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INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO RECOMMENDATION R 555

LIQUID FLOW MEASUREMENT IN OPEN CHANNELS
DILUTION METHODS FOR MEASUREMENT OF STEADY FLOW
PART I
CONSTANT RATE INJECTION METHOD

1st EDITION
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BRIEF HISTORY

The ISO Recommendation R 555, *Liquid Flow Measurement in Open Channels – Dilution Methods for Measurement of Steady Flow – Part 1 – Constant Rate Injection Method*, was drawn up by Sub-Committee ISO/TC 30/SC 1, *Measurement of Liquid Flow in Open Channels*, under the direction of Technical Committee ISO/TC 30, *Measurement of Fluid Flow in Closed Conduits*, the Secretariat of which is held by the Association Française de Normalisation (AFNOR). In November 1964, the Sub-Committee was raised to the status of Technical Committee ISO/TC 113, with the Indian Standards Institution (ISI) responsible for the Secretariat.

Work on this question by Technical Committee ISO/TC 30 began in 1958 and led, in 1963, to the adoption of a Draft ISO Recommendation.

In July 1963, this Draft ISO Recommendation (No. 592) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies:

Belgium	Hungary	Portugal
Chile	India	Romania
Colombia	Israel	Switzerland
Czechoslovakia	Italy	United Kingdom
France	Korea, Rep. of	U.S.A.
Germany	Netherlands	U.S.S.R.
Greece	New Zealand	

One Member Body opposed the approval of the Draft:

Japan.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in December 1966, to accept it as an ISO RECOMMENDATION.

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LIQUID FLOW MEASUREMENT IN OPEN CHANNELS

DILUTION METHODS FOR MEASUREMENT OF STEADY FLOW

PART I* CONSTANT RATE INJECTION METHOD

1. SCOPE

This ISO Recommendation deals with the measurement of flow in channels under steady flow conditions by the dilution method using constant rate injection. The method is applicable to the measurement of the flow in channels where the degree of turbulence is sufficiently high to ensure efficient mixing of the injected solution throughout the whole flow. This is generally the case in hill streams and torrents.

The apparatus and the chemicals to be used, the specifications of the techniques of injection and sampling, and also the methods of analysis, are detailed.

2. TERMINOLOGY

For the purposes of this ISO Recommendation, the definitions given in ISO Recommendation R ... ** apply.

3. UNITS OF MEASUREMENT

The units of measurement used in this ISO Recommendation are metres (or feet) and seconds.

4. PRINCIPLE OF THE CONSTANT RATE INJECTION METHOD

A solution of a suitably selected salt should be injected at a constant rate, at a cross-section, at entry of 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 should be taken at regular intervals of time. Provided that the concentration of the added chemical has attained a steady value, the rate of flow Q in the channel may be calculated from the equation:

$$Q = q N$$

where q = rate of injection of the chemical salt solution,

N = ratio of the concentration of the salt in the injected solution to that at the downstream cross-section of the channel; however, if traces of the chemical salt are already present in the stream prior to the injection, N is defined by the equation given at the end of clause 4.1.

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

4.1 Method of direct measurement of concentration

The concentration of the salt should be determined:

- (a) upstream of the point of injection where the water is in its natural state (concentration C_0). See however clause 7.4 (a)
- (b) in the injected solution (concentration C_1)
- (c) in samples obtained from the downstream section (where the concentration of the chemical has attained a steady value C_2).

Equating the mass of the salt passing the injection section ($C_0Q + C_1q$) and that passing the sampling section $C_2(Q + q)$ gives:

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

and if C_2 is small compared with C_1

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

* Further parts of this ISO Recommendation will deal in particular with the sudden injection method and the method using radio-active isotopes, which are at present under study.

** *Vocabulary of Terms and Symbols Used in Connection with the Measurement of Liquid Flow with a Free Surface*, at present Draft ISO Recommendation No. 954

4.2 Method of comparative dilutions

A set of standard solutions should 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 $N_1, N_2 \dots$ should be approximately the same as those expected of the samples from the downstream section.

The standard solutions and the samples taken downstream should be compared by a similar technique to establish the dilution ratio N of the unknown samples.

