INTERNATIONAL STANDARD

ISO 4377

Second edition
1990-02-15

Liquid flow measurement in open channels — Flat-V weirs

Mesure de débit des liquides dans les canaux découverts — Déversoirs en V ouvert

Reference number
ISO 4377 : 1990 (E)

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. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 4377 was prepared by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels.*

This second edition cancels and replaces the first edition (ISO 4377 : 1982), of which it constitutes a technical revision.

Annexes A and B form an integral part of this International Standard. Annex C is for information only.

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Printed in Switzerland

Liquid flow measurement in open channels — Flat-V weirs

1 Scope

1.1 This International Standard deals with the measurement of flow in rivers and artificial channels using flat-V weirs under steady or slowly varying flow conditions. 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.

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

a) the upstream head;

b) the head developed within the separation pocket which forms just downstream of the crest.

2 General

2.1 The standard flat-V weir is of triangular profile with an upstream vertical:horizontal slope of 1:2 and a downstream slope of 1:5. The cross-slope is in the range 0 to 1:10 and at the limit, when the cross-slope is zero, the weir becomes a two-dimensional triangular profile weir (see ISO 4360).

2.2 The flat-V weir will measure a wide range of flows and has the advantage of high sensitivity to low flows. Operation in the drowned flow range minimizes afflux at very high flows. Flat-V weirs should not be used in steep rivers, particularly where there is a high sediment load.

2.3 ISO 8368 gives guidelines for the selection of weirs and flumes for the measurement of the discharge of water in open channels.

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

Table 1 — The range of discharge for three typical flat-V weirs

Elevation of crest above bed m	Crest cross-slope	Width m	Range of discharge m^3/s
0,2	1:10	4	0,015 to 5
0,5	1:20	20	0,03 to 180 (within maximum head of 3 m)
1	1:40	80	0,055 to 630 (within maximum head of 3 m)

3 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 772 : 1988, *Liquid flow measurement in open channels — Vocabulary and symbols.*

ISO 5168 : 1978, *Measurement of fluid flow — Estimation of uncertainty of a flow-rate measurement.*

4 Definitions and symbols

For the purposes of this International Standard, the definitions given in ISO 772 apply. A full list of symbols together with the corresponding units of measurement is given in annex A.

5 Installation

5.1 Selection of site

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

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

a) the adequacy of the length of channel of regular cross-section available (see 5.2.2.2);

b) the uniformity of the existing velocity distribution (see annex B);

c) the avoidance of a steep channel (but see 5.2.2.6);

d) the effects of increased upstream water levels 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 (including 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 cross-section of the approach channel;

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

5.1.3 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 described in annex B, the site shall not be used unless suitable improvements are practicable. Alternatively, the performance of the installation should be checked using independent flow measurements.

5.2 Installation conditions

5.2.1 General requirements

5.2.1.1 The complete measuring installation consists of an approach channel, a weir structure and a downstream channel. The condition of each of these three components affects 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.

5.2.1.2 The distribution and direction of velocity may have an important influence on the performance of a weir (see 5.2.2 and annex B).

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

5.2.2 Approach channel

5.2.2.1 If the flow in the approach channel is disturbed by irregularities of the bottom and the banks, for example by 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 should have a symmetrical velocity distribution (see annex B). This can most readily be achieved by providing a long straight approach channel of uniform cross-section.

5.2.2.2 A length of straight approach channel five times the water-surface width at maximum flow will usually suffice provided that flow does not enter the approach channel with high velocity via a sharp bend or angled sluice gate. However, a greater length of uniform approach channel is desirable if it can readily be provided.

5.2.2.3 The length of uniform approach channel suggested in 5.2.2.2 refers to the distance upstream of the head measuring position. However, in a natural channel it could be uneconomic to line the bed and banks with concrete for this distance, and it could be necessary to provide a contraction in plan if the width between the vertical walls of the lined approach to the weir is less than the width of the natural channel. The unlined channel upstream of the contraction should nevertheless comply with the requirements of 5.2.2.1 and 5.2.2.2.

5.2.2.4 Vertical side walls constructed to effect a narrowing of the natural channel shall be symmetrically disposed with respect to the centreline of the channel and should preferably be curved with a radius R of not less than $2H_{max}$, as shown in figure 1. The tangent point of this radius nearest to the weir shall be at least H_{max} upstream of the head measurement section. The height of the side walls shall be chosen to contain the design maximum discharge.

5.2.2.5 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 from vertical laths, but no baffle shall be nearer to the point at which the head is measured than a distance of $10H_{max}$.

