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Crude petroleum and liquid petroleum products — Volumetric metering of viscous hydrocarbons

Pétrole brut et produits pétroliers liquides — Mesurage volumétrique des hydrocarbures visqueux

Reference number
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Foreword

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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 9200 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, Sub-Committee SC 2, *Dynamic petroleum measurement*.

Annex A of this International Standard is for information only.

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Introduction

This International Standard is intended as a guide to the design, installation, operation and proving of meters and their auxiliary equipment used in metering viscous hydrocarbons.

The objective of this International Standard is to stress the differences between metering high viscosity hydrocarbons and the normal application of metering to less viscous hydrocarbon liquids.

Some operations require purging the viscous liquids from the lines to prevent congealing during idle periods or to prevent contamination. If the air or gas used to displace the liquid is pumped through the meter when refilling the lines, the meter may operate at excessively high rates. This can cause damage to the moving parts of the meter and may result in erroneous meter registration. The recommendations in this International Standard should assist in avoiding misoperation, and the recommendations, if followed, should protect the meter from damage and inaccurate measurement due to entrapment of air or gas. Where alternative procedures are given, the recommendations of the meter manufacturer should be followed.

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Crude petroleum and liquid petroleum products — Volumetric metering of viscous hydrocarbons

1 Scope

This International Standard defines viscous hydrocarbons and describes the difficulties that arise when viscous hydrocarbons are raised to high temperatures. The effects of such temperatures upon meters, auxiliary equipment and fittings are discussed, and advice and warnings to overcome or mitigate difficulties are included.

2 Definition

For the purposes of this International Standard, a viscous hydrocarbon is defined as any liquid hydrocarbon that requires special treatment or equipment in its handling or storage because of its resistance to flow.

Examples of liquid hydrocarbons which are generally considered as viscous are residual fuels with a viscosity greater than 750 m^2/s at 50 °C, bitumens (both penetration grades and cutbacks), most lubricating oils and grease components, as well as some crude oils. Note that viscosity is a parameter in its own right, regardless of temperature.

NOTE 1 It is possible that another liquid not needing these precautions might have some of the characteristics or present some of the measurement problems characteristic of viscous hydrocarbons.

3 Description of metering systems

3.1 Selection and installation of meters and auxiliary equipment

3.1.1 General

Care should be taken in the selection and installation of meters and auxiliary equipment. The selection of air removers (eliminators) is of particular importance when used in viscous liquid service and is discussed separately in 3.1.6.

If the meter is to be installed in a vertical line, special consideration should be given to equipment design. Some types of meters are not designed for such an installation, and the performance of these types could be affected.

Because of the various types of meters available and the wide differences in liquids and measurement conditions, it is important that the meter manufacturer be given complete information on the proposed application. The information that should be provided is listed in 3.1.2.

3.1.2 Special meter construction

Many viscous liquids are heated in order to reduce viscosity and facilitate handling. If the viscous liquids are to be heated, certain special details in the meter's construction and manufacture are required. Extra clearance between moving parts may be provided to prevent interference, to reduce the work load required, and to compensate for the higher temperature and altered viscosity. Certain viscous liquids can contain corrosive materials, and this corrosivity can increase as the liquid temperature increases. Where significant, the metallurgy of the meter, its trim and auxiliary equipment shall be capable of resisting this corrosion. At elevated temperatures, special meter construction materials may be required. Where dissimilar metals are used, the high temperature can result in mechanical interference caused by differences in metal expansion. This is particularly true where liners or lining sleeves are used. The use of devices such as ventilated counter extensions may be necessary to separate the counter and the meter adjuster from the heat source.

