, therefore the datum selected for operating purposes should be below the elevation of zero flow on the control.

If an arbitrary datum plane is used, it should be referred to a bench mark of known elevation above sea level by accurate levelling so that the arbitrary datum may be recovered if the gauge and reference marks are destroyed. A permanent datum must be maintained so that only one datum for the stage record is used for the life of the station.

8.1 Gauge zero

The zero of the gauge should be correlated with a national datum through a station bench mark. The relation between the gauge zero and the station bench mark shall be checked at least annually. Also, the relation between the gauge zero and other divisions shall be checked from time to time. The tolerance on the transfer of the level from the station bench mark to the gauge shall not exceed ± 1,0 mm.

8.2 Station bench mark

The station bench mark shall be set in a position offering maximum security against disturbance. It should be securely fixed in a concrete block or similar mounting that extends below the ground surface to a level free from disturbance, such as frost. It should be correlated with a national survey datum by accurate levelling. To facilitate accurate levelling between the station bench mark and the gauge zero, the bench mark should be located in a position such that the transfer of the level may be carried out by reciprocal levelling or with equally balanced foresights and backsights on the setting of the level.

9 Direct water-level indication devices

Water level gauges may be either the direct or the indirect type, with measuring instruments of the fixed or movable type, such as vertical and inclined gauges, needle gauges, float gauges, and wire weight gauges classified as direct reading instruments. The significant feature of this group of water-level indicators is that the reading may be made directly in units of length, without any intervening influences.

9.1 Vertical and inclined gauges

Such gauges comprise a scale marked on or attached to a suitable surface.

9.1.1 Functional requirements

These gauges shall meet the following functional requirements :

a) they shall be accurate and clearly marked;

b) they shall be durable and easy to maintain;

c) they shall be simple to install and use.

9.1.2 Material

The material of which a gauge is constructed shall be durable, particularly in alternating wet and dry conditions and also in respect of the resistance to wear or fading of the markings. The material should have a low coefficient of expansion with respect to temperature or wetting effects.

9.1.3 Graduation

9.1.3.1 The graduations of a vertical gauge shall be clearly and permanently marked directly on a smooth surface or on a gauge board. The numerals shall be legible and placed in such a way that there is no possibility of any ambiguity. A typical example is shown in figure 1.

9.1.3.2 The graduations of an inclined gauge may be directly marked on a smooth surface or on a gauge board as described in 9.1.3.1, or may be carried on manufactured gauge plates designed to be set for particular slopes. Except where use is made of manufactured gauge plates designed to be set to a specified slope, an inclined gauge should be calibrated in-situ by precise levelling from the station bench mark.

9.1.3.3 Gauge plates shall be manufactured in suitable lengths with the width of the scale not less than 50 mm.

9.1.3.4 The marking on the gauge should be made to read in multiples of millimetres. The smallest graduation shall depend on the accuracy required, but may correspond to 10 mm.

9.1.3.5 The markings of the subdivisions shall be accurate to ± 0,5 mm, and the cumulative error shall not exceed 0,1 % or 0,5 mm whichever is greater.

9.1.4 Installation and use

9.1.4.1 General

The gauge should preferably be placed near the side of the stream so that a direct reading of water level may be made. If this is impractical because of excessive turbulence, wind effect, or inaccessibility the measurement may be made in a suitable permanent stilling bay or stilling well in which the wave actions are damped and the level of the water surface closely follows the fluctuations of the water level in the stream. To ensure this, intakes to stilling wells should be properly designed and located.

The gauge should be located as closely as possible to the measuring section without affecting the flow conditions at this point. It should not be placed where the water is disturbed by turbulence, or there is danger of damage by drift. Bridge abutments or piers are generally unsuitable locations. Wherever the gauge is situated, it shall be readily and conveniently accessible so that the observer may make readings as nearly as possible at eyelevel. Where necessary, the construction of a flight of steps to give convenient access is recommended. The gauge board or plate shall be securely fixed to the backing but provision must be made for removing the gauge board or plate for maintenance or adjustment. The edges of the gauge board should be protected.

