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Hydrometry — Open channel flow measurement using rectangular broad-crested weirs

Hydrométrie — Mesure de débit des liquides dans les canaux découverts au moyen de déversoirs rectangulaires à seuil épais

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Foreword

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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 3846 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 3846:1989), of which it constitutes a technical revision.

Hydrometry — Open channel flow measurement using rectangular broad-crested weirs

1 Scope

This International Standard lays down requirements for the use of rectangular broad-crested weirs for the accurate measurement of flow of clear water in open channels under free flow conditions.

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*

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 weir crest perpendicular to flow direction
C	—	discharge coefficient (gauged head)
f	—	drowned flow reduction factor
fC	—	combined coefficient of discharge
C_d	—	discharge coefficient (total head)
C_v	—	coefficient of velocity
E	m	encoder height from datum
e_b	m	random uncertainty in the width measurement
g	m/s^2	acceleration due to gravity
H	m	total head above crest level
h	m	gauged head above crest level (upstream head is inferred if no subscript is used)
L	m	length of weir in the direction of flow
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
S	—	submergence ratio, h_2/h_1
S_1	—	modular limit
$\bar{v}_1$	m/s	mean velocity in the approach channel
U	%	expanded percentage uncertainty
$u^*(b)$	%	percentage uncertainty in b
$u^*(C)$	%	percentage uncertainty in C
$u^*(h_1)$	%	percentage uncertainty in h_1
$u^*(Q)$	%	percentage uncertainty in Q

Subscripts

1 upstream

2 downstream

c combined

E encoder

t distance between the (upstream) gauged head and the encoder

5 Installation

5.1 General

The conditions regarding the preliminary survey, selection of site, installation, approach channel, maintenance, measurement of the head, and stilling or float wells, which are generally necessary for flow measurement, are given in 5.2, 5.3, 6 and 7. The particular requirements for the rectangular broad-crested weir are given separately in Clause 8.

5.2 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 flow measurement by the weir.

Particular attention shall be paid to the following features in selecting the site for the weir:

a) the 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 (see 5.3.2);

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

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

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 effects of wind, which can have a considerable effect on the flow in a river, or over a weir, especially when the river or weir is 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 measurements, 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 the 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. These include velocity rods, floats or concentrations of dye, which can be used in small channels; the last is useful to check the conditions at the bottom of the channel. A complete and quantitative assessment of the velocity distribution may be made by means of a current-meter or other point velocity instruments. More 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 [3].

5.3 Installation conditions

5.3.1 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 from the gauging structure.

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

Once a weir has been installed, the user shall prevent any changes which could affect the discharge characteristics.

5.3.2 The approach channel

On all installations, the flow in the approach channel shall be smooth, free from disturbance and 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. The following general requirements shall be complied with.

a) The altered flow conditions owing 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.

5.3.3 The 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.

5.3.4 Downstream of the structure

If the downstream channel is rectangular and of the same width as the weir for a distance equal to twice the maximum head downstream from the downstream face of the weir, then it is not necessary to ventilate the nappe, particularly for high values of h_1/L.

The channel further downstream from the structure is usually of no importance as such, provided that the weir has been designed to ensure that the flow is modular (i.e. unaffected by tailwater level) under all operating conditions.

However, the water level may be raised sufficiently to drown the weir if the altered flow conditions due to the construction of the weir cause the build-up of shoals of debris immediately downstream of the structure or if river works are carried out at a later date.

Any accumulation of debris downstream of the structure shall therefore be removed.

6 General maintenance requirements

Maintenance of the measuring structure and the approach channel is important to secure continued accuracy of the measurements.

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

It is essential that the approach channel to weirs be kept clean and free from silt and vegetation as far as practicable for at least the distance specified in 5.3.2. The float well and the entry from the approach channel shall also be kept clean and free from deposits.

The weir 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.

7 Measurement of head(s)

7.1 General

The head upstream of the measuring structure may be measured by a hook gauge, point gauge or staff gauge where spot measurements are required or by a recording gauge where a continuous record is required. In many cases, it is preferable to measure heads in a separate stilling well to reduce the effects of surface irregularities.

