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Petroleum and liquid petroleum products — Tank calibration by liquid measurement — Incremental method using volumetric meters

Pétrole et produits pétroliers liquides — Jaugeage des réservoirs par épalement — Méthode par empotement utilisant des compteurs volumétriques

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 4269 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 3, *Static petroleum measurement*.

Annex A forms a normative part of this International Standard. Annex B is for information only.

Introduction

This International Standard forms part of a series on tank calibration including the following:

ISO 7507-1, ISO 7507-2, ISO 7507-3, ISO 7507-4, ISO 7507-5, ISO 7507-6, ISO 8311, ISO 9091-1 and ISO 9091-2.

Liquid calibration methods may be used in the calibration of either the total or partial capacity of a tank. A high degree of accuracy may be obtained provided that great care is taken at all stages of the operation. The method is particularly useful where tanks are of irregular shape, for the calibration of the bottom of any storage tank, or for the calibration of ship and barge tanks having irregular cross sections.

The method offers a degree of accuracy which may exceed other methods when used in the calibration of small tanks, especially small horizontal cylindrical tanks.

The calibration liquid may be either water or a suitable petroleum product having a low volatility and viscosity. Water is recommended where wide temperature variations are expected during calibration as water has a low coefficient of cubical expansion. However, the use of water may introduce unacceptable risks and difficulties depending on the use to which the tank being calibrated is to be put (e.g. the use and subsequent removal of water when used in the calibration of underground storage tanks at retail sites). In such circumstances the use of a suitable petroleum product would be preferable.

Petroleum and liquid petroleum products — Tank calibration by liquid measurement — Incremental method using volumetric meters

1 Scope

This International Standard specifies a method for the calibration of tanks by addition of batches of liquid. The liquid is used as a volume-transfer medium, measured accurately by means of a meter.

This International Standard is not applicable to the calibration of reference measuring instruments, proving tanks, or meter provers.

NOTE Applicable standards are given in the bibliography.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 91-1:1992, *Petroleum measurement tables — Part 1: Tables based on references temperature of 15 °C and 60 °F*.

ISO 91-2:1991, *Petroleum measurement tables — Part 2: Tables based on a reference temperature of 20 °C*.

ISO 2714:1980, *Liquid hydrocarbons — Volumetric measurement by displacement meter systems other than dispensing pumps*.

ISO 2715:1981, *Liquid hydrocarbons — Volumetric measurement by turbine meter systems*.

ISO 4268, *Petroleum and liquid petroleum products —Temperature measurements — Manual methods.*

ISO 7507-1:1993, *Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks — Part 1: Strapping method*.

ISO/TR 7507-6:1997, *Petroleum and liquid petroleum products — Calibration of vertical cylindrical tanks — Part 6: Recommendations for monitoring, checking and verification of tank calibration and capacity tables*.

ISO 9770:1989, *Crude petroleum and petroleum products — Compressibility factors for hydrocarbons in the range 638 kg/m³ to 1074 kg/m³*.

IEC 60079-10, *Electrical apparatus for explosive gas atmospheres — Part 10: Classification of hazardous areas*.

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 7507-1, and the following, apply.

3.1
K-factor
number of pulses generated by a meter per unit of volume passing through it

3.2
pre-set device
equipment which shuts off the delivery of calibration liquid to the meter after a predetermined volume has passed through the meter

4 Precautions

4.1 The general precautions and safety precautions in ISO 7507-1 and IEC 60079-10 shall apply to this International Standard.

4.2 When a petroleum product is used as the calibration liquid, the following additional safety precautions, which are not exhaustive, shall be observed:

a) control of sources of ignition;

b) prevention of electrostatic accumulation by

1) the correct bonding of transfer hoses,

2) control of pumping speeds,

3) prevention of free fall and splashing of liquid,

4) maintenance of the velocity of the liquid in the line below 1 $ms^{–1}$ until the end of the filling pipe is submerged.

5 Meters

5.1 General specifications

5.1.1 The meter shall be of the positive displacement or turbine type.

5.1.2 The meter shall be fabricated from materials suitable for the calibration liquid to be used.

5.1.3 The meter shall be selected so that the flow rate, at which the meter will operate during the tank calibration, is within the linear range of the meter factor curve of the meter.

The meter should either be fitted with a flow-rate indicator, or average flow rates should be calculated by timing deliveries by means of a stop watch.

5.1.4 The meter shall have either a device giving a read-out in volumetric units or an electronic pulse counter used to calculate volume.

To enable the required repeatability to be determined during the proving of the meter, and depending on the volume passed by the meter during such proving, a special counter or other indicator capable of being read to a fraction of the unit of volume should be provided.

5.1.5 A volumetric proving tank, a pipe prover or a small volume prover, suitable for use with the type of meter chosen, shall be provided for calibrating the meter. The selected apparatus shall be provided with a calibration certificate showing any corrections which may be required when in use.

5.1.6 A thermowell (thermometer pocket) shall be provided in the metering system adjacent to the meter.

To ensure adequate immersion and thermal response, and to avoid undesirable thermal conduction effects from the pipe wall, it is recommended that, particularly in the case of small diameter lines, the pocket should be installed in the body of the meter if a positive displacement meter is used. If a turbine meter is used, then the thermowell shall be installed in the pipework at least five pipe diameters downstream of the meter position. The thermowell should be in direct contact with the calibration liquid and should be filled with a light oil to aid thermal response. The thermowell, and the fitting in which the sensitive element of the thermometer is immersed, should be designed in accordance with sound thermo-technical principles. It may be desirable to provide external insulation round the pipe or fitting at the position of, and adjacent to, the thermowell.

5.1.7 A rapid operating valve or shut off device shall be installed downstream of the meter (see 6.4.5).

5.2 Positive displacement meters

The meter factor shall not deviate by more than ± 0,20 % from the average meter factor between 10 % and 100 % of the maximum rated flow rate of the meter.

5.3 Turbine meters

5.3.1 The K-factor shall not deviate by more than ± 0,20 % between 10 % and 100 % of the maximum capacity of the meter.

5.3.2 A back pressure in excess of 100 kPa (gauge) shall be applied in order to prevent cavitation.

5.4 Selection of meter

5.4.1 The selection of a meter for tank calibration is contingent on the following:

a) the operating rate of flow to be used when calibrating the tank (see 5.4.4);

b) the maximum pressure to which the meter will be subjected;

c) the liquid which the meter is required to measure (see 5.1.2);

d) the temperature range over which the meter will operate;

e) the range of viscosities over which the meter will operate.

5.4.2 Meters incorporating a temperature compensator shall not be used for tank calibration.

5.4.3 The meter shall be provided with a meter factor or K-factor curve (error–flow curve) for the type of liquid, viscosity, temperature and range of flow rates over which it will be used.

5.4.4 The repeatability of the meter shall be such that the results of five consecutive proving runs shall be within a range of ± 0,025 % of the average after correcting for temperature, pressure and viscosity.

5.4.5 Meters shall be installed and operated in accordance with the appropriate recommendations contained in ISO 2714 or ISO 2715.

6 Apparatus

6.1 Dip-tape and dip-weight

This shall be as specified in ISO 7507-1:1993, B.6 and B.7.

6.2 Ullage paste

NOTE The term "oil-finding paste" is synonymous.

6.3 Water-finding paste

6.4 Ancillary equipment

6.4.1 Air/vapour separator

An air separator, when utilized, shall be fitted upstream of the meter.

A back-pressure valve may be required to maintain an adequate pressure drop across the air release valve fitted to the air separator.

6.4.2 Flow limiter

A flow limiting device shall be fitted in the line, downstream of the meter, to limit the rate of flow if the pressure of the calibration liquid supply is such that the flow rate through the installation is too great for the rated capacity of the meter.

6.4.3 Pre-set device

The pre-set device should be leak proof and operate quickly with a smooth action, without causing any undue pressure surge.

