International Standard 2714

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Liquid hydrocarbons — Volumetric measurement by displacement meter systems other than dispensing pumps

Hydrocarbures liquides — Mesurage volumétrique au moyen de compteurs à chambre mesureuse autres que ceux des ensembles de mesurage routiers

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Foreword

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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.

International Standard ISO 2714 was developed by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, and was circulated to the member bodies in December 1976.

It has been approved by the member bodies of the following countries :

Australia	France	Poland
Austria	Hungary	Romania
Belgium	India	Spain
Brazil	Iran	Sweden
Bulgaria	Israel	Turkey
Canada	Japan	United Kingdom
Chile	Korea, Rep. of	USA
Czechoslovakia	Mexico	USSR
Egypt, Arab Rep. of	Philippines	

The member body of the following country expressed disapproval of the document on technical grounds :

Germany, F. R.

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Liquid hydrocarbons — Volumetric measurement by displacement meter systems other than dispensing pumps

0 Introduction

Displacement meters measure by separating a liquid into discrete volumes and counting the separated volumes. Such meters carry through their measuring elements a theoretical swept volume of liquid plus the slippage for each stroke, revolution or cycle of the moving parts. The volume registered must be compared with a known volume by proving.

This International Standard has been prepared as a guide for those concerned with the design, installation, operation and maintenance of metering systems having one or more displacement meters. Its content is common to all displacement meters. A typical arrangement of a meter station with three displacement meters is shown in the annex.

Information on turbine meters appears in ISO 2715, *Liquid hydrocarbons — Volumetric measurement by turbine meter systems.*[1)] Future International Standards will deal with other types of meters, accessory equipment, provers and proving, the calculation of petroleum quantities, and specialized applications of metering assemblies containing displacement meters.

1 Scope and field of application

1.1 Scope

This International Standard specifies the characteristics of displacement meters and gives rules for systematically applying appropriate consideration to the nature of the liquids to be measured, to the installation of a metering system, and to the selection, performance, operation and maintenance of the same.

1.2 Field of application

The field of application is any division of the petroleum industry in which measurement is required, but it does not necessarily apply to two-phase liquids.

Measurement tolerance or limits of error are usually set by regulation or, in certain countries, by a mutual accord between parties. It is not the purpose of this International Standard to set tolerances or accuracy limits. However, these provisions should be adequate to achieve a degree of measurement accuracy acceptable for any metering requirement. The content of the International Standard is general and is intended as a guide. It can be applied to the metering of different hydrocarbon liquids, to the use of meters from any manufacturer and to the various applications encountered.

2 References

ISO 91, *Petroleum measurement tables.*[2)]

ISO 4124, *Petroleum metering systems — Measurement control charts and statistical methods.*[1)]

3 System design and selection of meters and ancillary equipment

3.1 Design considerations

All types of metering installations shall meet the following requirements :

a) They shall be suitable for the maximum and minimum flow rates, the maximum permissible operating pressure, the temperature range and the type of liquid to be measured. If necessary, protective devices shall be included to limit or control the operation within the design conditions of the metering installation.

b) National, state or municipal regulations for electrical equipment in hazardous areas shall be complied with if there is a possibility of a hazardous atmosphere being present at the installation site.

1) At present at the stage of draft.

2) At present at the stage of draft. (Revision of ISO/R 91).

c) All materials of construction in contact with the hydrocarbon liquid shall neither affect nor be affected by the liquid.

d) They shall be designed in a manner which will result in the maximum dependable operating life. This may require that strainers, filters or other protective devices be installed to remove abrasive or other entrained particles from the liquid which could stop or cause premature wear of the metering mechanism. A differential pressure gauge may be used to determine when the filter or strainer should be cleaned. In other services where the liquid is clean or where the type of meter installed does not require or warrant protection, the omission of the filter or strainer can be considered.

e) Where applicable, connections for proving facilities shall be provided and the installation for proving the meter shall comply with the national verification regulations.

