BRITISH STANDARD

BS EN ISO 8316:1997

BS 6199-2:1988 renumbered, incorporating Amendment No. 1

Measurement of liquid flow in closed conduits —

Method by collection of the liquid in a volumetric tank

The European Standard EN ISO 8316:1995 has the status of a British Standard

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the industrial-process Measurement and Control Standards Committee (PCL/-) to Technical Committee PCL/2, upon which the following bodies were represented:

British Compressed Air Society
British Gas plc.
Department of Energy (Gas and Oil Measurement Branch)
Department of Trade and Industry (National Engineering Laboratory)
Department of Trade and Industry (National Weights and Measures Laboratory)
Electricity Supply Industry in England and Wales
Energy Industries Council
GAMBICA (BEAMA Ltd.)
Institute of Measurement and Control
Institute of Trading Standards Administration
Institution of Gas Engineers
Institution of Mechanical Engineers
Water Authorities Association

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Society of British Gas Industries
University of Surrey

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 Board of BSI and comes into effect on
30 September 1988

The following BSI references relate to the work on this standard:
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Amendments issued since publication

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Contents

National foreword

This British Standard has been prepared by Technical Committee CPL/30 (formerly PCL/2). It is identical with ISO 8316:1987 "*Measurement of liquid flow in closed conduits — Method by collection of the liquid in a volumetric tank*", published by the International Organization for Standardization (ISO).

In 1995 the European Committee for Standardization (CEN) accepted ISO 8316:1987 as European Standard EN ISO 8316:1995. As a consequence of implementing the European Standard this British Standard is renumbered as BS EN ISO 8316 and any reference to BS 6199-2:1988 should be read as a reference to BS EN ISO 8316.

Terminology and conventions. The text of the international standard has been approved as suitable for publication as a British Standard without deviation. Some terminology and certain conventions are not identical with those used in British Standards; attention is drawn especially to the following.

Wherever the words "International Standard" appear, referring to this standard, they should be read as "Part of BS 6199".

The comma has been used as a decimal marker. In British Standards it is current practice to use a full point on the baseline as a decimal marker.

Cross-references

International standard	Corresponding British Standard
ISO 4006:1977	BS 5875:1980 *Glossary of terms and symbols for measurement of fluid flow in closed conduits* (Identical)
ISO 5168:1978	BS 5844:1980 *Methods of measurement of fluid flow: estimation of uncertainty of a flow-rate measurement* (Identical)

At present there is no corresponding British Standard for ISO 4373. The Technical Committee has reviewed the provisions of ISO 4373 and has decided that they are acceptable for use in conjunction with this standard.

ISO 4185, although listed in clause **2**, is not referred to in the text.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN ISO title page, pages 2 to 26, 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.

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN ISO 8316

September 1995

ICS 17.120.10

Descriptors: Liquid flow, pipe flow, flow measurements, volume measurements, tanks containers, gauging, flow rate, flowmeters, error analysis

English version

Measurement of liquid flow in closed conduits — Method by collection of the liquid in a volumetric tank

(ISO 8316:1987)

Mesure de débit des liquides dans les conduites fermées — Méthode par jaugeage d'un réservoir volumétrique
(ISO 8316:1987)

Durchflußmessung von Flüssigkeiten in geschlossenen Leitungen — Verfahren der Volumenbestimmung mit einem Meßbehälter
(ISO 8316:1987)

This European Standard was approved by CEN on 1995-08-31. CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. EN ISO 8316:1995 E

Foreword

This European Standard was taken over by CEN from the work of ISO/TC 30, *Measurement of fluid flow in closed conduits*, of the International Standards Organization (ISO).

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 1996, and conflicting national standards shall be withdrawn at the latest by March 1996.

According to the CEN/CENELEC Internal Regulations, the following countries are bound to implement this European Standard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.

1 Scope and field of application

This International Standard specifies methods for the measurement of liquid flow in closed conduits by determining the volume of liquid collected in a volumetric tank in a known time interval. It deals in particular with the measuring apparatus, the procedure, the method for calculating the flow-rate and the assessment of uncertainties associated with the measurements.

The method described may be applied to any liquid provided that

a) its vapour pressure is sufficiently low to ensure that any escape of liquid by vaporization from the volumetric tank does not affect the required measurement accuracy;

b) its viscosity is sufficiently low so as not to alter or delay unduly the measurement of the level in the volumetric tank;

c) it is non-toxic and non-corrosive.

Theoretically, there is no limit to the application of this method, but, for practical reasons, this method of measurement is normally used for flow-rates less than approximately 1,5 m^3/s and is used on the whole in fixed laboratory installations only. However, there is a variation of this method which uses a natural or artificial storage pond as a volumetric tank, but this application is not dealt with in this International Standard.

Owing to its high potential accuracy, this method is often used as a primary method for calibrating other methods or devices for volume flow-rate measurement or for mass flow-rate measurement; for the latter method or device, it is necessary to know the density of the liquid accurately.

If the installation for flow-rate measurement by the volumetric method is used for purposes of legal metrology, it shall be certified and registered by the national metrology service. Such installations are then subject to periodic inspection at stated intervals. If a national metrology service does not exist, a certified record of the basic measurement standards (length, time and temperature), and error analysis in accordance with this International Standard and ISO 5168, shall also constitute certification for legal metrology purposes.

Annex A forms an integral part of this International Standard. Annex B to Annex E, however, are given for information only.

2 References

ISO 4006, *Measurement of fluid flow in closed conduits — Vocabulary and symbols.*

ISO 4185, *Measurement of liquid flow in closed conduits — Weighing method.*

ISO 4373, *Measurement of liquid flow in open channels — Water level measuring devices.*

ISO 5168, *Measurement of fluid flow — Estimation of uncertainty of a flow-rate measurement.*

3 Symbols and definitions

3.1 Symbols (see also ISO 4006)

Table 1

Symbol	Quantity	Dimensions	SI unit
e_R	Random uncertainty, in absolute terms	[a]	[a]
E_R	Random uncertainty, as a percentage	—	—
e_S	Systematic uncertainty, in absolute terms	[a]	[a]
E_S	Systematic uncertainty, as a percentage	—	—
q_m	Mass flow-rate	MT^{-1}	kg/s
q_V	Volume flow-rate	L^3T^{-1}	m^3/s
t	Filling time of the tank	T	s
V	Discharged or measured volume	L^3	m^3
z	Liquid level in the tank	L	m
ϱ	Density	M^{-3}	kg/m^3

[a] The dimensions and units are those of the quantities in question.

3.2 Definitions

For the purposes of this International Standard, the definitions given in ISO 4006 apply. Only terms which are used with a particular meaning or the meaning of which might be usefully restated are defined below. The definitions of some of the terms concerned with error analysis are given in ISO 5168.

3.2.1
static gauging

a method by which the net volume of liquid collected is deduced from measurements of liquid levels (i.e. gaugings), made respectively before and after the liquid has been diverted for a measured time interval into the gauging tank, to determine the volume contained in the tank

3.2.2
dynamic gauging

a method by which the net volume of liquid collected is deduced from gaugings made while liquid flow is being delivered into the gauging tank. (A diverter is not required with this method.)

3.2.3
diverter

a device which diverts the flow either to the gauging tank or to its by-pass without changing the flow-rate during the measurement interval

3.2.4
flow stabilizer

a device inserted into the measuring system, ensuring a stable flow-rate in the conduit being supplied with liquid; for example, a constant level head tank, the level of liquid in which is controlled by a weir of adequate length

4 Principle

4.1 Statement of the principle

4.1.1 *Static gauging method*

The principle of the flow-rate measurement method by volumetric static gauging (see Figure 1 for a schematic diagram of a typical installation) is

- to determine the initial volume of liquid contained in the tank;
- to divert the flow into the volumetric tank, until it is considered to contain a sufficient quantity to attain the desired accuracy, by operation of a diverter which actuates a timer to measure the filling time;
- to determine the final volume of liquid contained in the tank. The volume contained at the initial and at the final times is obtained by reading the liquid levels in the tank and by reference to a preliminary calibration which gives the level-volume relationship.

The flow-rate is then derived from the volume of liquid collected and the filling time as explained in clause **7**.

One variation of this method uses two tanks which are successively filled (see **6.3**). A further variation, given in Annex D, uses a valve instead of a diverter mechanism to start and stop the flow into a volumetric tank.

Care shall be taken when using a valve instead of a diverter that the flow-rate does not change when the valve is operated.

4.1.2 *Dynamic gauging method*

The principle of the flow-rate measurement method by volumetric dynamic gauging (see Figure 2 for a schematic diagram of a typical installation) is

- to let liquid collect in the tank to a predetermined initial level (and thus volume), at which time the timer is started;
- to stop the timer when a second predetermined final level (and thus volume) is reached and then to drain the liquid collected.

The flow-rate is then derived as explained in clause **7**.

4.1.3 *Comparison of instantaneous and mean flow-rates*

It should be emphasized that only the mean value of flow-rate for the filling period is given by the volumetric method. Instantaneous values of flow-rate as obtained on another instrument or meter in the flow circuit may be compared with the mean flow-rate only if the flow is kept stable during the measurement interval, by a flow-stabilizing device, or if the instantaneous values are properly time-averaged during the whole filling period.

4.2 Accuracy of the method

4.2.1 *Overall uncertainty in the volumetric measurement*

The volumetric method gives a measurement of flow-rate which, in principle, requires only level and time measurements. After the weighing method, the static gauging method in a volumetric tank may be considered as one of the most accurate of all flow-rate measuring methods, particularly if the precautions given in **4.2.2** are taken. For this reason, it is often used as a standard or calibration method. When the installation is carefully constructed, maintained and used, an uncertainty of ± 0,1 % to ± 0,2 % (with 95 % confidence limits) may be achieved.

4.2.2 *Requirements for accurate measurements*

The volumetric method gives an accurate measurement of flow-rate provided that

a) there is no leak in the flow circuit and there is no unmeasured leakage flow across the diverter;

b) the conduit is running full at the measuring section and there is no vapour or air-lock between the measuring section and the volumetric tank;

c) there is no accumulation (or depletion) of liquid in a part of the circuit by thermal contraction (or expansion) and there is no accumulation (or depletion) by change in vapour or gas volume contained unknowingly in the flow circuit;

d) care has been taken to avoid any leakage from or unwanted flow into the tank, absorption of liquid by the walls or their coatings, deformation of the walls etc.;

e) the level-volume relationship in the tank has been established by transferring known volumes, or by calculation from dimensional measurements of the tank, as specified in **5.5**;

f) the level measuring devices and the means for starting and stopping the timer achieve the required accuracies;

g) the time required by the diverter (for the static gauging method) for traversing is short with respect to the filling time, the timer being started and stopped while the diverter is crossing the hydraulic centreline (this position shall be checked and adjusted, if necessary, using the methods described in Annex A);

h) the temperature of the liquid flowing through the flowmeter under test is either the same as that collected in the volumetric tank or it is corrected accordingly.

