

Methods for measurement of

Fluid flow in closed conduits, using tracers —

Part 1: Measurement of water flow —

Section 1.5 Transit time method using radioactive tracers

[ISO title: Measurement of water flow in closed conduits —
Tracer methods —
Part VII: Transit time method using radioactive tracers]

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- British Gas Corporation
- 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
- Institution of Gas Engineers
- Oil Companies Materials Association
- Post Office Engineering Union
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- 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-VII:1977 “*Measurement of water flow in closed conduits — Tracer methods — Part VII: Transit time 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”.

Cross-reference

International Standard	Corresponding British Standard
ISO 2975-I:1974	BS 5857 <i>Methods for measurement of fluid flow in closed conduits, using tracers</i> Part 1. <i>Measurement of water flow</i> Section 1.1:1980 <i>General</i> (Identical)

Additional information. In the table in 6.2 the SI unit for concentration is the Bq/cm³ where 1 Bq = 3.7 × 10¹⁰ Ci.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 12, 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.

0 Introduction

This International Standard is the seventh of a series of standards covering tracer methods of water flow measurement in closed conduits.

The complete series of standards is 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 transit time method using radioactive tracers for the measurement of water flow rate in closed conduits.

2 Principle

Flow-rate measurement by the transit time method (formerly called “Allen velocity method”) is based on measuring the transit time of “labelled” fluid particles between two cross-sections of the conduit a known distance apart. Labelling of the fluid particles is achieved by injecting a tracer into the flow upstream of the two measurement cross-sections (i.e. detector positions) and the transit time is determined from the difference of the mean arrival times of the tracer at each of the detector positions.

Under certain conditions (see clause 3), the flow rate q_v is given by

$$q_v = \frac{V}{\bar{t}}$$

where

V is the volume of the conduit between the detector positions;

$\bar{t}$ is the transit time of the labelled fluid particles.

In general, the theoretical condition for the validity of the formula is that the measuring section be “closed to diffusion”: i.e. that the ratio of the local velocity to the longitudinal dispersion coefficient be equal at both ends of the measuring section.

In practice this condition is fulfilled when the conduit has a constant cross-section.

The value of $\bar{t}$ is obtained by measuring the difference in abscissae of characteristic points (in theory: centre of gravity, but in practice other characteristic points may be found, see 5.6) of recorded distributions, corresponding to concentration/time distributions or their integrals, obtained at each detection

cross-section. The signal from the detectors shall be proportional to the tracer concentration. The value of the proportionality coefficient and hence the absolute concentration value need not, however, be known exactly.

3 Required conditions

3.1 Tracer

The tracer shall meet the general requirements defined in clause 5 of part I, when a list of tracers generally used, with their advantages and disadvantages, is also given.

3.2 Mixing of tracer

The tracer must be sufficiently mixed with the flow at the first detector position for the recorded concentration/time distributions at both detectors to be adequately representative of the mean flow (see 4.1). The selection of the positions for the injection and the detectors is controlled by the fluid velocity, tracer dispersion and the conduit layout. The conditions for this selection are dealt with in clause 4. At low Reynolds number, $Re \leq 5\,000$, the mixing of tracer is not sufficient and no measurement can be made.

3.3 Test procedure

The procedure for the preparation and injection of the tracer solution, which in practice should be injected as rapidly as possible to minimize the dispersion of the tracer, is covered in 5.2 and 5.3. The internal volume of the measuring section must be determined with sufficient accuracy (see 5.7). Other requirements relating to the tests and the calculation of the transit time from the data are given in clause 5.

4 Choice of measuring length

In the transit time method, the measuring length consists of two parts:

- the length of conduit between the injection point and the position of the first detector;
- the length of conduit between detectors.

4.1 Length of conduit between injection and first detector

When the concentration of tracer C_2 at only a single point in each measurement cross-section is measured, the length of conduit between the injection point and first detector shall be equal to or greater than the mixing distance.

The mixing distance is defined as the shortest distance at which the maximum variation of $\int_0^\infty C_2 dt$ over the cross-section is less than some predetermined value (for example 0,5 %), C_2 being the tracer concentration in the conduit — see clause 6 of part I. This distance can be calculated theoretically according to 6.2.1 of part I. Figure 3 of the latter shows the measured variation of mixing distance, with respect to variations in $\int_0^\infty C_2 dt$ across the cross-section, for various injection arrangements. Methods of reducing the mixing distance are described in 6.3 of part I.

There are, however, insufficient experimental results available to relate variations in $\int_0^\infty C_2 dt$ at the first detector position, to the overall accuracy of transit time as determined from concentration measurements at single points in the measurement cross-sections.

If the measurement of concentration at each detector position represents the mean concentration in the cross-section (for example by simultaneous measurements at many points or by a detector sensitive to tracer across the cross-section), the degree of mixing required at the first detector position is not as great as that corresponding to the mixing distance. In these circumstances the necessary distance between the injection position and the first detector position may be considerably less than the mixing distance. For example, when using a γ -emitting tracer centrally injected into a conduit and detected by three scintillation detectors positioned at each measurement cross-section, flow rate has been measured accurately with a distance between injection and the first detector equivalent to only twelve conduit diameters.

The length of conduit between the injection position and the first detector should preferably contain no pipe fittings or sections likely to increase significantly the longitudinal dispersion of tracer at the detector positions. Examples of such fittings and sections are valves, flow regulators, and flow distribution headers.

4.2 Length of conduit between detector positions

The length of conduit necessary between the detector positions depends on the linear velocity of the fluid, the spatial dispersion of the tracer at the detector positions and the required accuracy of the measurement of transit time.