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Hydrometric determinations — Flow measurement in open channels using structures — Flat-V weirs

Déterminations hydrométriques — Mesure de débit dans les canaux découverts au moyen de structures — Déversoirs en V ouvert

Reference number
ISO 4377:2012(E)

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 4377 was prepared by Technical Committee ISO/TC 113, *Hydrometry*, Subcommittee SC 2, *Flow measurement structures*.

This fourth edition cancels and replaces the third edition (ISO 4377:2002), which has been technically revised to update the treatment of uncertainty to be consistent with the other standards relating to flow measurement structures.

Hydrometric determinations — Flow measurement in open channels using structures — Flat-V weirs

1 Scope

This International Standard describes the methods of measurement of flow in rivers and artificial channels under steady or slowly varying conditions using flat-V weirs (see Figure 1).

Annex A gives guidance on acceptable velocity distribution.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies

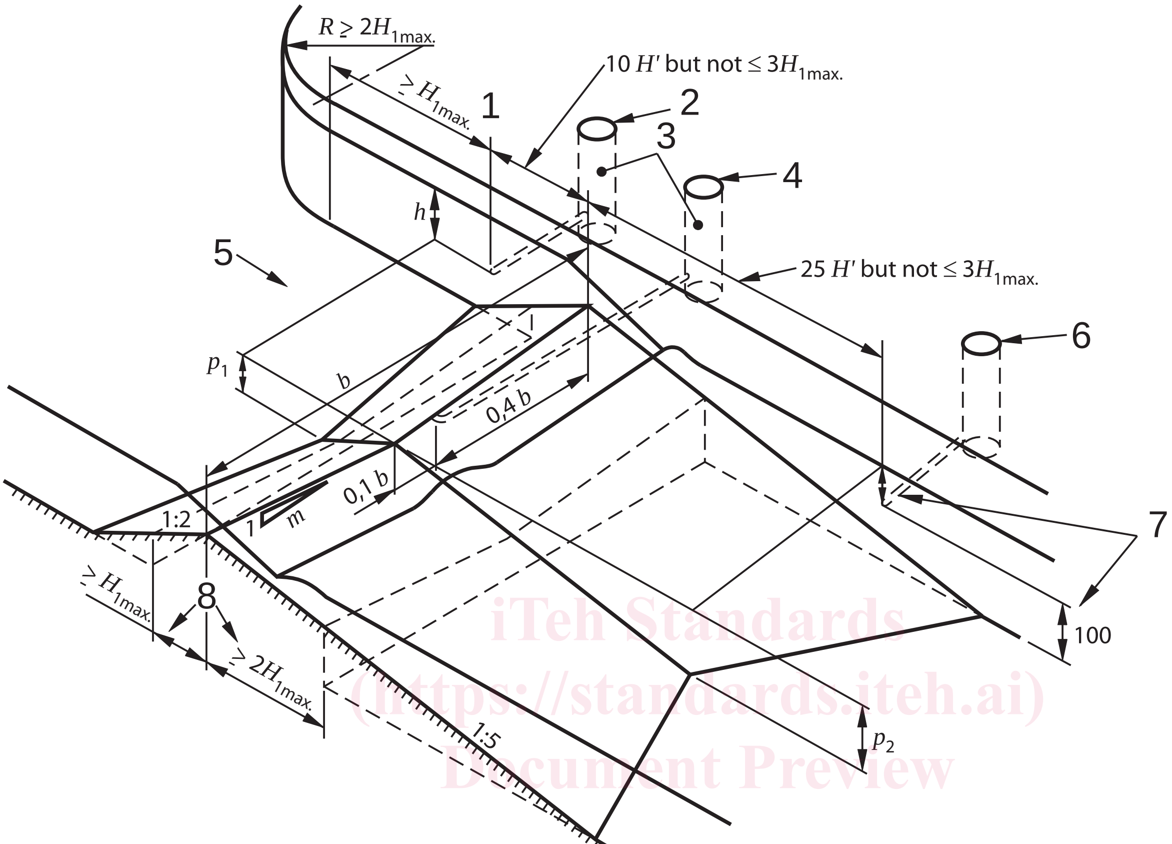
ISO 772, *Hydrometry — Vocabulary and symbols*

