

Liquid hydrocarbons — Dynamic measurement — Proving systems for Volumetric meters —

Part 4: Guide for operators of pipe provers

ICS 75.180.30

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National foreword

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The UK participation in its preparation was entrusted by Technical Committee PTI/12, Petroleum measurement and sampling, to Subcommittee PTI/12/1, Static and dynamic measurement, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or by using the “Find” facility of the BSI Standards Electronic Catalogue.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the ISO title page, pages ii to iv, pages 1 to 25 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.

This British Standard, having been prepared under the direction of the Sector Committee for Materials and Chemicals, was published under the authority of the Standards Committee and comes into effect on 15 August 1999

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Amendments issued since publication

Amd. No.	Date	Comments

ISBN 0 580 32797 3

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INTERNATIONAL STANDARD

**ISO
7278-4**

First edition
1999-04-01

Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters —

Part 4: Guide for operators of pipe provers

*Hydrocarbures liquides — Mesurage dynamique — Systèmes d'étalonnage
des compteurs volumétriques —*

Partie 4: Manuel de référence pour les opérateurs de tubes étalons



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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 voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 7278-4 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Subcommittee SC 2, *Dynamic petroleum measurement*.

ISO 7278 consists of the following parts, under the general title *Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters*:

- *Part 1: General principles;*
- *Part 2: Pipe provers;*
- *Part 3: Pulse interpolation techniques;*
- *Part 4: Guide for operators of pipe provers;*
- *Part 5: Small volume provers.*

Annex A of this part of ISO 7278 is for information only.

Introduction

All measuring instruments which have to meet a standard of accuracy need periodic calibration — that is to say, a test or series of tests has to be performed in which readings obtained from the instrument are compared with independent measurements of higher accuracy. Petroleum meters are no exception. Nearly all those used for the purpose of selling or assessing taxes, by national laws, need proving at intervals, and when there is a large amount of money at stake they are likely to be calibrated quite frequently. In the petroleum industry the term “proving” is used to describe the procedure of calibrating volume meters on crude oil and petroleum products.

The most usual way to prove a meter is to pass a quantity of liquid through it into an accurate device for measuring volume, known as a prover. With very small meters the proving device may be a volumetric flask or similarly shaped vessel of metal with an accurately known volume. There are, for instance, standard measuring vessels which can be used to prove the meters incorporated in gasoline dispensing pumps at roadside filling stations. If the pump dial registers 10,2 litres when enough gasoline has been delivered to fill a 10 litre vessel, it is evident that the meter is over-reading by 2 %.

In a large metering installation, where a single meter can be passing thousands of litres per second, the situation is much more complicated. The measuring elements of the meters generally do not drive mechanical dials graduated in units of volume like a gasoline dispenser, but instead cause a series of electrical pulses to be generated which are registered by electrical counters. With meters of this type the purpose of proving is to determine the relationship between the number of pulses generated/counted and the volume passed through the meter — a relationship which varies with the design and size of the meter and can be affected by flowrate and liquid properties.

Another difficulty is that where the meters are in a pipeline the flow through these large meters usually cannot be stopped and started at will. Consequently, both the meters and the prover have to be capable of being read simultaneously and “on the fly”, that is, while liquid is passing through them at a full flowrate. The proving is complicated still further by the effects of thermal expansion and compressibility on the oil, and that of thermal expansion and elastic distortion under pressure on the steel body of the prover.

This part of ISO 7278 is concerned with only one class of provers, known as pipe provers, which are used very widely where meters for crude oil and petroleum products have to be proved to the highest possible standards of accuracy. In principle, a pipe prover is only a length of pipe or a cylinder whose internal volume has been measured very accurately and having a well-fitted piston (or a tightly-fitted sphere acting like a piston) inside it, so that the volume swept out by the piston or sphere can be compared with the meter readout while a steady flow of liquid is passing through the meter and prover in series. In practice, however, various accessories must be added to the simple pipe-and-piston arrangement to produce a prover that will work effectively.

