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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Petroleum and liquid petroleum products — Calculation of oil quantities —

Part 2: Dynamic measurement

Pétrole et produits pétroliers liquides — Calcul des quantités de pétrole —

Partie 2 : Mesurage dynamique

Reference number
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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.

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 4267-2 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*.

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.

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0 Introduction

Before the compilation of this publication, words and expressions employed in dynamic measurement calculations were interpreted slightly differently by different people, and there was a lack of coherence in their use. In addition, because data were spread over so many standards, there was difficulty in readily comparing the finer points of calculations.

Rules for rounding, and the choice of how many significant figures entered each calculation, were open to a variety of interpretations. For different operators to obtain identical results from the same data, the rules for sequence, rounding and significant figures have to be defined. This International Standard aims, among other things, at defining the minimum set of rules required. Nothing in this International Standard precludes the use of more precise determinations of temperature, pressure and density or the use of more significant digits, by mutual agreement among the parties involved.

This International Standard aims at consolidating and standardizing calculations pertaining to the metering of petroleum liquids, and at clarifying terms and expressions by eliminating local variations of such terms. The purpose of standardizing calculations is to produce the same answer from the same data regardless of the computing system used.

Although ISO/TC 28 standards use 15 °C as a standard reference temperature, it is recognized that individual countries may use other reference temperatures, for example 20 °C, 12 °C or 60 °F.

This standard sets minimum levels of accuracy for industrial calculations, but, if parties consider agreeing to set tighter requirements, it is important to demonstrate whether such requirements can be met. Future technological progress in meter proving and operation may justify a tighter specification for calculation procedures.

1 Scope and field of application

This International Standard defines the various terms (be they words or symbols) employed in the calculation of metered petroleum quantities. Where two or more terms are customarily employed in the oil industry for the same quantity, a preferred term is selected.

This International Standard also specifies the equations which allow the values of correction factors to be computed. It also gives rules for the sequence, rounding and significant figures to be employed in a calculation. It provides tables which may be used to look up specific correction factors should it not be desired to calculate them by manual as well as computer methods. The calculation of prover base volumes, meter factors and measurement tickets is also covered.

The field of application of this International Standard is the volumetric measurement of liquid hydrocarbons, including liquefied petroleum gases, by meter and prover. It does not include two-phase fluids (though it may be found useful in such situations) except in so far as sediment and water may be mixed in with crude oil.

2 References

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

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

ISO 5024, *Petroleum liquids and gases — Measurement — Standard reference conditions.*

ISO 7278-2, *Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters — Part 2: Pipe provers.* [1]

ISO 8222, *Petroleum measurement systems — Calibration — Temperature corrections for use with volumetric reference measuring systems.*

ISO 9770, *Petroleum products — Compressibility factors for hydrocarbons in the range 638 kg/m³ to 1 074 kg/m³.* [1]

1) At the stage of draft.

3 Definitions

For the purposes of this International Standard, the following definitions apply to the terms used herein:

3.1 base volume: The volume of a prover under standard conditions.

3.2 indicated volume: The change in meter reading that occurs during a transfer through the meter.

3.3 *K*-factor: The number of pulses generated by a meter for a unit of volume delivered.

$$K\text{-factor} = \frac{\text{pulses generated by meter}}{\text{volume delivered by meter}}$$

3.4 measurement ticket: A generalized term for the written acknowledgment of the receipt or delivery of a quantity of crude oil or petroleum product, including a record of the measurement data (see clause 9). It may be a form to be completed, a data print-out or a data display depending on the degree of automation, remote control, or computerization. Previously described as "run ticket" and "receipt and delivery ticket".

3.5 meter factor: The ratio of the actual volume of liquid passed through a meter to the volume indicated by the meter.

$$\text{Meter factor} = \frac{\text{volume passed through a meter}}{\text{volume indicated by the meter}}$$

3.6 net standard volume: The total standard volume (see 3.9) minus the volume of water and sediment transferred through the meter.

NOTE — For clean, refined products, the total standard volume and net standard volume are usually equal.

3.7 reading; meter reading: The instantaneous display of meter volume (see *indicated volume*).

3.8 standard (reference) conditions: For the measurement of petroleum and its products, these are a pressure of 101,325 kPa (1,013 25 bar) and a temperature 15 °C, with the exception of liquids having a vapour pressure greater than atmospheric pressure at 15 °C, in which case the standard pressure is the equilibrium vapour pressure at 15 °C (see ISO 5024).

3.9 total standard volume: The total volume at standard temperature, also corrected to standard pressure.

3.10 total volume: The indicated volume multiplied by the appropriate meter factor for the liquid and flow rate concerned, without correction for temperature and pressure. It includes all water and sediment transferred through the meter.

4 Hierarchy of accuracies

4.1 Purpose and implications

4.1.1 There is an inevitable, or natural, hierarchy of accuracies in petroleum measurement. At the top are volume standard measures which are certified by a government agency or laboratory traceable to the appropriate national standard. From this level downwards, any uncertainty at a higher level must be reflected in all the lower levels as a systematic error. Whether such systematic error will be positive or negative is unknown; either is possible.

4.1.2 To expect equal or less uncertainty at a lower level of the hierarchy than exists in a higher level is unrealistic. The only way to decrease the random component of uncertainty in a given measurement system or method is to increase the number of determinations, and calculate the mean value. The number of significant digits in intermediate calculations of a value can be larger in the upper levels of the hierarchy than in the lower levels.

4.2 Hierarchy

4.2.1 The hierarchy of accuracies in this standard is structured, in general, as shown in table 1.

4.2.2 This standard gives rules for rounding, truncating and reporting final values for each level of the hierarchy.

5 Principal correction factors

5.1 Purpose and implications

5.1.1 Designation of correction factors by symbol rather than by words is recommended because, first, it abbreviates their expression; second, it allows algebraic manipulations; third, it indicates their similarity subject only to the particular liquid or metal involved; and fourth, it can more readily eliminate confusion, as for example the difference between the compressibility factor F of a liquid and the correction factor C_{pl}, which is a function of F.

There are six principal correction factors employed in calculations of liquid quantities.

5.1.2 The first of these six correction factors is the meter factor MF, a non-dimensional value which corrects the volume indicated on a meter or meter accessory to the actual volume, be that volume a raw or corrected volume (see clause 7). In some instances, the *K*-factor is used in place of or along with the meter factor (see clause 8).

Table 1 — Hierarchy of accuracies

Clause	Hierarchy level	Correction factors and intermediate calculations to	Number of significant digits in volume	Temperature and pressure determination, for entering calculations, to
6	Prover calibration	6 decimal places[1)]	5	0,05 °C 50 kPa[2)]
7	Meter factor	4 decimal places	5	0,25 °C[3)] 50 kPa[2)]
8	*K*-factor	4 decimal places	5	0,25 °C[3)] 50 kPa[2)]
9	Measurement tickets	4 decimal places	5	0,50 °C[3)] 50 kPa[2)]

1) When water is used as the calibration liquid, correction factors for the effect of temperature and pressure on the calibrating liquid to 6 decimal places are used.