ISO/TS 25377, *Hydrometric uncertainty guidance (HUG)*

3 Terms and definitions

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

Dimensions in millimetres



Key

1 head gauging section

2 upstream tapping

3 stilling wells

4 crest tapping

5 flow

6 downstream head measuring point

7 minimum 100 mm above stilling basin level

8 limits of permissible upstream and downstream truncations

b crest width

H' difference between the invert (apex) of the V and the top of the V

H_{1max} maximum upstream total head above crest elevation

h gauged head above lowest crest elevation

p difference between mean bed level and lowest crest elevation

Figure 1 — Triangular profile flat-V weir

4 Symbols

The following is a list of symbols used, with the corresponding units of measurement.

Symbol[a]	Meaning	Units
A	Area of cross-section of flow	m^2
B	Width of approach channel	m
b	Crest width	m
C_{D}	Coefficient of discharge	Non-dimensional
C_{De}	Effective coefficient of discharge	Non-dimensional
C_{dr}	Drowned flow reduction factor	Non-dimensional
C_{v}	Coefficient of approach velocity	Non-dimensional
g	Gravitational acceleration (standard value)	ms^{-2}
H	Total head above lowest crest elevation	m
$H_{1\mathrm{e}}$	Total effective upstream head	m
$H_{2\mathrm{e}}$	Total effective downstream head	m
$H_{1\mathrm{max}}$	Maximum upstream total head above crest elevation	m
h	Gauged head above lowest crest elevation	m
h_1	Upstream gauged head	m
$h_{1\mathrm{e}}$	Effective upstream gauged head	m
h_2	Downstream gauged head	m
$h_{2\mathrm{e}}$	Effective downstream gauged head	m
h_{p}	Separation pocket head	m
h_{pe}	Effective separation pocket head relative to lowest crest elevation	m
h', H'	Difference between lowest and highest crest elevations	m
K_1,K_2	Constants	Non-dimensional
k_{h}	Head correction factor	m
L_1	Distance of upstream head measurement position from crest line	m
m	Crest cross-slope (1 vertical: m horizontal)	Non-dimensional
n	Number of measurements in a set	Non-dimensional
p	Difference between mean bed level and lowest crest elevation	m
Q	Discharge	m^3s^{-1}
Q_{dfv}	Total daily flow volume	m^3d^{-1}
t	Measurement observation frequency time	minutes
$\bar{v}$	Mean velocity at cross-section	m/s
$\bar{v}_{\mathrm{a}}$	Mean velocity in approach channel	m/s
u_{h}	Absolute uncertainty in head measurement	m
$u(E)$	Absolute uncertainty in gauge zero	m
$u^*(_{\mathrm{CD}})$	Percentage uncertainty in discharge coefficient	Non-dimensional
$u^*(C_{\mathrm{v}})$	Percentage uncertainty in coefficient of velocity	Non-dimensional
$u^*(C_{\mathrm{dr}})$	Percentage uncertainty in drowned flow reduction factor	Non-dimensional
$u^*(h)$	Percentage uncertainty in head measurement	Non-dimensional
$u^*(H_{\mathrm{e}})$	Percentage uncertainty in total effective head	Non-dimensional
$U^*(Q)$	Percentage uncertainty in discharge determination	Non-dimensional
$U^*(Q_{\mathrm{dmf}})$	Percentage uncertainty in the daily mean flow	Non-dimensional
$U^*(Q_{\mathrm{dfv}})$	Percentage uncertainty in the total daily flow volume	Non-dimensional
Z_{h}, Z_{H}	Shape factors	Non-dimensional
α	Coriolis energy coefficient	Non-dimensional

Subscript

1 denotes upstream value

2 denotes downstream value

e denotes “effective” and implies that corrections for fluid effects have been made to the quantity

a denotes approach channel

5 Characteristics of flat-V weirs

The standard flat-V weir is a control structure, the crest of which takes the form of a shallow V when viewed in the direction of flow.

The standard weir has a triangular profile with an upstream slope of 1 (vertical): 2 (horizontal) and a downstream slope of 1:5. The cross-slope of the crest line shall not be steeper than 1:10. The cross-slope shall lie in the range of 0 to 1:10 and, at the limit when the cross-slope is zero, the weir becomes a two-dimensional triangular profile weir.

