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Hydrometry — Fishpasses at flow measurement structures

Hydrométrie — Échelles à poissons auprès des structures mesurant le débit

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Foreword

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The committee responsible for this document is ISO/TC 113, *Hydrometry*, Subcommittee SC 2, *Flow measurement structures*.

This second edition cancels and replaces the first edition (ISO 26906:2009), which has been technically revised.

Introduction

Flow gauging structures are commonly used for the determination of open channel flows. To operate satisfactorily, these structures require a head difference to be generated between the upstream and downstream water levels. At structures designed to operate in the modular flow range, an upstream head measurement is used to interpret flow rates. At structures designed to operate in both the modular and drowned flow ranges, the upstream head measurement is augmented by a second measurement which senses tailwater conditions. The former type tends to require higher head losses over the structure.

In recent years, greater emphasis has been placed on environmental issues, including the free migration of fish in watercourses. It is acknowledged that flow measurement structures, with their requirement for a head loss between upstream and downstream conditions, that create high velocities may inhibit the movement of fish. It has become important, therefore, to consider ways of aiding fish migration without significantly affecting flow measurement accuracy.

Hydrometry — Fishpasses at flow measurement structures

1 Scope

This International Standard specifies requirements for the integration of fishpasses with flow measurement structures. It identifies those fishpasses which have satisfactory hydrometric calibration data and gives methods for computing combined flows and uncertainties.

NOTE Flow measurement structures and fishpasses have inherently different hydraulic performance criteria. Flow measurement structures perform better with uniform flow patterns; conversely, fish passage performance is improved by the variability of the flow conditions that allow fish and other aquatic inhabitants to select the passage conditions that best meet their mode of movement. This International Standard does not suggest that the fishpasses discussed are the preferred methods of fish passage or that they are good enough that passage performance can be sacrificed to obtain a single structure that meets both the fish passage and flow measurement requirements.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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*

ISO 14139, *Hydrometric determinations — Flow measurements in open channels using structures — Compound gauging structures*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 772 and the following apply.

3.1
fish pass design range
range of flows within which fish require passage

Note 1 to entry: This may be defined on an annual or a seasonal basis, e.g. for spawning.

Note 2 to entry: In some countries the design range is determined in terms of flow statistics. For example, the design range for coarse fish in the UK is usually between the estimated mean daily flow that is exceeded 95 % of the time and the mean daily flow that is exceeded 20 % of the time. While for migratory salmonids including sea trout and salmon, it is 95 % and 90 % to 10 % respectively.

4 Symbols

Where a symbol applies to a particular type of fishpass, it is indicated as follows.

[L] indicates applicable to the Larinier super-active baffle fishpass (see 7.2)

[PT] indicates applicable to the pool type fishpass with V-shaped overfalls (see 7.3)

[PO] indicates applicable to the Dutch pool and orifice fishpass (see 7.4)

[D] indicates distance between baffles in a Larinier Fish Pass

[S] indicates the Slope of the Larinier Fish Pass in degrees

Symbol	Term	Unit
a	height of baffle [L]	m
a_{fp}	proportion of total flow through fish-pass [L]	
b	orifice width [PO]	m
b	crest breadth measured at transverse section of upstream baffle [L]	m
b_{fms}	proportion of total flow through flow measuring structure [L]	
B	total width of fishpass channel [L]	m
B	pool width [PT and PO]	m
B_2	width of the non-aerated nappe [PT]	m
C	characteristic discharge coefficient [PO]	
C_{de}	dimensionless coefficient of discharge [L]	
C_{D}	characteristic discharge coefficient [PT]	
C_{V}	coefficient for the approach velocity [PT]	
D	longitudinal spacing of transverse baffles [L]	m
D	pipe diameter [PO]	m
g	acceleration due to gravity [All]	m/s^2
h_{max}	maximum head	m
h_{v}	orifice height [PO]	m
h_1	upstream gauged head relative to transverse section of upstream baffle [L]	m
h_1	upstream head [PT]	m
h_2	downstream head [PT]	m
H_1	upstream total head relative to transverse section of upstream baffle [L]	m
H_1	upstream total head [PT]	m
$H_{1\mathrm{e}}$	effective upstream total head relative to transverse section of upstream baffle [L]	m