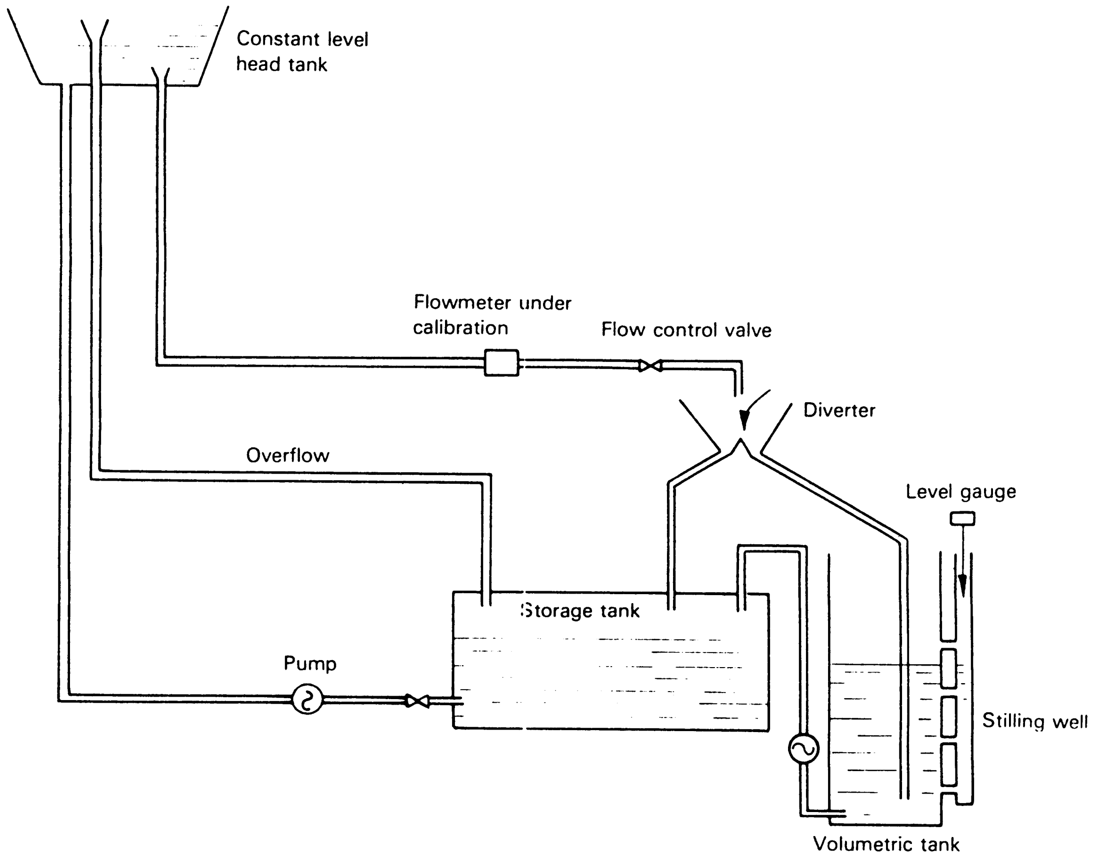

Figure 1 — Schematic diagram of a volumetric flow-rate installation using the static gauging method

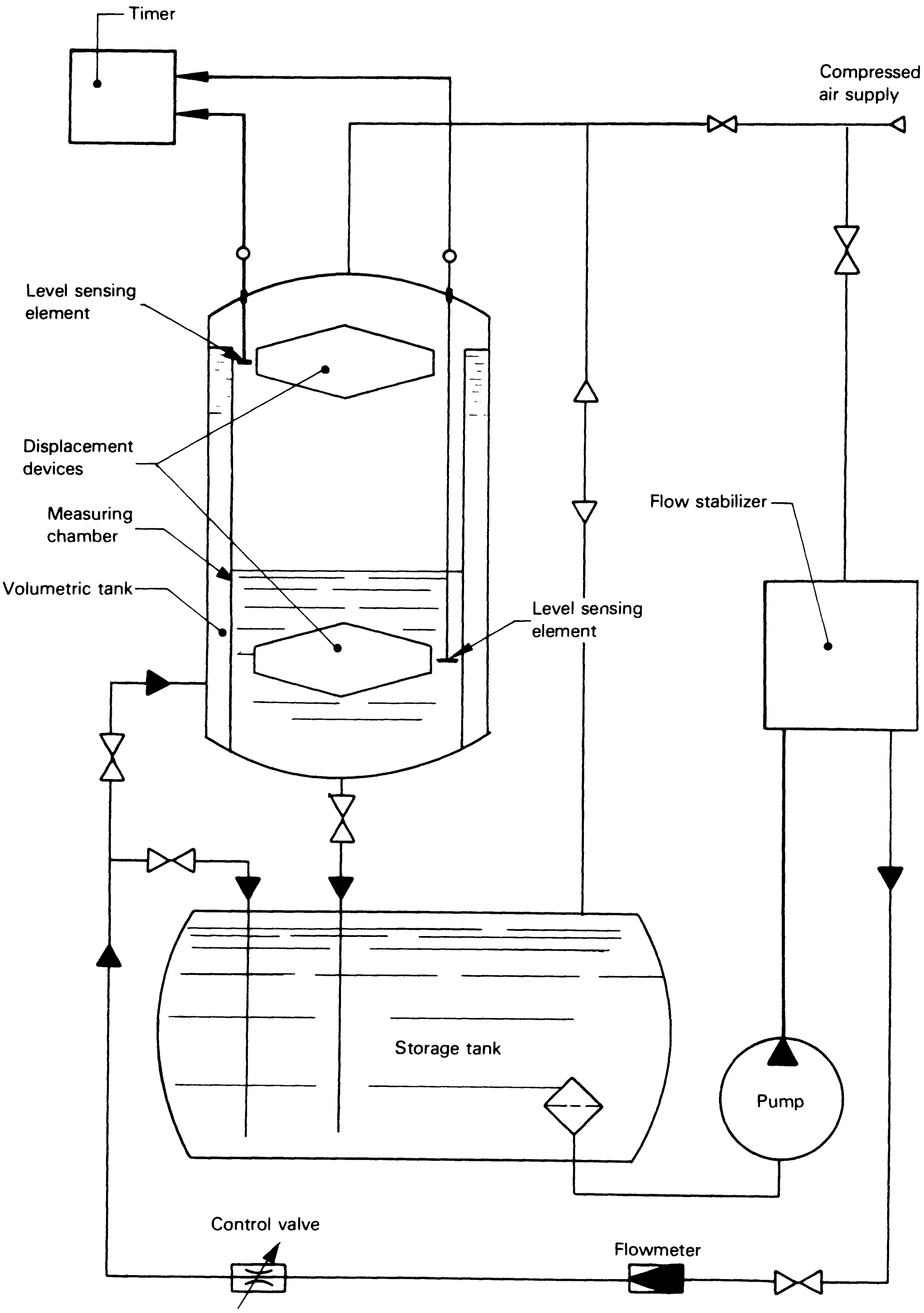

Figure 2 — Schematic diagram of a volumetric flow-rate installation using the dynamic gauging method

5 Apparatus

5.1 *Diverter*

The diverter is a moving device used to direct flow alternately along its normal course or towards the volumetric tank. It can be made up of a moving conduit or gutter, or by a baffle plate pivoting around a horizontal or vertical axis (see Figure 3).

The motion of the diverter shall be sufficiently fast (less than 0,1 s, for example) to reduce the possibility of a significant error occurring in the measurement of the filling time. This is achieved by ensuring, first, that the diverter travel across the flow is rapid and, second, that the flow is in the form of a thin stream, which is produced by passing it through a nozzle slot. Generally, this liquid stream has a length 15 to 50 times its width in the direction of diverter travel. The pressure drop across the nozzle slot shall not exceed about 20 kPa to avoid splashing, air entrainment[1] and flow across the diverter and turbulence in the volumetric tank. The movement of the diverter may be generated by an electrical, mechanical or electro-mechanical device, e.g. by a spring or torsion bar, or by an electrical or pneumatic actuator. The diverter shall in no way influence the flow in the circuit during any phase of the measurement procedure.

However, for large flow-rates, which could involve excessive mechanical stresses, a diverter with a proportionately longer travel time (1 to 2 s, for example) may be used provided that the operating law is constant and any variation in flow-rate distribution as a function of diverter stroke is approximately linear and is in any case known and can be verified. Any hysteresis between the two directions of diverter travel shall also be controlled.

In the design of the mechanical parts of the diverter and its movement device, care shall be taken to ensure that no leakage or splashing of liquid occurs when liquid is either removed from the volumetric tank or allowed to flow from one diverter channel to the other. This condition shall be checked frequently during service.

Alternatives to a thin flat liquid stream entering the diverter are acceptable provided that corrections to the diversion time, as indicated in Annex A, are applied.

5.2 *Time measuring apparatus*

The time of discharge into the volumetric tank is normally measured by using an accurate electronic timer, e.g. a quartz crystal timer. The diversion period may thus be read to within 0,01 s or better. The error arising from this source may be regarded as negligible provided that the resolution of the timer display is sufficiently high and the equipment is checked periodically against a national time standard, e.g. the frequency signals transmitted by certain radio stations.

The timer shall be actuated by the motion of the diverter itself through an optical, magnetic or other suitable switch fitted on the diverter. The time measurement shall be started (or stopped) at the instant when the hatched areas shown in Figure 4, which represent the diverted flow variations with time, are equal. In practice, however, it is generally accepted that this point corresponds to the mid-travel position of the diverter in the fluid stream. The error will generally be negligible provided that the time of passage of the diverter through the stream is very short in comparison with the period of diversion to the tank.

If, however, the error in the filling time measurement arising from the operation of the diverter and the starting and stopping of the timer is not negligible, a correction should be made in accordance with the directions given in Annex A.

