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Measurement of gas flow in conduits — Tracer methods — Part IV : Transit time method using radioactive tracers

*Mesurage de débits de gaz dans les conduites — Méthodes par traceurs —
Partie IV : Méthode fondée sur le mesurage du temps de transit, 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 4053/IV was developed by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, and was circulated to the member bodies in July 1977.

It has been approved by the member bodies of the following countries :

Australia	Germany	Poland
Belgium	India	South Africa, Rep. of
Chile	Ireland	Spain
Czechoslovakia	Italy	United Kingdom
Egypt, Arab Rep. of	Korea, Rep. of	U.S.A.
Finland	Mexico	U.S.S.R.
France	Netherlands	Yugoslavia

The member body of the following country expressed disapproval of the document on technical grounds :

Japan

Measurement of gas flow in conduits — Tracer methods — Part IV : Transit time method using radioactive tracers

0 INTRODUCTION

This International Standard is the fourth of a series of standards covering tracer methods of gas flow measurement in 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 : 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 gas flow in conduits.

2 REFERENCE

ISO 4053/1, *Measurement of gas flow in conduits — Tracer methods — Part I : General.*

3 PRINCIPLE

Flow-rate measurement by the transit time method (formerly called the "Allen velocity method") is based on measuring the transit time of "labelled" 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 4), the volume flow-rate q_v (see nomenclature in ISO 4053/1) in the measurement section 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, the centre of gravity, but in practice other characteristic points may be found, see 6.7) of recorded distributions, corresponding to concentration/time distributions or their integrals, obtained at each detector position. The signal from the detectors shall be proportional to the tracer concentration. The exact value of the proportionality constant and hence the concentration need not, however, be known.

The mass flow-rate is calculated by determining simultaneously the volume flow-rate and the gas density.

4 REQUIRED CONDITIONS

4.1 Tracer

The tracer shall meet the general requirements defined in clause 5 of ISO 4053/1. A list of tracers generally used, with their advantages and disadvantages, is also given in the same clause.

4.2 Mixing of tracer

The tracer shall 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 5.1). 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 5. At low Reynolds number, $Re \leq 5\,000$, the mixing of tracer is not sufficient and no reliable measurement can be made.

4.3 Test procedure

The procedure for the preparation and the injection of the tracer gas (which in practice should be injected as rapidly as possible to minimize the longitudinal dispersion of the tracer) is covered in 6.3 and 6.4. The internal volume of the measuring section shall 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 6.

5 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.

5.1 Length of conduit between injection and first detector

In theory, when the tracer concentration, C_2 , in the conduit is measured at only a single point in each measurement cross-section, the length of conduit between the injection 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 %). (See clause 5 of ISO 4053/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 can be considerably less than the mixing distance. For example, when using a γ -emitting tracer centrally injected into a conduit and detecting by three scintillation detectors positioned at each measurement cross-section, and when the distance between injection and the first detector is only 12 conduit diameters, no additional error in flow-rate measurement has been observed in practice.

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.

5.2 Length of conduit between detector positions

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

The length of straight conduit, L , between detector positions, the various ratios, p , of the transit time to the mean duration for the tracer "pulse" to pass each detector position (i.e. corresponding to the passage of 99,7 % of the tracer) and the various lengths of conduit, N , between the injection and first detector positions, are related to each other by the formula :

$$L = 4,25 p (p + \sqrt{N})$$

where L and N are expressed in conduit diameters.

This relationship is shown graphically in figure 1.

If the concentration/time distributions are recorded on a single-channel recorder, it is necessary for the length of conduit between detectors to be greater than the mean spatial dispersion of the tracer at the detector positions so that the recorded distributions do not overlap. This is achieved when $p > 1$.

If a multi-channel recorder is used, this distance can be reduced, but it is necessary that for accurate measurement of transit time the length of conduit between detectors is not less than a half of the mean spatial dispersion of the tracer. For guidance, it is recommended to use in practice $p \geq 0,5$.

5.3 Measuring section

For the highest accuracy of flow measurement, the length of conduit between detector positions shall consist of a straight pipe of uniform cross-section and shall contain no pipe fittings or sections where dead zones are likely to affect the concentration/time distribution measured at the second detector. Examples of such fittings and sections are valves, flow regulators, abrupt changes of cross-sectional area, closed-ended branch pipes or sharp bends.

The overall accuracy of the flow measurement depends on the accuracy with which the internal volume of the measuring section has been determined.

5.4 Losses and additions

Additions of fluid upstream of the first detector position, of the same nature as the fluid in the conduit, do not affect the result provided that this fluid is mixed with the main flow at the first detector position.

Losses of fluid from the conduit before the first detector position do not affect the result but, if the tracer is not completely mixed at the point of loss, the amplitude of the concentration/time distribution at the detector positions may be affected and its value changed by a constant factor.