Meters used in the transfer of liquids at elevated temperatures are often fitted with automatic temperature compensators that automatically adjust the counter registration to 15 °C. These compensators are designed to cover a certain range of operating temperatures. If a registration adjusted to 15 °C is desired, the range of operating temperatures shall be accurately specified, as well as the density of the liquid or its coefficient of expansion. Operating a temperature compensator at temperatures above its design range will result in inaccurate registration and can damage the device. Standby temperature during idle periods can exceed the design temperature rating and result in damage to the automatic temperature compensator or to the moving parts of the meter.

The meter manufacturer can make recommendations specific for the intended operating conditions to minimize possible problems. The manufacturer should be provided with the following information:

— flow rate range at maximum and minimum viscosities;

— maximum and minimum operating pressures;

— maximum and minimum temperatures;

— anticipated standby (or off-duty) temperature;

— viscosity of fluid at maximum and minimum temperatures (pascal-second, centipoise or any other recognized viscosity indication);

— specific gravity of fluid at maximum and minimum temperatures;

— type of proving equipment under consideration;

— nature and amount of any corrosive elements present;

— nature and amount of any abrasive elements present;

— compatibility (or noncompatibility) of construction material with the fluid.

3.1.3 Displacement meters

Displacement meters have performance characteristics on viscous fluids different from inferential and turbine meters. Performance in a displacement meter is affected by meter slippage. Slippage is the unmetered flow passing through the mechanical clearance between the moving parts of the meter, and is caused by the differential pressure across a heated meter resulting from mechanical and fluid friction. The magnitude of the slippage flow, which can be considered to have a laminar flow regime, is related to the meter flow rate, the size of the clearances, the viscosity and the fluid density. There is considerably less slippage through a meter as liquid viscosity increases. When a high degree of accuracy is required, re-proving is suggested with any viscosity change to re-establish accuracy.

Some types of displacement meters can handle any viscous liquid that can be pumped, whereas others may be limited to handling liquids of specified maximum viscosities. All types, however, have their maximum recommended flow rate reduced as the viscosity increases. The amount of flow rate reduction can vary with equipment from different manufacturers. A maximum limit on flow rate at high viscosity is necessary to maintain the meter pressure drop within the design limits, to prevent cavitation and to reduce the viscous shear load on moving parts.

3.1.4 Inferential and turbine-type meters

For turbine meters, changes in liquid viscosity result in a shift in the meter factor and a change in the range of flow rates over which the turbine meter will perform with close accuracy. A change in fluid viscosity requires re-proving of the meter for best accuracy. Turbine meters are available with viscosity-compensating devices or they can be designed to compensate for changes in viscosity, and are capable of operating over an acceptable flow range. In services where the turbine meter will be operating at flow rates which do not vary greatly, acceptable accuracy can be obtained if the meter is proved and if meter factors are established for the various expected viscosities and rates. These factors should be reproducible.

Since the viscosity of a liquid may change considerably with a change in temperature, all meters should be re-proved for changes in temperature as well as changes in viscosity. Re-proving will establish a basis for determining the frequency of proving that may be required to achieve the desired accuracy of measurement. When the temperature of the metered liquid can vary by more than a few degrees during deliveries, a temperature recorder is recommended.

Because of these viscosity factors, inferential and turbine-type meters for use on viscous hydrocarbons can be limited in performance; however, they should not be ruled out.

3.1.5 Heating methods

If it is necessary to heat the liquid for ordinary pumping and handling, the liquid in the meter and the upstream piping should also be kept heated. The principal objective is to reduce the viscosity to a practical flow condition and prevent solidification during idle periods.

Accessory equipment, such as valves, strainers and air eliminators, must be heated and insulated. This applies particularly to air eliminator venting mechanisms and control valve pilots.

For services in which the liquid is heated while in storage, it is sometimes possible to keep the liquid in the line to the meter and the accessories heated by circulating the liquid through a return line. This method is of particular value on tank trucks where auxiliary heating methods are difficult to provide. Some double-case meters can be installed so that the meter housing is part of the circulating system. In this type of installation, the return line is connected to the meter's outer housing. With single-case meters, the return line should tee off as close to the meter inlet as possible (see figure 1). In some applications, circulating the liquid through the entire meter system might be advisable; however, a means is necessary to prevent registration on the meter counter during such periods of circulation. An automatic method of controlling circulation and counter registration is suggested in this type of installation. Valves should be located in the return line to permit easy control of flow. Solenoid or motor-operated valves permit control of the circulation from a remote control point.

