INTERNATIONAL STANDARD ISO 1088

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Liquid flow measurement in open channels — Velocity-area methods — Collection of data for determination of errors in measurement

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up 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.

Prior to 1972, the results of the work of the Technical Committees were published as ISO Recommendations; these documents are now in the process of being transformed into International Standards. As part of this process, International Standard ISO 1088 replaces ISO Recommendation R 1088-1969, drawn up by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels.*

The Member Bodies of the following countries approved the Recommendation :

Australia	Germany	Portugal
Belgium	India	Romania
Brazil	Ireland	South Africa, Rep. of
Bulgaria	Israel	Switzerland
Chile	Italy	United Kingdom
Egypt, Arab Rep. of	Japan	U.S.A.
France	Netherlands	

The Member Body of the following country expressed disapproval of the Recommendation on technical grounds :

Canada*

* Subsequently, this Member Body approved the Recommendation.

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Liquid flow measurement in open channels — Velocity-area methods — Collection of data for determination of errors in measurement

1 SCOPE AND FIELD OF APPLICATION

This International Standard provides a standard basis for the collection of data for the determination of individual components of the total error in the measurement of liquid flow in open channels by velocity-area methods. These data are intended to supplement and improve the values given in section 9 of ISO 748, *Liquid flow measurements in open channels — Velocity area methods.*

2 GENERALITIES

2.1 Calculation of discharge by the velocity-area method

The generalized equation for calculating the discharge is as follows :

$$Q = \sum_{i=1}^{m} b_i d_i \bar{v}_i \qquad \ldots (1)$$

where

Q is the total discharge;

b_i is the width of the ith segment;

d_i is the depth of the ith vertical;

$\bar{v}_i$ is the mean velocity of the ith vertical;

m is the number of verticals.

2.2 Individual components of the error

The symbols used are those given in the table below :

Quantity	Percentage standard error 1)	
	random	systematic 2)
width	X'_{b_i}	X''_b
depth	X'_{d_i}	X''_d
mean velocity	$X'_{\bar{v}_i}$	$X''_{\bar{v}}$

When $\bar{v}_i$ has been derived from a one-point, two-point, multiple-point or velocity distribution method, the single velocity v at an individual point shall be considered in the determination of the accuracy of $\bar{v}_i$.

In practice it is found that the standard error X_f in v is increased when measurements are taken approaching the bed of the channel. As an approximation, if, during the actual measurement of the discharge, the average number of point measurements in the vertical is p, then the contribution of the standard error $X_{\bar{v}_i}$ of the mean velocity in the vertical from this source may be calculated from the formula :

$$X_{\bar{v}_i} = \pm \sqrt{\frac{X_f^2}{p}} \qquad \ldots (2)$$

2.3 Overall error in discharge

The overall standard error X_Q in the discharge Q is the resultant of the component errors. The shape of the cross-section of the channel and the horizontal velocity distribution also affect the accuracy of discharge measurement. The random error from this effect X_m decreases with an increase in the number of verticals.

The overall random standard error is as follows :

$$X'_Q = \pm \sqrt{X_m^2 + \frac{\sum_1^m \left(b_i d_i \bar{v}_i\right)^2 \left(X'^2_{b_i} + X'^2_{d_i} + X'^2_{\bar{v}_i}\right)}{\left(\sum_1^m b_i d_i \bar{v}_i\right)^2}} \qquad \ldots (3)$$

The overall systematic standard error is as follows :

$$X''_Q = \pm \sqrt{X''^2_b + X''^2_d + X''^2_{\bar{v}}} \qquad \ldots (4)$$

NOTE — Equation 4 is only applicable if the number of instruments used is such as to allow the expectation that the resultant of the systematic errors they introduce will be zero. If this is not the case, there will be a systematic deviation.

The overall standard error in the discharge may be taken from the following formula :

$$X_Q = \pm \sqrt{X'^2_Q + X''^2_Q} \qquad \ldots (5)$$

1) All the standard errors used in this International Standard are in terms of percentages.

2) These systematic errors are those of instruments and they vary randomly from instrument to instrument. They are not the systematic errors inherent in the types of instrument or measurements which cannot be eliminated or reduced by repeated measurements by the same instrument.

