
Methods of measurement of

Liquid flow in open channels

Part 6. Measurement of flow
in tidal channels

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The following BSI references relate to the work on this standard:

Committee reference INE/17, INE/17/1. Draft for comment 68/5371

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Methods of measurement of Liquid flow in open channels

Part 6. Measurement of flow in tidal channels

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Foreword

This British Standard has been prepared under the authority of the Instrument Industry Standards Committee and, at the same time, is in close agreement with an equivalent ISO Draft Standard DIS 2425; it provides information about the measurement of liquid flow in tidal channels in connection with which there are problems additional to those encountered in unidirectional streams. Two different methods used generally for measuring tidal flow are covered by this standard:

- (1) Direct measurement of flow by the measurement of velocities and cross-sectional areas.
- (2) Cubature methods.

For various reasons, direct measurements of velocity in tidal channels are more liable to large errors than are those made under conditions of unidirectional flow.

Appendices are included to illustrate examples and applications of the two basic equations which are to be used with the cubature method.

This Part of the standard continues the series, listed below, concerned with the various techniques used for the measurement of fluid flow in open channels.

- Part 1. Glossary of terms.
- Part 2. Dilution methods*.
- Part 2A. Dilution methods: constant rate injection.
- Part 2B. Dilution methods: sudden injection*.
- Part 2C. Dilution methods: radioisotope techniques.
- Part 3. Velocity area methods.
- Part 4. Weirs and flumes.
- Part 4A. Thin plate weirs and venturi flumes.
- Part 4B. Long base weirs.
- Part 4C. Flumes*.
- Part 5. Slope-area method of estimation.
- Part 6. Measurement of flow in tidal channels.
- Part 7. The measurement of stage.
- Part 8. Current meters*.
- Part 8A. Current meters incorporating a rotating element*.
- Part 8B. Current meters: suspension equipment*.
- Part 8C. Current meters: rating procedure*.
- Part 9. Water level instruments.
- Part 9A. Pressure-actuated water level instruments: installation and performance.

* In course of preparation.

British Standard methods of measurement of

Liquid flow in open channels

Part 6 . Measurement of flow in tidal channels

1. General

1.1 Scope

This part of this British Standard describes the methods by which measurement of velocities in tidal channels can be made in order to draw the total discharge curve and to compute the ebb and flood volumes. It also includes the determination of tidal discharge by the cubature method.

1.2 Definitions

For the purposes of this British Standard, the following definitions, together with those listed in BS 3680 Part 1 apply:

Cubature. The arithmetical integration of the equation of continuity or other technique of computing the total discharge at any station along a tidal channel.

Ebb tide. The phase of tidal cycle in which the water surface is falling.

Ebbing tide. The phase of tidal cycle in which the current (that is ebb current) is directed away from the land or down an estuary.

Flood tide. The phase of tidal cycle in which the water surface is rising.

Flooding tide. The phase of tidal cycle in which the current (that is flood current) is directed towards the land or up an estuary.

Salt water wedge. The wedge like intrusion of a large mass of salt water flowing in from the sea under the fresh water in a tidal waterway, where mixing by turbulence is inappreciable.

Estuary. A partially enclosed body of water in the lower reaches of a river, which is freely connected with the sea and which may generally receive fresh water supplies from upland drainage areas.

Tide. The periodic rise and fall in the water level due to periodic astronomical forces.

Tidal channel. That part of an estuary formed by the tides or subjected to tidal action.

Tidal prism. The volume enclosed within the banks of an estuary and the water surfaces prevailing at successive times t_1 and t_2 of the tidal curve.

Tide range. The difference in level between high water and low water of a tide. The range is specific to a particular tide if consecutive high and low water are used. Otherwise, the range can refer to extremes of high and low water over any specified period of time.

Tidal amplitude may be regarded as the difference in water level at high or low water, and mean sea level at a point, or the mean elevation of the tide.

1.3 Units of measurement

The units of measurement used in this British Standard are seconds (s) and metres (m), with imperial equivalents shown where relevant.

2. Principles of the method of measurement

2.1 Choice of method: general

The alteration of the direction of flow in tidal channels creates problems of measurement additional to those associated with the measurement of discharge of unidirectional streams. Choice of the method of measurement will be decided by the size and shape of the channel, by the tidal amplitude and, possibly, by the presence or absence of a salt wedge. The methods described in BS 3680 : Part 3 : 1964 cannot therefore be fully applied to tidal channels. In tidal channels, the flow is generally measured by one of the following methods.

2.2 Velocity area method

A gauging station shall be selected complying with the required conditions and its width shall be measured by one of the usual methods of survey; the depth shall be measured in a certain number of verticals distributed in the section; the number should be adequate to determine the profile and the area of the section. The velocities shall be measured with a current meter at different points on each of the verticals selected for the section. The number of verticals and the number of points on each vertical depends on the required precision and the availability of boats and meters. Necessary corrections have to be made to the velocities for the varying directions of flow particularly in the presence of a salt|water wedge.