5.3 *Volumetric tank*

The tank into which the liquid flows during each measuring stage is generally but not necessarily cylindrical in form, with the axis vertical, made of steel or reinforced concrete with a leak-proof lining. Attention shall be paid to the construction materials and protective coatings and to the dimensions so that the bottom and walls of the tank are perfectly leak-proof and rigid enough to retain their shape. If the tank is buried in the ground, it is advisable to provide a clear space around the tank so as to avoid any risk of distortion due to the effect of soil pressure and to make any possible leakage obvious. The walls of the tank shall be smooth in order to avoid water retention and to ensure complete drainage of the tank.

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[1] In certain designs of nozzle slot, however, special vents to allow air ingress to the fluid jet may be necessary to ensure stable flow within the test circuit.

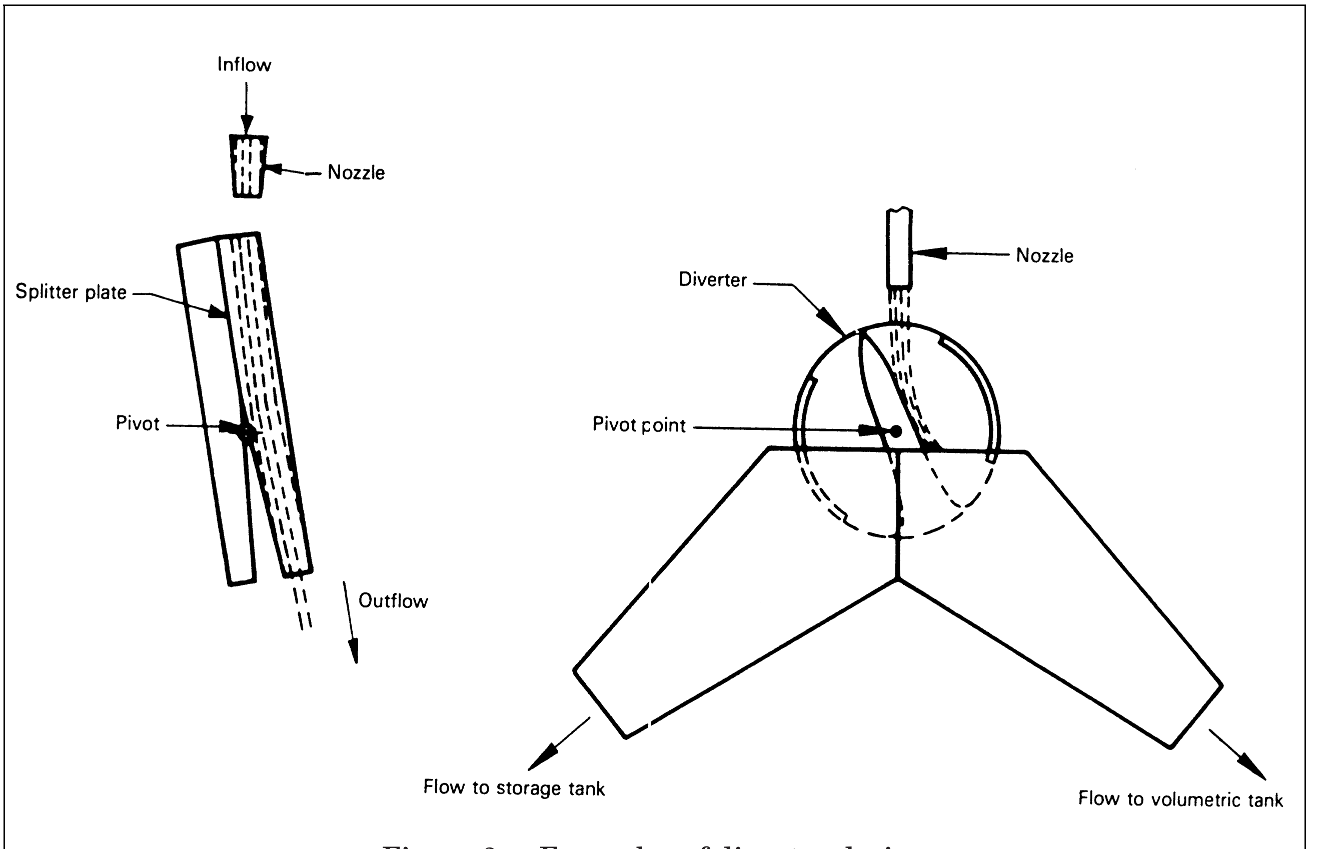

Figure 3 — Examples of diverter design

The tank shall be large enough to ensure that any errors in timing and in level measurements are negligible; moreover, it is necessary for the ratio of cylinder height to diameter to be large enough to provide acceptable accuracy in determining the filling volume on the one hand and to limit the oscillations in the level of the free liquid surface on the other hand. With account taken of the requirements of **5.1** and **5.2**, the minimum change in level shall be about 1 m and the tank filling time, at maximum flow-rate, shall be at least 30 s. However, these values may be reduced provided that it is possible to verify experimentally that the required accuracies have been achieved.

The flow into the tank, particularly if the tank is large, shall be provided with a guiding device for reducing the transmission of air into the tank and limiting the liquid oscillations.

The tank may be drained by various means as follows:

- — by a stop-valve at the base, the leak-proof quality of which shall be capable of being verified, such as by a free discharge or a transparent section of pipe;
- — by a siphon fitted with an efficient and checkable siphon break;
- — by a self-priming or submersible pump.

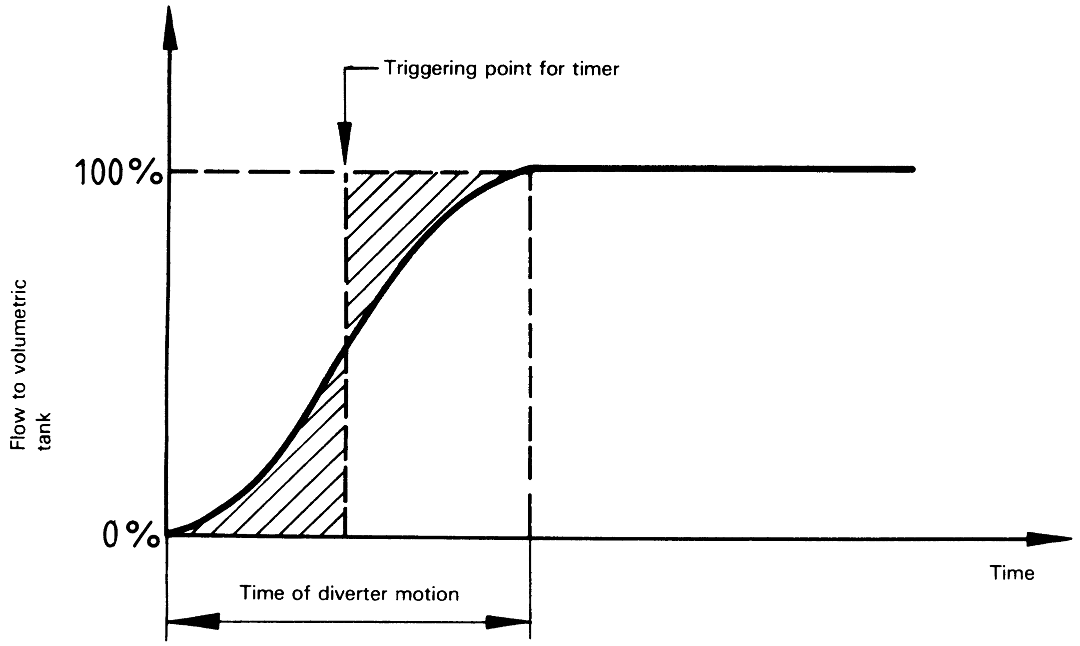

Figure 4 — Operating law of diverter

The rate of draining shall be sufficiently high that test runs may follow each other at short intervals.

5.4 *Level measuring apparatus*

The liquid level may be measured by a point or hook gauge (possibly with electrical contact), by a float gauge or by any other device providing equivalent accuracy (for the specifications of these apparatus, see ISO 4373).

For large discharges, because of the relatively large variations in the liquid surface, and in order to dampen the oscillations of the liquid in the tank, these devices should preferably be installed in a stilling well, having either a transparent side or a gauge glass with a fixed graduated scale. The stilling well should be connected with the tank by means of a number of tappings spaced over the entire height. It shall be of a constant cross-section, large enough to make the effect of capillarity negligible.

Care shall be taken to eliminate errors due both to temperature differences between the tank and the stilling well and to incorrect damping of oscillations by the stilling well.

5.5 *Calibration of the volumetric tank*

The greatest care shall be taken in establishing the capacity of the tank and this shall be regularly checked. It is important that the dimensions and shape of the tank do not change, as specified in **5.3**.

The most accurate method is, in the case of small movable tanks, to weigh the liquid contained in the tank, or, for large fixed tanks, to add together the successive volumes introduced by means of a graduated delivery vessel. This may take the form of a calibrated pipe so that the volume contained in it may be determined accurately by the filling level, or its contents may be weighed.

The volume-level relationship may also be determined by measuring accurately the geometric dimensions of the tank. In this case, it is necessary to take a large number of measurements to take account of any irregularities in the shape.

If variations in operating temperature are sufficient to introduce significant errors, then calibrations should be carried out at several temperatures over the operating range.

It is necessary to take into account any liquid that sticks to the walls of the graduated delivery vessel when empty. The volume of this residual liquid varies according to the draining time and, to a lesser extent, the temperature, owing to viscosity and surface tension effects. It is essential to wait for a sufficient length of time, usually approximately 30 s, until as much liquid as possible has drained down the walls of the tank.

Whatever the method used, a rating curve or preferably a rating table should be established which shows the volume against liquid level at intervals sufficiently close together that any linear interpolation will not introduce a significant error.

6 Procedure

6.1 Static gauging method

In order to take account of any residual liquid likely to have remained in the bottom of the tank or on the walls, first discharge into the tank (or leave at the end of draining after the preceding measurement) a sufficient quantity of liquid to reach the operational threshold of the gauge. Record this initial level, z_0, for which there is a corresponding initial volume, V_0, according to the rating table, while the diverter directs the flow to the storage tank and the flow-rate is being stabilized. After the test flow-rate has been achieved, operate the diverter to direct the liquid into the volumetric tank, thereby automatically starting the timer.

