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Proving systems for meters used in dynamic measurement of liquid hydrocarbons —

Part 1: Introduction

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Petroleum Standards Policy Committee (PTC/-) to Technical Committee PTC/12, upon which the following bodies were represented:

Department of Energy (Gas and Oil Measurement Branch)
Department of Trade and Industry (National Engineering Laboratory)
Department of Transport (Marine Directorate)
General Council of British Shipping
Institute of Petroleum
Royal Institution of Naval Architects
Salvage Association

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

GAMBICA (BEAMA Ltd.)
Institute of Measurement and Control
United Kingdom Offshore Operators' Association

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Contents

National foreword

This Part of BS 6866 has been prepared under the direction of the Petroleum Standards Policy Committee and is identical with ISO 7278-1:1987 *"Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters — Part 1: General principles"*. ISO 7278-1 was prepared by Technical Committee 28, Petroleum products and lubricants, of the International Organization for Standardization (ISO) as the result of discussions in which the United Kingdom participated.

BS 6866-1 forms part of a series, each of which is identical with the corresponding Part of ISO 7278. The other Parts of BS 6866 are as follows:

— Part 2: *Methods for design, installation and calibration of pipe provers* (Identical with ISO 7278-2:1988);

— Part 3: *Methods for pulse interpolation* (Identical with ISO 7278-3:1986).

Cross-references

International Standard	Corresponding British Standard
	BS 6169 *Methods for volumetric measurement of liquid hydrocarbons*
ISO 2714:1980	Part 1:1981 *Displacement meter systems (other than dispensing pumps)* (Identical)
ISO 2715:1981	Part 2:1984 *Turbine meter systems* (Identical)
ISO 4267-2:1988	BS 7286 *Method for calculation of petroleum and liquid petroleum products* Part 2:1990 *Dynamic measurement* (Identical)
	BS 6866 *Proving systems for meters used in dynamic measurement of liquid hydrocarbons*
ISO 7278-2:1988	Part 2:1990 *Methods for design, installation and calibration of pipe provers* (Identical)
ISO 7278-3:1986	Part 3:1987 *Methods for pulse interpolation* (Identical)

ISO 4124 to which reference is made in clause **2** and elsewhere in this standard has not yet been published but it is likely to be approved by the responsible BSI Committee for implementation as a British Standard.

With reference to the footnote to clause **9** both standards referred to have now been published.

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

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

0 Introduction

This document is the first part of an International Standard on proving systems for meters used in dynamic measurement of liquid hydrocarbons. Future parts of ISO 7278 will provide more detailed descriptions of pipe provers, tank provers and pulse interpolation techniques; these parts are in preparation. Parts covering other aspects or types of proving systems may be added as the need arises.

The purpose of proving a meter is to determine its relative error or its meter factor as a function of flow rate and other parameters such as temperature, pressure and viscosity.

The purpose of determining the relative error is to find out whether the meter is working within prescribed or specially accepted limits of error, whereas the meter factor is used to correct any error in the indication of a meter by calculation.

1 Scope and field of application

This part of ISO 7278 provides general principles for proving systems for meters used in dynamic measurement of liquid hydrocarbons.

2 Reference

ISO 4124, *Liquid hydrocarbons — Dynamic measurement — Statistical control of volumetric metering systems*[1].

3 Types of prover

3.1 The following types of proving systems are in use:

a) tank prover systems;

b) pipe provers, bidirectional and unidirectional. Pipe provers with precision tubes as described in **6.7** are available for special applications;

c) master meters. Indirect procedure of volume comparison which causes additional uncertainties can be used for all liquids and flow rates, provided that the master meter is proved against acceptable proving systems under conditions which simulate those under which it will operate. Sometimes, a meter is used as a means of standardization of transfer; this equipment is generally known as a "master meter".

3.2 Provers can be used either connected (fixed or mobile) to the metering station or in a central proving station to which the meters or the measures can be taken to be proved.