3.2 Selection of displacement meter and ancillary equipment

3.2.1 Consideration shall be given to, and the manufacturer consulted, regarding the following when selecting a meter and its ancillary equipment (see annex, figure) :

a) space for the meter installation and where applicable the proving facility;

b) class and type of connections required, and dimensions of the equipment to be used;

c) the properties of liquids that the meter will be required to measure, including viscosity, density ranges, vapour pressure, corrosiveness and lubricating properties. These properties may influence meter characteristics and choice of materials of construction. An increase in viscosity will generally increase pressure drop and bearing load. A change in viscosity may shift and change the shape of the calibration curve. Meter wear will be increased when non-lubricating liquids are being measured;

d) the quantity, size, particle distribution and type of foreign matter, and the quantity of water or vapour which may be carried in the stream. These may influence the size of straining, filtering and vapour or water separation equipment from the standpoints of flow rate capacity and pressure drop;

e) the maximum and minimum rates of flow and whether the flow is continuous or intermittent;

f) range of operating pressures and pressure losses across the meter when run at the maximum expected flow rate;

g) temperature range within which the meter will operate; whether volume correction to a reference or base temperature will be required; and whether or not heat tracing is used;

h) maintenance methods and cost; spare parts required;

j) type, method and frequency of proving;

k) the meter's rangeability and the degree of precision required;

m) a means whereby a meter read-out may be adjusted so that correction for meter factor is not necessary, and the ease or reliability of the adjustment and its suitability for sealing;

n) type of indicating or recording, or indicating and recording devices required and the standard units of volume in which read-out is required or, in the case of meters fitted with integrating counters giving read-out in mass, the unit of mass required;

p) suitability for use with remote registering equipment;

q) need for any other ancillary equipment such as quantity predetermining devices, pulsers, additive injection equipment, automatic temperature compensators, combinators, etc. When using mechanical ancillary devices driven by the meter, caution should be observed to limit the total torque applied to the meter element. Consideration should also be given to using an electrical device (transmitter) on the meter, and to having various functions operated electrically therefrom.

3.2.2 Automatic temperature compensators, if installed, shall be chosen to respond to the temperature range of the measured liquid within the required measurement tolerances under all ambient conditions.

3.2.3 Meter capacity shall be based on flow rate range required and allowable pressure drop requirements. Size of inlet/outlet connections do not necessarily indicate flow capacity.

4 Installation in metering systems

This clause includes details for the installation of displacement meters in metering systems.

4.1 Each meter shall be installed in such a manner as to prevent passage of air or vapour through it. If necessary, a degassing device shall be installed upstream of, and as close to, the meter as possible and the air release vents shall be piped to an appropriate and safe location or vessel. Vent piping shall meet safety and regulatory requirements.

4.2 The entire installation shall be designed to minimize the entry of air or vapour into the system, e.g. a pressure relief valve placed downstream of a meter shall not be linked to one upstream of the meter.

4.3 For meters designed for flow in one direction only, provision shall be made to prevent flow in the reverse direction.

4.4 Generally all valves, and especially spring-loaded or self-closing valves, shall be of such design that they will not open to admit air.

4.5 Any condition which may cause the release of vapour from the liquid shall be avoided by proper design.

4.6 Meters and piping shall be installed in such a manner that accidental drainage or vaporization of liquid is avoided.

4.7 Any connections for proving shall be installed so that the trapping of air or vapour in the piping between the metering system and the prover is avoided, or that adequate bleed-off connections are provided.

4.8 Meters shall be installed in the attitude suggested by the manufacturer and shall not be subjected to undue strain and vibration.

4.9 The installation of a bank of meters connected in parallel is recommended, especially where they are required in continuous service, or where the flow rate is too great for any one meter. Each meter in a bank should be protected against an excessive flow rate, and means should be provided for balancing the flow between individual meters.

4.10 Means shall be provided for relieving excessive pressures on the meter piping likely to be caused by thermal expansion of the liquid when the meters are not in use.

4.11 Valves in a meter installation which may affect measurement accuracy during metering or proving shall be capable of rapid yet smooth opening and closing. They shall provide a leak-proof shut-off with a method of checking for valve leakage (see figure), e.g. a block and bleed valve.

4.12 If a bypass around a meter or battery of meters is permitted by national regulations, it shall be provided with a blanking device or other acceptable positive shut-off device with leak indicator.