When a hydrocarbon is used as the calibrating liquid, correction factors for the effect of temperature and pressure on the calibrating liquid shall be calculated using the procedures referred to in ISO 91-1. Factors calculated using ISO 91-1 will be limited to 5 significant figures (4 or 5 decimal places). Cases may arise where calibration personnel do not have the capability to calculate ISO 91-1 values but do have access to the printed tables referred to in ISO 91-1. Under these conditions, linear interpolation of the tables over a limited span is acceptable for use in correcting for the temperature difference between master meter and prover during calibration.

2) In all hierarchies above, pressures shall be read, recorded and rounded to the nearest 50 kPa (0,5 bar). Where the gauge scale permits a closer tolerance, readings should be read, recorded and rounded to the nearest gauge scale division.

3) The use of a temperature determination device that can perform to a more stringent determination level than outlined in table 1 is acceptable provided that the installation, maintenance, operation and calibration practices are adequate to ensure performance to the level chosen.

5.1.3 The next four correction factors employed in calculations of liquid quantities are needed because of changes in volume from the effects of temperature and pressure upon both the containing vessel (usually made of mild steel) and upon the liquid involved. These four correction factors are:

C_{ts} (or CTS) ... the correction factor for the effect of temperature on steel (see 5.2)

C_{ps} (or CPS) ... the correction factor for the effect of pressure on steel (see 5.3)

C_{pl} (or CPL) ... the correction factor for the effect of pressure on liquid (see 5.4)

C_{tl} (or CTL) ... the correction factor for the effect of temperature on liquid (see 5.5)

5.1.4 Finally, there is a correction factor C_{sw} (or CSW) for accounting for the presence of sediment and water in crude oil (see 9.3.1).

5.1.5 Additional subscripts may be added to the symbolic notations above to make it clear to what part of the measuring apparatus they apply, namely p for prover, m for meter and M for a volume standard measure.

While the customary subscript notation is used in this standard, the allowed upper case notation is needed for computer programming and is convenient in typing. In such cases, M for measure shall be SM while m for meter shall be M.

5.1.6 The method for correcting volumes by 2 or more factors is to first obtain a CCF (combined correction factor) by multiplying the individual correction factors together in a set sequence, rounding at each step. Only then multiply the volume by the CCF. The set sequence is MF, C_{ts}, C_{ps}, C_{pl}, C_{tl} and C_{sw}, omitting any factors that may not be required in the calculation.

NOTE — This is considered the theoretically correct sequence for applying the six correction factors. However, it is acknowledged that, in some cases where mechanical or electronic devices are used to apply one or more of these factors, the order may be changed. This is especially true of temperature-compensated meters. However, if the correction factors are determined using the correct basis of temperature, pressure and density, the numerical value of the combined correction factor (CCF) will not be significantly different from the theoretical value.

5.1.7 All multiplication within a single operation shall be completed before the division is started.

5.2 C_{ts}

5.2.1 The volume of a metal container, such as a pipe prover, tank prover or volume standard measure, will change when subjected to a change in temperature. The volume change, regardless of shape, is directly proportional to the temperature change of the material of which the container is made. The correction factor for the effect of temperature on steel (C_{ts}) shall be calculated from the equation

$$C_{ts} = 1 + (t - 15)\gamma \qquad \ldots (1)$$

where

t is the temperature, in degrees Celsius, of the container walls;

γ is the coefficient of cubical expansion per degree Celsius of the material of which the container is made.

Thus, C_{ts} will be greater than 1 when the temperature t is greater than 15 °C, and less than 1 when the temperature t is less than 15 °C.

5.2.2 The value of γ is $3{,}3 \times 10^{-5}$ (or 0,000 033) per degree Celsius for mild or low-carbon steels, and has a range of $4{,}30 \times 10^{-5}$ to $5{,}40 \times 10^{-5}$ per degree Celsius for Series 300 stainless steels. The value used in the calculations shall be that given on the certificate from the calibrating agency for a volume standard measure or from the manufacturer of a prover. Tables of C_{ts} values against observed temperature will be found in annex A of this standard, the table for stainless steels being based upon a typical value of γ of $5{,}10 \times 10^{-5}$ for Series 300 stainless steels.

5.2.3 When the volume of the container at standard temperature (15 °C) is known, the volume at any other temperature t can be calculated from the equation

$$V_t = V_{15} \times C_{ts} \qquad \ldots (2)$$

5.2.4 Conversely, when the volume of the container at any temperature t is known, the volume at standard temperature (15 °C) can be calculated from the equation

$$V_{15} = V_t / C_{ts} \qquad \ldots (3)$$

5.3 C_{ps}

5.3.1 If a metal container such as a tank prover, pipe prover or volume standard measure is subjected to an internal pressure, the walls of the container will stretch elastically and the volume of the container will change accordingly.

While it is recognized that simplifying assumptions enter the equations below, for practical purposes the correction factor C_{ps} for the effect of internal pressure on the volume of a cylindrical container shall be calculated from the equation

$$C_{ps} = 1 + PD/ET \qquad \ldots (4)$$

where

P is the internal gauge pressure in kilopascals;

D is the internal diameter in millimetres;

E is the modulus of elasticity of the container material ($2{,}1 \times 10^8$ kPa for mild steel and $1{,}9 \times 10^8$ kPa to $2{,}0 \times 10^8$ kPa for stainless steels);

T is the wall thickness of the container in millimetres.

5.3.2 C_{ps} values for specific sizes and wall thicknesses of mild-steel pipe provers and pressures may be found in tables 6 and 7 of annex A of this International Standard. When the volume of the container at atmospheric pressure V_{atmos} (i.e. zero gauge pressure) is known, the container volume at any other pressure V_p can be calculated from the equation

$$V_p = V_{atmos} \times C_{ps} \qquad \ldots (5)$$

5.3.3 When the container volume at any gauge pressure P is known, the equivalent container volume at atmospheric pressure V_{atmos} can be calculated from the equation

$$V_{atmos} = V_p / C_{ps} \qquad \ldots (6)$$

5.4 C_{pl}

5.4.1 The volume of a liquid is inversely proportional to the pressure acting on that liquid. The correction factor C_{pl} for the effect of pressure on a volume of liquid can be calculated from the equation

$$C_{pl} = \frac{1}{1 - (P - P_e)F} \qquad \ldots (7)$$

where

P is the gauge pressure in kilopascals;

P_e is the equilibrium vapour pressure of the liquid at the measurement temperature, in kilopascals gauge pressure [P_e is taken as zero gauge pressure for liquids which have an equilibrium vapour pressure less than atmospheric pressure (101,325 kPa absolute pressure) at the measurement temperature];

F is the compressibility factor for hydrocarbons from ISO 9770 (this is determined at the meter operating temperature and the oil density at 15 °C; for water, the compressibility factors at various water temperatures are listed in table 2 below).

