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

*Mesure de débit de l'eau dans les conduites fermées — Méthodes par traceurs —
Partie III : Méthode d'injection à débit constant, utilisant des traceurs radioactifs*

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FOREWORD

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Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2975/III was drawn up by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, and was circulated to the Member Bodies in April 1975.

It has been approved by the Member Bodies of the following countries :

Australia	Italy	Turkey
Belgium	Netherlands	United Kingdom
Czechoslovakia	Romania	U.S.S.R.
France	Spain	Yugoslavia
Germany	Switzerland	

The Member Body of the following country expressed disapproval of the document on technical grounds :

U.S.A.

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

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 I.)

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.

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

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

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.

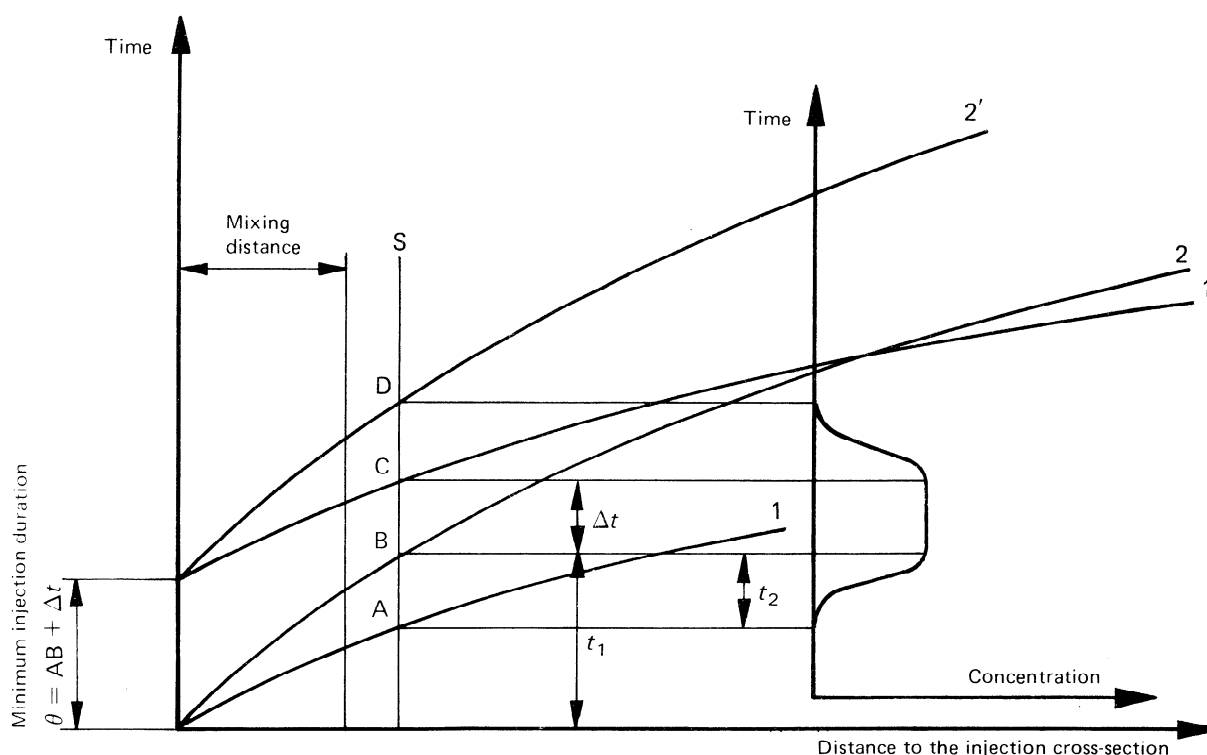


FIGURE 1 – Determination of the duration of injection

4.2 Experimental checking

It is seldom possible in conduits to check experimentally, in a large number of cross-sections, the homogeneity of the mixture and the duration of the tracer passage resulting from an instantaneous injection.

In practice, therefore, the experimentation consists of

- a) determining the minimum period of injection in the measuring length chosen by a preliminary test (see 3.2);
- b) checking, where possible, at the time of the measurement, that the mixture is homogeneous by taking samples from at least two points of the measuring cross-section. In the case of high accuracy measurements (for example 0,2 %), it is necessary to check the homogeneity of the mixture, prior to the measurement itself, when a doubt exists on the quality of this mixture;
- c) studying, whenever possible by taking samples from another cross-section further downstream, whether there are any systematic differences between the mean concentrations at the two measuring cross-sections. In particular, this method permits verification that the injected tracer is not absorbed in the measuring length either by entrained products in the liquid or by the conduit walls.¹⁾

4.3 Losses and additions

The losses and additions of the same liquid as that in the measuring length do not affect results provided certain conditions are met as described in 6.5.1 of part I.

5 PROCEDURE

5.1 Handling of radio-isotopes

The use of radio-isotopes (storage, transportation, handling) shall comply with any existing statutory regulations.

5.2 Preparation of the concentrated solution

It is essential for the injected solution to be homogeneous. Homogeneity of the solution can be obtained by vigorous mixing, by means of a mechanical stirrer or a closed-circuit pump. It is advisable to prepare the injection solution in a separate container from the supply container with water filtered using an appropriate procedure. However, if mixing is carried out in the supply container, the latter shall have sufficient capacity so that it is not necessary to add liquid or tracer during the injection. The solution shall be taken at a certain level above the bottom of the container, and every precaution shall be taken so that undissolved particles of the tracer are not carried in the solution injected. In the

case of an injection of long duration, provision shall be made as required to avoid a variation in time of the solution concentration (for example by evaporation under the influence of the ambient temperature).

To minimize possible adsorption effects with the radioactive tracer it is advisable to add to this solution a carrier constituted by a certain amount of non-radioactive substance identical to that containing the radioactive tracer.

5.3 Injection of the concentrated solution

The concentrated solution shall be injected into the conduit at a constant rate and for a sufficient duration to ensure a satisfactory period of constant concentration at the measuring cross-section.

The injection may be made by means of a positive displacement pump. It shall be possible to check the following :

- that the injection system is always free from leaks;
- that the injection rate is constant over the whole injection duration.

5.4 Measurement of injection rate

The measurement of injection rate shall be based on the measurement of the basis quantities of mass, length, time, directly involved in the definition of the quantity of flow.

The injection system shall be calibrated before and after the tests. The mean value of injection rate shall be used in the calculation of flow rate provided that the two calibrations do not differ by more than a value consistent with the overall required accuracy of flow measurement (for example 1 %).

When the injection is carried out by means of a positive displacement pump driven by a synchronous motor, which is the normal method, the checking of flow rate consists in fact in the measurement of the frequency of the electrical supply.

5.5 Sampling

5.5.1 Samples

Samples shall be taken :

- from the conduit, to verify that the background concentration of tracer in the flow system is constant;

1) See 5.1 of part I.