4.13 For intermittent flow control, valves should be of the fast-acting, shock-free type to minimize the effects of starting and stopping liquid movement.

4.14 Meters and meter piping shall be protected from pressure pulsations and excessive surges as well as excessive pressure caused by thermal expansion. This may require the installation of surge tanks, an expansion chamber, relief valves and/or other protective devices. Pressure relief valves placed downstream of the meters should not be linked to those placed upstream. A means of detecting spillage from relief valves shall be provided. When a pressure reducing valve is installed upstream of the meters it is recommended that manifolding be designed in such a way as to prevent reverse flow through the meter, and to obviate generating vapours by such a reducing valve.

4.15 A reliable temperature-measuring device or thermometer well shall be installed immediately downstream or upstream of the meter to permit determination of the temperature of the metered stream. If temperature-compensated meters are used, a suitable procedure shall be adopted for checking the operation of the compensating device.

4.16 Where determination of meter pressure is required a pressure gauge of suitable range and accuracy shall be installed near the inlet or the outlet of every meter.

4.17 An automatic device such as a flow-limiting valve or restricting orifice, if required to prevent flows in excess of the maximum flow rate of the meter, shall be installed downstream from the meter. If a throttling type of control valve is used, the flow rate shall not be permitted to drop below the minimum allowable flow rate of the meter. Should a pressure reducing means be required on the inlet side of a meter, it shall be installed well upstream from the meter. It shall be adjusted so that sufficient pressure will be maintained downstream of the meter to prevent vaporization of liquid.

4.18 When placing a new meter installation in service, the measuring element shall be removed from the meter or a pipe spool or by-pass shall be provided around the meter, and the line shall be operated without the measuring element until examination indicates that entrained foreign matter is being satisfactorily removed by the filter or straining equipment provided. Alternatively, initial line flushing should be carried out as nearly as possible at the maximum designed flow rate, before the meter is installed.

4.19 If pipe compounds are used, they shall be applied to male threads only so as to prevent gumming of the meter by the compound.

4.20 Measurement accuracy can be greatly affected by the torque requirements of counters and ancillary equipment driven by the meter. Special consideration shall therefore be given to possible future extension of the meter register or read-out parts of the system.

4.21 The design of a heat-traced system shall be such that the liquid temperature cannot exceed the meter and automatic temperature control ratings even during initial start-up or after the line has been standing idle for some time.

4.22 The vapour vent lines on degassing devices shall be of adequate size and special attention shall be paid to the safety aspects of the design of the venting system.

4.23 Because a degassing device cannot vent when operating below a minimal pressure, and may even allow air to be drawn into the system under adverse conditions, the design of the metering system shall ensure adequate back pressure to operate the vent valve.

4.24 As hydrocarbons are readily flammable, precautions against electrostatic arcing shall be designed into the metering system so as to prevent ignition.

5 Meter performance

5.1 General

This clause deals with how well a metering system produces, or can be made to produce accurate measurement. Meter factors must be determined when commissioning a meter.

5.2 Meter factor[1)]

Two types of meter proving may be carried out depending upon the application intended.

5.2.1 In the first type the meter calibrator mechanism is adjusted until the change in meter reading during a proving equals, or very nearly equals, the volume measured in the prover.

5.2.2 In the second type, the meter calibrator mechanism is not adjusted, but a meter factor is calculated. The meter factor is a number obtained by dividing the actual volume of liquid passed through the meter during proving by the volume registered by the meter. For subsequent metering operations, the actual throughput or gross measured volume is determined by multiplying the volume as registered by the meter, by the meter factor.

5.2.3 Which type of proving is used depends upon the application and the operating conditions.

5.2.4 Adjusted meters (the first type) are most frequently used at retail dispensing pumps, retail delivery trucks, and truck and rail car loading racks where it is desirable to have direct reading meters without the need to apply mathematical corrections to the meter reading.

