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**Hydrometric determinations — Flow  
measurement in open channels using  
structures — Trapezoidal broad-crested weirs**

*Déterminations hydrométriques — Mesure de débit dans les canaux  
découverts au moyen de structures — Déversoirs trapézoïdaux à seuil  
épais*

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 4362 was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 2, *Notches, weirs and flumes*.

This second edition cancels and replaces the first edition (ISO 4362:1992), which has been extended to include the use of the weir in trapezoidal channels in addition to its use in rectangular channels.

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# Hydrometric determinations — Flow measurement in open channels using structures — Trapezoidal broad-crested weirs

## 1 Scope

This International Standard specifies a method of steady-flow measurement in open channels using a trapezoidal broad-crested weir under modular and non-modular conditions. Consideration is given to the use of the weir in both rectangular and trapezoidal channels.

Limitations to the use of the weir are given in 7.6 and 8.6.

## 2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, the document do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 772:1996, *Hydrometric determinations — Vocabulary and symbols*.

## 3 Terms and definitions

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

## 4 Installation — General considerations

NOTE Particular requirements for trapezoidal broad-crested weirs are given in clause 7 for trapezoidal broad-crested weirs in rectangular channels; in clause 8 for trapezoidal broad-crested weirs in trapezoidal channels.

### 4.1 Selection of site

A preliminary survey shall be made of the physical and hydraulic features of the proposed site, to check that it conforms (or may be made to conform) with the requirements necessary for discharge measurement by a weir.

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

- a) the availability of an adequate length of channel of regular cross-section;
- b) the existing velocity distribution;
- c) the avoidance of a steep channel, if possible;
- d) the effects of an excessive increase in upstream water level owing to installation of the measuring structure;
- e) the sediment content of the stream and whether heavy deposition just upstream of the weir is likely to occur;

- f) the impermeability of the ground on which the structure is to be founded and the necessity for piling, grouting or other means of controlling seepage;
- g) the necessity for flood banks to confine the maximum discharge to the channel;
- h) the stability of the banks and the necessity for trimming and/or revetment in natural channels;
- i) the need for clearance of rocks or boulders from the bed of the approach channel;
- j) the effect of wind on the flow over the weir, especially when the weir is wide and the head is small and when the prevailing wind is in a direction transverse to the direction of flow.

If the site does not possess the characteristics necessary for satisfactory measurements, it shall not be used unless suitable improvements are practicable.

The existing velocity distribution in the approach channel shall be checked by inspection and measurement using, for example, current-meters, velocity rods and floats.

NOTE 1 Concentrations of dye are also useful to check the conditions at the bottom of the channel.

NOTE 2 A complete and quantitative assessment of the velocity distribution may be made by using a current-meter. More information on the use of current-meters is given in ISO 748.

If an inspection of the stream shows that the existing velocity distribution is regular, then it may be assumed that the velocity distribution will remain satisfactory after the weir has been constructed.

If the existing velocity distribution is irregular and no other site for a weir is feasible, due consideration shall be given to checking the distribution after the installation of the weir and to improving it if necessary.

## 4.2 Installation conditions

### 4.2.1 General

The complete measuring installation consists of an approach channel, a measuring structure and a downstream channel. The condition of each of these components affects the overall accuracy of the measurements.

In addition, features such as the surface finish of the weir, the cross-sectional shape of the channel and its roughness, and the influences of the control section and devices upstream or downstream of the gauging structure shall be taken into consideration.

These features together determine the distribution and direction of velocity, which have an important influence on the performance of a weir.

Once an installation has been designed and constructed, the user shall prevent or rectify any physical changes in the installation which could affect the discharge characteristics.

### 4.2.2 Approach channel

The flow in the approach channel shall be smooth, free from disturbances and shall have a velocity distribution as symmetrical as possible over the cross-sectional area.

NOTE This can usually be verified by inspection or measurement.

In the case of natural streams or rivers, these flow conditions can only be attained by having a long straight approach channel of uniform cross-section, free from projections at the side or on the bottom.

Unless otherwise specified, the following general requirements shall be met.

- a) After construction of the weir, the flow conditions in the approach channel can alter owing to the build-up of shoals of debris upstream of the structure. The likely consequential changes in the water level shall be taken into account in the design of the structure.

- b) In an artificial channel, the cross-section shall be uniform and the channel shall be straight for a length equal to at least 10 times its width.
- c) If the entry of the approach channel is through a bend or if the flow is discharged into the channel either through a conduit of smaller cross-section or at an angle, then a greater length of straight approach channel is required to achieve a regular velocity distribution. There shall be no baffle nearer to the points of measurement than 10 times the maximum head to be measured.
- d) Under certain conditions, a standing wave may occur upstream of the gauging device, for example if the approach channel is steep. Provided that this wave is at a distance upstream of not less than 30 times the maximum head, flow measurement is feasible, subject to confirmation that a regular velocity distribution exists at the gauging station. If a standing wave occurs within this distance, the approach conditions and/or the gauging device shall be modified.

#### 4.2.3 Weir structure

The structure shall be rigid and watertight, and capable of withstanding flood-flow conditions without displacement, distortion or fracture. It shall be at right angles to the direction of flow and the geometry of the weir shall conform with the dimensions given in this International Standard.

#### 4.2.4 Downstream channel

The channel downstream of the structure is usually of no importance if the weir has been designed to operate under free-flow conditions. If the weir is designed to operate under drowned conditions also, the downstream channel shall be straight for a length of at least eight times the maximum head to be measured.

A downstream gauge shall be provided to determine the submergence ratio.

### 5 Maintenance

Maintenance of the measuring structure and the approach channel is important to secure accurate continuous measurements.

It is essential that, as far as practicable, the approach channel to the weir be kept clean and free from silt and vegetation for the minimum distance specified in 4.2.2. The float well and the entry from the approach channel shall also be kept clean and free from deposits. The weir structure shall be kept clean and free from clinging debris and care shall be taken in the process of cleaning to avoid damage to the weir crest.

### 6 Measurement of water levels

#### 6.1 General

Where spot measurements are required, water levels (heads) upstream and downstream of the measuring structure may be measured by using a hook gauge, a point gauge or a staff gauge. Where continuous records are required, a float-operated recording gauge may be used; however, to reduce the effects of water surface irregularities, it is preferable to measure water levels in a separate stilling well. Other head-measuring methods may be used provided that sufficient accuracy is obtainable.

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

#### 6.2 Stilling or float well

Where provided, the stilling well shall be vertical and shall be 0,6 m higher than the maximum water level to be recorded in the well. The bottom of the well shall be lower than the elevation of the weir crest.

The well shall be connected to the channel by an inlet pipe or slot, which is large enough to permit the water in the well to follow the rise and fall of head without significant delay.

The connecting pipe or slot shall, however, be as small as possible consistent with ease of maintenance, or shall alternatively be fitted with a constriction to damp out oscillations due to short-period waves.

The well and the connecting pipe or slot shall be watertight. Where provided for the accommodation of the float of a level recorder, the well shall be of adequate diameter and depth to give clearance around and beneath the float at all stages. Adequate additional depth shall be provided in wells to avoid the danger of floats grounding on any accumulation of silt or debris. The float well arrangement may include an intermediate chamber of similar size and proportions between the stilling well and the approach channel to enable silt and other debris to settle out where they may be readily removed.

**6.3 Zero setting**

An accurate means of checking the zero setting of the water-level measuring device shall be provided. For this purpose, a pointer, set exactly level with the crest of the weir and fixed permanently in the approach channel, or alternatively in the stilling well or float well where provided, may be used.

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

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

**7 Trapezoidal broad-crested weirs in rectangular channels**

**7.1 Specification for the standard weir**

The weir comprises an upstream slope of 1:Z<sub>1</sub>, a horizontal crest, and a downstream slope of 1:Z<sub>2</sub> (see Figure 1), constructed in a rectangular channel section.

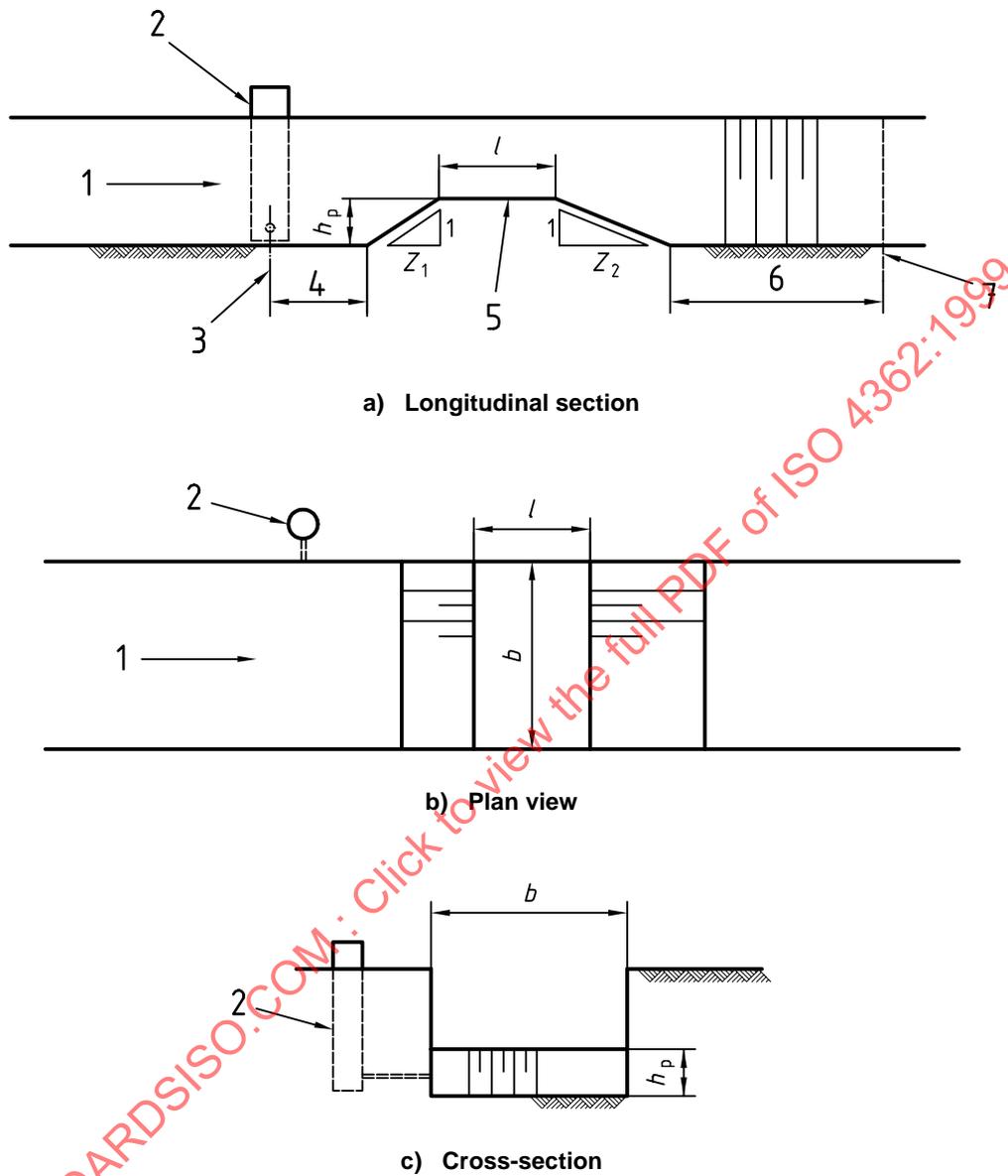
The values of Z<sub>1</sub> and Z<sub>2</sub> for standard trapezoidal broad-crested weirs in rectangular channels in accordance with this International Standard are specified in Table 1.