The weir can be used in both the modular and drowned ranges of flow. In the modular flow range, discharges depend solely on upstream water levels and a single measurement of upstream head is sufficient. In the drowned flow range, discharges depend on both upstream and downstream water levels, and two independent head measurements are required. For the standard flat-V weir, these are

— the upstream head, and

— the head developed within the separation pocket which forms just downstream of the crest or, as a less accurate alternative, the head measured just downstream of the structure.

The flat-V weir will measure a wide range of flows and has the advantage of high sensitivity at low flows.

Operation in the drowned flow range minimizes afflux at very high flows. Flat-V weirs shall not be used in steep rivers (see 6.2.2.6), particularly where there is a high sediment load.

There is no specified upper limit for the size of this structure. Table 1 gives the ranges of discharges for three typical weirs.

Table 1 — Ranges of discharge

Elevation of crest above bed m	**Crest/cross-slope ratio**	**Width** m	**Range of discharge** m^3s^{-1}
0,2	1:10	4	0,015 to 5
0,5	1:20	20	0,030 to 180 (within maximum head of 3 m)
1,0	1:40	80	0,055 to 630 (within maximum head of 3 m)

6 Installation

6.1 Selection of site

6.1.1 The weir shall be located in a straight section of the channel, avoiding local obstructions, roughness or unevenness of the bed.

6.1.2 A preliminary study of the physical and hydraulic features of the proposed site shall be made, to check that it conforms (or can be constructed or modified to conform) to the requirements necessary for measurement of discharge by the weir. Particular attention shall be paid to the following:

a) the adequacy of the length of channel of regular cross-section available (see 6.2.2.2);

b) the uniformity of the existing velocity distribution (see Annex A);

c) the avoidance of a steep channel (see 6.2.2.6);

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

e) the conditions downstream (including such influences as tides, confluences with other streams, sluice gates, mill dams and other controlling features, such as seasonal weed growth, 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;

i) the uniformity of the approach channel section;

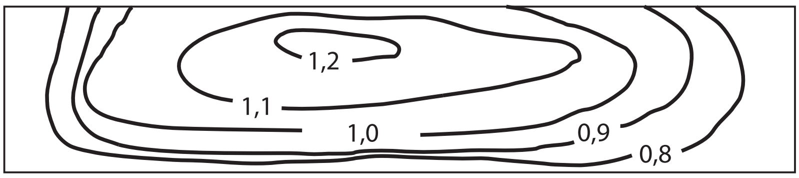
j) the effect of wind on the flow over the weir, especially when it is wide and the head is small and when the prevailing wind is in a transverse direction.

k) If silt removal could be an operation and maintenance requirement, consideration should be given to the accessibility of the site for heavy plant following construction and reinstatement of the site.

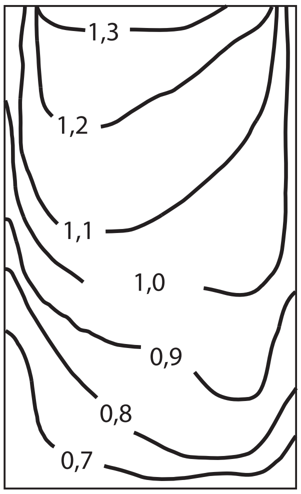
l) A suitable location is required for the instrument building/housing to allow the effective operation and maintenance of the intake pipe and stilling well.

6.1.3 If the site does not possess the characteristics necessary for satisfactory measurements, or if an inspection of the stream shows that the velocity distribution in the approach channel deviates appreciably from the examples shown in Figure 2, the site shall not be used unless suitable improvements are practicable.