Symbol	Term	Unit
k_h	head correction factor taking into account fluid property effects [L]	m
l	pool length [PT]	m
L	crest length [PT]	m
L	pool length [PO]	m
$\underline{L}$	width of one unit of Larinier fishpass [L]	m
n	number of partitions [PO]	
n_l	length scale factor [PO]	
n_V	flow velocity scale [PO]	
n_Q	discharge scale [PO]	
n_ℓ	scale factor for length dimensions [PT]	
P	height of the top baffle above the upstream bed [L]	m
P	pool depth [PT]	m
Q	discharge [All]	m^3/s
Q_d	design discharge [PT and PO]	m^3/s
S	bed slope of fishpass [PO and L]	
U	burst velocity of fish [PO]	m/s
v	flow velocity [PT and PO]	m/s
v_1	velocity of approach at tapping location [L]	m/s
$\bar{V}$	mean flow velocity [PO]	m/s
W_{L1}	upstream water level [PO]	m
W_{L2}	downstream water level [PO]	m
X	distance to h_1 measurement section [PT]	m
u^*C_{De68}	standard uncertainty in discharge coefficient C_D [L, PT and PO]	%
u^*_b	uncertainty in the gauging structure breadth measurement [L, PT and PO]	%
$u(E)$	absolute uncertainty in gauge/head zero [L, PT and PO]	m or mm
u^*_{H1e}	uncertainty in the total head measurement [L, PT and PO]	%
u_{h1}	absolute uncertainty in the measured upstream head [L, PT and PO]	m or mm
U^*_{fp}	overall uncertainty in fish pass flow [L, PT and PO]	%
U^*_{fms}	overall uncertainty in flow measurement structure [L, PT and PO]	%

Symbol	Term	Unit
U^*_c	combined overall uncertainty in fish pass and flow measurement structure flows [L, PT and PO]	%
Y_d	downstream water depth, related to upstream bed level [PO]	m
Y_0	upstream water depth, related to upstream bed level [PO]	m
α	angle of V-shape [PT]	deg
δ_h	error in measurement of h_1 [PT]	m
Δh	drop over the fishpass for modular flow [PT]	m
$\overline{\Delta h}$	head drop per pool [PO]	m
$\overline{\Delta h_d}$	design head drop per pool [PO]	m
Δt	pool drop [PT]	m

5 Principle

The discharge over a flow measurement structure is a function of the upstream head (plus a measure of the downstream head in the case of those structures designed to operate in the non-modular flow range). When a fishpass is placed alongside a flow gauging structure, an additional flow path is created. In certain circumstances, where the fishpass has a well-defined hydrometric calibration, total flows and uncertainties may be calculated. Thus the fishpass becomes an integral part of the flow measurement system. This International Standard provides the necessary design and performance information for this type of arrangement.

6 Installation

NOTE General requirements of combined flow measurement structure and fishpass installations are given in the following clauses.

6.1 Requirements for gauging structure and fishpass installations

NOTE Requirements for the installation of measuring structures are given in the appropriate International Standard (see Clause 2 and the Bibliography). There is much in common between the different structures and the requirements, which can also be applied to flow measurement structure and fishpass installations, and are summarized in the following clauses.

6.1.1 Selection of site

6.1.1.1 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 flow determination by a structure, or combination of structures.

6.1.1.2 Particular attention shall be paid to the following features when investigating a site:

— at existing measurement locations the type(s), state of repair and hydraulic performance of existing structures shall be assessed;

— availability of an adequate length of channel of regular cross-section;

— availability of an adequate width of cross sectional area outside the channel to install a bypass channel if required. The banks of the river need to be low enough to install a bypass channel that is not overdeep;

— the existing velocity distribution;

— the avoidance of a steep channel, if possible;

— the effects of any increased upstream water level due to the measuring structure;

— conditions downstream, including such influences as tides, confluences with other streams, sluice gates, mill dams and other controlling features which might cause submerged flow;

— the impermeability of the ground on which the structure is to be founded, and the necessity for piling, grouting or other sealing, in river installations;

— the necessity for the use of flood banks to confine the maximum discharge to the channel;

— the stability of the banks and the necessity for trimming and/or revetment in natural channels;

— the clearance of rocks or boulders from the bed of the approach channel;

— the effect of wind; wind can have a considerable effect on the flow in a river or over a weir, especially when these are wide and the head is small and when the prevailing wind is in a transverse direction.

