TECHNICAL REPORT

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Liquid flow measurement in open channels — Velocity-area method using a restricted number of verticals

Mesure de débit des liquides dans les canaux découverts — Méthode d'exploration du champ des vitesses utilisant un nombre réduit de verticales

Reference number
ISO/TR 9823:1990(E)

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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 9823, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels.*

Annexes A and B form an integral part of this Technical Report.

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Introduction

The measurement of discharge using the velocity-area method is a laborious and costly procedure. There is often a great temptation to use fewer verticals for the measurement than is recommended in ISO 748 but such a short-cut can lead to considerable loss in the accuracy of the discharge determination. This Technical Report illustrates how the accuracy of such a short-cut discharge measurement can be improved considerably by optimization of the interpolation method.

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Liquid flow measurement in open channels — Velocity-area method using a restricted number of verticals

1 Scope

This Technical Report describes a velocity-area method which can be carried out using three verticals only, without significant loss of accuracy, and gives advice on when such a "short-cut" method should be used.

The method specified in this Technical Report is not an alternative to the velocity-area method specified in ISO 748, which gives accurate results and should be used under normal conditions. This short-cut method has a limited field of application and is intended for use only in special circumstances, examples of which are given in clause 7.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 748:1979, *Liquid flow measurement in open channels — Velocity-area methods.*

ISO 772:1988, *Liquid flow measurement in open channels — Vocabulary and symbols.*

ISO 1100-1:1981, *Liquid flow measurement in open channels — Part 1: Establishment and operation of a gauging station.*

3 Definitions

For the purposes of this Technical Report, the definitions given in ISO 772 apply.

4 Symbols

The symbols used in this Technical Report are listed in table 1. The convention has been adopted that upper case letters refer to values based on the total discharge measurement, whilst lower case letters refer to values relating to some portion less than the total.

Table 1 — Symbols

Symbol	Quantity	Dimensions	Unit
A	Area of cross-section	L^2	m^2
B	Width of channel at water surface	L	m
C	Value derived from $C = Q/(\overline{D}^{3/2}B)$	—	—
c	Value derived at measured vertical from $c = \bar{v}/\sqrt{d}$	—	—
$\bar{c}$	Arithmetic mean of c values for a discharge measurement	—	—
$\overline{D}$	Mean depth, derived from $\overline{D} = A/B$	L	m
d	Measured depth at vertical	L	m
H	Stage, as read at gauge	L	m
Q	Total discharge	$L^3 T^{-1}$	m^3/s
q	Unit width discharge	$L^2 T^{-1}$	m^2/s
$\bar{v}$	Mean velocity at the vertical	LT^{-1}	m/s

5 Theory

The discharge per unit width q may be expressed as

$$q = cd^{3/2}$$

Therefore,

$$c = q/d^{3/2} = d\bar{v}/d^{3/2} = \bar{v}/\sqrt{d}$$

and

$$C = Q/(\overline{D}^{3/2}B)$$

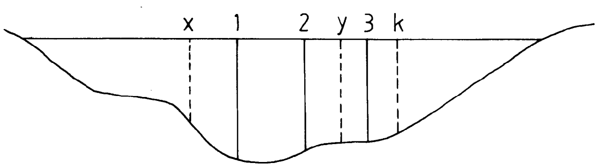

Figure 1 — Cross-section of river

With reference to figure 1, $\bar{v}_1, \bar{v}_2$ and $\bar{v}_3$ are the measured mean velocities, and d_1, d_2 and d_3 are the measured depths, at the verticals 1, 2 and 3 respectively. The mean velocity $\bar{v}_x$ at the vertical x is calculated from the equation

$$\bar{v}_x/\sqrt{d_x} = \bar{v}_1/\sqrt{d_1} = c_1$$

and the mean velocity $\bar{v}_y$ at the vertical y is calculated from

$$\bar{v}_y/\sqrt{d_y} = \bar{v}_2/\sqrt{d_2} = c_2$$

or

$$\bar{v}_y/\sqrt{d_y} = \bar{v}_3/\sqrt{d_3} = c_3$$

Similarly,

$$\bar{v}_k/\sqrt{d_k} = \bar{v}_3/\sqrt{d_3} = c_3$$

6 Methodology

6.1 The method proposed has been derived from work carried out by Dutch water engineers in the Netherlands. From studies carried out on the River Rhine and on tidal rivers, they have established the following relationships (see also table 1):

$$C = Q/(\overline{D}^{3/2}B)$$

$$c = \bar{v}/\sqrt{d}$$

Their work has been extended to apply these relationships to other rivers in other parts of the world, to develop these relationships, as well as to determine the optimum number of verticals to be used and where in the section these verticals should be located.

