# TECHNICAL REPORT

# ISO TR 9824-1

First edition
1990-05-15

## Measurement of free surface flow in closed conduits —

## Part 1:
## Methods



*Mesurage du débit des écoulements à surface dénoyée dans les conduites fermées —*
*Partie 1: Méthodes*



Reference number
ISO/TR 9824-1:1990(E)

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:



— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;



— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 9824-1, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 113, *Measurement of liquid flow in open channels.*

ISO/TR 9824 consists of the following parts, under the general title *Measurement of free surface flow in closed conduits* :

— *Part 1: Methods*

— *Part 2: Equipment*



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Annex A of this part of ISO/TR 9824 is for information only.

## Introduction

The measurement of fluid flow and level in partially filled closed conduits presents particularly difficult problems and is not fully documented. This part of ISO/TR 9824 has been prepared therefore to give guidance to users on the existing methods employed and on recent developments in this field.

The measurement of free surface flow in closed conduits is analogous to normal gauging in open channels, and thus open channel gauging techniques may be applied to free surface flows in closed conduits. Closed conduits may be classified as

a) foul (sanitary), where only domestic and industrial waste are conveyed in the conduit,



b) storm, where, following a rainstorm, run-off from impermeable areas is conveyed to the nearest watercourse,



c) combined, where both domestic and industrial waste together with storm run-off are contained in one conduit, and

d) culvert, where the watercourse is conveyed under a road, railway, etc.

The purpose of closed conduit systems types a), b) and c) is to remove waste products from urban areas to a site where treatment (mechanical, chemical and/or biological) can be undertaken. The cheapest way of conveying sewage in a conduit is by laying the conduit so that it follows the natural topography, while providing sufficient gradient where necessary so that sewage will not stagnate but will flow under gravity. In very flat areas conduits may have to be laid at great depths to attain a sufficient hydraulic gradient, or alternately, if they are laid at shallow depths, pumping/lifting stations may have to be incorporated.

At times of heavy rainfall, systems of type b) may become surcharged (i.e. full pipe flow). Therefore, overflows are constructed to convey the excess water to the nearest watercourse or storage area, thus relieving the surcharge and avoiding the chances of surface flooding.

Conduits may be constructed as closed or open, and may be made of various materials such as vitreous clayware, concrete, asbestos cement, cast iron, brick and, more recently, plastic and resin-bonded materials. They may range in diameter from 150 mm upwards, although it is rare, except in large cities, to have conduits greater than 3 m in diameter.

Sewage consists of floating and suspended solids and may contain effluents of a corrosive nature. In addition, the atmosphere within the closed conduit system may contain both inflammable and corrosive gases. Thus the total environment within the closed conduit system may be described as hostile.

A flow-meter will have to operate in these hostile conditions over a wide range of flows, from free surface open channel flow to conduit full pressure flow. The nature of urban drainage is such that steady flow conditions are rare except near the outfall from large catchment areas where flow attenuation has occurred. Non-uniform flow also occurs as a result of bends, junctions and displaced joints.

The access to any closed conduit system is limited to the outfall or to specially built access points (i.e. manholes). Manholes are sited at irregular intervals where the sewer changes in direction or gradient or at a junction. These sites are hydraulically unsatisfactory for discharge measurement. Within the channel at a manhole an additional difficulty may be encountered when the depth of flow is above half-pipe full as the construction of the manhole frequently allows for benching to enable workmen to stand within the manhole. When the depth of flow rises above half-pipe full, the change in cross-sectional area of the closed conduit is discontinuous.

It is recommended that in deep conduits a platform or gallery be constructed at vertical intervals of 10 m. This is for safety reasons when ascending and descending into manholes. Thus, the sensing and recording elements need not be more than 10 m apart, but they must be capable of withstanding inundation.

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# Measurement of free surface flow in closed conduits —

## Part 1: Methods

### 1 Scope

This part of ISO/TR 9824 provides a synopsis of the methods of flow gauging that can be employed in closed conduits flowing part full and details the advantages and disadvantages of the various methods.



### 2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO/TR 9824. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO/TR 9824 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 772:1988, *Liquid flow measurement in open channels — Vocabulary and symbols*.

### 3 Definitions

For the purposes of this part of ISO/TR 9824, the definitions given in ISO 772 and the following definitions apply.