6.4.4 Pressure gauge

Where a positive displacement meter is used, a pressure gauge shall be mounted in the line as close to the meter as possible, preferably on the downstream side. Where a turbine meter is used, a pressure gauge shall be installed at least five pipe diameters downstream from the meter. It may be preferable that two pressure gauges are installed equidistant from the meter upstream and downstream

6.4.5 Shut-off valve

The valve shall be leak proof, and shall operate quickly with a smooth action and without causing an undue pressure surge.

If a pre-set device is not fitted, a shut-off valve, to shut off the flow at the required intervals, shall be installed downstream of the meter.

6.4.6 Strainer

6.4.7 Surge suppressor

If surge pressures are likely to occur, a suitable surge suppressor should be fitted to the line.

6.4.8 Syphon breaker

If fitted, the syphon breaker shall be downstream of the meter as close to the delivery point as is possible.

When a tank is being calibrated by top filling, then the syphon breaker should be installed in conjunction with a weir. The assembly should be fitted at the highest point in the system.

6.4.9 Viewing glass

A viewing glass shall be provided adjacent to/in the air separator if utilized.

6.4.10 Weir

If installed, the weir shall be positioned in such a way as to ensure that the delivery pipe downstream of the meter is full at all times.

7 Calibration procedure

7.1 General requirements

7.1.1 A tank shall only be calibrated after it has been filled at least once with a liquid of density equal to or greater than that which it will hold when in use.

NOTE The hydrostatic test applied to new or repaired tanks will satisfy this requirement in most cases.

7.1.2 Before commencing calibration, the system shall be checked for leakage downstream of the meter. Any leaks found shall be eliminated.

7.1.3 The serial numbers, or identification marks, of thermometers used in the course of calibration shall be recorded together with their location during the calibration. The thermometers shall be calibrated in accordance with ISO 4268 and shall be provided with a certificate showing corrections.

7.1.4 Care shall be exercised to avoid the ingress of air into the system when using a meter to calibrate a tank.

It is important that the meter, ancillary equipment and lines be liquid filled before the commencement of calibration.

7.1.5 If fitted, a strainer/filter shall be installed in the line upstream of the meter to protect the meter from abrasion or other damage from entrained foreign matter.

7.1.6 If the variation of the volume of calibration liquid in the hose connecting the meter to the tank, compared with the total volume of liquid in the tank, is such that the accuracy of the calibration would be significantly affected, a syphon breaker shall be placed at the end of the hose to ensure that the hose remains filled with a constant quantity of liquid.

7.1.7 Excessive variations in the temperature of the calibration liquid shall be avoided if the required accuracy is to be maintained.

Large fluctuations make it difficult to determine an accurate mean temperature and this in turn causes the following:

a) uncertainties in applying the volume correction factors to the liquid;

b) uncertainties in applying the correction factor for the expansion/ contraction of the measuring equipment;

c) uncertainties in applying the correction factor for the expansion/ contraction of the tank being calibrated.

7.1.8 An adequate supply of the calibration liquid shall be available. The pressure available shall be sufficient, at all times, to maintain stable flow rates within the normal operating range of the meter.

7.1.9 If a petroleum product is used as the calibration liquid, its depth in the tank shall be measured with product-finding paste applied in a smooth even film to the dip-tape and dip-weight.

7.1.10 If water is used as the calibration liquid, its depth in the tank shall be measured with water-finding paste applied in a smooth even film to the dip-tape and dip-weight.

7.1.11 The exact height of the upper reference point above the dip-point shall be determined at the time of calibration. The overall dipping height shall be marked on the roof of the tank at or near to the dip hatch to which it applies.

In tanks with a single dip point, the upper reference point shall be clearly marked on the tank and its height above the dipping datum point shall be recorded at the head of the table. In tanks with more than one dip point, the overall height at each dip point shall be clearly marked adjacent to the point. This measurement may require adjustment to correct for the difference between the actual and the certified reference temperature of the dip-tape and dip-weight used to measure the overall dipping height. The correction shall be calculated in accordance with the equation given in A.3.

7.1.12 If the calibration of the tank is interrupted, it may be resumed at a later date provided that

a) if there is a change of equipment or personnel, sufficient check measurements are made to ensure that the results obtained prior to the changes correspond within the tolerances laid down in this method,

b) all records of work previously carried out are complete and legible, and

c) the new liquid mean temperature and depth at resumption of operations are recorded.

7.2 Equipment

The calibration of a tank may not necessarily require all of the equipment listed in clause 6. The requirements for each operation shall be considered before selecting equipment.

7.3 Installation

7.3.1 Figure 1 shows a schematic diagram of a typical installation for calibration by meter.

7.3.2 Attention shall be paid to pipework to ensure minimum pressure drop and turbulence.

Any condition which tends to increase the turbulence of the liquid stream should be avoided.

7.3.3 The meter shall be installed in such a manner that no undue strain is imposed upon it due to the mass or thermal expansion/contraction of the pipework.

7.3.4 Flexible hoses may be used to provide a supply of liquid for calibration purposes. If they are used on the downstream side, the total length shall be kept to a minimum.

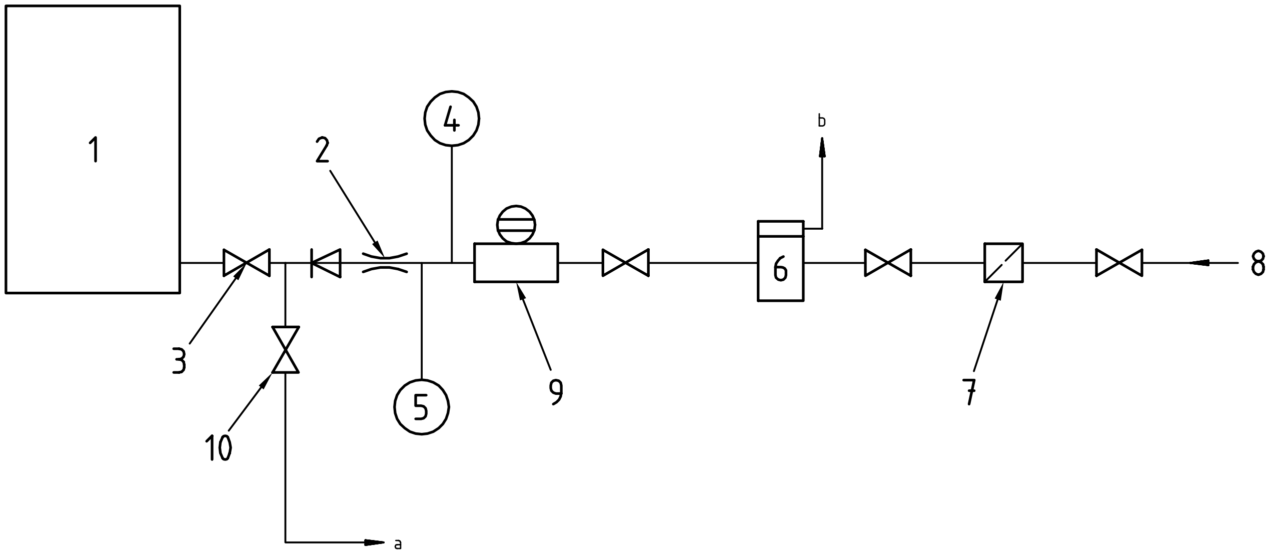
7.4 Meter proving

7.4.1 The meter shall be proved, on site, using either a volumetric prover tank, meter or pipe prover.

Proving should preferably be carried out using the same fluid as that in the tank.

7.4.2 Proving shall be carried out, as a minimum, immediately prior to commencement and on completion of any calibration. If the calibration process extends over more than one day, the meter shall be proved at commencement of calibration and on completion of calibration on each day. Proving may be carried out at shorter intervals to ensure that the meter or K-factor has not drifted.

NOTE Proving at a central proving station/installation may be acceptable if meters are proved under conditions which closely replicate those encountered at the calibration site.



Key

1 Tank to be calibrated
2 Flow limiter
3 Non-return valve
4 Thermometer
5 Pressure gauge
6 Air/vapour separator
7 Strainer
8 Supply
9 Meter
10 Syphon breaker

[a] To air/vapour separator.
[b] To vent.

