INTERNATIONAL STANDARD

ISO 4360

Third edition
2008-03-01

Hydrometry — Open channel flow measurement using triangular profile weirs

Hydrométrie — Mesure de débit des liquides dans les canaux découverts au moyen de déversoirs à profil triangulaire

Reference number
ISO 4360:2008(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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 4360 was prepared by Technical Committee ISO/TC 113, *Hydrometry*, Subcommittee SC 2, *Flow measurement structures*.

This third edition cancels and replaces the second edition (ISO 4360:1984), of which it constitutes a technical revision.

Hydrometry — Open channel flow measurement using triangular profile weirs

1 Scope

This International Standard specifies methods for the measurement of the flow of water in open channels under steady flow conditions using triangular profile weirs. The flow conditions considered are steady flows which are uniquely dependent on the upstream head and drowned flows which depend on downstream as well as upstream levels.

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, *Hydrometric determinations — Vocabulary and symbols*

3 Terms and definitions

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

4 Symbols

A	m^2	area of approach channel
B	m	width of approach channel
b	m	breadth of weir crest perpendicular to flow direction
C		discharge coefficient
C_d		coefficient of discharge
C_v		coefficient of velocity
$C_v f$		combined coefficient of velocity
E	m	elevation of ultrasonic air range sensor above hydraulic datum
f		drowned flow reduction factor
g	m^2/s	acceleration due to gravity
H	m	total head relative to crest level
h	m	gauged head relative to crest level (upstream head is inferred if no subscript is used)
N		number of measurements in a set
p	m	height of weir (difference between mean bed level and crest level)
Q	m^3/s	volumetric rate of flow
$u^*(\ )$		percentage uncertainty in parameter
$\bar{v}$	m/s	mean velocity
U	%	expanded percentage uncertainty

Subscripts:

1 upstream
2 downstream
c combined
p measured crest tapping head above crest level

5 Principle

The discharge over a triangular profile weir is a function of the upstream head on the weir (for free flow), upstream and downstream head (for drowned flow), experimentally determined coefficients, the geometrical properties of the weir and approach channel and the dynamic properties of the water.

6 Installation

6.1 General

The required conditions regarding selection of site, installation conditions, the measuring structure, the approach channel, the downstream channel, maintenance, measurement of head, and stilling or float wells which are generally necessary for flow measurement are given in the following sub-clauses.

6.2 Selection of site

A preliminary survey shall be made of the physical and hydraulic features of the proposed site, to check that it conforms (or can be made to conform) to the requirements necessary for accurate measurement by a weir.

Particular attention should be paid to the following features in selecting the site:

a) availability of an adequate length of channel of regular cross-section;

b) the existing velocity distribution;

c) the avoidance of a steep channel, if possible;

d) the effects of any increased upstream water level due to the measuring structure;

e) conditions downstream including such influences as tides, confluences with other streams, sluice gates, mill dams and other controlling features which might cause submerged flow;

f) the impermeability of the ground on which the structure is to be founded, and the necessity for piling, grouting or other means of controlling seepage;

g) the necessity for flood banks to confine the maximum discharge to the channel;

h) the stability of the banks, and the necessity for trimming and/or revetment in natural channels;

i) the clearance of rocks or boulders from the bed of the approach channel;

j) the effect of wind; wind can have a considerable effect on the flow in a river or over a weir, especially when these are wide and the head is small and when the prevailing wind is in a transverse direction.

