International Standard ISO 2715

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

Liquid hydrocarbons — Volumetric measurement by turbine meter systems

Hydrocarbures liquides — Mesurage volumétrique au moyen de compteurs à turbine

First edition — 1981-08-15

UDC 665.7 : 681.121.4 **Ref. No. ISO 2715-1981 (E)**

Descriptors : petroleum products, hydrocarbons, liquids, volumetric measurement, measuring instruments, electrical installation, equipment specification.

Price based on 15 pages

ISO 2715-1981 (E)

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Foreword

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International Standard ISO 2715 was developed by Technical Committee ISO/TC 28, *Petroleum products and lubricants*, and was circulated to the member bodies in February 1977.

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

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Austria	India	Romania
Belgium	Iran	South Africa, Rep. of
Brazil	Israel	Spain
Bulgaria	Italy	Sweden
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Liquid hydrocarbons — Volumetric measurement by turbine meter systems

0 Introduction

Turbine meters consist essentially of a rotor which senses the mean velocity of a flowing stream. The moving liquid imparts a rotational or tangential velocity to the rotor which is proportional to the rate of flow. The movement of the rotor is detected by mechanical, optical, magnetic or electrical means and is recorded on a read-out device. The volume so 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 turbine metering assemblies for liquid hydrocarbons. Annex A gives details of the parts and characteristics of turbine meters, and annex B provides a trouble-shooting guide.

Information on displacement meters appears in ISO 2714, *Liquid hydrocarbons — Volumetric measurement by displacement meter systems other than dispensing pumps*. 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 systems containing turbine meters.

1 Scope and field of application

1.1 Scope

This International Standard specifies the characteristics of turbine meters and gives rules for systematically applying 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. The content of this International Standard is general. It can be applied to the metering of different hydrocarbon liquids, to the use of turbine meters from any manufacturer, and to the various applications encountered. It does not necessarily apply to two-phase fluids.

2 References

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

ISO 6551, *Petroleum liquids and gases — Fidelity and security of dynamic measurement — Electric and/or electronic pulsed data cabled transmission*[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 to control the operation within the design conditions of the metering installation.

b) National or state 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.

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

d) There shall be provisions for proving the meter for the entire range of normal operating conditions.

1) At present at the stage of draft.

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3.2 Selection of turbine 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 :

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

b) class and type of end connections installed on meter;

c) the properties of the liquid on which the meter will be required to operate, including viscosity, density ranges, vapour pressure, corrosiveness and lubricating properties;

d) the nature and quantity of abrasive and corrosive contaminants that may be carried in the liquid stream, including the size and distribution of solid matter;

e) operating rates of flow, maximum and minimum, and whether flow will be continuous, intermittent or fluctuating;

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 be required to operate, and applicability of automatic temperature compensation;

h) maintenance methods and cost; and spare parts required;

j) type, method and frequency of proving;

k) the meter characteristics including linearity, maximum allowable pressure loss, and frequency and voltage output (see annex A, figure 2);

m) types of read-out devices or indicating systems to be employed and signal preamplification (see annex A, figure 3);

n) compatibility of ancillary meter read-out equipment and flow rate indication; and the method of meter registration adjustment, if applicable;

p) power supply requirements for continuous or intermittent meter read-out;

q) electrical code requirements;

r) security of electrical transmission system.

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

3.3 Selection of read-out devices

3.3.1 Special consideration shall be given to the selection of read-out devices for a turbine meter system to prevent possible difficulties arising from climate, system layout and electrical incompatibilities. These include :

a) *Climate*. Ascertain the need for electrical safety, weatherproofing, corrosion- or fungus-proofing devices. Evaluate the high and low temperature and humidity extremes, and protect accordingly.

b) *System layout*. Provide easy access for maintenance and obtain recommended spare parts for items, such as electronic digital read-outs and electromechanical registers, that have a predictable failure rate. Alternative or back-up devices and stand-by power supplies are suggested where continuous service is essential.

c) *Electrical incompatibilities*. All read-out devices shall be compatible with the turbine meter and the transmission system to which they are connected. In those instances where a read-out device is a link in a data transmission system, special care shall be taken to ensure that it has an output compatible with the data transmission system.

3.3.2 Read-out devices are available which perform a number of different functions. They shall be selected to ensure read-out in the desired form. The limits of each individual read-out device shall be noted so that it may perform optimally as part of the turbine meter system. Read-out devices may be either analog or digital.

3.3.3 Optimum discrimination is obtained with a digital read-out device which counts the individual pulses produced by the turbine meter to plus or minus one count, for a given interval. The basic pulse counter does not necessarily display flow or volumetric units until after logic functions are performed with the appropriate factors to convert the accumulated pulses into units of volume or flow rate.

