INTERNATIONAL STANDARD

ISO 8316

First edition 1987-10-01

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION
ORGANISATION INTERNATIONALE DE NORMALISATION
МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

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

Mesure de débit des liquides dans les conduites fermées — Méthode par jaugeage d'un réservoir volumétrique

Reference number
ISO 8316 : 1987 (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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8316 was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Printed in Switzerland

Contents

This page intentionally left blank

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

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. Annexes B to 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	*	*
E_R	Random uncertainty, as a percentage	—	—
e_S	Systematic uncertainty, in absolute terms	*	*
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	ML^{-3}	kg/m^3

* 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.

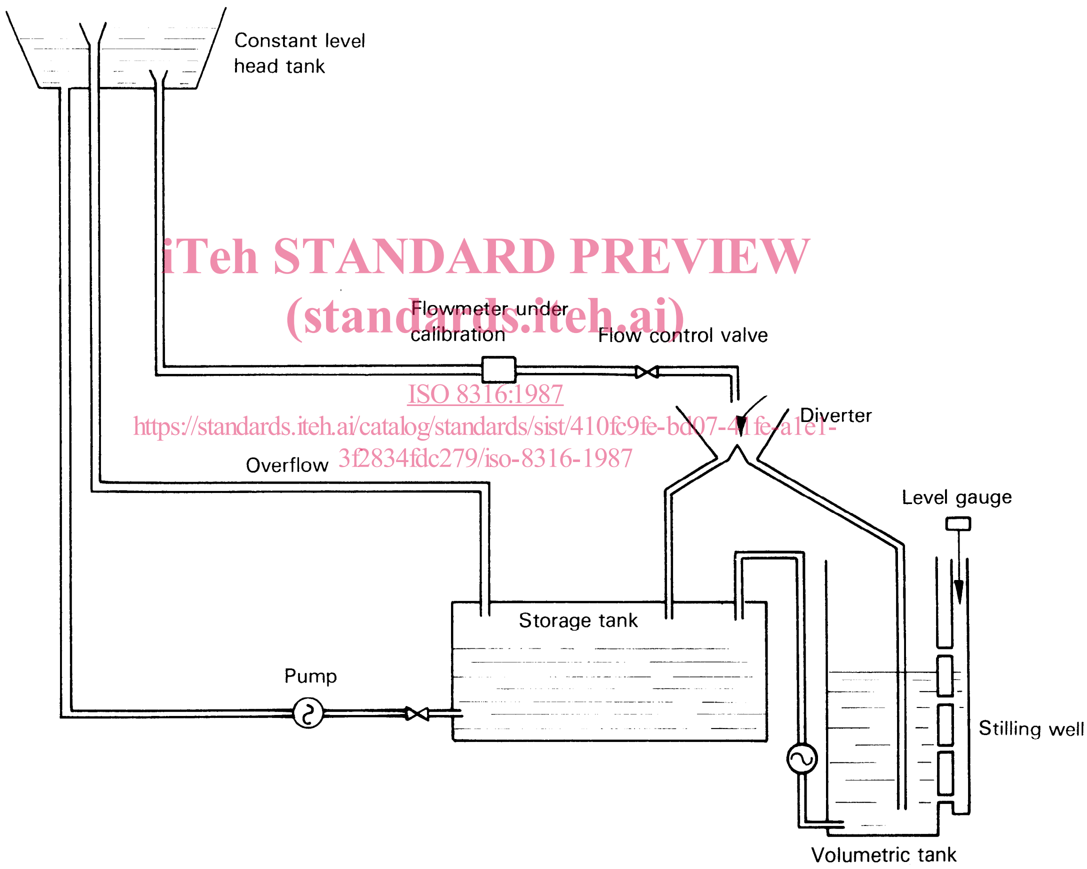

Figure 1 — Schematic diagram of a volumetric flow-rate installation using the static gauging method

