

Methods for measurement of

Fluid flow in closed conduits, using tracers —

Part 1: Measurement of water flow —

Section 1.3 Constant rate injection method using radioactive tracers

[ISO title: Measurement of water flow in closed conduits — Tracer methods — Part III: Constant rate injection method using radioactive tracers]

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- British Industrial Measuring and Control Apparatus Manufacturers' Association
- British Steel Corporation
- CBMPE (Council of British Manufacturers of Petroleum Equipment)
- Control and Automation Manufacturers' Association (BEAMA)
- Department of Industry (Computers Systems and Electronics)
- Electrical, Electronic, Telecommunications and Plumbing Union
- Electricity Supply Industry in England and Wales*
- Electronic Engineering Association
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- Institution of Electrical Engineers
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- Oil Companies Materials Association
- Post Office Engineering Union
- Scientific Instrument Manufacturers' Association
- Sira Institute

The organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

- Department of Energy (Gas Standards)
- United Kingdom Atomic Energy 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 Executive Board and comes into effect on 31 March 1980

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National foreword

This British Standard has been prepared under the direction of the Industrial-process Measurement and Control Standards Committee and is identical with ISO 2975-III:1976 *“Measurement of water flow in closed conduits — Tracer methods — Part III: Constant rate injection method using radioactive tracers”* published by the International Organization for Standardization (ISO).

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

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

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

Additional information. In the table in 7.2 the SI unit for concentration is the Bq/cm³ where 1 Bq = 3.7×10^{10} Ci.

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.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 13 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.

0 Introduction

This International Standard is the third of a series of standards covering tracer methods of water flow measurement in closed conduits. The complete series of standards will be as follows:

- *Part I: General;*
- *Part II: Constant rate injection method using non-radioactive tracers;*
- *Part III: Constant rate injection method using radioactive tracers;*
- *Part IV: Integration (sudden injection) method using non-radioactive tracers;*
- *Part V: Integration (sudden injection) method using radioactive tracers;*
- *Part VI: Transit time method using non-radioactive tracers;*
- *Part VII: Transit time method using radioactive tracers.*

1 Scope and field of application

This International Standard specifies the constant rate injection method using radioactive tracers for the measurement of water flow rate in closed conduits.

2 Principle

Flow rate measurement by a constant rate injection method is based on a comparison between the concentration C_1 of a tracer continuously introduced with a known volume rate of flow q , and the concentration of samples C_2 taken at some place beyond the distance¹⁾. The mixing distance is defined as the shortest distance at which the variation in concentration of the tracer over the cross-section is less than some pre-determined value (for example 0,5 %). (See clause 6 of part 1.)

The tracer rate at the injection point is equal to the rate at which it passes the sampling point:

$$q C_1 + Q C_0 = (Q + q) C_2$$

Where C_0 is the initial concentration in the stream which is flowing at the rate Q .

Hence:

$$Q = q \frac{C_1 - C_2}{C_2 - C_0} \quad \dots (1)$$

Generally C_1 is much greater than C_2 which leads to a simplification of equation (1) as follows:

$$Q = q \frac{C_1}{C_2 - C_0}$$

When C_2 is much greater than C_0 , the equation can be reduced still further to

$$Q = q \frac{C_1}{C_2}$$

Flow rate Q can thus be determined by comparing the concentration of the injected solution with the concentration of samples removed from the conduit.

3 Required conditions

3.1 Tracer

For the constant rate injection method the tracer shall meet the general requirements defined in 5.1 of part I. A list of generally used tracers is given in 5.1.2 of part I and their advantages with respect to non-radioactive tracers are stated in 5.2.1.1 and 5.2.1.2.

3.2 Duration of injection

The duration of injection shall be such that stable concentration conditions are established at all points of the measuring cross-section over a sufficient period of time.

Constant concentration shall be obtained for a period of at least several minutes.

¹⁾ Another method can be contemplated which would not involve sampling.

Determination of the injection duration

A suitable duration of injection may be determined by a preliminary investigation involving the instantaneous injection of a dye such as fluorescein or a radioactive tracer. Curves 1 and 2 of Figure 1 may be plotted for a given flow rate from the observation of the moment when the tracer (dye or activity) appears and disappears in each cross-section.

If it is required to achieve steady conditions for a period of time Δt in a selected measuring cross-section S, it is sufficient to add this period of time Δt to the time t_1 corresponding to the disappearance of the tracer at this point (i.e. on curve 2) and to plot through the resulting point C a curve 1' similar to curve 1 characteristic of the appearance of the dye (or activity). The ordinate at the origin of this curve gives the duration of the injection to obtain a concentration level of duration Δt at cross-section S.

In practice, to obtain a concentration level of duration Δt at cross-section S, a calculation is made of the minimum required period of injection by adding to the value of Δt the time $t_2 = AB$ taken by the instantaneously injected tracer to pass through S.

The time interval t_1 between the beginning of the injection and the establishment of stable conditions can be read from curve 2 (ordinate of point B) and is directly obtained by measuring the time interval between the instantaneous injection and the tracer disappearance in cross-section S.

In the case of central injection, straight measuring length and turbulent flow, $t_2 = AB$ may be estimated from the relationship

$$t_2 = \frac{6}{U} \sqrt{\frac{DX}{2}}$$

where

U is the mean velocity of the flow;

X is the distance to the injection point;

D is the conduit diameter.

The fraction of maximum concentration remaining after time t_2 as given by this formula is 0,3 %.

It is possible, when no preliminary injection is made, to check the appearance of the concentration level, and therefore the minimum injection time, by continuously sampling the flow and measuring its count rate, with the apparatus used for the measurement. This procedure enables the concentration variation to be determined as a function of time.

4 Choice of measuring length

4.1 Mixing distance

This is defined in 6.1 of part I and may be calculated theoretically according to 6.2.1 of part I. Figure 3 of part I indicates the measured variation of the actual mixing distance according to the required accuracy in the case of central injection and in the case of three other injection methods. Methods for reducing the mixing distance are described in 6.3 of part I.