5.2.5 Where direct reading is not a consideration, there are several reasons for preferring the use of a meter factor. It is difficult or impossible to adjust a meter calibrator mechanism to give exact registration within 0,02 % which is the usual resolution with which a meter factor is determined. In addition, adjustment generally requires one or more reprovings to confirm the accuracy of the adjustment. The most important reason, however, is that for applications where the meter is to be used with several different liquids, or at several different flow rates, a different meter factor can be determined for each liquid or for each flow rate, or for each combination of liquid and flow rate. An adjusted or direct reading meter is correct for only the one liquid and the one flow rate for which it was adjusted. Most pipelines, terminals and ship loading and unloading facilities prefer to adjust their meters to be approximately correct at average conditions and to seal the calibrator mechanism at that setting. Meter factors can then be determined for each petroleum liquid and/or for each flow rate with which the meter is used. This provides flexibility while maintaining maximum accuracy.

5.2.6 An assessment of meter performance can best be made by keeping a meter factor control chart (see ISO 4124) which is essentially a plot of successive meter factor values for a given petroleum liquid over an extended period of time. It is thus a record of the reproducibility of a particular meter's meter factor value.

5.2.7 Variable conditions which may affect meter factor are :

a) liquid viscosity;

b) change in measuring element clearances due to wear or damage which affects the slippage;

c) hydraulic head loss (pressure loss across the meter);

d) cleanliness and lubricating qualities of the liquid;

e) flow rate;

f) liquid temperature;

g) pressure in the measuring chamber;

h) torque load required to drive the register, printer and all ancillary equipment.

5.3 Causes of variation in meter factor value and their impact on calculation of petroleum volumes

There are many causes which change the performance of a displacement meter. Some, such as the entrance of dirt, can only be remedied by eliminating the cause of the problem. The normal content of solids and water have the same effect on the meter when measuring crude oil as when measuring products but in the former case they are regarded as normal constituents to be included in the measurement. Other causes depend on the properties of the liquid being measured, and must be overcome by proper design and operation of the meter system.

The independent variables which have the greatest effect on the metering system are temperature, pressure, viscosity, flow rate and lubricating properties. If a meter is proved and operated on liquids with inherently identical properties, and under the same conditions as in service, the highest level of accuracy may be expected. If there are differences in one or more of the parameters between the proving and the operating cycles, then a change in meter factor value could be expected between proving and operation.

5.3.1 Variations in flow rate

At the lower end of the flow rate ranges as assigned by the meter manufacturer, the meter factor curve tends to become less reliable and less consistent than is the case for the middle and faster rates. If a reliable plot of meter factor versus flow rate has been developed for otherwise like operating conditions, it is safe to select a meter factor from the curve; although if a proving system is permanently installed it is still preferable to re-prove the meter and to apply the value so determined. If a change in total flow rate occurs, the usual procedure with displacement meters, which are typically installed to operate two, three or more in a bank, in parallel, is to avoid overranging

1) The details of calculating meter factors and bills of lading when using "meter factor meters", as well as the correction factors required to adjust any volume at a given temperature t and a given pressure p, to standard conditions, will be covered by future International Standards.

or underranging an individual meter by varying the number of meters in use, thereby distributing the total flow among a suitable number of parallel displacement meters.

5.3.2 Variations in viscosity

The meter factor value of a displacement meter is considerably affected by changes in viscosity as a result of variable slippage. Viscosity may change as a result of changes in the liquids to be measured or by changes in temperature occurring without any change in the liquid. Should a plot of meter factor versus viscosity be attempted, it is therefore important to take into account what parameters have changed, before selecting a meter factor for application to a bill of lading. It is preferable to reprove the meter when either the liquid changes or when a significant change occurs in temperature with no change in liquid.

5.3.3 Variations in temperature

Changes in liquid temperature, considered separately from their effect on liquid viscosity, have an important effect on meter performances as reflected in meter factor value. This arises because the volume displaced by a cycle of movements of the measuring chambers is affected by temperature. The mechanical clearances of the displacement meter are affected by temperature and too high a temperature can partly vaporize the liquid, and the measurement of a two-phase fluid can be very inexact.

A further reason for change in meter factor is the change in slippage with viscosity, which is an unavoidable side effect of change in liquid temperature.

5.3.3.1 When a displacement meter is being proved, the temperature of the liquid in meter and in the prover must be the same, or both must be corrected to a reference temperature, to obtain a correct meter factor. Petroleum measurement tables referred to in ISO 91 should be used for such corrections.[1)]

5.3.3.2 Either an automatic temperature compensator, or a manual temperature correction based upon the observed average temperature of the delivery, may be used to correct registered volume to a base or reference temperature.

