

**SASO ISO 1438: 2019**

**ISO 1438: 2017**

**Hydrometry — Open channel flow measurement using thin-plate  
weirs**

**ICS 17.040.10**

**Saudi Standards, Metrology and Quality Org (SASO)**

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this document is a draft saudi standard circulated for comment. it is, therefore subject to change and may not be referred to as a saudi standard until approved by the board of directors

## **Foreword**

The Saudi Standards ,Metrology and Quality Organization (SASO) has adopted the International standard No. ISO 1438:2017 “Hydrometry — Open channel flow measurement using thin-plate weirs ” issued by the (ISO). The text of this international standard has been translated into Arabic so as to be approved as a Saudi standard without introducing any technical modification.

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## 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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document 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 1438:2008), which has been technically revised. It also incorporates the Technical Corrigendum ISO 1438:2008/Cor 1:2008.

The major changes from ISO 1438:2008 are as follows:

- a) the modular flow discharge formula for weirs with weir plate height of  $1\text{ m} \leq p \leq 2,5\text{ m}$  has been supplemented in 9.7.1;
- b) the  $C_d$  formula for rectangular weir with  $b/B = 1,0$ , Formula (5), has been corrected to the same formula as the full-width weir, Formula (15);
- c) subclause numbers of 9.6 have been re-numbered.

# Hydrometry — Open channel flow measurement using thin-plate weirs

## 1 Scope

This document defines the requirements for the use of rectangular and triangular (V-notch) thin-plate weirs for the measurement of flow of clear water in open channels under free flow conditions. It includes the requirements for the use of full-width rectangular thin-plate weirs in submerged (drowned) flow conditions.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

## 4 Symbols and abbreviated terms

Symbol	Unit	Description
$A$	m <sup>2</sup>	Area of approach channel
$B$	m	Width of approach channel
$b$	m	Measured width of the notch
$b_{\max}$	m	Width of notch at maximum head (V-notch)
$C$		Discharge coefficient (gauged head)
$C_d$		Coefficient of discharge
$f$		Drowned flow reduction factor
$C_v$		Coefficient of velocity
$e_b$	m	Random uncertainty in the width measurement
$g$	m/s <sup>2</sup>	Acceleration due to gravity
$H$	m	Total head above crest level
$h$	m	Upstream gauged head above crest level (upstream head is inferred if no subscript is used)
$J$		Numerical constant
$l$	m	Distance of the head measurement section upstream of the weir

$n$		Number of measurements in a set
$p$	m	Height of the crest relative to the floor
$Q$	m <sup>3</sup> /s	Volumetric rate of flow
$S$		Submergence ratio, $h_2/h_1$
$S_1$		Modular limit
$\bar{V}$	m/s	Mean velocity
$U$	%	Expanded percentage uncertainty
$u^*(b)$	%	Percentage uncertainty in $b$
$u^*(C)$	%	Percentage uncertainty in $C$
$u^*(E)$	%	Percentage uncertainty in datum measurement
$u^*(h_1)$	%	Percentage uncertainty in $h_1$
$u^*(Q)$	%	Percentage uncertainty in $Q$
$\alpha$	°	Notch angle

### Subscripts

- 1 upstream
- 2 downstream
- e effective
- r rectangular
- t triangular

## 5 Principle

The discharge over thin-plate weirs is a function of the upstream head on the weir (for free-flow), upstream and downstream head (for drowned flow), the size and shape of the discharge area, and an experimentally determined coefficient which takes into account the head, the geometrical properties of the weir and approach channel, and the dynamic properties of the water.

## 6 Installation

### 6.1 General

General requirements of weir installations are described in the following clauses. Special requirements of different types of weirs are described in clauses which deal with specific weirs (see Clause 9 and Clause 10).

### 6.2 Selection of site

The type of weir to be used for discharge measurement is determined in part by the nature of the proposed measuring site. Under some conditions of design and use, weirs shall be located in rectangular flumes or in weir boxes which simulate flow conditions in rectangular flumes. Under other conditions, weirs may be located in natural channels, as well as flumes or weir boxes, with no significant difference in measurement accuracy. Specific site-related requirements of the installation are described in 6.3.

### 6.3 Installation conditions

#### 6.3.1 General

Weir discharge is critically influenced by the physical characteristics of the weir and the weir channel. Thin-plate weirs are especially dependent on installation features which control the velocity

distribution in the approach channel and on the construction and maintenance of the weir crest in meticulous conformance with standard specifications.

### 6.3.2 Weir

Thin-plate weirs shall be vertical and perpendicular to the walls of the channel. The intersection of the weir plate with the walls and floor of the channel shall be watertight and firm, while the weir shall be capable of withstanding the maximum flow without distortion or damage.

Stated practical limits associated with different discharge formulae such as minimum width, minimum weir height, minimum head, and maximum values of  $h/p$  and  $b/B$  (where  $h$  is the measured head,  $p$  is the height of crest relative to floor,  $b$  is the measured width of the notch and  $B$  is the width of the approach channel), are factors which influence both the selection of weir type and the installation.

### 6.3.3 Approach channel

For the purposes of this document, the approach channel is the portion of the weir channel which extends upstream from the weir a distance not less than five times the width of the nappe at maximum head. If the weir is located in a weir tank, ideally, the length of the tank should equal up to 10 times the width of the nappe at maximum head. Information on the use of small weir tanks is given in Annex A.

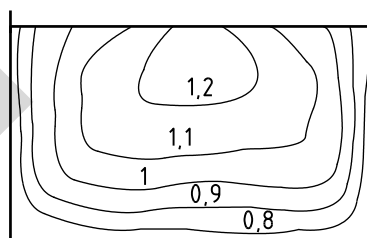
The flow in the approach channel shall be uniform and steady, with the velocity distribution approximating that in a channel of sufficient length to develop satisfactory flow in smooth, straight channels. Figure 1 shows measured velocity distributions perpendicular to the direction of flow in rectangular channels, upstream from the influence of a weir. Baffles and flow straighteners can be used to simulate satisfactory velocity distribution, but their location with respect to the weir shall be not less than the minimum length prescribed for the approach channel.

The influence of approach-channel velocity distribution on weir flow increases as  $h/p$  and  $b/B$  increase in magnitude. If a weir installation unavoidably results in a velocity distribution that is appreciably non-uniform, the possibility of error in calculated discharge should be checked by means of an alternative discharge-measuring method for a representative range of discharges.

If the approach conditions are judged to be unsatisfactory, then flow straighteners shall be introduced in accordance with Annex B.

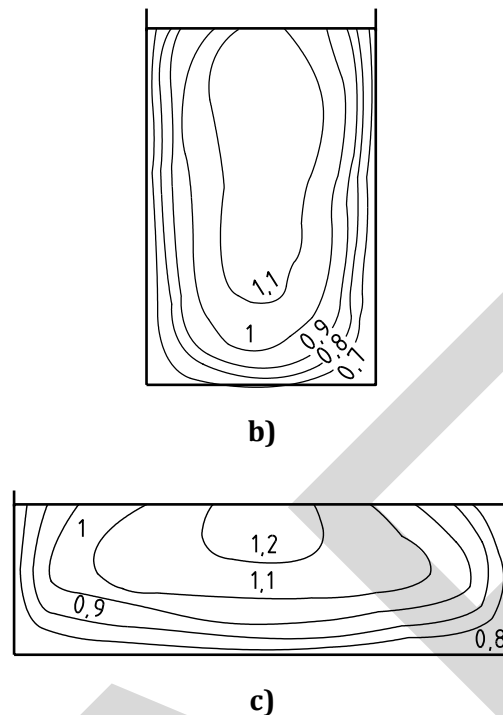
If the maximum head to be measured is restricted to  $(2/3)p$  for all types of weirs, flow straighteners can be used to reduce the effective length of the approach channel to  $B + 3h_{\max}$  for triangular and rectangular weirs and to  $B + 5h_{\max}$  for full-width weirs.

NOTE This restriction on the maximum head to be measured is necessary due to distortion of the velocity near the water surface in the approach channel that results from flow coming through the openings in the baffle of the flow straightener.



a)





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

**Figure 1 — Examples of normal velocity distribution in rectangular channels**

#### 6.3.4 Downstream channel

For most applications, the level of the water in the downstream channel shall be a sufficient vertical distance below the crest to ensure free, fully ventilated discharges. Free (non-submerged) discharge occurs when the discharge is independent of the downstream water level. Fully ventilated discharge is ensured when the air pressure on the lower surface of the nappe is fully ventilated. Drowned flow operation is permitted for full-width weirs under certain conditions (see 9.7.2). Under these circumstances, downstream water levels may rise above crest level.

## 7 Measurement of head

### 7.1 Head-measuring devices

In order to obtain the discharge measurement accuracies specified for the standard weirs, the head on the weir shall be measured with a laboratory-grade hook gauge, point gauge, manometer, or other gauge of equivalent accuracy. For a continuous record of head variants, precise float gauges and servo-operated point gauges can be used. Staff and tape gauges can be used when less accurate measurements are acceptable.

Additional specifications for head-measuring devices are given in ISO 4373.

### 7.2 Stilling or float well

For the exceptional case where surface velocities and disturbances in the approach channel are negligible, the headwater level can be measured directly (for example, by means of a point gauge mounted over the water surface). Generally, however, to avoid water-level variations caused by waves, turbulence or vibration, the headwater level should be measured in a separate stilling well.

Separate stilling wells are connected to the approach channel by means of a suitable conduit, equipped if necessary with a throttle valve to damp oscillations. At the channel end of the conduit, the connection is made to floor or wall piezometers or a static tube at the head-measurement section.

Additional specifications for stilling wells are given in ISO 18365.

### 7.3 Head-measurement section

#### 7.3.1 Upstream head-measurement

The head-measurement section shall be located a sufficient distance upstream from the weir to avoid the region of surface drawdown caused by the formation of the nappe. On the other hand, it shall be sufficiently close to the weir that the energy loss between the head-measurement section and the weir is negligible. For the weirs included in this document, the location of the head-measurement section will be satisfactory if it is at a distance equal to two to four times the maximum head ( $2h_{\max}$  to  $4h_{\max}$ ) upstream from the weir.

If high velocities occur in the approach channel or if water-surface disturbances or irregularities occur at the head-measurement section because of high values of  $h/p$  or  $b/B$ , it may be necessary to install several pressure intakes to ensure that the head measured in the gauge well is representative of the average head across the measurement section.

In the case of a full-width thin-plate weir, the effect of frictional effects upon the upstream channel requires an adjustment to the standard coefficient of discharge. The correction is in terms of both  $l/h$  and  $h/p$  and given in Table 1.

**Table 1 — Factors to be applied to the standard discharge coefficient values**

$h/p$	$l/h$			
	2	4	6	8
<b>3.5 to 4.0</b>	1.00	1.00	0.96	0.92
<b>3.0 to 3.5</b>	1.00	1.00	0.97	0.94
<b>2.5 to 3.0</b>	1.00	1.00	0.98	0.96
<b>2.0 to 2.5</b>	1.00	1.00	0.99	0.98
<b>Less than 2.0</b>	1.00	1.00	1.00	1.00

#### 7.3.2 Downstream head measurement

If the weir is to be operated in the submerged (drowned) flow range, a measurement of downstream head is required in addition to the upstream. The downstream head measurement position shall be  $10 h_{\max}$  downstream from the upstream face of the weir. If a stilling well is included in the design, it is recommended that the downstream head measurement be located no closer to the weir than  $4 h_{\max}$ .

### 7.4 Head-gauge datum (gauge zero)

Accuracy of head measurements is critically dependent upon the determination of the head-gauge datum or gauge zero, which is defined as the gauge reading corresponding to the level of the weir crest (rectangular weirs) or the level of the vertex of the notch (triangular-notch weirs). When necessary, the gauge zero shall be checked. Numerous acceptable methods of determining the gauge zero are in use. Typical methods are described in subsequent clauses dealing specifically with rectangular and triangular weirs. See Clause 9 and Clause 10.

Because of surface tension, the gauge zero cannot be determined with sufficient accuracy by reading the head gauge with the water in the approach channel drawn down to the apparent crest (or notch) level.

## 8 Maintenance

Maintenance of the weir and the weir channel is necessary to ensure accurate measurements.

The approach channel shall be kept free of silt, vegetation and obstructions which might have deleterious effects on the flow conditions specified for the standard installation. The downstream channel shall be kept free of obstructions which might cause submergence or inhibit full ventilation of the nappe under all conditions of flow.

The weir plate shall be kept clean and firmly secured. In the process of cleaning, care shall be taken to avoid damage to the crest or notch, particularly the upstream edges and surfaces. Construction specifications for these most sensitive features should be reviewed before maintenance is undertaken.

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

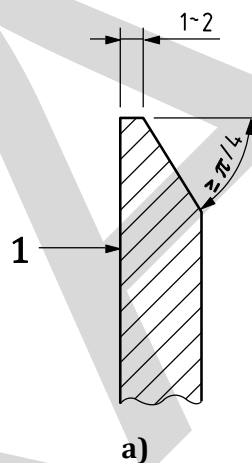
If a flow straightener is used in the approach channel, perforated plates shall be kept clean so that the percentage open area remains greater than 40 %.

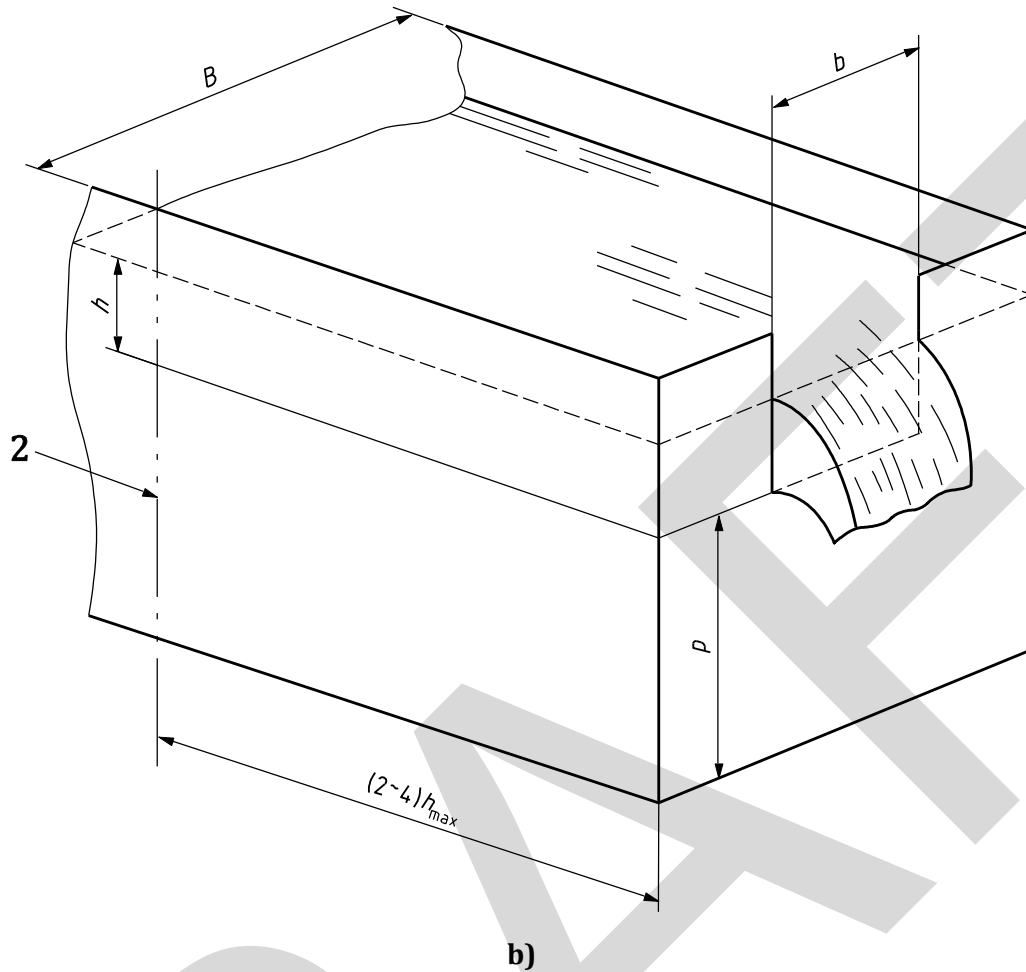
## 9 Rectangular thin-plate weir

### 9.1 Types

The rectangular thin-plate weir is a general classification in which the rectangular-notch weir is the basic form and the full-width weir is a limiting case. A diagrammatic illustration of the basic weir form is shown in Figure 2 with intermediate values of  $b/B$  and  $h/p$ . When  $b/B = 1,0$ , that is, when the width of the weir ( $b$ ) is equal to the width of the channel at the weir section ( $B$ ), the weir is of full-width type (also referred to as a “suppressed” weir, because its nappe lacks side contractions).

Dimensions in millimetres



**Key**

- 1 upstream face of weir plate
- 2 head measurement section, measured value  $h$

**Figure 2 — Rectangular-notch, thin-plate weir**

## 9.2 Specifications for the standard weir

The basic weir form consists of a rectangular notch in a vertical thin plate. The plate shall be plane and rigid and perpendicular to the walls and the floor of the approach channel. The upstream face of the plate shall be smooth (in the vicinity of the notch, it shall be equivalent in surface finish to that of rolled sheet-metal).

The vertical bisector of the notch shall be equidistant from the two walls of the channel. The crest surface of the notch shall be a horizontal, plane surface, which shall form a sharp edge at its intersection with the upstream face of the weir plate. The width of the crest surface, measured perpendicular to the face of the plate, shall be between 1 mm and 2 mm. The side surfaces of the notch shall be vertical plane surfaces which shall make sharp edges at their intersection with the upstream face of the weir plate. For the limiting case of the full-width weir, the crest of the weir shall extend to the walls of the channel, which, in the vicinity of the crest, shall be plane and smooth (see also 9.3).

