International Standard ISO 8368

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Liquid flow measurement in open channels — Guidelines for the selection of flow gauging structures

Mesure de débit des liquides dans les canaux découverts — Principes directeurs pour le choix d'un dispositif de jaugeage

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8368 was prepared by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Liquid flow measurement in open channels — Guidelines for the selection of flow gauging structures

1 Scope and field of application

This International Standard gives guidelines for selection of a particular type of flow gauging structure for liquid flow measurement in open channels. It sets out the factors, and summarizes the parameters, which may influence such a selection.

In general, a flow gauging structure is used when high accuracy is required for continuous records of flow.

2 References

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

ISO 1438/1, *Water flow measurement in open channels using weirs and venturi flumes — Part 1: Thin-plate weirs.*

ISO 3846, *Liquid flow measurement in open channels by weirs and flumes — Free overfall weirs of finite crest width (rectangular broad-crested weirs).*

ISO 3847, *Liquid flow measurement in open channels by weirs and flumes — End-depth method for estimation of flow in rectangular channels with a free overfall.*

ISO 4359, *Liquid flow measurement in open channels — Rectangular, trapezoidal and U-shaped flumes.*

ISO 4360, *Liquid flow measurement in open channels by weirs and flumes — Triangular profile weirs.*

ISO 4374, *Liquid flow measurement in open channels — Round-nose horizontal crest weirs.*

ISO 4377, *Liquid flow measurement in open channels — Flat-V weirs.*

3 Definitions and symbols

For the purpose of this International Standard, the definitions and symbols given in ISO 772 apply.

4 Units of measurement

The units of measurement used in this International Standard are seconds and metres.

5 Types of structure

The types of structure that can be used for the purpose of liquid flow measurement are as follows:

a) thin-plate weirs:

   i) rectangular,
   ii) V-notch;

b) broad-crested weirs:

   i) round-nose,
   ii) rectangular,
   iii) V-shaped;

c) triangular profile weirs;

d) flat-V weirs;

e) flumes:

   i) rectangular,
   ii) trapezoidal,
   iii) U-throated;

f) end-depth method.

6 Factors affecting choice

6.1 General

The factors which affect choice can be considered under the following headings:

a) purpose;

b) range of flow;

c) afflux;

d) size and nature of channel;

e) channel slope and sediment load;

f) operation and maintenance;

g) passage of fish;

h) cost.

6.2 Purpose

Table 1 tabulates the various structures and indicates some of the purposes for which they may be applicable, together with a guide to their limitations.

The purpose for which the structure is required will determine the range of accuracy which is necessary. The accuracy in a single determination of discharge depends upon the estimation of the component uncertainties involved.

In broad terms, thin-plate weirs will have a range of uncertainties from 1 to 4 % and flumes and other types of weirs a range from 2 to 5 %. Deviations from the construction, installation or use as laid down in the appropriate International Standard will result in measurement errors.

6.3 Range of flow

It is necessary to consider the relation between maximum flow and minimum flow when deciding which type of structure to use, and an indication of the range of some typical structures is given in table 2. For the best overall accuracy over a wide range of small discharges, a thin-plate V-notch weir should be used in preference to a thin-plate rectangular notch or rectangular full-width weir. For a wide range of larger discharges, a trapezoidal flume, a flat-V weir or a triangular profile weir should be used in preference to a broad-crested weir, free overfall or rectangular throat flume.

6.4 Afflux

The rise in level immediately upstream of, and due to, a structure may interfere with the flow system and cause drainage problems, or limit the effectiveness of irrigation systems, or cause extra pumping costs. A number of structures have been developed with high coefficients of discharge and whose accuracy is relatively unimpaired by high submergence ratios. The triangular profile and flat-V weirs, and flumes are examples of this type of structure.

6.5 Size and nature of channel

The shape and size of the channel have a bearing on the practicality of selecting any particular type of structure. The material forming the bed and sides of the channel will influence the acceptable head loss through the structure without introducing appreciable leakage through the bed and banks. It will also determine the degree of protection necessary to alleviate scour downstream of the structure.

Broad-crested weirs are best used in rectangular channels, but they can be used with good accuracy in non-rectangular channels if a smooth, rectangular approach channel extends upstream of the weir for a distance not less than twice the maximum head. Flumes can be used in channels of any shape if flow conditions in the approach channel are reasonably uniform and steady. The modular limit of each device requires careful consideration. The submergence ratio should be checked for the whole range of flows to be measured and compared with values for the modular limit given in table 1.