**Table 1— Upstream and downstream slope combinations**

| Upstream slope<br>1:Z <sub>1</sub> | Downstream slope<br>1:Z <sub>2</sub> |
|------------------------------------|--------------------------------------|
| 1:1                                | 1:5                                  |
| 1:2                                | 1:2                                  |
| 1:2                                | 1:3                                  |
| 1:2                                | 1:5                                  |
| 1:3                                | 1:3                                  |
| 1:3                                | 1:5                                  |

The intersection of the surfaces of the upstream and downstream slopes with the horizontal crest shall form a well-defined straight sharp corner which shall be horizontal and at right angles to the direction of flow in the approach channel. The crest shall be horizontal and shall have a rectangular plane surface. The surfaces of the crest and the slopes shall be smooth. The width *b* of the crest perpendicular to the direction of flow shall be equal to the width of the channel in which the weir is located.

A sketch of a typical trapezoidal broad-crested weir in a rectangular channel is given in Figure 1.



**Key**

- |                                |                                       |
|--------------------------------|---------------------------------------|
| 1 Direction of flow            | 5 Horizontal crest                    |
| 2 Stilling well                | 6 $5 h_{\max}$ to $6 h_{\max}$        |
| 3 Head measurement section     | 7 Tailwater level measurement section |
| 4 $3 h_{\max}$ to $4 h_{\max}$ |                                       |

Figure 1 — Trapezoidal broad-crested weir in a rectangular channel

## 7.2 Location of head measurement section

Piezometers or a point-gauge station for the measurement of the head on the weir shall be located at a sufficient distance upstream from the weir to avoid the region of surface drawdown. However, they (it) shall be close enough to the weir to ensure that the energy loss between the section of measurement and the control section on the weir is negligible.

It is recommended that the head measurement section be located at a distance equal to three to four times the maximum head (i.e.  $3h_{\max}$  to  $4h_{\max}$ ) upstream from the toe of the upstream face of the weir, as shown in Figure 1.

## 7.3 Location of tailwater level measurement section

Piezometers or a point-gauge station for the measurement of the tailwater level shall be located at a sufficient distance downstream from the weir to avoid regions of fluctuation.

Generally, it is recommended that the tailwater level measurement section be located at a distance of five to six times the maximum head (i.e.  $5h_{\max}$  to  $6h_{\max}$ ) downstream from the toe of the downstream face of the weir, so that the measurement is downstream of any unstable water surface or jump.

## 7.4 Conditions for free flow

Flow is free flow when it is independent of variations in the tailwater level. For each upstream and downstream slope combination of the weir, correlations for the modular limit  $\sigma_c$  are given in 7.5.2. The tailwater head shall not rise more than  $\sigma_c$  times the upstream head above the crest level, if the flow is not to be affected by more than 1 % for subcritical conditions in the tailwater.

## 7.5 Determination of discharge

### 7.5.1 Determination of discharge under free flow conditions

#### 7.5.1.1 Discharge equation

The discharge equation for trapezoidal broad-crested weirs in rectangular channels is as follows:

$$Q = \left(\frac{2}{3}\right)^{3/2} C_D C_V C_{dr} \sqrt{g} b h^{3/2}$$

where

$b$  is the width of the weir perpendicular to the direction of flow, in metres;

$C_{dr}$  is the drowned-flow coefficient, which is dimensionless;

$C_D$  is the coefficient of discharge, which is dimensionless;

$C_V$  is the approach velocity coefficient, which is dimensionless [ $= (H/h)^{3/2}$ , where  $H$  is the total head, in metres];

$g$  is the acceleration due to gravity, in metres per second squared;

$h$  is the measured head, in metres;

$Q$  is the discharge across the weir, in cubic metres per second.

#### 7.5.1.2 Approach velocity coefficient, $C_V$

$C_V$  is given by the following implicit equation:

$$C_v = \left[ 1 + \frac{4}{27} C_v^2 \left( \frac{C_D b h}{A} \right)^2 \right]^{3/2}$$

Values of  $C_v$  may be determined from Figure 2 which gives  $C_v$  as a function of  $C_D b h / A$ , where  $A$  is the cross-sectional area of the channel at the head measurement section, in square metres.

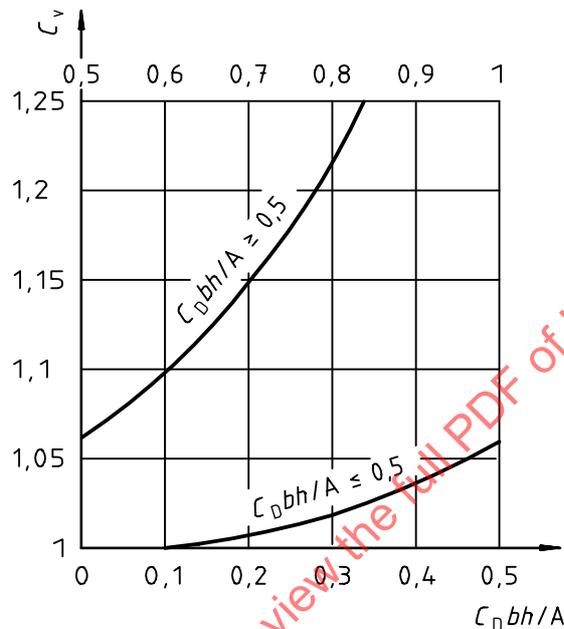


Figure 2 — Approach velocity coefficient,  $C_v$

### 7.5.1.3 Coefficient of discharge, $C_D$

Values of  $C_D$  as a function of  $h/l$  are given in Figures 3 and 4, and Table 2 for the upstream and downstream slope combinations given in Table 1.

### 7.5.2 Modular limit, $\sigma_c$

The modular limit is a function of  $h/l$  and the upstream and downstream slopes. It is taken to be equal to the value of the submergence ratio  $\sigma = h_{dr}/h$  (where  $h_{dr}$  is the tailwater head above the crest) above which the reduction in discharge exceeds 1 % of the free flow (or modular flow) discharge. Values of  $\sigma_c$  as a function of  $h/l$  are given in Figures 5 to 10 for the various slope combinations specified in Table 1.

### 7.5.3 Determination of discharge under submerged-flow conditions

$C_{dr}$  is a function of  $h/l$  and the upstream and downstream slopes. For free-flow and submerged-flow conditions where the submergence ratio is less than the modular limit specified in 7.5.2, the drowned-flow coefficient  $C_{dr}$  may be taken to be unity.

For flow conditions where the submergence ratio is greater than the modular limit, the value of  $C_{dr}$  may be determined from Figures 11 to 16, where  $C_{dr}$  is given as a function of  $h/l$  and  $\sigma$  for the various slope combinations specified in Table 1.

**Table 2 — Variation in the coefficient of discharge  $C_D$**

| $h/l$ | $C_D$ for the following upstream and downstream slope combinations |                    |                    |                    |                    |                    |
|-------|--|--------------------|--------------------|--------------------|--------------------|--------------------|
|       | $Z_1 = 1, Z_2 = 5$   | $Z_1 = 2, Z_2 = 2$ | $Z_1 = 2, Z_2 = 3$ | $Z_1 = 2, Z_2 = 5$ | $Z_1 = 3, Z_2 = 3$ | $Z_1 = 3, Z_2 = 5$ |
| 0,1   | 0,908  | 0,936              | 0,936              | 0,936              | 0,946              | 0,946              |
| 0,2   | 0,920  | 0,952              | 0,952              | 0,952              | 0,963              | 0,963              |
| 0,3   | 0,928  | 0,964              | 0,964              | 0,964              | 0,974              | 0,974              |
| 0,4   | 0,938  | 0,974              | 0,974              | 0,974              | 0,984              | 0,984              |
| 0,5   | 0,949  | 0,985              | 0,985              | 0,985              | 0,992              | 0,992              |
| 0,6   | 0,962  | 1,000              | 0,999              | 0,998              | 1,003              | 1,003              |
| 0,7   | 0,976  | 1,018              | 1,014              | 1,012              | 1,014              | 1,012              |
| 0,8   | 0,988  | 1,036              | 1,029              | 1,025              | 1,028              | 1,022              |
| 0,9   | 1,002  | 1,052              | 1,042              | 1,035              | 1,041              | 1,032              |
| 1,0   | 1,014  | 1,066              | 1,054              | 1,046              | 1,054              | 1,042              |
| 1,1   | 1,026  | 1,080              | 1,067              | 1,056              | 1,066              | 1,050              |
| 1,2   | 1,038  | 1,094              | 1,080              | 1,066              | 1,076              | 1,058              |
| 1,3   | 1,049  | 1,106              | 1,092              | 1,076              | 1,086              | 1,064              |
| 1,4   | 1,060  | 1,120              | 1,102              | 1,085              | 1,096              | 1,071              |
| 1,5   | 1,072  | 1,130              | 1,112              | 1,092              | 1,103              | 1,078              |
| 1,6   | 1,082  | 1,140              | 1,121              | 1,098              | 1,110              | 1,084              |
| 1,7   | 1,090  | 1,150              | 1,130              | 1,104              | 1,116              | 1,090              |
| 1,8   | 1,098  | 1,158              | 1,138              | 1,109              | 1,122              | 1,096              |
| 1,9   | 1,103  | 1,165              | 1,145              | 1,114              | 1,128              | 1,102              |
| 2,0   | 1,108  | 1,173              | 1,152              | 1,119              | 1,133              | 1,106              |
| 2,1   | 1,113  | 1,180              | 1,158              | 1,123              | 1,138              | 1,110              |
| 2,2   | 1,116  | 1,187              | 1,164              | 1,127              | 1,142              | 1,114              |
| 2,3   | 1,119  | 1,194              | 1,168              | 1,130              | 1,146              | 1,116              |
| 2,4   | 1,121  | 1,200              | 1,171              | 1,133              | 1,149              | 1,120              |
| 2,5   | 1,124  | 1,206              | 1,174              | 1,136              | 1,152              | 1,122              |
| 2,6   | 1,126  | 1,212              | 1,176              | 1,139              | 1,156              | 1,126              |
| 2,7   | 1,128  | 1,216              | 1,178              | 1,140              | 1,160              | 1,128              |
| 2,8   | 1,130  | 1,220              | 1,181              | 1,142              | 1,164              | 1,132              |
| 2,9   | 1,132  | 1,222              | 1,183              | 1,143              | 1,166              | 1,134              |
| 3,0   | 1,134  | 1,224              | 1,185              | 1,144              | 1,168              | 1,135              |