To ensure that the upstream edges of the crest and the sides of the notch are sharp, they shall be machined or filed, perpendicular to the upstream face of the weir plate, free of burrs or scratches, and untouched by abrasive cloth or paper. The downstream edges of the notch shall be chamfered if the weir plate is thicker than the maximum allowable width of the notch surface. The surface of the chamfer shall make an angle of not less than  $\pi/4$  radians ( $45^\circ$ ) with the crest and side surfaces of the notch (see detail shown in Figure 2). The weir plate in the vicinity of the notch preferably shall be made of corrosion-resistant metal; but if it is not, all specified smooth surfaces and sharp edges shall be kept coated with a thin protective film (for example, oil, wax and silicone) applied with a soft cloth.

### 9.3 Specifications for installation

The specifications stated in 6.3 shall apply. In general, the weir shall be located in a straight, horizontal, rectangular approach channel if possible. However, if the effective opening of the notch is so small in comparison with the area of the upstream channel that the approach velocity is negligible, the shape of the channel is not significant. In any case, the flow in the approach channel shall be uniform and steady, as specified in 6.3.3.

If the width of the weir is equal to the width of the channel at the weir section (i.e. a full-width weir), the sides of the channel upstream from the plane of the weir shall be vertical, plane, parallel and smooth (equivalent in surface finish to that of rolled sheet-metal). The sides of the channel above the level of the crest of a full-width weir shall extend at least  $0,3 h_{\max}$  downstream from the plane of the weir. Fully ventilated discharge shall be ensured as specified in 6.3.4.

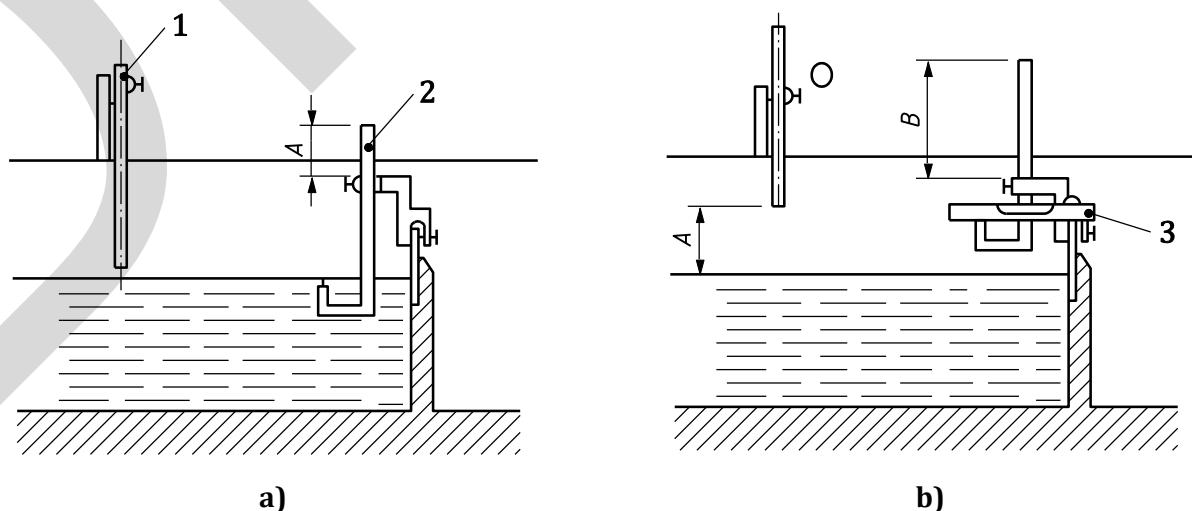
The approach channel floor shall be smooth, flat and horizontal when the height of the crest relative to the floor ( $p$ ) is small and/or  $h/p$  is large. For rectangular weirs, the floor should be smooth, flat and horizontal, particularly when  $p$  is less than 0,1 m and/or  $h_{\max}/p$  is greater than 1. Additional conditions are specified in connection with the recommended discharge formulae.

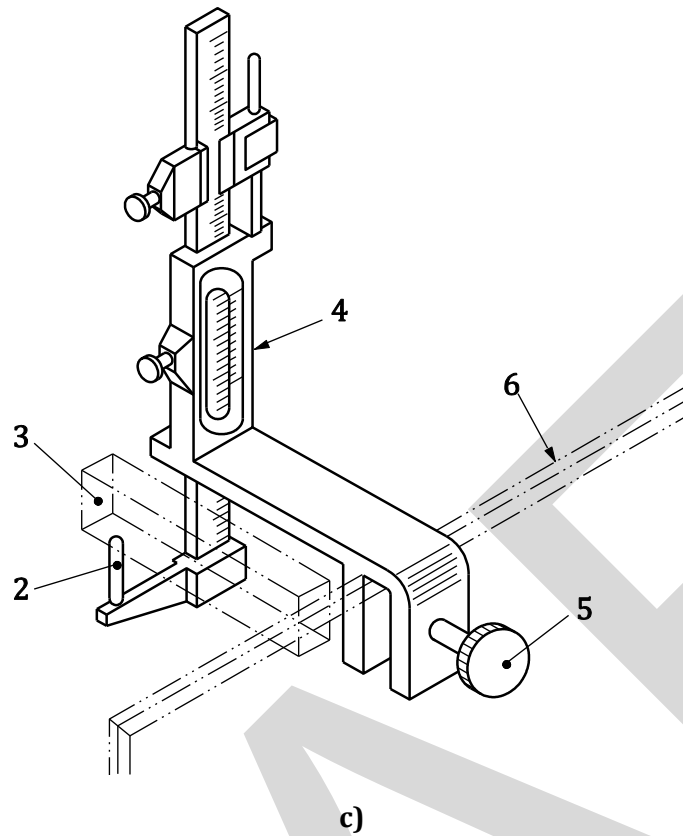
### 9.4 Determination of gauge zero

The head-gauge datum or gauge zero shall be determined with great care and it shall be checked when necessary. A typical, acceptable method of determining the gauge zero for rectangular weirs is described as follows.

- Still water in the approach channel is drawn to a level below the weir crest.
- A temporary hook gauge is mounted over the approach channel, a short distance upstream from the weir crest.
- A precise machinists' level is placed with its axis horizontal, with one end lying on the weir crest and the other end on the point of the temporary hook gauge (the gauge having been adjusted to hold the level in this position). The reading of the temporary gauge is recorded.
- The temporary hook gauge is lowered to the water surface in the approach channel and its reading is recorded. The permanent gauge is adjusted to read the level in the gauge well and this reading is recorded.
- The computed difference between the two readings of the temporary gauge is added to the reading of the permanent gauge. The sum is the gauge zero for the permanent gauge.

Figure 3 illustrates the use of this procedure with a form of temporary hook gauge which is conveniently mounted on the weir plate.



**Key**

- 1 permanent gauge
- 2 temporary hook gauge
- 3 precision level
- 4 vernier micrometer
- 5 set screw
- 6 weir crest

**Figure 3 — Determination of gauge zero for rectangular weir**

## 9.5 Discharge formulae — General

Recommended discharge formulae for rectangular thin-plate weirs are presented in three categories:

- a) modular discharge formula for the basic weir form (all values of  $b/B$ );
- b) modular discharge formula for full-width weirs ( $b/B = 1,0$ );
- c) non-modular discharge formula for full-width weirs.

## 9.6 Formulae for the basic weir form (all values of $b/B$ )

### 9.6.1 Kindsvater-Carter formula

The Kindsvater-Carter formula for the basic weir form is given in Formula (1):

$$Q = C_d \frac{2}{3} \sqrt{2g} b_e h_e^{3/2} \quad (1)$$

where

$C_d$  is the coefficient of discharge;

$b_e$  is the effective width;

$h_e$  is the effective head.

### 9.6.2 Evaluation of $C_d$ , $k_b$ and $k_h$

Figure 4 shows experimentally determined values of  $C_d$  as a function of  $h/p$  for representative values of  $b/B$ . Values of  $C_d$  for intermediate values of  $b/B$  can be determined by interpolation.

The coefficient of discharge  $C_d$  has been determined by experiment as a function of two variables from Formula (2):

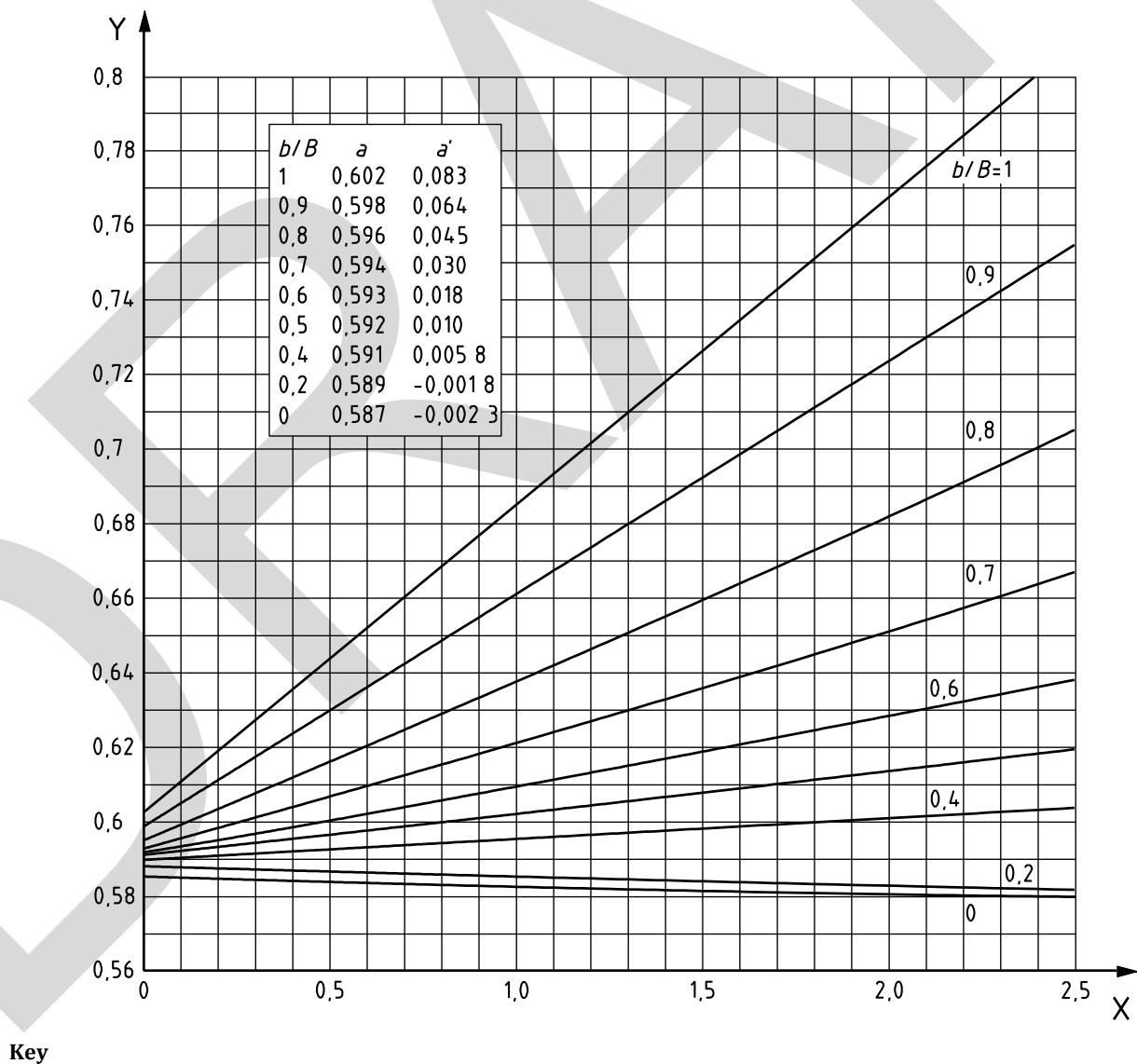
$$C_d = f\left(\frac{b}{B}, \frac{h}{p}\right) \quad (2)$$

The effective width and head are defined by Formula (3) and Formula (4):

$$b_e = b + k_b \quad (3)$$

$$h_e = h + k_h \quad (4)$$

in which  $k_b$  and  $k_h$  are experimentally determined quantities, in metres, which compensate for the combined effects of viscosity and surface tension.

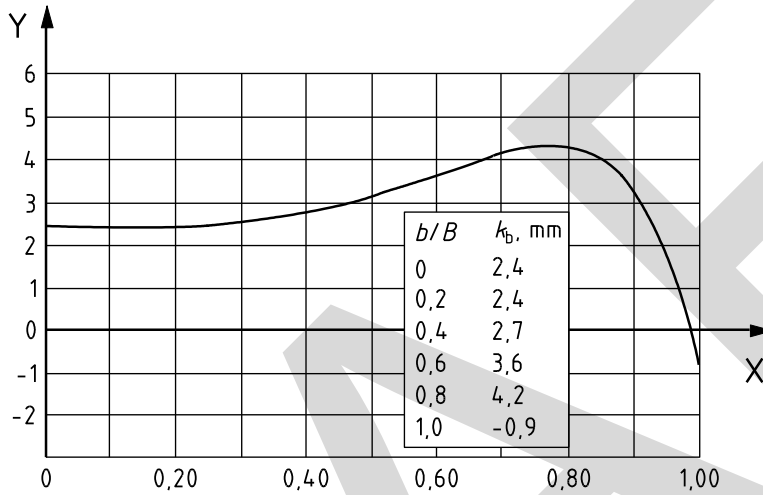


X value of  $\frac{h}{p}$   
 Y value of  $C_d$

**Figure 4 — Coefficient of discharge**

Figure 5 shows values of  $k_b$ , which have been experimentally determined as a function of  $b/B$ .

Experiments have shown that  $k_h$  can be taken to have a constant value of 0,001 m for weirs constructed in strict conformance with recommended specifications.



**Key**  
 X  $b/B$   
 Y  $k_b$ , in millimetres

**Figure 5 — Value of  $k_b$  related to  $b/B$**

**9.6.3 Formulae for  $C_d$**

For specific values of  $b/B$ , the relationship between  $C_d$  and  $h/p$  has been shown by experiment (see Figure 4) to be of the linear form  $C_d = a + a' \left( \frac{h}{p} \right)$ .

Thus, for the values of  $b/B$  shown on Figure 4, formulae for  $C_d$  can be written as given in Formula (5) to Formula (13):

$$\left( \frac{b}{B} = 1,0 \right) : C_d = 0,602 + 0,083 \frac{h}{p} \tag{5}$$

$$\left( \frac{b}{B} = 0,9 \right) : C_d = 0,598 + 0,064 \frac{h}{p} \tag{6}$$

$$\left( \frac{b}{B} = 0,8 \right) : C_d = 0,596 + 0,045 \frac{h}{p} \tag{7}$$

$$\left( \frac{b}{B} = 0,7 \right) : C_d = 0,594 + 0,030 \frac{h}{p} \tag{8}$$

$$\left( \frac{b}{B} = 0,6 \right) : C_d = 0,593 + 0,018 \frac{h}{p} \tag{9}$$



$$\left(\frac{b}{B}=0,5\right): C_d = 0,592 + 0,010 \frac{h}{p} \quad (10)$$

$$\left(\frac{b}{B}=0,4\right): C_d = 0,591 + 0,0058 \frac{h}{p} \quad (11)$$

$$\left(\frac{b}{B}=0,2\right): C_d = 0,589 - 0,0018 \frac{h}{p} \quad (12)$$

$$\left(\frac{b}{B}=0\right): C_d = 0,587 - 0,0023 \frac{h}{p} \quad (13)$$

For intermediate values of  $b/B$ , formulae for  $C_d$  can be determined satisfactorily by interpolation.

#### 9.6.4 Practical limitations on $h/p$ , $h$ , $b$ and $p$

Practical limits are placed on  $h/p$  because head-measurement difficulties and errors result from surges and waves which occur in the approach channel at larger values of  $h/p$ . Limits are placed on  $h$  to avoid the “clinging nappe” phenomenon which occurs at very low heads. Limits are placed on  $b$  because of uncertainties regarding the combined effects of viscosity and surface tension represented by the quantity of  $k_b$  at very small values of  $b$ . Limits are placed on  $p$  and  $B - b$  to avoid the instabilities which result from eddies that form in the corners between the channel boundaries and the weir when values of  $p$  and  $B - b$  are small.

For conservative practice, limitations applicable to the use of the Kindsvater-Carter formulae are:

- $h/p$  shall be not greater than 2,5;
- $h$  shall be not less than 0,03 m;
- $b$  shall be not less than 0,15 m;
- $p$  shall be not less than 0,10 m;
- either  $(B - b)/2 = 0$  (full-width weir) or  $(B - b)/2$  shall not be less than 0,10 m (contracted weir).