Table 2 — Isothermal compressibility factor for water

Temperature °C	Compressibility factor kPa^{-1}
5	$4{,}9 \times 10^{-7}$
10	$4{,}8 \times 10^{-7}$
15	$4{,}7 \times 10^{-7}$
20	$4{,}6 \times 10^{-7}$
25	$4{,}5 \times 10^{-7}$
30	$4{,}5 \times 10^{-7}$
35	$4{,}4 \times 10^{-7}$
40	$4{,}4 \times 10^{-7}$
45	$4{,}4 \times 10^{-7}$
50	$4{,}4 \times 10^{-7}$

5.4.2 When P_e is zero, equation (7) becomes:

$$C_{pl} = \frac{1}{1 - PF} \quad \ldots (8)$$

5.4.3 When P_e is greater than zero gauge pressure, equation (7) shall be used.

NOTE — A convenient field method of determining P_e while proving a meter against a pipe prover is to proceed as follows:

a) On conclusion of the last proving round, stop the flow through the pipe prover and isolate it from the flowing lines by shutting the appropriate valves.

b) Reduce the pressure on the pipe prover by bleeding off liquid until the gauge pressure stops falling. This will imply that a vapour space has been created, and that the liquid has reached its equilibrium vapour pressure. Shut the bleed valve, and read P_e on the gauge, making a record of the temperature at the time. The above procedure may be used for the determination of P_e for liquid mixtures that do not conform with published charts showing P_e values plotted against temperature, or it may be used as a routine procedure.

5.4.4 When the volume of a low-vapour-pressure liquid is known at any pressure (V_p), the equivalent liquid volume at standard pressure (zero gauge pressure, or V_{atmos}) can be calculated from the equation

$$V_{atmos} = V_p \times C_{pl} \quad \ldots (9)$$

5.4.5 When the volume of a low-vapour-pressure liquid is known at zero gauge pressure, the equivalent volume at any other pressure V_p can be calculated from the equation

$$V_p = V_{atmos}/C_{pl} \quad \ldots (10)$$

5.4.6 When the volume of a high-vapour-pressure liquid is known at any measurement temperature t and pressure P, pressure correction is done in two steps. The equivalent volume at such a liquid's equilibrium vapour pressure P_e at the measurement temperature can be calculated from the equation

$$V_{pe} = V_p \times C_{pl} \quad \ldots (11)$$

where C_{pl} is calculated from equation (7).

When this volume is in turn temperature-corrected to 15 °C using equation (12), the value of C_{tl} taken from the appropriate table, or calculated, also corrects the volume for the change in pressure from P_e at the measurement temperature to the equilibrium vapour pressure at the standard temperature of 15 °C. It should be noted that, while P_e at the measurement temperature t may be higher than atmospheric pressure (101,325 kPa absolute pressure), equilibrium vapour pressure at 15 °C may have fallen to atmospheric pressure or less. As noted under equation (7), the distinction between a low-vapour-pressure liquid and high-vapour-pressure liquid is based on whether its equilibrium vapour pressure is less than or greater than atmospheric pressure at the measurement temperature.

5.5 C_{tl}

5.5.1 If a quantity of petroleum liquid is subjected to a change in temperature, its volume change will be dependent upon the magnitude of the temperature change, the location within a range of temperatures that this change occurs at and the density of the liquid.

The values of C_{tl} for the correction of volume to that at 15 °C shall be taken from tables referenced in ISO 91-1.

5.5.2 When the volume of a petroleum liquid is known at any temperature t, the equivalent volume at standard temperature (15 °C) can be calculated from the equation

$$V_{15} = V_t \times C_{tl} \quad \ldots (12)$$

5.5.3 When the volume of a petroleum liquid is known at 15 °C, the equivalent volume at any temperature t can be calculated from the equation

$$V_t = V_{15}/C_{tl} \quad \ldots (13)$$

6 Calculation of prover volume

6.1 Purpose and implications

6.1.1 The purpose of calibrating a prover is to determine its base volume, that is, the volume of the prover under standard conditions. The procedures to be used for a pipe prover are described in ISO 7278-2.

6.1.2 Base volume is expressed in cubic metres or litres. Whereas volumetric units (e.g. the litre) do not vary with temperature and pressure, the volume of a metal prover does. Therefore to define the base volume of a prover or volumetric standard, it is necessary to specify standard conditions, namely 15 °C and 101,325 kPa absolute pressure (atmospheric pressure).

6.2 Volume standard measures

Volume standards used to calibrate provers shall be certified by a government agency or by a laboratory traceable to the appropriate national standard. Their certified volumes are given in measurement units at standard conditions. The uncertainty figure of field standards is usually the main component in the uncertainty figure of the prover calibration.

6.3 Rule for rounding — Provers

When calculating a prover volume, determine individual correction factors to 6 decimal places by using the appropriate formula (4 or 5 decimal places for C_{tl} values when hydrocarbons are used). Record the combined correction factor (CCF) rounded to 6 decimal places.

When using the water draw method, each individual volume in a volume standard shall be corrected by C_{tdw} [see 6.6.1a)] and

C_{tsM} [see 6.6.1b)]. This corrected volume is rounded to the same number of significant digits as the uncorrected volume. The corrected volumes are summed and then divided by C_{tsp}, C_{psp} and C_{plp} [see 6.6.1c)]. This volume is then rounded to 5 significant digits.

6.4 Temperature and pressure

During the calibration of a prover by the water draw method, the temperature and pressure of the water in the prover at the start of calibration are observed and recorded. Likewise, the water temperatures of the individual withdrawals into volume standards are observed and recorded at the time of recording the volume standard volume.

During the calibration of a prover by the master meter method, the temperature and pressure of the calibration liquid in the prover and meter are observed and recorded.

The temperatures and pressures shall be read, recorded and rounded as specified in table 1.

6.5 Calculation of base volumes

The procedure for calibrating pipe provers will be found in ISO 7278-2. The following sub-clauses specify the procedures for the calculation of the base volume of both pipe and tank provers calibrated by the water draw and the master meter method.

6.6 Corrections applied to measured-volume water draw method

6.6.1 In the water draw calibration procedure, the volume observed in the volume standards must be subjected to certain corrections in order to determine the base volume of the prover. In the examples, the final subscripts p for prover, and M for measure, have been added to the correction factor designations.

Thus:

a) The individual volume standard water volumes shall be corrected for any difference in temperature between the starting temperature of the water in the prover and the temperature of the water in the volume standards when their volume was determined (6.4); this is done by multiplying the individual volume standard volumes by C_{tdw}. C_{tdw} is defined as the correction for the temperature difference between the water in the test measure and in the prover; this is not the same as C_{tl} which corrects to 15 °C rather than to prover temperature. The values of C_{tdw} can be determined by methods explained in ISO 8222.

b) The individual volume standard water volumes shall also be corrected for the effect of temperature on the volume standard shell. This is done by multiplying the individual volume standard volumes determined in a) above by C_{tsM}. All individual volume standard volumes corrected as above are now totaled. In actual practice, C_{tdw} and C_{tsM} are multiplied to arrive at a CCF before any multiplication of individual volumes.

c) Finally, the volume shall be corrected for the effects of temperature on the prover shell (C_{tsp}), pressure on the prover shell (C_{psp}) and the compressibility of the water when in the prover C_{plp}. This is done by dividing the total volume determined in b) above by C_{tsp}, C_{psp} and C_{plp}. With open-top prover tanks, C_{psp} and C_{plp} are unity (1,000 000).