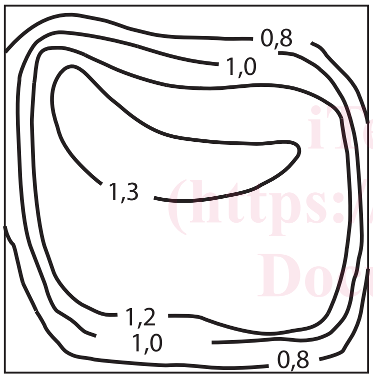
6.1.4 Weirs act as obstacles to the movement of most fish and other aquatic species. Care should therefore be taken to ensure that the installation of gauging structures such as flat-V weirs does not have a detrimental effect on the aquatic ecology where this might be an issue. In addition, care should be taken to ensure that any gauging structure complies with the relevant national and international legislation and regulations, for example the European Parliament EU Water Framework Directive (Directive 2000/60/EC). Where the movement of aquatic life could be compromised by the installation of a flow measurement structure, this may have to be reflected in the design, e.g. limit the crest height and provide an adequate depth of stilling basin. Alternatively, a fishpass could be installed (ISO 26906).

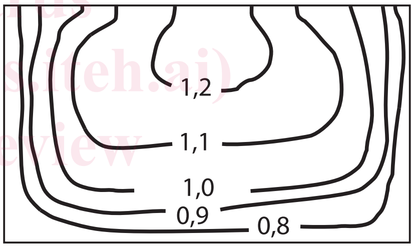


a) $\left(\frac{\alpha_{\text{left}}}{\alpha_{\text{right}}}-1\right)\times 100 = 6{,}9\ \%$



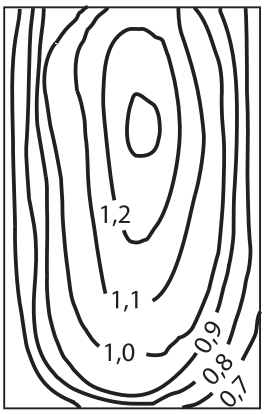
b) $\left(\frac{\alpha_{\text{left}}}{\alpha_{\text{right}}}-1\right)\times 100 = 9{,}0\ \%$

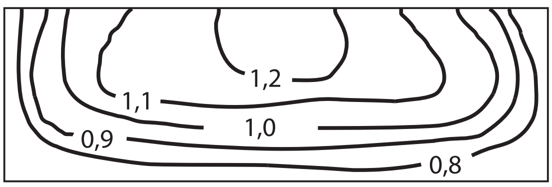




c) $\left(\frac{\alpha_{\text{left}}}{\alpha_{\text{right}}}-1\right)\times 100 = 12{,}3\ \%$

d) $\left(\frac{\alpha_{\text{left}}}{\alpha_{\text{right}}}-1\right)\times 100 = 1{,}2\ \%$





e) $\left(\frac{\alpha_{\text{left}}}{\alpha_{\text{right}}}-1\right)\times 100 = 0{,}6\ \%$

f) $\left(\frac{\alpha_{\text{left}}}{\alpha_{\text{right}}}-1\right)\times 100 = 0{,}9\ \%$

Figure 2 — Examples of velocity profiles in the approach channel

6.2 Installation conditions

6.2.1 General requirements

The complete measuring installation consists of an approach channel, a weir structure and a downstream channel.

NOTE 1 The condition of each of these three components affects the overall accuracy of the measurements. Installation requirements include such features as the surface finish of the weir, the cross-sectional shape of the channel, channel roughness and the influence of control devices upstream or downstream of the gauging structure.

NOTE 2 The distribution and direction of velocity can have an important influence on the performance of a weir (see 6.2.2 and Annex A).

NOTE 3 Once a weir has been installed, any physical changes in the installation will change the discharge characteristics; recalibration will then be necessary.

6.2.2 Approach channel

6.2.2.1 If the flow in the approach channel is disturbed by irregularities in the boundary (e.g. large boulders or rock outcrops, or by a bend, sluice gate or other feature which causes asymmetry of discharge across the channel), the accuracy of gauging may be significantly affected. The flow in the approach channel shall have a symmetrical velocity distribution (see Annex A). This can be achieved by providing a long, straight approach channel of uniform cross-section.

6.2.2.2 A minimum required length of straight approach channel shall be five times the width of the water surface at maximum flow, provided flow does not enter the approach channel with high velocity via a sharp bend or angled sluice gate.

NOTE 1 The length of straight approach channel required refers to the distance upstream from the upstream head measuring location (see Figure 1).

NOTE 2 A greater length of uniform approach channel is desirable if it can be readily provided.