6.6 Channel slope and sediment load

For flows with suspended load, the use of thin-plate weirs should be avoided because the crest edge may be damaged or worn by the suspended materials. In addition, the rating of weirs can be affected by deposition and scour of sediment in the approach section to the weir. In streams with bed load, the use of structures which significantly reduce the stream velocity is not recommended, as it may result in fluctuations of the bed level as the flow varies. Flumes will generally perform better than weirs in streams with sediment load.

For gradients less than 1 : 1 000 and Froude numbers less than 0,25, there is no restriction on the type of structure.

For gradients between 1 : 1 000 and 1 : 250, and Froude numbers between 0,25 and 0,5, flumes have an advantage over weirs with regard to the transport of sediment.

For gradients greater than 1 : 250 and Froude numbers greater than about 0,5, standard weirs and flumes are not usually suitable, unless there is no transport of sediment.

6.7 Operation and maintenance

The accuracy of any device is very dependent upon the degree of maintenance it receives. However, flumes are particularly susceptible to errors of calibration due to algal growths in the throat.

When structures operate at temperatures below freezing point, consideration shall also be given to the effect of the accumulation of ice on the calibration. In general, weirs, and thin-plate weirs in particular, are less affected by ice than flumes. In some cases, the problem of calibration errors can be overcome by heating the air space over a structure.

The calibration of thin-plate weirs can be affected by damage to the crest and corners and failure to clean the upstream face where algal growths will introduce errors into the calibration. The choice of structure, therefore, will be influenced by the regularity with which maintenance can be carried out. Broad-crested weirs, triangular profile weirs, long-throated flumes and free overfall structures will normally pass floating debris more effectively than thin-plate weirs. The use of the thin-plate V-notch weir, in particular, should be avoided unless a debris trap is installed upstream.

6.8 Passage of fish

The movement of fish upstream for spawning may be restricted if a structure fails to make proper provision for their passage.

The principal factors which affect their movement past such an obstruction are the afflux at the obstruction and its overall length, and the depth of water below the obstruction and over its crest.

If a thin-plate or broad-crested weir is to be installed, there should be a sufficient depth of water from which the fish can take off to clear the weir. Flumes constitute a minimal obstruction, depending upon the velocities through the throat and the overall length. Triangular profile weirs need careful consideration as they may form a serious obstruction, particularly where energy dissipators are incorporated in the stilling basin.

The flat-V weir will minimize the obstruction by concentrating the flow. This will give a relatively greater depth of flow over a section of the crest for a given discharge than will be obtained using a weir with a horizontal crest.

6.9 Cost

The financial value of the flow passing through the device and the benefit in terms of improved accuracy against the cost of the structure will have a direct bearing on the relative investment values of different types of structure. The total construction and long-term maintenance costs should be considered.

7 Recommendations

7.1 Thin-plate weirs

Thin-plate weirs are dependent on the full development of the contraction below the nappe but are relatively inexpensive to construct, although the manufacture of the crest requires particular care. They are recommended where high accuracy is required and are particularly suitable for laboratory work and use in artificial channels and other circumstances where good maintenance can be assured and there is little risk of damage to, or deterioration of, the crest. Particular applications include the gauging of compensation flows, flow measurement in water supply pumping tests and flow measurement in many industrial situations. Thin-plate V-notch weirs are particularly suitable where the ratio of high to low flow is large and where accuracy at low is important, owing to their greater sensitivity. Thin-plate weirs of both rectangular and V-notch types are well suited for temporary installations.

7.2 Broad-crested weirs

Broad-crested weirs are relatively inexpensive to construct and robust and thus insensitive to minor damage. They are best used in rectangular channels where regular maintenance permits clearance of any deposition upstream and of algae from the crest. Round-nose broad-crested weirs have a good discharge range and submergence ratio and are appropriate for use in smaller and medium size installations.

V-shaped broad-crested weirs are suitable where a large discharge range is expected. They are recommended for use in small rivers and artificial channels with little fall available. V-shaped broad-crested weirs can be constructed either with a fixed crest or a movable one in vertical slots.

7.3 Triangular profile weirs

Triangular profile weirs are particularly appropriate for the measurement of flow in natural watercourses where minimum head losses are sought and where relatively high accuracy is required. They have a good discharge range and modular limit, are robust, insensitive to minor damage and will operate even when the flow is silt-laden.

The triangular profile has a constant coefficient of discharge over a wide range of heads. The weir can also be used under submerged flow conditions; in this case, a second head measurement is necessary achieved by means of tapping points at the crest.

The accuracy obtained over a wide range of flows and heads makes them excellent structures for hydrometric work.

7.4 Flat-V weirs

Flat-V weirs are extremely sensitive and are recommended where low flows are such as to introduce unacceptable inaccuracies if a horizontal crest were to be considered. They are relatively expensive structures, particularly if erosion is liable to occur downstream, and protective works are required. If, however, high accuracy is required and instrumentation giving continuous records is installed, the additional costs, compared to those of other gauging devices, are marginal.