5.2.2.6 Under certain conditions a hydraulic jump may occur upstream of the measuring structure, e.g. if the approach channel is steep. Provided that this wave is at a distance upstream of not less than about $30H_{max}$, flow measurement will be feasible, subject to confirmation that a regular velocity distribution exists at the gauging station.

5.2.2.7 Conditions in the approach channel can be verified by inspection or measurement for which several methods are available, such as current-meters, floats, velocity rods and con-

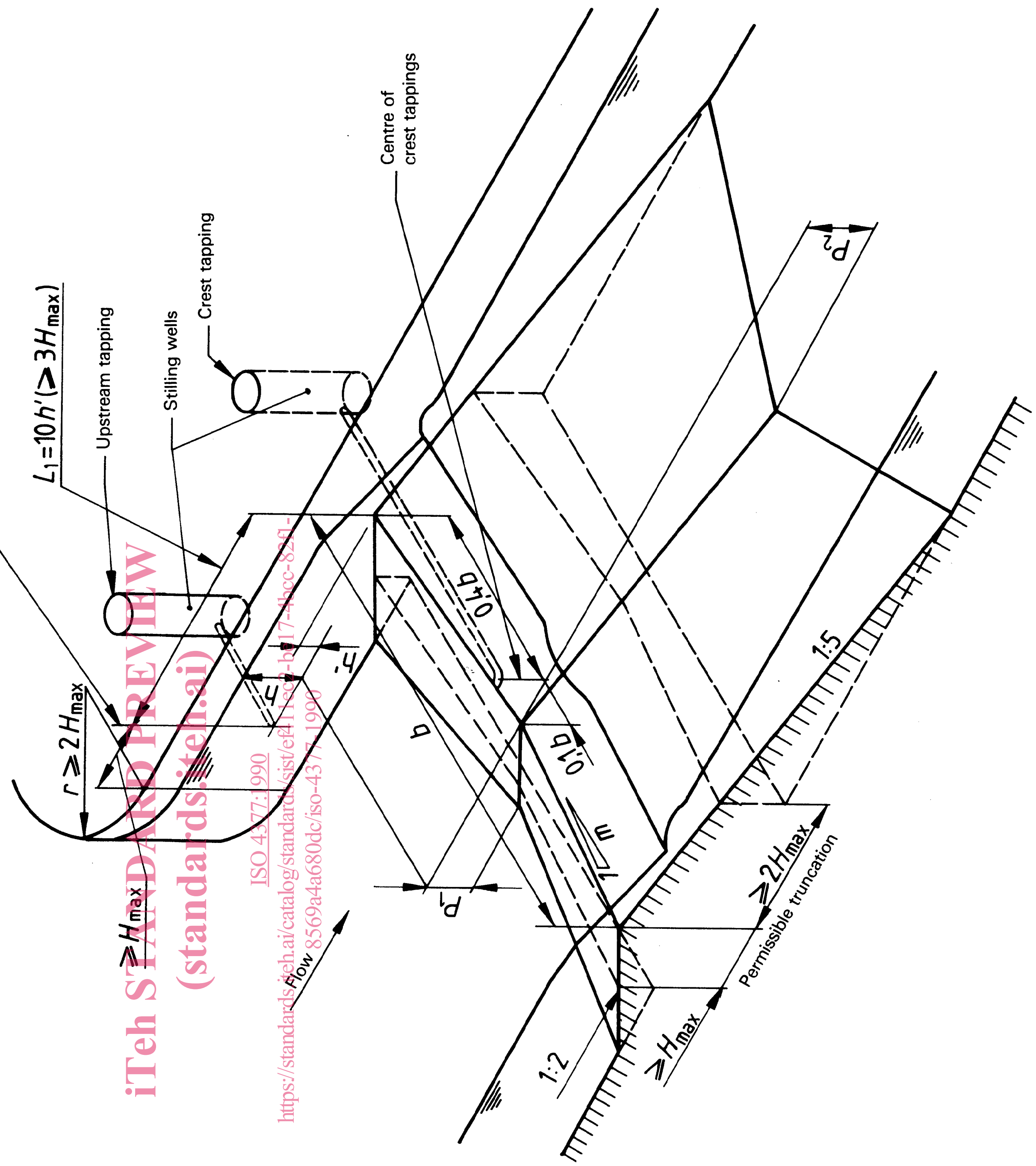

Figure 1 — Triangular profile of a flat-V weir

centrations of dye; 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. More information about the use of current-meters is given in ISO 748. The velocity distribution should then be assessed by reference to annex B.

5.3 Weir structure

5.3.1 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 in plan and perpendicular to the direction of flow in the upstream channel, and the geometry shall conform to the dimensions given in the relevant clauses.

