

BRITISH STANDARD 3680 : Part 2A : 1964

**METHODS OF
MEASUREMENT OF
LIQUID FLOW
IN OPEN CHANNELS**

**PART 2. DILUTION METHODS
2A. Constant Rate Injection**

BRITISH STANDARDS INSTITUTION

Gr 7

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THIS BRITISH STANDARD, having been approved by the Instrument Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 10th April, 1964.

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 4000, indexed and cross-indexed for reference, together with an abstract of each standard, will be found in the Institution's Yearbook.

This standard makes reference to the following British Standards:

B.S. 353. Method of testing water turbine efficiency.

B.S. 1042. Methods for the measurement of fluid flow in pipes.

B.S. 3680. Methods of measurement of liquid flow in open channels.

Part 1. Glossary of terms.

Part 3. Velocity area method.

Part 4. Weirs and flumes.

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

The following B.S.I. references relate to the work on this standard:
Committee reference INE/17 and INE/17/4.
Draft for comment AB(INE) 5387.

CO-OPERATING ORGANIZATIONS

The Instrument Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Association of Scientific Workers
 British Clock and Watch Manufacturers Association
 British Electrical and Allied Manufacturers Association
 *British Industrial Measuring and Control Apparatus
 Manufacturers' Association
 British Iron and Steel Federation
 British Nautical Instrument Trade Association
 British Railways Board
 British Scientific Instrument Research Association
 Council of British Manufacturers of Petroleum Equipment
 Electrical Research Association
 Electricity Council, The Generating Board and the
 Area Boards in England and Wales
 Electronic Engineering Association
 Engineering Equipment Users' Association
 Gauge and Tool Makers' Association
 Institution of Chemical Engineers
 Institution of Electrical Engineers
 Institution of Heating and Ventilating Engineers
 Institution of Mechanical Engineers
 Iron and Steel Institute
 Meteorological Office
 Ministry of Health
 *Ministry of Housing and Local Government
 National Coal Board
 National Physical Laboratory (D.S.I.R.)
 Oil Companies Materials Association
 Scientific Instrument Manufacturers' Association
 Society of Instrument Technology
 War Office
 Water-tube Boilermakers' Association

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committees entrusted with the preparation of this standard:

Department of Agriculture and Fisheries for Scotland
 D.S.I.R.—Hydraulics Research Station
 D.S.I.R.—National Engineering Laboratory
 Institution of Civil Engineers
 Institution of Water Engineers
 International Commission on Irrigation and Drainage
 (British Section)

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BRITISH STANDARD

METHODS OF MEASUREMENT OF

LIQUID FLOW IN OPEN CHANNELS

Part 2. Dilution methods

2A. Constant rate injection

FOREWORD

This British Standard dealing with the subject of dilution methods of measurement of steady flow is one of a series on the measurement of flow in open channels.

The dilution methods are particularly applicable to the measurement of the flow of rivers in mountainous districts and at other sites where the degree of turbulence is sufficiently high to ensure efficient mixing of the injected solution throughout the whole flow. The methods are equally applicable to the measurement of flow in closed conduits*.

This first edition of Part 2A deals with the constant rate injection method and with the techniques of analysis in present day use such as the colorimetric, the conductivity and the volumetric techniques. It is based on a Recommendation to be published by the International Organization for Standardization (ISO), which has taken into account research carried out in the United Kingdom and France during recent years. Other analytical techniques, such as those using a flame photometer or fluorimeter, may be included in later editions.

A future part of this British Standard will deal with the sudden injection method, where a known concentration of salt is suddenly injected into the stream, and with other techniques such as those using radioactive tracers.

To assist the user in its application, a selection of terms and definitions have been included from the new British Standard, B.S. 3680, 'Method of measurement of liquid flow in open channels, Part 1, Glossary of terms'. In addition examples are given in the appendices for the estimation of errors using the conductivity and volumetric titration techniques.

Two other British Standards in this series dealing with the measurement of flow in open channels are: B.S. 3680: Part 3, 'Velocity area methods' and B.S. 3680: Part 4, 'Weirs and flumes'.