3.3 In order to limit the maximum uncertainty to ± 0,01 % when using a pulse generator for proving, at least 10 000 pulses shall be obtained from the meter per proving run. This number of pulses can be reduced by pulse-interpolation techniques which allow either the use of meters with fewer pulses per unit volume or reduction of the prover volume.

4 General considerations

4.1 A meter should be proved at the expected operating or prescribed or agreed rates of flow, under the pressure and temperature at which it will operate and on the liquid which it will measure. In situations where it is not feasible to prove the meter on the liquid to be metered, the meter should be proved on a liquid having a density, viscosity and, if possible, temperature as close as possible to those of the liquid to be measured. A meter that is used to measure several different liquids shall be proved on each such liquid. Similar liquids may be used if a simple, known relationship exists between the relative error, flow rate and viscosity, provided that the uncertainty of measurement remains within acceptable limits. In any event, calibration should take place at a flow rate equivalent to that at which the meter will be used.

A meter shall be proved in different circumstances as follows:

a) Initial proving. This shall be carried out on the permanent location or in a central station where the expected conditions of operation can be reproduced. The initial proving makes it possible to determine the relationship between the relative error (or meter factor) and different parameters such as viscosity or temperature.

b) Occasional or periodical proving. If a simple relationship between the relative error (or meter factor) and influencing parameters can be determined, the meters shall be reproved periodically using a prover either on the site or in a centralised station. Otherwise, the meter shall be reproved on the site whenever significant changes in the influencing parameters, such as viscosity or temperature, occur. Regular provings are also needed to follow effects of mechanical changes.

4.2 Many petroleum liquids of high vapour pressures are measured by meter. If liquid evaporation during normal operation or proving could occur and affect measurement, the proving system should provide means to avoid evaporation.

[1] At present at the stage of draft.

4.3 The proving of a meter is like a laboratory test: when properly done, it provides a high degree of repeatability, which is necessary for measurement accuracy. There are as many details of the meter, its piping and the proving systems, which can contribute to measurement uncertainty, as there are in determining physical properties of the measured liquid. Furthermore, the proving system shall be maintained in good operating condition. Thorough inspection of provers and their ancillary equipment should be made with sufficient frequency to ensure reproducibility of proving results. It is essential that meter performance data be observed, recorded and studied and that calculations be correct (see ISO 4124).

The accuracy and repeatability of the proving can be affected by observation errors in determining the opening meter reading or the closing meter reading, the test volume passing through or delivered to the prover and in reading temperature and pressure, and by implicit errors in computation in the process of correcting a measurement to standard conditions.

4.4 Meter proving can be classified according to procedure, as described below.

a) The standing start-and-stop procedure uses registers (counters) from which the opening and closing readings are obtained at no-flow conditions. Opening and closing of valves shall be performed rapidly.

b) The running start-and-stop procedure involves obtaining the opening and closing meter readings of the proof while the meter is in operation. This is accomplished by the use of auxiliary or secondary registers of high discrimination which can be started and stopped while the meter and primary register continue to operate.

4.5 Every meter proof shall be made with the same register equipment as is used in regular operation or with additional synchronised auxiliary registers for the running start-and-stop procedure [**4.4** b)]. Inclusion of special auxiliary equipment such as the following is permitted: density selector, temperature compensator, and quantity-predetermining register. If employed, the auxiliary equipment shall be set and operative when making the proof runs. Time between proving runs shall be kept to a minimum.

4.6 There are two general objectives to meter proving which usually depend on the type of service.

In the first, a meter can be proved to establish its performance by adjustment of its registration, if necessary, to give a meter factor of 1,000 0 so that its indicated volume will be the volume of liquid actually delivered (gross volume within desired tolerances). This is the normal practice for a meter operating on intermittent deliveries, such as a tank truck meter or a loading rack meter at a terminal or bulk plant.