The overall equation for corrections as described above is

$$\text{Prover base volume} = \frac{\sum \left[\begin{array}{l} \text{volume standard} \\ \text{individual} \\ \text{volumes} \end{array} \times (C_{tdw} \times C_{tsM}) \right]}{(C_{tsp} \times C_{psp} \times C_{plp})} \qquad \ldots (14)$$

6.6.2 In practice, when several test measures are filled, the calculation is performed according to the equation in the manner specified in the following example.

6.7 Example of calculation — Calibration of pipe prover by water draw method using field standards

The form or record used for a water draw calibration of a pipe prover shall make provision for at least the information shown in A, B, C, D and E below. The values shown hereunder are given by way of example only. The example is limited to only one determination, although at least three are required.

A General information

Calibration report No.:	Prover serial No.: ....
Prover dimensions:	Pipe ϕ ext.: 273,1 mm, wall thickness: 9,27 mm
Prover type: unidirectional	Metal: mild steel
Date: .... Place:	Calibrator's name : ....

B Certified volume standards

1. Nominal size, litres	100	200
2. Basic volume, in litres, from calibration certificate at 15 °C and zero gauge pressure	100,00	200,00
3. Serial number	m	n
4. Material	mild steel	mild steel
5. Reference temperature, °C	15	15

C Volume standard volumes and their correction

6. Starting gauge pressure in prover, kPa	280			
7. Starting average temperature in prover, °C	28,00			
Fill No.	1	2	3	4
Volume standard used	m	n	n	n
8. Base volume, litres at 15 °C	100,00	200,00	200,00	200,00
9. Scale reading, litres + above zero − below zero	− 0,20	+ 0,64	+ 0,56	+ 0,40
10. Measured volume (8 + 9)	99,80	200,64	200,56	200,40
11. Withdrawal temperature, °C	28,00	28,00	28,00	29,00
12. Change for starting temperature, °C	0	0	0	+ 1,00
13. C_{tdw} [see 6.6.1a)]	1,000 000	1,000 000	1,000 000	0,999 710
14. C_{tsM} [see 6.6.1b)]	1,000 429	1,000 429	1,000 429	1,000 462
15. CCF_M (see 5.1.6) (13 × 14)	1,000 429	1,000 429	1,000 429	1,000 172
16. Corrected volume	99,84	200,72	200,64	200,43
17. Sum of corrected volumes:	701,63			

D Additional correction factors needed to calculate base volume

18. C_{tsp} at 28,00 °C (see 5.2)	1,000 429
19. C_{psp} at 280 kPa (see 5.3)	1,000 037
20. C_{plp} for water at 280 kPa [see 5.4, equation (8)]	1,000 126
21. CCF_p [see 5.1.6 and 6.6.1c)] (18 × 19 × 20)	1,000 592

E Final calculation

$$\text{Base volume} = \frac{\sum \left[\text{Measured volume (10)} \times \left(C_{tdw}\ (13) \times C_{tsM}\ (14)\right)\right]}{\left[C_{tsp}\ (18) \times C_{psp}\ (19) \times C_{plp}\ (20)\right]}$$

BV = 701,214 88 litres at standard conditions

BV = 0,701 214 88 m^3 at standard conditions

Rounded to 5 significant digits,

BV = 701,21 litres at standard conditions

BV = 0,701 21 m^3 at standard conditions

6.8 Example of calculation — Calibration of tank prover[1] by water draw method using field standards

6.8.1 The form or record used for a water draw calibration of a tank prover shall make provision for at least the information shown in the example that follows.

6.8.2 It is assumed that this is a field recalibration, that the top and bottom necks do not need recalibration, that any small adjustments to the top or bottom zero marks will be made by sliding the reading scales up or down as needed, and that both scales will then be resealed.

6.8.3 Since the tank prover is at atmospheric pressure, no pressure correction for either liquid or prover tank shell is required.

A General information

Calibration Report No.:	Prover serial No.: ....
Prover type: open stationary tank with top and bottom gauge glasses	
Material: mild steel	Nominal capacity: 4 010 litres
Date: .... Place:	Calibrator's name: ....

B Certified volume standards

Nominal size, litres	1 000	5
Basic volume, in litres, from calibration certificate at 15 °C and zero gauge pressure	1 000,00	5,00
Serial number	m	n
Material	mild steel	mild steel
Reference temperature, °C	15	15

C Volume standard volumes and their correction

Prover starting temperature, °C	top	27,20
	middle	27,10
	bottom	27,00
	average	27,10

1	2	3	4	5	6	7	8	9
Withdrawal	**Base volume** litres	±	**Temperature** °C	ΔT	C_{tdw}	C_{tsM}	(6 × 7) CCF_M	(2 ± 3 × 8)[1] **Corrected volume** litres
1	1 000,00	+ 0,10	27,00	− 0,10	1,000 028	1,000 396	1,000 424	1 000,52
2	1 000,00	+ 0,05	27,00	− 0,10	1,000 028	1,000 396	1,000 424	1 000,47
3	1 000,00	− 0,10	27,10	0	1,000 000	1,000 399	1,000 399	1 000,30
4	1 000,00	+ 0,10	27,10	0	1,000 000	1,000 399	1,000 399	1 000,50
5	5,00	− 0,20	27,20	+ 0,10	0,999 972	1,000 403	1,000 375	4,80
6	5,00	− 0,50	27,20	+ 0,10	0,999 972	1,000 403	1,000 375	4,50
Total volume, litres = 4 011,09 Rounded to five significant digits, total volume, litres = 4 011,1								
1) The corrected volumes are rounded to the same number of significant digits as the base volume (see 6.3.1).								

1) The term "tank prover" designates a large capacity field standard in a fixed position.

6.8.4 The calibration shall be repeated and, if the two runs after correction for temperature agree to within 0,02 % (in this example, to within 0,80 l), the mean value of the two runs becomes the calibrated volume of the prover at 15 °C.

6.8.5 If the reading on the top neck was, for example, 4 010,4 l at the start of calibration, and as the true volume is now known to be 4 010,7 l (average of the two runs), the top scale will have to be moved down 0,3 l. If the neck contains 1,5 l per 10 millimetres (which is a typical value), the top scale will be moved down 2,0 mm. An alternative would be to move the zero mark on the bottom neck scale upwards. Both scales should be resealed afterwards.

6.9 Example of calculation — Calibration of pipe prover by master meter method

6.9.1 The procedure for calibrating a pipe prover using the master meter method will be found in ISO 7278-2.

6.9.2 The first step is to prove the master meter in the liquid selected for the prover calibration, which in this example is diesel oil. In this example, a displacement meter is used as the master meter, proved against a master tank prover (calibration standard). A master meter proved against a master pipe prover may be equally well employed. The flow rate through a master meter while it is being used to calibrate a prover should be held to within 2 % of the rate at the time of its proving.

An alternative method is to develop an accuracy curve and read off the meter factor for the rate observed during the calibration.