9.1.4.2 Vertical gauges

A suitable backing for a vertical gauge is provided by the surface of a wall having a vertical or nearly vertical face parallel to the direction of flow. The gauge board or backing plate shall be attached to the surface so as to present a truly vertical face to receive the graduations. The gauge board and backing plate shall be securely fastened to the wall. Gauges may be fixed to piles, either driven firmly into the river bed or banks, or set in concrete so as to be free from sinking, tilting, or washing away. In either case the anchorage shall extend below the ground surface to a level free of disturbance by frost. In order to avoid velocity effects which may hinder accurate reading, a pile may be shaped to present streamlined cutwaters upstream and downstream or the gauge may be situated in a bay where it will not be exposed to the force of the current. Where the range of water levels exceeds the capacity of a single vertical gauge additional sections may be installed on the line of the cross section normal to the direction of flow.

9.1.4.3 Inclined gauges

An inclined gauge shall be installed in such a manner to closely follow the contour of the river bank. The profile of the bank may be such that a gauge of a single slope may be installed; frequently however, it may be necessary to construct the gauge in several sections, each with a different slope. The general installation requirements given in 9.1.4.2 apply.

9.2 Needle gauges

9.2.1 General

A needle water-level gauge consists of a point and some means of determining its exact vertical position relative to a datum. The two types of needle gauges are :

a) the point gauge, whose tip approaches the free surface from above, and

b) the hook gauge, which is hook-shaped, and whose tip is immersed and approaches the free surface from below. (See figure 2.)

The vertical position may be determined by a graduated scale, a tape with some vernier arrangement, or a digital indicator. The scale is movable and graduated to read downward from top to bottom in metres. Application of needle gauges consists of positioning the needle of the gauge near the water surface and detecting the moment the tip just touches the free surface, apparently trying to pierce its skin. Setting a point exactly at the water surface may be facilitated by electrical means.

The advantage of water-level needle gauges is their high measuring accuracy, whereas their disadvantage is their small measuring range, usually about 1 m. However, this disadvantage can be overcome by installing a series of datum plates at different levels.

9.2.2 Functional requirements

9.2.2.1 A hook or point gauge installation shall permit measurement of stage to be made at all levels from below the lowest to above the highest level anticipated.

9.2.2.2 There shall be good illumination of the place where the tip meets the free liquid surface.

9.2.2.3 The hook or point shall be made of metal sufficiently strong to resist deformation in transport and under field conditions of use. The tip shall be tapered to a point having an included angle of approximately 60° and the point shall be rounded to a radius of approximately 0,25 mm. (See figure 3.)

9.2.3 Material

A hook or point gauge and auxiliary parts shall be made throughout with durable corrosion resistant materials.

9.2.4 Graduation

The graduations of a hook or point gauge shall be in millimetres and shall be clearly and accurately marked. A vernier or micrometer head may be provided which allows reading to 0,1 mm. However, such a reading accuracy is normally only required for laboratory measurements.

9.2.5 Installation and use

9.2.5.1 A hook or point gauge may be mounted over an open water surface at the edge of a stream if conditions permit. If this is not practicable because of turbulence, wind effect, or inaccessibility, a suitable permanent stilling bay or stilling well should be installed.

9.2.5.2 The location of the hook or point gauge should be as close as possible to the measuring section and should be conveniently accessible to the observer.

9.2.5.3 The gauge shall not be installed in a location where the water surface is disturbed by turbulence, wind effect, or afflux. The vicinity of bridge abutments or piers is generally unsuitable.

9.2.5.4 Where more than one datum plate or bracket is provided at different levels, it is preferable that all should lie on the line of a single cross section normal to the direction of flow in the stream. If this is not practicable and it is necessary to stagger the points, all should lie within a distance of 1 m on either side of the cross section line.

9.2.5.5 Datum plates and brackets shall be mounted on a secure foundation which extends below the frost line.

9.2.5.6 The elevation of the datum plates, with references to which the level of the free surface is determined, shall be established with great care. This elevation shall be checked from the station bench mark at least annually. The tolerance on the transfer of level from the station bench mark to each datum plate shall not exceed ± 1,0 mm.