6.2 It has been established that three verticals, located in terms of width alone, should be used. For rivers where discharge has not been measured previously, the best results appear to be given when the verticals are located at one-quarter, one-half and three-quarters of the width.

6.3 From the normal surveys carried out after the selection of the measurement section (see ISO 1100-1) it is necessary to derive relationships between stage and other dimensions such that a reading of stage defines the other values. Thus, by reading the stage, the related width and cross-sectional area, and hence the mean depth, may be obtained.

7 Applications

The method is applicable whenever there is an exceptional need for speed in the completion of a discharge measurement. Examples of such applications are as follows.

a) One example is that of a new measurement section on a river where measurements have not been carried out before, and where there is a need to derive a stage-discharge relationship[1] quickly, so that studies on the potential yield of the river for some development project can commence.

b) Another example is when high stage does not permit the normal amount of time for measurement, or during flash floods when the rapid variation in the stage may limit the amount of time available.

c) A special case may be that of a gauging station which is in constant use, where expenditure constraints may dictate economies. In such a case, special calibration techniques can be used (see 8.2 and annex B), which should enhance the accuracy of the results.

d) A further example is the measurement of the discharge of tidal rivers[2].

8 Procedure

8.1 Rivers on which no previous measurements have been carried out

8.1.1 Select the measuring section in accordance with the recommendations given in ISO 1100-1.

8.1.2 Carry out a topographic and hydrographic survey of the section and install a gauge in accordance with the recommendations given in ISO 1100-1.

8.1.3 From the survey data, define the following relationships:

a) stage versus width;

b) stage versus cross-sectional area;

c) stage versus mean depth.

Prepare a table or a graph illustrating these relationships.

8.1.4 On arrival at the site to perform the measurements, read the stage. From the table or graph prepared in 8.1.3, determine the corresponding values of the width, cross-sectional area and mean depth.

8.1.5 Locate the first vertical at one-quarter of the width (determined in 8.1.4) from the water's edge. Sound for depth and measure the velocity using a current-meter to determine the mean velocity at the vertical. Repeat these operations at verticals located at one-half and three-quarters of the width.

8.1.6 Compute c for each of the three verticals from the equation

$$c = \bar{v}/\sqrt{d}$$

8.1.7 Carry out the computations specified in either a) or b) below.

a) Determine the average of the three values of c. Assume that this value of $\bar{c}$ is equal to C, and compute the discharge from the equation

$$Q = \bar{D}^{3/2} BC$$

NOTE 1 See annex A for a worked example.

b) For each of the values of c, calculate the value of $\bar{v}$ using the equation

$$\bar{v} = \sqrt{d}\, c$$

Compute the discharge from the equation

$$Q = \sum_{i=1}^{n} \bar{v}_i d_i b_i$$

where

n is the total number of verticals (i.e. 3);

b_i is the width of the ith segment.

8.2 Rivers on which previous measurements have been carried out

8.2.1 From the original or most recent survey data of the measurement section, define the relationships specified in 8.1.3.

Prepare a table or a graph illustrating these relationships.

1) See ISO 1100-2:1982, *Liquid flow measurement in open channels — Part 2: Determination of the stage-discharge relation.*

2) See ISO 2425:1974, *Measurement of flow in tidal channels.*

8.2.2 From the existing records, compute c for each vertical of each measurement, and compute C for each total measurement. Compute the value of c/C for verticals spaced across the width at intervals of 5 % of B for the entire range of stage.

Plot these values to give isolines of c/C as a function of the river width and stage (see for example figure B.1). Alternatively, or in addition, plot the deviation of the c/C values from 1,00 as a function of the river width and stage (see for example figure B.2).