After an appropriate quantity of liquid has been collected, the diverter operates in the opposite direction to return the liquid to storage, which automatically stops the timer and thus determines the filling time, t. When the oscillations in the tank have subsided, record the apparent final level, z_1, for which there is a corresponding final volume, V_1, according to the rating table. Then drain the tank, unless the total volume of the tank is sufficient to allow several successive measurements without draining it in between.

6.2 Dynamic gauging method

If the incoming flow is such that no significant disturbance of the liquid level occurs, it is possible to proceed as follows. Close the tank valve and start the timer when the liquid level reaches a predetermined value, z_0, corresponding to an initial volume, V_0, according to the rating table. Stop the timer (preferably automatically) when the level reaches a second predetermined value, z_1, corresponding to a final volume, V_1, according to the rating table. Record the filling time, t, after which the tank may be drained.

Depending on the type of level measuring device used, this procedure may be carried out either by positioning the gauge (or level sensors) successively at levels z_0 and z_1 or by recording continuously the motion of the gauge.

6.3 Twin tanks method

This method can reduce the error due to the time required to switch the flow and it enables the discharge to be measured over a long time period. Two similar tanks, having approximately the same capacity, may be used, measurements being made on the one tank while the other is being filled. The reduced timing error means that the total error depends mainly on the accuracy of measuring the volumes.

The two tanks are usually connected at the top by a sharp angle splitter weir. Check valves or quick-acting valves are located at the bottom of each tank. A movable tipping channel diverts the liquid into one or other of these tanks (see Figure 5).

Measurements are made in the following manner. At the start of the run, operate the switching device to divert the liquid towards one of the empty tanks whose shut-off valve is closed. Proceed with the filling until the liquid overflows into the second tank and the flow is then switched to the second tank.

While filling the latter, let the liquid level of the first tank become stable and then empty it rapidly (the stabilizing time of the liquid level may be shortened by reducing the cross-sectional areas at the tops of the tanks). At the end of the run, before the filling tank is full, divert the flow towards the empty tank. The total volume discharged is thus equal to the product of the number of total fillings and the volume of the tanks, plus the volume of liquid in the partially filled tank at the end of the run.

6.4 Common provisions

It is recommended that at least two successive measurements be carried out for each of a series of flow-rate measurements if a subsequent analysis of random errors is to be carried out.

The various quantities to be measured may be noted manually by an operator or transmitted by an automatic data acquisition system to be recorded in numerical form on a printer or to be fed directly into a computer.

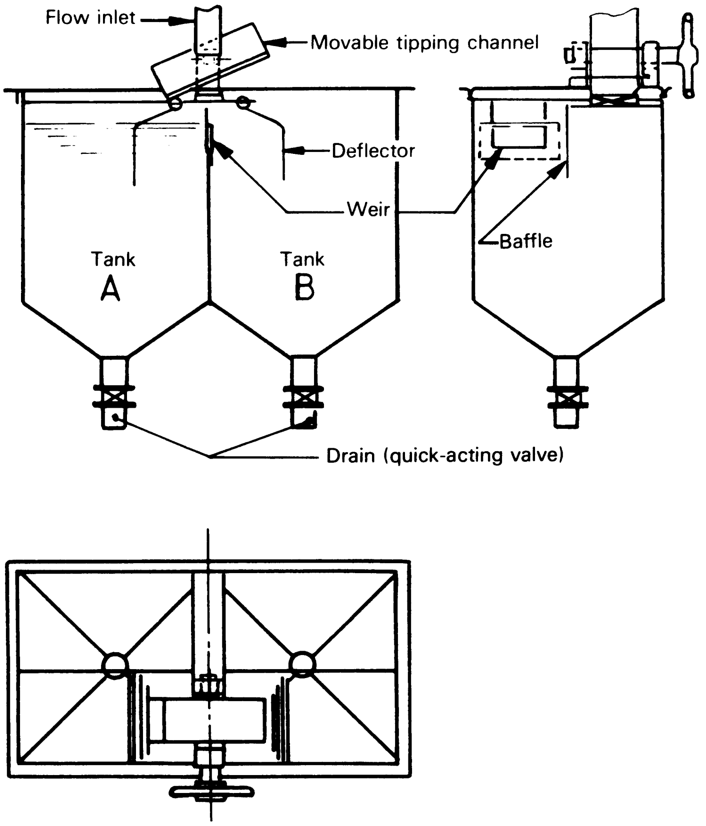

Figure 5 — Twin tanks method

7 Calculation of flow-rate

7.1 Calculation of volume flow-rate

The volume discharged during the filling time is equal to the difference in the volumes V_1 and V_0 contained in the volumetric tank filled up to the levels z_1 and z_0 respectively, these volumes being obtained from the rating tables of the tank applicable at the test temperature.

The mean volume flow-rate, q_v, during the filling time is thus

$$q_v = \frac{V_1 - V_0}{t}$$

where t is the filling time which should be corrected in accordance with Annex A to take account of any timing error.

7.2 Calculation of mass flow-rate

The mean mass flow-rate during the filling time may be derived from the volume flow-rate, calculated as stated in **7.1**, and from the density of the liquid at the temperature in the volumetric tank, this density being obtained from standard tables.[2)]

NOTE For unusual liquids or when the best possible accuracy is required, the density should be measured directly.

The mean mass flow-rate, q_m, is thus equal to

$$q_m = \varrho q_V = \frac{\varrho (V_1 - V_0)}{t}$$

[2)] A table of water densities for the range of ambient temperatures is given in Annex B.

8 Calculation of the overall uncertainty in the flow-rate measurement

The calculation of the uncertainty in the flow-rate measurement shall be carried out in accordance with ISO 5168. For convenience, the main procedures to be followed are given here as they apply to the flow-rate measurement by the volumetric method.

8.1 Sources of errors

The sources of systematic and random errors are considered separately here, but it should be noted that only a single determination of flow-rate is being considered. It should also be noted that the purpose of the measurement is considered to be the determination of the mean flow-rate during the period of the diversion. Thus the instability in the flow need not be taken into account between two successive measurements. It should also be appreciated that only the main sources of error have been described, and that the numerical values of errors are only mentioned as examples.

8.1.1 *Systematic errors*

8.1.1.1 *Errors due to the volumetric tank*

The systematic errors due to the volumetric tank are associated with imperfect knowledge of the level-volume relationship and are mainly due to

a) the uncertainties arising during the calibration of the tank;

b) the changes in this calibration in terms of temperature, accidental deformations or any other external factor;

c) the interpolation between the figures given by a rating table or the use, in graphical or analytical form, of the best-fit rating curve through the individual calibration points.

If the systematic error in the determination of each volume V_0 and V_1 is taken as $(e_S)_V$, it may be assumed that this error varies in a random manner from one point of the rating curve to another and thus $\sqrt{2}\,(e_S)_V$ should be taken as the estimation of the systematic error in the measured volume $V = V_1 - V_0$.

8.1.1.2 *Errors due to the level gauge*

The readings of the levels z_0 and z_1 are affected by any error due to the level measuring apparatus used; a part of this error, say $(e_S)_z$, associated, for instance, with the imperfections of the scale, is of a systematic nature for a given level.

Nevertheless, it may be assumed that this error varies in a random manner over the length of the gauge and thus the estimation of the systematic error in the measurement of the levels should be taken as $\sqrt{2}\,(e_S)_z$.

8.1.1.3 *Errors due to the timing device*

Any error in the calibration of the timing device will result in a systematic error $(e_S)_t$ in the time measured for a diversion, but with modern equipment this will be negligible (less than 1 ms).

It is important that the resolution of the timing device be adequate. Instruments with a digital display will give a reading which is in error by up to one last-order digit, the sign of the error depending on whether the digit is advanced at the end or beginning of the corresponding time interval. In order to render this effect negligible, the resolution of any timing device used shall be set at less than 0,01 % of the diversion time.

8.1.1.4 *Errors due to the diverter system*

Provided either that a correction is made for any timing error, as described in Annex A, or that the triggering of the timing system is adjusted so that the timing error is negligible, the uncertainty introduced into the flow-rate measurement from this source will be equal to the uncertainty in the measurement of the timing error.

This uncertainty $(e_S)_p$ may be calculated in accordance with method 1 (see **A.1.1**, Annex A), using the general principle outlined in ISO 5168, or from the uncertainty in the gradient of the line on the graph (see Figure 7) when method 2 (see **A.1.2**, Annex A) is used.

8.1.1.5 *Errors due to density measurement*

When the mass flow-rate has to be calculated, there will be a systematic error associated with the value used for the density of the liquid, which will arise from the measurement of the temperature in the volumetric tank and at the meter during the collection period, and the use of the density measuring equipment or density tables.

Errors in the measurement of density will be negligible in general provided that the temperature is measured to within ± 0,5 °C. This accuracy is easily attainable with simple thermometers, but it is important to ensure that the liquid flowing into the tank is at a constant temperature so that there is no possibility of the temperature of the liquid close to the thermometer being unrepresentative of that of the liquid in the tank as a whole.

When density tables are used, no significant error should be introduced, but, if the density of a liquid is to be measured directly, an assessment of the method used shall be carried out in order to determine the uncertainty $(e_S)_d$ in the result. This value of $(e_S)_d$ is then the value to be used in calculating the uncertainty in the mass flow-rate measurement.

8.1.1.6 *Maximum permissible value*

The maximum permissible value of each systematic component of the uncertainty (dealt with in **8.1.1.1** to **8.1.1.5**) shall be taken as ± 0,05 % if an overall uncertainty less than ± 0,2 % is desired, as stated in **4.2.1**.

To obtain these figures, the volume of liquid collected and the filling time should be above certain minimum values. These values depend on the characteristics of the installation (scatter of the calibration points, quality of the diverter, level gauge, timer etc.), as discussed in **5.3**.

8.1.2 ***Random errors***

8.1.2.1 *Errors in the determination of the volume collected*

From the readings recorded during the calibration of the tank, the standard deviation of the distribution of points about the best-fit curve may be calculated and the 95 % confidence limits of this distribution may be determined using the appropriate Student's t value (see Annex E). Since the volume of liquid collected has been obtained from the difference between two level gaugings, this error volume $(e_R)_v$ shall be multiplied by $\sqrt{2}$. As the procedure and the devices used for the calibration and for the measurements of flow into the tank, the time for level stabilization, the level gauges etc. are the same, then the resultant $\sqrt{2}\,(e_z)_V$ is the random uncertainty in the volume collected due to the volumetric tank and the level measurements. It should be noted that this uncertainty is generally dependent on the flow-rate.