Figure 1 — Schematic diagram of a typical installation for calibration by meter

7.5 Calibration procedure

7.5.1 The calibration liquid shall be transferred into the tank at a flow rate for which the meter has been calibrated and at such a rate as to minimize disturbance of the liquid surface in the tank.

Care should be taken during the initial filling of the system to avoid over-ranging of the meter when the air in the system is being displaced. If flow rates are likely to exceed the rated capacity of the meter, a suitable flow control valve should be fitted downstream of the meter (see 6.4.2).

7.5.2 The calibration liquid shall be added in incremental volumes sufficient to produce a significant change in the liquid level with reference to the section of the tank being calibrated, and having due regard to the uncertainty of liquid level gauging.

NOTE During calibration, the increase in the liquid level is dependent on the size of the liquid volumes introduced into the tank; i.e. the liquid level is the dependent variable. In a capacity table, the liquid level is the independent variable; the calculation of the table from field measurements is dependent on the size of the increments added to the tank and to the interpolation techniques used to calculate the capacity table. Care should be exercised to ensure that the incremental volumes added to the tank during calibration are of a size which ensures a significant movement in the liquid level but are small enough to minimize the uncertainty arising from the interpolation technique used in calculating the capacity table.

7.5.3 After the addition of each increment, the liquid surface shall be allowed to settle and the liquid depth measured at the dip-point by use of a dip-tape and dip-weight.

Liquid depth measurements shall be made and recorded to the nearest millimetre. The depth measurement shall be taken and shall be repeated. The two measurements shall agree to within 1 mm. If the readings differ from each other by more than 1 mm, then the depth measurements shall be repeated until two consecutive readings are within the tolerance limit.

NOTE If ripples on the surface give rise to difficulties in making measurements, a ripple damping device may be used.

7.5.4 After each increase in depth has been measured and recorded, the temperature of the liquid at the meter, using the thermowell (see 5.1.6) and in the tank shall be taken to the nearest 0,25 °C or better.

NOTE The number of temperature readings may be reduced to one in every five increments if the temperature is found to be constant.

7.5.5 The ambient air temperature in close proximity to the tank being calibrated shall be measured to the nearest 0,25 °C, or better, at intervals throughout the calibration period. The recorded temperatures shall be taken at intervals of time which will accurately reflect the ambient air temperature throughout the calibration process.

7.5.6 If a petroleum product is being used as a calibration liquid, then the pressure on the liquid at the meter shall be measured and recorded at intervals through out the calibration period. The recorded pressures shall be taken at intervals of time which will accurately reflect the pressures exerted on the liquid throughout the calibration process.

7.5.7 If the volume displaced by the inlet hose, compared to the total volume of liquid in the tank, is such that the accuracy of the calibration would be significantly affected, the inlet hose shall be withdrawn until its lower end is above the level of the liquid in the tank. Special care and attention shall be exercised to obtain the same amount of draining before measurements are made of the liquid depth; the liquid surface shall be quiescent.

8 Corrections to observed volumes

8.1 General

Corrections to the observed volumes are required for one or more of the following:

a) calibration error of the meter used;

b) effect of temperature variations on the meter used;

c) effect of temperature variations on the calibration liquid used;

d) effect of temperature variations on the tank being calibrated;

e) effect of temperature variations on the dip-tape and dip-weight used.

If necessary, these corrections shall be calculated and applied when computing a tank capacity table. The tank calibrator shall ensure that all necessary details for the calculation of the corrections are included in the calibration notes.

8.2 Meter factor and K-factor

8.2.1 The meter factor or K-factor for the meter in use shall be the average of the factors calculated at the commencement and completion of the calibration.

8.2.2 The meter factor or K-factor at the commencement and completion of the calibration shall not differ by more than 0,05 %. If the two factors differ by more than 0,1 % then the reason for the difference shall be determined and, if necessary, the calibration shall be repeated.

8.3 Temperature changes in the calibration liquid

8.3.1 A correction shall be made for any change in the temperature of the calibration liquid between the time that it is measured in the meter and the time that it is measured in the tank being calibrated.

8.3.2 If the calibration liquid used is a petroleum product and the tank calibration table is required to be correct at either 15 °C or 20 °C, the volume delivered shall be corrected for temperature changes in the calibration liquid by using the Volume Correction Factor (VCF) table for petroleum products in ISO 91-1:1992 or ISO 91-2:1991 respectively.

8.3.3 If the calibration liquid used is water and the tank calibration table is required to be correct at 15 °C, the volume delivered shall be corrected for temperature changes in the calibration liquid by using the table of water densities or the formula given in annex A.

8.3.4 The corrections shall be made in the following order:

a) correction of the observed calibration liquid temperature to reference temperature;

b) correction of the capacity of the container shell for thermal effects;

c) correction of the liquid level measurement/dip-tape and dip-weight for thermal effects.

8.4 Temperature changes in the tank shell

A correction for the difference in temperature between the shell of the tank at the time of calibration and its average temperature in service, or between the temperature at calibration and a standard reference temperature, e.g. 15 °C, shall be made according to the method given in annex A. The tank shell temperature shall be determined by one of the methods given in annex A of either ISO 7507-1:1993 or ISO 7507-6:1997.

8.5 Temperature effects on dip-tapes and other measures of length

Dip-tapes and other measures of length are calibrated at 20 °C but if they are used at other temperatures, within the range 20 °C ± 5 °C, the corrections for temperature changes are small (of the order of 1 mm in 18 m) and may be neglected in all cases. Outside this range, a correction is required (see A.3).

8.6 Method of correcting for temperature effects

8.6.1 When the total capacity of the tank has been calibrated by meter and the tank capacity table is required to be at a reference temperature of either 15 °C or 20 °C the corrections in 8.4 to 8.5 may be conveniently combined.

8.6.2 If calibration is required to be correct at some other temperature, the adjustment to the standard temperature shall first be made and a further correction calculated for the thermal expansion or contraction of the tank shell shall be in accordance with annex A.

9 Calculation of tank capacity tables

9.1 All calculations shall be made in accordance with accepted mathematical principles.

Errors in calculation are minimized and checking facilitated by the adoption of a standard form of data and calculation sheet. The use of the forms illustrated in annex B is recommended for site data collection and for calculation.

9.2 Tank capacity tables

9.2.1 Provided that tank capacity tables have been calculated in accordance with the principles given in this part of ISO 4269, the format adopted will not affect the mathematical correctness of the table. However, the principles laid down in this clause are recommended since they provide a table in a form most convenient for use. Each tank calibrated in accordance with this part of ISO 4269 shall be issued with a certificate of calibration as specified in ISO 7507-1:1993, annex E.

9.2.2 At the head of each tank calibration table it shall be clearly stated the method by which the liquid level for entry to the tank capacity table shall be determined.

9.2.3 Table headings shall show the tank reference number and location, the temperature at which the table is correct, and the date of calibration.

9.2.4 The intervals of dip at which the table is set out shall be chosen so as to allow linear interpolation for intermediate dips without significant loss of accuracy.

10 Requirements for calculations

10.1 All readings of instruments shall be recorded as observed, without correction for errors which shall be shown separately. Recorded figures shall be checked for consistency before proceeding to the next entry. In all cases of doubt, the readings shall be verified.

10.2 Temperature shall be recorded to at least the nearest 0,25 °C.

10.3 Volumetric readings shall be recorded to the nearest graduation on the meter registers.

10.4 All correction factors obtained from tables shall be used without rounding.

10.5 Other correction factors which require to be calculated shall be correct to 5 significant figures.

10.6 All calculations shall be carried out to be correct to at least 5 significant figures.

10.7 Depth measurements which shall be recorded to the nearest 1 mm, and shall be shown corrected to the nearest 1 mm.

10.8 The final tables shall be calculated by interpolation from the corrected cumulative volumes.

10.9 Final volumes in tank capacity tables obtained by interpolation shall be rounded off to the nearest whole litre and shown against the required tabular interval of dip or ullage.

10.10 If a petroleum product is being used as a calibration liquid, then the pressure on the liquid shall have been measured and recorded at intervals throughout the calibration period. If required, a correction for the compressibility of the liquid used may be calculated using either a factor from Table 1 or from the tables contained in ISO 9770:1989, of which Table 1 is an extract.