6.2.2.3 In a natural channel where it is uneconomic to line the bed and banks with concrete for this distance, and iwhere the width between the vertical walls of the lined approach to the weir is less than the approach width of the natural channel, the banks shall be profiled to give a smooth transition from the approach channel width to the width between the vertical side walls. The unlined channel upstream of the contraction shall nevertheless conform to 6.2.2.1 and 6.2.2.2.

6.2.2.4 Vertical side walls constructed to effect a narrowing of the natural channel shall be symmetrically aligned with the centre line of the channel and curved to a radius not less than 2 H_{1max} as shown in Figure 1. The tangent point of this radius nearest to the weir crest shall be at least H_{1max} upstream of the head measurement section. The height of the side walls shall be chosen to contain the design maximum discharge.

6.2.2.5 In a channel where the flow is free from floating and suspended debris, good approach conditions can also be provided by suitably placed baffles formed of vertical laths. No baffle shall be nearer to the point at which the head is measured than 10 times the maximum upstream head.

6.2.2.6 Under certain conditions, a hydraulic jump may occur upstream of the measuring structure, for example if the approach channel is steep. Provided the wave created by the hydraulic jump is at a distance upstream of no less than 20 times the maximum upstream depth, flow measurement is feasible, subject to confirmation that an even velocity distribution exists at the gauging station.

6.2.2.7 Conditions in the approach channel can be verified by inspection or measurement for which several methods are available such as acoustic Doppler current profilers (ADCPs), current meters, floats or concentrations of dye, the last being useful in checking conditions at the bottom of the channel. A complete and quantitative assessment of velocity distribution can be made by means of an ADCP or a current meter. The velocity distribution shall comply with the requirements of A.5.

6.3 Weir structure

6.3.1 The structure shall be rigid and watertight and capable of withstanding flood flow conditions without damage from outflanking or from downstream erosion. The weir crest shall be straight when viewed from above and at right angles to the direction of flow in the upstream channel. The geometry shall conform to the dimensions given in Clause 5 and Figure 1.

The weir shall be contained within vertical side walls, and the crest width shall not exceed the width of the approach channel (see Figure 1). Weir blocks may be truncated but their horizontal dimensions shall not be reduced in the direction of flow to less than $H_{1\text{max}}$ and 2 $H_{1\text{max}}$, upstream and downstream of the crest line respectively, where $H_{1\text{max}}$ is the maximum upstream total head, expressed in metres, relative to the lowest crest elevation.

6.3.2 The weir and the approach channel as far as the upstream tapping point shall be constructed with a smooth non-corrodible material. A good surface finish is important near the crest but can be relaxed a distance along the profile of 0,5 $H_{1\text{max}}$ upstream and downstream of the crest line.

The crest shall be formed by using smooth material resistant to erosion and corrosion, for example, an embedded stainless steel insert with bevelled edges to conform with the surface of the weir block.

6.3.3 In order to minimize uncertainty in the discharge, the following tolerances are acceptable:

a) crest width (0,2 % with a maximum of 0,01 m);

b) upstream slope 1,0 %;

c) downstream slope 1,0 %;

d) crest cross-slope 1,0 %;

e) point deviations from the mean crest line ± 0,2 % of the crest width.

NOTE Laboratory installations will normally require higher accuracy.

6.3.4 The structure shall be measured upon completion and mean dimensional values and their standard deviations (SD) at the 68 % confidence limits computed. The former are used for computation of discharge and the latter are used to obtain the overall uncertainty of a single determination of discharge (see 11.2).

6.4 Downstream conditions

Conditions downstream of the structure are an important factor controlling the tailwater level. This level is one of the factors which determines whether modular or drowned flow conditions will occur at the weir. It is essential, therefore, to calculate or observe tailwater levels over the full discharge range and make decisions regarding the type of weir and its required geometry in light of this evidence.

7 Maintenance

Maintenance of the measuring structure and the approach channel is important to enable accurate measurements to be made. The approach channel shall be kept clean and free from silt and vegetation for at least the distance specified in 6.2.2.2. The float wells, tappings and connecting pipework shall also be kept clean and free from deposits.

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

The weir crest shall be inspected for erosion damage regularly. If the mean effective radius of the crest exceeds 5 mm, then refurbishment shall be considered. Algae growth on weir crests can be a particular