### 9.7 Formulae for full-width weirs ( $b/B = 1,0$ )

#### 9.7.1 Modular flow discharge formula

The Rehbock formula in the form proposed in 1929<sup>[8]</sup> is of the effective-head variety and is given in Formula (14):

$$Q = C_d \frac{2}{3} \sqrt{2g} b h_e^{3/2} \quad (14)$$

in which for the case of  $p \leq 1$  m, Formula (15) and Formula (16) apply:

$$C_d = 0,602 + 0,083 \frac{h}{p} \quad (15)$$

$$h_e = h + 0,0012 \quad (16)$$

where practical limitations applicable to the use of the Rehbock formula are:

- $h/p$  shall be not greater than 4,0<sup>[3]</sup>;
- $h$  shall be between 0,03 and 1,0 m;

- c)  $b$  shall be not less than 0,30 m;  
 d)  $p$  shall be between 0,06 and 1 m;

and for the case of  $1 \text{ m} \leq p \leq 2,5 \text{ m}$ <sup>[7]</sup>,

$$C_d = 0,602 + 0,004(p-1) + \{0,083 + 0,036(p-1)\} \frac{h}{p} \quad (17)$$

$$h_e = h + 0,0012 \text{ same as Formula (16)}$$

where practical limitations for this case are:

- a)  $h$  shall be between 0,03 and 0,80 m but not greater than  $b/4$ ;  
 b)  $b$  shall be not less than 0,50 m;  
 c)  $p$  shall be between 1,0 and 2,5 m.

### 9.7.2 Non-modular flow discharge formula

Submerged (drowned) flow occurs when the tailwater level downstream from a weir affects the flow. The weir operates in the non-modular condition. For this condition, an additional downstream measurement of head ( $h_2$ ) is required and a drowned flow reduction factor ( $f$ ) is applied to the modular discharge formula.

Since the modular limit of a full-width thin-plate weir is significantly influenced by the ratio  $h/p$ , the modular limit increasing with  $h/p$ , drowned flow performance of the typical full-width thin-plate weir is shown in Figure 6 and defined by the formulae below:

For  $h/p = 0,5$ , then  $f = 1,007 [0,975 - (h_2/h) 1,45]^{0,265}$  in the range  $0,00 < h_2/h < 0,97$

For  $h/p = 1,0$ , then  $f = 1,026 [0,960 - (h_2/h) 1,55]^{0,242}$  in the range  $0,20 < h_2/h < 0,97$

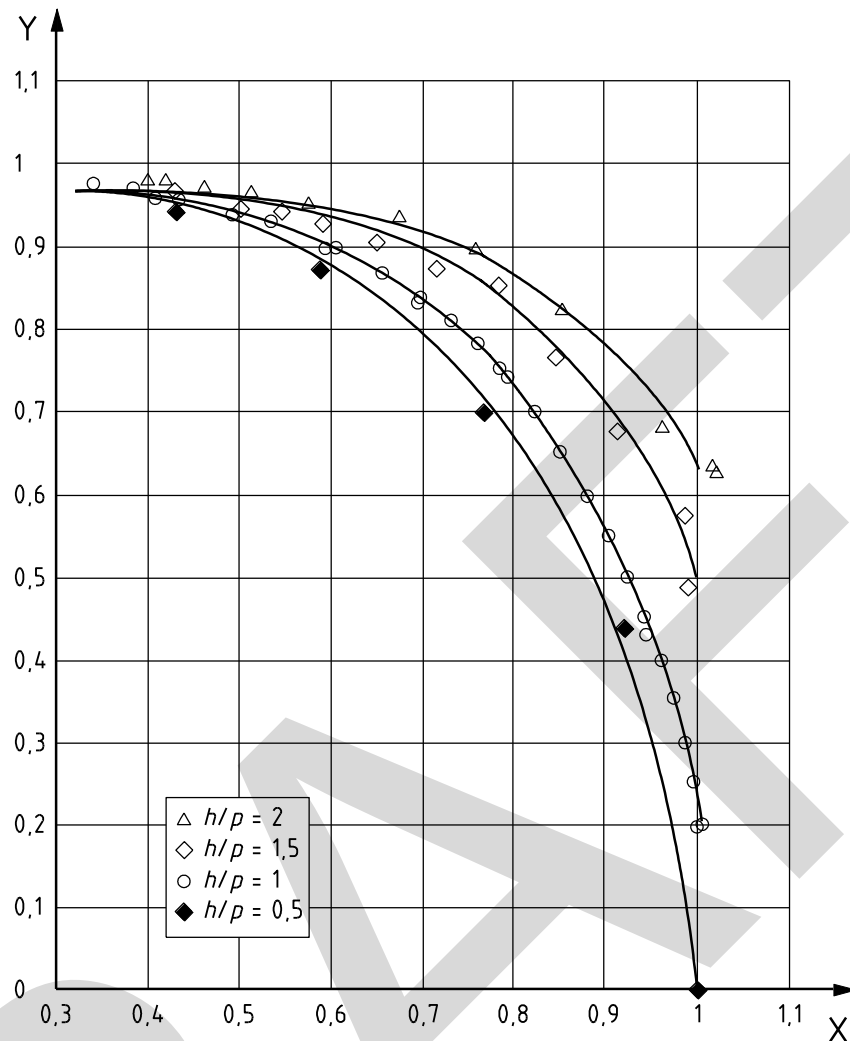
For  $h/p = 1,5$ , then  $f = 1,098 [0,952 - (h_2/h) 1,75]^{0,220}$  in the range  $0,50 < h_2/h < 0,97$

For  $h/p = 2,0$ , then  $f = 1,155 [0,950 - (h_2/h) 1,85]^{0,219}$  in the range  $0,63 < h_2/h < 0,97$

Thus, the Rehbock Formula (1929) for drowned flow becomes Formula (18):

$$Q = f C_d \frac{2}{3} \sqrt{2g} b h_e^{3/2} \quad (18)$$

NOTE This adjustment only applies where the upstream and downstream measurements are in the same horizontal plane, i.e. there is no drop in the channel bottom at, or downstream, of the weir.

**Key**

X value of  $\frac{h_2}{h}$

Y value of  $f$

**Figure 6 — Drowned flow performance of the full-width thin-plate weir**

## 10 Triangular-notch thin-plate weir

### 10.1 Specifications for the standard weir

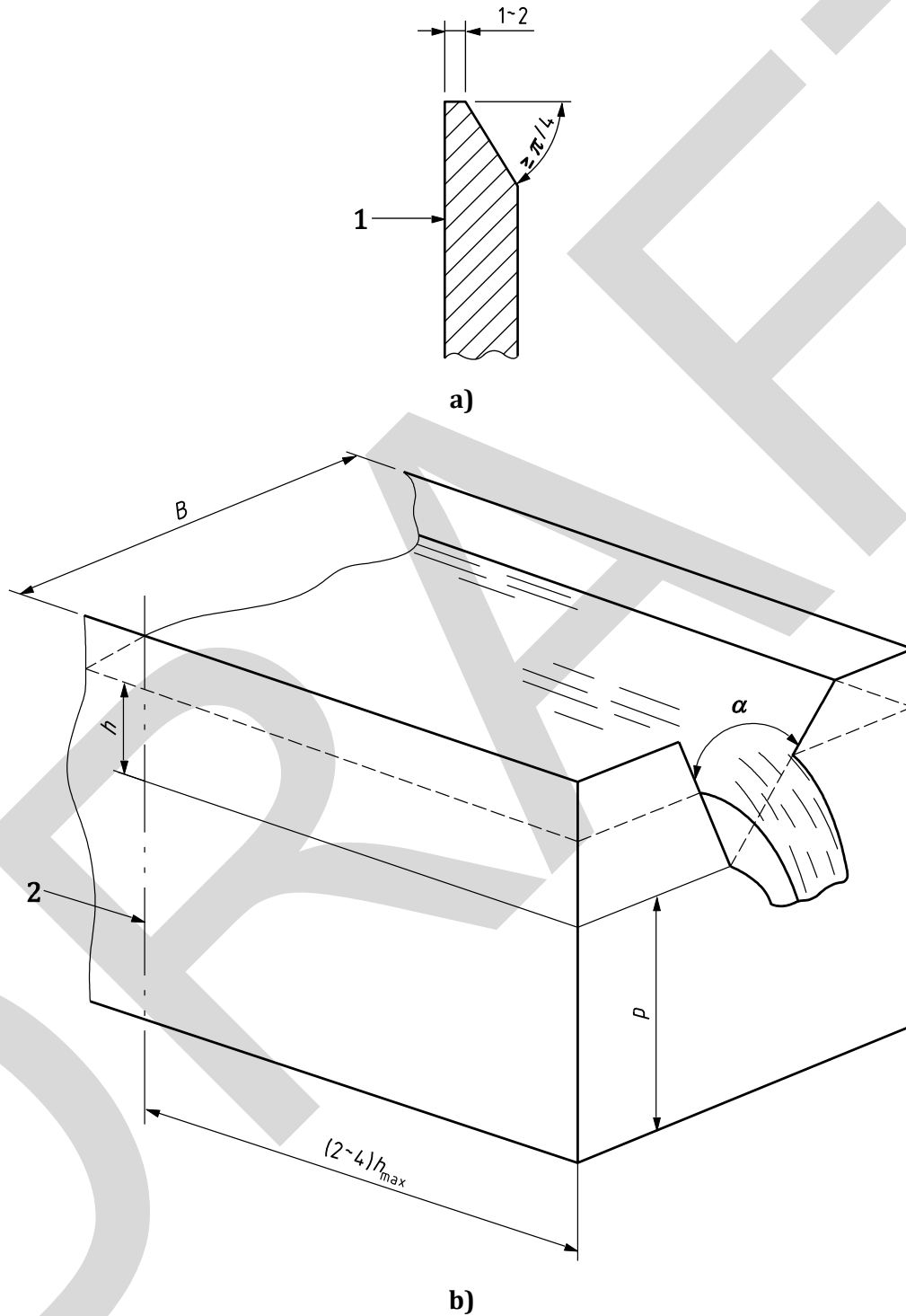
The triangular-notch thin-plate weir consists of a V-shaped notch in a vertical, thin plate. A diagrammatic illustration of the triangular-notch weir is shown in Figure 7. The weir plate shall be plane and rigid and perpendicular to the walls and the floor of the channel. The upstream face of the plate shall be smooth (in the vicinity of the notch, it shall be equivalent in surface finish to that of rolled sheet-metal).

The bisector of the notch shall be vertical and equidistant from the two walls of the channel. The surfaces of the notch shall be plane surfaces, which shall form sharp edges at their intersection with the upstream face of the weir plate. The width of the notch surfaces, measured perpendicular to the face of the plate, shall be between 1 mm and 2 mm.

To ensure that the upstream edges of the notch are sharp, they shall be machined or filed, perpendicular to the upstream face of the plate, free of burrs or scratches and untouched by abrasive cloth or paper. The downstream edges of the notch shall be chamfered if the weir plate is thicker than

the maximum allowable width of the notch surface. The surface of the chamfer shall make an angle of not less than  $\pi/4$  radians ( $45^\circ$ ) with the surface of the notch (see detail, Figure 7). The weir plate in the vicinity of the notch preferably shall be made of corrosion-resistant metal; but if it is not, all specified smooth surfaces shall be kept coated with a thin protective film (for example, oil, wax, silicone) applied with a soft cloth.

Dimensions in millimetres



- Key**
- 1 upstream face of weir plate
  - 2 head measurement section

Figure 7 — Triangular-notch thin-plate weir

## 10.2 Specifications for the installation

The specifications stated in 6.3 shall apply. In general, the weir shall be located in a straight, horizontal, rectangular channel if possible. However, if the effective opening of the notch is so small in comparison with the area of the upstream channel that the approach velocity is negligible, the shape of the channel is not significant. In any case, the flow in the approach channel shall be uniform and steady, as specified in 6.3.3.

If the top width of the nappe at maximum head is large in comparison with the width of the channel, the channel walls shall be straight, vertical and parallel. If the height of the vertex relative to the level of the floor is small in comparison with the maximum head, the channel floor shall be smooth, flat and horizontal. In general, the approach channel should be smooth, straight and rectangular when  $B/b_{\max}$  is less than 3 and/or  $h_{\max}/p$  is greater than 1. Additional conditions are specified in connection with the recommended discharge formulae.

## 10.3 Specifications for head measurement

### 10.3.1 General

The conditions specified in 7.1, 7.2 and 7.3 shall apply without exception.

### 10.3.2 Determination of notch angle

Precise head measurements for triangular-notch weirs require that the notch angle (angle included between sides of the notch) be measured accurately. One of several satisfactory methods is described as follows.

- a) Two true disks of different, micrometered diameters are placed in the notch with their edges tangent to the sides of the notch.
- b) The vertical distance between the centres (or two corresponding edges) of the two disks is measured with a micrometer caliper.
- c) The notch angle  $\alpha$  is twice the angle whose sine is equal to the differences between the radii of the disks divided by the distance between the centres of the disks.

### 10.3.3 Determination of gauge zero

The head-gauge datum or gauge zero shall be determined with great care and it shall be checked when necessary. A typical acceptable method of determining the gauge zero for triangular notch weirs is described as follows.

- a) Still water in the approach channel is drawn to a level below the vertex of the notch.
- b) A temporary hook gauge is mounted over the approach channel, with its point a short distance upstream from the vertex of the notch.
- c) A true cylinder of known (micrometered) diameter is placed with its axis horizontal, with one end resting in the notch and the other end balanced on the point of the temporary hook gauge. A machinists' level is placed on top of the cylinder, and the hook gauge is adjusted to make the cylinder precisely horizontal. The reading of the temporary gauge is recorded.
- d) The temporary hook gauge is lowered to the water surface in the approach channel and the reading is recorded. The permanent gauge is adjusted to read the level in the gauge well, and this reading is recorded.
- e) The distance ( $y$ ) from the top of the cylinder to the vertex of the notch is computed with the known value of the notch angle ( $\alpha$ ) and the radius ( $r$ ) of the cylinder  $\left[ y = \left( r / \sin \frac{\alpha}{2} \right) + r \right]$ . This distance is

then subtracted from the reading recorded in c), the result being the reading of the temporary gauge at the vertex of the notch.

- f) The difference between the computed reading in e) and the reading of the temporary gauge in d) is added to the reading of the permanent gauge in d). The sum is the gauge zero for the permanent gauge.

An advantage of this method is that it refers the gauge zero to the geometrical vertex which is defined by the sides of the notch.

### 10.4 Discharge formulae — General

Recommended discharge formulae for triangular-notch thin-plate weirs are presented in two categories:

- a) formula for all notch angles between  $\pi/9$  and  $5\pi/9$  radians ( $20^\circ$  and  $100^\circ$ );  
 b) formulae for specific notch angles (fully contracted weirs).

### 10.5 Formula for all notch angles between $\pi/9$ and $5\pi/9$ radians ( $20^\circ$ and $100^\circ$ )

#### 10.5.1 Kindsvater-Shen formula

The Kindsvater-Shen formula for triangular notch weirs is given in Formula (19):

$$Q = C_d \frac{8}{15} \tan \frac{\alpha}{2} \sqrt{2g} h_e^{5/2} \quad (19)$$

where

$C_d$  is the coefficient of discharge;

$h_e$  is the effective head.

The coefficient of discharge,  $C_d$ , has been determined by experiment as a function of three variables (see Figure 8), and is given in Formula (20):

$$C_d = f\left(\frac{h}{p}, \frac{p}{B}, \alpha\right) \quad (20)$$

where

$p$  is the height of the vertex of the notch with respect to the floor of the approach channel;

$B$  is the width of the approach channel;

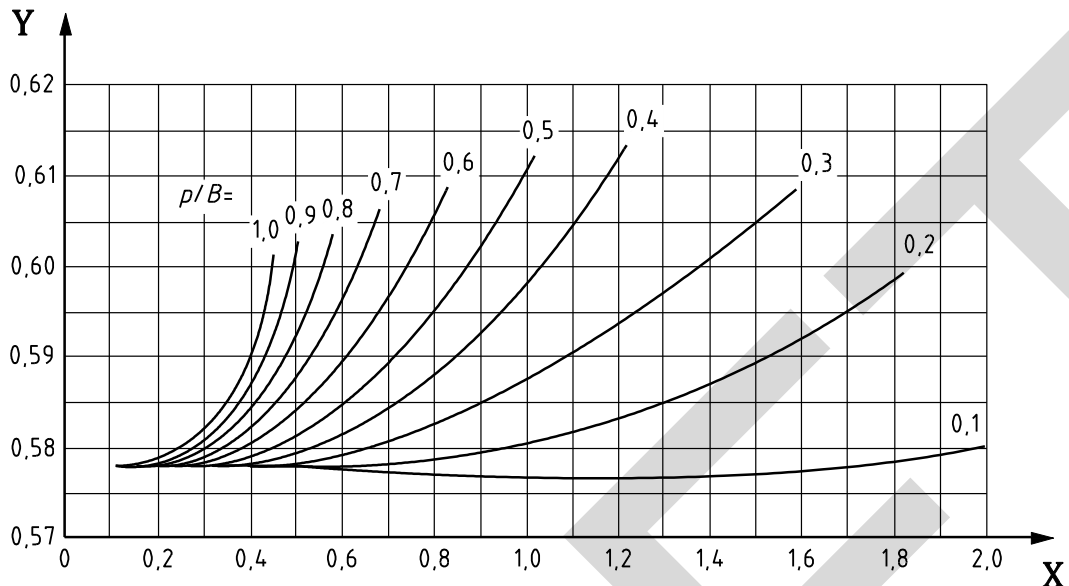
$h_e$  is defined by Formula (21):

$$h_e = h + k_h \quad (21)$$

in which  $k_h$  is an experimentally determined quantity, in metres, which compensates for the combined effects of viscosity and surface tension.