The second step is to calibrate the pipe prover (establish its base volume) using the master meter as the link between prover and volumetric standard (master prover). Where possible, correction factors should be calculated and used to 6 decimal places. However, in cases where a hydrocarbon is used as the calibration liquid and/or a master prover as the volumetric standard of calibration, the C_{tl} factors and master prover volume will be stated to 5 significant digits. This being the case, all intermediate calculations involving these 5-significant-digit numbers shall be rounded to 5 significant digits.

$$\text{Prover base volume} = \frac{\text{Master meter registration} \times (\text{MF} \times C_{plm} \times C_{tlm})}{(C_{tsp} \times C_{psp} \times C_{plp} \times C_{tlp})} \qquad \ldots (15)$$

6.9.3 The form of work sheet used to record data and calculations should provide for at least the information shown in the following example. Only one worked example of a master meter calibration run is shown, although five runs are desirable in such a calibration.

6.9.4 Proving of the master meter (step 1)

$$\text{Meter factor} = \frac{\text{prover tank base volume} \times (C_{tsp} \times C_{psp} \times C_{plp} \times C_{tlp})}{\text{indicated meter volume} \times (C_{plm} \times C_{tlm})}$$

A General information

Proving report No.:		Time:	Date: ....
Liquid: diesel oil	Density: 830 kg/m³ at 15 °C		Rate: 115 m³/h
Operator's name:		Witness:	

B Master prover information

1. Base volume, in m³, at 15 °C and zero gauge pressure		3,247 6
2. Prover material		mild steel
3. Temperature, °C	top	23,20
	middle	23,10
	bottom	23,00
	average	23,10
4. Gauge pressure, kPa		0
5. C_{tsp} for prover (see 5.2)		1,000 267
6. C_{psp} for prover (see 5.3)		1,000 00 1)
7. C_{plp} for prover (see 5.4)		1,000 00 1)
8. C_{tlp} for prover (see 5.5)		0,993 00 2)
9. CCF_p for prover (5 × 6 × 7 × 8) (see 5.1.6)		0,993 27 (to five significant digits)
10. Corrected master prover volume, m³ (1 × 9)		3,225 7 (to five significant digits)

C Master meter information

11. Closing reading, m^3	2 334,488 8
12. Opening reading, m^3	2 331,255 5
13. Indicated meter volume, m^3	3,233 3
14. Temperature, °C	22,90
15. Gauge pressure, kPa	280
16. C_{plm} (see 5.4)	1,000 227
17. C_{tlm} (see 5.5)	0,993 17[2]
18. CCF_m (16 × 17) (see 5.1.6)	0,993 40 (to five significant digits)
19. Corrected master meter volume, m^3 (13 × 18)	3,212 0 (to five significant digits)

D Meter factor (10/19) for this run **1,004 3** (to five significant digits)[3].

1) As this example is for an open-tank prover, the gauge pressure is zero so C_{plp} and C_{psp} are unity. If a pipe prover is employed, these factors would have other values.

2) Value as calculated using ISO 91-1 sub-routine.

3) The meter factor to be used in the calibration of the prover shall be the average for all runs made when proving the master meter that meet the repeatability requirements in ISO 7278-2.

6.9.5 Calibration of the pipe prover (step 2)

A General information

Calibration report No.:	Prover serial No.: . . . .
Prover ϕ ext.: 406,4 mm	Wall thickness: 9,53 mm
Material: mild steel	
Calibration liquid: diesel oil	Density: 830 kg/m^3 at 15 °C
Date: . . . . Place:	Calibrator's name: . . . .
Flow rate during master meter proving: 115 m^3/h	
2 % flow rate tolerance range: 113 to 117 m^3/h	

B Pipe prover information

20. Temperature, °C	23,90
21. Gauge pressure, kPa	690
22. C_{tsp} (see 5.2)	1,000 294
23. C_{psp} (see 5.3)	1,000 134
24. C_{plp} (see 5.4)	1,000 563
25. C_{tlp} (see 5.5)	0,992 30 [see 2), 6.9.4]
26. CCF_p (22 × 23 × 24 × 25) (see 5.1.6)	0,993 28 (to five significant digits)

C Master meter information

27. Rate, m^3/h	114
28. Temperature, °C	24,20
29. Gauge pressure, kPa	520
30. Closing reading	2 420,856 7
31. Opening reading	2 414,421 3
32. Indicated meter volume (30 – 31)	6,435 4
33. Master meter factor[4)]	1,004 5
34. C_{plm} (see 5.4)	1,000 424
35. C_{tlm} (see 5.5)	0,992 04 [see [2)], 6.9.4]
36. CCF_m (33 × 34 × 35) (see 5.1.6)	0,996 93 (to five significant digits)
37. Corrected master meter volume, m^3 (32 × 36)	6,415 6 (to five significant digits)
38. Volume of prover this run, m^3 (37/26)	6,459 0

D Base volume of pipe prover, in m^3, at standard conditions[5)] **6,459 2**

4) The master meter factor (33) does not agree with the value shown for one run in step 1, line D, as the value used in line 33 is an average of more than one run.

5) The base volume of the pipe prover (D) does not agree with the value for one run (38) as it is assumed that at least five runs have been made and averaged. Also the base volume to be reported should be realistic; that is, it should be rounded to five significant figures. Any theoretical sacrifice of "accuracy" that this may entail is largely imaginary, and is also offset by the advantage of having a standard method of calculating and reporting values.

7 Calculation of meter factor

7.1 Purpose and implications

7.1.1 Even when the quantity passed through a meter is read directly in units of volume, by mechanical or electronic means, this indicated volume may not be the actual metered volume. This is due to meter or liquid characteristics which may change with time or operational conditions.

Some transfers of liquid petroleum measured by meter are sufficiently small in volume or value, or are performed at essentially uniform conditions, so that the meter can be mechanically or electronically adjusted to read within a required accuracy. Examples are retail measurements and some bulk plant measurements into and/or out of tank wagons. However, in most large-scale custody transfers when a single meter is used to measure several different liquids or to measure at several different flow rates, meter adjustment for each change is impracticable. In such service, accuracy can be achieved by leaving the calibrator setting undisturbed and sealed, or dispensing with the calibrator entirely, and by determining within narrow limits a meter factor for each operating condition.

Meter performance is affected by changes in operating conditions and the qualities of the liquid being metered. Conditions which affect meter performance include

a) viscosity;

b) flow rate;

c) temperature of the liquid;

d) pressure in the meter;

e) lubricating properties of the liquid.

It is thus a fundamental requirement that meters are proved under conditions which simulate those encountered in operation and that the meter factor selected for calculation of throughput is appropriate to the operation under consideration. The meter factor shall either be read from performance charts prepared for the meter and relating closely to the conditions of the transfer, or be obtained by proving the meter under the conditions of the transfer.

When selecting a meter factor from a performance chart it may be necessary to make additional corrections so as to duplicate current operating conditions.

7.1.2 The basic definition of meter factor is given in 3.5.

A meter factor is a non-dimensional number. Its value is the same whatever system of units is used to measure volume. The meter factor should not be confused with the K-factor which is covered in clause 8 of this standard.