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 not so as to reduce their horizontal dimensions in the direction of flow to less than H_{max} and $2H_{max}$ upstream and downstream respectively of the crest line.

5.3.2 The weir and the immediate approach channel (the part with vertical side walls) may be constructed in concrete with a smooth cement finish or surfaced with a smooth non-corrodible material. In laboratory installations, the finish shall be equivalent to that of rolled sheet metal or planed, sanded and painted timber. The surface finish is of particular importance near the crest but the requirements may be relaxed beyond a distance $1/2H_{max}$ upstream and downstream of the crest line.

5.3.3 To minimize uncertainty in the discharge, the following tolerances should be aimed at during construction:

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

b) on the upstream and downstream slopes, 0,5 %;

c) on the crest cross-slope, 0,1 %;

d) on point deviations from the mean crest line, 0,05 % of the crest width.

Laboratory installations will normally require greater accuracy of dimensions.

5.3.4 The structure shall be measured on completion of construction and average values of the relevant dimensions and their standard deviations at 95 % confidence limits shall be computed. The average values are used for computation of the discharge and the standard deviations are used to obtain the overall uncertainty in a single determination of discharge (see 10.6).

5.4 Downstream of the structure

Conditions downstream of the structure are important in that they control the tail-water levels. 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 tail-water levels over the full discharge range and to make decisions regarding the type of the weir and its required geometry in the light of this evidence.

Consideration should be given to providing means for downstream energy dissipation together with protection works to prevent erosion and/or possible undermining of the structure.

6 Maintenance — General requirements

Maintenance of the measuring structure and the approach and downstream channels is important to secure accurate measurements. It is essential that the approach channel be kept clean and free from silt and vegetation as far as practicable for the minimum distance specified in 5.2.2.2. The float well and the entry from the approach channel shall also be kept clean and free from deposits.

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.

7 Measurement of head(s)

7.1 General requirements

7.1.1 Where spot measurements are required, heads can be measured by using vertical gauges, hooks, points, wires or tape gauges. Where continuous records are required, recording gauges shall be used. The locations which shall be used for the head measurements are dealt with in 7.4.

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

7.2 Gauge wells

7.2.1 It is preferable to measure the upstream head in a gauge well to reduce the effects of water-surface irregularities. When this is done, it is also desirable to measure the head in the approach channel as a check from time to time. Where the weir is designed to operate in the drowned flow range, a separate gauge well is required to record the piezometric head within the separation pocket which forms immediately downstream of the crest.

7.2.2 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 0,3 m above the maximum water levels expected. Gauge wells shall be connected to the appropriate head measurement positions by means of pipes.

7.2.3 Both the well and the connecting pipe shall be watertight, and where the well is provided for the accommodation of the float of a level recorder, it shall be of adequate size and depth to give clearance around and beneath the float at all stages. The float shall not be nearer than 0,075 m to the wall of the well.

7.2.4 The pipe shall have its invert not less than 0,06 m below the lowest level to be gauged.

7.2.5 The pipe connection to the upstream head measurement position shall terminate flush with the boundary of the approach channel and at right angles thereto. The approach channel boundary shall be plain and smooth (equivalent to carefully finished concrete) within a distance of 10 times the diameter of the pipe from the centreline of the connection. The pipe may be oblique to the wall only if it is 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.

7.2.6 The pipe connection to the measurement position for the separation pocket head shall terminate in a manifold set within the crest of the weir. For large field installations, the outlet from this manifold shall consist of 10 holes 10 mm in diameter spaced at 50 mm intervals along a line parallel to, and 20 mm downstream of, the crest line. For laboratory and small field installations (b < 2,5 m), these dimensions shall be halved. The centre position of the 10 crest-tapping holes shall be offset laterally from the position of the lowest crest elevation at a distance of 0,1 times the total crest width (see figure 1). The holes shall be flush with the downstream face of the weir block, preferably in a metal cover plate which can be removed to facilitate maintenance of the system. It is important that this cover plate has an efficient seal around its perimeter. Locations for the head measurement positions are given in 7.4.

7.2.7 Adequate additional depth shall be provided in wells to avoid the danger of floats 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 between it and the approach channel to enable silt and other debris to settle out where they may be readily seen and removed.

7.2.8 The diameter of the connecting pipe or the width of the slot shall be sufficient to permit the water level in the well to follow the rise and fall of head without appreciable delay, although they shall be as small as possible, consistent with ease of maintenance, to damp out oscillations due to short-period waves.