#### 10.5.2 Evaluation of $C_d$ and $k_h$

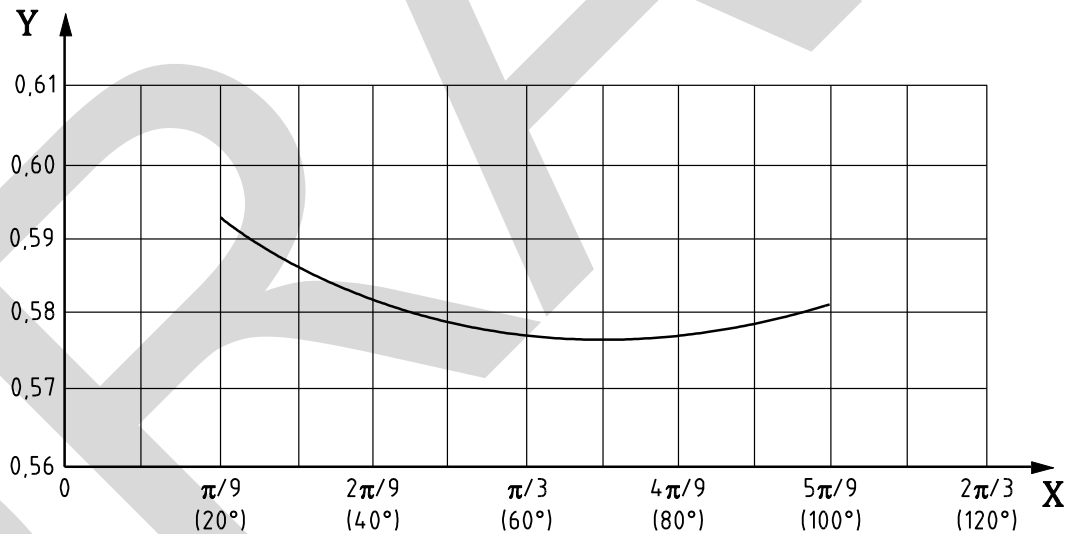
For triangular weirs with notch angle  $\alpha$  equal to  $\pi/2$  radians ( $90^\circ$ ), Figure 8 shows experimentally determined values of  $C_d$  for a wide range of values of  $h/p$  and  $p/B$ . For  $\alpha = \pi/2$  radians ( $90^\circ$ ),  $k_h$  has been shown to have a constant value of 0,000 85 m for a corresponding range of values of  $h/p$  and  $p/B$ .



**Key**

- X value of  $\frac{h}{p}$
- Y value of  $C_d$

**Figure 8 — Coefficient of discharge,  $C_d$  ( $\alpha = 90^\circ$ )**



**Key**

- X value of notch angle,  $\alpha$  (radians)
- Y value of  $C_d$

**Figure 9 — Coefficient of discharge,  $C_d$ , related to notch angle,  $\alpha$**

For notch angles other than  $\pi/2$  radians ( $90^\circ$ ), experimental data are insufficient to define  $C_d$  as a function of  $h/p$  and  $p/B$ . However, for weir notches which are small relative to the area of the approach channel, the velocity of approach is negligible and the effects of  $h/p$  and  $p/B$  are also negligible. For this condition (the so-called “fully-contracted” condition), Figure 9 shows experimentally determined values of  $C_d$  as a function of  $\alpha$  alone. Corresponding values of  $k_h$  are shown in Figure 10.

**10.5.3 Practical limitations on  $\alpha$ ,  $h/p$ ,  $p/B$ ,  $h$  and  $p$** 

For reasons related to hazards of measurement error and lack of experimental data, the following practical limits are applicable to the use of the Kindsvater-Shen formula:

- a)  $\alpha$  shall be between  $\pi/9$  radians and  $5\pi/9$  radians ( $20^\circ$  and  $100^\circ$ );
- b)  $h/p$  shall be limited to the range shown in Figure 8 for  $\alpha = \pi/2$  radians ( $90^\circ$ );  $h/p$  shall be not greater than 0,35 for other values of  $\alpha$ ;
- c)  $h$  shall be not less than 0,06 m;
- d)  $p$  shall be not less than 0,09 m.

**10.6 Formula for specific notch angles (fully-contracted weir)**

The British Standards Institution (BSI) formula is for three notch angles that have a special geometric relationship to each other:

- a)  $\tan \alpha/2 = 1$  ( $\alpha = \pi/2$  radians or  $90^\circ$ );
- b)  $\tan \alpha/2 = 0,50$  ( $\alpha = 0,927\ 3$  rad or  $53^\circ\ 8'$ );
- c)  $\tan \alpha/2 = 0,25$  ( $\alpha = 0,489\ 9$  rad or  $28^\circ\ 4'$ ).

The BSI discharge formula is given in Formula (22):

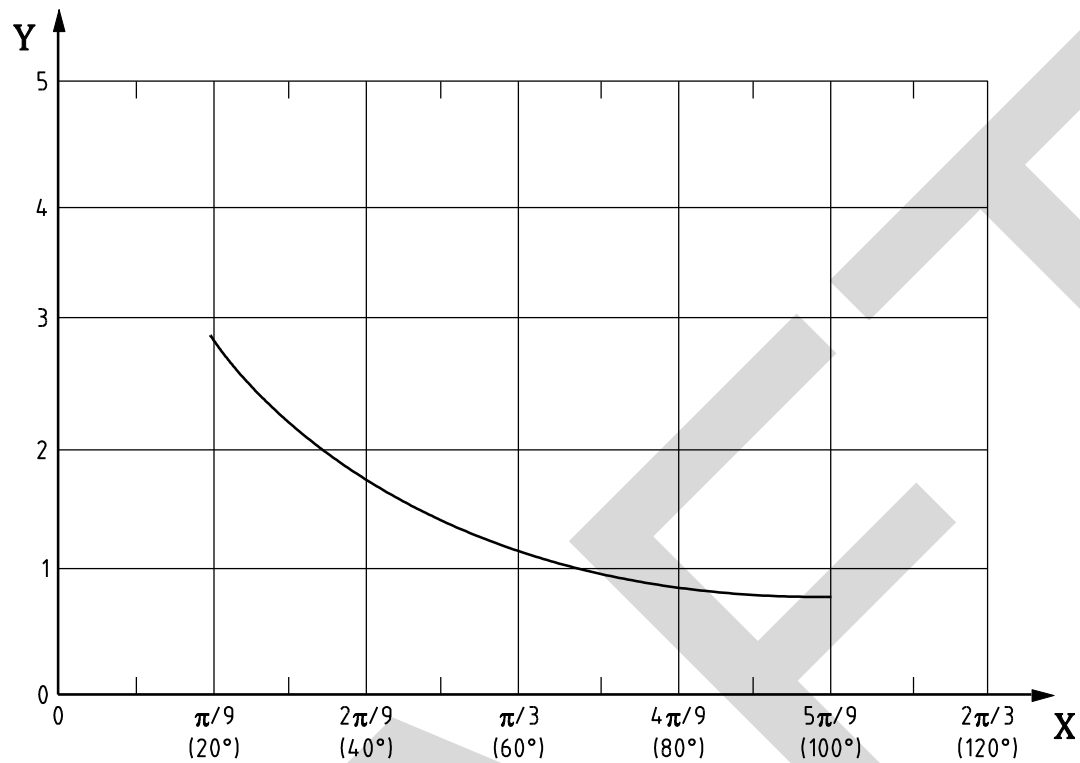
$$Q = C \frac{8}{15} \tan \frac{\alpha}{2} \sqrt{2g} h_e^{5/2} \quad (22)$$

and the experimentally determined values of  $C$  and  $Q$  for the condition of “full contraction” are shown in Tables E.1, E.2 and E.3.

Practical limitations applicable to the use of this formula are:

- a)  $h/p$  shall be not greater than 0,4;
- b)  $h/B$  shall be not greater than 0,2;
- c)  $h$  shall be between 0,05 and 0,38 m;
- d)  $p$  shall be not less than 0,45 m;
- e)  $B$  shall be not less than 1,0 m.



**Key**X notch angle,  $\alpha$ Y  $k_h$ , in millimetres**Figure 10 — Value of  $k_h$  related to notch angle,  $\alpha$** **10.7 Accuracy of discharge coefficients — Triangular-notch weirs**

The accuracy of discharge measurements made with a triangular-notch thin-plate weir depends primarily on the accuracy of the head and notch-angle measurements and on the applicability of the discharge formula and coefficients used. If great care is exercised in meeting the construction, installation and operational conditions specified in this document, uncertainties (at 95 % confidence level) attributable to the coefficients of discharge will be not greater than 1,0 %. The combination of all uncertainties which contribute significantly to the uncertainty of discharge measurements is treated in Clause 11. Examples of estimated uncertainties in measured discharge are given in Clause 12.

**11 Uncertainties of flow measurement****11.1 General**

**11.1.1** This clause provides information for the user of this document to state the uncertainty of a measurement of discharge.

**11.1.2** Annex C is an introduction to measurement uncertainty. It provides supporting information based on ISO/IEC Guide 98-3<sup>[1]</sup> and ISO/TS 25377<sup>[5]</sup>. Refer to Annex C for definitions.

Previous versions of this document have expressed the uncertainty of discharge coefficient  $u(C)$  at the 95 % level of confidence. This is equivalent to two standard deviations or twice the value of standard uncertainty.

This document expresses discharge coefficient as standard uncertainty (one standard deviation) to be in accordance with ISO/IEC Guide 98-3.

Hydrometry requires measurements using various techniques, the results of which are used to calculate a value for flow. Annex D provides sample values for the various techniques. These are presented in tabular form with uncertainty estimates ascribed to each technique for the purpose of illustration only.

These sample values are not to be interpreted as norms of performance.

The example given in Clause 12 uses values from Annex D.

### 11.1.3 A measurement result comprises

- a) an estimate of the measured value, with
- b) a statement of the uncertainty of the measurement.

11.1.4 A statement of the uncertainty of a flow measurement in a channel has four separate components of uncertainty:

- a) uncertainty of the measurement of head in the channel;
- b) uncertainty of the dimensions of the structure;
- c) uncertainty of the discharge coefficient stated in this document from laboratory calibration of the flow structure being considered;
- d) uncertainty of channel velocity distribution related to the velocity coefficient,  $C_v$ .

This clause does not accommodate component d). It is assumed that the channel hydraulics are substantially equivalent to those existing in the calibration facility at the time of derivation of component c) as defined in 6.3.3.

11.1.5 The estimation of measurement uncertainty associated with items a) and b) of 11.1.4 is provided in Annex D.

Values taken from Annex D are used in the examples in Clause 12. These values are for illustrative purpose only and should not be interpreted as norms of performance for the types of equipment listed. In practice, uncertainty estimates should be taken from test certificates for the equipment, preferably obtained from laboratories which are accredited to ISO/IEC 17025<sup>[3]</sup>.

## 11.2 Combining measurement uncertainties

Refer to C.7.

The proportion in which each flow formula parameter contributes to flow measurement uncertainty,  $U(Q)$ , is derived by analytical solution using partial differentials of the discharge formula.

For this purpose, the formulae for rectangular and triangular forms have been simplified as shown in Formula (23) and Formula (24):

$$Q_r = J_r \sqrt{g} C_d b_e h_e^{1,5} \quad (23)$$

$$Q_t = J_t \sqrt{g} C_d \tan \frac{\alpha}{2} h_e^{2,5} \quad (24)$$

where  $J$  is a numerical constant, dependent on the form of weir but not subject to error. The subscripts r and t denote the rectangular form and the triangular form of weir, respectively. From Formula (23) and Formula (24), the dispersion of the value  $Q$  of the formula can be written as Formula (25) and Formula (26):

$$\Delta Q_r = J_r \sqrt{g} \left( \frac{\partial Q_r}{\partial C_d} \Delta C_d + \frac{\partial Q_r}{\partial b_e} \Delta b_e + \frac{\partial Q_r}{\partial h_e} \Delta h_e \right) \quad (25)$$

$$\Delta Q_t = J_t \sqrt{g} \left[ \frac{\delta Q_t}{\delta C_d} \Delta C_d + \frac{\partial Q_t}{\partial \tan\left(\frac{\alpha}{2}\right)} \Delta \tan\left(\frac{\alpha}{2}\right) + \frac{\partial Q_t}{\partial h_e} \Delta h_e \right] \quad (26)$$

where the partial derivatives are the sensitivity coefficients described in ISO/TS 25377 and where  $\Delta Q$  is the dispersion of  $Q$  due to small dispersions of  $\Delta C$ ,  $\Delta b$  or  $\Delta \tan\left(\frac{\alpha}{2}\right)$  and  $\Delta h_e$ . Evaluating the partial differentials and using Formula (23) and Formula (24), the relationship can be written as Formula (27) and Formula (28):

$$\frac{\Delta Q_t}{Q_t} = \frac{\Delta C_d}{C_d} + \frac{\Delta b_e}{b_e} + 1,5 \frac{\Delta h_e}{h_e} \quad (27)$$

$$\frac{\Delta Q_t}{Q_t} = \frac{\Delta C_d}{C_d} + \frac{\Delta \tan\frac{\alpha}{2}}{\tan\frac{\alpha}{2}} + 2,5 \frac{\Delta h_e}{h_e} \quad (28)$$

In uncertainty analysis, the values  $\frac{\Delta Q}{Q}$ ,  $\frac{\Delta b}{b}$ ,  $\frac{\Delta C}{C}$ ,  $\frac{\Delta \tan\frac{\alpha}{2}}{\tan\frac{\alpha}{2}}$  and  $\frac{\Delta h}{h}$  are referred to as dimensionless

standard uncertainties and have the notation  $u^*(Q)$ ,  $u^*(C)$ ,  $u^*(b)$ ,  $u^*\left[\tan\left(\frac{\alpha}{2}\right)\right]$  and  $u^*(h)$ .

Note that the value  $u^*\left[\tan\left(\frac{\alpha}{2}\right)\right]$  is derived from the relationship given in Formula (29):

$$\tan\left(\frac{\alpha}{2}\right) = \frac{b_t}{2h_t} \quad (29)$$

where  $b_t$  is the crest width and  $h_t$  is the height of the notch.

Since the uncertainties of  $b$ ,  $\alpha$ ,  $C$  and  $h$  are independent of each other, probability requires summation in quadrature rather than a simple summation, as given in Formula (30) and Formula (31):

$$u_c^*(Q)_r = \sqrt{u^*(C_d)^2 + u^*(b_e)^2 + [1,5u^*(h_e)]^2} \quad (30)$$

$$u_c^*(Q)_t = \sqrt{u^*(C_d)^2 + u^*\left[\tan\left(\frac{\alpha}{2}\right)\right]^2 + [2,5u^*(h_e)]^2} \quad (31)$$

### 11.3 Uncertainty of discharge coefficient, $u^*(C_d)$ , for thin-plate weirs

The discharge coefficient,  $C_d$ , of Clause 9 and Clause 10 have been determined from a series of hydraulics tests using a high resolution calibration facility. From these tests, the values of discharge coefficient uncertainty,  $u^*(C_d)$ , are summarized in Table 2.

**Table 2 — Values of discharge coefficient uncertainty,  $u^*(C_d)$ , against head,  $h$**

Type	Head, $h$	$u^*(C_d)$
Rectangular	$h < 1,0p$	0,75 %

Rectangular	$1,0p < h < 1,5p$	1,00 %
Rectangular	$1,5p < h < 2,5 p$	1,50 %
Triangular	—	0,5 %

### 11.4 Uncertainty budget

In reports, an uncertainty budget table may be presented (or referenced) to provide the following information for each source of uncertainty:

- the method of evaluation (from Annex C);
- the determined value of standard uncertainty  $u^*(C_d)$ ,  $u^*\left[\tan\left(\frac{\alpha}{2}\right)\right]$  and  $u^*(h_e)$ , including datum uncertainty of  $u^*(h_e)$ ;
- the relative sensitivity coefficients, Formula (27) and Formula (28).

The values for each source are then applied according to Formula (30) or Formula (31) to give the combined standard uncertainty,  $u^*(Q)$ .

The expanded uncertainty  $U^*(Q)$  for a confidence level of 95 % is calculated using Table C.1.

It is customary to present these steps in tabular form with one row for each source and a column for each of the items a) to c).

The table may include, where appropriate, the critical thinking behind the subjective allocation of uncertainty to the quantities  $b$  and  $h$ . This section of the table may be replicated for a range of values of  $h_1$  to determine a relationship between  $u^*(Q)$  and  $h_1$ .

## 12 Example

### 12.1 General

In presenting examples, the formulae given in Clause 10 and Clause 11 define the relationship between the parameters which determine flow rate.

Uncertainty of the discharge coefficient is a fundamental uncertainty and is defined in 12.3. To complete overall uncertainty estimation, practical estimations shall be made of the head measurement uncertainty and the uncertainty of the measurement of physical dimensions.

Annex D provides a consistent framework for evaluating these uncertainties for the commonly used measurement techniques.

One such technique is selected in 12.3 for the example that follows.

### 12.2 Characteristics — Gauging structure

The example relates to modular flow conditions for a 90° V-notch weir. The crest height  $p$  above the bed of the approach channel is 0,151 m. The channel is 0,503 m wide. The angle of the V-notch is estimated to lie between 89,5° and 90,5°.

### 12.3 Characteristics — Gauged head instrumentation

In this example, a pressure transducer is used to determine head. The transducer is located in the approach channel about 1 m upstream of the weir.

- The signal indicates a head of 0,212 m. Referring to Annex D, the measurement uncertainty from Table D.1, at this head, is  $u(h_1) = 0,002$  m.

- b) The transducer is susceptible to drift over a period of time. Over a period of time, it has been noted that the nominal datum signal varies in the range 0,000 m to 0,007 m. Datum uncertainty is estimated according to the rectangular distribution given in Formula (C.5).

$$u(E) = \frac{1}{\sqrt{3}} \left( \frac{0,007 - 0,000}{2} \right)$$

$$u(E) = 0,002 \text{ m}$$

### 12.4 Discharge coefficient

The value of the gauged head discharge coefficient is determined from Figure 8 for the 90° V-notch weir. The key ratios of  $h/p$  and  $p/B$  are:

$$\frac{h}{p} = \frac{0,212}{0,151} = 1,40$$

$$\frac{p}{B} = \frac{0,151}{0,503} = 0,30$$

from which  $C_d = 0,600$ .