1 Scope

This part of ISO 7278 provides guidance on operating pipe provers to prove turbine meters and displacement meters. It applies both to the types of pipe prover specified in ISO 7278-2, which are referred to here as “conventional pipe provers”, and to other types referred to here as “compact pipe provers” or “small volume provers”.

It is intended for use as a reference manual for the operation of pipe provers, and also for use in staff training. It does not cover the detailed differences between provers of broadly similar types made by different manufacturers.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 7278. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 7278 are encouraged to investigate the possibility of applying the most recent editions of the International Standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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 4124:1994, *Liquid hydrocarbons — Dynamic measurement — Statistical control of volumetric metering systems*.

ISO 4267-2:1988, *Petroleum and liquid petroleum products — Calculation of oil quantities — Part 2: Dynamic measurement*.

ISO 7278-2:1988, *Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters — Part 2: Pipe provers.*

ISO 7278-3:1998, *Liquid hydrocarbons — Dynamic measurement — Proving systems for volumetric meters — Part 3: Pulse interpolation techniques.*

3 Principles

3.1 Ways of expressing a meter's performance

The object of proving meters with a pipe prover is to provide a number with (usually) four or five significant digits — such as 1,002 9, 0,999 8, or 21 586 which can afterwards be used to convert the readout of the meter into an accurate value of the volume passed through the meter.

There are several different forms that this numerical expression of a meter's performance can take, but only three of them are of importance to the pipe prover operator. They are discussed below.

3.1.1 Meter factor

The earliest petroleum meters were of the displacement type (see 4.1) with dials reading directly in units of volume such as litres or cubic metres. Readings on the display are usually approximate values. These values may be corrected to reflect a more accurate number by either changing the gear ratio in the display mechanism or through the use of a meter factor. Since difficulty can arise in attempting to achieve a given volume through changing the gears, the meter factor is more commonly used.

The meter factor, MF, is defined as the ratio of the actual volume of liquid passed through the meter (V) to the volume indicated on the dial of the meter (V_m). That is:

$$MF = V/V_m \quad (1)$$

In a proving operation the value of V is derived from the prover while V_m is read directly from the meter. Afterwards, when the meter is being used to measure throughput, readings can be multiplied by MF to give the corrected values of the volumes delivered.

Meter factor is a non-dimensional quantity, a pure number. This means that its value does not vary with a change in units used to measure volume.

3.1.2 K factor

During the past quarter of a century, turbine meters (see 4.1) have come into widespread use in the petroleum industry. They do not usually have a dial reading in units of volume, because their primary readout is simply a train of electrical pulses. These are collected in an electronic counter, and the number of pulses counted (n) is proportional to the volume passed by the meter.

The object of proving such a meter is to establish the relationship between n and V . One way of expressing this relationship is through a quantity called K factor, which is defined as the number of pulses emitted by the meter while one unit volume is delivered. That is:

$$K = n/V \quad (2)$$

When a meter is being proved it is necessary to obtain simultaneous values of n and V , with n coming from the meter and V from the prover. In subsequent use of the meter, the procedure is to *divide* the K factor into the number of pulses emitted by the meter in order to obtain the volume delivered.

The K factor is not a pure number. It has the dimensions of reciprocal volume ($1/V$) and so its value depends upon the units used to measure volume. A value of K factor expressed as pulses per cubic metre, for instance, is a thousand times the value expressed as pulses per litre.

3.1.3 One pulse volume

Because it is easier to multiply than to divide, the reciprocal of the K factor is a more useful quantity for field use when hand calculations are employed (but not when computers are used). This reciprocal is called the “one-pulse volume” (q) because it indicates the volume delivered by the meter (on average) while one pulse is emitted. It is defined by the equation:

$$q = 1/K = V/n \quad (3)$$

q has the dimensions of volume per pulse. When it is multiplied by the number of pulses emitted by the meter, the result is the volume delivered through the meter.