Heating will reduce the viscosity of most liquids, and the best heat transfer function may be effected by a variety of devices or methods. Where steam is available, the lines may be steam-traced. Many recent installations use hot oil for tracing the lines. In either case, the meter and the accessories also can be heat-traced. In handling very viscous liquids, it may be necessary to use steam-jacketed meters and accessory equipment. This equipment can also be used where hot oils are the tracing medium. Where steam or hot-oil tracing or jacketing is not possible, electric heating can be used as an alternative method. In smaller installations, the use of electric heating cable may be adequate and less costly.

It is important that the desired temperature of the liquid be maintained within reasonably close limits, not only for safety reasons, but also because meter accuracy is affected by variations in viscosity resulting from temperature fluctuations.

If a displacement meter is provided with extra clearances for use at a high operating temperature, that temperature should not be exceeded, and the meter should be operated within a reasonable limit of this specified temperature.

If the meter is operated at a temperature higher than that for which it is designed, interference between moving parts resulting in wear (or prevention of operation) can occur. Meters provided with extra clearance for use in high temperature and/or high viscosity operation are not suitable for use with liquids of low viscosity and/or at low temperature.

The liquid temperature must be held below the point which might cause vaporization of the product or any of its components and might result in inaccurate meter registration. In some cases, care must be exercised to prevent overheating of the liquid to a point where ignition might occur when it is exposed to the atmosphere. Overheating can also cause coking or chemical changes in some liquid hydrocarbons, which may affect meter performance or even damage the meter, and could possibly cause undesirable changes in the liquid.

3.1.6 Air remover (eliminator)

It is difficult to separate entrained air or vapour from most viscous liquids. As viscosity increases, the time required for separating fine bubbles of air or vapour from the liquid increases. The removal of entrained bubbles requires a large air-eliminator tank to effect separation. In most instances, this approach is uneconomical from the point of cost and required space.

The pumping of air or vapour should be prevented. A return line, as mentioned in 3.1.5, permits purging the system by returning any air or vapour to the storage tank. In effect, this uses the storage tank as an air eliminator. Where a return line can be used, circulation should be maintained long enough to ensure that all air or vapour has been carried back to the storage tank. This may be based on time, with liquid being pumped for a period of time more than sufficient to displace the original contents of the line to the meter.

A new installation must be started up carefully. The entire metering system should be filled at a reduced rate until all air pockets have been eliminated from the equipment. An air pocket in a meter can result in damage if flow is stopped or started quickly, creating a surge pressure.

The liquid in storage tanks can contain air or vapour bubbles, possibly caused by the method of heating or by pumping liquid into the storage tank at the same time that liquid is being pumped out. Some crude oils foam when heated, and it may be necessary to allow the tank to settle out before withdrawing the product. A sampling device or test method may be required to determine when the air or vapour content is at an acceptable level. If this type of operation must be used without allowing sufficient time for separating out the air or vapour, an air eliminator designed for the particular operating conditions is suggested. In this case the manufacturer should be consulted.

Where air or vapour must be pumped and cannot be removed with a circulating line or return line, a control valve may be used to stop the flow when air or vapour is detected (see figures 2 and 3). Several systems are available which use valves that are operated electrically, hydraulically or by air. A means is provided for detecting the presence of air or vapour in the pump, in the line or in the air eliminator. The detector then actuates the control valve. With these systems, the amount of air or vapour that must be eliminated is not large, and an air eliminator of moderate size should be sufficient. Examples of installations where this type of system might be required are tank truck meter systems and systems for unloading tank cars, barges, tankers and transport trucks.