### 12.5 Discharge estimate

The flow rate is calculated from Formula (19):

$$Q_t = C_d \frac{8}{15} \tan \frac{\alpha}{2} \sqrt{2gh_e}^{5/2}$$

where  $h_e = h + k_h = 0,212 + 0,00085$

$$Q_t = 0,600 \times 0,5333 \times 4,429 \times 1 \times 0,21285^{2,5}$$

$$\therefore Q_t = 0,0296 \text{ m}^3/\text{s}$$

Specimen tables for the discharge of water over a V-notch with  $\tan 1/\alpha$  equal to 1,  $1/2$  and  $1/4$  are given in Annex E.

### 12.6 Uncertainty statement

12.6.1 From Table 2, the value for uncertainty of the discharge coefficient is:

$$u^*(C) = 0,50\%$$

12.6.2 Using Formula (C.4), the value of uncertainty of the V-angle may be written as follows:

$$u \left[ \tan \left( \frac{\alpha}{2} \right) \right] = \frac{1}{\sqrt{6}} \left[ \frac{\tan \left( \frac{90,5}{2} \right) - \tan \left( \frac{89,5}{2} \right)}{2} \right]$$

$$= 0,0036$$

$$\text{or } u^* \left[ \tan \left( \frac{\alpha}{2} \right) \right] = 100 \times \frac{0,0036}{\tan \left( \frac{90}{2} \right)} = 0,36 \%$$

**12.6.3** The combined uncertainty of gauged head  $u(h)$ , calculated in 12.3, is combined with instrumentation measurement uncertainty and datum measurement uncertainty.

$$u(h) = \sqrt{(0,002)^2 + (0,002)^2} \text{ m}$$

$$u(h) = 0,0028 \text{ m}$$

$$u^*(h) = \frac{0,0028}{0,212} \times 100$$

$$u^*(h) = 1,32 \%$$

**12.6.4** The combined uncertainty estimate is determined from Formula (31).

$$u_c^*(Q) = \sqrt{u^*(C_d)^2 + u^* \left[ \tan \left( \frac{\alpha}{2} \right) \right]^2 + [2,5u^*(h_e)]^2}$$

$$u_c^*(Q) = \sqrt{0,50^2 + 0,36^2 + (2,5 \times 1,32)^2}$$

$$u_c^*(Q) = 3,35 \%$$

Therefore, at the 95 % confidence level:

$$u_c^*(Q) = 3,35 \times 2 = 6,7 \%$$

NOTE This estimate is dominated by the contribution from head measurement uncertainty and assumes sufficient measurement samples.

**12.6.5** The conventional statement of discharge is therefore:

0,029 3 m<sup>3</sup>/s with an uncertainty of 6,7 % at the 95 % level of confidence based on a coverage factor of  $k = 2$ .

**12.6.6** The uncertainty budget for the example could be expressed as in Table 3.

**Table 3 — Uncertainty budget for the example**

	Type/ Evaluation	$u, u^*$ Value	Sensitivity coefficients	Comment
$u^*(C_d)$	B/Normal	0,5 %	1,0	From laboratory tests
$u^*[\tan(\alpha/2)]$	B/Triangular	0,36 %	1,0	Using C.6.2
$u(E)$	B/Rectangular	0,002 m	—	Using C.6.3
$u(h_1)$	B/Rectangular	0,002 m	—	From Table D.1
$u^*(h_1)$	Combined	1,32 %	2,5	From 12.6.3
$u_c^*(Q)$	Combined	3,35 %	—	Using Formula (6)

## Annex A (informative)

### Flow measurement with small weir tanks

Whenever possible, weir tanks conforming to 6.3.3 should be used to measure flow in the field. When the highest accuracy is not required or where site conditions make it difficult to install or operate large tanks satisfactorily, smaller tanks may be used.

There is a limited amount of data on how the discharge coefficients of weirs are affected by the size of the tank, as well as by non-standard head-measuring positions, asymmetric and unsteady flow conditions at entry and sediment deposits. Further information can be obtained from *The performance of weir tanks fitted with V-notch and rectangular thin-plate weirs*<sup>1)</sup>.

In order to give some guide to the effect that a reduction in the size of the weir tank will have, values of the discharge coefficient have been tabulated for seven different sizes of weir tank. Table A.1 gives values of  $C$  in the BSI formula for a 90° V-notch and of  $C_d$  in the Kindsvater-Carter formula for a contracted rectangular-notch.

Some indication of the influence of sediment deposit is given in Table A.2, which shows values of  $C_d$  for a tank with dimensions conforming to 6.3.3 but with differing amounts of sediment deposited against the weir plate. The uncertainty of these coefficients is approximately 1 %.

Within the range of tank sizes and heads covered in Table A.1, the location of the head-measuring device is relatively unimportant. Positions between 100 mm and 720 mm upstream of the weir produce discharge coefficients which vary by less than 0,5 %. Heads should not be measured, however, near the inlet baffle or in the downstream corner of a narrow tank.

**Table A.1 — Discharge coefficients for 90° V-notches and rectangular notches in small weir tanks**

Tank size (length, width, height) m	C values for 90° V-notches <sup>a</sup>			C <sub>d</sub> values for rectangular notches <sup>b</sup>		
	Head (h) mm			Head (h) mm		
	115	150	180	65	100	135
2,62 × 0,92 × 0,45	0,593	0,592	0,587	0,609	0,592	0,588
1,50 × 0,92 × 0,45	0,603	0,592	0,587	0,604	0,592	0,588
1,00 × 0,92 × 0,45	0,603	0,592	0,587	0,600	0,590	0,588
2,62 × 0,75 × 0,45	0,597	0,592	0,590	0,606	0,593	0,588
2,62 × 0,50 × 0,45	0,605	0,596	0,595	0,611	0,598	0,598
2,62 × 0,92 × 0,30	0,600	0,590	0,586	0,606	0,592	0,588
2,62 × 0,92 × 0,15	0,602	0,597	0,593	0,613	0,598	0,595

<sup>a</sup>  $Q = C \frac{8}{15} \sqrt{2g} h^{5/2}$

<sup>b</sup>  $Q = C \frac{2}{3} \sqrt{2g} b_e h_e^{3/2}$

<sup>1)</sup> Available from Hydraulics Research Ltd., Wallingford, Oxon., England, as Report No. EX1243, 1985.

**Table A.2 — Discharge coefficients for rectangular notches in small weir tanks with sediment deposits**

Tank size (length, width, height) m	Max. level of deposits relative to weir crest mm	$C_d$ values for rectangular notches <sup>a</sup>		
		Head ( $h$ ) mm	65	100
2,62 × 0,92 × 0,45	-150	0,605	0,591	0,588
	-40	0,606	0,597	0,590
	-40	0,613	0,601	0,595
	(+ 100 at sides)			

<sup>a</sup>  $Q = C \frac{2}{3} \sqrt{2g} b_e h_e^{3/2}$



## Annex B (normative)

### Guide to the design and installation of a flow straightener

A flow straightener may be used for reducing the approach channel length.

The purpose of a flow straightener is to modify the flow in a shortened approach channel so that the velocity distribution of the flow is normal and steady.

6.3.3 and Figure 1 specify a normal velocity distribution.

A flow straightener should consist of several perforated plates (at least four), installed vertically and perpendicular to the flow direction with a minimum spacing of 0,2 m between adjacent plates. The percentage of the open area of each plate should be between 40 % and 60 % inclusive.

Figure B.1 shows an example of perforation. Holes are distributed in a staggered formation; in the example, the distance between the centres of two neighbouring holes is 30 mm while the hole diameter is 20 mm. This gives a percentage of open area equal to 40,31 %.

The plates should be thick and sufficiently strong to sustain the force exerted by the channel flow. The dimension of the holes may be varied in accordance with the channel width, provided that the spacing between the plates is adjusted in proportion to the hole diameter.

The straightener plates may be fixed on the approach channel, either with the perforations of the different plates aligned on the general direction of the stream (see Figure B.2), or with them positioned in a staggered formation, provided that the distance between adjacent plates is large compared with the hole diameter (see Figure B.3).

Dimensions in millimetres

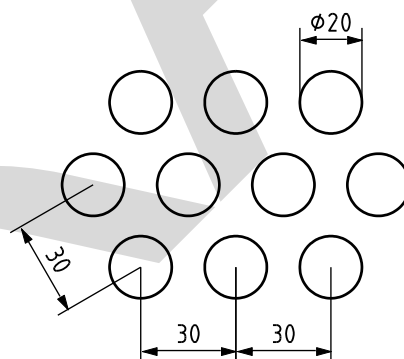
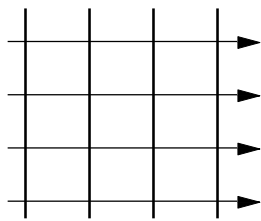
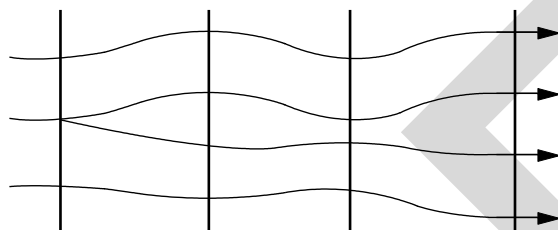


Figure B.1 — Example of perforation



**Figure B.2 — Aligned perforations**



**Figure B.3 — Staggered perforations**

## Annex C (informative)

### Introduction to measurement uncertainty

#### C.1 General

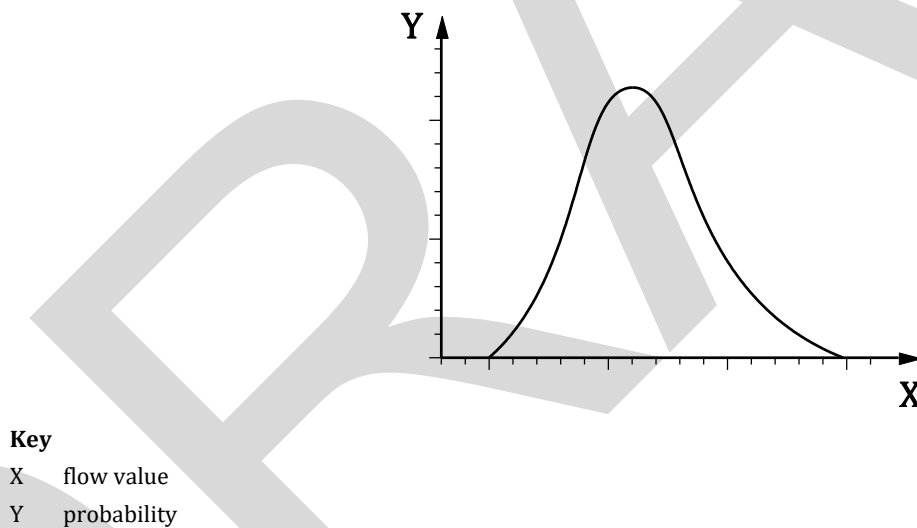
Results of measurements or analysis cannot be exact. The discrepancy between the true value, which is unknowable, and the measured value is the measurement error. The concept of uncertainty is a way of expressing this lack of knowledge. For example, if water is controlled to flow at a constant rate, then a flow meter will exhibit a spread of measurements about a mean value. If attention is not given to the uncertain nature of data, incorrect decisions can be made which have financial or judicial consequences. A realistic statement of uncertainty enhances the quality of information, making it more useful.

The uncertainty of a measurement represents a dispersion of values that could be attributed to it. Statistical methods provide objective values based on the application of theory.

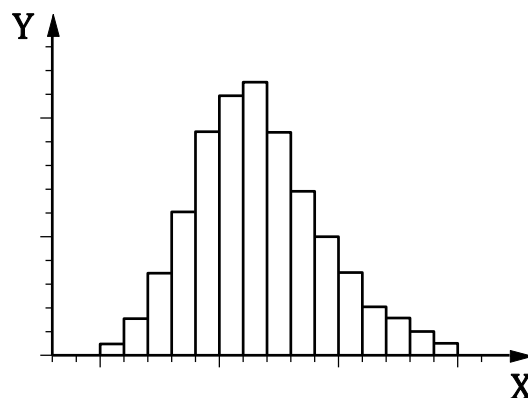
Standard uncertainty is defined as:

*Standard uncertainty equates to a dispersion of measurements expressed as a standard deviation.*

From this definition, uncertainty can be readily calculated for a set of measurements.

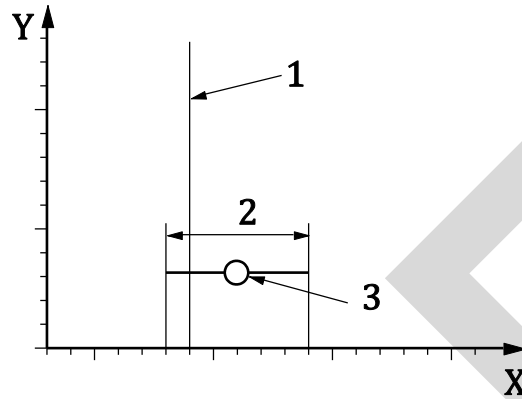


**Figure C.1 — Pictorial representation of some uncertainty parameters — Example 1**



**Key**

- X flow value  
Y number of samples

**Figure C.2 — Pictorial representation of some uncertainty paramaters — Example 2****Key**

- 1 limit  
2 standard deviation  
3 mean value  
X flow value  
Y number of samples

**Figure C.3 — Pictorial representation of some uncertainty paramaters — Example 3**

Figure C.1 shows the probability that a measurement of flow under steady conditions takes a particular value due to the uncertainties of various components of the measurement process, in the form of a probability density function.

Figure C.2 shows sampled flow measurements, in the form of a histogram.

Figure C.3 shows standard deviation of the sampled measurements compared with a limiting value. The mean value is shown to exceed the limiting value but is within the band of uncertainty (expressed as the standard deviation about the mean value).

## C.2 Confidence limits and coverage factors

For a normal probability distribution, analysis shows that 68 % of a large set of measurements lies within one standard deviation of the mean value. Thus, standard uncertainty is said to have a 68 % level of confidence.

However, for some measurement results, it is customary to express the uncertainty at a level of confidence which will cover a larger portion of the measurements; for example, at a 95 % level of confidence (see Figure C.6). This is done by applying a factor, the coverage factor  $k$ , to the computed value of standard uncertainty.

For a normal probability distribution, 95,45 % (effectively 95 %) of the measurements are covered for a value of  $k = 2$ . Thus, uncertainty at the 95 % level of confidence is twice the standard uncertainty value.

In practice, measurement variances rarely follow closely the normal probability distribution. They may be better represented by triangular, rectangular or bimodal probability distributions and only sometimes approximate to the normal distribution.

So a probability distribution must be selected to model the observed variances. To express the uncertainty of such models at the 95 % confidence limit requires a coverage factor that represents 95 %

of the observations. However, the same coverage factor,  $k = 2$ , is used for all models. This simplifies the procedure while ensuring consistency of application within tolerable limits.

### C.3 Random and systematic error

The terms “random” and “systematic” have been applied in hydrometric standards to distinguish between a) random errors that represent an inherent dispersion of values under steady conditions, and b) systematic errors that are associated with inherent limitations of the means of determining the measured quantity.

A difficulty with the concept of a systematic error is that a systematic error cannot be determined without pre-knowledge of true values. If its existence is known or suspected, then steps should be taken to minimize such an error either by recalibration of the equipment or by reversing its effect in the calculation procedure. At which point, a systematic error contributes to uncertainty in the same way as random components of uncertainty.

For this reason, ISO/IEC Guide 98-3 does not distinguish between the treatment of random and systematic uncertainties. Generally, when determining a single discharge, random errors dominate and there is no need to separate random and systematic errors. However, where (say) totalized volume is established over a long time base, the systematic errors, even when reduced, can remain dominant in the estimation of uncertainty.

### C.4 Measurement standards

ISO/IEC Guide 98-3 and ISO/TS 25377 provide rules for the application of the principles of measurement uncertainty, in particular on the identification of components of error, the quantification of their corresponding uncertainties and how these are combined using methods derived from statistical theory into an overall result for the measurement process.

The components of uncertainty are characterized by estimates of standard deviations. There are two methods of estimation.

- a) **Type-A estimation** (by statistical analysis of repeated measurements from which an equivalent standard deviation is derived).

This process may be automated in real-time for depth or for velocity measurement.

- b) **Type-B estimation** (by ascribing a probability distribution to the measurement process).

This is applicable to:

- 1) human judgement of a manual measurement (distance or weight),
- 2) manual readings taken from instrumentation (manufacturer's statement), or
- 3) calibration data (from manufacturer).

### C.5 Evaluation of Type-A uncertainty

Defined in C.1, the term “standard uncertainty” equates to a dispersion of measurements expressed as a standard deviation. Thus, any single measurement of a set of  $n$  measurements has, by definition, an uncertainty given in Formula (C.1):

$$u(x) = t_e \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2} \quad (\text{C.1})$$

where  $\bar{x}$  is the best estimate of the true mean, as given in Formula (C.2):

$$\bar{x} = \frac{1}{n}(x_1 + x_2 + \dots + x_n) \quad (\text{C.2})$$

and  $t_e$  is a factor derived from statistical theory to account for the increased uncertainty when small numbers of measurements are available (refer to Table C.1).

If, instead of a single measurement from the set, the uncertainty is to apply to the mean of all  $n$  values, then Formula (C.3) applies:

$$u(\bar{x}) = \frac{t_e}{\sqrt{n}} \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2} \quad (\text{C.3})$$

For continuous measurement, Type-A evaluations may be derived as a continuous variable from the primary measurement, i.e. from water level or water velocity.