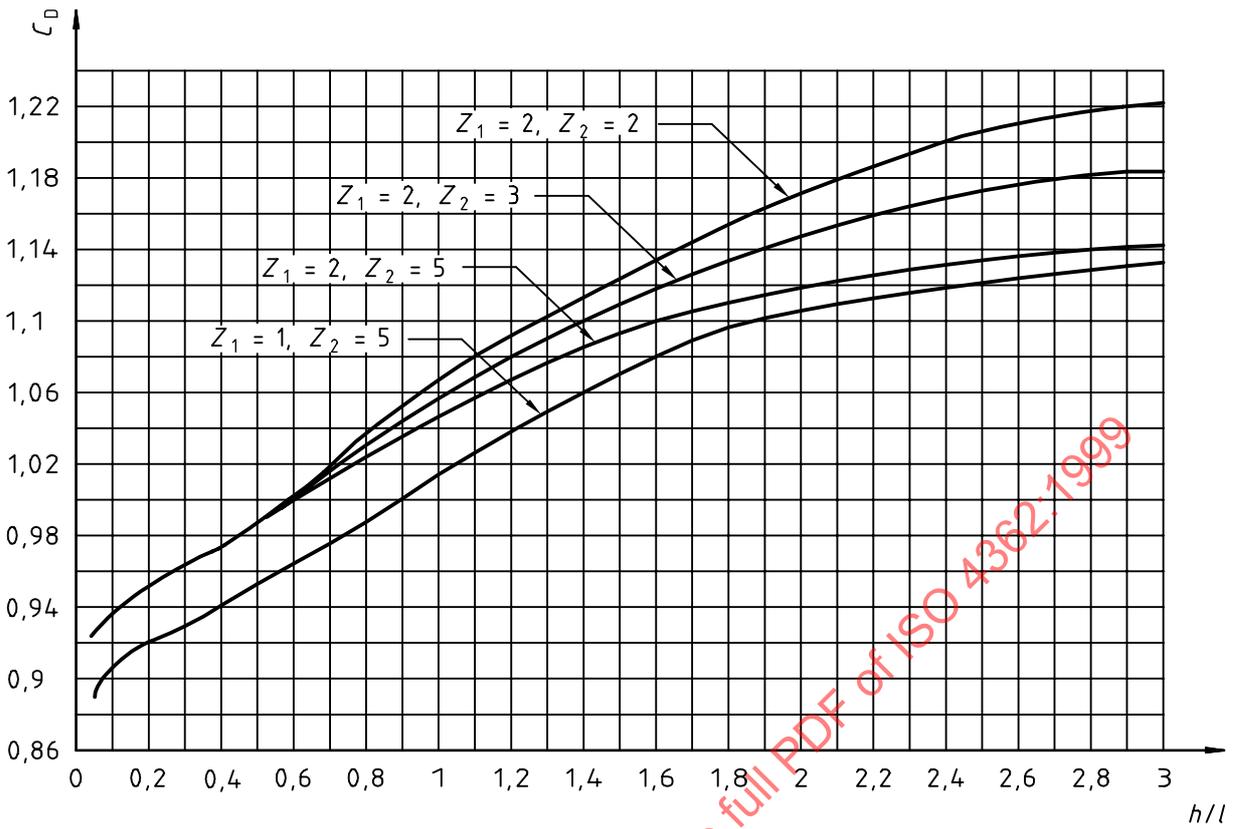


Figure 3 — Variation in the coefficient of discharge for  $Z_1 = 1$  and  $Z_1 = 2$

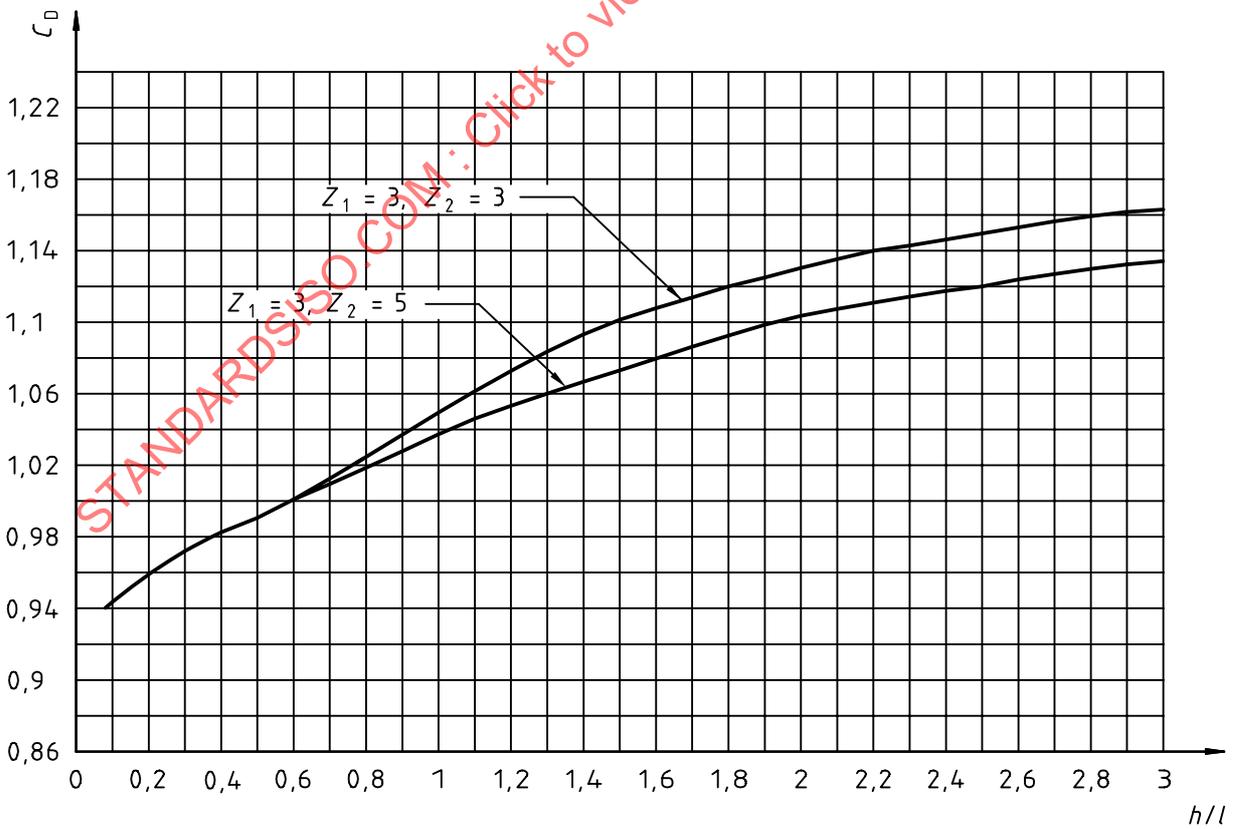


Figure 4 — Variation in the coefficient of discharge for  $Z_1 = 3$

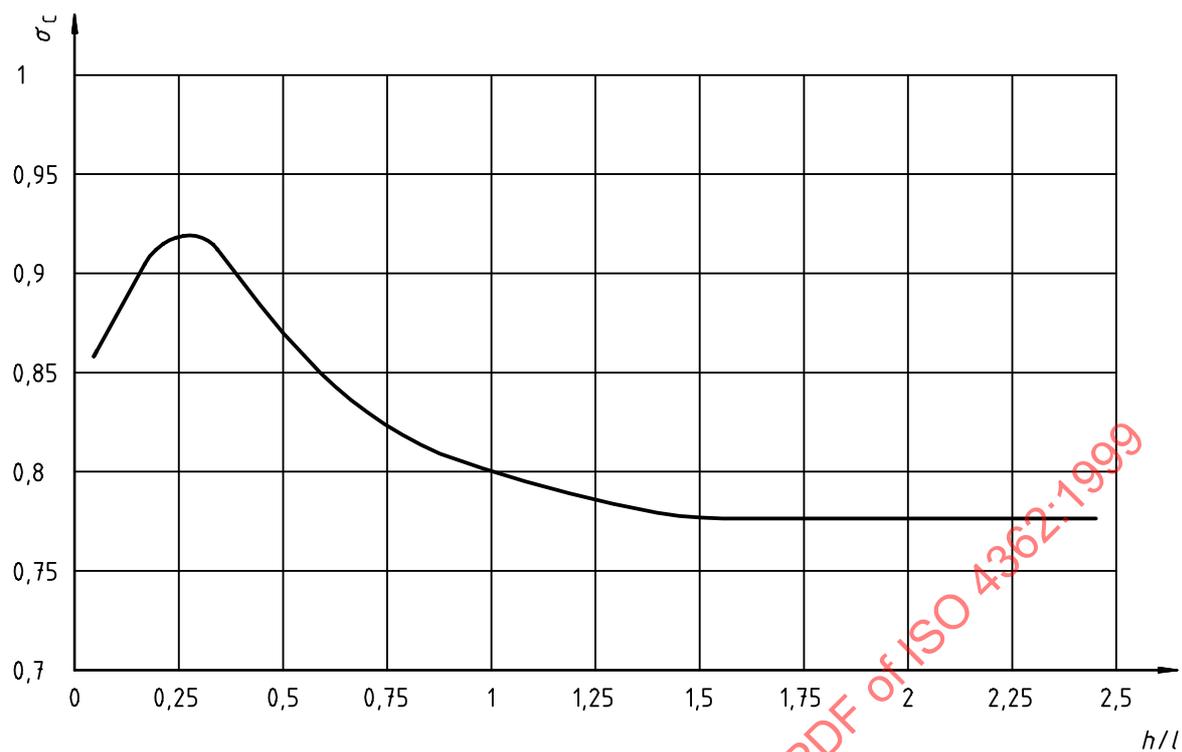


Figure 5 — Variation in the modular limit  $\sigma_c$  for  $Z_1 = 1$  and  $Z_2 = 5$

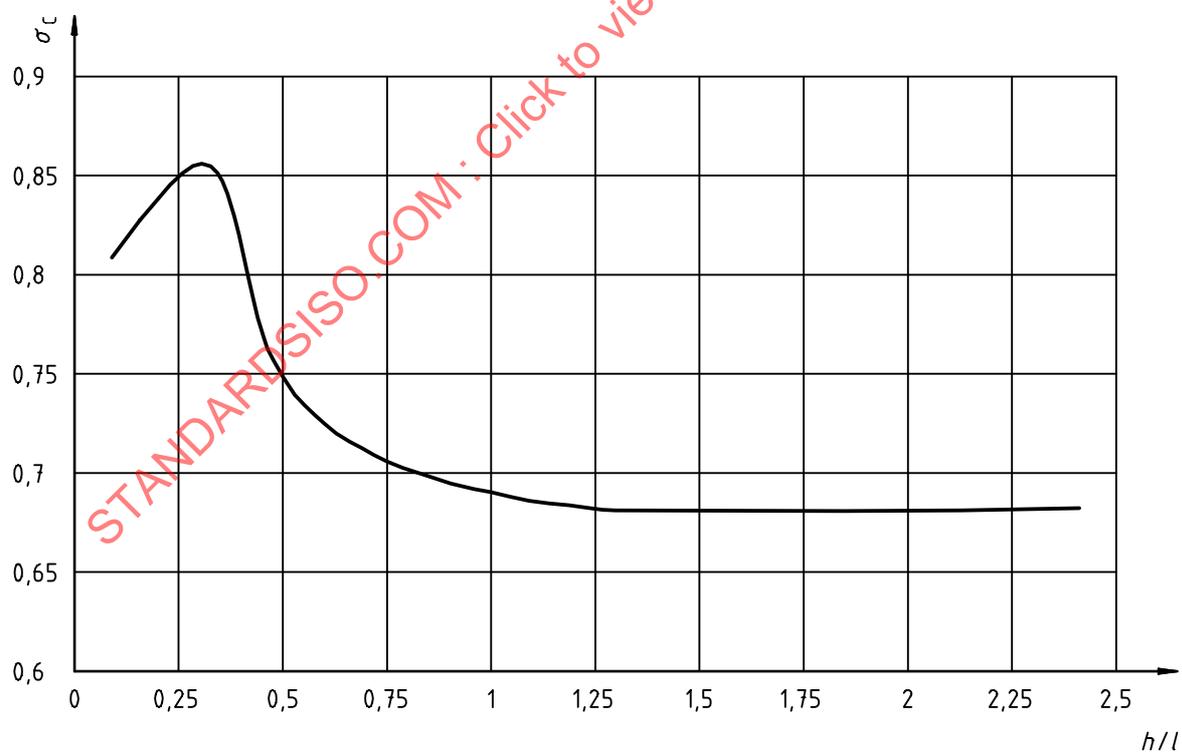


Figure 6 — Variation in the modular limit  $\sigma_c$  for  $Z_1 = 2$  and  $Z_2 = 2$