10.11 If a vertical cylindrical tank is completely calibrated by the liquid calibration method, corrections for the hydrostatic effect of the liquid (liquid head correction) due to changes in dimension of the tank are automatically included in the final tank capacity tables, but only for liquids having similar densities to that of the calibration liquid used. If the liquid which the tank is to hold in operation differs significantly in density from that of the calibration liquid, correction for the effects of liquid head is required. Liquid head corrections shall be calculated in accordance with ISO 7507-1.

10.12 If a vertical cylindrical tank is partly calibrated by liquid filling and partly by some other method, a correction for liquid head may be required when the tank capacity table is calculated. Liquid head corrections shall be calculated in accordance with ISO 7507-1.

Table 1 — Compressibility of liquid hydrocarbons — Percent change in volume per 100 kPa pressure

Density at 15 °C kg/m^3	**Temperature** °C			
	–15	0	15	30
900	0,005 3 %	0,005 8 %	0,006 3 %	0,006 8 %
850	0,006 0 %	0,006 6 %	0,007 2 %	0,007 9 %
800	0,007 0 %	0,007 7 %	0,008 6 %	0,009 5 %
750	0,008 3 %	0,009 3 %	0,010 %	0,012 %

Annex A
(normative)

Correction for thermal effects

A.1 Volume correction factors

A.1.1 Calibration using water as a calibration liquid

The correction factor, C_{fw}, to be applied for the correction of the effects of temperature differences of the liquid between the meter and the tank being calibrated, when using water as a calibration liquid, are based on the ratio of the density of fresh water at the two measured temperatures.

The correction factor, C_{fw}, is obtained from the following equation:

$$C_{fw} = \frac{\rho_{t1}}{\rho_{t2}} \tag{A.1}$$

where

ρ_{t1} is the density of the water at the temperature of the water at the meter (t_1);

ρ_{t2} is the density of the water at the temperature of the water in the tank under calibration (t_2).

NOTE 1 C_{fw} is the correction factor for temperature difference between the water in the meter and the water in the tank being calibrated; this correction factor does not correct the volume to 15 °C or 20 °C.

The following equation shall be used for determining the density of pure, air-free water, ρ_t, in kilograms per cubic metre, at temperature t of between 1 °C and 40 °C (see note 2).

$$\rho_t = \rho_0 \left\{ 1 - \left[A(t - t_0) + B(t - t_0)^2 + C(t - t_0)^3 + D(t - t_0)^4 + E(t - t_0)^5 \right] \right\} \tag{A.2}$$

where

ρ_t is the density of water, in kilograms per cubic metre;

ρ_0 is the density of water at temperature t_0;

t_0 is the temperature (3,981 8 °C) at which water attains its maximum density;

t is the temperature of the fluid, in degrees Celsius;

A is a polynomial coefficient, and equals 7,013 4 $\times 10^{-8}$ °C^{-1};

B is a polynomial coefficient, and equals 7,926 504 $\times 10^{-6}$ °C^{-2};

C is a polynomial coefficient, and equals – 7,575 677 $\times 10^{-8}$ °C^{-3};

D is a polynomial coefficient, and equals 7,314 894 $\times 10^{-10}$ °C^{-4};

E is a polynomial coefficient, and equals – 3,596 458 $\times 10^{-12}$ °C^{-5};

The result of the equation shall be rounded to three decimal places.

NOTE 2 Values for the density of water are based on reference [8]. The equation is valid over the temperature range 1,0 °C to 40 °C as measured on the International Temperature Scale of 1990, ITS-90.

If the water used in the calibration is air-saturated, a correction to the water density calculated by equation (A.2) shall be applied, before rounding, by means of the following equation:

$$\text{Correction} = -\left(4{,}612 - 0{,}10 t_{\text{w}}\right) \times 10^{-3} \text{ kg/m}^3 \tag{A.3}$$

where t_{w} is the temperature of the water.

The corrected water density shall be rounded to four decimal places.

NOTE 3 Equation (A.3) was derived [9] for water in the temperature range 0 °C to 25 °C. For the purpose of this International Standard, it is applied at water temperatures of up to 40 °C. Any error in tank calibration arising from using the equation in the extended temperature range may be significant.

Table A.1 — Density of air-free water in kilograms per cubic metre against temperature in degrees Celsius on the International Temperature Scale 1990 (P&M Equation)

Temp. °C	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	Air correction
1	999,9012	999,9061	999,9108	999,9153	999,9196	999,9237	999,9277	999,9316	999,9352	999,9387	– 0,0045
2	999,9420	999,9451	999,9481	999,9509	999,9536	999,9560	999,9583	999,9605	999,9625	999,9643	– 0,0043
3	999,9659	999,9674	999,9688	999,9699	999,9709	999,9718	999,9724	999,9730	999,9733	999,9735	– 0,0042
4	999,9736	999,9735	999,9732	999,9728	999,9722	999,9714	999,9705	999,9695	999,9683	999,9669	– 0,0041
5	999,9654	999,9637	999,9619	999,9599	999,9578	999,9555	999,9530	999,9504	999,9477	999,9448	– 0,0040
6	999,9418	999,9386	999,9352	999,9317	999,9281	999,9243	999,9204	999,9163	999,9121	999,9077	– 0,0039
7	999,9032	999,8985	999,8937	999,8888	999,8837	999,8784	999,8730	999,8675	999,8618	999,8560	– 0,0038
8	999,8500	999,8439	999,8377	999,8313	999,8248	999,8181	999,8113	999,8044	999,7973	999,7901	– 0,0037
9	999,7827	999,7753	999,7676	999,7599	999,7519	999,7439	999,7357	999,7274	999,7190	999,7104	– 0,0036
10	999,7017	999,6928	999,6838	999,6747	999,6654	999,6561	999,6465	999,6369	999,6271	999,6172	– 0,0035
11	999,6072	999,5970	999,5867	999,5762	999,5657	999,5550	999,5442	999,5332	999,5221	999,5109	– 0,0034
12	999,4996	999,4881	999,4765	999,4648	999,4530	999,4410	999,4289	999,4167	999,4043	999,3919	– 0,0033
13	999,3793	999,3665	999,3537	999,3407	999,3276	999,3144	999,3011	999,2876	999,2740	999,2603	– 0,0032
14	999,2465	999,2326	999,2185	999,2043	999,1900	999,1756	999,1611	999,1464	999,1316	999,1167	– 0,0031
15	999,1017	999,0865	999,0713	999,0559	999,0404	999,0248	999,0091	998,9932	998,9773	998,9612	– 0,0030
16	998,9450	998,9287	998,9123	998,8958	998,8791	998,8624	998,8455	998,8285	998,8114	998,7942	– 0,0029
17	998,7768	998,7594	998,7418	998,7242	998,7064	998,6885	998,6705	998,6524	998,6342	998,6158	– 0,0028
18	998,5974	998,5788	998,5602	998,5414	998,5225	998,5035	998,4844	998,4652	998,4459	998,4265	– 0,0027
19	998,4069	998,3873	998,3675	998,3477	998,3277	998,3076	998,2875	998,2672	998,2468	998,2263	– 0,0025
20	998,2057	998,1850	998,1642	998,1433	998,1222	998,1011	998,0799	998,0586	998,0371	998,0156	– 0,0024
21	997,9939	997,9722	997,9503	997,9284	997,9063	997,8842	997,8619	997,8396	997,8171	997,7945	– 0,0023
22	997,7719	997,7491	997,7262	997,7033	997,6802	997,6570	997,6338	997,6104	997,5870	997,5634	– 0,0022
23	997,5397	997,5160	997,4921	997,4681	997,4441	997,4199	997,3957	997,3713	997,3469	997,3223	– 0,0021
24	997,2977	997,2729	997,2481	997,2232	997,1981	997,1730	997,1478	997,1225	997,0971	997,0715	– 0,0020
25	997,0459	997,0202	996,9944	996,9686	996,9426	996,9165	996,8903	996,8641	996,8377	996,8112	– 0,0019
26	996,7847	996,7581	996,7313	996,7045	996,6776	996,6506	996,6235	996,5963	996,5690	996,5416	– 0,0018
27	996,5141	996,4865	996,4589	996,4311	996,4033	996,3754	996,3474	996,3192	996,2910	996,2627	– 0,0017
28	996,2344	996,2059	996,1773	996,1487	996,1199	996,0911	996,0622	996,0332	996,0041	995,9749	– 0,0016
29	995,9456	995,9163	995,8868	995,8573	995,8276	995,7979	995,7681	995,7382	995,7082	995,6782	– 0,0015
30	995,6480	995,6178	995,5874	995,5570	995,5265	995,4959	995,4653	995,4345	995,4037	995,3727	– 0,0014
31	995,3417	995,3106	995,2794	995,2482	995,2168	995,1853	995,1538	995,1222	995,0905	995,0587	– 0,0013
32	995,0269	994,9949	994,9629	994,9307	994,8985	994,8663	994,8339	994,8014	994,7689	994,7363	– 0,0012
33	994,7036	994,6708	994,6379	994,6050	994,5719	994,5388	994,5056	994,4723	994,4390	994,4055	– 0,0011
34	994,3720	994,3384	994,3047	994,2709	994,2371	994,2031	994,1691	994,1350	994,1008	994,0666	– 0,0010
35	994,0322	993,9978	993,9633	993,9287	993,8941	993,8593	993,8245	993,7896	993,7546	993,7196	– 0,0008
36	993,6844	993,6492	993,6139	993,5785	993,5431	993,5075	993,4719	993,4362	993,4004	993,3646	– 0,0007
37	993,3287	993,2927	993,2566	993,2204	993,1842	993,1478	993,1115	993,0750	993,0384	993,0018	– 0,0006
38	992,9651	992,9283	992,8914	992,8545	992,8175	992,7804	992,7432	992,7060	992,6687	992,6313	– 0,0005
39	992,5938	992,5563	992,5186	992,4809	992,4431	992,4053	992,3674	992,3294	992,2913	992,2531	– 0,0004
40	992,2149										– 0,0004