The discharges calculated using the working equation are volumetric figures, and the liquid density does not affect the volumetric discharge for a given head provided that the operative head is gauged using a liquid of identical density. If the gauging is carried out in a separate well, correction for the difference in density may be necessary if the temperature of the liquid in the well is significantly different from that of the flowing liquid. However, it is assumed herein that the densities are equal.

It shall, however, be ensured that the gauge is not located in a pocket or still pool, but that it measures the piezometric head.

7.2 Stilling or float well

Where provided, the stilling well shall be vertical and, for field installations, shall extend at least 0,6 m above the maximum estimated water level.

Stilling wells shall be connected to the channel by an inlet pipe, or slot, large enough to permit the water in the well to follow the rise and fall of the head without significant delay. For field installations, the level of the inlet pipe shall be at least 0,1 m below minimum water level.

The connecting pipe or slot shall, however, be as small as possible with regard to ease of maintenance. Alternatively, the connecting pipe or slot shall be fitted with a constriction to damp out oscillations due to short amplitude waves.

The well and the connecting pipe or slot shall be watertight. The well shall be of adequate diameter and depth to accommodate the float of a level recorder, if used.

The well shall also be deep enough to accommodate any sediment which may enter, without the float grounding. The float well arrangement may include an intermediate chamber between the stilling well and the approach channel, of similar proportions to those of the stilling well to enable sediment to settle out. For ease of maintenance, the pipework may be fitted with valves.

More detailed information on the stilling well may be obtained from ISO 1100-1 [2].

7.3 Zero setting

A means of checking the zero setting of the head measuring device shall be provided, consisting of a datum related to the level of the weir crest.

A zero check based on the level of the water when the flow ceases is liable to incur serious errors from surface tension effects and shall not be used.

With decreasing size of the weir and the head, small errors in construction and in the zero setting and reading of the head measuring device become of greater importance.