7.2.9 No firm rule can be laid down for determining the size of the connecting pipe because this is dependent on the circumstances of the particular installation, e.g. whether the site is exposed, and thus subject to waves, and whether a large diameter well is required to house the floats of recorders. It is preferable to make the connection too large rather than too small because a restriction can easily be added later if short-period waves are not adequately damped out. A pipe 100 mm in diameter is usually suitable for a flow measurement in the field. A diameter of 3 mm may be appropriate for precision head measurement with steady flows in the laboratory.

7.2.10 Isolating valves with extended spindles shall preferably be fitted to connecting pipes inside the gauge wells so that the wells can be drained or pumped out and cleaned. If possible, the weir shall be connected to a drainage system via a sludge plug valve and pipeline.

7.3 Zero setting

7.3.1 Accurate initial setting of the zeros of the head measuring devices with reference to the level of the crest, and regular checking of these settings thereafter, is essential if overall accuracy is to be attained.

7.3.2 An accurate means of checking the zero at frequent intervals shall be provided. Bench marks, in the form of horizontal metal plates, shall be set up on the top of the vertical side walls and in the gauge wells. These shall be accurately levelled such that their elevation relative to crest level is known. Instrument zeros can then be checked relative to these bench marks without the necessity of re-surveying the crest each time. Any settlement of the structure may, however, affect the relationships between crest and bench mark levels and hence occasional checks on these relationships shall be made.

7.3.3 A zero check based on the water level (when the flow either ceases or just begins) is liable to serious errors due to surface tension effects and shall not be used.

7.3.4 Values for the crest cross-slope m and the gauge zero can be obtained by measuring the crest elevation at regular intervals along the crest line. A best-fit straight line is then fitted through the measured points for each side of the weir and the intersection of these lines is the gauge zero level. The average of the two side slopes is used for the value of m in the discharge formulae. For field installations, the use of standard levelling techniques is recommended but precise micrometer or vernier gauges shall be used for laboratory installations.

7.4 Location of head measurement sections

7.4.1 The approach flow to a flat-V weir is three dimensional. Drawdown in the approach to the lowest crest elevation is more pronounced than in the approaches to other positions across the width of the approach channel and this results in a depression in the water surface immediately upstream of the lowest crest position. Further upstream, this depression is less pronounced and at a distance of 10 times the V-height, $10h'$, the water-surface elevation across the width of the channel is approximately constant. Thus, to achieve an accurate assessment of the upstream head, the tapping shall be set a distance $10h'$ upstream of the crest line. $h' = b/2m$ is the difference between the lowest and the highest crest elevation in metres. However, if this distance is less than $3H_{max}$ the tapping shall be set a distance $3H_{max}$ upstream of the crest to avoid drawdown effects.

7.4.2 If other considerations necessitate siting the tapping closer to the weir, then corrections to the discharge coefficients will be necessary if $H_1/P_1 > 1$. In all cases an increase in coefficient is applicable and the percentage increase will depend on the tapping point location L_1 and the value of H_1/P_1 as shown in table 2 where

H_1 is the upstream total head relative to the lowest crest elevation;

P_1 is the height of the lowest crest elevation relative to the upstream bed level;

L_1 is the distance of the upstream head measurement position from the crest line.

Table 2 — Corrections to the discharge coefficient

L_1	Increase (%) in C_D for the following values of H_1/P_1		
	1	2	3
$10h'$	0	0	0
$8h'$	0	0,3	0,6
$6h'$	0	0,6	0,9
$4h'$	0	0,8	1,2

7.4.3 Flat-V weirs can be used for gauging purposes in the drowned flow range if a tapping is incorporated at the crest (see 7.2.6).

8 Discharge relationships

8.1 Discharge equation

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

$$Q = \left(\frac{4}{5}\right)^{5/2} \left(\frac{1}{2}\right)^{1/2} C_D C_v C_S C_{dr} m g^{1/2} h^{5/2} \qquad \ldots (1)$$

where

Q is the total discharge;

C_D is the discharge coefficient;

C_v is the velocity of approach factor;

C_S is the shape factor;

C_{dr} is the drowned flow reduction factor;

m is the crest cross-slope;

g is the acceleration due to gravity;

h is the upstream gauged head relative to the lowest crest elevation.

8.2 Discharge coefficent

The discharge coefficent is given by

$$C_D = C_{Dm}\left(\frac{h_e}{h}\right)^{5/2} = C_{Dm}(1 - k_m/h)^{5/2} \qquad \ldots (2)$$

where

C_{Dm} is the modular coefficent of discharge;

h_e is the effective gauged head, which is equal to $h - k_m$;

k_m is the head correction factor.