7.5 Flumes

7.5.1 General

Flumes are recommended where material is being transported along the channel, particularly where there is bed movement. Protective works downstream of the throat to contain the hydraulic jump are easily incorporated into the main structure.

7.5.2 Rectangular flumes

The dimensions of rectangular flumes are easily adapted to the size of the channel and such flumes readily fit into rectangular channels and are almost universally used in measuring the inflow to sewage treatment works. They are suitable where the afflux needs to be kept to a minimum.

7.5.3 Trapezoidal flumes

Trapezoidal flumes are used for purposes similar to those employing rectangular flumes but are particularly recommended if it is necessary to accommodate the gauging station in a trapezoidal channel and skilled labour is available for the construction work. They are suitable where relatively high accuracy is required over a wide range of flows.

7.5.4 U-throated flumes

U-throated flumes are well suited to the measurement of flows in sewers and other conduits running partly full.

7.6 End-depth method

The method utilizing existing falls is convenient for approximate measurement where accuracy is not of paramount importance.

8 Summary

Tables 1 and 2 set out the broad parameters which may be considered in the choice of a structure. Limitations and values of coefficients are set out in the appropriate International Standard to which reference should be made for detailed design purposes.

Table 1 — Applications and limitations of structures

Type	International Standard	Typical uncertainties in computed discharge, %	Modular limit	Geometric limitations	Typical application
Thin-plate weirs	ISO 1438/1	1 to 4	*	2 **	Laboratory, pump tests, sediment-free water
Broad-crested weirs a) rectangular profile b) round-nose horizontal crest c) V-shaped	 ISO 3846 ISO 4374	3 to 5	 66 % 80 % 80 %	 1,5 ** 1,5 ** 1,5 – 3,0 **	Where economy and ease of construction are important factors. Irrigation channels with little fall available and wide range of flow
Triangular profile weirs	ISO 4360/1	2 to 5	75 %	3,5**	Hydrometric networks and principal irrigation channels
Flat-V weirs	ISO 4377	2 to 5	70 %	2,5**	Hydrometric works with wide range of flow
Long-throated flumes	ISO 4359	2 to 5	74 %	0,7†	Sediment-laden channels, flow with debris, flow with migratory fish, conduits and partially filled pipes, flow in sewers
End-depth method	ISO 3847	5 to 10	*	N/A ‡	Where accuracy may be relaxed for simplicity and economy

* Nappe to be fully aerated.

** Maximum H/P, where H is the total upstream head and P is the height of the weir.

† Maximum A_t/A_u, where A_t and A_u are the cross-sectional areas of the throat and approach channel, respectively.

‡ N/A = Not applicable

Table 2 — Comparative discharges for various weirs and flumes

Structure	D[1)] (m)	P[1)] (m)	b[1)] (m)	m[1)] (slope)	L[1)] (m)	Discharge, m^3/s min.	max.
Weirs							
Thin-plate, full width	—	0,2	1,0	—	—	0,005	0,67
	—	1,0	1,0	—	—	0,005	7,70
Thin-plate, contracted	—	0,2	1,0	—	—	0,009	0,45
	—	1,0	1,0	—	—	0,009	4,90
Thin-plate, V-notch	—	—	$\theta = 90°$	—	—	0,001	1,80
Round-nose broad-crest	—	0,15	1,0	—	0,6	0,030	0,18
	—	1,0	1,0	—	5,0	0,100	3,13
Rectangular broad-crested	—	0,2	1,0	—	0,8	0,030	0,26
	—	1,0	1,0	—	2,0	0,130	3,07
V-shaped broad-crested	—	0,30	$\theta = 90°$		1,50	0,002	0,45
	—	0,15	$\theta = 150°$		1,50	0,007	1,68
Triangular profile	—	0,2	1,0	—	—	0,010	1,17
	—	1,0	1,0	—	—	0,010	13,00
Flat-V	—	0,2	4	1:10	—	0,014	5,00
	—	1,0	80	1:40	—	0,055	630
Flumes							
Rectangular	—	0,0	1,0	—	2,0	0,033	1,70
Trapezoidal	—	0,0	1,0	5:1	4,0	0,270	41,00
U-throated	0,3	0,0	0,3	—	0,6	0,002	0,07
	1,0	0,0	1,0	—	2,0	0,019	1,40

1) Key:

D: diameter of U-shaped throat

P: height of weir

b: breadth of weir or flume throat

m: side slopes: 1 vertical; *m* horizontal

L: length of flume throat or weir crest.

NOTE — Dimensions are given as examples for comparison purposes only.