6.1.1.3 If the site does not possess the characteristics necessary for satisfactory measurement, the site shall be rejected unless suitable improvements are practicable.

6.1.1.4 If an inspection of the stream shows that the existing velocity distribution is uniform, then it may be assumed that the velocity distribution will remain satisfactory after the construction of a structure.

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

6.1.1.6 Several methods are available for obtaining a more precise indication of non-uniform velocity distribution. Velocity rods, floats or concentrations of dye can be used in small channels, the latter being useful in checking conditions at the bottom of the channel. A complete and quantitative assessment of velocity distribution may be made by means of a current meter or acoustic doppler current profiler.

6.1.2 Installation conditions

6.1.2.1 The complete installation consists of an approach channel, the flow measurement and fishpass structures and a downstream channel. The conditions of each of these three components affect the overall accuracy of the measurements.

6.1.2.2 Installation requirements include such features as the quality of the structures, the cross-sectional shape of channel, channel roughness and the influence of control devices upstream or downstream of the structures.

6.1.2.3 The distribution and direction of velocity, determined by the features outlined in 6.1.1, have an important influence on the performance of the flow measurement structure and the fishpass.

6.1.2.4 Once an installation has been constructed, the user shall prevent any change which could affect the flow characteristics, particularly the accumulation of sediment or debris within the fishpass.

6.1.3 Upstream channel

6.1.3.1 At all installations the flow in the upstream channel shall be smooth, free from disturbance and shall have a velocity distribution as uniform as possible over the cross-sectional area. This can usually be verified by inspection or measurement. In the case of natural streams or rivers, this can only be attained by having a long, straight upstream channel free from projections either at the side or on the bottom. It is recommended that wherever possible the approach shall be straight for a distance of five times the channel width upstream of the head measuring section. Unless otherwise specified in the appropriate clauses, the following general 6.1.3.2 to 6.1.3.8 shall be complied with.

6.1.3.2 The altered flow-conditions due to the construction of the structure(s) might have the effect of building up shoals of debris and sediment upstream of the structure, which in time might affect the flow conditions. Changes in upstream bed level at the head measuring section may result in significant changes in the distance between the bed elevation and the crest of the structure (P value) which can affect the stage-discharge relationship due to the resultant variations in the velocity head.

6.1.3.3 In an artificial channel, the cross-section shall be uniform and the channel shall be straight for a length equal to at least five times its breadth upstream of the head monitoring point. This also applies to the approach to the fishpass.

6.1.3.4 In a natural stream or river, the cross-section shall be reasonably uniform and the channel shall be straight for a length equal to at least five times its breadth upstream of the head monitoring point

6.1.3.5 If the entry to the upstream channel is through a bend or if the flow is discharged into the channel through a conduit submerged entrance of a smaller cross-section, or at an angle, then a longer length (say 10 channel widths) of straight approach channel may be required to achieve a regular velocity distribution.

6.1.3.6 There shall be no baffles in the upstream channel, which are nearer than five times the maximum head to the point of head measurement.

6.1.3.7 Under certain conditions, a standing wave may occur upstream of the installation, for example if the approach channel is steep. Provided this wave is at a distance of not less than 30 times the maximum head upstream, flow measurement will be feasible, subject to confirmation that a regular velocity distribution exists at the structure.

6.1.3.8 Stop log slots, and/or fish observation camera housings shall be designed so as not to create disturbances and irregular velocity distributions in the approach channel to the flow measuring structure, or in specific components thereof, e.g. fish pass in separate channel. For example, where cameras may be fixed in slots/compartments in the approach channel walls then the slot/compartment should be protected with a transparent cover set flush with the channel wall.