5.3.4 Variations in pressure

5.3.4.1 A meter factor as defined in 5.2.2 applies for all metering pressures, but a metered volume shown on a bill of lading must be corrected for the effect of pressure on a liquid if pressure is significant. A meter factor is affected only if changes in operating pressure are high enough to affect dimensions of the measurement chambers by elastic deformation; and use of double case meters obviates even this problem.

5.3.4.2 An increased pressure gradient across a displacement meter will tend to increase slippage, and thus increase meter factor values.

5.3.4.3 For any liquid being measured which has a saturated vapour pressure above atmospheric pressure, both the registered volume of the meter, and the prover volume with which it is to be compared to develop a meter factor, must be corrected for pressure from the volumes observed at proving pressure to the equivalent volumes at the vapour pressure of the liquid at the desired base or reference temperature. This is a two-step operation involving, first, correcting the volumes to the equivalent volumes at the vapour pressure of the liquid at the observed proving temperature, and then correcting the volumes to the equivalent volumes at the vapour pressure of the liquid at the desired base or reference temperature. The second step is accomplished automatically when correcting volumes from observed temperature to base temperature. The values referenced in ISO 91 (tables 6 and 24) covering change in volume with change in temperature incorporate a pressure correction factor for the change in vapour pressure which occurs as a result of the subject change in temperature.[2)]

6 Operation and maintenance of metering systems

6.1 General

This section covers recommended operating and maintenance practices for displacement meter installations. All operating data pertaining to measurement, including the meter factor control charts, should be accessible to interested parties.

6.2 Conditions affecting operation

6.2.1 The accuracy of measurement by a displacement meter depends on the condition of the meter, the proving system, the frequency of proving and variations, if any, between operating and proving conditions because a meter factor obtained for one set of conditions will not necessarily apply for a changed set of conditions. All equipment shall be selected, operated and maintained in such a manner as to ensure the desired accuracy which may be established by policy, mutual consent of the parties or in certain countries, the appropriate regulations.

6.2.2 Displacement meters shall be operated within their specified flow range and the operating conditions which produce the desired accuracy. They shall be operated with the necessary ancillary equipment. They should not be used to make deliveries less than a minimal quantity below which slack in the gear train etc., may have a relatively large effect.

1) Other correction factors will be specified in future International Standards on calculation of petroleum quantities in dynamic measurement.

6.2.3 Displacement meters other than those designed to flow in either direction, shall be installed so that flow cannot be reversed. Reversible meters shall have meter factors developed for each direction of flow. Protective devices shall then be placed on both ends of the meter.

6.2.4 Definite procedures for both operating metering systems and for calculating measured quantities shall be furnished to meter station personnel. These should include :

a) standard procedure for meter proving;

b) rates above and below which an additional meter in the meter bank shall be put on stream, or taken off stream;

c) maximum and minimum flow rates for each meter, and maximum operating temperature and pressure;

d) instructions for applying pressure and temperature correction factors;

e) procedure for recording and reporting of corrected meter volumes and other observed data;

f) procedure for estimating the volume passed in the event of meter failure;

g) instructions in the use of control charts and the action to be taken should a meter factor value fall outside acceptable limits;

h) instructions with respect to who may witness meter provings and repairs;

j) instructions covering the reporting of broken seals, if fitted;

k) instructions in the use of forms and tables necessary to record the data to support proving reports and meter tickets;

m) instructions for routine maintenance;

n) instructions for taking samples;

p) details of the general policy for the frequency of meter proving and re-proving when changes in flow rate or other operating variables may affect meter accuracy;

q) procedures for operations not included in the foregoing, but which may be important for an individual installation.

6.2.5 A statistical analysis of meter proving results, and the use of control charts (see ISO 4124), will aid judgement in determining :

a) the optimum time lapse between provings;

b) the need for maintenance;

c) the constancy and quantitative value of the mean meter factor.

