

CONFIRMED
MARCH 1998

Measurement of liquid flow in open channels —

Part 3: Stream flow measurement —

Part 3F: Collection and processing of data for determination of errors in measurement

[ISO title: Liquid flow measurement in open channels — Velocity-area methods — Collection and processing of data for determination of errors in measurement]

UDC 532.543:532.57.088.2

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

BSI
Documents

AVA

Document Sharing Hub

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Industrial-process Measurement and Control Standards Committee (PCL/-) to Technical Committee PCL/3, upon which the following bodies were represented:

- Department of the Environment for Northern Ireland
- Institute of Measurement and Control
- Institution of Civil Engineers
- Institution of Water Engineers and Scientists
- Scottish Development Department
- Water Authorities Association
- Welsh Office

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- Institute of Hydrology
- Severn Trent Water Authority
- South West Water Authority
- Southern Water Authority
- Yorkshire Water Authority

This British Standard, having been prepared under the direction of the Industrial-process Measurement and Control Standards Committee, was published under the authority of the Board of BSI and comes into effect on 31 January 1986

© BSI 10-1999

The following BSI references relate to the work on this standard:
Committee reference PCL/3
Draft for comment 82/26980 DC

ISBN 0 580 14912 9

Amendments issued since publication

Amd. No.	Date of issue	Comments

Contents

	Page
Committees responsible	Inside front cover
National foreword	ii
1 Scope and field of application	1
2 References	1
3 General	1
4 Data on the local point velocity	5
5 Data on the average velocity	5
6 Data on the velocity-area method	6
7 Integration method	7
8 Calibration curves	7
9 Distance measurements	7
10 Depth measurements	7
11 Data processing	8
12 List of symbols	14
Annex A Local point velocity measurements — Report form	17
Annex B Average velocity measurements — Report form	19
Annex C Velocity-area method — Report form	22
Figure 1 — Definition sketch	3
Figure 2 — Computation of discharge	16
Table — Compilation of results	12
Publications referred to	Inside back cover

National foreword

This Part of BS 3680 has been prepared under the direction of the Industrial-process Measurement and Control Standards Committee and is identical with ISO 1088:1985 — “*Liquid flow measurement in open channels — Velocity area methods — Collection and processing of data for determination of errors in measurement*”, published by the International Organization for Standardization (ISO).

Terminology and conventions. The text of the International Standard has been approved as suitable for publication as a British Standard without deviation. Some terminology and certain conventions are not identical with those used in British Standards; attention is drawn especially to the following.

Wherever the words “International Standard” appear, referring to this standard, they should be read as “British Standard”.

The comma has been used as a decimal marker. In British Standards it is current practice to use a full point on the baseline as the decimal marker.

Cross-references

International Standard	Corresponding British Standard
	BS 3680 <i>Methods of measurement of liquid flow in open channels</i>
ISO 748:1979	Part 3A:1980 <i>Velocity-area methods</i> (Identical)
ISO 4363:1977	Part 10B:1980 <i>Measurement of suspended sediment</i> (Identical)
ISO 4364:1977	Part 10C:1980 <i>Bed material sampling</i> (Identical)
ISO 5168:1978	BS 5844:1980 <i>Methods of measurement of fluid flow: estimation of uncertainty of a flow-rate measurement</i> (Identical)

The Technical Committee has reviewed the provisions of ISO 772:1978, to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

A related British Standard to ISO 772 is BS 3680-1:1983 “*Glossary of terms*”.

At present there is no corresponding British Standard for ISO/TR 7178:1983 which is quoted for information purposes only.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 24, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope and field of application

This International Standard specifies a standard basis for the collection and processing 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.

For determining the discharge in open channels by the velocity-area method, components of the flow need to be measured. The total uncertainty in discharge is a combination of the uncertainties in these components. This International Standard specifies a standard basis for collecting and processing the data required to compute the component uncertainties for determining the total uncertainty in discharge. This International Standard may be used when carrying out an investigation of component uncertainties from data taken from a large sample of rivers in a basin or in a country or for international investigations.

2 References

ISO 748, *Liquid flow measurement in open channels — Velocity-area methods*.

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

ISO 4363, *Liquid flow measurement in open channels — Methods for measurement of suspended sediment*.