5. REQUIRED CHARACTERISTICS OF INJECTED SOLUTIONS

The chemical substance to be used for the injected solution should comply with the following requirements:

- (a) it should not give any reaction with the natural water of the river concerned or with any matter (organic matter in particular) which this may contain in solution or suspension, or with the material which forms the river bed,
- (b) it should be stable to light,
- (c) it should not be toxic to fish in the dilutions used,
- (d) it should be capable of being accurately determined at the concentration level of the diluted sample,
- (e) it should be used only when the concentration of the chemical in solution in the natural water is relatively low.

The following substances, which may not be suitable for all waters, are given as examples, together with final minimum concentrations at which they can be used after dilution:

— sodium dichromate	($\text{Na}_2 \text{Cr}_2 \text{O}_7, 2\text{H}_2\text{O}$)	: 0. 2mg/l
— sodium chloride	(NaCl)	: 2 mg/l

Other salts have been used, and in particular:

— sodium nitrite	(Na NO ₂) and
— manganese sulphate	(Mn SO ₄ , 4H ₂ 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 is useful particularly in preliminary tests to check the delay period before sampling (see clause 6.2.1).

6. CHOICE OF THE MEASURING REACH

6.1 General considerations for selection of site

There should be no loss or gain of water in the measuring reach (for example, from a tributary joining or a distributary leaving the main flow, or overflow from or to 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 should 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 injection and the quantity of salt injected.

For rivers, this condition is easier to satisfy in relatively narrow channels; mixing is also improved by disturbances such as 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.

Great care is required to make a satisfactory choice of a reach suitable for the measurement of discharge by the dilution method using constant rate injection. This choice is facilitated by carrying out the preliminary tests described in clause 6.2.

6.2 Preliminary tests

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

Before selecting the measuring reach, it is advisable to make preliminary tests to ensure that efficient mixing in the river will be achieved, to choose the injection and sampling cross-sections and, once these have been chosen, to determine the duration of the injection period.

6.2.1 Determination 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 a point on a cross-section of the upstream portion of the measuring reach. Study of the diffusion of the solution will make it possible to determine whether there are any dead zones or similar side-tracking of the chemical and be a rough guide on the minimum distance between the injection point and a suitable sampling cross-section.

6.2.2 Duration of injection and of the steady regime condition. Duration of injection should be such that a steady regime of the concentration may be achieved for an adequate duration, generally 10 to 15 minutes, in the sampling section.

The duration of the injection, which is generally related to the degree of turbulence, will vary directly according to the length of the measuring reach and the extent of the dead water zones, and inversely according to the mean velocity of the water.

When the measuring reach has been selected, preferably where the river bed is stable, the duration of injection may be determined from preliminary tests at different values of the rate of flow. These tests consist of determining the variation, as a function of time, of the concentrations of an injected chemical substance at a number of sampling cross-sections.

* The length of the measuring reach I , between the injection cross-section and a cross-section where mixing may be expected to be within 1% of complete homogeneity, cannot be predicted with certainty; but, as a guide, an empirical formula has been evolved, though not widely established on experimental data, as follows:

$$I = 0.13 K \frac{b^3}{d} \text{ (in SI units)}$$

where b = average width of the water surface in the measuring reach (in SI units)
 d = average depth of the water in this same reach (in SI units)
 K = coefficient defined below:

$$K = \frac{C (0.7 C + 2 \sqrt{g})}{g}$$

where C = Chezy coefficient for the measuring reach, and $15 < C < 50$
 g = acceleration due to gravity (in SI units).

It is emphasized that the length obtained from the above equation may only be used as a preliminary guide, because the equation may not at all apply in certain instances due to very low turbulence, and the actual length required should be established by practical tests. For example, since the equation was based on injection at a single point in a straight reach, the length will be shortened if multiple injections across the cross-section are used. In addition, some tests seem to show that the equation under-estimates the length for small streams of the order of 5 m in width and over-estimates the length for rivers of the order of 50 m in width.

An instantaneous injection of fluorescein may also be used for this purpose. For a given flow, observation of the time of appearance and disappearance of colouration in each cross-section allows curves 1 and 2 of Figure 1 to be plotted. If it is desired to obtain, at a selected sampling cross-section, a steady regime condition of duration Δt , it is only necessary to add the time Δt to the time of disappearance of colouration at this point (Fig. 2), and to trace through the point obtained in this way a curve (1') parallel to the curve (1) of appearance of the colouration. The ordinate at the origin of this curve gives the minimum duration of injection to be made.