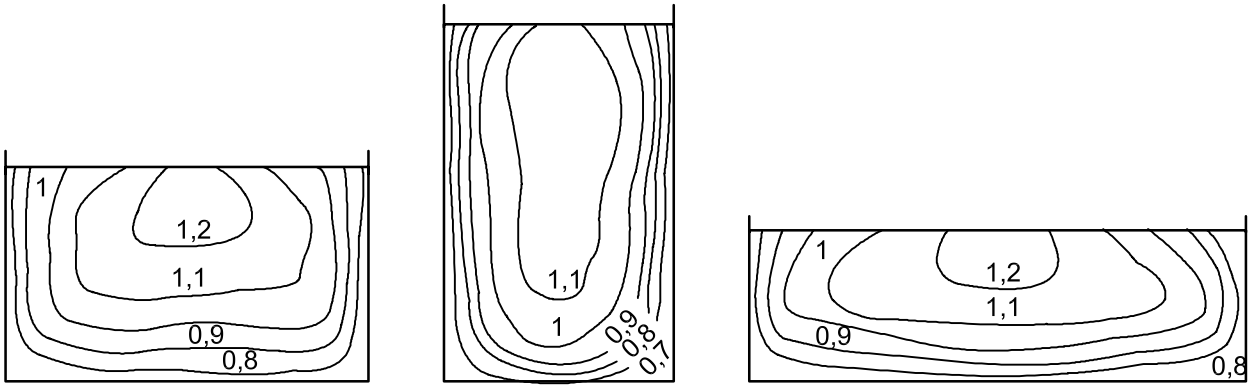
If the site does not possess the characteristics necessary for satisfactory measurement, the site shall be rejected unless suitable improvements are practicable.

If an inspection of the stream shows that the existing velocity distribution is regular, then it may be assumed that the velocity distribution will remain satisfactory after the construction of a weir.

If the existing velocity distribution is irregular and no other site for a gauge is feasible, due consideration shall be given to checking the distribution after the installation of the weir and to improving it if necessary.

Several methods are available for obtaining a more precise indication of irregular velocity distribution: velocity rods, floats or concentrations of dye can be used in small channels, the latter being useful in checking conditions at the bottom of the channel. A complete and quantitative assessment of velocity distribution may be made by means of a current-meter or other point velocity measurements. Information about the use of current-meters is given in ISO 748 [1]. Further information on measuring river velocities using acoustic Doppler profilers can be found in ISO/TS 24154 [5].

Figure 1 gives examples of satisfactory velocity distributions.



NOTE The contours refer to values of local flow velocity relative to the mean cross-sectional velocity.

Figure 1 — Examples of satisfactory velocity distributions

6.3 Installation conditions

6.3.1 General

The complete measuring installation consists of an approach channel, a measuring structure and a downstream channel. The conditions of each of these three components affect the overall accuracy of the measurements.

Installation requirements include features such as the surface finish of the weir, the cross-sectional shape of the channel, the channel roughness and the influence of control devices upstream or downstream of the gauging structure.

The distribution and direction of velocity have an important influence on the performance of the weir, these factors being determined by the features mentioned above.

Once an installation has been installed, the user shall prevent any change which could affect the discharge characteristics.

6.3.2 Measuring structure

The structure shall be rigid and watertight and capable of withstanding flood flow conditions without distortion or fracture. It shall be at right angles to the direction of flow and shall conform to the dimensions given in the relevant clauses.

The weir comprises an upstream slope of 1 (vertical) to 2 (horizontal) and a downstream slope of 1 (vertical) to 5 (horizontal). The intersection of these two surfaces forms a straight line crest, horizontal and at right angles to the direction of flow in the approach channel. Particular attention shall be given to the crest itself, which shall possess a well-defined corner of durable construction. The crest may be made of pre-formed sections, carefully aligned and jointed, or may have a non-corrodible metal insert, as an alternative to *in situ* construction throughout.

The dimensions of the weir and its abutments shall conform to the requirements indicated in Figure 2. Weir blocks may be truncated but not so as to reduce their dimensions in plan to less than h_{max} for the 1:2 slope and 2 h_{max} for the 1:5 slope.

Figure 2 shows the general arrangement of the triangular profile weir.