Both C_{Dm} and k_m depend on the cross-slope of the weir. They are given in table 3.

For field measurement, k_m is negligible because it is less than 1 mm.

8.3 Velocity of approach factor

Since the discharge equation is derived from a formula in which the total head is used, a velocity of approach factor C_v is introduced to correct the gauged head, i.e.

$$C_v = (H_1/h)^{5/2} \qquad \ldots (3)$$

where H_1 is the upstream total head with respect to the lowest crest elevation.

Using equation (1)

$$H_1 = h + \frac{v_1^2}{2g}$$

$$= h + \frac{1}{2}\left[\frac{0{,}4\, C_v C_D C_S C_{dr}\, m\, h^{5/2}}{b(P_1 + h)}\right]^2$$

where

v_1 is the mean velocity in the approach channel;

P_1 is the difference between the lowest crest elevation and the mean bed level in the approach channel;

b is the crest width.

Therefore

$$C_v^{2/5} = 1 + \frac{1}{2} Y_1 C_v^2 \qquad \dots (4)$$

where

$$Y_1 = \left[\frac{0{,}4\, C_D\, C_S\, C_{dr}\, m\, h^2}{b\,(P_1 + h)} \right]^2 \qquad \dots (5)$$

Equation (4) can be solved iteratively; the values of C_v are obtained in terms of Y_1 and are given in table 4.

For $Y_1 < 0{,}08$, C_v is given to a good approximation by

$$C_v = 1 + \frac{1{,}25\, Y_1}{1 - 2{,}5\, Y_1} \qquad \dots (6)$$

The relative error due to this approximation is less than 0,7 %.

8.4 Shape factor

A shape factor is introduced into the discharge equation for the flat-V weir because the geometry of flow changes when the discharge exceeds the V-full condition. Thus

$$C_S = 1 \qquad \text{if } h_e \leqslant h'$$

$$C_S = 1 - (1 - h'/h_e)^{5/2} \qquad \text{if } h_e > h' \qquad \dots (7)$$

where $h' = b/2m$ is the difference between the lowest and highest crest elevations.

8.5 Drowned flow reduction factor

When the weir becomes drowned, i.e. $h_{pe} > 0{,}4\, H_e$, the discharge decreases. A reduction factor is used for calculating the drowned flow discharge:

$$C_{dr} = 1 \qquad \text{if } h_{pe}/H_e \leqslant 0{,}4$$

$$C_{dr} = 1{,}078 \left[0{,}909 - \left(\frac{h_{pe}}{H_e} \right)^{3/2} \right]^{0{,}183} \qquad \text{if } h_{pe}/H_e > 0{,}4 \qquad \dots (8)$$

where

h_{pe} is the effective separation pocket head relative to the lowest crest elevation, $h_{pe} = h_p - k_m$;

h_p is the gauged separation pocket head relative to the lowest crest elevation;

H_e is the effective upstream total head relative to the lowest crest elevation, $H_e = h + v^2/2g - k_m$.

The values of C_{dr} calculated using equation (8) are given in table 5 in terms of h_{pe}/h_e and Y_2, where $Y_2 = C_D\, C_S\, m h^2/[b\,(P_1 + h)]$.

For $h_{pe}/h_e < 0{,}9$, C_{dr} can be calculated to a good approximation by using a two-step procedure (relative error less than 1 %) as follows.

a) Estimate the value of C_{dr0} according to the value of h_{pe}/h_e using the following relations:

$$C_{dr0} = 1 \qquad \text{if } h_{pe}/h_e < 0{,}55$$

$$C_{dr0} = 0{,}9 \qquad \text{if } 0{,}55 \leqslant h_{pe}/h_e < 0{,}7$$

$$C_{dr0} = 0{,}8 \qquad \text{if } 0{,}7 \leqslant h_{pe}/h_e < 0{,}85 \qquad \dots (9)$$

$$C_{dr0} = 0{,}75 \qquad \text{if } 0{,}85 \leqslant h_{pe}/h_e < 0{,}9$$

b) Calculate the following quantities:

$$Y_2 = \frac{C_D\, C_S\, m\, h^2}{b\,(P_1 + h)}$$

$$Y_1 = 0{,}16\, C_{dr0}^2\, Y_2^2$$

$$C_v^{0{,}4} = 1 + 0{,}5\, Y_1\, C_v^2 \qquad \dots (10)$$

$$H_e = C_v^{0{,}4}\, h_e$$

$$C_{dr} = 1{,}078 \left[0{,}909 - \left(\frac{h_{pe}}{H_e} \right)^{3/2} \right]^{0{,}183}$$

When $h_{pe}/h_e \geqslant 0{,}9$, more iteration steps are needed and table 5 should be referred to.