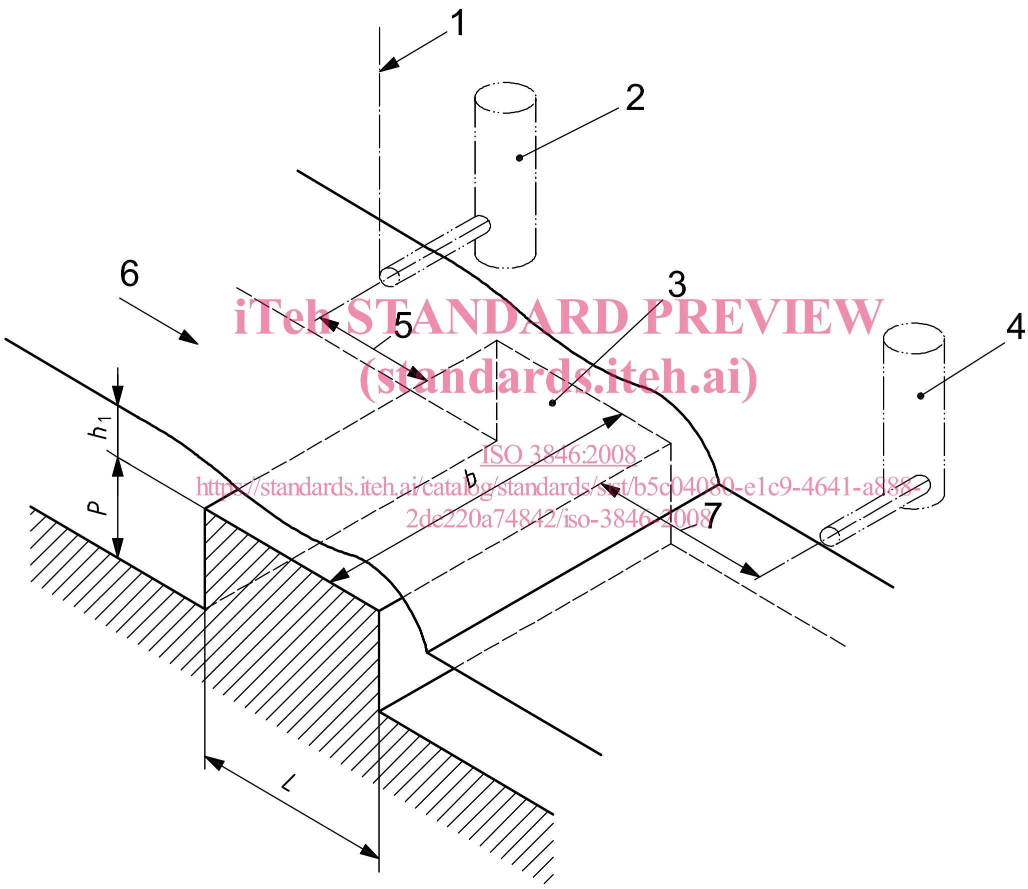
8 Rectangular broad-crested weirs

8.1 Specification for the standard weir

The crest of the standard weir shall be a smooth, horizontal, rectangular plane surface (in these specifications a "smooth" surface shall have a surface finish equivalent to that of rolled sheet metal). The width of the crest perpendicular to the direction of flow shall be equal to the width of the channel in which the weir is located. The upstream and downstream end faces of the weir shall be smooth, plane surfaces and they shall be perpendicular to the sides and the bottom of the channel in which the weir is located. The upstream face, in particular, shall form a sharp right-angle corner at its intersection with the plane of the crest.

If the upstream corner of the weir is slightly rounded, the discharge coefficient can increase significantly.

A typical sketch of the weir is shown in Figure 1.



Key

1 head gauging station
2 upstream stilling well
3 horizontal crest
4 downstream stilling well
5 $3h_{1,max}$ to $4h_{1,max}$
6 flow
7 $10h_{1,max}$

Figure 1 — Rectangular broad-crested weir

8.2 Location of the head gauge section

8.2.1 Upstream head measurement

Piezometers or a point-gauge station for the measurement of the head on the weir shall be located at a sufficient distance upstream from the weir to avoid the region of surface drawdown. They (or it) shall, however, be close enough to the weir for the energy loss between the section of the measurement and the control section on the weir to be negligible. It is recommended that the head measurement section be located at a distance equal to three to four times the maximum head (i.e. 3 $h_{1,\text{max}}$ to 4 $h_{1,\text{max}}$) upstream from the upstream face of the weir.

8.2.2 Downstream head measurement

If the weir is to be operated in the drowned flow range, a measurement of downstream head is required. The downstream head measurement position shall be 10$h_{1,\text{max}}$ downstream from the face of the weir. At this location, the turbulence associated with energy dissipation near to the weir has subsided to an acceptable level. The downstream head measurement position should be located within the parallel sidewalls of the weir structure.

8.3 Provision for modular flow

Flow over a rectangular broad-crested weir is not affected by tailwater levels if the crest level is chosen such that the submergence ratio, $S = \frac{h_2}{h_1}$, does not exceed the modular limit. The modular limit is given in Annex A.

9 Discharge relationships

9.1 Modular flow discharge equation

The equation of discharge is based on the use of a gauged head:

$$Q = \left(\frac{2}{3}\right)^{3/2} g^{1/2}\, b\, C\, h_1^{3/2} \tag{1}$$

where

Q is the volumetric rate of flow;

g is the acceleration due to gravity;

b is the width of the weir perpendicular to the direction of flow;