6.3.3 Approach channel

On all installations, the flow in the approach channel shall be smooth, free from disturbance and shall have a velocity distribution as satisfactory as possible over the cross-sectional area. This can usually be verified by inspection or measurement. In the case of natural streams or rivers, this can only be attained by having a long straight approach channel free from projections into the flow. Figure 1 gives examples of satisfactory velocity distributions.

The following general requirements shall be complied with.

a) As the altered flow conditions due to the construction of the weir might cause a build-up of shoals of debris upstream of the structure, which in time might affect the flow conditions, the likely consequential changes in the water level shall be taken into account in the design of gauging stations.

b) In an artificial channel, the cross-section shall be uniform and the channel shall be straight for a length equal to at least 5 times its water-surface width.

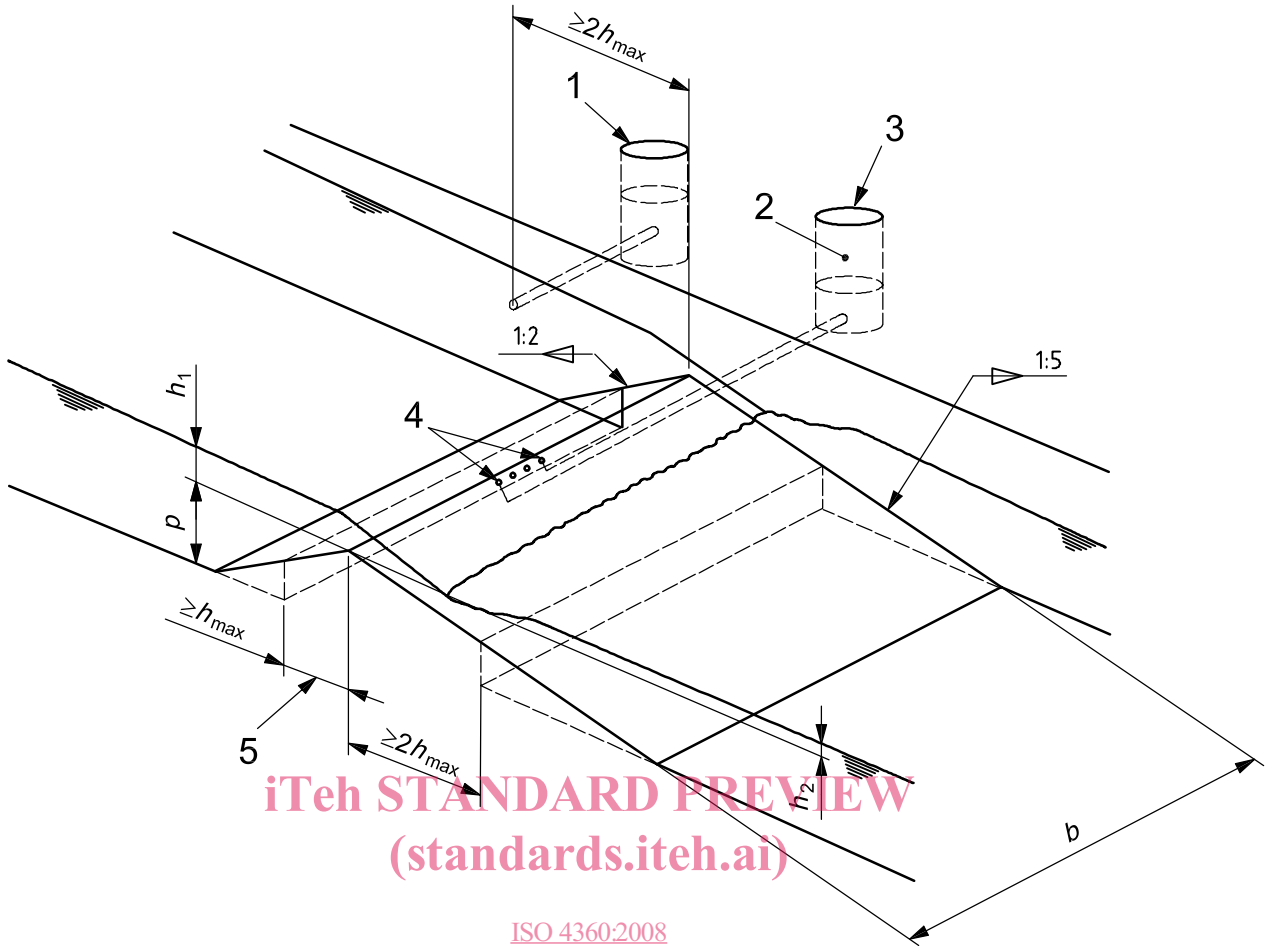
c) In a natural stream or river, the cross-section shall be reasonably uniform and the channel shall be straight for a sufficient length to ensure a regular velocity distribution.