By the same reasoning as in **8.1.1.6**, this uncertainty $\sqrt{2}\,(e_z)_V$ shall be less than ± 0,1 %. The achievement of this will require the collection of a minimum volume of liquid, this minimum volume being determined from the absolute value of the scatter of the calibration points.

8.1.2.2 *Errors due to the diverter system*

The accuracy with which the duration of a diversion is measured depends on the uniformity and repeatability of the movement of the diverter which triggers the timing device. For any given installation, this may be determined experimentally by setting the flow-rate to a steady value and then carrying out a series of, say, 10 diversion periods of approximately the same duration to provide a series of 10 estimations of the flow-rate.

If this procedure is repeated for several different diversion periods and the 95 % confidence limits are found for each series of measurements from the standard deviation, s, a graph of the form shown in Figure 6 may be developed for a well-designed diverter system.

Above some minimum diversion period, the 95 % confidence limits will be relatively constant, and the value so obtained should be used as the uncertainty, $(e_R)_p$, in the flow-rate measurement due to random effects in the diverter system.

It is important that $(e_R)_p$ be evaluated at several flow-rates over the range of the system since its value may be dependent on the flow-rate.

By the same reasoning as in **8.1.1.6**, this uncertainty $(e_R)_p$ shall be less than ± 0,1 %. In any given system, the achievement of this will require a minimum duration of collection determined from the absolute value of this uncertainty.

8.1.2.3 *Errors due to dynamic gauging*

The accuracy with which the collection period is measured in the dynamic gauging method may be assessed in a similar manner to that given in **8.1.2.2**.

8.2 Calculation of the overall uncertainty in flow-rate measurement

8.2.1 *General*

The uncertainty associated with a flow-rate measurement is obtained by combining the uncertainties arising from the sources described in **8.1**. Although "systematic" errors have been distinguished from "random" errors, the probability distribution of the possible values of each systematic component is essentially gaussian, and, in accordance with ISO 5168, the combination of all the uncertainties may therefore be made by the root-sum-square method.

Although all the uncertainties theoretically liable to affect any one of the measured quantities should be considered, only those set out in **8.1** need be included in the analysis if the measurements have been made in accordance with this International Standard, since any other source of error will make a negligible contribution to the overall uncertainty.

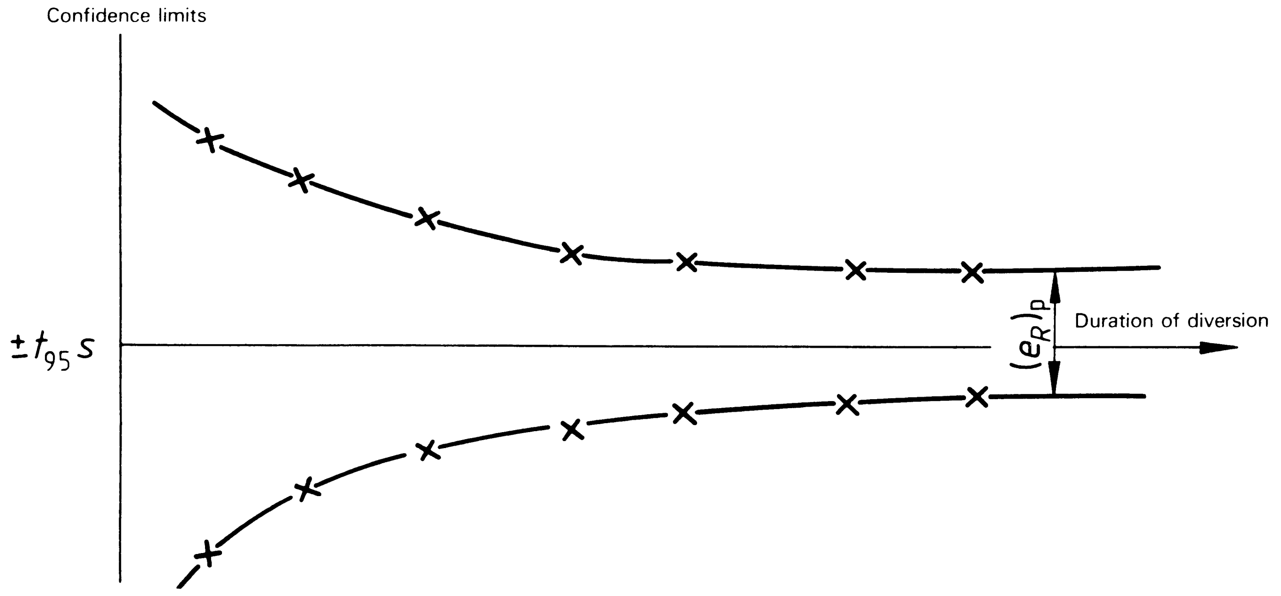

Figure 6 — Typical graph used in evaluation of $(e_R)_p$ for a diverter system

Hence, the relative systematic uncertainty, expressed in percentage terms, in a volume flow-rate measurement, E_s, is given by the following equation:

$$E_S = \pm\ 100 \times$$

$$\times \sqrt{2\left[\frac{(e_S)_V}{V}\right]^2 + 2\left[\frac{(e_S)_z}{V}\,\frac{\partial V}{\partial z}\right]^2 + \left[\frac{(e_S)_t}{t}\right]^2 + \left[\frac{(e_S)_p}{t}\right]^2}$$

The relative random uncertainty, expressed in percentage terms, at the 95 % confidence level is given by

$$(E_R)_{95} = \pm\ 100 \sqrt{2\left[\frac{(e_R)_V}{V}\right]^2 + \left[\frac{(e_R)_p}{t}\right]^2}$$

8.2.2 *Example of the calculation of uncertainty*

The example taken here is one using the static gauging method, in which a cylindrical volumetric tank collected a volume of 8 m^3 of water in 40 s, corresponding to a rise in the level of 2 m, and where the volume flow-rate of water is required.

The example considers only the sources of error listed in **8.1** and uses values of uncertainty for these sources of error which are characteristic of a high accuracy flow-rate measurement facility. It should be emphasized, however, that, in any particular case, calculation shall be carried out separately since other sources of error may exist and the values of uncertainty corresponding to any given source of error may vary.

8.2.2.1 *Systematic errors*

It is assumed that the procedures outlined in ISO 5168 have already been carried out in order to provide the values of systematic uncertainties which are used below.

The systematic uncertainty due to the tank, $(e_S)_V$, has been estimated in this particular case as ± 2 dm^3 in each of the two volume measurements, and thus

$$\sqrt{2}\,\frac{(e_S)_V}{V} = \pm\sqrt{2} \times \frac{2 \times 10^{-3}}{8} = \pm\ 0{,}035\ \%$$

The systematic uncertainty due to the gauge, $(e_S)_z$, in each of the two level measurements (taken with a hook gauge in a stilling well) characteristically has a value of ± 0,2 mm, and if it is assumed that the height-volume relationship is linear,

$$\sqrt{2}\,\frac{\partial V}{\partial z}\,\frac{(e_S)_z}{V} = \pm\sqrt{2} \times \frac{8}{2} \times \frac{0{,}2 \times 10^{-3}}{8} = \pm\ 0{,}014\ \%$$

The systematic uncertainty due to the timing device, $(e_S)_t$, is characteristically less than ± 1 ms, and thus

$$\frac{(e_S)_t}{t} = \pm\frac{10^{-3}}{40} = \pm\ 0{,}002\,5\ \%$$

The systematic uncertainty due to the diverter system, $(e_S)_p$, is characteristically ± 25 ms, and thus

$$\frac{(e_S)_p}{t} = \pm\frac{25 \times 10^{-3}}{40} = \pm\ 0{,}062\,5\ \%$$

8.2.2.2 *Random errors*

The confidence limits, at the 95 % confidence level, of the distribution of the level-volume calibration points about the best-fit curve are characteristically ± 0,05 %, and thus

$$\sqrt{2}\,\frac{(e_R)_V}{V} = \pm\sqrt{2} \times 0{,}05\ \% = \pm\ 0{,}07\ \%$$

The random uncertainty due to the diverter system, $(e_R)_p$, is characteristically ± 10 ms, and thus

$$\frac{(e_R)_p}{t} = \pm\frac{10 \times 10^{-3}}{40} = \pm\ 0{,}025\ \%$$

8.2.2.3 *Calculation of the overall uncertainty*

The relative systematic uncertainty, E_s, of the flow-rate measurement (see **8.2.1**) is

$$\begin{aligned} E_S &= \pm\sqrt{(0{,}035)^2 + (0{,}014)^2 + (0{,}002\,5)^2 + (0{,}062\,5)^2} \\ &= \pm\ 0{,}073\ \% \end{aligned}$$

NOTE It may be noted that this value would not be altered significantly if the systematic uncertainties due to the gauge and the timer were ignored.

The relative random uncertainty, $(E_R)_{95}$, in the flow-rate measurement (see **8.2.1**) is

$$\begin{aligned} (E_R)_{95} &= \pm\sqrt{(0{,}07)^2 + (0{,}025)^2}\ \% \\ &= \pm\ 0{,}074\ \% \end{aligned}$$

Thus the flow-rate measurement result may be presented as

$$q_v = \frac{8}{40} = 0{,}2\ \text{m}^3/\text{s}$$

with

$E_s = \pm\ 0{,}07\ \%$

$(E_R)_{95} = \pm\ 0{,}07\ \%$

The uncertainties are calculated in accordance with ISO 5168.

8.3 Presentation of results

The following equation

$$e_q = \left[\left(\frac{\partial q}{\partial x_1} e_1 \right)^2 + \left(\frac{\partial q}{\partial x_2} e_2 \right)^2 + \ldots + \left(\frac{\partial q}{\partial x_k} e_k \right)^2 \right]^{1/2}$$

where $\partial q/\partial x_1$, $\partial q/\partial x_2$, ..., $\partial q/\partial x_k$ are partial derivatives (see ISO 5168), should preferably be calculated separately for any uncertainties due to the random and systematic components of error. By denoting the contributions to the uncertainty in the flow-rate measurement from these two sources by $(e_R)_{95}$ and e_s respectively, when expressed in absolute terms, and by $(E_R)_{95}$ and E_s when expressed as percentages, the flow-rate measurement shall then be presented in one of the following forms:

a) Flow-rate q = ...