6.1.4 Separate channel

6.1.4.1 For some fish passes, or at some sites, separate channels may be required to facilitate the movement of fish into or out of the fish pass, These will help minimize the operational and maintenance requirements such as the removal of debris and create a more favourable hydraulic conditions for flow determination purposes. For example, the performance of Larinier fish passes as flow measurement structures is very dependent on the crests being kept clear of trash/debris and this should be considered when developing the design. A separate channel with a deflector/boom or submerged entrance should be considered. It is recommended that the upstream exit of the separate fishpass channel is set laterally to the line of the river to help reduce trash ingress.

6.1.4.2 Where a separate channel is required, an additional head measurement device will be required in the approach channel to the fish pass at the recommended distance upstream for the type of structure or fish pass concerned. The water level sensing device and the supporting arrangement shall be installed in accordance with the appropriate hydrometric standards and the manufacturer's guidance.

6.1.5 Downstream channel

6.1.5.1 The channel downstream of the structure is of no importance to flow measurement if the measuring structure or gauging structure installation has been so designed that the flow is modular under all operating conditions. A downstream gauge shall be provided to measure tailwater levels to determine if and when submerged flow occurs. The downstream conditions will affect the location of the downstream entrance to the fishpass and its performance. See 6.2.3.

6.1.5.2 In the event of the possibility of scouring downstream, which may lead to the instability of the structure, particular measures to prevent this happening may be necessary.

6.1.5.3 A downstream water level sensor shall be installed if there is a possibility that the structure may become non-modular in the future or if it is required to assess the modular limit.

6.1.5.4 The circumstances described in 6.1.4.3 may arise if the altered flow conditions, due to the construction of the structure, have the effect of building up shoals of debris immediately downstream of the structure or if river works are carried out downstream at a later date.

6.1.5.5 For optimum fishpass performance, the jet of water issuing into the downstream channel shall be discernable to the fish amongst all the other competing flows and from as far away as possible. Care shall be taken to avoid the jet being masked by cross-flows or turbulence in the receiving water. Further details, which specifically relate to the fishpass, are given in 6.2.3.

6.1.5.6 Prior to the design of a fishpass at an existing flow gauge, it is recommended that a downstream water level sensor is installed for a period of time in order to gain a record of water levels across the appropriate fish migration window. This is important because the downstream level record is essential to ensure the correct design of the fish pass.

6.1.6 Flow measurement and fishpass structures

6.1.6.1 The flow measurement structure(s) should comply with the requirements given in the appropriate International Standard (see Bibliography).

6.1.6.2 The fishpass shall conform to with the requirements of Clause 7.

6.1.7 Maintenance

6.1.7.1 Maintenance of the flow measurement structure, the fishpass and the approach channel is important to secure accurate continuous measurements of discharge.

6.1.7.2 It is essential that the approach channel to flow measurement structure and fishpass installation need to be kept clean and free from silt, debris and vegetation. The float well and the entry from the upstream channel shall also be kept clean and free from deposits.

6.1.7.3 The flow measurement structure and fishpass 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 or fishpass.

6.1.7.4 The provision of remote surveillance cameras is recommended in order to reduce manpower operating resource requirements.

6.1.8 Measurement of head

6.1.8.1 When a fishpass is set alongside a flow measurement structure, an additional flow path is created and the fishpass flow needs to be evaluated with a similar precision to that of the measuring structure itself. The following are the two ways of doing this.

6.1.8.2 Head gauges are placed at both the fishpass and the gauging structure, and the two flows are determined separately and then combined to give the total river flow. This method requires more computation and instrumentation but is reliable, particularly where the upstream entry to the fishpass is remote from the gauging structure.

6.1.8.3 Head gauges are placed only at the gauging structure and the flow at the fishpass is determined by transferring the single measured head to the fishpass using the established principles which apply to compound weirs. This method is more economical and is particularly useful where the upstream entry to the fishpass is close to the gauging structure. This method should not be used when the fish pass channel is totally separated and has an orifice or boom at the upstream end. Checks shall be undertaken to ensure that there is no significant water level difference between the main structure head measuring point and the level upstream of the fish pass. If the level difference is consistently greater than 3 mm, consideration should be given to installing a separate water level sensor in the fish pass.