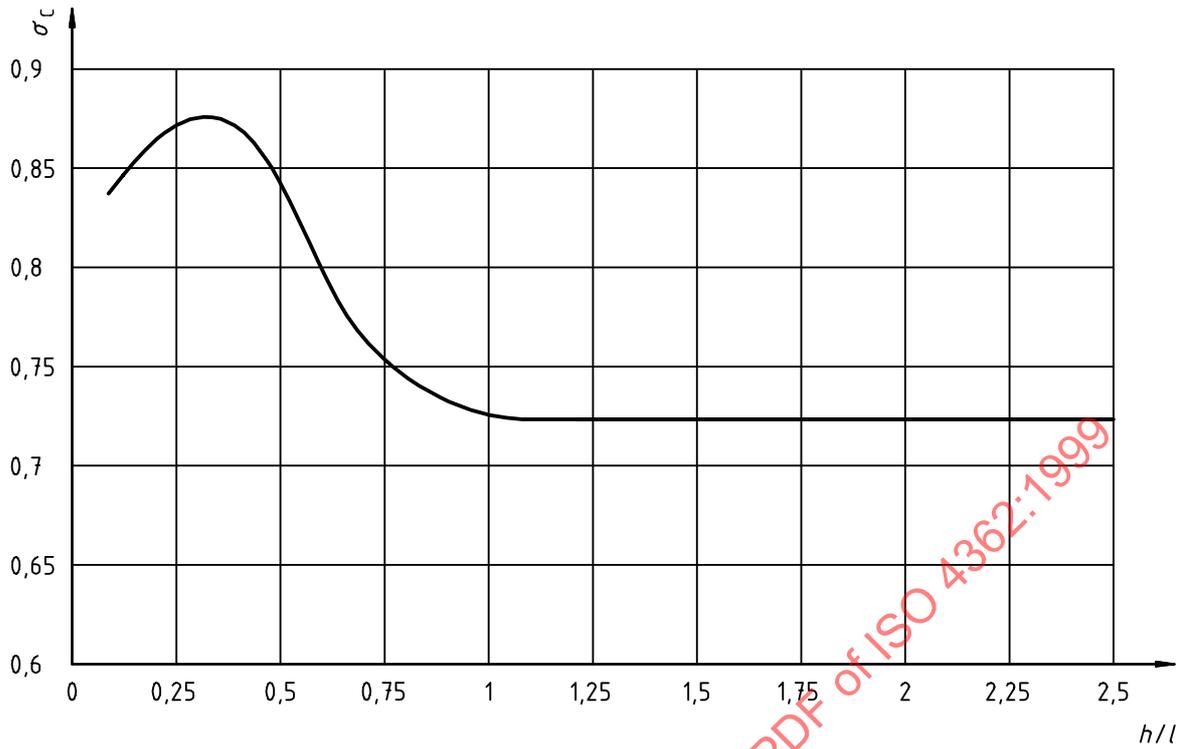


Figure 7 — Variation in the modular limit  $\sigma_c$  for  $Z_1 = 2$  and  $Z_2 = 3$

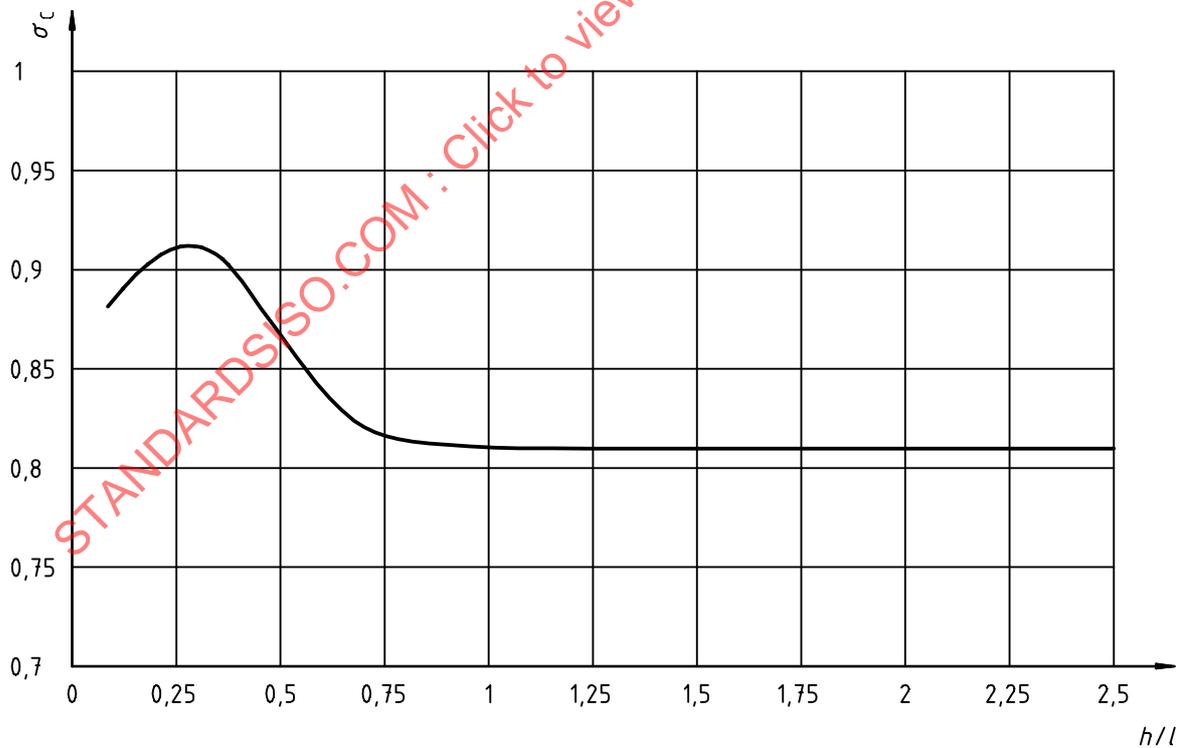


Figure 8 — Variation in the modular limit  $\sigma_c$  for  $Z_1 = 2$  and  $Z_2 = 5$

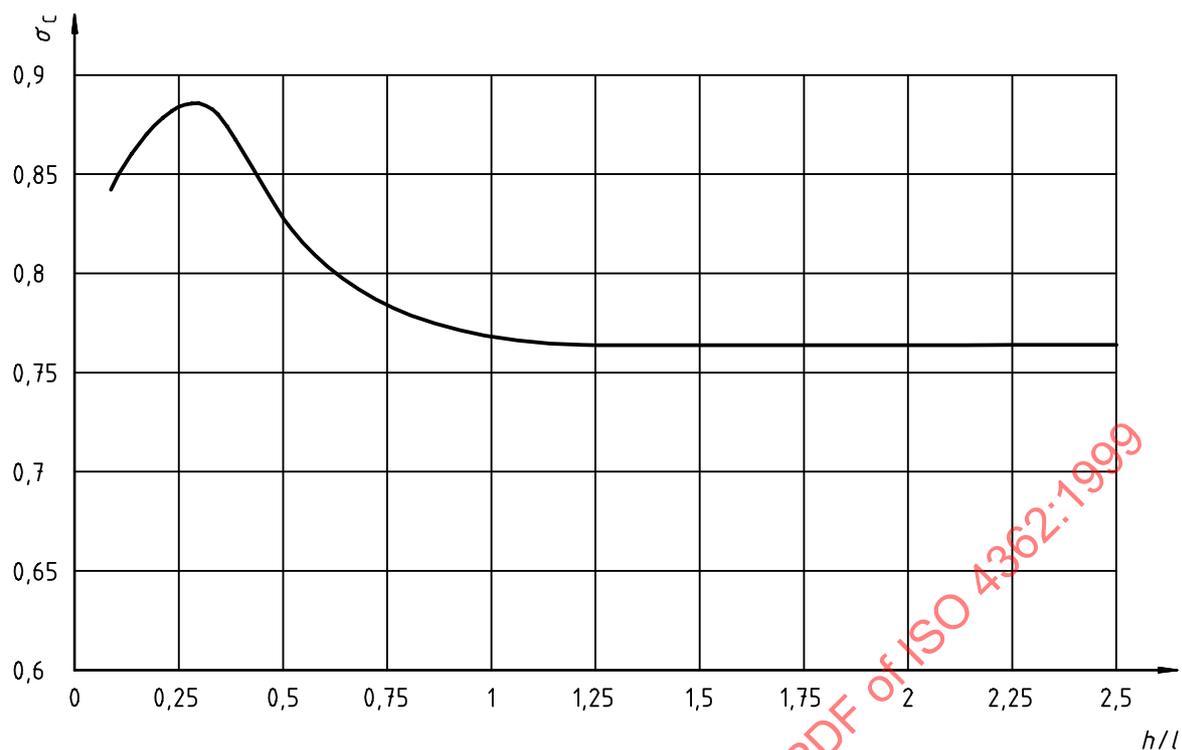


Figure 9 — Variation in the modular limit  $\sigma_c$  for  $Z_1 = 3$  and  $Z_2 = 3$