The major source of the error in the velocity will arise from errors in the calibration of the current-meters.

2.4 Evaluation of the error in the individual components

The evaluation of the error in the individual components of the total error can be obtained by a statistical analysis of a large number of observations for a particular component under operating conditions. To incorporate this procedure in the normal routine measurement is not feasible, and therefore centralized processing of collected data according to standardized programmes, as indicated in this International Standard, is recommended with a view to providing a general standard on the errors of the components within the practical range of measurements.

3 DATA ON THE LOCAL POINT VELOCITY[1)]

To judge the value of a single velocity measurement the following procedure is required :

At each point of measurement on a vertical, an uninterrupted observation of the velocity over a period of 50 min shall be made with a current-meter. Every 30 s a reading of the instrument shall be taken, so that 100 readings become available. When pulses are emitted by the current-meter, the number of pulses shall be recorded every 30 s; or, when the time is measured at a fixed number of pulses, this time shall be about 30 s on the average. When a continuous record is produced, the complete record shall be sent and the response characteristics of the electronic instrument mentioned.

In each vertical this procedure shall be carried out at 0,2 – 0,6 – 0,8 and, where possible, 0,9 of the depth measured from the surface. When possible, the data shall be obtained during the same 50 min period.

The verticals to be taken for this measurement shall be the vertical situated at the deepest point and the verticals situated at places where the depths are 0,6 and 0,3 of the greatest depth, both located on the side of the greater segment of the width from the deepest point.

The measurements shall be repeated for different discharges.

The data thus obtained shall be tabulated in the form given in Appendix X. In the case of a continuous recorder, the values at intervals of 30 s shall be given, indicating the method of determination.

4 DATA ON THE AVERAGE VELOCITY[2)]

The average velocity may be obtained in various ways. The velocity-distribution method is, however, taken as a basis for comparison with the results of other methods generally used or special methods adopted owing to special circumstances.

The following procedure is required.

4.1 Location of the vertical

The vertical to be taken for this measurement shall be that at maximum depth.

It is recommended that if, at the measuring cross-section, velocity profiles are available at more verticals as a result of the routine discharge measurements, a check should be made to ascertain whether the velocity profile at the chosen vertical is representative of the section.

4.2 Distribution of measuring points

In the vertical, the velocity shall be measured at the following points :

1) near the surface;
2) 0,2 of the depth;
3) 0,3 of the depth;
4) 0,4 of the depth;
5) 0,5 of the depth;
6) 0,6 of the depth;
7) 0,7 of the depth;
8) 0,8 of the depth;
9) 0,9 of the depth;
10) near the bed.

4.3 Period of measurement of local point velocities

The period of measurement of local point velocity at any point shall be 60 s, or the number of pulses shall be that observed in 60 s at 0,6 of the depth.

4.4 Number of measurements

The measurements in the vertical shall be repeated five times, preferably consecutively. Measurements affected by navigation shall be indicated.

These sets of observations shall be made for various discharges.

4.5 Presentation of data

Compilation of data shall be made in the form shown in Appendix Y.

The velocity profiles shall be drawn to a scale in such a way that the maximum velocity and the depth are represented by 0,10 m and 0,20 m respectively.

The mean velocity shall be determined with the use of a planimeter from an adequately large graphical plot (preferably not less than 300 cm^2). The type and accuracy of the planimeter shall be given, together with the scale of the discharge. The accuracy of the graph paper shall be checked.

1) Reference may be made to 9.1.3.3 of ISO 748.

2) Reference may be made to 9.1.3.4 of ISO 748.

5 DATA ON THE VELOCITY-AREA METHOD[1)]

There are two possible ways of determining the accuracy of the velocity-area method, one requiring special measurements, the other mainly using routine measurements.

Wherever possible, data for both should be produced.

5.1 0,6 depth measurement

In this method, the continuous profile of the cross-section at the measuring site is required. This can be obtained by echo-sounder measurements or by measuring the depth with a rod at intervals of not more than 1/50 of the total width subject to an absolute minimum spacing of 0,25 m (0.75 ft).