* The use of the dilution method for flow measurement acceptance tests in closed conduits is described in B.S. 353: 1962, 'Method of testing water turbine efficiency'.

SPECIFICATION

SECTION 1: GENERAL

SCOPE

1. This British Standard deals with the measurement of flow in rivers and artificial channels by the dilution method, during a period in which the discharge is steady, using the constant rate injection method. It specifies the apparatus and chemicals to be used, and the technique of injection, sampling and analysis.

TERMINOLOGY

2. For the purposes of this British Standard the following definitions extracted from B.S. 3680 : Part 1, apply:

<i>Constant rate injection method</i>	A method of measuring discharge whereby a constant flow of a solution of known concentration is injected at one cross-section of the stream and the dilution is measured at another cross-section downstream, where complete mixing has taken place.
<i>Cross-section of a stream</i>	The section normal to the mean direction of flow bounded by the free surface and wetted perimeter of the stream.
<i>Dead water zone</i>	A zone in which water is temporarily detained.
<i>Depth</i>	The linear dimension measured in the vertical direction.
<i>Dilution methods</i>	Methods of determining discharge by measuring the dilution of an injected solution.
<i>Discharge</i>	The volume of liquid flowing through a cross-section in a unit time.
<i>Discharge measurement</i>	The operation of measuring the discharge of liquid in an open channel.
<i>Flow</i>	The movement of a volume of liquid.
<i>Gauging station</i>	A selected site on an open channel for making systematic observations for the purpose of determining the discharge or liquid levels or both.
<i>Hydraulic mean depth (Hydraulic radius)</i>	The value obtained by dividing the cross-sectional area of the stream by the wetted perimeter.

<i>Injection station</i>	The cross-section of the stream at which a solution is injected into the liquid for the purposes of stream gauging.
<i>Left (right) bank</i>	The bank to the left (right) of an observer looking downstream.
<i>Length</i>	The linear dimension measured in the direction of the stream.
<i>Mean depth</i>	The depth obtained by dividing the wetted cross-sectional area by the width of the free surface.
<i>Open channel</i>	The longitudinal boundary surface consisting of the bed and banks or sides within which the liquid flows with a free surface. NOTE. The term 'channel' alone generally means the deep part of a river or other waterway. Its meaning is usually made clear by a descriptive adjective such as 'low water' channel, 'main' channel, or artificial channel, but these terms are not used in the measurement of liquid flow in open channels.
<i>Reach</i>	A length of river between two defined cross-sections.
<i>River</i>	The stream of water in a natural open channel.
<i>Sampling station</i>	The cross-section of the stream at which the dilution of the injected solution (or cloud) will be sampled, observed or directly measured.
<i>Stage</i>	The elevation of the surface of a stream relative to a datum.
<i>Stream</i>	The longitudinal flow in an open channel.
<i>Wetted perimeter</i>	The length of the wetted boundary of an open channel at a specified cross-section.
<i>Width (breadth)</i>	The linear dimension measured across the direction of the stream.

PRINCIPLE OF THE CONSTANT RATE INJECTION METHOD

3. A solution of the selected chemical substance shall be injected, at a constant rate, at a cross-section at entry to the measuring reach of the channel in which the rate of flow is constant over the period of test.

In a downstream cross-section of this reach, far enough from the first for the injected solution to be uniformly diluted throughout this cross-section, samples shall be taken at regular intervals of time. Provided that the concentration of the

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added chemical has attained a steady value, the rate of flow Q in the channel may be calculated from the equation:

$$Q = qN$$

where q is the rate of injection of the solution

N is the dilution ratio, which may be determined by one of the following methods.

a. Direct measurement of concentrations. The concentration of the chemical substance shall be determined:

- (i) in samples of the water in its natural state (concentration c_0): these samples shall be taken upstream of the injection point to avoid any possibility of contamination with the injected solution (see, however, Clause 10a).
- (ii) in the injected solution (concentration c_1).
- (iii) in samples obtained from the downstream cross-section (where the concentration with the added injected solution has attained a steady value c_2).