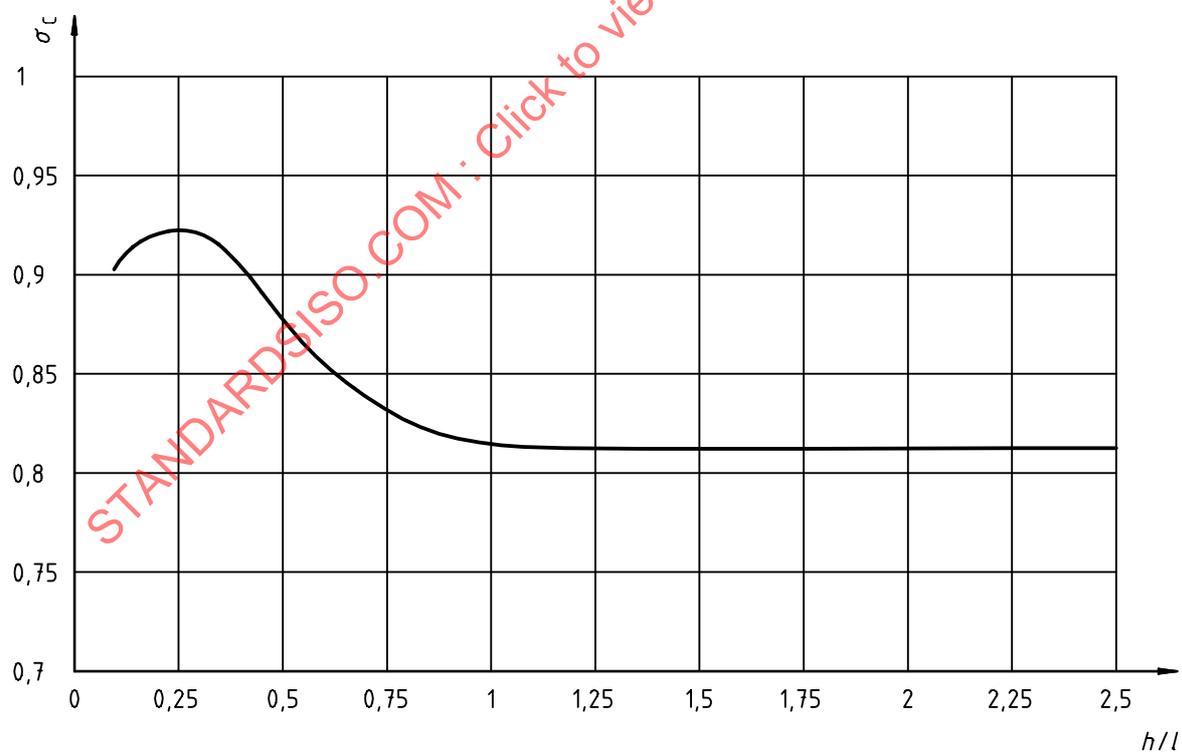
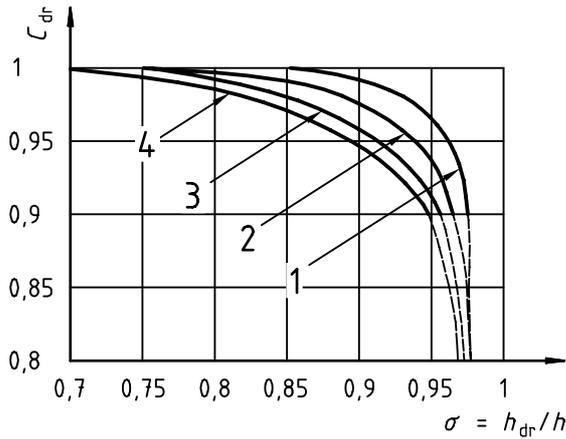
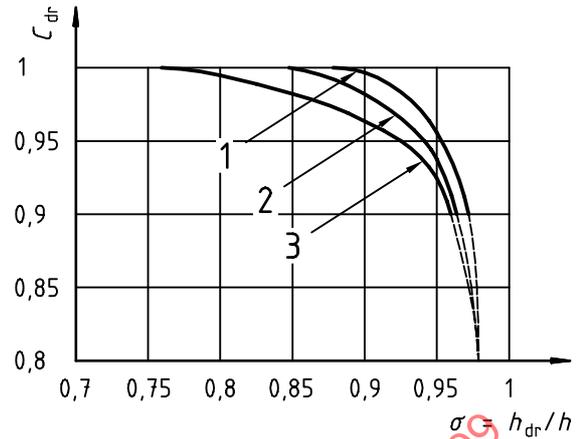


Figure 10 — Variation in the modular limit  $\sigma_c$  for  $Z_1 = 3$  and  $Z_2 = 5$



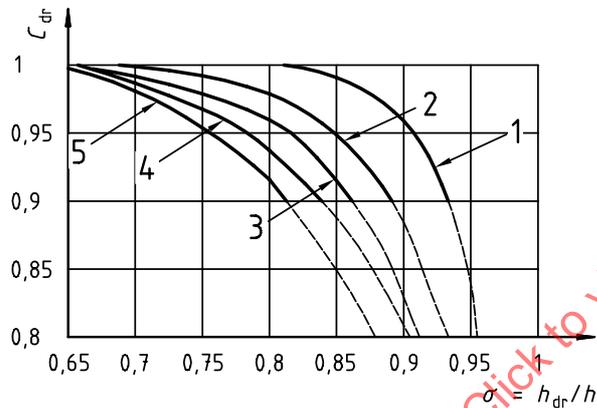
- Key**
- 1  $h/l = 0,3$
  - 2  $h/l = 0,6$
  - 3  $h/l = 1$
  - 4  $h/l = 2$

**Figure 11 — Variation in the drowned-flow coefficient for  $Z_1 = 1$  and  $Z_2 = 5$**



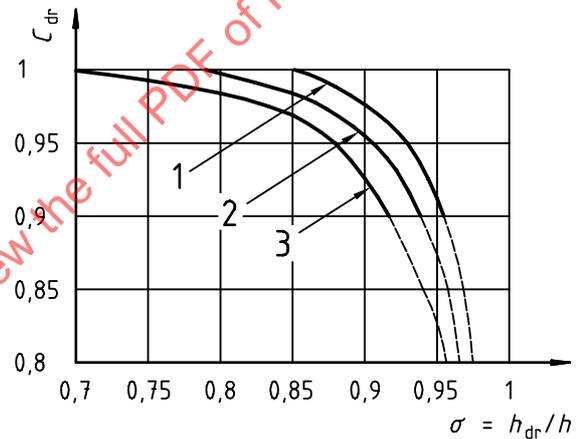
- Key**
- 1  $h/l = 0,3$
  - 2  $h/l = 0,6$
  - 3  $h/l = 2$

**Figure 14 — Variation in the drowned-flow coefficient for  $Z_1 = 2$  and  $Z_2 = 5$**



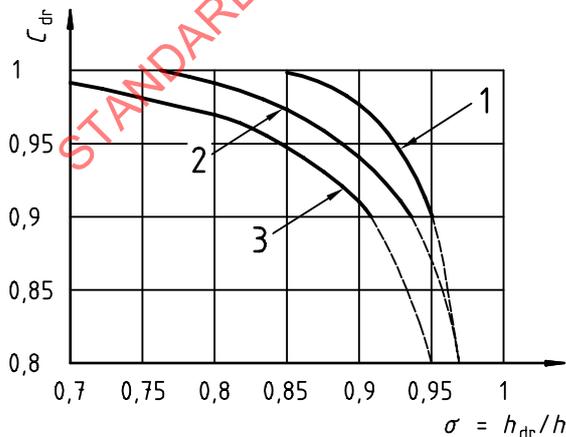
- Key**
- 1  $h/l = 0,3$
  - 2  $h/l = 0,6$
  - 3  $h/l = 1$
  - 4  $h/l = 1,5$
  - 5  $h/l = 2$

**Figure 12 — Variation in the drowned-flow coefficient for  $Z_1 = 2$  and  $Z_2 = 2$**



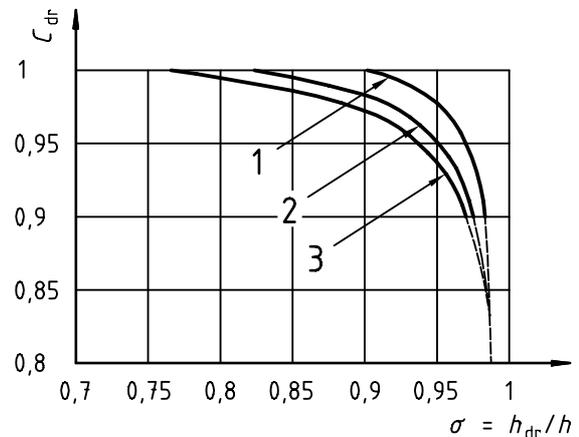
- Key**
- 1  $h/l = 0,3$
  - 2  $h/l = 0,6$
  - 3  $h/l = 2$

**Figure 15 — Variation in the drowned-flow coefficient for  $Z_1 = 3$  and  $Z_2 = 3$**



- Key**
- 1  $h/l = 0,3$
  - 2  $h/l = 0,6$
  - 3  $h/l = 2$

**Figure 13 — Variation in the drowned-flow coefficient for  $Z_1 = 2$  and  $Z_2 = 3$**



- Key**
- 1  $h/l = 0,3$
  - 2  $h/l = 0,6$
  - 3  $h/l = 1,5$

**Figure 16 — Variation in the drowned-flow coefficient for  $Z_1 = 3$  and  $Z_2 = 5$**

## 7.6 Limitations

The discharge relationships specified in this International Standard are subject to the following limitations. To avoid surface tension and viscous effects, the following general limitations are recommended:

$$h \geq 0,05 \text{ m}$$

$$h_p \geq 0,15 \text{ m}$$

$$b \geq 0,3 \text{ m}$$

On the basis of the experimental data currently available, the following specific limitations are recommended for free and submerged flows.

### a) Free flow

$$0,2 \leq \frac{l}{h_p} \leq 2$$

$$\frac{h}{h_p} \leq 1,3$$

$$0,1 \leq \frac{h}{l} \leq 3$$

### b) Submerged flow

$$0,2 \leq \frac{l}{h_p} \leq 2$$

$$\frac{h}{h_p} \leq 1,3$$

$$0,1 \leq \frac{h}{l} \leq x$$

where  $x$ , the upper limit for  $h/l$ , is the limit up to which correlations are given in Figures 11 to 16, i.e.  $x = 1,5$  for  $Z_1 = 3$ ,  $Z_2 = 5$  and  $x = 2$  for all other pairs of  $Z_1$  and  $Z_2$  given in Table 1.

In addition,  $\sigma$  should not exceed a value such that  $C_{dr}$  becomes less than 0,9.

## 7.7 Uncertainty in measurement

**7.7.1** The overall uncertainty in flow measurements made using trapezoidal broad-crested weirs in rectangular channels depends on the uncertainties in the head measurements, in the measurements of the dimensions of weir and in the coefficients as they apply to the weir in use.

**7.7.2** With reasonable care and skill in the construction and installation of a trapezoidal broad-crested weir, the systematic uncertainty in the combined coefficient  $C_D C_V$  is within  $\pm 4\%$ . There is no uncertainty in the coefficient  $C_{dr}$  for free flow. For submerged flow, the uncertainty in  $C_{dr}$  increases as the submergence ratio increases. For those submergence ratios for which  $C_{dr}$  is more than 0,9, the systematic uncertainty in the combined coefficient  $C_D C_V C_{dr}$  is within  $\pm 6\%$ .

The random uncertainty in the coefficient of discharge  $C_D$  reflects the real but marginal differences in coefficient values for different discharges, and may be taken as  $\pm 0,5\%$ . The random uncertainty in the coefficients  $C_V$  and  $C_{dr}$  may be ignored.

**7.7.3** The method by which the uncertainties in the coefficients shall be combined with other sources of uncertainty is given in clause 9.

In general, the discharge coefficients quoted in this International Standard have been determined using calibration experiments on small-scale model structures. It should be borne in mind that these coefficients will not be identical for larger structures, owing to scale effects.