9.3 Float gauges

9.3.1 General

The float gauge is used chiefly as an inside reference gauge in water stage measurements. The typical float gauge consists of a float operating in a stilling well, a graduated steel tape, a counterweight, a pulley, and a pointer. The float pulley is grooved on the circumference to accommodate the tape, and mounted on a support. The tape is fastened to the upper side of the float and runs slip-free over the pulley in the gauge shed above the well. It is kept tight by a counterweight at the free end or by a spring. In this way stage fluctuations are sensed by the float which positions the tape with respect to the pointer.

9.3.2 Functional requirements

9.3.2.1 A float gauge installation shall permit measurement of stage to be made at all levels from below the lowest to above the highest level anticipated.

9.3.2.2 Float and counterweight dimensions and the quality of the elements of the mechanical device for remote indication shall be selected so that there is a sufficiently high indication accuracy and working reliability.

9.3.2.3 The float shall be made of durable corrosion-resistant and anti-fouling material. It shall be leakproof and function in a truly vertical direction. Its density shall not change significantly.

9.3.2.4 The float shall be checked at frequent intervals to make sure that it is floating properly, and care should be taken to see that the tape does not become twisted or fouled and that the indicated stage is the same as the water level in the stream.

9.3.3 Graduation

The graduations of the float gauge shall be in millimetres and shall be clearly and accurately marked.

9.4 Wire-weight gauge

9.4.1 General

The typical wire-weight gauge consists of a drum wound with a single layer of cable, a bronze weight attached to the end of the cable, a graduated disc, and a counter, all housed within a protective housing (see figure 4). The disc is graduated and is permanently connected to the counter and the shaft of the drum. The cable is guided to its position on the drum by a threading sheave. The reel is equipped with a pawl and ratchet for holding the weight at any desired elevation. The gauge is set so that when the bottom of the weight is at the water surface, the gauge height is indicated by the combined readings of the counter and the graduated disc.

9.4.2 Functional requirements

A wire-weight gauge should permit measurement of stage to be made at all levels.

9.4.3 Material

A wire-weight gauge shall be made throughout with durable corrosion-resistant materials.

9.4.4 Graduation

The graduations of the wire-weight gauge should be in millimetres.

9.4.5 Installation and use

9.4.5.1 The wire-weight gauge is used as an outside reference gauge where other outside gauges are difficult to maintain. The wire-weight gauge is normally mounted where there is a bridge, or other structure over the water.

9.4.5.2 The gauge shall not be installed in a location where the water surface is disturbed by turbulence, wind effects, or afflux. The vicinity of bridge abutments or piers is generally unsuitable.

9.4.5.3 The check bar elevation of the wire-weight gauge should be read frequently to ensure reliability of correct base elevation.

9.5 Other direct reading gauges

There exist other direct reading gauges of various types, for example, those where the water level is detected by one or several points or by a small float, and where the sensing element is positioned with a servo-mechanism.

However, these instruments are not so commonly used as to be included in this International Standard.

10 Indirect water-level indication devices

Indirect water-level indication devices include those gauging systems which convert a pressure or electrical signal to an output which is proportional to the water level. Of the indirect devices available, those in most common usage are the pressure type, such as the servo-manometer and the servo-beam balance.

10.1 Pressure gauges

Pressure-gauges are frequently used at sites where it would be too expensive to install stilling wells. They are also used on sand-channel streams because the intake line can be extended to follow a stream channel that shifts its location, and if the gas-purge technique is used, the gas flow tends to keep the orifice from becoming plugged with sand.

10.1.1 *General*

One widely used method of measuring water level is to measure the height of a column of water with respect to some datum plane. This can be accomplished indirectly by sensing the water pressure at a fixed point below the water surface, and then utilizing the hydrostatic principle that the pressure of a liquid is proportional to the depth.

10.1.1.1 Direct transmission of pressure

The method of transmitting pressure from the water column to the sensor may be direct or indirect. When the sensor is located below the point in the water column at which the pressure is to be measured, the water pressure may be transmitted directly to the sensor. However, if the sensor is located above the water column, the direct method is usually not satisfactory because gases entrained in the water can create air locks in the line. Also, if the water is highly corrosive, it is undesirable to bring it into direct contact with the sensor.

10.1.1.2 Gas-purge (bubbler) technique

The most successful and widely used method of transmitting pressure is the gas-purge technique. This technique may be used regardless of the elevation of the pressure device with respect to the water column; and because the water does not come into direct contact with the pressure sensor, it is suitable for use in highly corrosive waters.