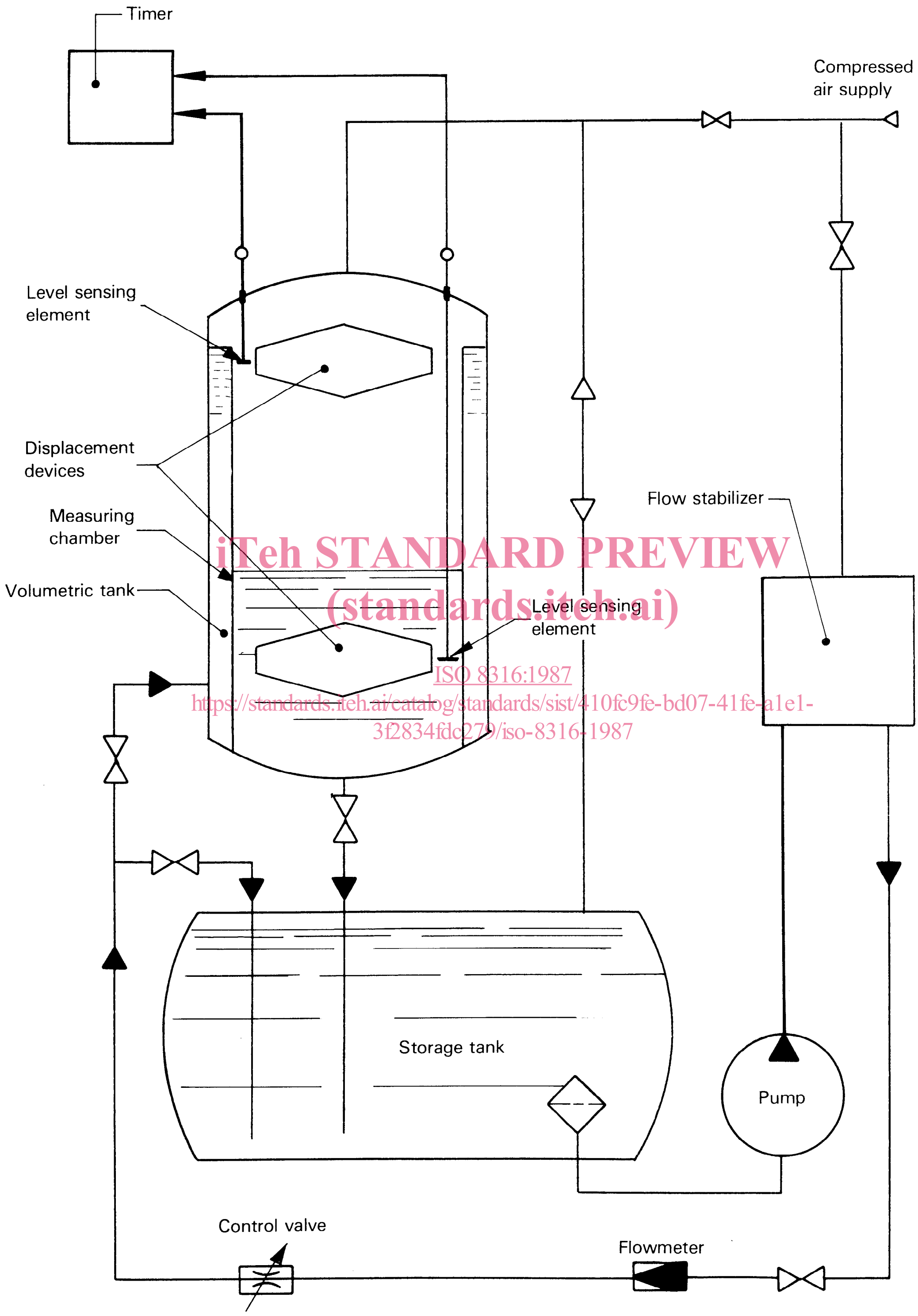

Figure 2 — Schematic diagram of a volumetric flow-rate installation using the dynamic gauging method

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.