8.6 Limits of application

8.6.1 The practical lower limit of the upstream head is related to the magnitude of the influence of the fluid properties and the boundary roughness. For a well-maintained weir with a smooth crest section, the minimum head recommended is 0,03 m. If the crest is made of smooth concrete, or a material of similar texture, a lower limit of 0,06 m is suggested.

8.6.2 There is also a limiting value for the ratio h'/P_1 of 2,5 and there are limitations on h'/P_2, where P_2 is the elevation of the lowest crest elevation relative to the downstream bed level, as shown in table 3. These are governed by the scope of experimental verification and vary with the cross-slope.

Table 3 — Summary of recommended coefficients, limitations and uncertainties

Type of flat-V weir	Recommended value for the following values of the crest cross-slope		
	$\leqslant$ 1:40	1:20	1:10
$H_1/h' \leqslant 1$			
Modular discharge coefficient C_{Dm} [1)]	1,23	1,22	1,21
Head correction factor k_m	0,000 4 m	0,000 5 m	0,000 8 m
Random uncertainty in the modular discharge coefficient $X'_{C_{Dm}}$	± 0,5 %	± 0,5 %	± 0,5 %
Systematic uncertainty in the modular discharge coefficient $X''_{C_{Dm}}$	± 3 %	± 3,2 %	± 2,9 %
Modular limit	65 % to 75 %	65 % to 75 %	65 % to 75 %
Other limitations			
h'/P_1	$\leqslant$ 2,5	$\leqslant$ 2,5	$\leqslant$ 2,5
h'/P_2	$\leqslant$ 2,5	$\leqslant$ 2,5	$\leqslant$ 2,5
Upstream tapping	$10h'$	$10h'$	$10h'$
$H_1/h' > 1$			
Modular discharge coefficent C_{Dm} [1)]	1,24	1,23	1,22
Head correction factor k_m	0,000 4 m	0,000 5 m	0,000 8 m
Random uncertainty in the modular discharge coefficient $X'_{C_{Dm}}$	± 0,5 %	± 0,5 %	± 0,5 %
Systematic uncertainty in the modular discharge coefficient $X''_{C_{Dm}}$	± 2,5 %	± 2,8 %	± 2,3 %
Modular limit	65 % to 75 %	65 % to 75 %	65 % to 75 %
Other limitations			
h'/P_1	$\leqslant$ 2,5	$\leqslant$ 2,5	$\leqslant$ 2,5
h'/P_2	$\leqslant$ 8,2	$\leqslant$ 8,2	$\leqslant$ 4,2
Upstream tapping	$10h'$	$10h'$	$10h'$

1) Computations under non-modular conditions should be based on C_{Dm} = 1,25, 1,24 and 1,22 for values of the crest cross-slope of 1:40 or less, 1:20 and 1:10 respectively.

Table 4 — Velocity of approach factor in terms of Y_1

NOTE — Table 4 is presented as follows: the column labelled Y_1 gives the value of Y_1 to two decimal places; the row labelled Y_1 gives the third decimal place of Y_1. For example, the value of C_v for Y_1 = 0,064 is 1,100.

	C_v for the following values of Y_1				
Y_1	**0,000**	**0,002**	**0,004**	**0,006**	**0,008**
0,00	1,000	1,002	1,005	1,008	1,010
0,01	1,013	1,016	1,018	1,021	1,024
0,02	1,027	1,030	1,032	1,035	1,038
0,03	1,041	1,044	1,047	1,050	1,054
0,04	1,057	1,060	1,063	1,067	1,070
0,05	1,074	1,077	1,080	1,084	1,088
0,06	1,092	1,096	1,100	1,104	1,108
0,07	1,112	1,116	1,120	1,124	1,129
0,08	1,133	1,138	1,143	1,148	1,153
0,09	1,158	1,163	1,168	1,174	1,180
0,10	1,185	1,191	1,197	1,203	1,210
0,11	1,216	1,223	1,230	1,237	1,244
0,12	1,252	1,260	1,268	1,277	1,286
0,13	1,295	1,305	1,316	1,326	1,338
0,14	1,350	1,363	1,377	1,392	1,408
0,15	1,426	1,446	1,468	1,492	1,523