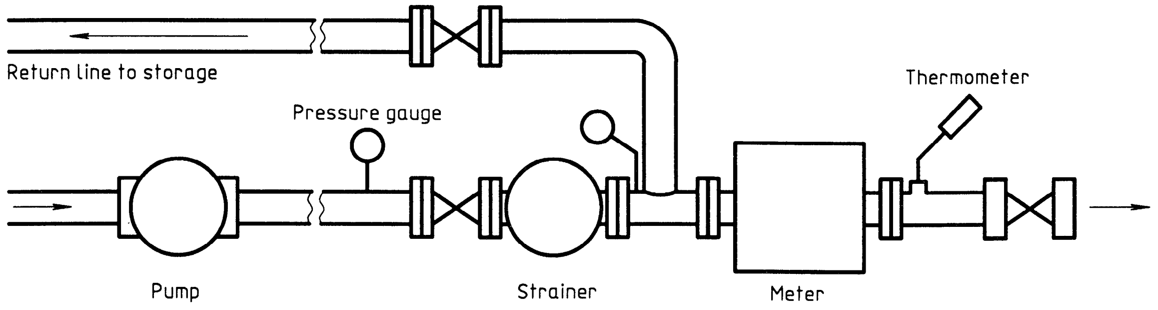

Figure 1 — Single-case meter installation with return line

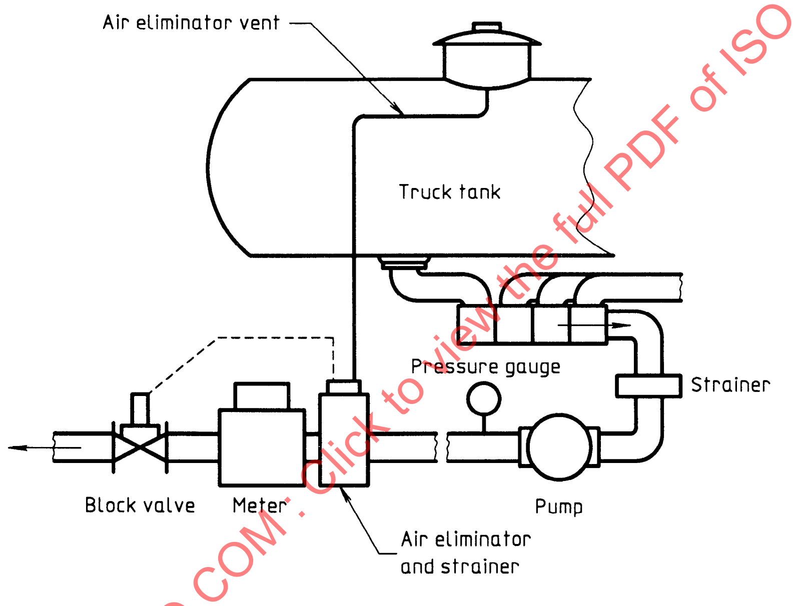

Figure 2 — Truck meter installation with control valve system

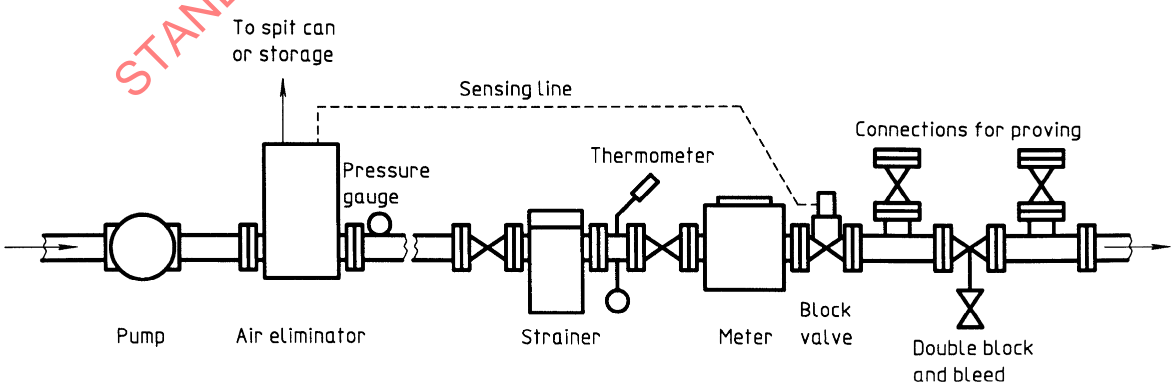

Figure 3 — Line meter installation with control valve system

The accuracy requirements of the installation are a major factor in determining the design of the air eliminator installation. The removal of free air or vapour that might exist in the piping system may be all that is required. An air eliminator of moderate size could be used provided the vent and vent lines are of adequate size to handle air at the maximum pumping rate.

The type and size of system needed to eliminate the air or vapour is determined by the installation design, pumping method and operating methods. A centrifugal pump will not pump a large amount of air, even on viscous products. A positive displacement pump will pump considerable quantities of air. The possibility of drawing a vortex when liquid level is low in the storage tanks can create a problem. The purging or evacuation of lines between pumpings can cause large quantities of air to be pumped.

The type or size of air eliminator equipment depends on the amount of air to be encountered, the form in which it will occur, the pumping rate, the viscosity of the liquid, and the overall accuracy requirements of the installation. To maintain both precision and reliability, particular attention to the selection of air-eliminating equipment is recommended.

4 Meter proving

In the petroleum industry the term "proving" is used to describe the procedure of calibrating volumetric 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 some proving methods, certain precautions shall be taken because of the viscosity or opacity of the liquid or because of its heated condition. When the liquid being measured is heated, the proving system should be insulated.

In general, meters used on viscous liquids hold their accuracy longer and, as a rule, do not need to be proved as often as those used on lighter liquids. Choosing the proving method to be used depends on several considerations. Any comparison of proving methods should consider initial cost, space requirements and ease of operation as related to the meter accuracy desired.