**3.1 permanent flow-meter:** Flow-meter installed for a long period of time (in excess of about 12 months) and used to measure flow continuously or at discrete time intervals.

NOTE 1 The high costs incurred in the installation of these flow-meters may be tolerated as they are spread over a period of time.

The measurements provided may be used as the basis for an archive system to examine present trends, to forecast future trends and to determine daily operational requirements.

**3.2 temporary flow-meter:** Transportable flow-meter installed for a specific period of time (not more than about 12 months) and used to measure flow continuously or at discrete time intervals.

NOTE 2 The installation of the meter needs to be simple with minimal or no associated civil engineering costs.

**3.3 portable flow-meter:** Portable flow-meter used to obtain instantaneous measurements of flow or the velocity and depth components thereof.

### 4 Methods of flow measurement

There are two basic types of flow measurement known as direct measurement and indirect measurement.

#### 4.1 Direct measurement

A direct measurement is one in which the flow is determined from measurements of various flow components, i.e. it is not inferred. The methods available for direct measurement are volumetric and dilution gauging.

##### 4.1.1 Volumetric method

The volume of a receiving tank is known and all the flow is directed into this tank. The time for the tank to fill is recorded whence the average flow during the time taken to fill the tank may be calculated.

This method is usually not practical in an underground system.

In a system where a sump or wet-well has been constructed, and a pump is available to empty the sump, the flow can be measured by

a) calculating the depth/volume relationship of the sump, and

b) measuring the water level (using a level recorder) in the wet-well at discrete time intervals. The time intervals will depend on the rate of fill of the tank. The aim is to measure the rate of rise of water level and to calculate the inflow rate.

In a drainage system where, during a storm, the pumps are functioning continuously, the discharge can be measured by

a) monitoring the level in the wet-well, and

b) monitoring which pumps are operating.

The pump and pump-combination discharges are calibrated by independent field tests, i.e. by monitoring the time it takes to empty the sump. If the sump cannot be isolated by closing the penstock then the inflow rate during the pump test is assumed to be constant.

The advantages of this method are that

a) flow is measured directly,

b) instrumentation can be powered by a mains electrical supply, and

c) sensing by remote methods can be employed.

The disadvantages are

a) the configuration of the system, i.e. if the inlet pipes to the sump are below the level of the pump-on switch then the depth/volume relationship of the sump is not easily calculated, and

b) in drainage systems with a large sediment and/or sludge content, the volume of the sump is reduced and sediment can also reduce the rate of discharge of the pumps.

#### 4.1.2 Dilution gauging

Standard dilution gauging techniques, either constant-rate injection or integration method [known formerly as sudden injection (gulp)], as laid down in ISO 555-1 and ISO 555-2 can be employed.

Dilution gauging is best suited to measure instantaneous flow or at best average flow over a short period (usually less than 1 hour), although it is possible to take measurements over a long period of time (i.e. days) if suitable devices for injection and analysis are available (e.g. radioactive tracers).

As with all dilution gauging techniques

a) it is necessary to obtain a sufficient degree of mixing at the sampling site, and

b) it is important that a tracer is chosen which is not absorbed and which does not react with the liquid that is being measured.

### 4.2 Indirect measurement

An indirect measurement is one in which flow is inferred from measurements of various flow components. The methods available for indirect measurement are those based on the use of weirs and flumes, the slope area method and the velocity area method.

#### 4.2.1 Flumes and weirs

In closed conduits where the liquid contains a high proportion of solid materials, and where pressure as well as free surface flow conditions occur, conventional flumes and weirs cannot be used. Therefore, special devices, designed and built to work under such conditions, have to be employed; they are described below.

##### 4.2.1.1 Vertical slot weir (see figure 1)



This weir allows solid materials to pass through the installation. The rating curve of the vertical slot weir may be affected by the conduit slope and roughness, particularly where the weir has wide slots and there are low flows. This type of weir is most suited for use in large diameter conduits where there is free surface flow only.

Dimensions in metres

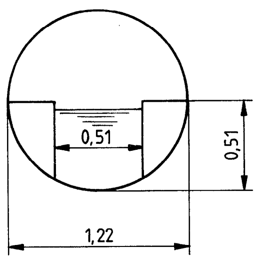


**Figure 1 — Vertical slot weir**

##### 4.2.1.2 Trapezoidal weir (see figure 2)

This weir functions in the same way as the vertical slot weir in that it allows the passage of solid materials, and does not excessively obstruct the flow. Again the rating curve is affected by the conduit slope and roughness, but the trapezoidal weir can measure lower depths and smaller flows than the vertical slot weir. This type of weir is most suited for use in large diameter conduits where there is no surcharging.