These velocity measurements should be carried out at least for the full duration of a tide and the intervals between successive measurements on the same vertical should be as short as possible. The measured velocities are then reduced to the same instant and the flow at this instant is calculated by multiplying the mean velocity by the cross-sectional area of the stream.

2.3 Cubature method

Discharges are computed from the changes in the volume of water in the channel at short intervals of time. Water level and widths are simultaneously observed at suitable intervals of time at a number of stations along the channel up to the tidal limit. The areas of water surface corresponding to various water levels are determined from each reach. Changes in the volume of water during the specified time intervals are computed. If the discharges of fresh water from the river at the head of the tidal channel and from other tributaries are known, then starting at the head of estuary, each successive reach can be considered in turn and the algebraic sum of the volume of seaward flow at the inland end of the reach, the volume of flow of tributaries into the reach and the decrease of the volume of water contained in the reach will give the volume of flow seaward during the specified time interval at the cross section of the seaward end of the reach. This volume divided by the time interval gives the discharge at the cross section.

3. Measurement difficulties affecting selection of method

3.1 Particular difficulties

3.1.1 Tidal action is the cause of a number of the possible difficulties listed below but it must be stressed that sometimes, particularly in the upstream part of the tidal channel, this action will not cause a change in direction of flow but will manifest itself in a form of pulsating flow. In this case, although the flow is always in the same direction, the use of BS 3680 : Part 3 : 1964 will not be sufficient and this Part 6 will apply.

The tidal difficulties are:

- (1) continuous change of water levels with or without changes in the direction of flow with time;
- (2) in a vertical at the same depth, continuous variation of the velocity with time and, at different depths, greater velocity gradients than in rivers with flow in the same direction;
- (3) changes in the distribution of velocities with time;
- (4) during the transition period from flood current to ebb current, or vice versa, there is a change of direction of current with an intermediate zero velocity;
- (5) the occurrence of high water and low water may not take place at the same time as the change in the direction of current;

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(6) the change in the direction of current does not take place at the same time throughout the width and depth of the water way;

(7) there may be stratification of flow by density currents (a salt water wedge) with the upper strata flowing in one direction and the lower strata flowing in the reverse direction, the change of direction of current and the maximum velocity occurring at different times at different depths;

(8) large and rapid variations of the width and capacity of the sections due to successively covering and uncovering of the banks by the tide;

(9) presence of macro turbulence (for example, pulsations with a period of more than 30 seconds and an amplitude of up to 50 % of the mean velocity have been measured) and seiches.

3.2 Selection of the method of measurement

It should be noted that the velocity area method requires a considerable number of observations at one cross section, whilst the cubature method requires fewer observations and at more than one cross section, these being of levels and areas only.

The choice of the method of measurement will be determined by the size and shape of the channel, by the tidal amplitude and absence of a salt water wedge.

3.2.1 As described in the above paragraph any direct measurement of velocity in a tidal channel is subject to greater errors than measurement of flow in rivers, where the current always flows in the same direction. Because of this, the usual corrections are not completely satisfactory. Due to the continuous variation of the flow, it would be necessary to measure velocities simultaneously and continuously and in a large number of verticals for an entire tidal cycle and, especially in the case of large rivers with wide estuaries, considerable equipment is required. This method is especially difficult when:

- (1) there is a large amplitude of tide;
- (2) there is a high density of traffic, which might interfere with the measurements;
- (3) where the width of the waterway varies between wide limits during a single tide;
- (4) where the mean direction of flow changes through a considerable angle during the ebb tide or during the flood tide.

Direct measurements of velocity might be desirable for particular reasons, for example the study of density currents, distribution of velocities in specific zones, etc.

3.2.2 In all other cases, it is generally better to use one of the direct methods of cubature that are comparatively easy and rapid, particularly due to the use of modern electronic computers and calculators. It would, however, be difficult to use these and the accuracy will drop in the following cases:

- (1) if the amplitude of the tide is small;
- (2) if there are a large number of flat spill areas and if a large variation of the tidal volume corresponds to only a small variation of the level of the water surface;
- (3) if the topography of the tidal estuary is not well defined due to existence of large mud or silt flats, which are submerged during a part of the tidal cycle and which are subject to frequent alterations;
- (4) if the tidal channel is interlinked with the other tidal channels, when there is generally a residual flow from one channel to another.

4. Direct measurement of tidal flow

4.1 Selection and demarcation of site

4.1.1 Initial survey of site. It is desirable that approximate measurements of width, depth and velocities should be made in a preliminary survey to decide on the suitability of a site conforming as far as possible to conditions given in 4.1.2 and 4.1.3. It is only intended that these measurements should serve as a guide that both the longitudinal and transverse bed profiles and the velocity distribution are acceptable for the purpose of discharge measurement.

4.1.2 Selection of site. The accuracy of the determination of the discharge by the velocity area method is increased if:

- (1) the tidal cycle, during which the measurement is carried out is periodical or almost periodical (small daily inequality);