For example, a meter measuring a viscous crude oil in a pipeline at a point of custody transfer would very likely require the highest degree of accuracy obtainable. This could justify a fairly expensive proving installation, thus a pipe prover would be recommended. Another example might be a dock installation where space is restricted. In this case, the proving method depends on the accuracy desired. If a high degree of accuracy is required, a pipe prover can be selected. In some installations of this type, meters may be removed from the installation and transported to an onshore location for proving. Space limitations and other considerations could indicate that the master meter method of proving is the most desirable.

Although some of the various proving methods discussed above can have apparent advantages for a particular installation, the pipe prover method is recommended for best results on viscous fluids.

4.1 Pipe provers

The inherent advantage of pipe provers over tank provers for proving viscous liquids is that the wiping of the prover pipe walls by the displacer is more reproducible. In a tank prover, clingage of liquid to the inside walls can be greatly affected by viscosity and therefore by changes in temperature.

4.2 Tank provers

It is possible to use a tank prover with viscous liquids. For maximum accuracy, the prover should be designed for this specific use and properly operated as outlined below. If it is to be used on viscous liquids that are opaque, a method should be provided for cleaning the sight or gauge glasses so the liquid level can be read accurately. If the tank prover is calibrated with water or a liquid of low viscosity, a clingage film should be established before calibration by filling and emptying the prover with the viscous liquid to be handled in the installation.

The clingage film is, in principle, a film of the liquid being handled, but with some liquids, exposure to the atmosphere or air may cause oxidation of the film. Oxidation can result in a gradual increase in thickness of the clingage, with one oxidized layer being formed on top of the previous layer. With some liquids, wax incrustation can be a problem because of a gradual buildup of the oxidized clingage film.