In the gas-purge technique a small discharge of non-corrosive gas or compressed air is allowed to bleed into a tube, the free end of which has been lowered into the water and fixed at an elevation below the water column to be measured. For example, dry nitrogen is frequently used. The sensor, which is located at the opposite end, detects the pressure of the gas required to displace the liquid in the tube; this pressure is directly proportional to the head of liquid above the orifice.

When using the gas-purge technique there are certain installation and operation requirements that should be observed. The principal ones are as follows :

a) An adequate supply of gas or compressed air must be provided. A continuous flow of gas to the tube is necessary to prevent the liquid from entering it when the water level is rising. A particular rate of gas supplied will cause the pressure in the system to rise at the same rate as the head. If gas is supplied at a lower rate, liquid will enter the tube; and conversely, a higher rate will provide a continuous discharge of gas from the opening in the bottom of the tube. The gas is usually supplied from a cylinder or by an air compressor. In either case, the supply must have a delivery pressure in excess of the range to be measured.

b) A pressure reducing valve must be provided so that a pressure safely in excess of that of the maximum range can be set. A flow control valve and some form of visual flow rate indicator is necessary, so that the discharge of gas supplied to the system can be properly adjusted. The pressure should be set to prevent water from entering the tube, even under the most rapid rates of change expected.

c) Incorrect readings due to the friction of the gas moving through the tube should be minimized. Long lengths of tube or very small diameter tubing aggravate the friction problem. This problem is frequently solved by running two tubes to a junction very near to the orifice with one tube serving as a gas-supply line and the other as a pressure-detection line. Under this arrangement the movement of gas in the pressure detection line is kept to a minimum, thereby reducing the friction to a minimum.

d) The tubing should be installed with a continuous negative slope to the orifice (see figure 5).

10.1.1.3 Pressure bulb system

Where there is no gas supply available, a pressure bulb system is sometimes used to transmit pressure to the sensor. This device, frequently referred to as an elastic pressure bulb, is usually made of a casting in the form of a short hollow cylinder with one open end. The open end is sealed with a slack, highly flexible diaphragm, and the cylinder is connected by means of tubing to the pressure sensor. The whole unit forms a closed gas system with pressure initially equal to atmospheric. The cylinder is lowered into the water and fixed at an elevation below the water column to be measured. The slack diaphragm permits water pressure to compress the gas in the cylinder until the pressure within the system is proportional to the height of the water column above. One of the major disadvantages of this device is that ultimately an excessive amount of gas will escape from the system with a resultant stretching of the diaphragm. When this occurs the pressure within the system will no longer be equal to the pressure head. This disadvantage can be overcome by periodic renewal of gas within the system or replacement of the pressure bulb and tubing. It is difficult to maintain the accuracy stipulated under clause 7 with this device.

10.1.2 Servo-manometer and servo-beam balance

Both the servo-manometer and the servo-beam balance are pressure sensors that convert the pressure detected to a rotational shaft position proportional to the height of the column of water. The shaft position is used for driving a recorder and a water-level indicator. As the name implies, the servo-manometer is essentially a manometer with a servo-system detecting and following the liquid differential within the manometer. The servo-beam balance is a beam balance with a pressure bellows on one side of the beam and a weight on the other. Here the servo system positions the weight so that the beam is in balance and detects this position.

10.1.2.1 Water density compensation

Since the density of the water which the sensor is to measure will vary with temperature and also with chemical and silt content, either automatic or manual means of compensating for these changes should be provided.

10.1.2.2 Changes in gas weight

If one of the gas techniques is used to transmit pressure, provisions should be made for compensating for changes in the weight of the gas, as all gases vary in weight with temperature and pressure changes.

10.1.2.3 Range

The range of the instrument shall be adequate to accommodate any anticipated ranges in water level.

10.1.2.4 Response

The response of the instrument shall be sufficiently rapid to follow any expected rate of change in water level.

10.1.3 Miscellaneous pressure sensors

There are numerous pressure sensors available commercially operating on numerous principles. Most of these have an electrical output which is proportional to the pressure sensed. They are occasionally used for the detection of water level. The proper selection is dependent upon the particular application involved. Their application is generally restricted to limited ranges because the accuracy requirements set out in clause 7 are difficult to meet over extended ranges.