NOTE Round values of water density from the table to three decimal places.

A.1.2 Calibration using a suitable petroleum product as a calibration liquid

The correction factors to be applied for the correction of the effects of temperature differences of the liquid between the meter and the tank being calibrated, when using a suitable petroleum product as a calibration liquid, are based on the ratio of the density of product at the two measured temperatures.

However, the correction factor is most simply obtained from Table 54B of ISO 91-1:1992 or ISO 91-2:1991. A VCF for the density at 15 °C or 20 °C, dependent on the standard reference temperature in use, and measured temperature, at the meter, of the petroleum product is obtained and a second VCF at the temperature measured in the tank. Application of the first VCF to the volume measured by the meter, after application of the meter factor, will correct the volume measured by the meter to a volume at 15 °C or 20 °C. Division of this volume by the second VCF will correct the measured volume to that in the tank at the temperature measured in the tank.

NOTE 1 This calculation is similar to that contained in A.1.1.

VCF values taken from Table 54B of ISO 91– 1:1992 or ISO 91– 2:1991 are ratios of the density of the petroleum product and its density at 15 °C or 20 °C respectively. Application of the two VCF values as described above reduces to the equation given in A.1.1:

$$\text{VCF} = \frac{\rho_{t1}}{\rho_{15}}$$

or

$$\text{VCF} = \frac{\rho_{t1}}{\rho_{20}} \qquad \text{(A.3)}$$

where

ρ_{t1} is the density of the petroleum product at the temperature of the petroleum product at the meter (t_1);

ρ_{15} is the density of the petroleum product at a temperature of 15 °C;

ρ_{20} is the density of the petroleum product at a temperature of 20 °C.

The order of application of the two VCFs is multiplication of the volume by the first and division by the second which results in the following:

$$\text{Correction factor} = \left[\frac{\rho_{t1}}{\rho_{15} \text{ or } \rho_{20}}\right] \Big/ \left[\frac{\rho_{t2}}{\rho_{15} \text{ or } \rho_{20}}\right] \qquad \text{(A.4)}$$

$$= \frac{\rho_{t1}}{\rho_{t2}} \qquad \text{(A.5)}$$

where ρ_{t2} is the density of the petroleum product at the temperature of the petroleum product in the tank under calibration (t_2).

Multiplying the metered volume by this correction factor gives the volume of liquid entering the tank, each volume expressed at its observed temperature.

NOTE 2 The VCFs are correction factors for the difference between the temperature of the petroleum product at the meter and the temperature of the petroleum product in the tank being calibrated; they do not correct the volume to 15 °C or 20 °C.

A.2 Correction for thermal effects on the tank shell

The cumulative volumes calculated using the factors in either A.1.1 or A.1.2, whichever is appropriate, result in volumes at the measured temperature of the liquid in the tank. These volumes are equivalent to the partial capacities of the tank at the measured liquid level. If the capacity table is required to be correct at some other temperature, the adjustment to that temperature, a correction shall be calculated for the thermal expansion or contraction of the tank shell, using the following equation:

$$V_{tc} = V_{ts}\,[1 + 2\alpha\,(t_c - t_s)] \qquad \text{(A.6)}$$

where

V_{tc} is the volume at required temperature of calibration, t_c;

V_{ts} is the adjusted volume, measured by the meter, at tank temperature, t_s;

t_c is the required temperature of calibration, in degrees Celsius;

t_s is the tank temperature, in degrees Celsius;

α is the linear coefficient of expansion per degree Celsius of the metal of the tank, in $°C^{-1}$.

The tank shell temperature, t_s, shall be determined by one of the methods given in annex A of either ISO 7507– 1:1993 or ISO 7507– 6:1997.

The following values of α may be used:

mild steel: $11 \times 10^{-6}\ °C^{-1}$

stainless steel: $17 \times 10^{-6}\ °C^{-1}$

If actual values of α are known, then these should be used in preference to the values given above.

A.3 Correction for thermal effects on the dip– tape and dip– weight

Dip– tapes and dip– weights are certified at a standard reference temperature of 20 °C. If they are used at other temperatures within the range 20 °C ± 5 °C, the corrections for temperature changes are small (of the order of 1 mm in 18 m) and may be neglected in all cases. Outside this range, a correction may be required.

The equation given in A.2 corrects the capacity of the tank to a standard reference temperature, t_c, but only for superficial expansion. The third dimension is the liquid level, measured by the dip– tape and dip– weight. This measurement shall be corrected to the standard reference temperature of the tank calibration table, as shown in the equation (A.7).

If the tank being calibrated is constructed of mild steel, the linear coefficients of expansion of both the tank metal and that of the dip– tape may be considered to be equivalent and that any liquid level measurement is, thus, a measurement at the certified standard reference temperature of the dip– tape, i.e. 20 °C. Any correction of the level measurement to the certified temperature of the tank capacity table shall be from 20 °C to the certified temperature of the tank capacity table.

If the tank being calibrated is constructed of another material, the linear coefficients of expansion of both the tank metal and that of the dip– tape will differ and the temperature of the dip– tape will be an average of the liquid filled and empty sections in the tank.

$$L_{tc} = L_{ts}\left[1 + \alpha\left(t_s - t_c\right)\right] \qquad \text{(A.7)}$$

where

L_{tc} is the level at the required temperature of calibration, t_c;

L_{ts} is the measured level at temperature t_s;

t_c is the required temperature of calibration;

t_s is the temperature of the dip– tape;

α is the coefficient of linear expansion, in °C^{-1}, of the metal of the tank.