The horizontal velocity distribution shall be observed by taking velocity readings at 0,6 of the depth at intervals of 1/50 of the total width subject to an absolute minimum spacing of 0,5 m (1.5 ft). The readings of the current-meter shall be made over a period of 120 s.

In addition, readings shall be taken from a reference current-meter at a fixed point, preferably at 0,6 of the depth in the vertical at greatest depth. It shall be read every 60 s.

5.2 Velocity-distribution method

In this method, the normal procedure for discharge measurement may be used provided the velocity-distribution method or integration method is used for the determination of the average velocity in the vertical.

Readings shall be taken every 60 s, from a reference current-meter at a fixed point, preferably at 0,6 of the depth in the vertical at greatest depth.

In addition to the data on the depth obtained by the normal discharge measurement, a continuous profile of the cross-section at the measuring site shall be provided, as indicated in 5.1.

5.3 Presentation of data

For the compilation of data, the form shown in Appendix Z should be used. Correction factors in the table on velocity at reference point can best be based on the average value of velocity at the reference point. In that table, the factors are set as a function of time. To obtain the corrected velocity in the table "Mean velocity at verticals", the velocity column must be multiplied by this correction factor.

A graphical representation of the cross-section shall be drawn to an adequate scale; the width of the river on the drawing shall be not less than 0,5 m (1.5 ft). The representation shall indicate the numerical values of depth at the measuring points when a rod has been used, and shall show the location of the verticals and of the reference current-meter.

A graphical representation of the measured velocity profiles shall also be given. This shall indicate the numerical values of the velocities at the measuring-points.

6 INTEGRATION METHOD

To determine the standard error in the mean velocity in the verticals obtained by the integration method, a sufficient number of measurements (for example, fifty) shall be carried out at steady stage in three verticals and the results shall be tabulated.

The verticals to be taken for this measurement shall be the vertical situated at the greatest depth and the verticals situated at places where the depths are 0,6 and 0,3 of the greatest depth, both located on the side of the greater segment of the width from the deepest point.

The measurements shall be repeated for different discharges. Data of a general character can be compiled in a table similar to that given in Appendix X.

7 CALIBRATION CURVES

In connection with the study of the instrument error, calibration curves together with all calibration points shall be given, especially data of successive calibrations of a representative current-meter with dates and years of calibration and the intensity of use.

8 DISTANCE MEASUREMENTS

No generally applicable method of determining the accuracy of distance measurements can be given at present. Detailed descriptions of the method of distance measurement shall be given, together with the distances involved, and other relevant factors shall be given for theoretical examination.

Radio-electric instruments give an almost absolutely accurate standard of comparison for distance measurements. Where these instruments are available, independent research programmes concerning the error of different methods of distance measurement may be carried out and the results stated.

The conditions under which the study is carried out shall be similar to normal operating conditions in the field.

9 DEPTH MEASUREMENTS

The accuracy of depth measurement is dependent on the channel conditions and the method of measurement. In the case of lined channels, the bed conditions are not likely to influence the accuracy of the measurement.

In natural channels, i.e. rivers, the configuration of the bed varies in longitudinal as well as transverse directions.

1) Reference may be made to 9.1.3.4 of ISO 748.

In relation to the measuring-procedure, it is important to know whether the measurement is carried out from a rigid position or from an anchored launch. In the latter case, the influence of the irregularity of the bed may result in a greater contribution to the total error of the depth measurement.

Owing to the complex nature of the depth measurements, general directives cannot be given. In carrying out a study, the following considerations may give guidance.

9.1 In a river with movable bed, consecutive measurements at one point shall be avoided.

9.2 It is advisable to study the bed configuration in the vicinity of the actual measuring-point by determining longitudinal and transverse sections.

9.3 For all instruments, the accuracy of the reading in relation to the scale intervals shall be determined.

9.4 Sounding-rods yield errors due to

a) penetration into the bed;

b) deviation from vertical position;

c) stagnation head due to velocity.

9.5 Sounding-lines (including suspended current-meters) yield errors due to

a) penetration into the bed;

b) deviations from the ideal conditions for which the correction for wire bending has been calculated;

c) shape and suspension point of the lead.

9.6 Echo-sounders yield errors due to

a) beam width of the transmitted pulse at the bottom;

b) penetration of the pulse into the bottom, which is a function of the frequency of the pulse and of bed consistency.