## 8 Trapezoidal broad-crested weirs in trapezoidal channels

### 8.1 Specification for the standard weir

The weir comprises an upstream slope of 1: $Z_1$ , a horizontal crest, and a vertical or a sloping downstream face 1: $Z_2$ , constructed in a trapezoidal channel section (see Figure 17).

The values of  $Z_1$  and  $Z_2$  for standard trapezoidal broad-crested weirs in trapezoidal channel sections, specified in this International Standard are as follows:

$$2 \leq Z_1 \leq 4 \text{ and } 0 \leq Z_2 \leq 5 \text{ for free-flow conditions}$$

$$2 \leq Z_1 \leq 4 \text{ and } Z_2 = 0 \text{ for submerged flow conditions}$$

The intersection of the surface of the upstream and downstream slopes with the horizontal crest shall form a well-defined straight sharp corner which shall be horizontal and at right angles to the direction of flow in the approach channel. The crest shall be horizontal and shall have a rectangular plane surface. The surfaces of the crest and the slopes shall be smooth. The width  $b_c$  of the crest perpendicular to the direction of flow follows from the channel's bottom-width  $b$ , the side slope  $m$  and the apex height  $h_p$ :

$$b_c = b + 2mh_p$$

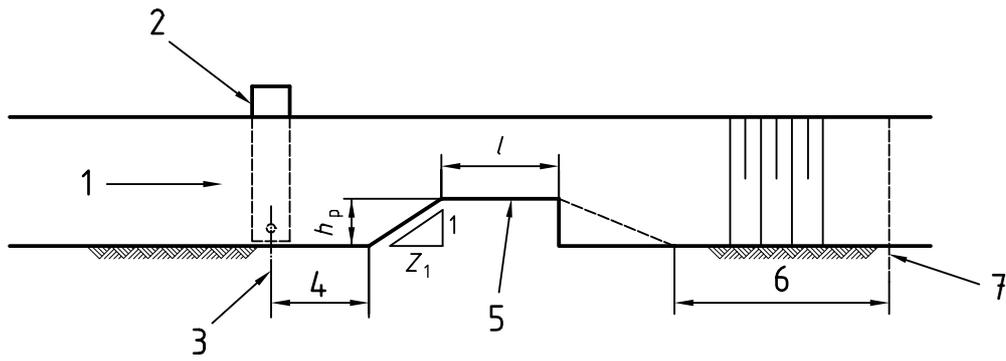
The weir width  $b_c$  shall be checked after construction of the weir.

A sketch of the trapezoidal broad-crested weir in a trapezoidal channel is given in Figure 17.

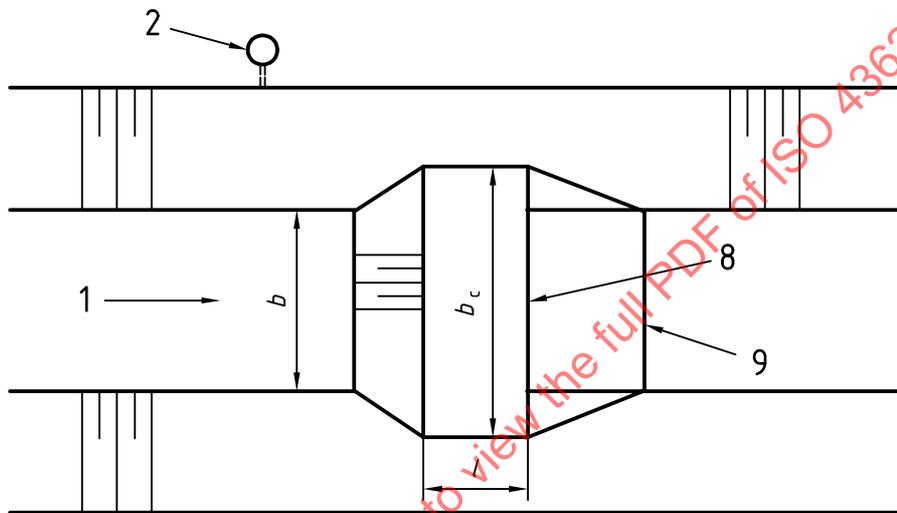
### 8.2 Location of head measurement section

Piezometers or a point-gauge station for the measurement of the head on the weir shall be located at a sufficient distance upstream from the weir to avoid the region of surface drawdown. However, they (it) shall be close enough to the weir to ensure that the energy loss between the section of measurement and the control section on the weir is negligible.

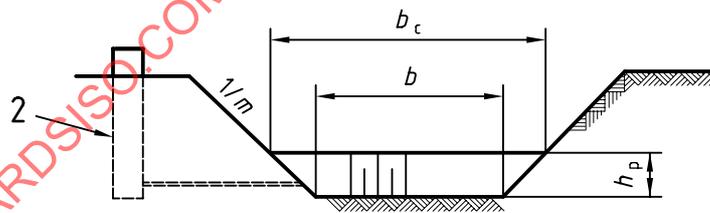
It is recommended that the head measurement section be located at a distance equal to three to four times the maximum head (i.e.  $3h_{\max}$  to  $4h_{\max}$ ) upstream from the toe of the upstream face of the weir.



a) Longitudinal section



b) Plan view



c) Cross-section

**Key**

- |                            |                                       |
|----------------------------|---------------------------------------|
| 1 Direction of flow        | 6 $5h_{max}$ to $6h_{max}$            |
| 2 Stilling well            | 7 Tailwater level measurement section |
| 3 Head measurement section | 8 Vertical backface, $Z_2 = 0$        |
| 4 $3h_{max}$ to $4h_{max}$ | 9 Sloping backface                    |
| 5 Horizontal crest         |                                       |

Figure 17 — Trapezoidal broad-crested weir in a trapezoidal channel

### 8.3 Location of tailwater level measurement section

Piezometers or a point-gauge station for the measurement of the tailwater level shall be located at a sufficient distance downstream from the weir to avoid regions of fluctuation.

Generally, it is recommended that the tailwater level measurement section be located at a distance of five to six times the maximum head (i.e.  $5h_{\max}$  to  $6h_{\max}$ ) downstream from the toe of the downstream face of the weir, so that the measurement is downstream of any unstable water surface or jump.

### 8.4 Conditions for free flow

Flow is free flow when it is independent of variations in the tailwater level. For each upstream and downstream slope combination of the weir, correlations for the modular limit  $\sigma_c$  are given in 8.5.2. The tailwater head shall not rise more than  $\sigma_c$  times the upstream head above the crest level, if the flow is not to be affected by more than 1 % for subcritical conditions in the tailwater.

### 8.5 Determination of discharge

#### 8.5.1 Determination of discharge under free-flow conditions

The discharge equation for trapezoidal broad-crested weirs in trapezoidal channels is expressed in terms of the total upstream energy head  $H_1$  over the weir. Bernoulli's equation, applied for the  $H_1$ -section upstream of the weir and the control section above the weir gives:

$$Q = A_c \{2g(H_1 - y_c)\}^{0.5} \text{ for ideal flow}$$

The effects of non-ideal flow are accounted for by the introduction of a discharge coefficient  $C_D$ , which depends on the shape and type of the structure and a drowned flow coefficient  $C_{dr}$  for submerged flow conditions.

In a trapezoidal control section, the cross-sectional area is  $A_c = b_c y_c + m y_c^2$ .

The discharge equation for trapezoidal broad-crested weirs in trapezoidal channels is as follows:

$$Q = C_D C_{dr} (b_c y_c + m y_c^2) [2g(H_1 - y_c)]^{0.5}$$

where

$b_c$  is the width of the weir-crest perpendicular to the direction of flow, in metres;

$y_c$  is the critical depth in the control section, in metres;

$m$  is the channel side slope in the control section, which is dimensionless;

$C_D$  is the coefficient of discharge, which is dimensionless;

$C_{dr}$  is the drowned-flow coefficient, which is dimensionless;

$g$  is the acceleration due to gravity, in metres per second squared;

$H_1$  is the total upstream energy-head, in metres.

The critical depth  $y_c$  can be calculated using Table 3, giving the ratio  $y_c/H_1$  as a function of  $m$  and  $H_1/b_c$  for trapezoidal control sections.

The coefficient of discharge  $C_D$  is given in Figure 18 and Table 4 as a function of  $H_1/l$ .

Under free flow conditions  $C_{dr} = 1$ .

After calculation of the rating curve  $Q$  versus  $H_1$ , this relation shall be converted into the head-discharge relation  $Q$  versus  $h_1$ , where  $h_1$  is the measured head, in metres.

### 8.5.2 Modular limit $\sigma_c$

The modular limit  $\sigma_c$  is a function of  $H_1/l$  and the downstream slope. It is taken to be equal to the value of the submergence ratio  $\sigma = h_{dr}/h$  (where  $h_{dr}$  is the tailwater head above the crest) above which the reduction in discharge exceeds 1 % of the free-flow (or modular flow) discharge. Values of  $\sigma_c$  as a function of  $H_1/l$  are given in Figure 19 for weirs with a vertical downstream face.

### 8.5.3 Determination of discharge under submerged flow conditions

$C_{dr}$  is a function of  $H_1/l$  and the downstream slope  $Z_2$ .

For free flow and submerged flow conditions where the submergence ratio is less than the modular limit specified in 8.5.2, the drowned flow coefficient  $C_{dr}$  may be taken to be unity.

For flow conditions where the submergence ratio is greater than the modular limit, the value of  $C_{dr}$  may be determined from Table 5, where  $C_{dr}$  is given for a weir with a vertical downstream face,  $Z_2 = 0$ , and as a function of  $H_1/l$  and the submergence ratio  $H_2/H_1$ .