Equating the weight of chemical substance passing the injection section ($c_0 Q + c_1 q$) and that passing the sampling section $c_2 (Q + q)$ gives:

$$Q = \left(\frac{c_1 - c_2}{c_2 - c_0} \right) q$$

and if c_2 is small compared with c_1

$$\frac{Q}{q} = N \simeq \frac{c_1}{c_2 - c_0}$$

b. Comparative dilutions. A set of standard solutions shall be made by diluting samples from the injected solution with different amounts of water from the natural stream, taken from a point upstream of the injection station. These known dilution ratios N_1 , N_2 , etc., shall be approximately the same as that expected of the samples from the downstream section.

The standard solution and unknown samples shall be compared by a similar technique to establish the dilution ratio N of the unknown samples.

REQUIRED CHARACTERISTICS OF INJECTED SOLUTIONS

4. The chemical substance to be used for the injected solution shall comply with the following requirements within the limits of accuracy required for the measurement.

a. It shall not give any reaction with the natural water of the river or channel or with any matter (organic matter in particular) which this contains in solution or suspension, or with the material which forms the channel.

- b.* It shall be stable to light.
- c.* It shall not be injurious to fish or animal life in the dilutions used.
- d.* It shall be capable of being accurately determined at the concentration level of the diluted sample.
- e.* It shall be used only when the concentration of the chemical solution in natural water is relatively low.

The following substances, which may not be suitable for all waters, are given as examples, together with the final minimum concentrations at which they should be present at the downstream sampling cross-section.

Sodium dichromate ($\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$) : 0.2 mg/l

Sodium chloride (NaCl) : 2.0 mg/l

Other salts may be used, such as sodium nitrite (NaNO_2) and manganese sulphate ($\text{Mn SO}_4 \cdot 4 \text{H}_2\text{O}$).

A chemical substance such as fluorescein ($\text{C}_{20}\text{H}_{12}\text{O}_5$) having sufficient colouring power to allow the passage of the cloud in the river to be checked visually may also be used, particularly in preliminary tests to check the delay period before sampling (see Clause 6*a*).

SECTION TWO: SELECTION OF SITE AND PRELIMINARY TESTS

GENERAL CONSIDERATIONS FOR CHOICE OF THE MEASURING REACH

5. Great care is required to make a satisfactory choice of a reach suitable for the measurement of discharge by the dilution methods. This choice is facilitated by carrying out the preliminary tests described in Clause 6 (see also Fig. 7).

There should be no loss or gain of water in the measuring reach (for example, due to a branch joining or leaving the main stream, or spillage over the banks of the stream), and its length should be such that, allowing for the natural mixing action of the stream, the solution injected at its beginning shall be uniformly diluted throughout the sampling cross-section.

The distance between the injection and sampling cross-sections should be as short as practicable and the dead water zones should be as small as possible, to reduce the duration of the injection and the quantity of chemical substance used.

For rivers, this condition is easier to satisfy in relatively narrow channels where the degree of turbulence is high; mixing is also improved by disturbances of flow caused by bends, narrows, shelves, falls, etc. In particular, very wide channels should be avoided, and reaches in which the stream divides into a number of branches should not be used.

PRELIMINARY TESTS

6. When a measuring reach meeting the general requirements of Clause 5 has been located, preliminary tests should be made to ensure that efficient mixing in the river will be achieved, to choose the injection and sampling stations and, once these have been chosen, to determine the duration of the injection period.

It is essential to the success of the method that the injected substance shall have a constant concentration over the whole of the cross-section at the sampling station during the whole of the sampling period.

The injection station should be sited conveniently at the upstream end of the measuring reach.

Where the natural turbulence of the stream is not such as will assure uniform and homogeneous mixing of the two liquids within the selected measuring reach, the distribution of the concentrated solution may be assisted by the use of perforated pipes or spreader plates. Care should be taken to ensure that the whole of the concentrated solution reaches the stream, i.e., that none is deposited on the banks or on rocks above the water level.

a. Estimation of length of measuring reach. A first test can be made by using a strong dye such as fluorescein. A concentrated solution of this dye can be injected for a relatively short time at the injection station. Study of the diffusion of the solution will make it possible to determine whether there are any dead water zones or similar phenomena which would prevent the steady flow of the chemical substance past the sampling station. For example, some of the chemical