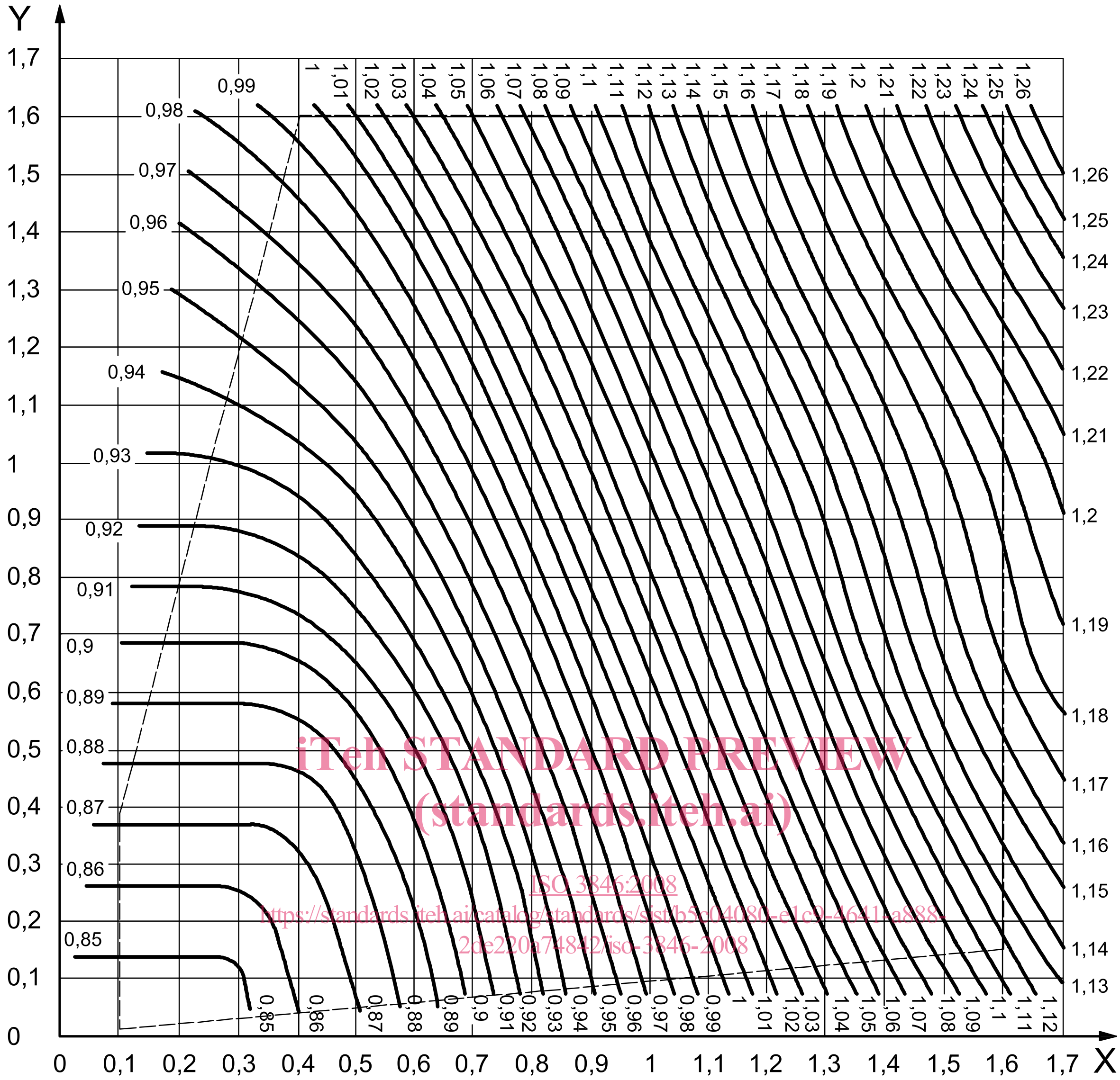
C is the gauged head discharge coefficient;

h_1 is the upstream gauged head related to the crest elevation.

9.2 Modular coefficient of discharge

The gauged head discharge coefficient, C, is given in Figure 2 and Table 1 as a function of h_1/L and h_1/p, where L is the length of the weir in the direction of flow and p is the height of the weir with respect to the bottom of the approach channel.

Intermediate values of C may be obtained by linear interpolation.



NOTE For the meaning of the dashed lines, see 9.3.

Key

X h_1/L

Y h_1/p

Figure 2 — Coefficient of discharge, C, in terms of h_1/p and h_1/L