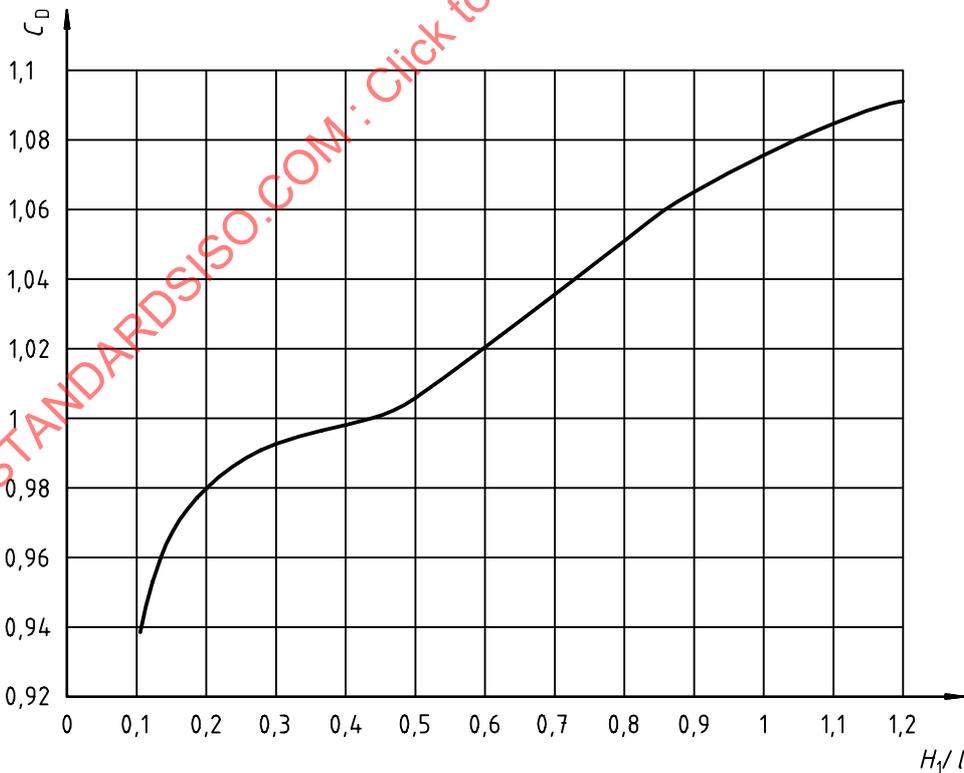
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**Table 3 — Values of  $y_c/H_1$  as a function of  $H_1/b_c$  and  $m$  for trapezoidal control sections**

| $H_1/b_c$ | Values of $y_c/H_1$    |       |       |       |       |       |       |       |
|-----------|------------------------|-------|-------|-------|-------|-------|-------|-------|
|           | Channel side slope $m$ |       |       |       |       |       |       |       |
|           | Vertical               | 0,50  | 0,75  | 1     | 1,5   | 2     | 2,5   | 3     |
| 0,00      | 0,667                  | 0,667 | 0,667 | 0,667 | 0,667 | 0,667 | 0,667 | 0,667 |
| 0,01      | 0,667                  | 0,667 | 0,668 | 0,668 | 0,669 | 0,670 | 0,670 | 0,671 |
| 0,02      | 0,667                  | 0,668 | 0,669 | 0,670 | 0,671 | 0,672 | 0,674 | 0,675 |
| 0,03      | 0,667                  | 0,669 | 0,670 | 0,671 | 0,673 | 0,675 | 0,677 | 0,679 |
| 0,04      | 0,667                  | 0,670 | 0,671 | 0,672 | 0,675 | 0,677 | 0,680 | 0,683 |
| 0,05      | 0,667                  | 0,670 | 0,672 | 0,674 | 0,677 | 0,680 | 0,683 | 0,686 |
| 0,06      | 0,667                  | 0,671 | 0,673 | 0,675 | 0,679 | 0,683 | 0,686 | 0,690 |
| 0,07      | 0,667                  | 0,672 | 0,674 | 0,676 | 0,681 | 0,685 | 0,689 | 0,693 |
| 0,08      | 0,667                  | 0,672 | 0,675 | 0,678 | 0,683 | 0,687 | 0,692 | 0,696 |
| 0,09      | 0,667                  | 0,673 | 0,676 | 0,679 | 0,684 | 0,690 | 0,695 | 0,698 |
| 0,10      | 0,667                  | 0,674 | 0,677 | 0,680 | 0,686 | 0,692 | 0,697 | 0,701 |
| 0,12      | 0,667                  | 0,675 | 0,679 | 0,684 | 0,690 | 0,692 | 0,701 | 0,706 |
| 0,14      | 0,667                  | 0,676 | 0,681 | 0,686 | 0,693 | 0,699 | 0,705 | 0,711 |
| 0,16      | 0,667                  | 0,678 | 0,683 | 0,688 | 0,696 | 0,703 | 0,709 | 0,715 |
| 0,18      | 0,667                  | 0,679 | 0,684 | 0,690 | 0,698 | 0,706 | 0,713 | 0,719 |
| 0,20      | 0,667                  | 0,680 | 0,686 | 0,692 | 0,701 | 0,709 | 0,717 | 0,723 |
| 0,22      | 0,667                  | 0,681 | 0,688 | 0,694 | 0,704 | 0,712 | 0,720 | 0,726 |
| 0,24      | 0,667                  | 0,683 | 0,689 | 0,696 | 0,706 | 0,715 | 0,723 | 0,729 |
| 0,26      | 0,667                  | 0,684 | 0,691 | 0,698 | 0,709 | 0,718 | 0,725 | 0,732 |
| 0,28      | 0,667                  | 0,685 | 0,693 | 0,699 | 0,711 | 0,720 | 0,728 | 0,734 |
| 0,30      | 0,667                  | 0,686 | 0,694 | 0,701 | 0,713 | 0,723 | 0,730 | 0,737 |
| 0,32      | 0,667                  | 0,687 | 0,696 | 0,703 | 0,715 | 0,725 | 0,733 | 0,739 |
| 0,34      | 0,667                  | 0,689 | 0,697 | 0,705 | 0,717 | 0,727 | 0,735 | 0,741 |
| 0,36      | 0,667                  | 0,690 | 0,699 | 0,706 | 0,719 | 0,729 | 0,737 | 0,743 |
| 0,38      | 0,667                  | 0,691 | 0,700 | 0,708 | 0,721 | 0,731 | 0,738 | 0,745 |
| 0,40      | 0,667                  | 0,692 | 0,701 | 0,709 | 0,723 | 0,733 | 0,740 | 0,747 |
| 0,42      | 0,667                  | 0,693 | 0,703 | 0,711 | 0,725 | 0,734 | 0,742 | 0,748 |
| 0,44      | 0,667                  | 0,694 | 0,704 | 0,712 | 0,727 | 0,736 | 0,744 | 0,750 |
| 0,46      | 0,667                  | 0,695 | 0,705 | 0,714 | 0,728 | 0,737 | 0,745 | 0,751 |
| 0,48      | 0,667                  | 0,696 | 0,706 | 0,715 | 0,729 | 0,739 | 0,747 | 0,752 |
| 0,5       | 0,667                  | 0,697 | 0,708 | 0,717 | 0,730 | 0,740 | 0,748 | 0,754 |
| 0,6       | 0,667                  | 0,701 | 0,713 | 0,723 | 0,737 | 0,747 | 0,754 | 0,759 |
| 0,7       | 0,667                  | 0,706 | 0,718 | 0,728 | 0,742 | 0,752 | 0,758 | 0,764 |
| 0,8       | 0,667                  | 0,709 | 0,723 | 0,732 | 0,746 | 0,756 | 0,762 | 0,767 |
| 0,9       | 0,667                  | 0,713 | 0,727 | 0,737 | 0,750 | 0,759 | 0,766 | 0,770 |
| 1,0       | 0,667                  | 0,717 | 0,730 | 0,740 | 0,754 | 0,762 | 0,768 | 0,773 |
| 1,2       | 0,667                  | 0,723 | 0,737 | 0,747 | 0,759 | 0,767 | 0,772 | 0,776 |
| 1,4       | 0,667                  | 0,729 | 0,742 | 0,752 | 0,764 | 0,771 | 0,776 | 0,779 |
| 1,6       | 0,667                  | 0,733 | 0,747 | 0,756 | 0,767 | 0,774 | 0,778 | 0,781 |
| 1,8       | 0,667                  | 0,737 | 0,750 | 0,759 | 0,770 | 0,776 | 0,781 | 0,783 |
| 2         | 0,667                  | 0,740 | 0,754 | 0,762 | 0,773 | 0,778 | 0,782 | 0,785 |
| 3         | 0,667                  | 0,753 | 0,766 | 0,773 | 0,781 | 0,785 | 0,787 | 0,790 |
| 4         | 0,667                  | 0,762 | 0,773 | 0,778 | 0,785 | 0,788 | 0,790 | 0,792 |
| 5         | 0,667                  | 0,768 | 0,777 | 0,782 | 0,788 | 0,791 | 0,792 | 0,794 |
| 10        | 0,667                  | 0,782 | 0,788 | 0,791 | 0,794 | 0,795 | 0,796 | 0,797 |
| ∞         |                        | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 |

**Table 4 — Variation in the coefficient of discharge  $C_D$  for a trapezoidal broad-crested weir,  $2 \leq Z_1 \leq 4$  and  $0 \leq Z_2 \leq 5$  in a trapezoidal channel,  $m = 1$  to 1,5**

| $H_1/l$ | $C_D$ |
|---------|-------|
| 0,10    | 0,937 |
| 0,15    | 0,963 |
| 0,20    | 0,979 |
| 0,25    | 0,988 |
| 0,30    | 0,994 |
| 0,35    | 0,997 |
| 0,40    | 0,999 |
| 0,45    | 1,002 |
| 0,50    | 1,007 |
| 0,55    | 1,014 |
| 0,60    | 1,021 |
| 0,65    | 1,029 |
| 0,70    | 1,037 |
| 0,75    | 1,044 |
| 0,80    | 1,051 |
| 0,85    | 1,058 |
| 0,90    | 1,064 |
| 0,95    | 1,069 |
| 1,00    | 1,074 |
| 1,05    | 1,079 |
| 1,10    | 1,084 |
| 1,15    | 1,087 |
| 1,20    | 1,090 |



**Figure 18 — Variation in the coefficient of discharge for a trapezoidal broad-crested weir  $2 \leq Z_1 \leq 4$  and  $0 \leq Z_2 \leq 5$  in a trapezoidal channel,  $m = 1$  to 1,5**

## 8.6 Limitations

The discharge relationships specified in this International Standard are subject to the following limitations. To avoid surface tension and viscous effects, the following general limitations are recommended:

$$h_1 \geq 0,05 \text{ m}$$

$$h_p \geq 0,15 \text{ m}$$

$$b \geq 0,3 \text{ m}$$

On the basis of the experimental data currently available, the following specific limitations are recommended for free and submerged flows.

### a) Free flow

$$0,2 \leq \frac{l}{h_p} \leq 2$$

$$\frac{h_1}{h_p} \leq 1,3$$

$$0,1 \leq \frac{H_1}{l} \leq 1,2$$

$$2 \leq Z_1 \leq 4 \text{ and } 0 \leq Z_2 \leq 5$$

### b) Submerged flow

$$0,2 \leq \frac{l}{h_p} \leq 2$$

$$\frac{h_1}{h_p} \leq 1,3$$

$$0,1 \leq \frac{H_1}{l} \leq 1,2$$

$$2 \leq Z_1 \leq 4 \text{ and } Z_2 = 0$$

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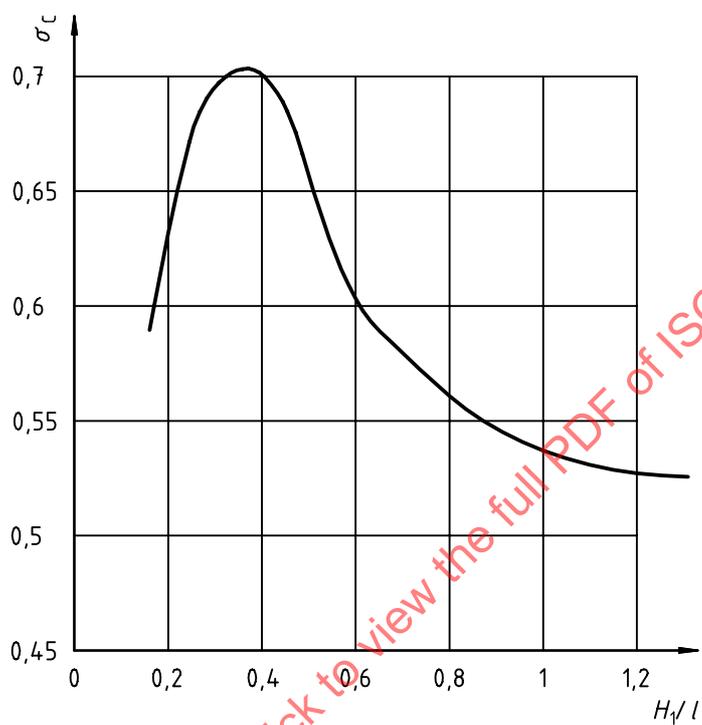