In the second, a meter can be proved to determine its meter factor or, if possible, a simple relationship between its meter factor and influencing parameters such as viscosity or temperature so that this factor or this relationship can be applied to the indicated volume to compute the gross volume delivered through the meter. This is the normal practice in the case of continuous or long-duration measurement.

4.7 When a meter is being proved for adjustment, a preliminary unrecorded run shall be made, as necessary, to equalise temperatures, displace vapours or gases and wet the interior of the prover. Subsequent recorded proving test runs shall be made in the required range of flow rates and the registration adjusted as necessary.

Each calibration point for the same flow should be repeated at least twice and preferably three times. Further repeats may be necessary, if specified. See ISO 4124.

4.8 When a meter is being proved to determine the meter factor at one or several flow rates, the procedure shall be essentially as specified in **4.7**, except that no changes shall be made to the meter registration adjusting device between runs. Proof runs shall be made and recorded until the specified number of consecutive runs at the same flow rate agree within an acceptable repeatability, at which point the average of these two runs shall be accepted as the established meter correction factor for this flow rate.

4.9 If the registration of a meter, during proving, is not changing in accordance with adjustments made to the register adjusting device, or if four individual unadjusted proving runs are made without any two successive runs checking within an acceptable repeatability, all phases of the proving operation shall be examined for the cause of the discrepancy. If the cause is not found, the meter and its register mechanisms shall be inspected for electronic or mechanical defects, repaired and proved before being returned to service.

4.10 The practical limit of accuracy in any observed value such as the volume in the reference vessel during a meter proof is one part in 10 000. For this reason, meter factors shall be rounded to four decimal places, not more and not less, for example 1,001 6.

4.11 The results of calculation can be adversely affected by the use of abbreviated tables, the unstandardized rounding of factors and/or intermediate calculations. The observed and computed data for all test runs made in obtaining a meter factor or other expression of meter performance shall be reported on a suitable meter proving report form. The completed form, when signed by the interested parties or by the legal authority, shall constitute approval, understanding and acceptance of the meter proof, unless otherwise limited to witnessing only by a notation on the report.

4.12 Most of the procedures specified above have been for the proving of a single meter. If the meter to be proved is part of a battery of meters handling a common stream, it is necessary either to divert the stream from the selected meter to be proved through the prover or remove the meter to a central proving station.

5 Tank prover systems

5.1 As far as possible, the use of all united supplementary bodies/matters inside the standard gauge shall be avoided, and in no case shall the gauge be adjusted to a given value by this means. The prover should be recalibrated after any changes to components within the calibrated volume section such as gauge glasses, thermometer well or spray lines. The tank prover should be designed in order to avoid any variation in its metrological characteristics and also to reduce clingage of liquid to the walls. The prover tank shall be inspected frequently for internal corrosion and for accumulation of sediment, rust, valve lubricant and other foreign material. Gauge scales shall be inspected frequently and the prover recalibrated if there is indication of gauge scale movements.

5.2 Proving with open prover tanks consists of a comparison of the change in volume of liquid indicated on the register and of the known volume in the tank prover. The liquid shall be passed through the meter under actual or simulated operating conditions of temperature, pressure, rate of flow, density and viscosity, into the prover, where its volume shall be determined from the gauge scales. The meter factor is the ratio between the actual volume measured with the prover reduced (or converted) to the conditions of temperature of the liquid during proving (i.e. flowing through the meter) and the change in volume indicated on the meter register.

5.3 After a preliminary filling and draining of the prover tank, the lower level of the test liquid shall be recorded. The meter to be proved shall then be stopped and the opening meter reading recorded. The proof run shall then be started by directing the liquid from the meter into the prover, maintaining the flow rate and meter pressure to simulate operating conditions. During the filling of the prover, the temperature of the metered stream near the meter shall be determined and recorded frequently enough to ensure an accurate average temperature of liquid as it passes through the meter. Flow shall be continued into the prover until the liquid reaches a suitable reading level. (Liquid levels in gauge glasses shall be determined by reading the bottom of the meniscus with transparent liquids, or the top of the meniscus with opaque liquids.) Flow shall then be stopped and the volume delivered to the prover promptly observed on the top gauge glass scale and recorded. The closing meter reading shall then be observed and recorded, after which the meter can be returned to service. Prover tank temperatures shall be taken, recorded and averaged, and the meter factor for the proof run calculated.