Annex B
(informative)

Field data and calculation sheets

Table B.1 — Field data sheet — Calibration by volumetric meter using water as calibration liquid

(Tank: XON 13; site: Vallon de Vinasse)

1	2	3	4	5	6	7	8	9
Batch No.	**Meter factor**	**Rate of flow**	**Below datum volume**	**Metered batch volume**	**Cumulative volume**	**Liquid level**	**Temp. at meter**	**Temp. at tank**
		m^3/h	l	l	l	mm	°C	°C
1	0,999 2	14	5		5	0	12,1	12,9
2	0,999 2	14	5	500	505	71	12,1	12,9
3	0,999 2	14	5	500	1 005	127	12,1	12,8
4	0,999 2	14	5	1 000	2005	212	12,2	12,8
5	0,999 2	14	5	1 000	3 005	284	12,2	12,8
6	0,999 2	14	5	1 000	4 005	353	12,2	12,7
7	0,999 2	14	5	1 500	5 505	448	12,3	12,7
8	0,999 2	14	5	1 500	7 005	538	12,3	12,7
9	0,999 2	14	5	1 500	8 505	622	12,4	12,7
10	0,999 2	14	5	1 500	10 005	701	12,4	12,6
11	0,999 2	14	5	2 000	12 005	798	12,5	12,6
12	0,999 2	14	5	2 000	14 005	893	12,5	12,6
13	0,999 2	14	5	2 000	16 005	985	12,5	12,6
14	0,999 2	14	5	2 000	18 005	1 075	12,6	12,6
15	0,999 2	14	5	2 000	20 005	1 163	12,6	12,6
16	0,999 2	14	5	2 500	22 505	1 271	12,6	12,6
17	0,999 2	14	5	2 500	25 005	1 379	12,6	12,6
18	0,999 2	14	5	2 500	27 505	1 488	12,7	12,6
19	0,999 2	14	5	2 500	30 005	1 597	12,7	12,6
20	0,999 2	14	5	2 000	32 005	1 685	12,7	12,7
21	0,999 2	14	5	2 000	34 005	1 774	12,7	12,7
22	0,999 2	14	5	2 000	36 005	1 864	12,7	12,7
23	0,999 2	14	5	2 000	38 005	1 955	12,7	12,7

Table B.1 *(continued)*

1	2	3	4	5	6	7	8	9
Batch No.	**Meter factor**	**Rate of flow**	**Below datum volume**	**Metered batch volume**	**Cumulative volume**	**Liquid level**	**Temp. at meter**	**Temp. at tank**
		m^3/h	l	l	l	mm	°C	°C
24	0,999 2	14	5	2 000	40 005	2 048	12,8	12,7
25	0,999 2	14	5	2 000	42 005	2 144	12,8	12,7
26	0,999 2	14	5	2 000	44 005	2 246	12,8	12,7
27	0,999 2	14	5	1 500	45 505	2 325	12,8	12,8
28	0,999 2	14	5	1 500	47 005	2 407	12,8	12,8
29	0,999 2	14	5	1 500	48 505	2 496	12,9	12,8
30	0,999 2	14	5	1 500	50 005	2 598	12,9	12,8
31	0,999 2	14	5	1 000	51 005	2 674	12,9	12,8
32	0,999 2	14	5	1 000	52 005	2 762	12,9	12,8
33	0,999 2	14	5	500	52 505	2 816	12,9	12,8
34	0,999 2	14	5	500	53 005	2 893	12,9	12,8

Table B.2 — Calculation sheet — Calibration by volumetric meter using water as calibration liquid

(Tank: XON 1; site: Vallon de Vinasse)

1	2	3	4	5	6	7	8	9a	9b	9c	10	11	12	13	14	15	16
Batch No.	**Rate of flow**	**Cumulative volume**	**Batch volume**	**Meter factor**	**Corrected volume** (4 × 5)	**Temp. at meter**	**Temp. at tank** t_T	**Air sat. water density at meter temp.**	**Air sat. water density at tank temp.**	**VCF** (9a/9b)	**Liquid volume at *t* °C** (6 × 9c)	**Cumulative volume at *t* °C**	**Tank shell temp. correction to 15 °C**	**Corrected cumulative volume at 15 °C** (11 × 12)	**Liquid level at *t* °C**	**Dip tape temp. correction to 15 °C**	**Corrected liquid level at 15 °C** (14 × 15)
	m^3/h	m^3	m^3		m^3	°C	°C	kg/m^3	kg/m^3		m^3	m^3		m^3	mm		mm
1	14	0,005	0,005	0,9992	0,0050	12,1	12,9	999,4848	999,3886	1,00010	0,0050	0,0050	1,00005	0,005	0	0,999977	0
2	14	0,505	0,500	0,9992	0,4996	12,1	12,9	999,4848	999,3886	1,00010	0,4996	0,5046	1,00005	0,505	71	0,999977	71
3	14	1,005	0,500	0,9992	0,4996	12,1	12,9	999,4848	999,3886	1,00010	0,4996	1,0043	1,00005	1,004	127	0,999976	127
4	14	2,005	1,000	0,9992	0,9992	12,2	12,8	999,4732	999,4010	1,00007	0,9993	2,0036	1,00005	2,004	212	0,999976	212
5	14	3,005	1,000	0,9992	0,9992	12,2	12,8	999,4732	999,4010	1,00007	0,9993	3,0028	1,00005	3,003	284	0,999976	284
6	14	4,005	1,000	0,9992	0,9992	12,2	12,7	999,4732	999,4134	1,00006	0,9993	4,0021	1,00005	4,002	335	0,999975	335
7	14	5,505	1,500	0,9992	1,4988	12,3	12,7	999,4615	999,4134	1,00005	1,4989	5,5010	1,00005	5,501	448	0,999975	448
8	14	7,005	1,500	0,9992	1,4988	12,3	12,7	999,4615	999,4134	1,00005	1,4989	6,9998	1,00005	7,000	538	0,999975	538
9	14	8,505	1,500	0,9992	1,4988	12,4	12,7	999,4497	999,4134	1,00004	1,4989	8,4987	1,00005	8,499	622	0,999975	622
10	14	10,005	1,500	0,9992	1,4988	12,4	12,6	999,4497	999,4256	1,00002	1,4988	9,9975	1,00005	9,998	701	0,999974	701
11	14	12,005	2,000	0,9992	1,9984	12,5	12,6	999,4377	999,4256	1,00001	1,9984	11,9960	1,00005	11,997	798	0,999974	798
12	14	14,005	2,000	0,9992	1,9984	12,5	12,6	999,4377	999,4256	1,00001	1,9984	13,9944	1.00005	13,995	893	0,999974	893
13	14	16,005	2,000	0,9992	1,9984	12,5	12,6	999,4377	999,4256	1,00001	1,9984	15,9928	1,00005	15,994	985	0,999974	985
14	14	18,005	2,000	0,9992	1,9984	12,5	12,6	999,4377	999,4256	1,00001	1,9984	17,9912	1,00005	17,992	1 075	0,999974	1 075
15	14	20,005	2,000	0,9992	1,9984	12,6	12,6	999,4256	999,4256	1,00000	1,9984	19,9896	1,00005	19,991	1 163	0,999974	1 163
16	14	22,505	2,500	0,9992	2,4980	12,6	12,6	999,4256	999,4256	1,00000	2,4980	22,4876	1,00005	22,489	1 271	0,999974	1 271
17	14	25,005	2,500	0,9992	2,4980	12,6	12,6	999,4256	999,4256	1,00000	2,4980	24,9856	1,00005	24,987	1 379	0,999974	1 379
18	14	27,505	2,500	0,9992	2,4980	12,6	12,6	999,4256	999,4256	1,00000	2,4980	27,4836	1,00005	27,485	1 488	0,999974	1 488
19	14	30,005	2,500	0,9992	2,4980	12,6	12,6	999,4256	999,4256	1,00000	2,4980	29,9816	1,00005	29,983	1 597	0,999974	1 597
20	14	32,005	2,000	0,9992	1,9984	12,7	12,7	999,4134	999,4134	1,00000	1,9984	31,9800	1,00005	31,982	1 685	0,999975	1 685

Table B.2 (*continued*)