6.3 Meter maintenance

Meters shall be maintained in accordance with manufacturers instructions. A maintenance policy shall be established to provide adequate servicing of the meter and ancillary equipment. Meters stored for a long period shall be kept under cover and shall have their working parts oiled to minimize corrosion.

Because of the many different sizes, services, liquids measured, flow rates and pressures it is difficult and often inadvisable to establish a definite schedule of meter maintenance for all installations. Determination of when to repair or inspect a displacement meter may best be found by keeping a control chart for each meter on each product or grade of crude. Slight changes in meter factor will naturally occur in normal operation, but if the value of such a change in meter factor exceeds three standard deviations ($\pm 3\sigma$), as recorded on the control chart, the cause of the change should be sought. The use of 3σ limits to determine acceptable normal variation in meter factor value strikes a balance between looking for trouble which does not exist and not looking for trouble that does exist (see ISO 4124).

6.4 Meter factor control charts

6.4.1 A meter factor control chart for displacement meters is an adaptation to liquid metering problems of the widely used statistical control chart method as explained and discussed in ISO 4124.

6.4.2 Meter factor control charts for displacement meters are essentially plots of successive meter factor values along the abscissa at the appropriate ordinate value and between limiting abscissa representing $\overline{X} \pm 1\sigma$, $\overline{X} \pm 2\sigma$, $\overline{X} \pm 3\sigma$, where σ is the standard deviation of the meter factor obtained from a set of proving runs and $\overline{X}$ is the mean value of all meter factors. Such a chart should be maintained for each product or grade of crude oil over the expected range of rates, for each meter.

6.4.3 Meter factor control charts can be used as a warning signal for measurement trouble by showing when and to what extent conditions have deviated from accepted norms. The charts can be used to detect when there is trouble, but not the nature of the trouble. When measurement trouble is encountered, a systematic checking of the measurement procedure is recommended. The following items may be considered, although not necessarily in the listed order :

a) the initial and final flow rates into the prover tank : the opening and closing of a diversion valve should be smooth yet rapid;

b) the condition of moving parts and bearing surfaces of the displacement meter; wear or solid contaminants can increase slippage;

c) changes in lubricating properties; gasolines with a high proportion of aromatics often have very poor lubricating qualities and can cause a displacement meter to stall and race and stall again during proving, especially as the use of a tank prover requires a standing start-and-stop procedure;

d) the possibility that a pocket of air has entered the piping between the meter and the prover tank;

e) if a pipe prover is used for proving, its detector switches and the diameter of the displacer may need checking;

