

Measurement of liquid flow in open channels —

Part 4: Weirs and flumes —

Part 4G: Flat-V weirs

ICS 17.120.20

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Industrial-process Measurement and Control Standards Policy Committee (PCL/-) to Technical Committee PCL/3, upon which the following bodies were represented:

- Clyde River Purification Board
- Department of the Environment
- Department of the Environment for Northern Ireland
- Institute of Measurement and Control
- Institution of Civil Engineers
- Institution of Water and Environmental Management
- Ministry of Agriculture, Fisheries and Food
- National Rivers Authority
- Water Services Association of England and Wales
- Welsh Office

The following body was also represented in the drafting of the standard, through subcommittees and panels:

GAMBICA (BEAMA Ltd.)

This British Standard, having been prepared under the direction of the Industrial-process Measurement and Control Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 31 August 1990

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First published June 1981
First revision August 1990

The following BSI references relate to the work on this standard:
Committee reference PCL/3
Draft for comment 87/32582 DC

ISBN 0 580 18836 1

Amendments issued since publication

Amd. No.	Date	Comments
9602	August 1997	Indicated by a sideline in the margin

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National foreword

This Part of BS 3680 has been prepared under the direction of the Industrial-process Measurement and Control Standards Policy Committee. It is identical with ISO 4377:1990 “*Liquid flow measurement in open channels — Flat-V weirs*”, published by the International Organization for Standardization (ISO).

This Part of BS 3680 is a revision of BS 3680-4G:1981, which is withdrawn.

Clause 8 of this standard concerns discharge relationships for flat-V weirs and presents the methodology for computing flows from measured water levels. Equation (3) in 8.3 is rigorous when flows are contained within the V but when upstream water levels exceed the highest point of the crest of the weir this equation represents a simplification of the true situation. The fully rigorous analysis is given in:

W R White. *The performance of two-dimensional and flat-V triangular profile weirs*. Paper 7350S. Proceedings of the Institution of Civil Engineers. 1971.

As a result of the simplification in equation (3), a systematic error develops in calculated flows as water levels increase above the highest point of the crest of the weir. Flows are overestimated and the error may be as high as 10 per cent in extreme cases.

A revision of this standard is currently being prepared for submission to ISO. The revision will include the rigorous version of equation (3), and will also re-introduce the successive approximation technique for calculating flows, this being more appropriate for computer applications.

Cross references

International Standard	Corresponding British Standard
	BS 3680 <i>Measurement of liquid flow in open channels</i>
ISO 748:1979	Part 3A:1980 <i>Velocity-area methods</i> (identical)
ISO 4360:1984	Part 4B:1986 <i>Triangular profile weirs</i> (Identical)
ISO 5168:1978	BS 5844:1980 <i>Methods of measurement of fluid flow: estimation of uncertainty of a flow-rate measurement</i> (identical)
ISO 8368:1985	BS 3680 <i>Measurement of liquid flow in open channels</i> Part 4H:1986 <i>Guide to the selection of flow gauging structures</i> (Identical)

The Technical Committee has reviewed the provisions of ISO 772:1988, to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard. A related British Standard to ISO 772 is BS 3680-1:1983 “*Glossary of terms*”.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 20, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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 down-stream 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 concentrations 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.

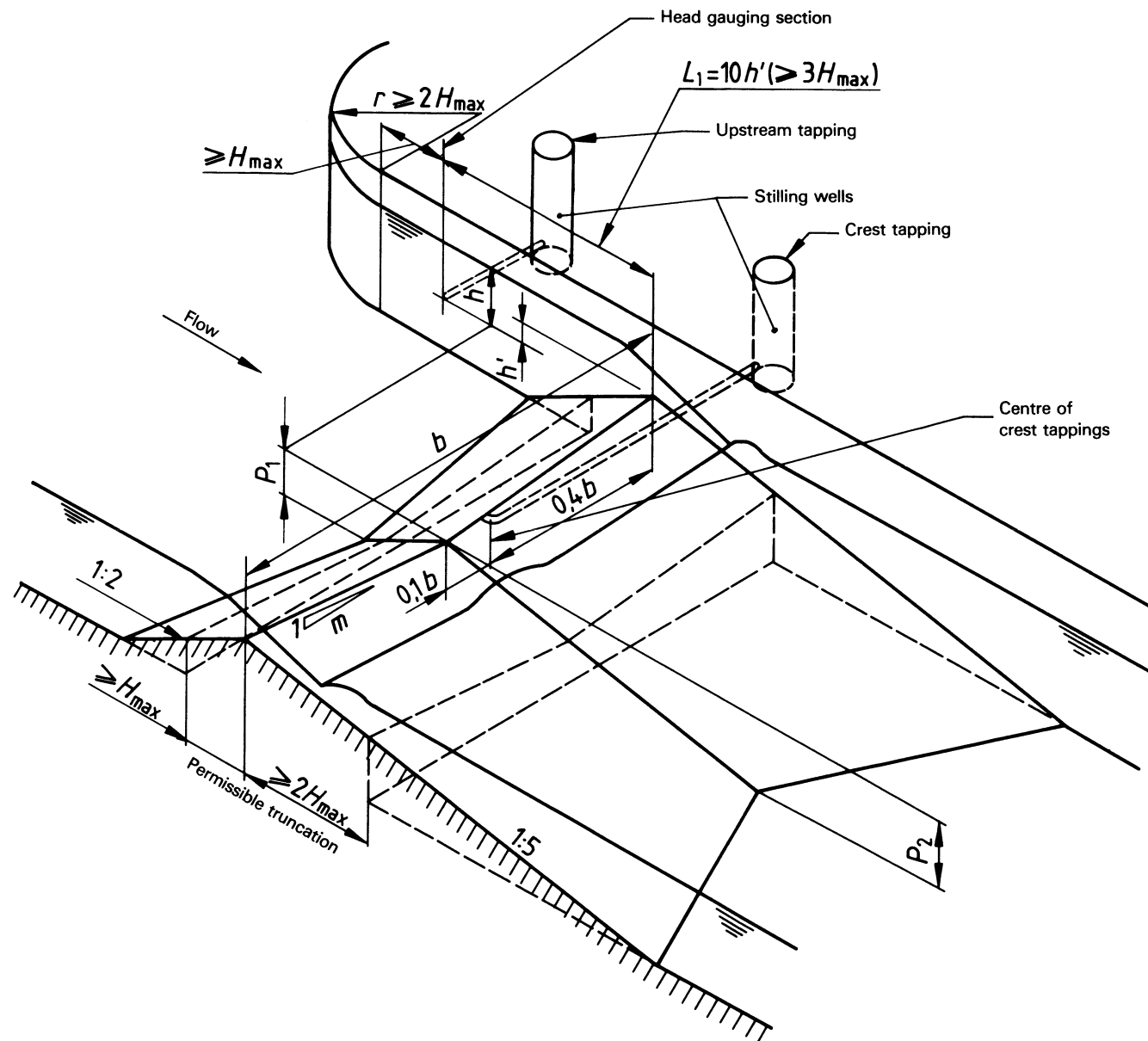


Figure 1 — Triangular profile of a flat-V weir

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.