The actual volume passed through the meter is derived from the prover base volume, or in some cases a master meter register (see 7.6). The volume indicated by the meter is derived from the meter register or an auxiliary proving counter.

It must be noted that various types of meter factor are required depending upon the type of meter registration equipment or calculation method used.

Table 3 lists some of the more commonly found throughput calculation and meter factor calculation relationships.

7.1.3 During proving, the temperature and pressure existing in the prover and in the meter are significant in calculating a meter factor. This is because the actual volume of liquid passed through the meter during proving must be determined indirectly from a knowledge of the exact volume measured in the prover. This calculation involves pressure and temperature differences between the prover and meter at the operational conditions during proving and at the standard or base conditions desired.

7.1.4 A meter factor is valid over a range of operating temperatures and pressures only if the temperature and pressure during metering do not differ from the temperature and pressure during proving sufficiently to cause a significant change in the mechanical dimensions of the meter, in the viscosity of the metered liquid or in flow rate. If conditions change sufficiently, the meter shall be proved under the new conditions, or corrections made to the meter factor based upon data previously taken and compiled into correction charts or tables.

7.1.5 Meter factors change with flow rate variations, and the extent of such change depends upon the type of meter and the

Table 3 — Throughput calculations and corresponding meter factor calculations

Throughput equation for net standard volume	Meter factor equation (reference number)	Remarks
$IV \times MF \times C_{plm} \times C_{tlm}$	$\dfrac{BV \times (C_{tsp} \times C_{psp} \times C_{plp} \times C_{tlp})}{IV \times (C_{plm} \times C_{tlm})}$ (16)	Standard meter factor.
$IV \times MF \times C_{plm} \times C_{tlm}$	$\dfrac{BV \times (C_{tsp} \times C_{psp})}{IV}$ (17)	Oil temperatures and pressures in prover and meter are identical during proving.
$IV \times MF \times C_{plm} \times C_{tlm}$	$\dfrac{BV \times (C_{tsp} \times C_{psp} \times C_{tlp})}{IV \times C_{tlm}}$ (18)	Oil pressures in prover and meter are identical during proving.
$IV \times MF \times C_{tlm}$	$\dfrac{BV \times (C_{tsp} \times C_{psp} \times C_{plp})}{IV}$ (19)	Oil temperatures and pressures in prover and meter are identical during proving; pressures encountered in proving are identical to those in normal operations.
$IV \times MF \times C_{tlm}$	$\dfrac{BV \times (C_{tsp} \times C_{psp} \times C_{plp} \times C_{tlp})}{IV \times C_{tlm}}$ (20)	Oil temperatures in prover and meter are different during proving; oil pressures in prover and meter are identical during proving; oil pressures encountered in proving are identical to those in normal operations.
$IV \times MF \times C_{plm}$	$\dfrac{BV \times (C_{tsp} \times C_{psp} \times C_{plp} \times C_{tlp})}{IV \times (C_{plm} \times C_{tlm})}$ (21)	Oil temperatures and pressures in prover and meter are different during proving; meter equipped with a temperature compensator, but pulse stream to prover counter is not temperature-compensated.
$IV \times MF \times C_{plm}$	$\dfrac{BV \times (C_{tsp} \times C_{psp} \times C_{plp} \times C_{tlp})}{IV \times C_{plm}}$ (22)	Oil temperatures and pressures in prover and meter are different during proving; meter equipped with a temperature compensator; pulse stream to prover counter is temperature-compensated.
$IV \times MF$	$\dfrac{BV \times (C_{tsp} \times C_{psp} \times C_{plp})}{IV}$ (23)	Oil temperatures and pressures in prover and meter are identical during proving; meter equipped with a temperature compensator; pulse stream to prover counter is not temperature-compensated; pressures encountered in proving are identical to those in normal operation.
$IV \times MF$	$\dfrac{BV \times (C_{tsp} \times C_{psp} \times C_{plp} \times C_{tlp})}{IV}$ (24)	Oil temperatures and pressures in prover and meter are identical during proving; meter equipped with a temperature compensator; pulse stream to prover counter is temperature-compensated; pressures encountered in proving are identical to those in normal operations.

NOTES

1) IV is the meter register indicated volume.

2) When using a tank prover, C_{psp} and C_{plp} will be equal to unity.

part of its operating range being used. A plot of meter factor against flow rate shows the range of flow rates over which the meter factor is not greatly influenced by changes in flow rate. If several flow rates are used during the transfer, the meter factor used for the calculation shall correspond to the weighted average of the flow rates.

7.2 Temperature and pressure

Meter factors fit into the hierarchy of accuracies between calibrated prover volumes (clause 6) and the calculation of measurement tickets (clause 9). Thus temperature readings for proving shall be read to the nearest 0,10 °C, averaged and rounded to the nearest 0,25 °C. Pressure readings for proving shall be read, recorded and rounded to the nearest 50 kPa (0,5 bar).

7.3 Rule for rounding — Meter factors

In calculating a meter factor, determine the numerator and denominator values separately, with each rounded to five significant digits. In intermediate calculations, determine individual correction factors to four decimal places. Multiply individual correction factors together, rounding to four decimal places at each step (for each of numerator and denominator) and record the combined correction factor (CCF) rounded to 4 decimal places. Divide the corrected prover volume by the corrected meter volume, and round the resulting meter factor to 4 decimal places. Prover counter pulse counts are read, recorded and rounded to the nearest count.

7.4 Calculation of standard meter factor for a displacement meter, using a prover tank

7.4.1 This example illustrates the calculation of a standard meter factor. However, the basic principle applies to all types of meter factor; only the required correction factors will change.

7.4.2 In calculating a standard meter factor, use expression (16) in table 3. Expression (16), restated to remove the prover pressure considerations not needed with an open tank prover, becomes

$$\text{MF} = \frac{\text{base volume} \times (C_{t\text{sp}} \times C_{t\text{lp}})}{\text{volume indicated by meter} \times (C_{p\text{lm}} \times C_{t\text{lm}})}$$

7.4.3 The prover base volume used in the equation is determined by reading the upper gauge glass of the tank after a proving run to one ten-thousandth part of the proving run total volume. If the bottom gauge glass was not at zero before the proving run was started, its reading shall be added to or subtracted from (as the case may be) the upper gauge glass reading, and the algebraic sum recorded as the prover base volume.

7.4.4 To calculate a meter factor, both prover and meter volumes must be in the same units and read and recorded to a resolution of one in ten thousand.

Read all prover thermometers to the nearest 0,10 °C, average them, round them and record them to 0,25 °C. Meter pressure shall be recorded to the nearest 50 kPa (0,5 bar). Calculate the correction factors C_{ts} and C_{tl} for the prover and round them to four decimal places (e.g. 0,996 2).

7.4.5 Determine the numerator of the expression by multiplying the prover base volume, as recorded, by the CCF and round to five significant digits.

7.4.6 Determine the denominator by subtracting the opening meter reading from the closing meter reading, read or estimated to 0,000 1 m³ or 0,1 l. Record as the indicated meter volume. Calculate correction factors C_{pl} and C_{tl} for the meter and record to four decimal places. Multiply the indicated meter volume by the CCF for the meter to obtain the corrected meter reading to five significant digits.