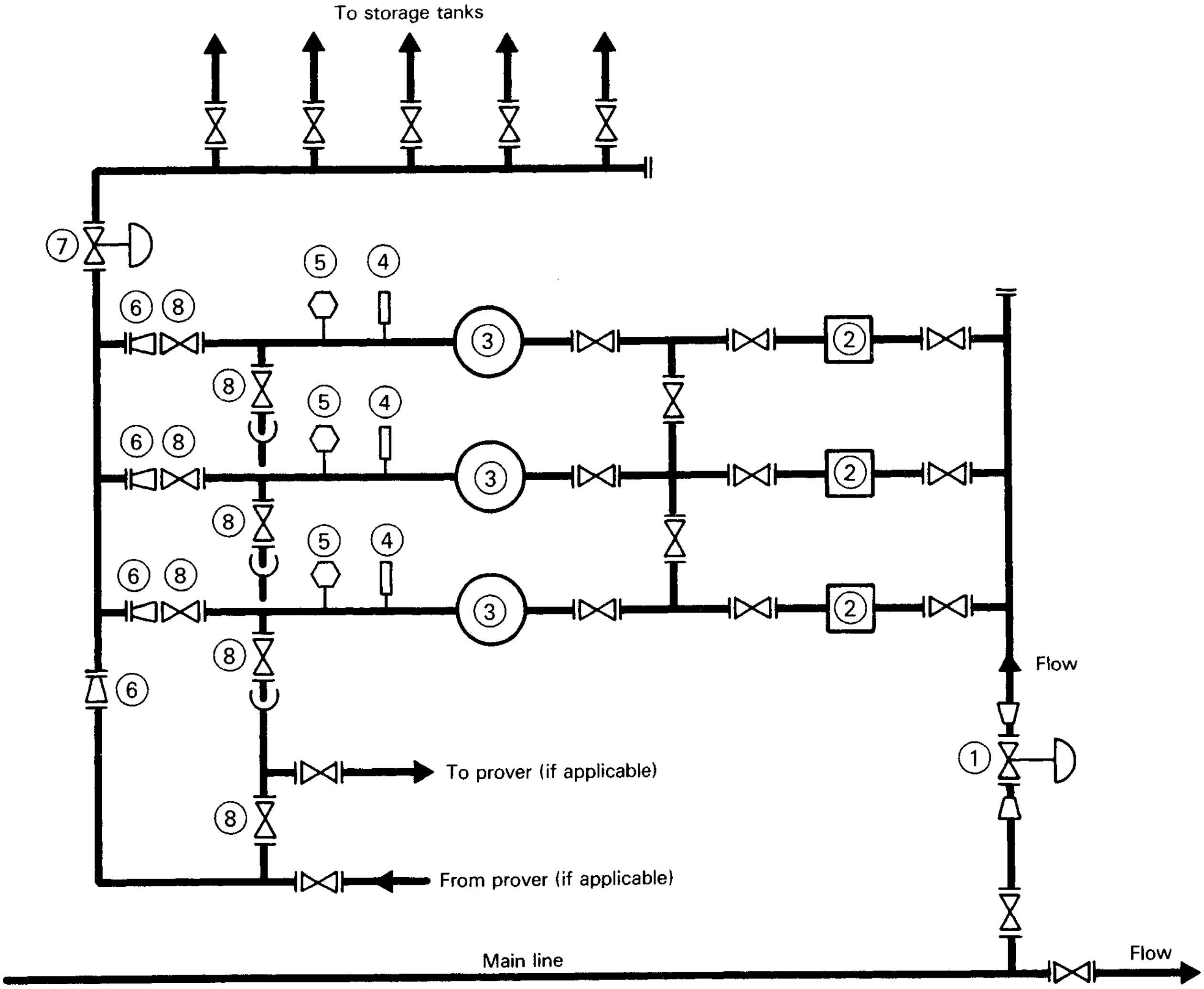
f) the pressure, temperature and density sensing devices;

g) if a pipe prover is used for proving, the tachometer, pulse counters, coil, preamplifiers, signal transmission system, power supply and all read-out devices.

Annex

Typical arrangement of meter station with three displacement meters

(Forms part of the Standard)



1. Pressure-reducing valve — manual or automatic (as required)
2. Filter, strainer and/or vapour separator (as required) for each meter or whole station (optional)
3. Displacement meter and register
4. Thermometer
5. Pressure gauge
6. Check valve
7. Back-pressure valve (as required)
8. Valve, positive shut-off

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Liquid hydrocarbons — Volumetric measurement by displacement meter systems other than dispensing pumps

ERRATUM

Page 2

Sub-clause 3.2.1 e), amend to read : ". . . whether the flow is continuous, intermittent or fluctuating;".

Sub-clause 3.2.1 g), amend final phrase to read : ". . .; and whether or not heat tracing and/or insulation is required."

Page 4

Sub-clause 5.2.4, line 2 : delete the words "at retail dispensing pumps," and insert the word "on" in their place.

Page 5

Sub-clause 5.3.2

Line 2, replace "as a result of" by "resulting in".

Line 5 to 11, replace with the following :

> "It is therefore important to take into account the parameters that have changed before selecting a meter factor for application to a bill of lading, from a plot of meter factor versus viscosity. It is preferable to re-prove the meter either if the liquid changes or if a significant change in temperature occurs without a change of liquid."

Sub-clause 5.3.4.3, footnote reference should be 1, not 2.

Page 6

Sub-clause 6.4.2, line 6, amend to read : ". . . and $\overline{X}$ is the mean of all these values."

Sub-clause 6.4.3 a), replace "prover tank" by "prover".

Page 7

Sub-clause 6.4.3 d), replace "prover tank" by "prover".

Page 8

Annex, add the following below the figure :

> "NOTE — All sections of line which may be blocked between valves shall have provisions for pressure relief."