ISO 4364, *Liquid flow measurement in open channels — Bed material sampling*.

ISO 5168, *Measurement of fluid flow — Estimation of uncertainty of a flow-rate measurement*.

ISO/TR 7178, *Liquid flow measurement in open channels — Velocity-area methods — Investigation of total error*.

3 General

3.1 Principle

The principle of the velocity-area method consists in determining from measurements the distribution of the flow velocity in the cross-section and the cross-sectional area, and using these observations for the computation of the discharge.

The measurements of the flow velocity are made in a number of verticals. In each vertical the mean velocity is determined from measurements at a selected number of points. The discharge per unit width may be found by multiplying the mean velocity by the depth in the vertical considered.

Each vertical is assumed to be representative of a segment of the cross-sectional area. The selection of the number and location of the verticals determines the width of these segments. Assuming that the discharge has remained constant during the measurements, summation of the discharge in the various segments gives the total discharge through the section.

3.2 Occurrence of error

When measuring width, depth and flow velocity, errors occur. The application of certain computational methods also introduces errors depending on the assumptions made.

A distinction shall be made between random and systematic errors, resulting from the instruments used, the measuring procedures and the processing of data. Random errors are also influenced by the nature of turbulent flow. The magnitude of random errors can be influenced favourably by the proper selection of instruments and methods. Systematic errors may be constant or variable and they cannot be eliminated by repeating the measurements or by increasing the duration of a measurement. There are, in addition, mistakes due to misreading an instrument or to instrument malfunction.

3.3 Sources of error (see Figure 1)

Theoretically the discharge

$$q = \iint_A v(x, y) dx dy \quad \dots (1)$$

where

q is the unobservable true discharge;

A is the cross-sectional area;

$v(x, y)$ is the velocity field over width, x , and depth, y .

In practice, the integral is approximated by the summation

$$Q = \sum_{i=1}^m b_i d_i \bar{v}_i \quad \dots (2)$$

where

- Q is the calculated discharge;
- b_i is the width of the i^{th} section;
- d_i is the depth of the i^{th} section;
- $\bar{v}_i$ is the mean velocity in the i^{th} vertical;
- m is the number of sections.

The error in Q is due to

- a) errors in the measurement of the quantities b_i , d_i and of the individual measurements of the flow velocity necessary for the determination of $\bar{v}_i$, and
- b) the approximation of the integral (1) by the summation (2).

3.4 Determination of the individual components of the error

3.4.1 Errors in width

The measurement of the width between verticals is normally made by measuring distances from a reference point on the bank. When a tape or tag-line is used, or the movement of the wire attached to a trolley is observed, the error depends on the distance but is usually negligible. Where optical means are used, the errors also depend on the distance measured but may be greater.

Where the distance is measured by electronic means, a constant error and an error depending on the distance measured occur.

The errors are mainly instrument errors.

3.4.2 Errors in depth

In ISO 748, clause 10, a number of sources of error in the measurement of depth is mentioned.

Some errors depend on the type and use of the instruments applied. Such errors are not included in this International Standard.

Errors arise due to the interpolation of the depth between the verticals at which depths are measured. These are included in 3.4.3 c) as “error-type III”.

3.4.3 Errors in determination of the mean velocity

These errors consist of three components:

- a) The error due to the restricted measuring time of the local point-velocity in each vertical. Because of turbulence the velocity fluctuates continuously over the wet cross-section. The mean velocity at any point, determined from a measurement during a certain time interval, is an approximation of the true mean velocity at that particular point. In this International Standard, errors of this nature are referred to as “error-type I”¹⁾.
- b) The error arising from the use of a limited number of sampling points in a vertical. Computation of the mean velocity in a vertical as an average or a weighted average of a number of point velocities results in an approximation of the true mean velocity in the vertical considered. In this International Standard, errors of this nature are referred to as “error-type II”¹⁾.
- c) The error arising from the restricted number of verticals in which velocities are measured. The horizontal velocity profile between two verticals has to be determined by interpolation which introduces an error.

¹⁾ Error-types I, II and III used in this International Standard have no connection with the statistical type I and type II errors.