$(e_R)_{95} = \pm\ \delta q_1$ $\quad$ $e_s = \pm\ \delta q_2$

Uncertainties calculated in accordance with ISO 5168.

b) Flow-rate q = ...

$(E_R)_{95} = \pm\ \delta q_3\ \%$ $\quad$ $E_s = \pm\ \delta q_4\ \%$

Uncertainties calculated in accordance with ISO 5168.

An alternative, though less satisfactory, method is to combine the uncertainties arising from random and systematic errors by the root-sum-square method. Even then, however, it is necessary to evaluate $(E_R)_{95}$ (see **8.2.1**) for the random components, since the value of $(e_R)_{95}$ or $(E_R)_{95}$ shall be given. In this case, the flow-rate measurement shall be presented in one of the following forms:

c) Flow-rate q = ... $\pm\ \delta q_5$

$(e_R)_{95} = \pm\ \delta q_1$

Uncertainties calculated in accordance with ISO 5168.

d) Flow-rate q = ... $\pm\ \delta q_6\ \%$

$(E_R)_{95} = \pm\ \delta q_3\ \%$

Uncertainties calculated in accordance with ISO 5168.

Annex A Corrections to the measurement of filling time

(This annex forms an integral part of the standard.)

Experience has shown that for a well-designed system the switching error for one start-stop cycle of the diverter may correspond to an error of less than 0 to 10 ms. This error is dependent on the flow-rate, the velocities of traverse in each direction of the diverter tip through the liquid stream, and the exact location of the timer actuator with respect to the liquid stream emerging from the nozzle slot. The switching error shall not be assumed *a priori* to be insignificant, but shall be evaluated by experimental tests, using one of the procedures described in clauses **A.1** and **A.2**.

A.1 Static gauging method

A.1.1 *Method 1*

A steady flow-rate is established using the control valve and a standard test run is made to determine the flow-rate. Then a series of short flows, or bursts of flow (as many as 25 bursts), is deflected into the volumetric tank without resetting the timer or the level gauge to zero; the flow-rate is then determined from the sum-total volume and sum-total time. To complete the run, a second standard determination is made of the steady flow-rate, and the average of the two normally measured flow-rates is compared with the sum-total flow-rate determination.

If the sum-total volume for n bursts is about equal to that of a standard run, it can be shown that the average timing error Δt due to timer control for one cycle is almost equal to

$$\frac{\Delta t}{t} = \frac{1}{n-1}\left[\frac{q}{q'}\,\frac{\sum_{1}^{n} \Delta V_i \Big/ \sum_{1}^{n} t_i}{(V_1 - V_0)/t} - 1\right]$$

where

$(V_1 - V_0)/t$ is the average flow-rate determined by the normal procedure;

$\sum_{1}^{n} \Delta V_i \Big/ \sum_{1}^{n} t_i$ is the flow-rate determined from the sum-total volume and sum-total time for n bursts;

q and q' are the flow-rates during the normal runs and during the n bursts respectively, as measured by a self-contained flowmeter in the flow circuit; the correction q/q' takes into account flow-rate variations, if any, between the measuring runs.

After this procedure has been repeated over a wide range of flow-rates, it will be possible, on any further measurement, to correct the measured filling time by the value of Δt determined thus.

A similar method may be used for calculating the volumetric error introduced by valve operation for the method described in clause **D.3**, Annex D.

A.1.2 *Method 2*

The following alternative method of setting the diverter timer actuator may also be used.

First, set the normal flow-rate control mechanism of the hydraulic circuit to give a flow-rate close to the maximum flow-rate capability of the system, with a good quality flowmeter in the circuit. Run the system in this state for several hours, during which time take many successive measurements of flow-rate using different diversion times. Suggested times are as follows: "normal", and 20 %, 10 % and 5 % of "normal". The highest number of tests is required at the 5 % of "normal" (or long) time interval, with the lowest number of tests at the "normal" diversion time. During each of these tests, the average reading on the flowmeter shall be recorded as accurately as possible.

The results obtained shall be transferred to the following equation, in which Δt is the required timing error of the diverter system:

$$\Delta t\left(\frac{1}{t_q} - \frac{1}{t_Q}\right) = \frac{(q - Q) - (\bar{q}_t - \bar{Q}_t)}{Q}$$

where

t_q is the diversion time for a particular "short" test;

t_Q is the diversion time for a "normal" length test occurring nearest chronologically in the testing sequence to the test chosen above;

q is the flow-rate calculated for a particular diversion time, t_q;

Q is the flow-rate calculated for a "normal" diversion time, t_Q, occurring nearest chronologically in the testing sequence to the test chosen above;

$\overline{q_t}$ is the average reading during the time t_q;

$\overline{Q_t}$ is the average reading during the time t_Q.

The values obtained for the right-hand side of this equation shall be plotted against $(1/t_q - 1/t_Q)$, as shown in Figure 7. The points should define a straight line of gradient Δt which passes through the origin.

If a significant value of Δt is obtained, the diverter timer actuator should be adjusted to minimize the value of the error as shown by repeated testing.

The procedure shall be repeated at a few lower flow-rates to ensure that the value of Δt obtained is not significantly dependent on the flow-rate. If significant changes in the Δt value are obtained, it will be necessary to improve the operation of the diverter system or to introduce a variable correction time Δt to be applied to the diversion time.

A.1.3 *Method 3*

The following method may be used when the diverter either starts or stops the timer under conditions different from those specified in **5.2**.

Figure 8 illustrates the filling of a volumetric tank when the flow-rate is measured using a diverter system. The timer may be started at various points such as 1 or 4, and stopped at points 5 or 8.

Sections 1 – 2 – 3 – 4 and 5 – 6 – 7 – 8 represent the durations of the transient movements of the diverter when the flow is switched to and from the measuring tank (time t_1 for "by-pass to tank" and time t_2 for "tank to by-pass").

Section 3 – 6 represents the filling time with a steady flow-rate.

Sections 2 – 9 and 12 – 7 represent, respectively, the variations in the flow-rate through the diverter when diverting the liquid to the tank and to the by-pass.

Section 9 – 12 shows the actual flow-rate through the measuring installation.

Sections 1 – 2, 9 – 10, 11 – 12 and 7 – 8 represent the idle travel of the diverter.

The circuit shown in Figure 9 may be used to determine the correction Δt due to the switching time difference of the diverter. The switches K_1 and K_2 are in the T_1 position to measure the switching time t_1, when the flow is switched from by-pass to the tank. Displacement of the beam A, rigidly connected to the diverter control (e.g. the lever of a spring mechanism), closes contacts 2 and 6, thus actuating the electronic timer. Closing contacts 1 and 4 stops the timer. Switches K_1 and K_2 are in the T_2 position to measure the switching time t_2. Displacement of the beam B closes the contacts 1 and 3, thus actuating the timer, which stops when contacts 2 and 5 close.

Take a series of 10 measurements of the diverter switching times t_1 and t_2. Then determine the mean values $\overline{t_1}$ and $\overline{t_2}$ from which the correction $\Delta t = \overline{t_1} - \overline{t_2}$ is calculated.

A.2 Dynamic gauging method

The level measuring system in the volumetric tank is used to control the starting and stopping of the timer. Such a system has a characteristic systematic error due to the switching time difference of the level sensors.

Figure 10 is based on the assumption that level sensors switch the timer only when submerged by the rising liquid.

In Figure 10

t_{ac} is the actual filling time of the volume V;

t_m is the measured filling time of the volume V;

t_{low} is the switching delay for the lower level sensor (timer is started at 1′);

t_{up} is the switching delay for the upper level sensor (timer is stopped at 2′);

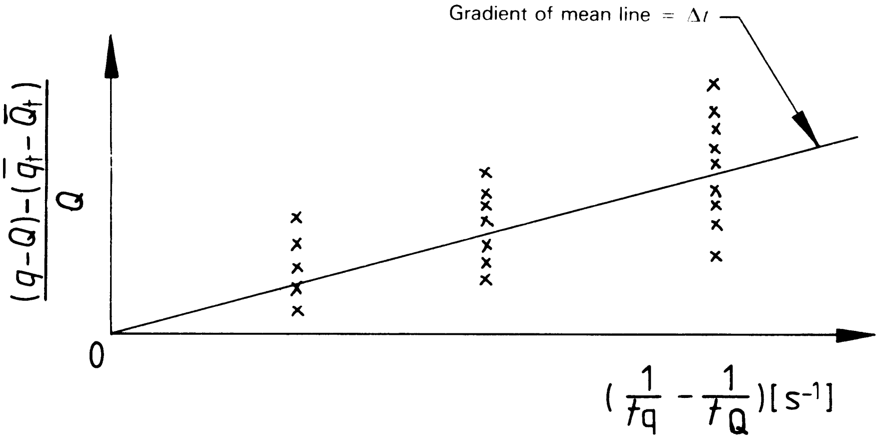

Figure 7 — Graph with plotting of results of diverter timer actuator tests, as given in A.1.2

