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Hydrometry — Liquid flow measurement using end depth method in channels with a free overfall

Hydrométrie — Mesure du débit liquide dans les chenaux à déversoir sans pelle

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Foreword

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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).

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

This first edition of ISO 18481 cancels and replaces ISO 3847:1977 and ISO 4371:1984, which have been merged and technically revised.

Hydrometry — Liquid flow measurement using end depth method in channels with a free overfall

1 Scope

This document specifies a method for the estimation of the sub-critical flow of clear water in a smooth, essentially horizontal channel (or a gently sloping channel), abruptly discontinued at bottom by a hydraulic structure, with a vertical drop and discharging freely. Such an overfall forms a control section and offers a means for the estimation of flow using the end depth measurement method. A wide variety of channel cross-sections with overfall have been studied, but only those which have received general acceptance after adequate research and testing, and therefore do not require in situ calibration, are considered. This document covers channels with the following types of cross-sections:

a) rectangular with confined and unconfined nappe;

b) trapezoidal;

c) triangular;

d) circular;

e) parabolic.

The flow at the brink is curvilinear; therefore, the measured depth at the drop is not equal to the critical depth as computed by the principle based on assumption of parallel flow. However, the end depth and the critical depth (as in the case of the assumption of parallel flow) have unique relation, which is used to estimate the flow through these structures.

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 https://www.iso.org/obp

4 Symbols and abbreviated terms

Symbol	Unit	Definition
A	m^2	area of approach channel
$2a$	m	semi-latus rectum of parabola
A_c	m^2	area of flow at critical depth
b	m	width of rectangular channel
C	—	coefficient of discharge
d	m	diameter of the circle
h_e	m	end depth corresponding to the maximum anticipated discharge
z	—	side slope 1 vertical to z horizontal
Q	m^3/s	total discharge
m_t	m	top width of flow
D_c	m	critical depth
D_e	m	end depth
θ	radian	apex angles subtended by the top width of flow at the centre of the circle
$\propto$	radian	semi-vertex angle of triangular channel

5 Principle

The un-submerged flow at an abrupt end of a long channel can be referred to as free overfall. In many cases, the measurement of flow depth at the free overfall is possible and could be used for discharge estimation. Such a discharge measurement method does not generally require any obtrusive structure to be built. Many available overfall structures constructed for other reasons could also be used for the discharge measurement with minor modifications.

There is a unique relationship between the flow discharge and the critical depth in an open channel. The ratio of end depth to the critical depth (EDR) established theoretically and verified experimentally offers an easy method to measure the discharge using end depth method.

6 Installation

6.1 General

General requirements of overfall discharge measurement installation are described in the following clauses. Special requirements of different types are described in clauses which deal with specific types.

6.2 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) to the requirements necessary for measurement by the end depth method. The potential application of this method of flow measurement is at proposed or existing water and waste water treatment plants, where flumes and channels form part of such installations. The discharge measurement using end depth can be installed on existing flumes and channels after verification that they conform to the requirements necessary for measurement by the end depth method or they can be modified to make them conform to the requirements. Particular attention should be paid to the following features in selecting the site and ensuring the necessary flow conditions.

a) An adequate straight length (at least $20h_e$, where h_e is the end depth corresponding to the maximum discharge anticipated) of channel of regular cross-section should be available upstream of the drop.

b) 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. Baffles and flow straighteners can be used to simulate satisfactory velocity distribution, but their location with respect to the measuring section shall be not less than the minimum length prescribed for the approach channel.

c) The channel bottom should be horizontal. Gentle positive slopes not greater than 1 in 2 000 are admissible; the flow shall be sub-critical, practically uniform upstream of the drop, and the water surface shall be relatively stable and free from perturbations at even during low velocities.

d) The side walls, as well as the bottom, shall be smooth as far as possible (in this document, a smooth surface shall correspond to a neat cement finish). The finish of the structure shall be well maintained; changes in wall roughness due to various forms of deposition will change the discharge relationship.

e) The end (face) of channel shall be normal to its longitudinal centre line and water shall be allowed to fall freely beyond this point.

f) In the case of a confined nappe, the downstream side walls shall be extended to a distance not less than six times the maximum end depth.

g) In the case of unconfined nappe, the side walls shall end at the drop and nappe should be completely free at the sides to permit unrestricted spreading.

h) The nappe bottom shall be fully aerated in all the cases.

7 Measurement of end depth

7.1 General

The end depth is computed by deducting the bed level (gauge datum) from water surface level, both measured at the end or at the fall. The depth shall be measured exactly at the end (drop) of the channel. The flow at the drop is fully curvilinear and any small error in the location of the gauge will result in large error in measurement of discharge.

7.2 Head measuring devices

The water surface at the fall or end may be measured using a point gauge or other suitable measuring device. The pointer shall be at the centre of the channel width. The use of hook gauge or any other measuring device requiring insertion inside water is not advised and is discouraged. The flow would drag the pointer and displace it away from the point of measurement or the pointer will vibrate leading to inaccurate measurement. The device selected should not disturb the flow conditions at the free fall. Stilling well or float well cannot be used for the measurement of the end depth.

7.3 Gauge datum

Accuracy of end depth measurement is critically dependent upon the determination of the gauge datum or gauge zero, which is defined as the gauge reading corresponding to the channel bed (bottom) at the end (drop) in case of rectangular or trapezoidal channels, or the lowest point of the triangular or circular channel at the end (drop).