Table 5 — Drowned flow reduction factor C_{dr} in terms of h_{pe}/h_e and Y_2

h_{pe}/h_e	C_{dr} for the following values of Y_2															
	0,10	0,20	0,30	0,40	0,44	0,48	0,52	0,56	0,60	0,64	0,68	0,72	0,76	0,80	0,84	0,88
0,41	0,995	0,996	0,996	0,997	0,997	0,998	0,998	0,998	0,999	0,999	1,000	1,000	1,000	1,000	1,000	1,000
0,42	0,993	0,993	0,993	0,994	0,994	0,995	0,995	0,996	0,996	0,997	0,998	0,998	0,999	1,000	1,000	1,000
0,43	0,990	0,990	0,991	0,991	0,992	0,992	0,993	0,993	0,994	0,994	0,995	0,996	0,996	0,997	0,998	1,000
0,44	0,987	0,987	0,988	0,989	0,989	0,989	0,990	0,990	0,991	0,992	0,992	0,993	0,994	0,995	0,996	0,997
0,45	0,984	0,984	0,985	0,986	0,986	0,987	0,987	0,988	0,988	0,989	0,990	0,990	0,991	0,992	0,993	0,994
0,46	0,981	0,981	0,982	0,983	0,983	0,984	0,984	0,985	0,985	0,986	0,987	0,988	0,988	0,989	0,991	0,992
0,47	0,977	0,978	0,979	0,980	0,980	0,981	0,981	0,982	0,982	0,983	0,984	0,985	0,986	0,987	0,988	0,989
0,48	0,975	0,975	0,976	0,977	0,977	0,978	0,978	0,979	0,979	0,980	0,981	0,982	0,983	0,984	0,985	0,986
0,49	0,972	0,972	0,973	0,973	0,974	0,974	0,975	0,976	0,976	0,977	0,978	0,979	0,980	0,981	0,982	0,984
0,50	0,968	0,969	0,969	0,970	0,971	0,971	0,972	0,972	0,973	0,974	0,975	0,976	0,977	0,978	0,979	0,981
0,51	0,965	0,965	0,966	0,967	0,967	0,968	0,969	0,969	0,970	0,971	0,972	0,973	0,974	0,975	0,976	0,978
0,52	0,961	0,962	0,962	0,963	0,964	0,965	0,965	0,966	0,967	0,967	0,968	0,969	0,971	0,972	0,973	0,975
0,53	0,958	0,958	0,959	0,960	0,960	0,961	0,962	0,962	0,963	0,964	0,965	0,966	0,967	0,969	0,970	0,972
0,54	0,954	0,954	0,955	0,956	0,957	0,957	0,958	0,959	0,960	0,961	0,962	0,963	0,964	0,965	0,967	0,968
0,55	0,950	0,951	0,951	0,953	0,953	0,954	0,954	0,955	0,956	0,957	0,958	0,959	0,961	0,962	0,963	0,965
0,56	0,946	0,947	0,948	0,949	0,949	0,950	0,951	0,952	0,952	0,953	0,954	0,956	0,957	0,958	0,960	0,962
0,57	0,942	0,943	0,944	0,945	0,945	0,946	0,947	0,948	0,949	0,950	0,951	0,952	0,953	0,955	0,956	0,958
0,58	0,938	0,939	0,940	0,941	0,941	0,942	0,943	0,944	0,945	0,946	0,947	0,948	0,950	0,951	0,953	0,955
0,59	0,934	0,934	0,935	0,937	0,937	0,938	0,939	0,940	0,941	0,942	0,943	0,944	0,946	0,947	0,949	0,951
0,60	0,929	0,930	0,931	0,932	0,933	0,934	0,935	0,936	0,937	0,938	0,939	0,940	0,942	0,943	0,945	0,947
0,61	0,925	0,926	0,927	0,928	0,929	0,929	0,930	0,931	0,932	0,934	0,935	0,936	0,938	0,939	0,941	0,943
0,62	0,920	0,921	0,922	0,923	0,924	0,925	0,926	0,927	0,928	0,929	0,931	0,932	0,934	0,935	0,937	0,939
0,63	0,916	0,916	0,917	0,919	0,920	0,920	0,921	0,922	0,923	0,925	0,926	0,928	0,929	0,931	0,933	0,935
0,64	0,911	0,911	0,912	0,914	0,915	0,916	0,917	0,918	0,919	0,920	0,922	0,923	0,925	0,927	0,929	0,931
0,65	0,905	0,906	0,907	0,909	0,910	0,911	0,912	0,913	0,914	0,915	0,917	0,918	0,920	0,922	0,924	0,927