By taking average values over large numbers,  $n$ , of measurements, the uncertainty of the mean value  $u(\bar{x})$  is reduced by a factor of  $\frac{1}{\sqrt{n}}$  compared to the uncertainty  $u(x)$  of an individual measurement. For this reason, monitoring equipment should specify measurement performance in terms including both  $u(\bar{x})$  and  $u(x)$  to show the extent to which averaging is applied.

**Table C.1 —  $t_e$  factors at 90 %, 95 % and 99 % confidence levels**

Degrees of freedom <sup>a</sup>	Confidence level %		
	90	95	99
1	6,31	12,71	63,66
2	2,92	4,30	9,92
3	2,35	3,18	5,84
4	2,13	2,78	4,60
5	2,02	2,57	4,03
10	1,81	2,23	3,17
15	1,75	2,13	2,95
20	1,72	2,09	2,85
25	1,71	2,06	2,79
30	1,70	2,04	2,75
40	1,68	2,02	2,70
60	1,67	2,00	2,66
100	1,66	1,98	2,63
Infinite	1,64	1,96	2,58

<sup>a</sup> In general, the number of terms in a sum minus the number of constraints on the terms of the sum (GUM).

## C.6 Evaluation of Type-B uncertainty

### C.6.1 General

When there is no access to a continuous stream of measured data or if a large set of measurements is not available, the type-B method of estimation is used to:

- a) assign a probability distribution to the measurement process to represent the probability of the true value being represented by any single measured value;
- b) define upper and lower bounds of the measurement;
- c) determine a standard uncertainty from a standard deviation implied by the assigned probability distribution.

The Type-B methods allow estimates of upper and lower bounding values to be used to derive the equivalent standard deviation.

Four probability distributions are described in ISO/IEC Guide 98-3 and in C.6.2 to C.6.5.

### C.6.2 The triangular distribution

The triangular distribution is represented in Figure C.4.

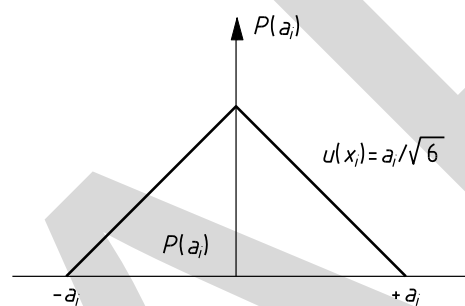


Figure C.4 — Triangular distribution

$$u(\bar{x}) = \frac{1}{\sqrt{6}} \left( \frac{x_{\max} - x_{\min}}{2} \right) \quad (\text{C.4})$$

This usually applies to manual measurements where the mean value is most likely to be closer to the true value than others between the discernible upper and lower limits of the measurement.

### C.6.3 The rectangular distribution

The rectangular distribution is represented in Figure C.5.

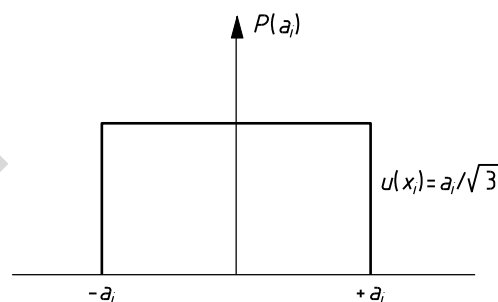


Figure C.5 — Rectangular distribution

$$u(\bar{x}) = \frac{1}{\sqrt{3}} \left( \frac{x_{\max} - x_{\min}}{2} \right) \quad (\text{C.5})$$

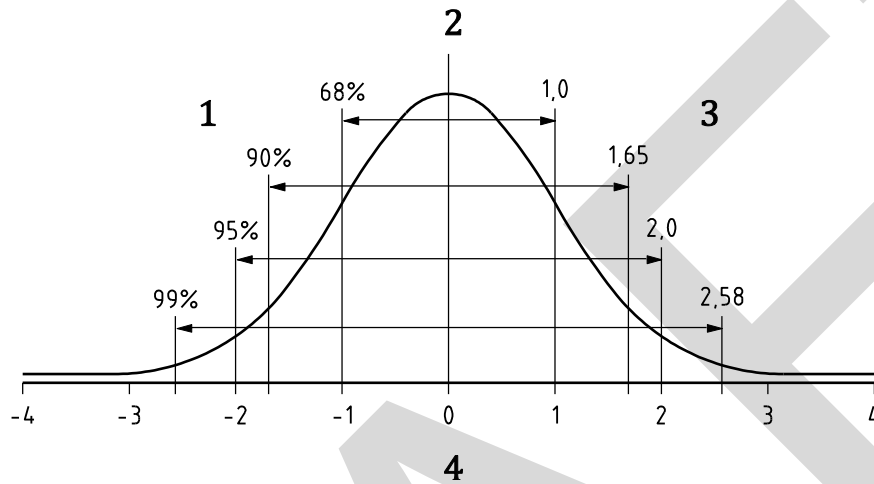
This probability distribution is usually applied to the resolution limit of the measurement instrumentation (i.e. the displayed resolution or the resolution of internal analogue/digital converters).

However, this is not the only source of uncertainty of measurement equipment. There may be uncertainty arising from the measurement algorithm used and/or from the calibration process.

If the equipment measures relative values, then there will also be uncertainty in the determination of its datum.

**C.6.4 The normal probability distribution**

The normal probability distribution is represented in Figure C.6.



- Key**
- 1 percent of readings in bandwidth
  - 2 probability
  - 3 coverage factor
  - 4 standard deviations

**Figure C.6 — Normal probability distribution**

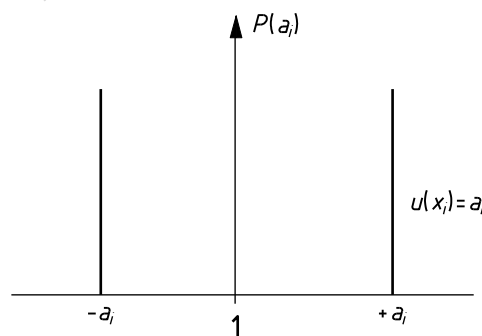
$$u(x_{\text{mean}}) = \frac{u(\text{specified})}{k} \tag{C.6}$$

where  $k$  is the coverage factor applying to the specified uncertainty value.

These are uncertainty statements based on “off-line” statistical analysis, usually as part of a calibration process where they have been derived using a Type-A process. When expressed as standard uncertainty, the uncertainty value is to be used directly with an equivalent coverage factor of  $k = 1$ .

**C.6.5 Bimodal probability distribution**

The bimodal probability distribution is represented in Figure C.7.



**Figure C.7 — Bimodal probability distribution**



$$u(x_{\text{mean}}) = \frac{(x_{\text{max}} - x_{\text{min}})}{2} \quad (\text{C.7})$$

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Measurement equipment with hysteresis can only exhibit values at the upper and lower bounds of the measurement.

An example of this is the float mechanism where friction and surface tension combine to cause the float to move in finite steps.

### C.7 Combined uncertainty value, $u_c$

For most measurement systems, a measurement result is derived from several variables. For example, flow measurement,  $Q$ , in a rectangular channel can be expressed as a function of independent variables as shown in Formula (C.8):

$$Q = b \times h \times \bar{V} \quad (\text{C.8})$$

where

$b$  is the channel width;

$h$  is the depth of water in the channel;

$\bar{V}$  is the mean velocity.

These three components are measured independently and combined to determine a value for  $Q$ .

Just as  $b$ ,  $h$  and  $\bar{V}$  are combined to determine the value  $Q$ , so each component of uncertainty must be combined to determine a value for  $u_c(Q)$ . This is done by evaluating the sensitivity of  $Q$  to small change,  $\Delta$ , in  $b$ ,  $h$  or  $V$ . Thus, Formula (C.9) applies:

$$\Delta Q = \frac{\partial Q}{\partial b} \Delta b + \frac{\partial Q}{\partial h} \Delta h + \frac{\partial Q}{\partial \bar{V}} \Delta \bar{V} \quad (\text{C.9})$$

where the partial differentials,  $\frac{\partial Q}{\partial b}$ ,  $\frac{\partial Q}{\partial h}$  and  $\frac{\partial Q}{\partial \bar{V}}$  are sensitivity coefficients. For the formula  $Q = b \times h \times \bar{V}$ , this is equal to Formula (C.10):

$$\frac{\Delta Q}{Q} = \frac{\Delta b}{b} + \frac{\Delta h}{h} + \frac{\Delta \bar{V}}{\bar{V}} \quad (\text{C.10})$$

In uncertainty analysis, the values  $\frac{DQ}{Q}$ ,  $\frac{Db}{b}$ ,  $\frac{Dh}{h}$  and  $\frac{D\bar{V}}{\bar{V}}$  correspond to dimensionless standard uncertainties. They are given the notation  $u_c^*(Q)$ ,  $u^*(b)$ ,  $u^*(h)$  and  $u^*(V)$ .

Since the uncertainties of  $b$ ,  $V$  and  $h$  are independent of each other, probability considerations require summation in quadrature, as given in Formula (C.11).

$$u_c^*(Q) \cong \sqrt{u^*(\bar{V})^2 + u^*(b)^2 + u^*(h)^2} \quad (\text{C.11})$$

**Annex D**  
(informative)

**Sample measurement performance for use in  
hydrometric worked examples**

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Table D.1 — Sample measurement performance for use in hydrometric worked examples

Measurement technologies		Comment	Symbol	Uncertainty options		Installed equipment to have corresponding values certified by the manufacturer									
						Nominal range of measurement					Corresponding standard uncertainty (68 % confidence limit)				
Velocity (continuous)				A	B	Minimum	25 %	50 %	75 %	Maximum	Minimum	25 %	50 %	75 %	Maximum
Point velocity	Propeller	Calibration certificate	$u(V)$	YES	Normal	0,005 m/s	1,250 m/s	2,500 m/s	3,750 m/s	5,000 m/s	0,000 5 m/s	0,010 m/s	0,022 m/s	0,030 m/s	0,040 m/s
	Electromagnetic	Calibration certificate	$u(V)$	YES	Normal	0,005 m/s	0,750 m/s	1,500 /s	2,250 m/s	3,000 m/s	0,000 5 m/s	0,010 m/s	0,018 m/s	0,025 m/s	0,025 m/s
Path velocity	Time of flight sonar	Sonic velocity path angle	$u(V)$	YES	Rectangular	0,030 m/s	0,250 m/s	0,500 m/s	0,750 m/s	1,000 m/s	0,003 m/s	0,005 m/s	0,007 m/s	0,007 m/s	0,010 m/s
	Gated Doppler sonar	Particle dependent - low velocity resolution	$u(V)$	YES	Rectangular	0,030 m/s	0,250 m/s	0,500 m/s	0,750 m/s	1,000 m/s	0,003 m/s	0,005 m/s	0,007 m/s	0,007 m/s	0,010 m/s
	Sonar correlation	Particle dependent	$u(V)$	YES	Rectangular	0,030 m/s	0,250 m/s	0,500 m/s	0,750 m/s	1,000 m/s	0,003 m/s	0,005 m/s	0,007 m/s	0,007 m/s	0,010 m/s
Section velocity	EM	To be calibrated <i>in situ</i>	$u(V)$		Rectangular	0,030 m/s	0,250 m/s	0,500 m/s	0,750 m/s	1,000 m/s	0,003 m/s	0,005 m/s	0,007 m/s	0,007 m/s	0,010 m/s
Water level (continuous)															
Relative datum (must be applied to all methods)		Manual process	$u(E)$		Triangular	Not applicable	0,500 m	1,000 m	1,500 m	2,000 m	0,001 m	0,001 m	0,001 5 m	0,001 5 m	0,001 5 m
In-contact methods	Encoder/float system	Requires regular maintenance	$u(h_1)$		Bimodal	Extension 0,200 m	Extension 1,250 m	Extension 2,500 m	Extension 3,750 m	Extension 5,000 m	0,001 5 m	0,002 0 m	0,002 0 m	0,002 5 m	0,002 5 m
	Pressure transducer	Datum value drift	$u(h_1)$		Rectangular	0,010 m	0,500 m	1,000 m	1,500 m	2,000 m	0,002 m	0,002 m	0,002 5 m	0,002 5 m	0,003 0 m
	Sonar	Surface wave effects	$u(h_1)$	YES	Rectangular	0,050 m	0,500 m	1,000 m	1,500 m	2,000 m	0,001 m	0,001 m	0,001 5 m	0,001 5 m	0,001 5 m
Non-contact	Pulse echo ultrasound	Surface wave effects	$u(R)$	YES	Rectangular	Range 0,300 m	Range 1,250 m	Range 2,500 m	Range 3,750 m	Range 5,000 m	0,002 m	0,004 m	0,010 m	0,025 m	0,060 m

methods		Air temperature Compensation													
	Pulse echo opto/radar	Surface wave effects	$u(R)$	Rectangular	Range 0,300 m	Range 1,250 m	Range 2,500 m	Range 3,750 m	Range 5,000 m	0,002 m	0,004 m	0,010 m	0,025 m	0,060 m	
Cross-section profile (distance measurement)															
	Natural channels	Sonar or dip gauging/GPRS or tracking	$u(B)$	Rectangular	0,500 m	5,000 m	10,000 m	15,000 m	20,000 m	0,002 m	0,020 m	0,060 m	0,100 m	0,200 m	
	Man-made channels	Manual measurement	$u(B)$	Triangular	Not applicable	0,500 m	1,000 m	1,500 m	2,000 m	0,001 m	0,001 m	0,001 5 m	0,001 5 m	0,001 5 m	

**Annex E**  
(informative)

**Specimen tables**

**Table E.1 — Discharge of water over a V-notch with  $\tan \alpha/2 = 1$  ( $\alpha = \pi/2$  radians or  $90^\circ$ ),  
 $Q = 2,362\ 5\ C_d h^{5/2}$ , ( $g = 9,806\ 6\ \text{m/s}^2$ )**

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $\text{m}^3/\text{s} \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $\text{m}^3/\text{s} \times 10^{-1}$
0,060	0,603 2	0,012 57	0,091	0,593 5	0,035 03
0,061	0,602 8	0,013 09	0,092	0,593 3	0,035 98
0,062	0,602 3	0,013 62	0,093	0,593 1	0,036 96
0,063	0,601 9	0,014 17	0,094	0,592 9	0,037 95
0,064	0,601 5	0,014 73	0,095	0,592 7	0,038 95
0,065	0,601 2	0,015 30	0,096	0,592 5	0,039 97
0,066	0,600 8	0,015 88	0,097	0,592 3	0,041 01
0,067	0,600 5	0,016 48	0,098	0,592 1	0,042 06
0,068	0,600 1	0,017 10	0,099	0,591 9	0,043 12
0,069	0,599 8	0,017 72	0,100	0,591 7	0,044 20
0,070	0,599 4	0,018 36	0,101	0,591 4	0,045 30
0,071	0,599 0	0,019 01	0,102	0,591 2	0,046 41
0,072	0,598 7	0,019 67	0,103	0,591 0	0,047 54
0,073	0,598 3	0,020 35	0,104	0,590 8	0,048 69
0,074	0,598 0	0,021 05	0,105	0,590 6	0,049 85
0,075	0,597 8	0,021 76	0,106	0,590 4	0,051 03
0,076	0,597 5	0,022 48	0,107	0,590 2	0,052 22
0,077	0,597 3	0,023 22	0,108	0,590 1	0,053 44
0,078	0,597 0	0,023 97	0,109	0,589 9	0,054 67
0,079	0,596 7	0,024 73	0,110	0,589 8	0,055 92
0,080	0,596 4	0,025 51	0,111	0,589 7	0,057 19
0,081	0,596 1	0,026 30	0,112	0,589 6	0,058 47
0,082	0,595 8	0,027 10	0,113	0,589 4	0,059 77
0,083	0,595 5	0,027 92	0,114	0,589 2	0,061 08
0,084	0,595 3	0,028 76	0,115	0,589 1	0,062 42
0,085	0,595 0	0,029 61	0,116	0,589 0	0,063 77
0,086	0,594 8	0,030 48	0,117	0,588 9	0,065 14
0,087	0,594 5	0,031 36	0,118	0,588 8	0,066 53
0,088	0,594 2	0,032 25	0,119	0,588 6	0,067 93
0,089	0,594 0	0,033 16	0,120	0,588 5	0,069 35

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Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,090	0,593 7	0,034 09
0,123	0,588 1	0,073 72
0,124	0,588 0	0,075 22
0,125	0,588 0	0,076 73
0,126	0,587 9	0,078 27
0,127	0,587 8	0,079 82
0,128	0,587 7	0,081 39
0,129	0,587 6	0,082 98
0,130	0,587 6	0,084 58
0,131	0,587 5	0,086 21
0,132	0,587 4	0,087 85
0,133	0,587 3	0,089 51
0,134	0,587 2	0,091 19
0,135	0,587 2	0,092 89
0,136	0,587 1	0,094 61
0,137	0,587 0	0,096 34
0,138	0,586 9	0,098 10
0,139	0,586 9	0,099 87
0,140	0,586 8	0,101 67
0,141	0,586 7	0,103 48
0,142	0,586 7	0,105 32
0,143	0,586 6	0,107 17
0,144	0,586 6	0,109 04
0,145	0,586 5	0,110 93
0,146	0,586 4	0,112 84
0,147	0,586 3	0,114 76
0,148	0,586 2	0,116 71
0,149	0,586 2	0,118 67
0,150	0,586 1	0,120 66
0,151	0,586 1	0,122 67
0,152	0,586 0	0,124 71
0,153	0,586 0	0,126 76
0,154	0,585 9	0,128 83
0,155	0,585 9	0,130 93
0,156	0,585 9	0,133 04
0,157	0,585 8	0,135 17