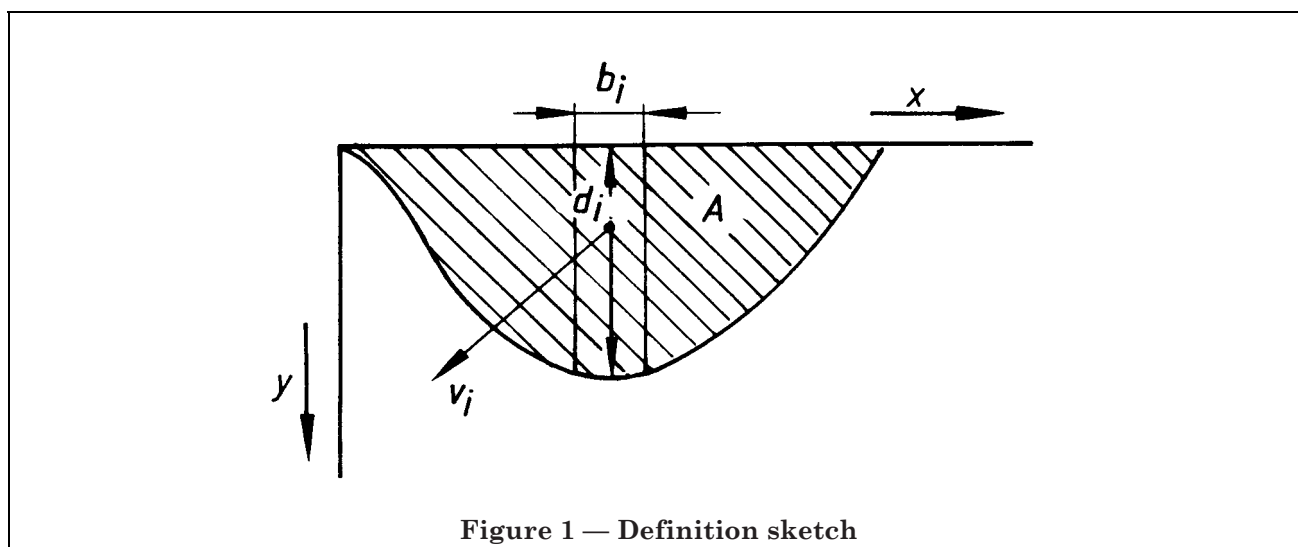


Figure 1 — Definition sketch

The values of depth d_i and the mean velocity $\bar{v}_i$ in the vertical are used to determine the discharge per unit width and the discharge through the section i . Summation of the discharges through each section according to equation (2) results in an approximation of the true total discharge. Errors of this nature are referred to as “error-type III”²⁾.

3.4.4 Symbols

The symbols used are given in the table below.

Quantity	Percentage uncertainty ^a	
	random	systematic ^b
Width	X'_{b_i}	X''_b
Depth	X'_{d_i}	X''_d
Mean velocity	$X'_{\bar{v}_i}$	$X''_{\bar{v}}$

^a All the uncertainties used in this International Standard are in terms of percentages expressed at the 95 % confidence limits. In this International Standard, X with a subscript refers to percentage uncertainty, X' refers to percentage random uncertainty and X'' refers to percentage systematic uncertainty.

^b The major source of the systematic uncertainty in the velocity will arise from errors in the calibration of the current-meters.

3.5 Description of the uncertainty

For the determination of the influence on the total uncertainty, the individual components are sufficiently described by their relative mean and relative standard deviations.

3.6 Total uncertainty in discharge

It can be shown (see ISO/TR 7178) that the total percentage random uncertainty in discharge, X'_Q , may be found from the following

$$X'_Q = \pm \left[X_{S_d}'^2 + X_{S_h}'^2 + \sum_{i=1}^m \left\{ (b_i d_i \bar{v}_i)^2 / Q \right\} \right. \\ \left. \left\{ X_{\bar{v}_i}'^2 + X_{F_i}'^2 + X_{S_{\bar{v}_i}}'^2 + X_{d_i}'^2 + X_{b_i}'^2 \right\} \right]^{1/2} \quad \dots (3)$$

²⁾ Error-types I, II and III used in this International Standard have no connection with the statistical type I and type III errors.