The same figure directly gives the time lag between the beginning of the injection and the beginning of the steady regime (Δt_1).

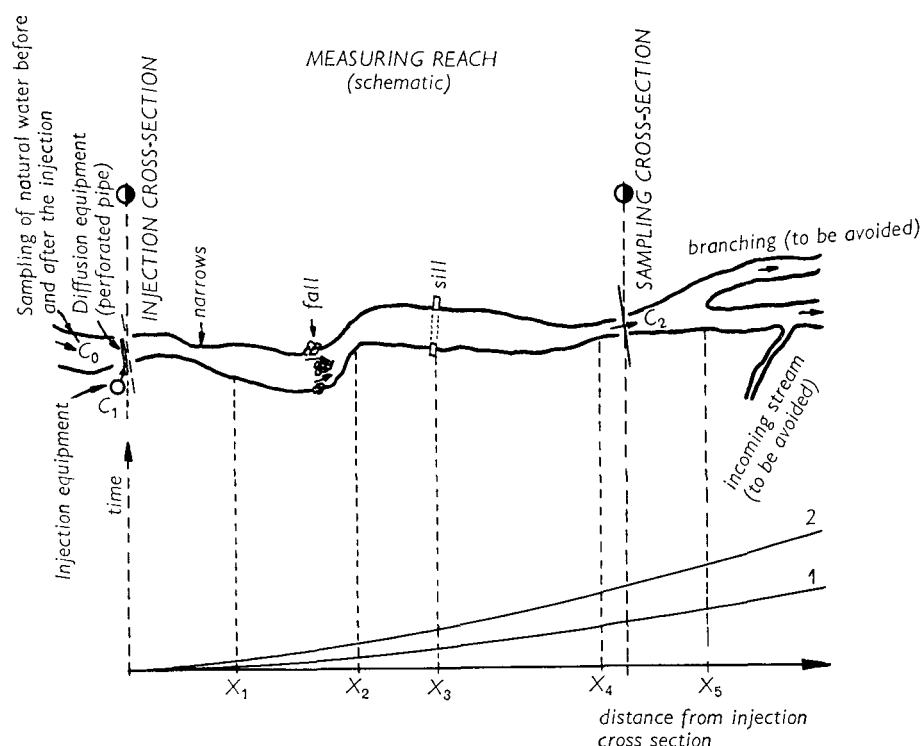


FIG. 1. — Curve of times of appearance and disappearance of coloured cloud as a function of distance from point of injection

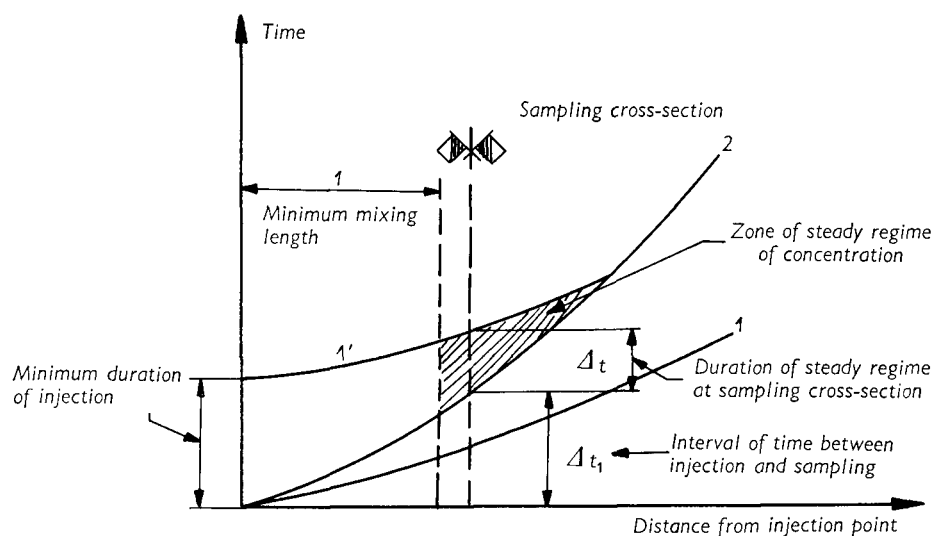


FIG. 2. — Determination of duration of injection