APPENDIX X

(See section 3)

TABLE FOR LOCAL POINT VELOCITY MEASUREMENTS

Measurements carried out under
the responsibility of . . . .

Address : . . . .

. . . .

For inquiry please refer to . . . .

Concerns river . . . . At location : . . . .

Country : . . . .

1 GENERAL DATA[1] ON THE RIVER DURING MEASURING PERIOD

Discharge	. . . .	m^3/s
Area of cross-section of stream	. . . .	m^2
Average velocity	. . . .	m/s
Width	. . . .	m
Maximum depth	. . . .	m
Average depth (area/width)	. . . .	m
Slope of stage-discharge curve (sensitivity in steady-stage condition)	. . . .	$m^3/s{\cdot}m$
Water temperature	. . . .	°C

2 GENERAL DATA ON MEASURING VERTICALS

Measuring verticals	Average velocity	Depth at vertical	Distance from right/left bank
	m/s	m	m
A Maximum depth			
B 0,6 of maximum depth			
C 0,3 of maximum depth			

3 METHOD OF VELOCITY MEASUREMENT (Please tick where appropriate)

☐ a) Number of pulses, counted every 30 s.

☐ b) Time (average 30 s) for a constant number of pulses, being for

A : . . . . pulses.

B : . . . . pulses.

C : . . . . pulses.

☐ c) Continuous velocity record :

Speed of paper at recorder : . . . . mm/s

Response characteristics of the electronic instrumentation : . . . .

☐ d) Integration method.

1) Use (or convert to) metres and seconds.

4 MEASURING APPARATUS

Type of current-meter *(Please give details such as diameter of propeller and pitch or size of cup, cup distance and number of cups)* : . . . .

. . . .

Serial number : . . . .

Type of suspension : . . . .

Date of calibration : . . . . *(Please add rating-curve and equations for calculation of velocity and indicate whether group calibration or direct calibration is meant. Check whether on the rating-curve the water temperature during calibration has been indicated.)*

5 MEASUREMENTS AT VERTICALS

A Vertical at maximum depth

1 *General data*

	Depth				Units
	0,2	0,6	0,8	0,9	
Date of measurement					–
Hour of measurement (local time)					–
Water-level at start (local units)					
Water-level at end (local units)					
Water-depth during measurement					m
Depth of instrument under surface					m
Average velocity over a period of 50 min					m/s
Minimum velocity					m/s
Maximum velocity					m/s
Method of velocity measurement					
Method a) or c)					
Time interval of readings	30	30	30	30	s
Method b)					
Number of pulses					–
Average time interval of readings					s

2 *Description of bed conditions*

Bed material (size, shape, density) : . . . .

Bed form (smooth, ripples, dunes) : . . . .

Sediment transport : yes/no; type of transport : bed load/suspended load.

Bed roughness (preferably expressed in Chezy coefficient, C) : . . . .

$$C = \frac{\bar{v}}{\sqrt{R_h S}}$$

where

C is the Chezy coefficient;

$\bar{v}$ is the mean velocity;

R_h is the hydraulic mean depth (area of cross-section of stream over wetted perimeter);

S is the slope.

Remarks : . . . .

. . . .

3 Velocity observations

a) Velocity at 0,2 depth every 30 s.

Serial No.	Reading	Velocity	Serial No.	Reading	Velocity	Serial No.	Reading	Velocity	Serial No.	Reading	Velocity
1			26			51			76		
.			.			.			.		
.			.			.			.		
.			.			.			.		
.			.			.			.		
.			.			.			.		
.			.			.			.		
25			50			75			100		
Average velocity			Average velocity			Average velocity			Average velocity		
Maximum velocity			Maximum velocity			Maximum velocity			Maximum velocity		
Minimum velocity			Minimum velocity			Minimum velocity			Minimum velocity		

NOTE — Please indicate special circumstances influencing the measurements, such as passing of ships.

b) For measurements at 0,6 — 0,8 and 0,9 depths, give details in the form shown at a) above.

B Vertical at 0,6 of the maximum depth.

Give details in the form shown under A.

C Vertical at 0,3 of the maximum depth.

Give details in the form shown under A.