10.2 Other indirect stage measuring devices

There are also a number of stage measuring devices based on electrical, acoustic or optical principles. However, since they are not frequently used in open channel measurements they are not covered in this International Standard.

Section four : Recording devices

11 Mechanical recorders

11.1 General

The mechanical recorder described in this section is the shaft-angular-input type. Such a recorder can be classified as either analog or digital, depending upon the mode used in recording the rotational position of the input shaft. The analog recorder produces a graphic record of the rise and fall of parameter values with respect to time, while the digital recorder punches coded parameter values on paper tape at preselected time intervals. Analog recorders can further be classified into two types, those which record continuously for an indefinite period of time or those which record continuously for a fixed period of time (daily, weekly, monthly, etc.).

Regardless of the type, any mechanical water-level recorder should satisfy the requirements enumerated in the following paragraphs.

11.2 Driving torque

Angular movement of the input shaft drives the stylus of an analog recorder or the coding mechanism of the digital recorder by the use of a mechanical linkage. Because mechanical linkages generate some friction, sufficient driving torque shall be supplied to overcome this friction. For a water-level recorder, this driving force is usually supplied by water displacing a float and is transmitted by a float line and counterweight to the drive pulley. If the friction is high, i.e. the driving torque required to position the recording element is high, then an appreciable lag, following a change in the water level, will result. It is therefore desirable for the driving torque to be as low as feasible, and in no case should it exceed 7 m N.m.

11.3 Hysteresis (lost motion)

The mechanical linkage mentioned in the preceding paragraph also results in some hysteresis. Usually either gear trains or sprockets and chains or a combination thereof form the mechanical linkage, and the play between the teeth of gears or the slack in the sprocket chain is the cause of this hysteresis. If the input shaft is rotated in one direction until the stylus follows and then the direction of rotation reversed, the total hysteresis is that amount of motion required to cause the stylus to follow in the reversed direction. It is desirable to keep such lost motion to a minimum but in no case should it exceed limits of accuracy, that is, 3 mm.

11.4 Timing mechanism

The timing mechanism consists essentially of a clock element which shall be both sturdy and reliable. In the case of analog recorders, the timing mechanism either rotates the chart paper past the stylus or governs the rate at which the chart paper moves past the stylus. In the case of the digital recorder, the timing mechanism programs the interval at which data are recorded.

High precision in time is not as important as reliable operation; however, both are of consequence. Therefore, best results will be obtained if the clock mechanism is of high quality. The clock mechanism itself should be protected from dirt, corrosion, and insects by its own housing.

11.4.1 Accuracy

The accuracy of the clock shall be within ± 30 s per day (accumulative) to be measured over a period of at least 30 days.

11.4.2 Movement adjustment

A movement adjustment is to be provided to permit regulation within the accuracy requirements set forth above.

11.5 Paper (chart or tape)

Paper expands and contracts with changes in both temperature and humidity; the amount of change depends upon the quality of the paper. A great portion of the accuracy of an analog recorder depends upon the accuracy with which the scale is printed on the chart paper and the stability of the paper. The paper tape from a digital recorder is machine-readable without errors only if the paper is stable within reasonable tolerances. The paper supplied should therefore remain stable within relatively close tolerance throughout the range of temperature and humidity conditions expected.

11.6 Stylus

The stylus of an analog recorder is usually a pen or pencil. If a pen is used, the pen and ink shall be such that an easily readable trace is produced without blotting or otherwise running. If a pencil is used, it shall be of proper hardness to produce a readable trace. A pencil too hard will fail to produce a legible trace and may tear the chart paper. A pencil too soft will wear rapidly and quickly fail to produce a legible trace.

11.7 Errors

There are several sources of errors when water level is sensed by float and transmitted to a shaft-angular-input recorder by a float line and counterweight. Some of these sources of errors have been discussed in the preceding paragraphs, others have not been previously mentioned. All will be summarized below.

11.7.1 Friction

The error, E, caused by friction in the driving mechanism can be calculated, in metres, from the following formula :

$$E = \frac{F}{\pi {R_1}^2 R_2 \varrho g}$$

where

F is the driving torque in newton metres;

ϱ is the density in kilograms per cubic metre;