A variety of electronic digital read-out devices is available for use with turbine meters. The following outline indicates the types and classes in general use and includes devices for special application.

3.3.4 Pulse counters which indicate every pulse received from the turbine meter usually incorporate one or more illuminated display units. Counters shall be compatible with meter output voltage and frequency. These counters may be classified as follows :

a) *Proving counters, in which a special gating circuit in the counter is triggered by switches in the proving system to start and stop the counter*. This type of proving counter may be supplemented when the meter pulse rate is low by multiple electronic timers utilized to provide acceptable discrimination in the proving results.

b) *Digital flow rate indicators, in which a gating circuit in the counter starts and stops the counter over a preselected time interval*. A fixed preselected time base provides uncorrected flow rate indication; a variable preselected time interval can provide corrected digital flow rate indication, since meter, temperature and pressure correction factors may be incorporated in the time base in order to provide a corrected read-out.

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3.3.5 Computing counters are those in which the read-out is in terms of the number of pulses or multiples of pulses received by the counter. The read-out display of these counters may be by means which require that the incoming pulses be divided. These counters may be classified as follows :

a) *Fixed ratio computing counters*, in which the incoming pulses are normally divided by 10, 100, 1 000 etc., so that the display is 1/10, 1/100, 1/1 000, etc., of the total pulses received. Some of these units are designed to divide by a fixed number other than a multiple of 10.

b) *Variable ratio computing counters*, in which the incoming pulses are divided (or multiplied and then divided) by a variable divide circuit. The divide circuits are selected manually by means of external knobs or patch boards based on turbine meter pulses per unit volume under specific operating conditions. The selection is made on pulses per volume or the reciprocal of pulses per volume depending on the counter design. Indicate is in practical units for the specific operating condition. Such counters may incorporate the meter temperature and pressure corrections into the variable ratio and read out the net volume corrected to the reference base. For each batch, if four or five digit reading discrimination is required, at least 10 000 pulses must be registered.

4 Installation

4.1 General

This clause includes details for the installation of metering systems incorporating turbine meters. A schematic diagram for turbine meter systems is presented in annex A, figure 4.

4.2 Flow conditioning

4.2.1 Turbine meter performance is affected by liquid swirl and non-uniform velocity profiles induced by upstream and downstream piping configurations, valves, pumps, joint misalignment, protruding gaskets, welding projections or other obstructions. To overcome swirl and non-uniform velocity profiles, flow conditioning sections shall be installed.

4.2.2 Flow conditioning is an accepted practice. It is accomplished by the use of sufficient lengths of straight pipe or by a combination of straight pipe and straightening elements, inserted in the meter run upstream and downstream of the turbine meter.

4.2.3 When only straight pipe is employed, the liquid shear, or internal friction between the liquid and the pipe wall, shall be sufficient to accomplish the required flow conditioning.

4.2.4 When a straightening element is employed, it usually consists of a cluster of tubes, vanes or equivalent devices inserted longitudinally in a section of straight pipe (see annex A, figure 5). Such straightening elements effectively assist in flow conditioning. Straightening elements may also consist of a series of perforated plates or wire mesh screens, but these forms normally cause a larger pressure drop than do tubes or vanes.

4.2.5 Proper design and construction of the straightening element is important to ensure that swirl will not be generated, thus negating the function of the flow conditioner. It is recommended therefore that :

a) the cross-section shall be as nearly uniform and symmetrical as possible;

b) the design and construction shall be sufficiently rugged to resist distortion or movement at high flow rates;

c) the general internal construction shall be clean and free of welding protrusions and other obstructions.

4.2.6 In addition to the use of flow straightening sections, there shall be ample distance between the meter run and any pumps, elbows, valves or other fittings which may induce swirl or a non-uniform velocity profile. Flanges and gaskets shall be internally aligned, and gaskets shall not protrude into the liquid stream. Meter flanges shall be dowelled or match marked to ensure proper alignment of the straightening sections and the meter after assembly.

4.2.7 Valves

4.2.7.1 Valves in a meter installation that 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 and shall be equipped with a double block and bleed or a telltale bleed.

4.2.7.2 A bypass around a meter or battery of meters, if it is authorized by national regulations, shall be provided with a blind or a positive shut-off device equipped with a valve with a double block and bleed or a tell-tale bleed.

4.2.7.3 Generally, all valves, and especially spring-loaded or self-closing valves, shall be of such design that they will not open to admit air when subjected to hydraulic shock or to vacuum conditions.

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

4.3 Piping installation

4.3.1 The schematic diagram (see annex A, figure 4) provides a working basis for the design of a turbine meter assembly with its related equipment. Certain items may or may not be required for a particular installation; others may be added if necessary.