Clingage will also be affected by the temperature of the delivered proving draft and by ambient temperatures. The effect is most pronounced when the liquid is not heated or when considerable time elapses between proving runs. If a tank prover is used on various liquids, the clingage film established with one liquid may be partially removed if the prover is subsequently used on a liquid having a higher temperature.

If the tank prover is to be used with various liquids covering a wide range of viscosities, the prover should be calibrated with a clingage film from liquids of two or more representative viscosities in order to obtain maximum accuracy. This may require different gauge scales, at either the top or the bottom neck of the prover. To avoid confusion, the various viscosity zero points on the gauge scales should be clearly marked.

If the clingage film on the prover walls will affect the volume of the prover, it is preferable to remove the film by spraying or washing the interior surfaces of the prover. However, the cone bottom and cone top of regular provers do not have a sufficient angle for proper draining. A tank prover used with viscous liquids should have a greater than usual angle of the cone top and cone bottom to ensure good drainage.

A tank prover used with a viscous liquid should be calibrated allowing a fixed time for draining. This draining time should be used when the prover is initially filled and emptied for establishing clingage. The draining time then becomes part of the prover calibration and should be used in any subsequent meter proving on viscous liquids. A metal tag or label, permanently attached to the prover, on which the draining time and temperature are stamped is suggested. The tag or label should clearly show that the draining time must be observed for maximum accuracy of the prover. If various viscosities will be encountered, the tag should define the time required for each viscosity.

The prover capacity should be sufficient for 1,5 min to 2 min of delivery time through the meter. When using a tank prover, allow sufficient time for entrained air to separate from the delivered liquid. During loading, many liquids will foam, and the air must be eliminated for accurate volumetric determination.

4.3 Gravimetric proving

In many installations, a feasible method for proving the meter is to weigh the mass of the delivered quantity of liquid, thus overcoming clingage problems in the tank prover. The density of the liquid predominating in the meter shall be known in order to use the gravimetric method. If this method is used, the parties involved shall agree on the details of procedure and calculation because gravimetric proving is seldom used with normal hydrocarbon liquids.

Any gravimetric proving method is only as accurate as the weighing scale used for a standard and the accuracy with which the relative density is determined. For maximum accuracy, the scale used as a standard should be checked prior to proving by a qualified scale-testing organization. Checking the accuracy of the scale over its complete range is important. At a minimum, the scale should be verified in the ranges that will encompass the mass of the prover or container when both empty and full.

4.4 Master meter proving

It may be more convenient to prove meters on viscous liquids by the use of a master meter.

It is recommended that the master meter be proved on a liquid of viscosity and temperature comparable to that used in the meter installation. This is particularly true when handling viscous liquids in the lower temperature ranges.

5 Meter operation

Many heavy liquids have some lubricating properties, consequently prolonging meter life. On the other hand, some crude liquids may contain high percentages of sand or foreign matter, which can drastically decrease meter life, make special meter construction desirable, or require suitable accessory equipment for removing these materials from the liquid.

It is recommended that meters be operated on viscous liquids at a maximum rate of flow somewhat less than the rated capacity on lighter liquids. This reduces the work load on the moving parts and bearings, and ensures complete filling of the measuring chamber during each cycle. Incomplete filling can cause error at higher rates of flow. The use of a rate-of-flow control valve is suggested to avoid exceeding the recommended rate. The type selected must be suitable for the viscosity of the liquid.

When the lines are evacuated during idle periods, as in the handling of asphalts, the operation should be set up so that the air contained in the line will bypass the meter during startup or is otherwise eliminated. Meters can be damaged by the passage of air at high operating speeds, resulting in erroneous meter registration.

The accurate determination of temperature of the liquid is important whenever a commercial transaction is involved. This is equally true for liquids that must be handled at elevated temperatures as it is for liquids that are heated only moderately. Accurate temperatures are necessary for conversion of the volume delivered to the volume represented at 15 °C. This conversion may be done mathematically or it can be done automatically using an automatic temperature compensator incorporated in the meter. The meter can be equipped to register both net and gross volumes. By adjusting the meter, the gross register can have a meter factor of 1. The net counter then will register the same volume corrected to 15 °C base.