where

- X'_{S_d} is the percentage uncertainty due to random sampling error of the depth profile (error-type III);
- X'_{S_h} is the percentage uncertainty due to the random sampling error of the horizontal velocity profile (error-type III);
- $X'_{\bar{v}_i}$ is the percentage uncertainty of the mean velocity due to the random instrumental error;
- X'_{F_i} is the percentage uncertainty due to the random fluctuation in velocity error (error-type I);
- $X'_{S_{\bar{v}_i}}$ is the percentage uncertainty due to the random sampling error of the mean velocity in the vertical (error-type II);
- X'_{d_i} is the percentage uncertainty due to the random instrumental error determining the depth of section;
- X'_{b_i} is the percentage uncertainty due to the random instrumental error determining the width of section;
- b_i is the width of section i ;
- d_i is the depth of section i ;
- $\bar{v}_i$ is the mean velocity in section i ;
- Q is the total discharge.

The total systematic uncertainty is as follows:

$$X''_Q = \pm \left(X''_b{}^2 + X''_d{}^2 + X''_{\bar{v}}{}^2 \right)^{1/2} \quad \dots (4)$$

The total uncertainty in the discharge is given by

$$X_Q = \pm \left(X'_Q{}^2 + X''_Q{}^2 \right)^{1/2} \quad \dots (5)$$

If it is assumed that the discharge in the respective sections are almost equal, then equation (3) simplifies with certain approximations (see ISO/TR 7178 and ISO 748) to:

$$X'_Q = \pm \left[X'_m{}^2 + \frac{1}{m} \left(X'_b{}^2 + X'_d{}^2 + X'_e{}^2 + X'_p{}^2 + X'_c{}^2 \right) \right]^{1/2} \quad \dots (6)$$

where

- X'_Q is the total random uncertainty in discharge at 95 % confidence level;
- X'_m is the percentage random uncertainty due to the restricted number of verticals used;
- X'_b is the percentage random uncertainty in the width measurement;
- X'_d is the percentage random uncertainty in the depth measurement;
- X'_e is the percentage random uncertainty due to the restricted time of exposure used;
- X'_p is the percentage random uncertainty due to the restricted number of velocity points taken in the vertical;
- X'_c is the percentage random uncertainty in the current meter rating of velocity.

NOTE From equation (3) or (6), it can be seen that in order to reduce the total random uncertainty the number of verticals would need to be increased or an improvement made in the measurement of the individual components, or both.

3.7 Evaluation of the error in the individual components

The evaluation of the uncertainty in the individual components of the total uncertainty can be obtained by a statistical analysis of a large number of observations for a particular component under operating conditions. Incorporating this procedure into the normal routine measurement is not feasible, 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 uncertainties of the components within the practical range of measurements.

4 Data on the local point velocity³⁾

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 2 000 s, or for a period during which the discharge does not change by more than 5 % of the initial value, whichever is the less, shall be made with a current-meter. Every 10 s a reading of the instrument should be taken, thus giving 200 readings altogether. When pulses are emitted by the current-meter, the number of pulses should be recorded every 10 s; or, when the time is measured at a fixed number of pulses, this time interval should average 10 s. When a continuous record is produced, the complete record should be given and the response characteristics of the electronic instrument stated.

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

In each vertical this procedure should be carried out at 0,2 – 0,6 – 0,8 and, where possible, 0,9 times the depth measured from the surface. Where possible the data should be obtained during the same 2 000 s period.

The measurements should be repeated for different discharges.

The data thus obtained should be indicated in the report form given in Annex A. In the case of a continuous recorder, the values at intervals of 10 s should be given, indicating the method of determination.

5 Data on the average velocity³⁾

The average velocity in a vertical 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.

5.1 Location of the vertical

The vertical chosen for this measurement shall normally be determined from the known velocity distributions in the gauging cross-section, so as to give velocities which are representative of the whole cross-section.

When the velocity distributions in the gauging cross-section are not known, the vertical taken for this measurement shall be that at maximum depth in the cross-section and at places where the depths are 0,6 and 0,3 times the maximum depth respectively, at the side of the greater segment and not too close to the bank.

5.2 Distribution of measuring points

The velocity should be measured at the following points in the vertical:

- 1) immediately below the surface;
- 2) at 0,2 times the depth;
- 3) at 0,3 times the depth;
- 4) at 0,4 times the depth;
- 5) at 0,5 times the depth;

³⁾ Reference may also be made to ISO 748 and ISO/TR 7178.