d) If the entry to the approach channel is through a bend, or if the flow is discharged into the channel through a conduit or a channel of smaller cross-section, or at an angle, then a longer length of straight approach channel may be required to achieve a regular velocity distribution.

e) Baffles shall not be installed closer to the points of measurement than a distance 10 times the maximum head to be measured.

f) Under certain conditions, a standing wave may occur upstream of the gauging device, e.g. if the approach channel is steep. Provided that this wave is at a distance of not less than 30 times the maximum head upstream, flow measurement is feasible, subject to confirmation that a regular velocity distribution exists at the gauging station and that the Froude number in this section is no more than 0,6. Ideally, high Froude numbers should be avoided for accurate flow measurement.

   If a standing wave occurs within this distance, the approach conditions and/or the gauging device shall be modified.



Key

1 upstream head measurement
2 crest tapping head measurement
3 gauge wells
4 crest tappings
5 limit of truncated sections

Figure 2 — General arrangements of the triangular profile weir

6.3.4 Downstream channel

The channel downstream from the structure is usually of no importance as such if the weir has been designed so that the flow is modular (i.e. unaffected by tailwater level) under all operating conditions. A downstream gauge shall be provided to measure tailwater levels to determine if and when drowned flow occurs.

In the event of the possibility of scouring downstream, which phenomenon may also lead to the instability of the structure, particular measures to prevent this happening may be necessary.

A crest tapping and separate stilling well shall be fitted if the weir is designed to operate in a drowned condition or if there is a possibility that the weir may drown in the future.

The latter circumstance may arise if the altered flow conditions due to the construction of the weir have the effect of building up shoals of debris immediately downstream of the structure or if river works are carried out downstream at a later date.

7 Maintenance

Maintenance of the measuring structure and the approach channel is important to secure accurate continuous measurements.

The approach channel shall be kept free of silt, vegetation and obstructions which might have deleterious effects on flow conditions specified for the standard installation. The float well and the entry from the approach channel shall also be kept clean and free from deposits. The downstream channel shall be kept free of obstructions which might cause the weir to drown.

The weir structure shall be kept clean and free from clinging debris and care shall be taken in the process of cleaning to avoid damage to the weir crest.

Head-measurement piezometers, connecting conduits and stilling wells shall be cleaned and checked for leakage. The hook or point gauge, manometer, float or other instrument used to measure head shall be checked periodically to ensure accuracy.

If a flow straightener is used in the approach channel, perforated plates shall be kept clean so that the percentage open area remains greater than 40 %.

8 Measurement of head(s)

8.1 General

Where spot measurements are required, the heads can be measured by vertical gauges, hooks, points, wires or tape gauges. Where continuous records are required, recording gauges shall be used.

NOTE As the size of the weir and head reduces, small discrepancies in construction and in the zero setting and reading of the head measuring device become of greater relative importance.

8.2 Location of head measurement(s)

8.2.1 Modular (free) flow

Flow is modular when it is independent of variations in tailwater level. This requirement is met when the tailwater total head is equal to or less than 75 % of the upstream total head.