7.4.7 Calculate the meter factor by dividing the numerator by the denominator, and round the meter factor to four decimal places.

7.4.8 The purpose of the above conventions is to establish standard procedures which will ensure the same results from the same data regardless of the computing system used. Any seeming sacrifice of hypothetical maximum accuracy is insignificant and must take second place to consistency.

7.4.9 A standard meter factor report form used for a non-temperature-compensated displacement meter proved against a tank prover shall allow for at least the information shown in A, B, C and D below. Two proving runs are shown in the example, for each of which a run meter factor calculation is made separately; the two results are then averaged to arrive at the meter factor to be used.

A General information

Proving report No.:	Batch:	Density: 830 kg/m³ at 15 °C
Rate, m³/h:	Meter No.:	Liquid: diesel oil
Time:	Date:	Station: ....
Operator's name (signature):		

B Data from prover tank

1. Indicated prover tank volume, m^3		3,251 3	3,250 7
2. Prover material		mild steel	
3. Temperature, °C	top	23,20	23,20
	middle	23,10	23,10
	bottom	23,10	23,10
	average	23,13	23,13
	rounded	23,25	23,25
4. C_{tsp} (see 5.2)		1,000 3	1,000 3
5. C_{tlp} (see 5.5)		0,992 9	0,992 9
6. CCF_p (4 × 5) (see 5.1.6)		0,993 2	0,992 9
7. Corrected prover volume, m^3 (1 × 6)		3,229 2	3,228 6
8. Closing meter reading, m^3		2 314,314 3	2 334,489 7
9. Opening meter reading, m^3		2 311,022 1	2 331,198 4
10. Indicated meter volume, m^3		3,292 2	3,291 3
11. Meter temperature, °C		22,5	22,5
12. Meter gauge pressure, kPa		280	280
13. C_{plm} (see 5.4)		1,000 2	1,000 2
14. C_{tlm} (see 5.5)		0,992 9	0,992 9
15. CCF_m (13 × 14) (see 5.1.6)		0,993 1	0,993 1
16. Corrected meter volume, m^3 (10 × 15)		3,269 5	3,268 6
17. Meter factor (7/16)		0,987 7	0,987 8

D Meter factor to be used (mean of 2 runs) **0,987 8**

7.5 Calculation of standard meter factor for a turbine meter, using a pipe prover

7.5.1 This procedure also applies to the proving of a displacement meter equipped with a high-resolution pulser.

7.5.2 Turbine meters and pipe provers were developed after displacement meters and tank provers; therefore, although the procedure for calculating a meter factor for a turbine meter proved against a pipe prover was generally modelled on the older procedure, some changes were made.

7.5.3 For this procedure to be applied, the meter must have a high-resolution electrical output, i.e. a large number of pulses per unit of volume, so that a sufficient number of pulses per unit of volume is collected to provide the required discrimination as defined in ISO 2715.

7.5.4 This example illustrates the calculation of a standard meter factor. However, the basic principle applies to all types of meter factor; only the required correction factors will change.

7.5.5 In calculating a standard meter factor, use expression (16) in table 3:

$$MF = \frac{\text{base volume} \times (C_{tsp} \times C_{psp} \times C_{plp} \times C_{tlp})}{\text{volume indicated by meter} \times (C_{plm} \times C_{tlm})}$$

7.5.6 Because a pipe prover is subject to the effects of both temperature and pressure on the steel, its base volume (which is at standard conditions) has to be corrected to obtain this volume at proving conditions (C_{tsp} and C_{psp}).

The volume of the displaced liquid at proving conditions must then be corrected to the equivalent volume at standard temperature and pressure (C_{plp} and C_{tlp}). This latter value becomes the numerator in the right-hand side of the equation in 7.5.5, and the indicated meter volume corrected to standard temperature and pressure becomes the denominator.

7.5.7 The other rules and conventions discussed in 7.4.4 and 7.4.6 apply to calculation of a meter factor using a pipe prover and a turbine meter or displacement meter.

7.5.8 It is important to bear in mind that, when proving a turbine meter, or a displacement meter equipped with a high-resolution electrical pulser, the change in the meter reading is rarely determined from the meter's normal totalizer register. Instead, the high-resolution pulses generated by the meter during the proving run are usually counted and displayed by a separate electronic proving counter. In some cases, the number of pulses generated by the meter is multiplied by a totalizer scaling factor and/or a temperature compensating factor before being counted by the proving counter. In either case, it is critical that the "change in meter reading" required to calculate the meter factor be determined by dividing the number of counts from the proving counter by exactly the number of proving counts required by the meter's totalizer to register one unit of volume. For a displacement meter, this is determined by the pulse-per-revolution rate of the electrical pulser and the ratio of the gear driving the mechanical register. For an electrical totalizer, the number of pulses at the meter required to register one unit of volume is generally the inverse of the product of the totalizer's scaler factor and its divider factor.

Thus, a meter with its totalizer scaler set to multiply by 0,250 0 and its divider set to divide by 100 (or multiply by 0,01) has a counts-per-unit-volume figure of

$$\frac{1}{0{,}250\,0 \times 0{,}01} = 400$$

If the pulses from the meter were passed through the scaler only before being directed to the prover counter, then the appropriate counts or pulses-per-unit-volume figure would be 100, as 100 counts would be required at that point to register one unit of volume.

The key distinction is that the pulses or counts-per-unit-volume figure used in the proving report form calculation is determined by the settings and arrangement of the totalizer used with the meter rather than by the particular pulse-per-unit-volume characteristic of the meter itself, unless the prover counter is connected directly to the meter output.

While connecting the prover counter directly to the meter outlet overcomes any possible errors in the meter totalizer affecting the counts-per-unit-volume figure, the need to check the meter totalizer itself occasionally should not be forgotten. A temperature compensating meter totalizer may need checking more than an ordinary totalizer.

7.5.9 In the following example, the standard meter factor is calculated using a unidirectional pipe prover to prove a turbine meter, with a liquid of low vapour pressure.

A General information

Proving report No.:	Batch:	Density: 830 kg/m³ at 15 °C
Prover ϕ ext.: 355,6 mm	Wall thickness: 7,92 mm	Metal: mild steel
Rate, m³/h: 250	Meter No.:	Liquid: diesel oil
Time:	Date:	Station: ....
Totalizer pulses per m³: 10 000		
Operator's name (signature):		

B Data from proving runs

Run No.	Temperature, °C		Gauge pressure, kPa		Pulse count
	Prover	Meter	Prover	Meter	
1	17,20	18,00	540	420	28 209
2	17,20	18,20	540	420	28 210
3	17,60	18,20	540	420	28 214
4	17,80	18,60	540	420	28 214
5	17,80	18,60	540	420	28 215
Average	17,52	18,32	540	420	28 212,4
1. Average (rounded)	17,50	18,25	540	420	28 212
2. Metered volume: 28 212/10 000 = 2,821 2 m³					

In line 2 (metered volume), the average pulse count (28 212) is divided by totalizer pulses/m³ (10 000) and reported as m³, rounded to 5 significant digits.