6.1.8.4 Head gauges shall be designed and installed in accordance with the relevant International Standard (see Bibliography for gauging structures and this International Standard for fishpasses).

6.1.8.5 Head gauges shall be zeroed to the crest of horizontal flow measurement weirs or to the invert level of flumes and v-shaped weirs Accuracy in zeroing gauges is very important, particularly for low flow determination. The gauge zero should be established to within no greater than 2 mm of the weir crest or structure invert level. See 7.2 for details of the gauge zero of a Larinier fishpass.

6.2 Requirements specific to the fishpass

6.2.1 General

The swimming performance of fish depends on many factors, including the following:

— species;

— individual size and ability;

— water temperature;

— water depth;

— water velocity;

— water quality;

— turbulence;

— motivation;

— migration period.

It is thus a complex subject with many variations. The data available are variable in both quantity and quality, and are complex to interpret. Furthermore, the effectiveness of a fishpass in terms of ease of passage depends on a suitable match between the type of fishpass, the specific hydraulic conditions within the fishpass and the particular species of fish wishing to migrate. It is not within the scope of this International Standard to cover this complex subject in detail. Instead, basic requirements which apply to a range of species of fish and a range of types of fishpass are identified to help those designing flow measurement structure/fishpass installations.

6.2.2 Guidelines for basic parameters of fishpasses

Guidelines for maximum water velocities within, head drops across and lengths of fishpasses are given in Table 1.

Table 1 — Guidelines for maximum water velocities within, head drops across and lengths of fishpasses

Pass parameters		Species			
		Coarse fish	Brown trout	Sea trout	Salmon
Pool pass	Max. velocity (ms^{-1})	1,4 to 2,0	1,7 to 2,4	2,4 to 3,0	3,0 to 3,4
	Max. head drop (m)	0,1 to 0,2	0,15 to 0,3	0,3 to 0,45	0,45 to 0,6
Baffled pass	Max. velocity (ms^{-1})	1,1 to 1,3	1,2 to 1,6	1,3 to 2,0	1,3 to 2,0
	Length of pass (m)	8 to 10	8 to 10	10 to 12	10 to 12

6.2.3 Location and attraction flows

6.2.3.1 General

In many respects, the most significant problem in fish pass design is creating both upstream and downstream conditions, to attract fish into the fish pass.

6.2.3.2 Location

For those fish travelling upstream, the entrance to the fishpass in the downstream reach shall be located as far upstream as possible and shall be near one of the banks wherever practicable since this is the preferred migration route for many species. This location facilitates monitoring and maintenance. See also 6.2.4 and 6.2.5.

6.2.3.3 Attraction flows

The jet of water issuing from the fishpass shall be discernible to the fish. Exit velocities shall be in excess of 0,75 ms^{-1} and preferably in excess of 1,5 ms^{-1} for salmonids.

The discharge through the fishpass shall be large enough to attract fish towards the downstream entrance. There are various criteria for this including the following:

— 5 % to 10 % of the competing river flow across the fish migration window;

— a starting flow of 5 % to 10 % of the annual daily flow of the river in the fish pass at a river flow exceeding 95 % of the time;

— a starting flow equal to the river flow which is exceeded 97 % of the time.

The discharge through the fishpass and the velocity of the outflow shall be determined in relation to the specific circumstances, and the specific species and size of fish which need to be conveyed.

6.2.4 Downstream entry/exit to fishpass

Fish normally find their way to the most upstream point. The downstream entrance to the fishpass shall therefore be located at the most upstream position which is easily accessible to the fish, for example close to the downstream truncation of a gauging structure. The downstream entry to the fishpass shall not be in areas of either re-circulating flows or highly turbulent flows. A vertical slot entry shall be installed such that a significant jet of water flows from the fishpass over a range of river flows.