4.3.2 Turbine meters are normally installed in a horizontal position. The manufacturer shall be consulted if space limitations dictate a different attitude.

4.3.3 Where the flow range is too great for any one meter or for its proving, the installation of a bank of meters in parallel may be used. Care should be taken so that each meter in a bank

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shall not operate outside its minimum and maximum flow rate. Means should be provided to balance flow through each meter.

4.3.4 Meters shall be installed in such a manner that they will not be subjected to undue stress or strain. Provision shall be made to minimize meter distortion caused by piping expansion and contraction.

4.3.5 Measurement systems shall be installed in a manner which will result in maximum dependable operating life. In certain services, this requires that 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. If strainers, filters, sediment traps, settling tanks, water separators, a combination of these items, or other suitable devices are required, they shall be sized and installed to prevent flash vaporization of the liquid prior to its passage through the meter. These protective devices may be installed singly or in interchangeable battery form, depending on the importance of continuous service. In services where the liquid is clean or the installed meter does not require or warrant protection, omission of protective devices may be acceptable. Pressure gauges shall be installed to determine when the protective device should be cleaned.

4.3.6 Measurement systems shall be installed so that they will perform satisfactorily within the viscosity, pressure, temperature and flow ranges that will be encountered.

4.3.7 Meters shall be adequately protected from pressure pulsations and excessive surges as well as excessive pressure caused by thermal expansion of the liquid. This may require the installation of surge tanks, expansion chambers, pressure limiting valves and/or other protective devices. A means of detecting spillage from pressure limiting valves shall be provided when such valves are placed downstream of the meter.

4.3.8 A back-pressure and/or flow-limiting device or restricting orifice should, wherever possible, be installed downstream from the meter run. An alarm should be installed for flow rates below design minimum. If a pressure-reducing device is used on the inlet side of the meter, it shall be installed as far upstream from the meter run as possible within that location. It shall be installed so that sufficient pressure will be maintained on the outlet side of the meter run to prevent any vaporization of the metered liquid.

4.3.9 Any condition which tends to contribute to the release of vapour from the liquid stream shall be avoided by suitable system design and by operating the meter within its flow range as specified by the manufacturer. The release of vapour can be minimized or eliminated by maintaining sufficient back-pressure immediately (approximately four pipe diameters) downstream of the meter. For low vapour pressure liquids, the numerical value of this back-pressure reading should be approximately $(2\,\Delta p + 1{,}25\,p_V)$, or more, where Δp is the pressure drop across the meter at maximum rate of flow, and p_V is the absolute vapour pressure at maximum operating temperature, both expressed in consistent units. This can be achieved by installing the appropriate type of valve (back-pressure, throttling or reducing) downstream of the meter. In the case of liquids with high vapour pressure, the numerical value of the back pressure may be reduced in accordance with the recommendations of the meter manufacturer and as mutually agreed between the interested parties.

NOTE — The back pressure recommended above is a typical value. Some manufacturers recommend substantially higher values of back pressure with their equipment.

4.3.10 Every meter shall be installed in such a way as to prevent passage of air or vapour through it. If necessary, air/vapour elimination equipment shall be installed upstream of the meter. Such equipment should be installed as close to the meter as is consistent with good practice — it must not be so close that it creates swirl or a distorted velocity profile at the entry to the meter. Any vapours shall be vented in a safe manner.

4.3.11 Meters and piping shall be installed so that accidental drainage or vaporization of liquid is avoided. The piping shall have no high points or pockets where air or vapour might accumulate and be carried through the meter by the added turbulence resulting from increased flow rate. The entire installation shall be such that air is not introduced into the system through holes, leaky valves, piping, glands of pump shafts, separators or connecting lines, etc.

4.3.12 Lines from the meter to the prover shall be such that the possibility of trapping air or vapour is minimized. The distance between a meter and its prover shall be kept short and the diameter of the connecting lines shall be large enough to prevent a significant decrease in flow rate during proving. Throttling valves downstream of the meters may be installed in multi-meter stations to equalize flow resulting from pressure drop through the prover when each meter is being proved. Manual bleed valves should be installed at high points to draw off air before proving.

4.3.13 Piping shall be designed so that the volume of liquid retained in the piping from the meter to the point of delivery into the prover shall remain constant during provings.

4.3.14 Special consideration shall be given to the location of each meter, its ancillary equipment and piping manifold in order to minimize mixing of unlike liquids.

4.3.15 Most turbine meters will register flow in both directions, although seldom with identical meter factor. If flow has to be restricted to a single direction because of meter design, flow reversal shall be prevented.

4.3.16 A thermometer, or a thermometer well permitting the use of a temperature-measuring device, shall be installed in or near the inlet or outlet of a meter run to permit determination of metered stream temperatures. If temperature-compensators are used, a suitable means of checking the operation of the compensators is required.