3.1.4 Alternative uses of meter factor, K factor and one pulse volume

It is shown in the previous subclauses how meter factor was originally used with displacement meters. With readout in units of volume, K factor and its reciprocal q are used with turbine meters, with the readout being a number indicated on a pulse-counter. Nowadays however, this distinction has largely disappeared. On the one hand, displacement meters intended for use with pipe provers are always fitted with electrical pulse-generators, so that for the purposes of proving they behave like turbine meters and the results can be expressed as a value of K factor or one pulse volume. On the other hand, some modern large-scale turbine metering systems incorporate a data processing module, sometimes known as a “scaler”, which converts the number of pulses emitted into a nominal value of the volume delivered; with such systems the earlier notion of meter factor again becomes useful in certain circumstances.

Detailed instructions for the use of meter factor, K factor and one pulse volume are given in ISO 4267-2.

3.2 How meter performance varies

Manufacturers' literature often states that the K factor of a certain meter is such-and-such, as if it were a constant value. But this is only approximately correct. K factor is affected to some extent by a number of variables, some of which are considered in 3.2.1 to 3.2.6.

3.2.1 Effect of flowrate

Meters are designed so that their factors are almost constant over a fairly wide range of flowrates. The ratio between flowrates at the top and bottom of this range is called the "rangeability", or the "turndown ratio", of the meter. Rangeabilities of the turbine and displacement meters widely used for hydrocarbon measurement generally do not exceed ten to one although some special meters may have considerably greater rangeabilities. Within this effective working range the K factor should not vary from its mean value by more than a small amount, and the extent to which it actually does vary — such as $\pm 0,25\%$ or $\pm 0,5\%$ — is known as the "linearity" of the meter. When complete information about the meter's performance is needed it has to be proved at several different flowrates, so that its rangeability and linearity can be established. Above and below the effective working range of a meter its K factor is liable to vary so greatly with flowrate that it is no longer practical to use the meter for accurate measurement.

3.2.2 Effect of viscosity

Meters of all types are affected to some degree by changes in the viscosity of the liquid being metered, although those of certain type and design are affected more seriously than others. When the viscosity of the liquid being metered changes it may be necessary for the meter to be re-proved. Whether it is necessary or not will depend upon:

- the amount by which the viscosity has changed;
- the extent to which the K factor of the meter concerned is affected by changes in viscosity;
- the accuracy required.

3.2.3 Effect of temperature

Temperature changes affect K factor in two ways. Thermal expansion in the meter causes dimensions and clearances to alter; and temperature changes cause the viscosity of the liquid to change, and thus produce the effect mentioned in 3.2.2. The thermal expansion effect is often negligible in turbine meters, except where large temperature changes occur. With displacement meters the thermal expansion effect is more significant because dissimilar metals are frequently used in the measuring chamber so clearances are changed.

3.2.4 Effect of pressure

Pressure affects K factor both by producing dimensional changes in the meter and by causing viscosity changes in the liquid. The effect of pressure on viscosity however, is too small to be significant in most metering applications. The dimensional effect is usually small in some designs of meters for operation at high pressures, but can be significant in some meters. Pressure changes will not often have enough effect on K factor to justify re-proving.

3.2.5 Effect of wear, damage and deposits

As a meter wears, its K factor will gradually change and so a meter used for custody transfer purposes should be re-proved at regular intervals to take account of this, even if re-proving because of changes in viscosity and temperature is not necessary. Deposits of wax and dirt can cause similar effects.

Accidental damage to a meter is likely to alter its K factor considerably. If a meter is stripped for repairs it should be proved after it has been reassembled.

3.2.6 Frequency of proving

The necessary frequency of proving varies enormously, from several times a day to once a year, or longer. Very frequent proving is often justified where the total value of the metered liquid is high — for instance, where crude oil is being metered for fiscal purposes, or in major pipeline installations — and in these circumstances, it is usual for a large pipe prover to be "dedicated" (permanently connected and stationary) to the metering system. The meters can easily be re-proved whenever the flowrate, temperature or viscosity change enough to warrant it, or whenever a new type of crude or product is being pumped. In some circumstances there may be a specified interval of time or a specified increment of throughput, after which the meter should be proved again.