The use of an automatic temperature compensator on liquids that are heated above the 15 °C base will give a volume reading on the net counter that is less than the volume reading on the gross counter. For this reason, the net counter is usually not used for delivery purposes when the liquid is being transferred to a container such as a transport truck. In this type of delivery, the use of a gross counter for loading is suggested to avoid overloading or spillage.

When the correction to 15 °C volume is performed mathematically, the average temperature of the liquid being delivered should be established as accurately as possible. One method of doing this is to maintain the liquid temperature at a constant value. If this is not possible and the liquid temperature shows wide variations, it may be necessary to take frequent readings of the liquid temperature during the delivery.

This may be done by using an indicating thermometer in the line or in the meter housing (automatic flow-weighted temperature devices), or in a riser. If the temperature is recorded on a chart, the average can be determined with acceptable accuracy.

Any testing or checking of an automatic temperature compensator, temperature recorders or averagers for accuracy or performance characteristics should be made with thermometers having accuracy characteristics appropriate to the function being performed. In this case, the thermometer is the standard for testing the automatic temperature compensator (ATC) and, as such, should have a tolerance no greater than 50 % of the tolerance allowed the device being tested.

The thermometer used should be calibrated in increments of 0,1 °C or smaller. The testing procedure may vary with the ATC manufacturer; therefore, the procedure suggested for the particular device should be followed.

A well-planned and executed inspection and maintenance programme can contribute a great deal to the value of any meter system. Proving data can be especially valuable if recorded over a period of time. A change in meter factor between proving runs conducted under identical conditions may indicate the need for inspection or maintenance.

In instances when the temperature can vary considerably, a meter with an automatic temperature compensator can afford the most accurate determination of the net standard volume if the product temperature cannot be recorded accurately.

Strainers should be included to protect the meter from foreign material. Fairly coarse basket mesh may be used. When pumping viscous liquids with pumps fitted with relief valves, the relief valves may not react fast enough, and high shut-off pressure may be experienced if the flow is stopped quickly. Any valves included in the installation for starting or stopping the flow should be of the slow-opening or slow-closing type. The time required for opening or closing should be selected so that pump relief valves will be able to react as intended to keep the pressure on the meter within design limits.

Annex A
(informative)

Sample gravimetric meter proving report form

A.1 Sample meter proving report form

Meter proving report No. ....
Gravimetric method for viscous liquids

Meter No. ....
Location ....
Date ....

Meter size ....
Meter type ....
Type of product ....

Temperature compensated ....
ATC serial No. ....
Other ....

	Run No.		
	1	2	3
Prover data			
1. Sample temperature	....	....	....
2. Sample relative density at line 1 temperature	....	....	....
3. Sample relative density at 15 °C	....	....	....
4. Sample weight per m^3 at 15 °C	....	....	....
5. Gross prover weight	....	....	....
6. Tare prover weight	....	....	....
7. Delivery weight (line 5 minus line 6)	....	....	....
8. Volume in prover at 15 °C (line 7 divided by line 4)	....	....	....
Meter data			
9. Meter pressure	....	....	....
10. Meter temperature	....	....	....
11. Closing meter reading, m^3	....	....	....
12. Opening meter reading, m^3	....	....	....
13. m^3 registered (line 11 minus line 12)	....	....	....
14. Temperature correction factor, C_{tlm} (if no ATC)	....	....	....
15. Pressure correction factor, C_{plm}	....	....	....
16. Net m^3 metered, (line 13 × line 14 × line 15)	....	....	....
17. Meter factor (line 8 divided by line 16)	....	....	....

Average meter factor ....

Signed by ....
for ....

Signed by ....
for ....