Piezometers or point-gauge stations for the measurement of head on the weir shall be located at a sufficient distance upstream from the weir to avoid the region of surface drawdown. On the other hand, they shall be close enough to the weir to ensure that the energy loss between the section of measurement and the control section on the weir shall be negligible. In this International Standard, it is recommended that the head-measurement section shall be located at a distance equal to twice the maximum head ($2h_{max}$) upstream of the crest.

8.2.2 Drowned flow

A significant error in the calculated discharge will develop if the tailwater total head above crest level exceeds 75 %, unless a crest tapping is provided and two independent head measurements are made.

The optimum position for the crest tapping is at the centre of the weir crest. The tapping may be off-centre on weirs wider than 2,0 m provided that the distance from the centreline of the crest tapping to the nearest side wall or pier is greater than 1,0 m.

8.3 Gauge wells

It is usual to measure the upstream head in a gauge well to reduce the effects of water surface irregularities.

NOTE 1 Devices for the measurement of head are described in ISO 4373 [2].

Periodic checks on the measurement of the head in the approach channel shall be made.

Where the weir is designed to operate under drowned flow, a second measurement of head is required. For accurate flow measurement, the head shall be measured within the separation pocket immediately downstream of the crest. Alternatively, but with less precision, the head may be measured in the channel downstream of the structure.

Gauge wells shall be vertical and of sufficient height and depth to cover the full range of water levels. In field installations, they shall have a minimum height of 0,6 m above the maximum water levels expected. Gauge wells shall be connected to the appropriate head measurement positions by means of pipes.

Both the well and the connecting pipe shall be watertight. Where the well is provided for the accommodation of the float of a level recorder, it shall be of adequate size and depth.

The pipe shall have its invert not less than 0,10 m below the lowest level to be gauged.

Pipe connections to the upstream and downstream head measurement positions shall terminate either flush with, or at right angles to, the boundary of the approach and downstream channels. The channel boundary shall be plain and smooth (equivalent to carefully finished concrete) within a distance 10 times the diameter of the pipes from the centre line of the connection. The pipes may be oblique to the wall only if they are fitted with a removable cap or plate, set flush with the wall, through which a number of holes are drilled. The edges of these holes shall not be rounded or burred. Perforated cover plates are not recommended where weed or silt are likely to be present.

The static head at the separation pocket behind the crest of the weir shall be transmitted to its gauge well as follows.

a) An array of tapping holes shall be set into a plate covering a cavity in the crest of the weir block.

b) The underside of the plate shall be supported on a manifold into which the static head is communicated via an array of feed tubes.

NOTE 2 No firm rule can be laid down for determining the size of the connecting pipe to the upstream well, because this is dependent on a particular installation, e.g. whether the site is exposed and thus subject to waves, and whether a larger diameter well is required to house the floats of recorders.

c) A horizontal conduit shall lead from the cavity through the weir block beneath the crest and terminating at the gauge well.

d) A flexible transmission tube shall communicate static head within the manifold to the gauge well.

e) A watertight seal around the transmission tube shall prevent static head within the cavity from influencing the static head transmitted from within the manifold.

NOTE 3 This may be at a different pressure because of leakage around the perimeter of the cover plate.

These arrangements minimize the occurrence of silting within the communication path between the separation pocket and the gauge well and allow effective purging of the pipework by the occasional backflushing of the system. For this purpose, a volume of water shall periodically be introduced to the gauge well.