5.4 Meter registration adjustments, if called for, can be made as required and subsequent proof runs can be made by repeating the proof run procedure just described.

5.5 In some types of open prover tanks, a top spray is used during the emptying of the prover to saturate the air drawn into the prover with the vapour of the test liquid to reduce evaporation of the test liquid during a subsequent proof run. Where this is done, the spray shall be turned on prior to each emptying of the prover and closed off prior to zeroing the liquid level.

5.6 There are certain variations inherent in the foregoing general procedure, arising primarily from design differences with respect to the method of establishing the starting liquid or zero level at the beginning of the proof run.

6 On-line pipe prover systems

6.1 In proving with pipe provers, checking of equipment prior to proving shall include inspection of all valves to ensure against internal leakage, and of the attachment of accessories used for proving and energizing electrical circuits. Thermometers and pressure gauges shall be checked periodically.

6.2 The entire liquid stream from the meter or battery of meters to be proved shall be diverted to flow through the pipe prover. In some permanently installed pipe proving systems, flow through the meter and the prover is continuous. Flow shall always be maintained through the meter and prover sections until stable conditions of temperature are reached. Vent connections shall be checked to ensure that the meter and prover sections are completely purged and that no pockets of air or vapour remain in the system.

6.3 A trial proving run is frequently conducted as a final check before starting the recorded meter proving. This is a good practice and is recommended for those provers where it can be readily accomplished. The trial run shall include checking of the electronic or other register. Observation of the readings from the trial run will often indicate equipment mal-adjustment not otherwise apparent.

6.4 Operations necessary to conduct proving runs will vary with the installations and can range from completely manual to fully automatic. The essential step will consist of operating a valve or combination of valves, that causes the metered stream to move the movable element (piston, sphere, ...) through the calibrated section of the prover. The proving counter register shall be recorded prior to the start of every run or, if so equipped, it may be reset to zero. The switching operation shall be completed well before the movable element enters the calibrated section of the prover. In automatic systems, a push-button normally initiates a complete meter proof cycle and the timing of the operations is a matter of adjustment of the valve and the proper sequencing of the control system.

6.5 In unidirectional provers, a proving run shall consist of one trip of the movable element through the calibrated sections.

6.6 In bidirectional provers, a proving run shall consist of a round-trip of the movable element, i.e. the sum of two consecutive trips through the calibrated section. The standard volume is that which is defined by the total of the two operations.

6.7 A precision bore tube prover is composed of a movable element moving in a smooth bore tube with a precise device giving the position of the movable element either at the ends of the precision bore section or at intermediate positions. The performance of this type of prover is critically dependent on the mechanical precision of the tube bore and movable element position detecting system, the measurement accuracy and stability of temperature and pressure, tightness of the moving parts and the ratio between the diameter of the tube and the actual displacement of the movable element.

NOTE The term "tube" differentiates from the pipe prover.

6.8 Upon completion of each proving run, the data shall be recorded, the initial proving counter reading again determined or reset to zero and additional proving runs made as required. The data for each direction shall also be recorded for bidirectional provers. Runs should be made to check the repeatability of the systems. A meter proving report shall be prepared upon which to record the data and calculate the resulting meter factor or relative error. See ISO 4124.

7 Centralized prover systems

7.1 A central station is generally composed of the following parts:

a) pipe circuit in which product flow is caused by a variable-speed pump;

b) bench for setting up meters for calibration;

c) pipe prover or tank prover;

d) system for adjusting the static pressure of the circuit;

e) storage tanks for draining and filling the circuits with products of different viscosities;

f) instruments for the measurement of influencing parameters, such as viscosity or temperature.