1	2	3	4	5	6	7	8	9a	9b	9c	10	11	12	13	14	15	16
Batch No.	**Rate of flow**	**Cumulative volume**	**Batch volume**	**Meter factor**	**Corrected volume** (4 × 5)	**Temp. at meter**	**Temp. at tank** t_T	**Air sat. water density at meter temp**	**Air sat. water density at tank temp.**	**VCF** (9a/9b)	**Liquid volume at *t* °C** (6 × 9c)	**Cumulative volume at *t* °C**	**Tank shell temp. correction to 15 °C**	**Corrected cumulative volume at 15 °C** (11 × 12)	**Liquid level at *t* °C**	**Dip tape temp. correction to 15 °C**	**Corrected liquid level at 15 °C** (14 × 15)
	m^3/h	m^3	m^3		m^3	°C	°C	kg/m^3	kg/m^3		m^3	m^3		m^3	mm		mm
21	14	34,005	2,000	0,9992	1,9984	12,7	12,7	999,4134	999,4134	1,00000	1,9984	33,9784	1,00005	33,980	1 774	0,999975	1 774
22	14	36,005	2,000	0,9992	1,9984	12,7	12,7	999,4134	999,4134	1,00000	1,9984	35,9768	1,00005	35,979	1 864	0,999975	1 864
23	14	38,005	2,000	0,9992	1,9984	12,7	12,7	999,4134	999,4134	1,00000	1,9984	37,9752	1,00005	37,977	1 955	0,999975	1 955
24	14	40,005	2,000	0,9992	1,9984	12,8	12,7	999,4010	999,4134	0,99999	1,9984	39,9736	1,00005	39,976	2 048	0,999975	2 048
25	14	42,005	2,000	0,9992	1,9984	12,8	12,7	999,4010	999,4134	0,99999	1,9984	41,9720	1,00005	41,974	2 144	0,999975	2 144
26	14	44,005	2,000	0,9992	1,9984	12,8	12,7	999,4010	999,4134	0,99999	1,9984	43,9704	1,00005	43,973	2 246	0,999975	2 246
27	14	45,505	1,500	0,9992	1,4988	12,8	12,8	999,4010	999,4010	1,00000	1,4988	45,4692	1,00005	45,471	2 325	0,999976	2 325
28	14	47,005	1,500	0,9992	1,4988	12,8	12,8	999,4010	999,4010	1,00000	1,4988	46,9678	1,00005	46,970	2 407	0,999976	2 407
29	14	48,505	1,500	0,9992	1,4988	12,9	12,8	999,3886	999,4010	0,99999	1,4988	48,4667	1,00005	48,469	2 496	0,999976	2 496
30	14	50,005	1,500	0,9992	1,4988	12,9	12,8	999,3886	999,4010	0,99999	1,4988	49,9655	1,00005	49,968	2 598	0,999976	2 598
31	14	51,005	1,000	0,9992	0,9992	12,9	12,8	999,3886	999,4010	0,99999	0,9992	50,9647	1,00005	50,967	2 674	0,999976	2 674
32	14	52,005	1,000	0,9992	0,9992	12,9	12,8	999,3886	999,4010	0,99999	0,9992	51,9639	1,00005	51,967	2 762	0,999976	2 762
33	14	52,505	0,500	0,9992	0,4996	12,9	12,8	999,3886	999,4010	0,99999	0,4996	52,4635	1,00005	52,466	2 816	0,999976	2 816
34	14	53,005	0,500	0,9992	0,4996	12,9	12,8	999,3886	999,4010	0,99999	0,4996	52,9631	1,00005	52,966	2 893	0,999976	2 893

Meter No. 4321

Average ambient air temp. A = 14 °C

Standard temperature of calibration table to be 15 °C

Tank construction of mild steel

Superficial coefficient of expansion = 0, 000 022/ °C/m/m

Linear coefficient of expansion of dip-tape metal (stainless steel) 0, 000 017 °C/m/m

Reference temperature of dip-tape = 20 °C

Table B.3 — Field data sheet — Calibration by volumetric meter using kerosene as calibration liquid

(Tank: XON 1; site: Vallon de Vinasse)

1	2	3	4	5	6	7	8	9
Batch No.	Meter factor	Rate of flow	Below datum volume	Metered batch volume	Cumulative volume	Liquid level	Temp. at meter	Temp. at tank
		m^3h	l	l	l	mm	°C	°C
1	0,998 2	18	10		10	0	18,3	17,5
2	0,998 2	18	10	200	210	63	18,3	17,5
3	0,998 2	18	10	250	460	110	18,4	17,6
4	0,998 2	18	10	240	700	149	18,4	17,7
5	0,998 2	18	10	250	950	185	18,4	17,8
6	0,998 2	18	10	400	1 350	250	18,4	17,8
7	0,998 2	18	10	400	1 750	315	18,4	17,9
8	0,998 2	18	10	450	2 200	365	18,4	17,9
9	0,998 2	18	10	600	2 800	423	18,4	17,9
10	0,998 2	18	10	900	3 700	510	18,4	18,0
11	0,998 2	18	10	1 000	4 700	589	18,4	18,0
12	0,998 2	18	10	1 400	6 100	690	18,4	18,1
13	0,998 2	18	10	1 500	7 600	794	18,4	18,1
14	0,998 2	18	10	2 000	9 600	918	18,4	18,2
15	0,998 2	18	10	2 400	12 000	1 065	18,4	18,2
16	0,998 2	18	10	2 005	14 005	1 180	18,4	18,2
17	0,998 2	18	10	1 800	15 805	1 270	18,5	18,3
18	0,998 2	18	10	1 800	17 605	1 360	18,5	18,3
19	0,998 2	18	10	1 520	19 125	1 446	18,5	18,3
20	0,998 2	18	10	1 950	21 075	1 555	18,5	18,3
21	0,998 2	18	10	1 950	23 025	1 666	18,5	18,3
22	0,998 2	18	10	2 100	25 125	1 784	18,5	18,3
23	0,998 2	18	10	1 800	26 925	1 898	18,5	18,3
24	0,998 2	18	10	1 500	28 425	2 012	18,6	18,4
25	0,998 2	18	10	1 500	29 925	2 126	18,6	18,4
26	0,998 2	18	10	1 295	31 220	2 225	18,6	18,4
27	0,998 2	18	10	1 275	32 495	2 355	18,6	18,4
28	0,998 2	18	10	980	33 475	2 455	18,7	18,4
29	0,998 2	18	10	930	34 405	2 555	18,7	18,5

Table B.3 *(continued)*

1	2	3	4	5	6	7	8	9
Batch No.	**Meter factor**	**Rate of flow**	**Below datum volume**	**Metered batch volume**	**Cumulative volume**	**Liquid level**	**Temp. at meter**	**Temp. at tank**
		m^3h	l	l	l	mm	°C	°C
30	0,998 2	18	10	550	34 955	2 640	18,7	18,5
31	0,998 2	18	10	400	35 355	2 750	18,7	18,5
32	0,998 2	18	10	450	35 805	2 890	18,7	18,6
33	0,998 2	18	10	350	36 155	2 999	18,8	18,7
34	0,998 2	18	10	195	36 350	3 120	18,8	18,7
35	0,998 2	18	10	14	36 364	3 129	18,8	18,7
Kerosene density at 15 °C = 792,0 kg/m^3 Meter No. 6464								

Table B.4 — Calculation sheet — Calibration by volumetric meter using kerosene as calibration liquid

(Tank: XON 1; site: Vallon de Vinasse)