Figure 19 — Modular limit  $\sigma_c$  for trapezoidal broad-crested weirs with a vertical downstream face ( $Z_2 = 0$ ) as a function of  $H_1/l$

Table 5 — The drowned-flow coefficient  $C_{dr}$  as a function of  $H_1/l$  and  $H_2/H_1$ 

| $H_2/H_1$ | Values of the drowned-flow coefficient $C_{dr}$ |                   |                   |      |      |      |      |      |      |      |      |
|-----------|---|-------------------|-------------------|------|------|------|------|------|------|------|------|
|           | $H_1/l$   |                   |                   |      |      |      |      |      |      |      |      |
|           | 0,2   | 0,3               | 0,4               | 0,5  | 0,6  | 0,7  | 0,8  | 0,9  | 1,0  | 1,1  | 1,2  |
| 0,95      | 0,60 <sup>a</sup>                               | 0,62 <sup>a</sup> | 0,64 <sup>a</sup> | 0,67 | 0,69 | 0,70 | 0,71 | 0,74 | 0,75 | 0,75 | 0,75 |
| 0,94      | 0,63 <sup>a</sup>                               | 0,66              | 0,69              | 0,72 | 0,74 | 0,75 | 0,76 | 0,78 | 0,79 | 0,79 | 0,79 |
| 0,93      | 0,67  | 0,70              | 0,74              | 0,76 | 0,78 | 0,80 | 0,80 | 0,81 | 0,81 | 0,82 | 0,82 |
| 0,92      | 0,70  | 0,75              | 0,78              | 0,80 | 0,82 | 0,82 | 0,83 | 0,83 | 0,84 | 0,84 | 0,84 |
| 0,91      | 0,74  | 0,78              | 0,81              | 0,83 | 0,85 | 0,85 | 0,85 | 0,86 | 0,85 | 0,85 | 0,85 |
| 0,90      | 0,77  | 0,81              | 0,84              | 0,86 | 0,87 | 0,87 | 0,87 | 0,87 | 0,87 | 0,87 | 0,86 |
| 0,89      | 0,80  | 0,85              | 0,87              | 0,88 | 0,89 | 0,89 | 0,89 | 0,88 | 0,88 | 0,88 | 0,87 |
| 0,88      | 0,83  | 0,87              | 0,89              | 0,90 | 0,90 | 0,90 | 0,90 | 0,89 | 0,90 | 0,88 | 0,88 |
| 0,87      | 0,85  | 0,88              | 0,90              | 0,91 | 0,91 | 0,91 | 0,91 | 0,90 | 0,91 | 0,89 | 0,89 |
| 0,86      | 0,87  | 0,89              | 0,92              | 0,92 | 0,92 | 0,92 | 0,91 | 0,91 | 0,91 | 0,90 | 0,90 |
| 0,85      | 0,88  | 0,91              | 0,94              | 0,93 | 0,93 | 0,92 | 0,92 | 0,92 | 0,92 | 0,91 | 0,90 |
| 0,84      | 0,90  | 0,93              | 0,95              | 0,94 | 0,94 | 0,93 | 0,92 | 0,92 | 0,92 | 0,92 | 0,91 |
| 0,83      | 0,91  | 0,95              | 0,96              | 0,95 | 0,94 | 0,94 | 0,93 | 0,93 | 0,93 | 0,92 | 0,92 |
| 0,82      | 0,92  | 0,96              | 0,97              | 0,96 | 0,95 | 0,94 | 0,93 | 0,93 | 0,93 | 0,93 | 0,92 |
| 0,81      | 0,93  | 0,96              | 0,97              | 0,96 | 0,95 | 0,95 | 0,94 | 0,94 | 0,94 | 0,93 | 0,93 |
| 0,80      | 0,94  | 0,97              | 0,98              | 0,97 | 0,96 | 0,95 | 0,94 | 0,94 | 0,94 | 0,94 | 0,93 |
| 0,79      | 0,94  | 0,97              | 0,98              | 0,97 | 0,96 | 0,95 | 0,95 | 0,94 | 0,94 | 0,94 | 0,94 |
| 0,78      | 0,95  | 0,97              | 0,98              | 0,97 | 0,96 | 0,96 | 0,95 | 0,95 | 0,95 | 0,94 | 0,94 |
| 0,77      | 0,95  | 0,98              | 0,98              | 0,98 | 0,97 | 0,96 | 0,95 | 0,95 | 0,95 | 0,95 | 0,94 |
| 0,76      | 0,96  | 0,98              | 0,98              | 0,98 | 0,97 | 0,96 | 0,96 | 0,95 | 0,95 | 0,95 | 0,95 |
| 0,75      | 0,96  | 0,98              | 0,99              | 0,98 | 0,97 | 0,97 | 0,96 | 0,96 | 0,95 | 0,95 | 0,95 |
| 0,74      | 0,97  | 0,98              | 0,99              | 0,98 | 0,97 | 0,97 | 0,96 | 0,96 | 0,96 | 0,96 | 0,95 |
| 0,73      | 0,97  | 0,99              | 0,99              | 0,98 | 0,98 | 0,97 | 0,97 | 0,96 | 0,96 | 0,96 | 0,95 |
| 0,72      | 0,97  | 0,99              | 0,99              | 0,99 | 0,98 | 0,97 | 0,97 | 0,96 | 0,96 | 0,96 | 0,96 |
| 0,71      | 0,97  | 0,99              | 0,99              | 0,99 | 0,98 | 0,98 | 0,97 | 0,97 | 0,96 | 0,96 | 0,96 |
| 0,70      | 0,98  | 0,99              | FF                | 0,99 | 0,98 | 0,98 | 0,97 | 0,97 | 0,97 | 0,97 | 0,96 |
| 0,69      | 0,98  | FF                |                   | 0,99 | 0,98 | 0,98 | 0,98 | 0,97 | 0,97 | 0,97 | 0,96 |
| 0,68      | 0,98  |                   |                   | 0,99 | 0,98 | 0,98 | 0,98 | 0,97 | 0,97 | 0,97 | 0,97 |
| 0,67      | 0,98  |                   |                   | 0,99 | 0,98 | 0,98 | 0,98 | 0,98 | 0,97 | 0,97 | 0,97 |
| 0,66      | 0,99  |                   |                   | 0,99 | 0,99 | 0,98 | 0,98 | 0,98 | 0,97 | 0,97 | 0,97 |
| 0,65      | 0,99  |                   |                   | FF   | 0,99 | 0,98 | 0,98 | 0,98 | 0,98 | 0,98 | 0,97 |
| 0,64      | FF  |                   |                   |      | 0,99 | 0,99 | 0,98 | 0,98 | 0,98 | 0,98 | 0,98 |
| 0,63      |   |                   |                   |      | 0,99 | 0,99 | 0,98 | 0,98 | 0,98 | 0,98 | 0,98 |
| 0,62      |   |                   |                   |      | 0,99 | 0,99 | 0,99 | 0,98 | 0,98 | 0,98 | 0,98 |
| 0,61      |   |                   |                   |      | 0,99 | 0,99 | 0,99 | 0,99 | 0,98 | 0,98 | 0,98 |
| 0,60      |   |                   |                   |      | FF   | 0,99 | 0,99 | 0,99 | 0,98 | 0,98 | 0,98 |
| 0,59      |   |                   |                   |      |      | 0,99 | 0,99 | 0,99 | 0,98 | 0,98 | 0,98 |
| 0,58      |   |                   |                   |      |      | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| 0,57      |   |                   |                   |      |      | FF   | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| 0,56      |   |                   |                   |      |      |      | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| 0,55      |   |                   |                   |      |      |      | FF   | 0,99 | 0,99 | 0,99 | 0,99 |
| 0,54      |   |                   |                   |      |      |      |      | FF   | 0,99 | 0,99 | 0,99 |
| 0,53      |   |                   |                   |      |      |      |      |      | FF   | FF   | 0,99 |
| 0,52      |   |                   |                   |      |      |      |      |      |      |      | FF   |

<sup>a</sup> Extrapolated.

## 8.7 Uncertainty in measurement

**8.7.1** The overall uncertainty in flow measurements made using trapezoidal broad-crested weirs in trapezoidal channels depends on the uncertainties in the head measurements, in the measurements of the dimensions of the weir and in the coefficients as they apply to the weir in use.

**8.7.2** With reasonable care and skill in the construction and installation of a trapezoidal broad-crested weir, the systematic uncertainty in the discharge coefficient  $C_D$  is within  $\pm 3\%$ . There is no uncertainty in the coefficient  $C_{dr}$  for free flow. For submerged flow, the uncertainty in  $C_{dr}$  increases as the submergence ratio increases. For those submergence ratios for which  $C_{dr}$  is more than 0,9, the systematic uncertainty in the combined coefficient  $C_D \cdot C_{dr}$  is within  $\pm 5\%$ .

The random uncertainty in the coefficient of discharge  $C_D$  reflects the real but marginal differences in coefficient values for different discharges, and may be taken as  $\pm 0,5\%$ . The random uncertainty in the coefficient  $C_{dr}$  may be ignored.

**8.7.3** The method by which the uncertainties in the coefficients shall be combined with other sources of uncertainty is given in clause 9.

In general, the discharge coefficients quoted in this International Standard have been determined using calibration experiments on small-scale model structures. It should be borne in mind that these coefficients will not be identical for larger structures, owing to scale effects.

## 9 Uncertainties in flow measurement

### 9.1 General

**9.1.1** For general information, reference should be made to ISO/TR 5168.

**9.1.2** In general, the component uncertainties arising from various sources of error may be assessed (see 9.4 and 9.5) and combined (see 9.6) to obtain an estimation of the total uncertainty in the discharge measurement. This total uncertainty allows judgement of whether the discharge can be measured with sufficient accuracy for the purpose in hand.

Clause 9 is intended to provide sufficient information for the user of this International Standard to estimate the uncertainty in a measurement of discharge.

**9.1.3** The error may be defined as the difference between the actual rate of flow and that calculated in accordance with the equation for the weir, which is assumed to be constructed and installed in accordance with this International Standard.

The term "uncertainty" is used to denote the range of values, around the measured value, within which the true rate of flow is expected to lie 19 times out of 20 (i.e. 95 % confidence limits).

### 9.2 Sources of error

**9.2.1** The sources of error in the discharge measurement may be identified by considering the generalized form of the discharge equations as given in 7.5.1 and 8.5.1

For rectangular channels:

$$Q = \left(\frac{2}{3}\right)^{3/2} C_D C_v C_{dr} \sqrt{g} b h^{3/2}$$

where

$$\left(\frac{2}{3}\right)^{3/2} \text{ is a numerical constant not subject to error;}$$