Dimensions in metres

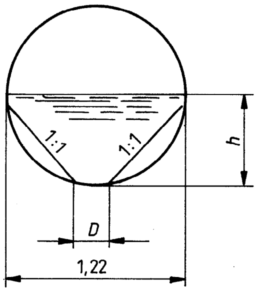


**Figure 2 — Trapezoidal weir**

#### 4.2.1.3 US Geological Survey meter (USGS meter) (see figure 3)

Since drainage systems frequently become surcharged, a device which can measure flows under both free surface and pressure flow conditions is necessary; the US Geological Survey meter is such a device. Under free surface flow conditions the meter acts as a flume and offers the reliability and accuracy of a flume. The accuracy, however, has to be traded off against constriction of the conduit, i.e. the greater the constriction, the better the accuracy. For pressure flow conditions, the meter operates as a nozzle, and flow is determined by measuring the pressure upstream and downstream of the nozzle.



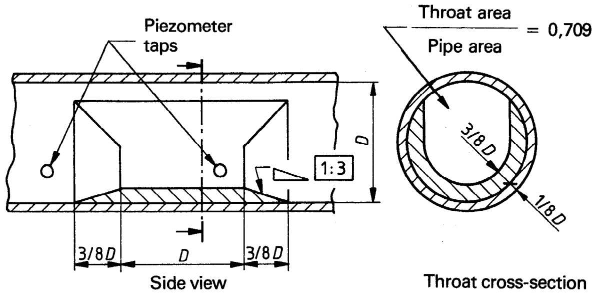


**Figure 3 — US Geological Survey sewer flow-meter**

#### 4.2.1.4 University of Illinois meter (UI) (see figure 4)

This meter is similar in performance to the USGS meter and measures flow under both free surface and pressure flow conditions in an identical way. The transition from free surface to pressure flow, however, is not as smooth for this meter as for the USGS meter owing to the shape of the constriction in the conduit soffit.

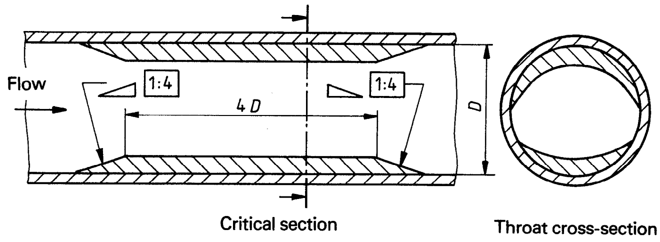


**Figure 4 — University of Illinois sewer flow-meter**

#### 4.2.1.5 Parshall flume (see figure 5)

The critical-depth or venturi flume has been developed in many different forms. One of the more popular designs is the Parshall flume, originally developed in 1920 for irrigation channels. For this device the head/discharge relationship is dependent on the throat width. Again, this device is most suited for large diameter conduits.

Dimensions in metres

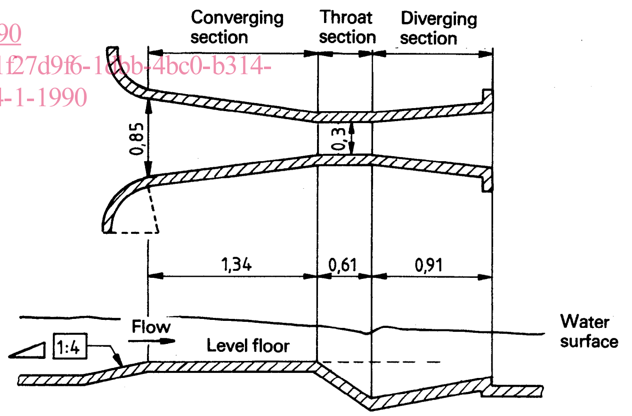


**Figure 5 — Parshall flume**

#### 4.2.1.6 Palmer-Bowlus flume (see figure 6)

Another critical-depth flume, the Palmer-Bowlus flume, has recently been tested for sloping conduits. It exhibits a successful head/discharge calibration for both subcritical and supercritical free surface flow. Modifications to the flume design are recommended to improve the head/discharge relationship in the transition zone from free surface to pressure flow.