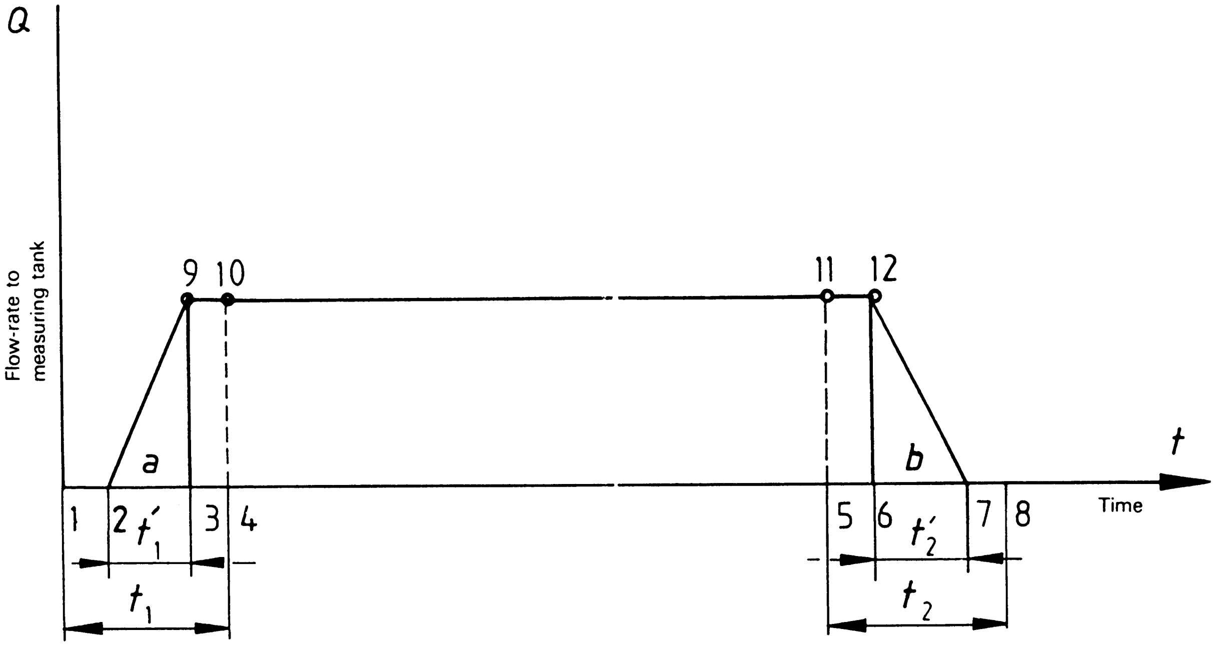

Figure 8 — Graph of the filling process for the measuring tank

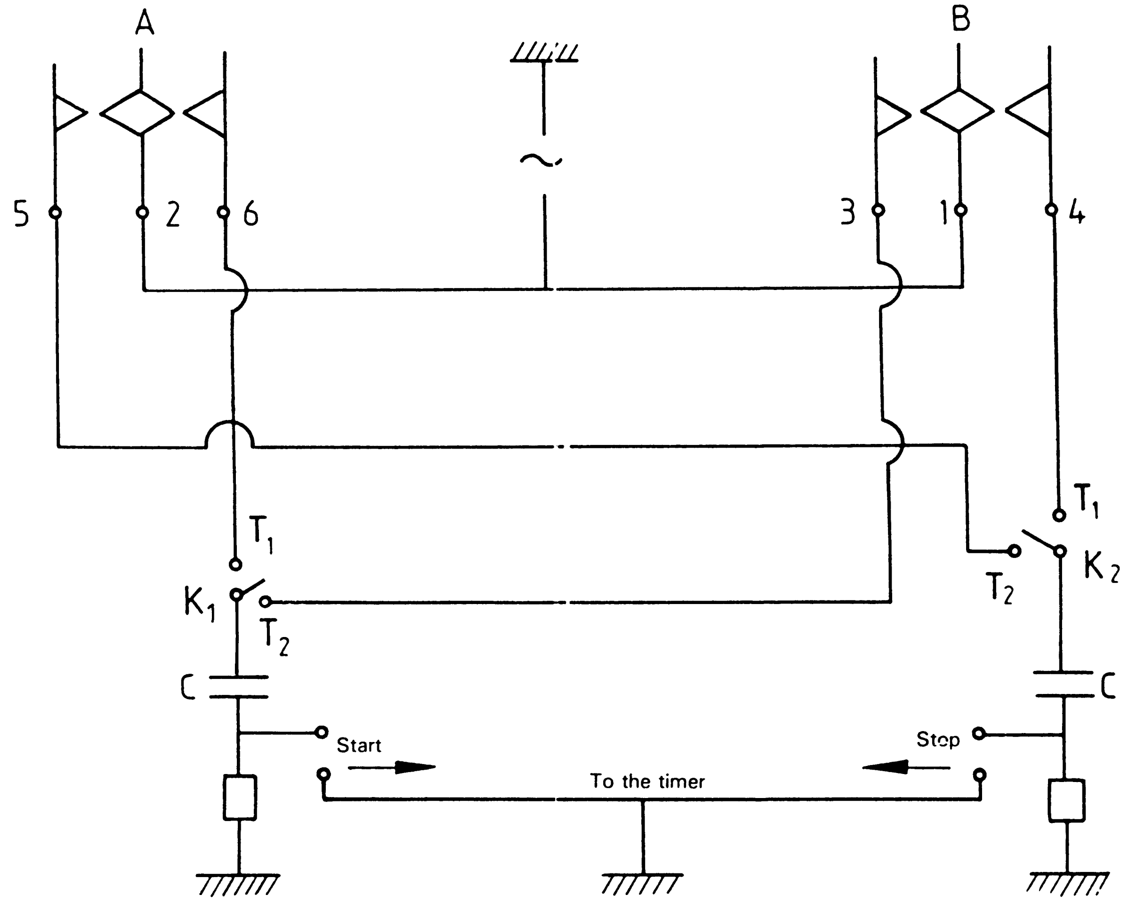

Figure 9 — Diagram of system for measuring the switching time and switching time difference of the diverter

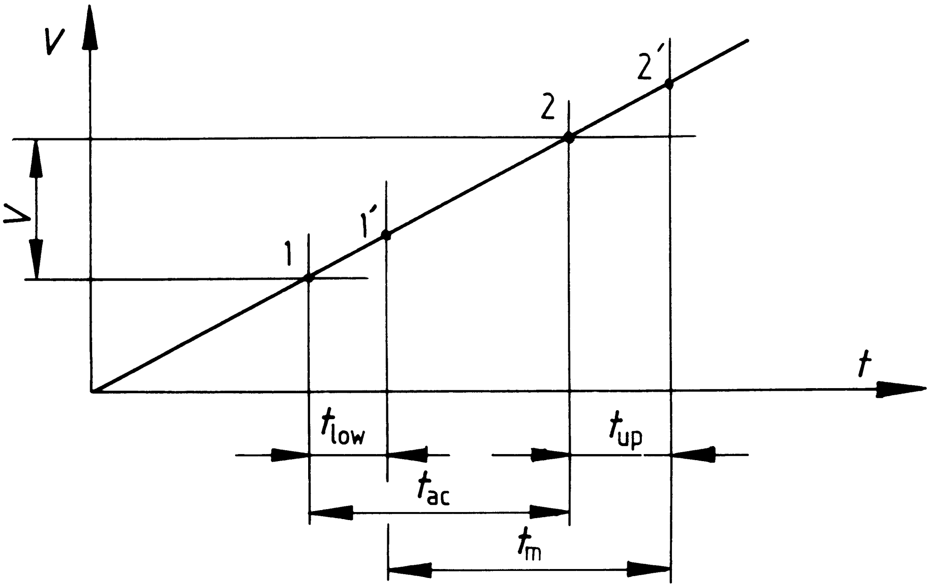

Figure 10 — Graph of volume collected against time at constant flow-rate

It is clear that

$$t_{ac} - t_{low} = t_m - t_{up}$$

from which

$$t_{ac} = t_m + (t_{low} - t_{up})$$

thus

$$\Delta t = (t_{low} - t_{up})$$

is the correction to the measured filling time of the tank.

The switching time difference of the level sensors can be evaluated using one of the following methods:

a) the level sensors are set at the same level and the rising liquid is used to trigger them both simultaneously;

b) the level sensors are both driven down together to contact the static liquid.

The timer is used to measure any time difference between points 1′ and 2′ (which in these cases, should coincide) and hence to measure Δt directly.

Alternatively, method 2 described in **A.1.2** may be used to determine Δt.+

Annex B Density of pure water at standard atmospheric pressure of 101,325 kPa

(This annex does not form an integral part of the standard.)

Table 2

Temperature °C	Density kg/m³	Temperature °C	Density kg/m³
0	999,84	18	998.59
2	999,94	20	998.20
4	999,97	22	997.77
6	999,94	24	997.30
8	999,85	26	996.78
10	999,70	28	996.23
12	999,50	30	995.65
14	999,24	32	995.03
16	998,94	34	994.37

Annex C Example of a volumetric flow-rate installation using the dynamic gauging method

(This annex does not form an integral part of the standard.)

Figure 2 shows details of an installation using the dynamic gauging method.

The measuring chamber is a vertical cylinder of reduced height located in, and rigidly fastened to the bottom of, the measuring tank filled with liquid.

The working liquid which is under pressure in the storage tank is fed by a pump to the flow stabilizer. Then the liquid goes through the test run to the outer annulus of the measuring tank, and then to the measuring chamber over its upper wall.

Displacement devices are situated in the measuring chamber.

These diminish the cross-sectional area of the chamber in the level indication zones. Each displacement device has a longitudinal channel to locate the sensing elements of the level gauge which control the timer.

During the operation of such an installation, the wall of the measuring chamber is under double-sided pressure. This reduces any deformation of the chamber thus making any change in volume minimal. The difference in pressure between the flow stabilizer and the tank shall not exceed the maximum head lift of the pump. This will allow the use of a low-pressure pump when working at high pressure.

Annex D Example of a volumetric flow-rate installation using the standing start and finish method

(This annex does not form an integral part of the standard.)

D.1 Principle

Figure 11 shows details of a volumetric installation using the standing start and finish method.

Liquid is pumped through the flowmeter under test, via a stop-valve, into a volumetric tank. A typical design for such a tank is illustrated in Figure 12. The stop-valve shall be sited downstream of the meter under test to reduce the possibility of cavitation.

The volumetric tank is calibrated using a graduated delivery vessel for filling so that the reading of the liquid level in the sight tube can be related to the actual volume of liquid in the tank. The final volume is obtained by reading from a graduated scale alongside this sight tube. Sufficient time should be allowed for any entrapped air (this may occur especially during very rapid filling of the tank) to disperse through the open vent at the top of the tank before taking readings. The zero point is established by allowing the tank to drain initially to a major weir and then by opening valve C (see Figure 12) to a minor weir situated inside a sight glass, thus establishing a constant position at the start of each test.

Again sufficient time should be allowed for the test liquid to drain from the interior walls of the volume tank. (Such tanks are not therefore normally used with viscous oils, and the calibration liquid shall have a viscosity similar to that of the liquid with which the volumetric tank is subsequently to be used.)

The flow-rate as indicated by the meter during the test is then compared to the calculated mean flow-rate obtained from the readings of volume of liquid in the measuring tank together with the filling period measured by the timer (see **4.1.1**).