8 Maintenance

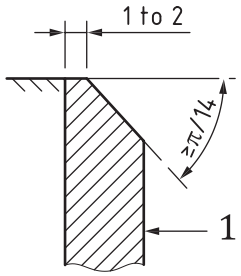
8.1 General

Maintenance of the drop structure is necessary to achieve the accuracy in measurement. 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 drop structure shall be kept clean. In the process of cleaning, care shall be taken to avoid damage to the surface of the drop structure, particularly brink edge and upstream bed and side surface. The head measuring devices like point gauge shall be checked periodically to ensure accuracy.

Dimensions in millimetres



Key

1 downstream face

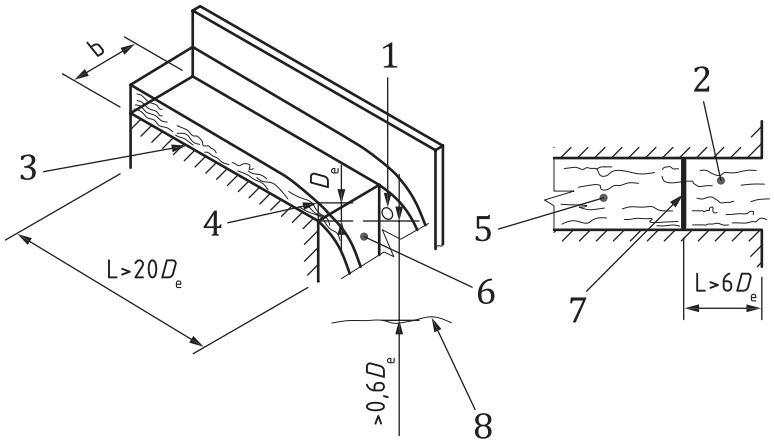
Figure 1 — Drop edge of overfall

The drop edge shall be sharp at its intersection without any burrs. To ensure that the brink edge and sides are sharp, a machined metallic rim could be fitted at the end of the channel. The thickness of the metallic rim should be uniform and it should be between 1 mm and 2 mm along the flow. The metallic rim shall be fitted flush with the vertical face of the overfall structure to ensure that no gaps exist between the rim and the channel. The downstream edges of the metallic rim shall be chamfered if the rim plate is thicker than the maximum allowable width along the flow. The surface of the chamfer shall make an angle of not less than π/4 radians (45°) with a line extending along the horizontal channel bed or side surfaces of the fall (see detail, Figure 1). The metallic rim shall be made of corrosion-resistant metal; but if it is not, all the smooth surfaces and sharp edges shall be kept coated with a thin, protective film (for example, oil, wax, silicone) applied with a soft cloth. 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 %.

8.2 Types

The free overfall structures in rectangular channels are further classified into two types: confined nappe and unconfined nappe.

The confined nappe is the jet formed by the flow where the guide walls of the structure extend to at least six times the end depth at maximum flow beyond the brink edge and where the bottom of nappe is sufficiently ventilated to ensure atmospheric pressure below the nappe (see Figure 2).

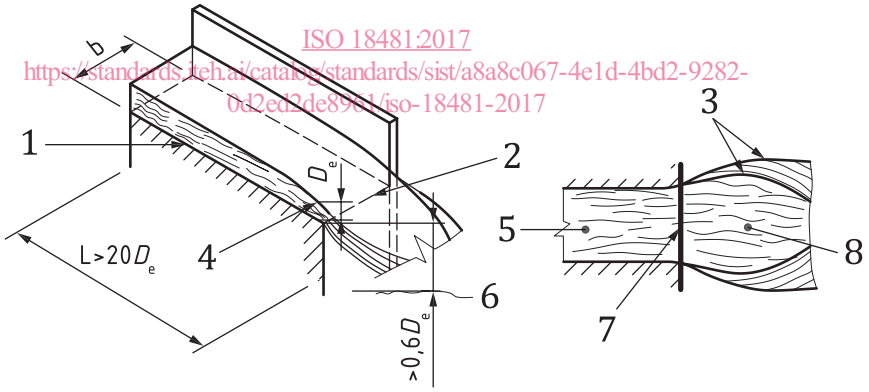


Key

1	aeration hole in side wall	5	flow
2	nappe width same as channel	6	overfall at the end of the channel
3	horizontal bottom	7	fall
4	point of measurement exactly at the drop	8	tail water level (TWL)

Figure 2 — Rectangular channel with confined nappe (bottom nappe aerated)

The unconfined nappe is the jet formed by the flow where the guide walls of the structure end at the edge of the drop structure and permit free lateral expansion of flow and where the nappe is sufficiently ventilated to ensure atmospheric pressure below the nappe (see Figure 3).



Key

1	horizontal bottom	5	flow
2	overfall (at the end of channel)	6	tail water level
3	two alternative forms of nappe	7	fall
4	point of measurement exactly at the drop	8	nappe

Figure 3 — Rectangular channel with unconfined nappe

8.3 Specifications for the drop structure

The basic overfall structure consists of an abrupt drop or discontinuity in the bed at the end of a rectangular channel. The overfall shall be plane, rigid and perpendicular to the walls and the floor of the approach channel. The surface finish along the bed and sides shall be the same until the drop. The side walls of the rectangular channel shall be parallel to each other and the distance between them (width of channel) shall be the same for the specified length of the channel. The brink (overfall edge) line shall be horizontal and perpendicular to the longitudinal axis of the rectangular channel.