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,121	0,588 3	0,070 79
0,122	0,588 2	0,072 24
0,162	0,585 6	0,146 14
0,163	0,585 6	0,148 40
0,164	0,585 5	0,150 67
0,165	0,585 5	0,152 97
0,166	0,585 5	0,155 29
0,167	0,585 4	0,157 63
0,168	0,585 4	0,159 99
0,169	0,585 3	0,162 37
0,170	0,585 3	0,164 77
0,171	0,585 3	0,167 19
0,172	0,585 2	0,169 64
0,173	0,585 2	0,172 10
0,174	0,585 1	0,174 59
0,175	0,585 1	0,177 09
0,176	0,585 1	0,179 63
0,177	0,585 1	0,182 19
0,178	0,585 1	0,184 78
0,179	0,585 1	0,187 38
0,180	0,585 1	0,190 01
0,181	0,585 1	0,192 65
0,182	0,585 0	0,195 31
0,183	0,585 0	0,198 00
0,184	0,585 0	0,200 71
0,185	0,585 0	0,203 45
0,186	0,585 0	0,206 21
0,187	0,585 0	0,208 99
0,188	0,585 0	0,211 80
0,189	0,585 0	0,214 63
0,190	0,585 0	0,217 48
0,191	0,585 0	0,220 34
0,192	0,584 9	0,223 22
0,193	0,584 9	0,226 12
0,194	0,584 9	0,229 06
0,195	0,584 9	0,232 03

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Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,158	0,585 8	0,137 32	0,196	0,584 9	0,235 01
0,159	0,585 7	0,139 50	0,197	0,584 9	0,238 02
0,160	0,585 7	0,141 69	0,198	0,584 9	0,241 06
0,161	0,585 7	0,143 91	0,199	0,584 9	0,244 11
0,200	0,584 9	0,247 19	0,239	0,584 6	0,385 68
0,201	0,584 9	0,250 28	0,240	0,584 6	0,389 73
0,202	0,584 8	0,253 39	0,241	0,584 6	0,393 80
0,203	0,584 8	0,256 52	0,242	0,584 6	0,397 90
0,204	0,584 8	0,259 69	0,243	0,584 6	0,402 02
0,205	0,584 8	0,262 88	0,244	0,584 6	0,406 17
0,206	0,584 8	0,266 10	0,245	0,584 6	0,410 34
0,207	0,584 8	0,269 34	0,246	0,584 6	0,414 54
0,208	0,584 8	0,272 61	0,247	0,584 6	0,418 77
0,209	0,584 8	0,275 90	0,248	0,584 6	0,423 02
0,210	0,584 8	0,279 21	0,249	0,584 6	0,427 30
0,211	0,584 8	0,282 54	0,250	0,584 6	0,431 60
0,212	0,584 8	0,285 88	0,251	0,584 6	0,435 93
0,213	0,584 7	0,289 24	0,252	0,584 6	0,440 28
0,214	0,584 7	0,292 64	0,253	0,584 6	0,440 66
0,215	0,584 7	0,296 07	0,254	0,584 6	0,449 07
0,216	0,584 7	0,299 53	0,255	0,584 6	0,453 50
0,217	0,584 7	0,303 01	0,256	0,584 6	0,457 96
0,218	0,584 7	0,306 51	0,257	0,584 6	0,462 45
0,219	0,584 7	0,310 04	0,258	0,584 6	0,466 96
0,220	0,584 7	0,313 59	0,259	0,584 6	0,471 50
0,221	0,584 7	0,317 17	0,260	0,584 6	0,476 06
0,222	0,584 7	0,320 77	0,261	0,584 6	0,480 65
0,223	0,584 7	0,324 39	0,262	0,584 6	0,485 27
0,224	0,584 7	0,328 03	0,263	0,584 6	0,489 91
0,225	0,584 6	0,331 68	0,264	0,584 6	0,494 58
0,226	0,584 6	0,335 35	0,265	0,584 6	0,499 28
0,227	0,584 6	0,339 07	0,266	0,584 6	0,404 00
0,228	0,584 6	0,342 82	0,267	0,584 6	0,508 76
0,229	0,584 6	0,346 59	0,268	0,584 6	0,513 53
0,230	0,584 6	0,350 39	0,269	0,584 6	0,518 34



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Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,231	0,584 6	0,354 21			
0,232	0,584 6	0,358 06	0,270	0,584 6	0,523 17
0,233	0,584 6	0,361 93	0,271	0,584 6	0,528 02
0,234	0,584 6	0,365 82	0,272	0,584 6	0,532 91
0,235	0,584 6	0,369 74	0,273	0,584 6	0,537 82
0,236	0,584 6	0,373 69	0,274	0,584 6	0,542 76
0,237	0,584 6	0,377 66	0,275	0,584 6	0,547 72
0,238	0,584 6	0,381 66	0,276	0,584 6	0,552 72
0,277	0,584 6	0,557 74	0,316	0,584 9	0,775 66
0,278	0,584 6	0,562 82	0,317	0,584 9	0,781 81
0,279	0,584 7	0,567 94	0,318	0,584 9	0,788 02
0,280	0,584 7	0,573 06	0,319	0,585 0	0,794 28
0,281	0,584 7	0,578 19			
0,282	0,584 7	0,583 35	0,320	0,585 0	0,800 57
0,283	0,584 7	0,588 53	0,321	0,585 0	0,806 85
0,284	0,584 7	0,593 75	0,322	0,585 0	0,813 14
0,285	0,584 7	0,598 99	0,323	0,585 0	0,819 47
0,286	0,584 7	0,604 25	0,324	0,585 0	0,825 83
0,287	0,584 7	0,609 55	0,325	0,585 0	0,832 22
0,288	0,584 7	0,614 87	0,326	0,585 0	0,838 63
0,289	0,584 7	0,620 23	0,327	0,585 0	0,845 08
0,290	0,584 7	0,625 60	0,328	0,585 0	0,851 55
0,291	0,584 7	0,631 01	0,329	0,585 0	0,858 06
0,292	0,584 7	0,636 45			
0,293	0,584 7	0,641 95	0,330	0,585 0	0,864 59
0,294	0,584 8	0,647 48	0,331	0,585 0	0,871 16
0,295	0,584 8	0,653 03	0,332	0,585 0	0,877 75
0,296	0,584 8	0,658 58	0,333	0,585 0	0,884 38
0,297	0,584 8	0,664 16	0,334	0,585 0	0,891 03
0,298	0,584 8	0,669 76	0,335	0,585 0	0,897 72
0,299	0,584 8	0,675 39	0,336	0,585 0	0,904 48
			0,337	0,585 1	0,911 28
0,300	0,584 8	0,681 06	0,338	0,585 1	0,918 11
0,301	0,584 8	0,686 75	0,339	0,585 1	0,924 91
0,302	0,584 8	0,692 46			
0,303	0,584 8	0,698 21	0,340	0,585 1	0,931 75
0,304	0,584 8	0,703 98	0,341	0,585 1	0,938 62
0,305	0,584 8	0,709 80	0,342	0,585 1	0,945 51
			0,343	0,585 1	0,952 44

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,306	0,584 8	0,715 68	0,344	0,585 1	0,959 40
0,307	0,584 9	0,721 59	0,345	0,585 1	0,966 38
0,308	0,584 9	0,727 50	0,346	0,585 1	0,973 40
0,309	0,584 9	0,733 41	0,347	0,585 1	0,980 45
			0,348	0,585 1	0,987 53
0,310	0,584 9	0,739 36	0,349	0,585 1	0,994 71
0,311	0,584 9	0,745 34	0,350	0,585 2	1,001 92
0,312	0,584 9	0,751 35	0,351	0,585 2	1,009 12
0,313	0,584 9	0,757 38	0,352	0,585 2	1,016 33
0,314	0,584 9	0,763 44	0,353	0,585 2	1,023 56
0,315	0,584 9	0,769 54	0,354	0,585 2	1,030 82
0,355	0,585 2	1,038 12	0,370	0,585 4	1,151 67
0,356	0,585 2	1,045 45	0,371	0,585 4	1,159 47
0,357	0,585 2	1,052 80	0,372	0,585 4	1,167 30
0,358	0,585 2	1,060 19	0,373	0,585 4	1,175 16
0,359	0,585 2	1,067 67	0,374	0,585 4	1,183 10
			0,375	0,585 5	1,191 11
0,360	0,585 3	1,075 19	0,376	0,585 5	1,199 14
0,361	0,585 3	1,082 73	0,377	0,585 5	1,207 12
0,362	0,585 3	1,090 24	0,378	0,585 5	1,215 15
0,363	0,585 3	1,097 78	0,379	0,585 5	1,223 20
0,364	0,585 3	1,105 36			
0,365	0,585 3	1,112 97	0,380	0,585 5	1,231 28
0,366	0,585 3	1,120 63	0,381	0,585 5	1,239 40
0,367	0,585 3	1,128 37			
0,368	0,585 4	1,136 15			
0,369	0,585 4	1,143 91			

**Table E.2 — Discharge of water over a V-notch with  $\tan \frac{\alpha}{2} = 1/2$  ( $\alpha = 0,927\ 3$  radians or  $53^\circ\ 8'$ ),  
 $Q = 1,181\ 25\ C_d h^{5/2}$ , ( $g = 9,806\ 6\ \text{m/s}^2$ )**

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $\text{m}^3/\text{s} \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $\text{m}^3/\text{s} \times 10^{-1}$
0,060	0,611 4	0,006 37	0,097	0,602 6	0,020 86
0,061	0,611 1	0,006 63	0,098	0,602 4	0,021 39
0,062	0,610 8	0,006 91	0,099	0,602 2	0,021 94
0,063	0,610 6	0,007 18	0,100	0,602 1	0,022 49
0,064	0,610 1	0,007 47	0,101	0,601 9	0,023 05
0,065	0,609 8	0,007 76	0,102	0,601 7	0,023 62
0,066	0,609 5	0,008 06	0,103	0,601 6	0,024 20
0,067	0,609 2	0,008 36	0,104	0,601 4	0,024 78
0,068	0,609 0	0,008 67	0,105	0,601 3	0,025 37
0,069	0,608 7	0,008 99	0,106	0,600 9	0,026 59
			0,107	0,600 8	0,027 20
0,070	0,608 4	0,009 32	0,108	0,600 6	0,027 83
0,071	0,608 1	0,009 65	0,109		
0,072	0,607 9	0,009 99			
0,073	0,607 6	0,010 33	0,110	0,600 5	0,028 47
0,074	0,607 3	0,010 69	0,111	0,600 3	0,029 11
0,075	0,607 1	0,011 05	0,112	0,600 2	0,029 76
0,076	0,606 8	0,011 41	0,113	0,600 0	0,030 42
0,077	0,606 6	0,011 79	0,114	0,599 8	0,031 09
0,078	0,606 4	0,012 17	0,115	0,599 7	0,031 77
0,079	0,606 1	0,012 56	0,116	0,599 5	0,032 46
			0,117	0,599 4	0,033 15
0,080	0,606 0	0,012 96	0,118	0,599 2	0,033 86
0,081	0,605 8	0,013 36	0,119	0,599 1	0,034 57
0,082	0,605 6	0,013 77			
0,083	0,605 4	0,014 19	0,120	0,598 9	0,035 29
0,084	0,605 2	0,014 62	0,121	0,598 8	0,036 02
0,085	0,605 0	0,015 05	0,122	0,598 7	0,036 77
0,086	0,604 8	0,015 49	0,123	0,598 5	0,037 51
0,087	0,604 6	0,015 94	0,124	0,598 4	0,038 27
0,088	0,604 4	0,016 40	0,125	0,598 2	0,039 04
0,089	0,604 2	0,016 86	0,126	0,598 1	0,039 82
			0,127	0,598 0	0,040 60
0,090	0,604 0	0,017 34	0,128	0,597 9	0,041 40
0,091	0,603 8	0,017 82	0,129	0,597 8	0,042 20
0,092	0,603 6	0,018 30			

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $\text{m}^3/\text{s} \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $\text{m}^3/\text{s} \times 10^{-1}$
0,093	0,603 4	0,018 80	0,130	0,597 6	0,043 02
0,094	0,603 2	0,019 30	0,131	0,597 5	0,043 84
0,095	0,603 0	0,019 81	0,132	0,597 3	0,044 67
0,096	0,602 8	0,020 33	0,133	0,597 2	0,045 51
0,134	0,597 1	0,046 36	0,173	0,593 6	0,087 28
0,135	0,597 0	0,047 22	0,174	0,593 5	0,088 54
0,136	0,596 8	0,048 09	0,175	0,593 4	0,089 80
0,137	0,596 7	0,048 97	0,176	0,593 3	0,091 08
0,138	0,596 6	0,049 86	0,177	0,593 3	0,092 37
0,139	0,596 5	0,050 75	0,178	0,593 2	0,093 67
0,140	0,596 4	0,051 66	0,179	0,593 1	0,094 97
0,141	0,596 2	0,052 58			
0,142	0,596 1	0,053 51	0,180	0,593 0	0,096 29
0,143	0,596 0	0,054 44	0,181	0,592 9	0,097 62
0,144	0,596 0	0,055 39	0,182	0,592 9	0,098 96
0,145	0,595 9	0,056 35	0,183	0,592 8	0,100 32
0,146	0,595 8	0,057 32	0,184	0,592 7	0,101 68
0,147	0,595 7	0,058 30	0,185	0,592 6	0,103 05
0,148	0,595 6	0,059 29	0,186	0,592 6	0,104 44
0,149	0,595 7	0,060 29	0,187	0,592 5	0,105 84
			0,188	0,592 5	0,107 26
0,150	0,595 5	0,061 30	0,189	0,592 4	0,108 67
0,151	0,595 4	0,062 31			
0,152	0,595 2	0,063 34	0,190	0,592 3	0,110 10
0,153	0,595 2	0,064 37	0,191	0,592 3	0,111 55
0,154	0,595 1	0,065 42	0,192	0,592 2	0,113 00
0,155	0,595 0	0,066 48	0,193	0,592 2	0,114 47
0,156	0,594 9	0,067 55	0,194	0,592 1	0,115 95
0,157	0,594 8	0,068 63	0,195	0,592 0	0,117 43
0,158	0,594 8	0,069 71	0,196	0,592 0	0,118 93
0,159	0,594 7	0,070 81	0,197	0,591 9	0,120 44
			0,198	0,591 9	0,121 97
0,160	0,594 6	0,071 92	0,199	0,591 9	0,123 51
0,161	0,594 5	0,073 04			
0,162	0,594 4	0,074 17	0,200	0,591 8	0,125 06
0,163	0,594 4	0,075 31	0,201	0,591 8	0,126 62
0,164	0,594 3	0,076 46	0,202	0,591 7	0,128 19
0,165	0,594 2	0,077 62	0,203	0,591 7	0,129 77
0,166	0,594 1	0,078 79	0,204	0,591 6	0,131 36

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,167	0,594 1	0,081 17	0,205	0,591 6	0,132 96
0,168	0,594 0	0,075 31	0,206	0,591 5	0,134 57
0,169	0,593 9	0,082 37	0,207	0,591 5	0,136 20
0,170	0,593 8	0,083 58	0,208	0,591 4	0,137 84
0,171	0,593 7	0,084 81	0,209	0,591 3	0,139 49
0,172	0,593 7	0,086 04	0,210	0,591 3	0,141 15
0,211	0,591 2	0,142 82	0,250	0,589 8	0,217 72
0,212	0,591 2	0,144 50	0,251	0,589 8	0,219 90
0,213	0,591 1	0,146 20	0,252	0,589 8	0,222 09
0,214	0,591 1	0,147 92	0,253	0,589 7	0,224 29
0,215	0,591 0	0,149 64	0,254	0,589 7	0,226 49
0,216	0,591 0	0,151 38	0,255	0,589 7	0,228 73
0,217	0,591 0	0,153 13	0,256	0,589 7	0,230 98
0,218	0,590 9	0,154 89	0,257	0,589 7	0,233 23
0,219	0,590 9	0,156 66	0,258	0,589 6	0,235 49
0,220	0,590 8	0,158 44	0,259	0,589 6	0,237 77
0,221	0,590 8	0,160 24	0,260	0,589 6	0,240 05
0,222	0,590 8	0,162 04	0,261	0,589 5	0,242 35
0,223	0,590 7	0,163 86	0,262	0,589 5	0,244 66
0,224	0,590 7	0,165 70	0,263	0,589 4	0,246 99
0,225	0,590 6	0,167 54	0,264	0,589 4	0,249 33
0,226	0,590 6	0,169 40	0,265	0,589 4	0,251 68
0,227	0,590 6	0,171 27	0,266	0,589 3	0,254 04
0,228	0,590 5	0,173 15	0,267	0,589 3	0,256 42
0,229	0,590 5	0,175 04	0,268	0,589 2	0,258 81
0,230	0,590 4	0,176 95	0,269	0,589 2	0,261 21
0,231	0,590 4	0,178 86	0,270	0,589 2	0,263 63
0,232	0,590 4	0,180 79	0,271	0,589 1	0,266 06
0,233	0,590 3	0,182 74	0,272	0,589 1	0,268 51
0,234	0,590 3	0,184 69	0,273	0,589 1	0,270 98
0,235	0,590 2	0,186 66	0,274	0,589 1	0,273 47
0,236	0,590 2	0,188 64	0,275	0,589 1	0,275 96
0,237	0,590 2	0,190 63	0,276	0,589 0	0,278 45
0,238	0,590 1	0,192 63	0,277	0,589 0	0,280 97
0,239	0,590 1	0,194 65	0,278	0,589 0	0,283 51
0,240	0,590 1	0,196 68	0,279	0,589 0	0,286 07