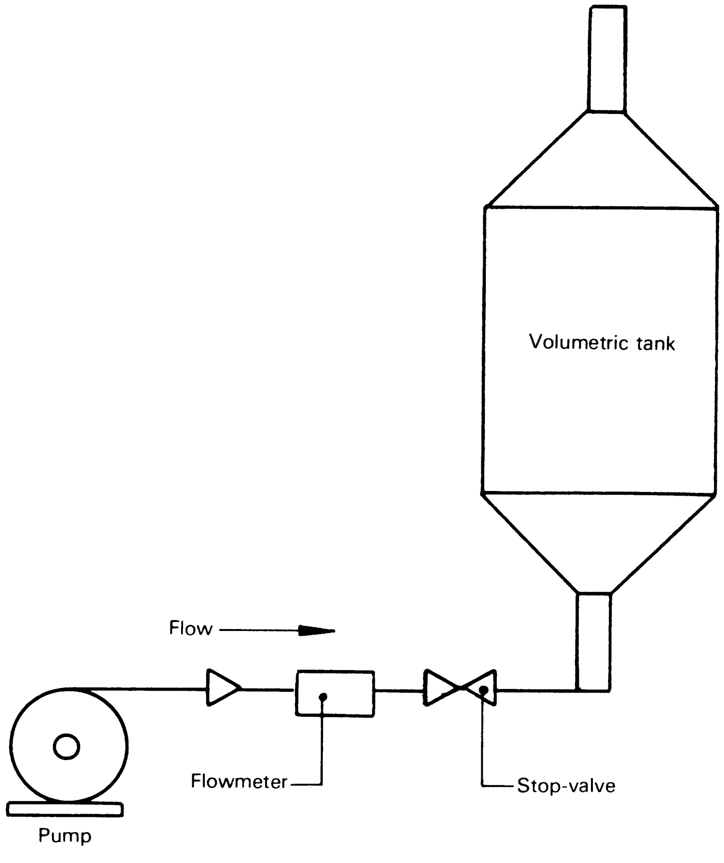

Figure 11 — Schematic diagram of a volumetric installation using the standing start and finish method

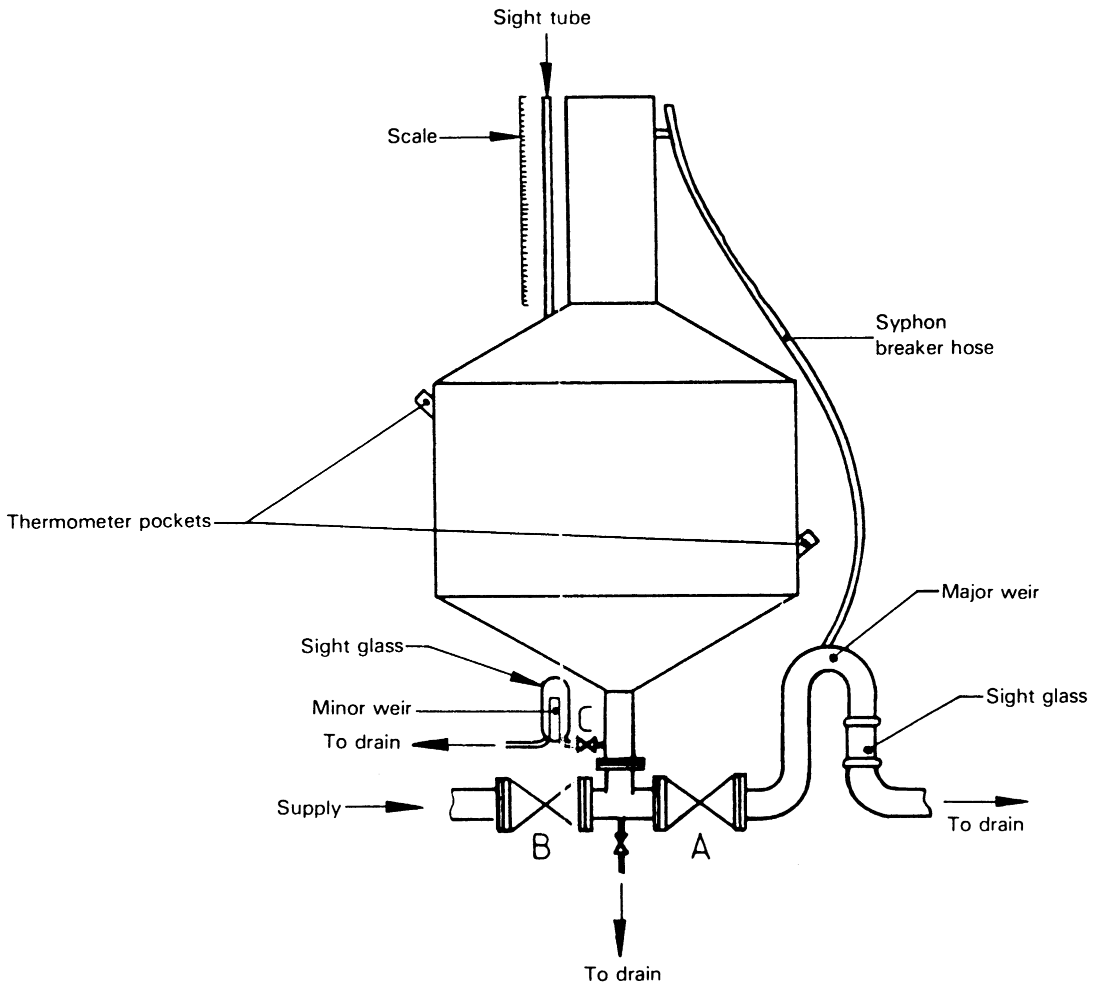

Figure 12 — Design of volumetric tank

D.2 Procedure

At the start of the test, the pipework from the pump through the meter under test and the stop-valve to the volumetric tank shall be completely full of liquid up to the zero point of the minor weir as described in clause **D.1**. At the same time, the pump shall be running. Having noted the initial reading of the meter under test or, alternatively, having set the reading to zero, open the stop-valve B as rapidly as possible and then close it as rapidly as possible when the level of liquid in the volumetric tank reaches the upper neck and a level reading in the sight tube can be taken. This may be carried out automatically using a photocell device or using a device connected to the meter under test.

It is an advantage to use as large a tank as possible in conjunction with a very fast-acting valve. An automatic timer coupled to the open and shut positions of the valve shall be used to measure the time interval (see **5.2**). Only when the valve is fully open is the flow-rate constant, and the meter operates under a reduced flow-rate during the period when the valve is opening or closing.

NOTE Since a positive displacement type of flowmeter is not particularly sensitive to changes in flow-rate, the effect on the readings of such a meter during these relatively short periods may be negligible. Hence, if desired, such a meter may be used as a secondary reference meter in the flow circuit.

Should any error in the flow-rate measurement, arising from the operation of the valve, be considered to be significant, then a correction should be made in accordance with one of the following methods.

D.3 Corrections to the volume measurement

Using a good quality highly accurate meter (such as the flowmeter described in clause **D.2**) in the circuit, the stop-valve is continuously opened and closed for as long as possible, until a suitable sum-total volume reading can be taken (a minimum of 25 short flows or bursts of liquid is recommended). A mean reading may then be established for the volume of liquid entering the tank during the opening and closing of the valve. As shown in Figure 13, the flow-rate of liquid entering the tank builds up from zero to a constant value, remains steady for a period and then falls back to zero. By rapidly, and successively, opening and closing the valve, the volumes AEB and DFC can be established. This procedure is repeated at various flow-rates over the operating range of the system. By this means, it is possible to compensate for any error introduced by the opening and closing of the valve using a method similar to that given in Annex A, but where the valve takes the place of the diverter mechanism.

NOTE In practice, if the times for opening and closing of the valve are very short in comparison with the long time period required to fill the tank, the error may be found to be negligible.

An alternative method, again using a good quality highly accurate flowmeter (such as a positive displacement meter giving an output of a relatively large number of pulses per unit volume), may be used. Using a high speed chart recorder reading the output from the meter, a trace of flow-rate against time is taken by performing a series of tests at flow-rates up to the maximum required for calibration purposes. From these traces, the volume correction factors are established. The lowest operational flow-rate is chosen such that the areas AEB and DFC are still very small in relation to area EFCB. The volume correction factor for each run may be determined from the sum of individual corrections over a number of intervals during the periods A – E and F – D, simply by multiplying the average flow-rate during that interval by the time interval involved.

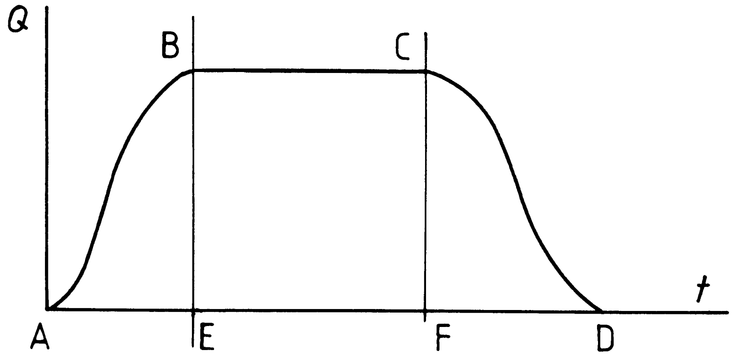

Figure 13 — Diagram of the flow-rate of liquid entering the tank

Annex E Student's *t*-distribution

(This annex does not form an integral part of the standard.)

The "Student's *t*-distribution" for small samples should be used to determine the uncertainty at the 95 % confidence level as described below.

a) If n is the number of measurements, $v = (n - 1)$ is taken as the number of degrees of freedom.

b) Obtain the value of t for the appropriate number of degrees of freedom v from Table 3.

c) Calculate the standard deviation, s_X, of the distribution of the measurements of the quantity X.

d) The range of values within which the true value would be expected to lie with 95 % confidence relative to a new reading X is $X \pm ts_X$.

e) The range of values within which the true mean would be expected to lie with 95 % confidence is $\bar{X} \pm ts_X/\sqrt{n}$.

Table 3

Number of degrees of freedom $v = n - 1$	95 % Confidence level	
	t	$t/\sqrt{n}$
1	12,706	8,984
2	4,303	2,484
3	3,182	1,591
4	2,776	1,241
5	2,571	1,050
6	2,447	0,925
7	2,365	0,836
10	2,228	0,672
15	2,131	0,533
20	2,086	0,455
30	2,042	0,367
60	2,000	0,256
∞	1,960	0

Annex ZA (normative)
Normative references to international publications with their relevant European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

Publication	Year	Title	EN	Year
ISO 4006	1991	*Measurement of fluid flow in closed conduits — Vocabulary and symbols*	EN 24006	1993
ISO 4185	1980	*Measurement of liquid flow on closed conduits — Weighing method*	EN 24185	1993

List of references

See national foreword.

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