8.2.3 Analyse the plot(s) prepared either to determine the three verticals on which the deviation of c/C from 1,00 is minimal or to determine the three verticals on which the value of c/C is the most constant throughout the range of stage.

8.2.4 On arrival at the site to perform the measurements, read the stage. From the table or graph prepared in 8.2.1, determine the corresponding values of the width, cross-sectional area and mean depth.

8.2.5 Locate the positions of the verticals determined in 8.2.3 by measurement from the water's edge at the appropriate bank. Sound for depth at the selected verticals, and determine the mean velocity at the selected verticals using a current-meter.

8.2.6 Compute c for each of the three verticals from the equation

$$c = \bar{v}/\sqrt{d}$$

Correct the values of c so obtained by multiplying them by the inverse of the corresponding mean c/C value indicated on the isoline or deviation plot.

Determine the average of the three corrected values of c.

8.2.7 Assume that $\bar{c}$ is equal to C, and compute the discharge from the equation

$$Q = \bar{D}^{3/2}BC$$

NOTE 2 See annex B for a worked example.

8.3 High stage or flash flood

8.3.1 In the case of a site where no previous measurements have been carried out, proceed as specified in 8.1.

8.3.2 In the case of a site having previous measurement records, proceed as specified in 8.2.

9 Uncertainty in the discharge determination

From the relatively restricted number of measurements taken and tested to date, indications are that the results obtained by using this short-cut method fall within ± 5 % of the values determined using the full number of verticals in accordance with ISO 748.

Results so far indicate that the accuracy of the discharge determination is likely to be greater when previous calibration data are available for use.

However, until many more tests have been conducted on many more rivers, the order of accuracy quoted above should be treated with caution.

Annex A
(normative)

Worked example for a river on which no previous measurements have been carried out

NOTE 3 This example is based on a discharge measurement, carried out using the full number of verticals, on the River Severn at Bewdley on 13th April 1962.

A.1 Select the measuring section in accordance with the recommendations given in ISO 1100-1.

A.2 Carry out a topographic and hydrographic survey and install a gauge on the river bank in accordance with the recommendations given in ISO 1100-1.

A.3 From the survey data, prepare tables or graphs of stage H versus width B, cross-sectional area A and mean depth $\overline{D}$ for the measuring section.

A.4 On arrival on site to perform the measurements, read the stage.

From the tables or graphs (clause A.3), determine the corresponding values of B, A and $\overline{D}$.

In this case, the following values were determined: stage H = 19,2 m; cross-sectional area A = 100,67 m^2; width B = 46,33 m; mean depth $\overline{D}$ = 2,173 m.

A.5 Locate the positions of the verticals at one-quarter, one-half and three-quarters of the width, i.e. at 11,58 m, 23,17 m and 34,75 m from the edge of the water on either bank.

Sound the depth at each of the selected verticals.

Determine the mean velocity at each vertical using a current-meter. In this case, the following values were determined:

a) at one-quarter of the width: depth d = 2,347 m; mean velocity $\bar{v}$ = 0,779 m/s;

b) at one-half of the width: depth d = 2,755 m; mean velocity $\bar{v}$ = 0,859 m/s;

c) at three-quarters of the width: depth d = 2,438 m; mean velocity $\bar{v}$ = 0,838 m/s.

A.6 Compute c from $c = \bar{v}/\sqrt{d}$ for each of the three verticals:

a) at one-quarter of the width, c = 0,508;

b) at one-half of the width, c = 0,517;

c) at three-quarters of the width, c = 0,537.

A.7 Follow the procedure specified in 8.1.7 a) or 8.1.7 b). In this case, the procedure specified in 8.1.7 a) is followed.

Compute the average value of c, i.e. $\bar{c}$ = 0,521.

Assume that $\bar{c} = C$, and compute the discharge from $Q = \overline{D}^{3/2}BC$, i.e. $Q = 2{,}173^{3/2} \times 46{,}33 \times 0{,}521 = 77{,}32$ m^3/s.

A.8 The discharge value obtained from the measurements using the full number of verticals was 78,35 m^3/s. The discharge value obtained using this method differs from the full value by −1,31 %.