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,241	0,590 0	0,198 72			
0,242	0,590 0	0,200 79	0,280	0,589 0	0,288 63
0,243	0,590 0	0,202 87	0,281	0,588 9	0,291 19
0,244	0,589 9	0,204 96	0,282	0,588 9	0,293 77
0,245	0,589 9	0,207 05	0,283	0,588 9	0,296 38
0,246	0,589 8	0,209 16	0,284	0,588 9	0,299 01
0,247	0,589 8	0,211 27	0,285	0,588 9	0,301 63
0,248	0,589 8	0,213 40	0,286	0,588 8	0,304 27
0,249	0,589 8	0,215 55	0,287	0,588 8	0,306 91
0,288	0,588 8	0,309 59	0,324	0,588 0	0,415 03
0,289	0,588 8	0,312 29	0,325	0,588 0	0,418 24
			0,326	0,588 0	0,421 47
0,290	0,588 8	0,314 99	0,327	0,588 0	0,424 71
0,291	0,588 7	0,317 69	0,328	0,588 0	0,427 96
0,292	0,588 7	0,320 40	0,329	0,588 0	0,431 23
0,293	0,588 7	0,323 15			
0,294	0,588 7	0,325 91	0,330	0,588 0	0,434 51
0,295	0,588 7	0,328 69	0,331	0,588 0	0,437 79
0,296	0,588 6	0,331 46	0,332	0,587 9	0,441 07
0,297	0,588 6	0,334 24	0,333	0,587 9	0,444 38
0,298	0,588 6	0,337 04	0,334	0,587 9	0,447 73
0,299	0,588 5	0,339 85	0,335	0,587 9	0,451 08
			0,336	0,587 9	0,454 46
0,300	0,588 5	0,342 68	0,337	0,587 9	0,457 85
0,301	0,588 4	0,345 52	0,338	0,587 9	0,461 25
0,302	0,588 4	0,348 37	0,339	0,587 9	0,464 67
0,303	0,588 4	0,351 24	0,340	0,587 9	0,468 10
0,304	0,588 3	0,354 12	0,341	0,587 9	0,471 53
0,305	0,588 3	0,357 02	0,342	0,587 8	0,474 97
0,306	0,588 3	0,359 95	0,343	0,587 8	0,478 42
0,307	0,588 3	0,362 90	0,344	0,587 8	0,481 91
0,308	0,588 3	0,365 85	0,345	0,587 8	0,485 42
0,309	0,588 2	0,368 80	0,346	0,587 8	0,488 95
			0,347	0,587 8	0,492 49
0,310	0,588 2	0,371 77	0,348	0,587 8	0,496 04
0,311	0,588 2	0,347 77	0,349	0,587 8	0,499 58
0,312	0,588 2	0,377 79			
0,313	0,588 2	0,380 81	0,350	0,587 7	0,503 13
0,314	0,588 1	0,383 84	0,351	0,587 7	0,506 72

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,315	0,588 1	0,386 87	0,352	0,587 7	0,510 33
0,316	0,588 1	0,389 95	0,353	0,587 7	0,513 97
0,317	0,588 1	0,393 04	0,354	0,587 7	0,517 58
0,318	0,588 1	0,396 15	0,355	0,587 6	0,521 21
0,319	0,588 1	0,399 27	0,356	0,587 6	0,524 87
			0,357	0,587 6	0,528 56
0,320	0,588 1	0,402 41	0,358	0,587 6	0,532 27
0,321	0,588 1	0,405 53	0,359	0,587 6	0,535 96
0,322	0,588 0	0,408 67			
0,323	0,588 0	0,411 84	0,360	0,587 5	0,539 67
0,361	0,587 5	0,543 40	0,374	0,587 3	0,593 45
0,362	0,587 5	0,547 17	0,375	0,587 3	0,597 42
0,363	0,587 5	0,550 96	0,376	0,587 3	0,601 41
0,364	0,587 5	0,554 73	0,377	0,587 3	0,605 42
0,365	0,587 4	0,558 51	0,378	0,587 3	0,609 44
0,366	0,587 4	0,562 31	0,379	0,587 3	0,613 46
0,367	0,587 4	0,566 16	0,380	0,587 2	0,617 47
0,368	0,587 4	0,570 03	0,381	0,587 2	0,621 50
0,369	0,587 4	0,573 91			
0,370	0,587 4	0,577 80			
0,371	0,587 4	0,581 71			
0,372	0,587 4	0,585 60			
0,373	0,587 3	0,589 50			

**Table E.3 — Discharge of water over a V-notch with  $\tan \alpha/2 = 1/4$  ( $\alpha = 0,489\ 9$  rad or  $28^\circ\ 4'$ ),  
 $Q = 0,590\ 625\ C_d h^{5/2}$ , ( $g = 9,806\ 6\ \text{m/s}^2$ )**

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $\text{m}^3/\text{s} \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $\text{m}^3/\text{s} \times 10^{-1}$
0,060	0,641 7	0,003 34	0,098	0,622 6	0,011 06
0,061	0,641 0	0,003 48	0,099	0,622 2	0,011 33
0,062	0,640 3	0,003 62			
0,063	0,639 6	0,003 76	0,100	0,621 9	0,011 61
0,064	0,639 0	0,003 91	0,101	0,621 5	0,011 90
0,065	0,638 3	0,004 06	0,102	0,621 2	0,012 19
0,066	0,637 6	0,004 21	0,103	0,620 9	0,012 49
0,067	0,637 0	0,004 37	0,104	0,620 5	0,012 78
0,068	0,636 4	0,004 53	0,105	0,620 2	0,013 09
0,069	0,635 8	0,004 70	0,106	0,619 9	0,013 39
			0,107	0,619 6	0,013 71
0,070	0,635 2	0,004 86	0,108	0,619 3	0,014 02
0,071	0,634 6	0,005 03	0,109	0,619 0	0,014 34
0,072	0,634 0	0,005 21			
0,073	0,633 5	0,005 39	0,110	0,618 7	0,014 66
0,074	0,632 9	0,005 57	0,111	0,618 4	0,014 99
0,075	0,632 4	0,005 75	0,112	0,618 1	0,015 33
0,076	0,631 8	0,005 94	0,113	0,617 9	0,015 66
0,077	0,631 3	0,006 13	0,114	0,617 6	0,016 01
0,078	0,630 8	0,006 33	0,115	0,617 3	0,016 35
0,079	0,630 3	0,006 53	0,116	0,617 1	0,016 70
			0,117	0,616 9	0,017 06
0,080	0,629 8	0,006 73	0,118	0,616 6	0,017 42
0,081	0,629 3	0,006 94	0,119	0,616 4	0,017 78
0,082	0,628 9	0,007 15			
0,083	0,628 5	0,007 37	0,120	0,616 2	0,018 15
0,084	0,628 0	0,007 59	0,121	0,616 0	0,018 53
0,085	0,627 6	0,007 81	0,122	0,615 8	0,018 91
0,086	0,627 2	0,008 03	0,123	0,615 5	0,019 29
0,087	0,626 7	0,008 26	0,124	0,615 3	0,019 68
0,088	0,626 4	0,008 50	0,125	0,615 1	0,020 07
0,089	0,626 0	0,008 74	0,126	0,614 8	0,020 46
			0,127	0,614 6	0,020 86
0,090	0,625 6	0,008 98	0,128	0,614 4	0,021 27
0,091	0,625 2	0,009 22	0,129	0,614 1	0,021 68
0,092	0,624 8	0,009 47			
0,093	0,624 4	0,009 73	0,130	0,613 9	0,022 09



Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,094	0,624 0	0,009 98	0,131	0,613 7	0,022 51
0,095	0,623 6	0,010 25	0,132	0,613 5	0,022 94
0,096	0,623 3	0,010 51	0,133	0,613 3	0,023 37
0,097	0,622 9	0,010 78	0,134	0,613 1	0,023 80
0,135	0,612 9	0,024 24	0,175	0,606 3	0,045 88
0,136	0,612 7	0,024 68	0,176	0,606 2	0,046 53
0,137	0,612 5	0,025 13	0,177	0,606 1	0,047 18
0,138	0,612 3	0,025 59	0,178	0,606 0	0,047 84
0,139	0,612 1	0,026 04	0,179	0,605 9	0,048 51
			0,180	0,605 7	0,049 18
0,140	0,611 9	0,026 51	0,181	0,605 6	0,049 86
0,141	0,611 7	0,026 97	0,182	0,605 5	0,050 54
0,142	0,611 5	0,027 44	0,183	0,605 4	0,051 22
0,143	0,611 3	0,027 92	0,184	0,605 3	0,051 92
0,144	0,611 2	0,028 40	0,185	0,605 1	0,052 61
0,145	0,611 0	0,028 89	0,186	0,605 1	0,053 32
0,146	0,610 8	0,029 38	0,187	0,605 0	0,054 03
0,147	0,610 6	0,029 88	0,188	0,604 9	0,054 75
0,148	0,610 5	0,030 38	0,189	0,604 8	0,055 47
0,149	0,610 3	0,030 89	0,190	0,604 7	0,056 20
			0,191	0,604 5	0,056 93
0,150	0,610 2	0,031 40	0,192	0,604 4	0,057 66
0,151	0,610 0	0,031 92	0,193	0,604 3	0,058 41
0,152	0,609 9	0,032 45	0,194	0,604 2	0,059 16
0,153	0,609 7	0,032 97	0,195	0,604 1	0,059 92
0,154	0,609 5	0,033 50	0,196	0,604 1	0,060 68
0,155	0,609 3	0,034 04	0,197	0,604 0	0,061 45
0,156	0,609 1	0,034 58	0,198	0,603 9	0,062 22
0,157	0,609 0	0,035 13	0,199	0,603 8	0,063 00
0,158	0,608 8	0,035 68			
0,159	0,608 7	0,036 24	0,200	0,603 8	0,063 79
			0,201	0,603 7	0,064 58
0,160	0,608 5	0,036 80	0,202	0,603 5	0,065 37
0,161	0,608 3	0,037 37	0,203	0,603 4	0,066 17
0,162	0,608 2	0,037 94	0,204	0,603 3	0,066 98
0,163	0,608 0	0,038 52	0,205	0,603 3	0,067 80
0,164	0,607 9	0,039 11	0,206	0,603 2	0,068 62
0,165	0,607 7	0,039 69	0,207	0,603 1	0,069 44
0,166	0,607 6	0,040 29	0,208	0,603 0	0,070 28

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,167	0,607 4	0,040 89	0,209	0,602 9	0,071 11
0,168	0,607 3	0,041 49	0,210	0,602 9	0,071 96
0,169	0,607 1	0,042 10	0,211	0,602 8	0,072 81
0,170	0,607 0	0,042 72	0,212	0,602 7	0,073 66
0,171	0,606 9	0,043 34	0,213	0,602 6	0,074 53
0,172	0,606 8	0,043 97	0,214	0,602 5	0,075 39
0,173	0,606 7	0,044 60	0,215	0,602 5	0,076 27
0,174	0,606 5	0,045 24	0,216	0,602 4	0,077 15
0,217	0,602 3	0,078 03	0,249	0,600 2	0,109 67
0,218	0,602 2	0,078 93	0,250	0,600 2	0,110 77
0,219	0,602 2	0,079 82	0,251	0,600 1	0,111 87
0,220	0,602 1	0,080 73	0,252	0,600 1	0,112 99
0,221	0,602 0	0,081 64	0,253	0,600 0	0,114 10
0,222	0,601 9	0,082 55	0,254	0,600 0	0,115 23
0,223	0,601 8	0,083 47	0,255	0,600 0	0,116 35
0,224	0,601 8	0,084 41	0,256	0,599 9	0,117 49
0,225	0,601 7	0,085 35	0,257	0,599 9	0,118 63
0,226	0,601 7	0,086 29	0,258	0,599 8	0,119 78
0,227	0,601 6	0,087 24	0,259	0,599 8	0,120 94
0,228	0,601 5	0,088 19	0,260	0,599 7	0,122 10
0,229	0,601 5	0,089 15	0,261	0,599 6	0,123 26
0,230	0,601 4	0,090 11	0,262	0,599 6	0,124 43
0,231	0,601 3	0,091 08	0,263	0,599 5	0,125 61
0,232	0,601 3	0,092 07	0,264	0,599 5	0,126 80
0,233	0,601 2	0,093 06	0,265	0,599 5	0,127 99
0,234	0,601 2	0,094 05	0,266	0,599 4	0,129 20
0,235	0,601 1	0,095 04	0,267	0,599 4	0,130 41
0,236	0,601 0	0,096 05	0,268	0,599 3	0,131 62
0,237	0,601 0	0,097 06	0,269	0,599 3	0,132 84
0,238	0,600 9	0,098 08	0,270	0,599 2	0,134 07
0,239	0,600 9	0,099 10	0,271	0,599 2	0,135 29
0,240	0,600 8	0,100 13	0,272	0,599 1	0,136 53
0,241	0,600 7	0,101 16	0,273	0,599 1	0,137 78
0,242	0,600 6	0,102 20	0,274	0,599 0	0,139 03
0,243	0,600 6	0,103 25	0,275	0,599 0	0,140 30
			0,276	0,598 9	0,141 57
			0,277	0,598 9	0,142 84

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$	Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,244	0,600 5	0,104 30	0,278	0,598 9	0,144 13
0,245	0,600 4	0,105 36	0,279	0,598 8	0,145 42
0,246	0,600 3	0,106 42			
0,247	0,600 3	0,107 50	0,280	0,598 8	0,146 71
0,248	0,600 2	0,108 58	0,281	0,598 7	0,148 02
0,282	0,598 7	0,149 33	0,320	0,597 2	0,204 32
0,283	0,598 7	0,150 65	0,321	0,597 2	0,205 90
0,284	0,598 6	0,151 97	0,322	0,597 1	0,207 50
0,285	0,598 6	0,153 30	0,323	0,597 1	0,209 10
0,286	0,598 5	0,154 64	0,324	0,597 0	0,210 71
0,287	0,598 5	0,155 98	0,325	0,597 0	0,212 32
0,288	0,598 5	0,157 34	0,326	0,597 0	0,213 95
0,289	0,598 4	0,158 70	0,327	0,596 9	0,215 58
			0,328	0,596 9	0,217 21
0,290	0,598 4	0,160 06	0,329	0,596 9	0,218 86
0,291	0,598 3	0,161 43	0,330	0,596 8	0,220 51
0,292	0,598 3	0,162 81	0,331	0,596 8	0,222 17
0,293	0,598 3	0,164 20	0,332	0,596 7	0,223 84
0,294	0,598 2	0,165 59	0,333	0,596 7	0,225 51
0,295	0,598 2	0,166 99	0,334	0,596 7	0,227 19
0,296	0,598 1	0,168 40	0,335	0,596 6	0,228 88
0,297	0,598 1	0,169 82	0,336	0,596 6	0,230 58
0,298	0,598 1	0,171 24	0,337	0,596 5	0,232 28
0,299	0,598 0	0,172 67	0,338	0,596 5	0,234 00
			0,339	0,596 5	0,235 72
0,300	0,598 0	0,174 10	0,340	0,596 4	0,237 44
0,301	0,597 9	0,175 55	0,341	0,596 4	0,239 18
0,302	0,597 9	0,177 00	0,342	0,596 3	0,240 92
0,303	0,597 9	0,178 45	0,343	0,596 3	0,242 57
0,304	0,597 8	0,179 92	0,344	0,596 3	0,244 42
0,305	0,597 8	0,181 39	0,345	0,596 2	0,246 19
0,306	0,597 8	0,182 87	0,346	0,596 2	0,247 96
0,307	0,597 7	0,184 35	0,347	0,596 1	0,249 74
0,308	0,597 7	0,185 85	0,348	0,596 1	0,251 52
0,309	0,597 6	0,187 35	0,349	0,596 1	0,253 32
0,310	0,597 6	0,188 85	0,350	0,596 0	0,255 12
0,311	0,597 6	0,190 37	0,351	0,596 0	0,256 93
0,312	0,597 5	0,191 89	0,352	0,595 9	0,258 75

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,313	0,597 5	0,193 42
0,314	0,597 4	0,194 95
0,315	0,597 4	0,196 50
0,316	0,597 4	0,198 05
0,317	0,597 3	0,199 60
0,318	0,597 3	0,201 17
0,319	0,597 2	0,202 74
0,360	0,596 0	0,255 12
0,361	0,596 0	0,256 93
0,362	0,595 9	0,258 75
0,363	0,595 9	0,260 57
0,364	0,595 9	0,262 40
0,365	0,595 8	0,264 24
0,366	0,595 8	0,266 09
0,367	0,595 7	0,267 94
0,368	0,595 7	0,269 81
0,369	0,595 7	0,271 68
0,370	0,595 2	0,292 75
0,371	0,595 2	0,294 72

Head $h$ m	Coefficient $C_d$	Discharge $Q$ $m^3/s \times 10^{-1}$
0,353	0,595 9	0,260 57
0,354	0,595 9	0,262 40
0,355	0,595 8	0,264 24
0,356	0,595 8	0,266 09
0,357	0,595 7	0,267 94
0,358	0,595 7	0,269 81
0,359	0,595 7	0,271 68
0,372	0,595 2	0,296 69
0,373	0,595 1	0,298 67
0,374	0,595 1	0,300 65
0,375	0,595 0	0,302 64
0,376	0,595 0	0,304 65
0,377	0,595 0	0,306 66
0,378	0,594 9	0,308 67
0,379	0,594 9	0,310 70
0,380	0,594 8	0,312 73
0,381	0,594 8	0,314 77

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