0,66	0,900	0,901	0,902	0,904	0,905	0,906	0,907	0,908	0,909	0,910	0,912	0,914	0,915	0,917	0,920	0,922
0,67	0,895	0,895	0,897	0,898	0,899	0,900	0,901	0,903	0,904	0,905	0,907	0,909	0,911	0,913	0,915	0,917
0,68	0,889	0,890	0,891	0,893	0,894	0,895	0,896	0,897	0,899	0,900	0,902	0,903	0,905	0,908	0,910	0,912
0,69	0,883	0,884	0,885	0,887	0,888	0,889	0,890	0,892	0,893	0,895	0,896	0,898	0,900	0,902	0,905	0,907
0,70	0,877	0,878	0,879	0,881	0,882	0,883	0,885	0,886	0,887	0,889	0,891	0,893	0,895	0,897	0,899	0,902
0,71	0,871	0,872	0,873	0,875	0,876	0,877	0,878	0,880	0,881	0,883	0,885	0,887	0,889	0,891	0,894	0,897
0,72	0,864	0,865	0,867	0,869	0,870	0,871	0,872	0,874	0,875	0,877	0,879	0,881	0,883	0,886	0,888	0,891
0,73	0,857	0,858	0,860	0,862	0,863	0,864	0,866	0,867	0,869	0,871	0,873	0,875	0,877	0,880	0,882	0,885
0,74	0,850	0,851	0,853	0,855	0,856	0,857	0,859	0,860	0,862	0,864	0,866	0,868	0,871	0,873	0,876	0,879
0,75	0,843	0,844	0,845	0,848	0,849	0,850	0,852	0,853	0,855	0,857	0,859	0,861	0,864	0,867	0,870	0,873
0,76	0,835	0,836	0,837	0,840	0,841	0,843	0,844	0,846	0,848	0,850	0,852	0,854	0,857	0,860	0,863	0,866
0,77	0,826	0,827	0,829	0,832	0,833	0,835	0,836	0,838	0,840	0,842	0,844	0,847	0,849	0,852	0,856	0,859
0,78	0,818	0,819	0,821	0,823	0,825	0,826	0,828	0,830	0,832	0,834	0,836	0,839	0,842	0,845	0,848	0,852
0,79	0,808	0,810	0,812	0,814	0,816	0,817	0,819	0,821	0,823	0,825	0,828	0,831	0,834	0,837	0,840	0,844
0,80	0,799	0,800	0,802	0,805	0,806	0,808	0,810	0,812	0,814	0,816	0,819	0,822	0,825	0,828	0,832	0,836
0,81	0,788	0,789	0,792	0,795	0,796	0,798	0,800	0,802	0,804	0,807	0,810	0,813	0,816	0,819	0,823	0,827
0,82	0,777	0,778	0,781	0,784	0,786	0,788	0,790	0,792	0,794	0,797	0,800	0,803	0,806	0,810	0,814	0,818
0,83	0,765	0,766	0,769	0,772	0,774	0,776	0,778	0,781	0,783	0,786	0,789	0,792	0,796	0,799	0,804	0,808
0,84	0,752	0,754	0,756	0,760	0,762	0,764	0,766	0,768	0,771	0,774	0,777	0,781	0,784	0,788	0,793	0,797
0,85	0,738	0,739	0,742	0,746	0,748	0,750	0,753	0,755	0,758	0,761	0,765	0,768	0,772	0,776	0,781	0,786
0,86	0,722	0,724	0,727	0,731	0,733	0,736	0,738	0,741	0,744	0,747	0,751	0,755	0,759	0,763	0,768	0,773
0,87	0,705	0,707	0,710	0,715	0,717	0,719	0,722	0,725	0,728	0,732	0,736	0,740	0,744	0,749	0,754	0,760
0,88	0,685	0,687	0,691	0,696	0,698	0,701	0,704	0,707	0,711	0,714	0,719	0,723	0,728	0,733	0,738	0,745
0,89	0,662	0,665	0,669	0,674	0,677	0,680	0,683	0,687	0,690	0,695	0,699	0,704	0,709	0,715	0,721	0,727
0,90	0,635	0,638	0,642	0,649	0,652	0,655	0,659	0,662	0,667	0,671	0,676	0,682	0,688	0,694	0,700	0,708
0,91	0,602	0,605	0,610	0,617	0,620	0,624	0,628	0,633	0,638	0,643	0,649	0,655	0,662	0,669	0,676	0,684
0,92	0,556	0,560	0,566	0,575	0,579	0,584	0,589	0,595	0,600	0,607	0,614	0,621	0,629	0,637	0,646	0,655
0,93	0,483	0,488	0,497	0,510	0,516	0,522	0,529	0,537	0,545	0,553	0,563	0,572	0,582	0,593	0,604	0,615