C Data for prover

3. Base volume of prover, in m^3, at 15 °C and zero gauge pressure	2,806 8
4. C_{tsp} (see 5.2)	1,000 1
5. C_{psp} (see 5.3)	1,000 1
6. C_{plp} (see 5.4)	1,000 4
7. C_{tlp} (see 5.5)	0,997 8
8. CCF_p (see 5.1.6) (4 × 5 × 6 × 7)	0,998 4
9. Corrected prover volume, m^3 (3 × 8)	2,802 3

D Data for meter

10. Metered volume, m^3 (2)	2,821 2
11. C_{plm} (see 5.4)	1,000 3
12. C_{tlm} (see 5.5)	0,997 2
13. CCF_m (11 × 12)	0,997 5
14. Corrected metered volume, m^3 (10 × 13)	2,814 1

E Meter factor (9/14) **0,995 8**

7.5.10 In the following example, the standard meter factor is calculated using a bidirectional pipe prover to prove a turbine meter, with liquid of vapour pressure above atmospheric.

It is assumed for this example that the liquid measured is a propane mix with a density at 15 °C of 0,554 kg/l, and that a non-temperature-compensated turbine meter is used.

A General information

Proving report No.:	Batch:	Company: ....
Density: 554 kg/m^3 at 15 °C	Vapour pressure at operating temperature, kPa gauge pressure: 790	
Meter size: 38,1 mm	Meter manufacturer:	
Totalizer pulses/m^3: 82 950	Liquid: propane mix	
Prover diameter: 323,9 mm	Wall thickness: 9,53 mm	Metal: mild steel
Operator's signature:		
Date:	Station:	

B Data from proving runs

Run No.	Temperature, °C		Gauge pressure, kPa		Pulse count/round trip
	Prover	Meter	Prover	Meter	
1	24,80	24,40	2 650	2 720	28 629
2	24,60	24,40	2 650	2 720	28 626
3	24,80	24,40	2 650	2 720	28 635
4	25,20	25,20	2 650	2 720	28 634
5	25,40	25,40	2 650	2 720	28 633
Average	24,96	24,76	2 650	2 720	28 631,4
1. Average (rounded)	25,0	24,75	2 650	2 720	28 631
2. Metered volume: 28 631/82 950 = 0,345 16 m^3					

In line 2 (metered volume), the average pulse count (28 631) is divided by totalizer pulses/m^3 (82 950) and reported as m^3, rounded to 5 significant digits.

C Data for prover

3. Base volume of prover, in m^3, at 15 °C and zero gauge pressure	0,329 64
4. C_{tsp} (see 5.2)	1,000 3
5. C_{psp} (see 5.3)	1,000 4
6. C_{plp} (see 5.4)	1,007 7
7. C_{tlp} (see 5.5)	0,977 0
8. CCF_p (see 5.1.6) (4 × 5 × 6 × 7)	0,985 2
9. Corrected prover volume, m^3 (3 × 8)	0,324 76

D Data for meter

10. Metered volume, m^3 (2)	0,345 16
11. C_{plm} (see 5.4)	1,008 0
12. C_{tlm} (see 5.5)	0,977 0
13. CCF_m (11 × 12) (see 5.1.6)	0,984 8
14. Corrected metered volume, m^3 (10 × 13)	0,339 9

E Meter factor (9/14) **0,995 5**

7.5.11 In this example, the equilibrium pressure P_e is given as 790 kPa gauge, determined by the method explained in the note to 5.4.3. The C_{pl} factors used in lines C6 and D11 are calculated using equation (7) in 5.4.1.

7.5.12 For C_{tl} values see 5.5, for C_{ts} see 5.2 and for C_{ps} see 5.3, which references are also shown in the example.

7.5.13 For both meter and prover, a combined correction factor (CCF) is calculated according to instructions in 5.1.6.

7.6 Calculation of meter factor at standard conditions for a displacement meter, using a master meter

7.6.1 This example illustrates the calculation of a meter factor at standard conditions, using a displacement-type master meter volume standard. In this example, the meter totalizers are used to indicate the metered volumes. However, some master meters are equipped with an electrical switch which, under control of the meter's output, transfers at some repetitive volume and is used to gate a high-resolution counter. This counter in turn is connected to a high-resolution pulser mounted on the meter to be proved. The repetitive indicated volume is then the master meter metered volume, and the pulse count divided by the nominal number of pulses per unit volume is the volume through the meter being proved.

7.6.2 While this example illustrates a displacement meter as the master meter, a turbine meter is equally suitable for use as a master meter with most liquids.

7.6.3 When this procedure is used, the master meter shall have been proved using a pipe or tank-type prover as the volume standard. The meter factor applied to the master meter registration during the subsequent meter proving calculations shall have been determined at the flow and liquid conditions existing during this meter proving or be taken from a family of curves which accurately predict the factor based upon flow and liquid conditions.

7.6.4 To obtain a meter factor expressed to 4 decimal places, it is necessary to obtain an output from both the master meter and the meter to be proved representing not less than 10 000 discrete units of volume.

7.6.5 Meter registers, or proving counters used to register the volume of the meters, shall be connected in such a way that they can be started and stopped simultaneously.

7.6.6 In the following example, the meter factor is calculated at standard conditions, using a master meter. At the least, the following shall be recorded:

A General information

Proving report No.:	Batch:	Density: 738 kg/m³ at 15 °C
Rate, m³/h:	Meter No.:	Liquid: gasoline
Time:	Date:	Station: ....
Operator's name (signature):		

B Data from master meter

	Run 1	Run 2	Run 3
1. Meter pressure, kPa gauge pressure	670	670	670
2. Meter temperature, °C	21,3	21,1	20,5
3. Closing meter reading, m³	5 615,07	5 726,22	5 831,32
4. Opening meter reading, m³	5 502,01	5 615,07	5 726,22
5. Indicated metered volume, m³ (3 – 4)	113,06	111,15	105,10
6. Meter factor	1,001 5	1,001 5	1,001 5
7. C_{plm} (see 5.4)	1,000 8	1,000 8	1,000 8
8. C_{tlm} (see 5.5)	0,992 3	0,992 6	0,993 2
9. CCF (6 × 7 × 8) (see 5.1.6)	0,994 6	0,994 9	0,995 5
10. Corrected master meter volume, m³ (5 × 9)	112,45	110,58	104,63

C Data from line meter

	Run 1	Run 2	Run 3
11. Meter pressure, kPa gauge pressure	665	665	665
12. Meter temperature, °C	21,0	20,8	20,2
13. Closing meter reading, m³	10 265,01	10 873,69	11 450,66
14. Opening meter reading, m³	10 151,93	10 762,50	11 345,52
15. Indicated meter volume, m³ (3 – 4)	113,08	111,19	105,14
16. C_{plm} (see 5.4)	1,000 8	1,000 8	1,000 8
17. C_{tlm} (see 5.5)	0,992 6	0,992 9	0,993 5
18. CCF (6 × 7) (see 5.1.6)	0,993 4	0,993 7	0,994 3
19. Corrected line meter volume, m³ (5 × 18)	112,33	110,49	104,54