7.2 The meters shall be selected so that the influence of the following parameters is either negligible under operating conditions or accurately evaluated.

a) Variations in flow rate and viscosity

Several tests shall be carried out corresponding to different flow rates and viscosities covering the limits of operation.

The resulting meter factors should be plotted in a three-dimensional space and smoothed with a mathematical function.

Other methods can be used, particularly the method based on the Reynolds number: the meter factors are associated with the corresponding value of the flow rate divided by the kinematic viscosity (corrected at a given temperature: 15 °C is recommended).

The resulting points can be smoothed by a single curve.

b) Variations in pressure and temperature

Mathematical corrections can be applied for changes in physical dimensions of the meter, provided that the change due to other effects (mechanical tolerance, blade angle, etc.) is negligible at the operating and proving conditions.

c) Curve drift

The overall reliability of the metering system shall not be affected between two consecutive provings, considering:

— long-term drift of the metering system;

— metered liquid quality.

7.3 The central proving station need not be connected to the metering location and may be remote from it. Every care shall be taken during handling and transportation of the meter.

7.4 For turbine meters, special care shall be taken in the installation to avoid misalignment. In any case, the straightener, or equivalent, should be kept attached to the meter for transportation and proving.

7.5 The results from a large number of tests on a range of meters of one type can be used statistically to predict the overall reproducibility of the meter, taking into account all the parameters and the curve drift due to operation and transportation.

The statistical analysis of a sufficient number of tests will aid judgement in determining

a) the optimum proving frequency;

b) the need for maintenance.

8 Master meter systems

8.1 The master meter method of proving meters requires the selection of a meter with better performance characteristics than the meter to be proved. The master meter can be one of a battery of parallel meters, a mobile meter or a meter at a test station used specifically for proving meters.

The master meter shall be reliable, consistent in its performance and maintained in the best operating condition. If used in mobile service, the master meter shall be adequately protected against damage in transportation or from mishandling in installation. The master meter shall be frequently proved against an acceptable proving system at as many flow rates as may be required and under conditions which simulate those under which it will operate.

Its consistency established, it shall be maintained within the desired tolerances, compatible with the quality of measurement desired.

In proving the master meter, a record of all data shall be kept so that necessary corrections can subsequently be applied when using the master meter to prove meters. If the pressure and temperature conditions are different from those existing during the proof of the master, the results of the meter proving shall be corrected as far as necessary. It should also be stated that a master meter is a secondary device and does not give as high an accuracy as a primary measuring device such as a pipe prover and a tank prover.

8.2 The master meter shall be connected in series with and in close proximity to the meter to be proved and care shall be taken to avoid any interaction between the two meters. The two meters shall be operated at the desired flow rate for an interval sufficient for at least 10 000 times the minimum increment to be passed through the meter.

With the standing start-and-stop method, flow shall be stopped and both opening meter readings recorded. To start the proof run, flow shall be started through the two meters simultaneously by using a valve on the downstream side of the meters to give the desired flow rate. Pressures and temperatures shall be observed and recorded during the proving. When sufficient time has elapsed to provide a satisfactory meter proof, the flow should be stopped by closing the same valve and the meter readings recorded.

With the running start-and-stop method, the registers or counters shall be electrically started and stopped simultaneously.

8.3 If a block valve had to be closed to divert the product through a master meter, then the block valve should be of a suitable design or provided with means to verify that no product is passing by leakage through the block valve.

9 Bibliography

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

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

ISO 4267-2, *Petroleum and liquid petroleum products — Dynamic measurement — Pert 2: Calculation of oil quantities*[2)].

ISO 7278, *Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters*

— *Part 2: Pipe provers*[2)].

— *Part 3: Pulse interpolation techniques.*

[2)] At present at the stage of draft.

Publications referred to

See national foreword.

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