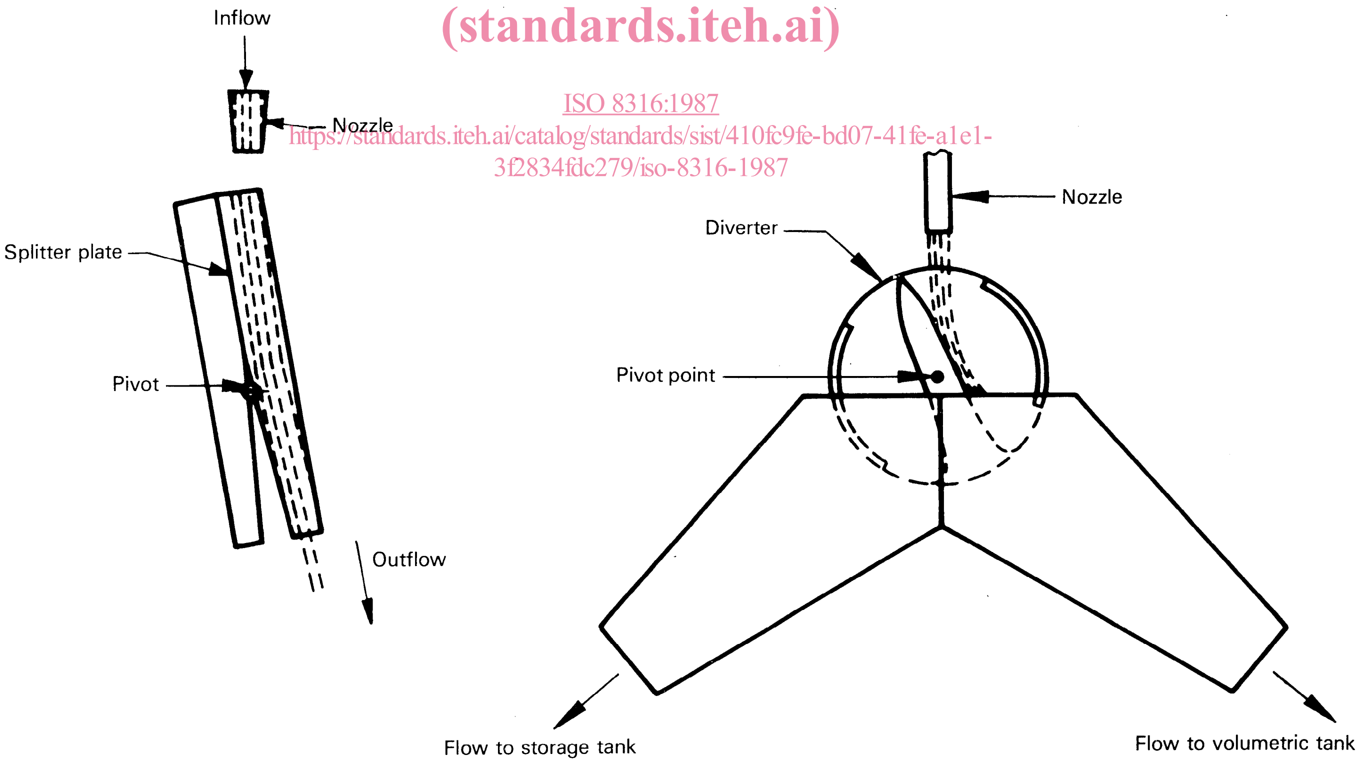

Figure 3 — Examples of diverter design

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.

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.

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.

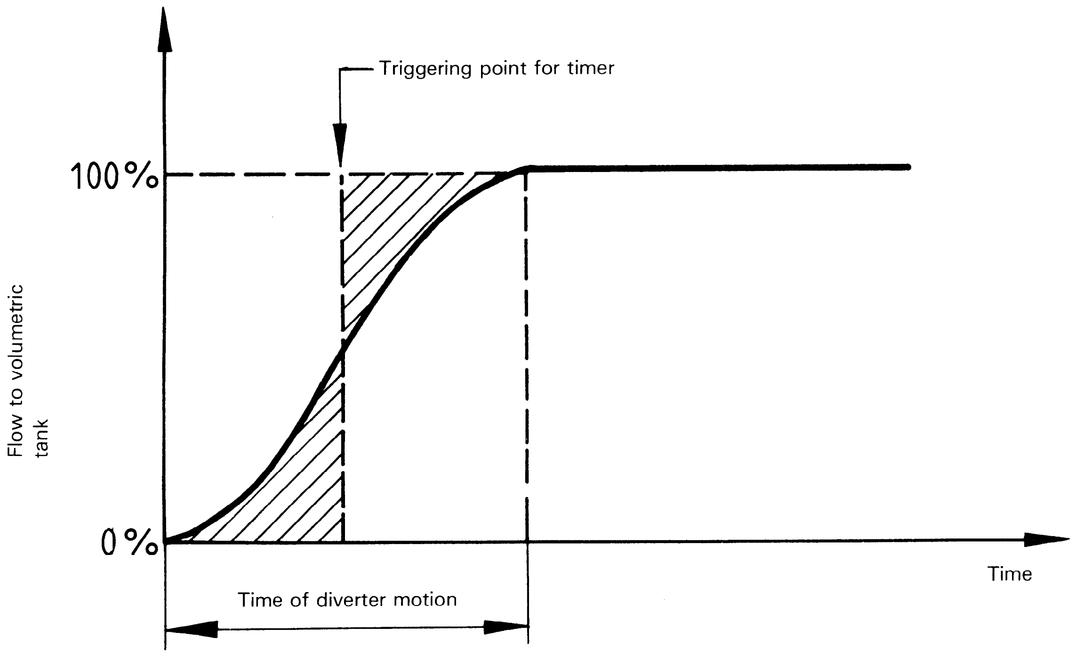

Figure 4 — Operating law of diverter

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.