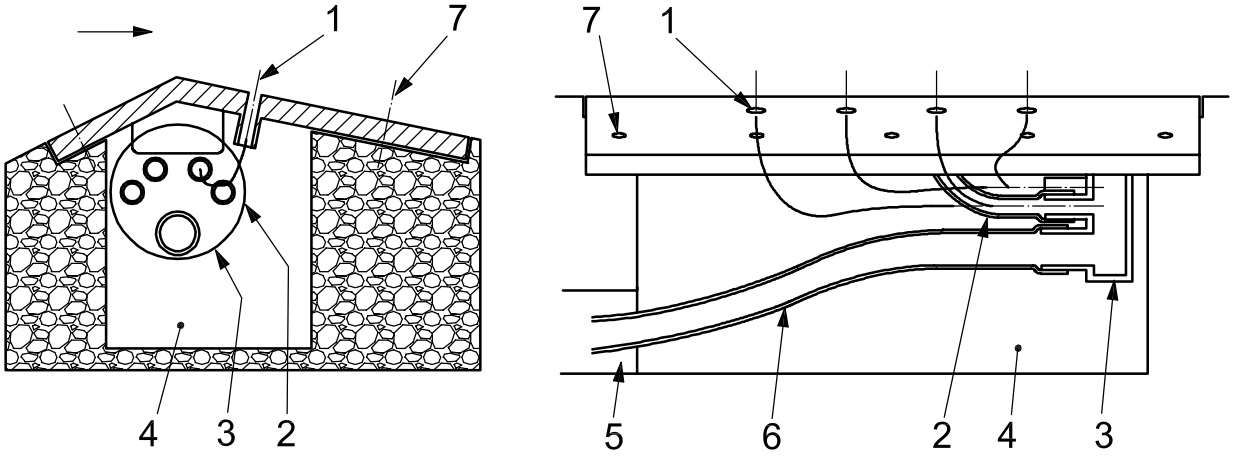
Figure 3 shows the general arrangement for the crest tapping installation.

The crest tapping shall consist of five to ten holes of 10 mm diameter drilled in the weir block with centres 75 mm apart, 20 mm down from the weir crest on the 1:5 slope. The edges of the holes shall not be rounded or burred. The number of holes shall be sufficient to ensure that the water level in the stilling well follows variations in crest separation pocket pressure without significant delay.

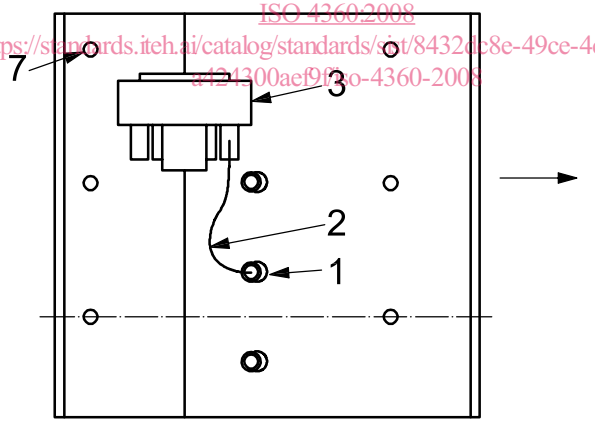
Adequate additional depth shall be provided in wells to avoid the danger of floats (if used) grounding either on the bottom or on any accumulation of silt or debris.

The gauge well arrangement may include an intermediate chamber of similar size and proportions to the approach channel, to enable silt and other debris to settle out where it may be readily seen and removed.

The diameter of the connecting pipe or width of slot to the upstream well shall be sufficient to permit the water level in the well to follow the rise and fall of head without appreciable delay. Care should be taken however not to oversize the pipe, in order to ensure ease of maintenance and to damp out any oscillations due to short period waves.



a) Side view (in direction of flow) b) Side view (normal to flow)



c) View of tappings from underneath the weir

Key

1 crest tappings
2 feed tubes communicating crest head to the manifold (some shown as single lines only)
3 manifold [section in view b)]
4 cavity in the crest of the weir block
5 conduit leading to a gauge well
6 transmission tube (other end sealed within the conduit but communicating head in the manifold to the gauge well)
7 holes for screw-mounting the crest plate onto the weir block

Figure 3 — General arrangement for the crest tapping installation