1	2	3	4	5	6	7	8	9a	9b	10	11	12	13	14	15	16	17
Batch No.	**Rate of flow**	**Cumulative volume**	**Incre– mental volume**	**Meter factor**	**Corrected volume**	**Temp. at meter**	**Temp. at tank** t_T	**VCF at temp. of meter**[a]	**VCF at temp. of tank**[a]	**Volume at 15 °C (6 × 9a)**	**Total volume at 15 °C**	**Tank volume at t °C (11/9b)**	**Tank shell temp. correction Tank temp.** $= (7t_T+A)/8$	**Corrected cumulative volume (12 × 13)**	**Liquid level t °C**	**Dip tape temp. corr. to 15 °C**	**Corrected liquid level**
Unit	m^3/h	l	l		l	°C	°C			l	l	l		l	mm		mm
1	18	10			10.,0	—	17,5	0,996 9	0,997 6	9,97	9,97	9,99	0,999 955	10	0	—	0
2	18	210	200	0,998 20	199,64	18,3	17,5	0,996 9	0,997 6	199,02	208,98	209,48	0,999 955	209	63	1,000 042	63
3	18	460	250	0,998 20	249,55	18,4	17,6	0,996 8	0,997 5	248,74	457,73	458,86	0,999 953	459	110	1,000 044	110
4	18	700	240	0,998 20	239,57	18,4	17,7	0,996 8	0,997 4	238,79	696,52	698,31	0,999 951	698	149	1,000 046	149
5	18	950	250	0,998 20	249,55	18,4	17,8	0,996 8	0,997 3	248,74	945,27	947,79	0,999 949	948	185	1,000 048	185
6	18	1 350	400	0,998 20	399,28	18,4	17,8	0,996 8	0,997 3	397,99	1 343,26	1 346,84	0,999 949	1 347	250	1,000 048	250
7	18	1 750	400	0,998 20	399,28	18,4	17,9	0,996 8	0,997 3	397,99	1 741,25	1 746,05	0,999 947	1 746	315	1,000 049	315
8	18	2 200	450	0,998 20	449,19	18,4	17,9	0,996 8	0,997 3	447,74	2 188,99	2 195,02	0,999 947	2 195	365	1,000 049	365
9	18	2 800	600	0,998 20	598,92	18,4	17,9	0,996 8	0,997 3	596,99	2 785,97	2 793,65	0,999 947	2 794	423	1,000 049	423
10	18	3 700	900	0,998 20	898,38	18,4	18,0	0,996 8	0,997 2	895,48	3 681,45	3 691,97	0,999 945	3 692	510	1,000 051	510
11	18	4 700	1 000	0,998 20	998,20	18,4	18,0	0,996 8	0,997 1	994,98	4 676,43	4 689,79	0,999 945	4 690	589	1,000 051	589
12	18	6 100	1 400	0,998 20	1 397,48	18,4	18,1	0,996 8	0,997 1	1 392,97	6 069,39	6 087,29	0,999 943	6 087	690	1,000 053	690
13	18	7 600	1 500	0,998 20	1 497,30	18,4	18,1	0,996 8	0,997 1	1 492,46	7 561,86	7 584,15	0,999 943	7 484	794	1,000 053	794
14	18	9 600	2 000	0,998 20	1 996,40	18,4	18,2	0,996 8	0,997 0	1 989,95	9 551,81	9 580,93	0,999 941	9 580	918	1,000 054	918
15	18	12 000	2 400	0,998 20	2 395,68	18,4	18,2	0,996 8	0,997 0	2 387,94	11 939,75	11 976,16	0,999 941	11 975	1 065	1,000 054	1 065
16	18	14 005	2 005	0,998 20	2 001,39	18,4	18,2	0,996 8	0,997 0	1 994,93	13 934,68	13 977,17	0,999 941	13 976	1 180	1,000 054	1 180
17	18	15 805	1 800	0,998 20	1 796,76	18,5	18,3	0,996 7	0,996 9	1 790,79	15 725,49	15 774,85	0,999 939	15 774	1 270	1,000 056	1 270
18	18	17 605	1 800	0,998 20	1 796,76	18,5	18,3	0,996 7	0,996 9	1 790,79	17 516,26	17 571,26	0,999 939	17 570	1 360	1,000 056	1 360
19	18	19 125	1 520	0,998 20	1 517,26	18,5	18,3	0,996 7	0,996 9	1 512,23	19 028,49	19 088,24	0,999 939	19 087	1 446	1,000 056	1 446
20	18	21 075	1 950	0,998 20	1 946,49	18,5	18,3	0,996 7	0,996 9	1 940,03	20 968,52	2 134,36	0,999 939	21 033	1 555	1,000 056	1 555

Table B.4 *(continued)*

1	2	3	4	5	6	7	8	9a	9b	10	11	12	13	14	15	16	17
Batch No.	**Rate of flow**	**Cumulative volume**	**Incre– mental volume**	**Meter factor**	**Corrected volume**	**Temp. at meter**	**Temp. at tank** t	**VCF at temp. of meter**[a]	**VCF at temp. of tank**[a]	**Volume at 15 °C (6 × 9a)**	**Total volume at 15 °C**	**Tank volume at t °C (11/9b)**	**Tank shell temp. correction Tank temp.**	**Corrected cumulative volume (12 × 13)**	**Liquid level t °C**	**Dip tape temp. corr. to 15 °C**	**Corrected liquid level**
Unit	m^3/h	l	l		l	°C	°C			l	l	l	$= (7t_T+A)/8$	l	mm		mm
21	18	23 025	1 950	0,998 20	1 946,49	18,5	18,3	0,996 7	0,996 9	1 940,03	22 908,55	22 980,48	0,999 939	22 979	1 666	1,000 056	1 666
22	18	25 125	2 100	0,998 20	2 096,22	18,5	18,3	0,996 7	0,996 9	2 089,26	24 997,81	25 076,30	0,999 939	25 075	1 784	1,000 056	1 784
23	18	26 925	1 800	0,998 20	1 796,76	18,5	18,3	0,996 7	0,996 9	1 790,79	26 788,60	26 872,71	0,999 939	26 871	1 898	1,000 056	1 898
24	18	28 425	1 500	0,998 20	1 497,30	18,6	18,4	0,996 6	0,996 8	1 492,18	28 280,78	28 372,42	0,999 937	28 371	2 012	1,000 058	2 012
25	18	29 925	1 500	0,998 20	1 497,30	18,6	18,4	0,996 6	0,996 8	1 492,18	29 772,96	29 869,44	0,999 937	29 868	2 126	1,000 058	2 126
26	18	31 220	1 295	0,998 20	1 292,67	18,6	18,4	0,996 6	0,996 8	1 288,25	31 061,21	31 161,86	0,999 937	31 160	2 225	1,000 058	2 225
27	18	32 495	1 275	0,998 20	1 272,70	18,6	18,4	0,996 6	0,996 8	1 268,35	32 329,56	32 434,32	0,999 937	32 432	2 355	1,000 058	2 355
28	18	33 475	980	0,998 20	978,24	18,7	18,4	0,996 5	0,996 8	974,80	33 304,26	33 412,29	0,999 937	33 410	2 455	1,000 058	2 455
29	18	34 405	930	0,998 20	928,33	18,7	18,5	0,996 5	0,996 7	925,07	34 229,43	34 343,45	0,999 935	34 341	2 555	1,010 060	2 555
30	18	34 955	550	0,998 20	549,01	18,7	18,5	0,996 5	0,996 7	547,08	34 776,51	34 892,36	0,999 935	34 890	2 640	1,000 060	2 640
31	18	35 355	400	0,998 20	399,28	18,7	18,5	0,996 5	0,996 7	397,88	35 174,39	35 291,56	0,999 935	35 289	2 750	1,000 060	2 750
32	18	35 805	450	0,998 20	449,19	18,7	18,6	0,996 5	0,996 6	447,61	35 622,01	35 744,25	0,999 933	35 742	2 890	1,000 061	2 890
33	18	36 155	350	0,998 20	349,37	18,8	18,7	0,996 4	0,996 5	348,11	35 970,11	36 096,81	0,999 932	36 094	2 999	1,000 063	2 999
34	18	36 350	195	0,998 20	194,65	18,8	18,7	0,996 4	0,996 5	193,95	36 164,06	36 291,44	0,999 932	36 289	3 120	1,000 063	3 120
35	18	36 364	14	0,998 20	13,97	18,8	18,7	0,996 4	0,996 5	13,92	36 177,99	36 305,42	0,999 932	36 303	3 129	1,000 063	3 129

Meter No. 4321
Average ambient air temp. (A) = 14 °C

Standard temperature of calibration table to be 15 °C
Tank construction of mild steel
Superficial coefficient of expansion = 0,000 022/ °C/m/m
Linear coefficient of expansion of dip-tape metal = 0,000 011/°C/m/m
Reference temperature of dip-tape = 20 °C

N.B. All calculations have been carried out to comply with clause 10. Results are displayed to two decimal places for presentation purposes only.

[a] From Table 54 B of ISO 91– 1:1992 or ISO 91– 2:1991.

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