4.3.17 A recording or indicating pressure gauge of suitable range and accuracy shall be installed in or near the inlet or outlet of every meter run where determination of the meter case pressure is required.

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4.4 Electrical installation[1)]

4.4.1 A turbine meter system has a minimum of three components : the meter (pulse producer), the transmission line (pulse carrier) and the read-out device (pulse counter and display). It is essential that these three components be compatible and that each meet the recommended specifications of the turbine meter manufacturer.

4.4.2 Electrical noise may be the most troublesome element in turbine meter systems employing low-level signal outputs. Even in high-level output systems it is necessary to eliminate noise and/or spurious electrical signals. Noise signals are superimposed on meter signals from three distinct sources — electromagnetic induction, electrostatic or capacitive coupling and electrical conduction.

4.4.3 Great care shall be exercised in effectively isolating the system from external electrical influences. To minimize unwanted noise, earthing (grounding) shall be independent and shielding of meter and prover detector transmission cables (where used) is essential. See also ISO 6551.

4.4.4 For estimating the maximum transmission line length for any given turbine meter system, ISO 6551 shall be consulted.

4.4.5 Most turbine meters have the capability of producing an electrical output which may be used to operate a wide variety of read-out devices. More than one pick-up may be required according to mandatory national regulations or design criteria.

4.4.6 Every turbine meter system must meet two general requirements to operate properly. The read-out device shall be sufficiently sensitive to respond to every pulse produced by the turbine meter throughout its operating range. The signal-to-noise ratio shall be sufficiently high to prevent spurious electrical signals from influencing the read-out device.

4.4.7 The output signal of a turbine meter may be considered to be a train of electrical pulses, with each pulse representing a discrete volume of liquid passing through the meter. Examples of two approaches which have been taken to produce electrical pulses follow. The first directly translates the mechanical motion of the rotor into electrical energy through magnetic induction. The second requires that external electrical power be supplied to a proximity or photosensing device, which may be externally shaft driven, but which does not actually generate electrical energy by the rotational movement of the metering element.

In the first method, both pulse frequency and amplitude are generally proportional to flow rate. In the second method, only pulse frequency is proportional to flow rate since output voltage is virtually of constant amplitude.

4.4.8 Most electronic read-out devices condition a wave form for the counting of each pulse or measure the meter output frequency for flow rate indication. Signal strength may be of relatively low power level, thus installation conditions shall be suitable for low power level signals. The recommendations described herein are not applicable to all turbine meters but relate to low power level signal systems.

4.4.9 Pulse characteristics which influence proper system operation are :

a) *Amplitude*. Any read-out device connected to a pulse producer (meter) shall have the sensitivity needed to operate with the pulse amplitudes generated over the rated flow range;

b) *Frequency*. The read-out device shall be able to cope with the maximum output frequency of the pulse producer (meter) at its highest expected flow rate;

c) *Width*. The duration, after shaping, of every pulse generated by the pulse producer (meter), shall be long enough to be detected and counted by the read-out device;

d) *Shape*. A sine wave output shall not be used to operate a read-out device requiring a square wave input without preamplification and shaping.

4.4.10 Great care shall be exercised in the electrical transmission installation so that the signal amplitude from the turbine meter can be maintained at the highest level while reducing the magnitude of noise, whenever possible. Optimum signal level is maintained by :

a) limiting the length of transmission line from the meter to the read-out devices;

b) ensuring the correct impedance;

c) using the best available and technically compatible signal transmission cable as recommended by the equipment manufacturer;

d) introducing a signal preamplifier into the transmission system at the turbine meter, if transmission distance or manufacturer's requirements so dictate;

e) ensuring that supply voltages to preamplifiers and constant amplitude pulse generating systems are of proper magnitude and do not exceed the maximum noise level or ripple requirements as specified by the equipment manufacturer;

f) ensuring that all pick-up coils are securely mounted and properly located;

g) periodically inspecting and cleaning all terminals, connectors, connector pins and wiring junctions;

h) replacing components which, through deterioration, give a weakened signal.

1) Additional information, regarding electrical installation will appear in a future International Standard on ancillary equipment for meters.

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5 Meter performance

5.1 General

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

5.2 Meter factor[1)]

Two procedures for meter proving may be carried out depending upon the application intended.

5.2.1 In the first procedure, 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 procedure, 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 procedure for proving is used depends upon the application and the operating conditions.

5.2.4 Adjusted meters (see 5.2.1) 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. For most pipelines, terminals and ship loading and unloading facilities, it is preferred 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 values.

5.2.7 Variable conditions which may affect meter factor values are :

a) liquid viscosity;

b) the change in mechanical tolerances and blade angle or length due to wear or damage;

c) line pressure and pressure drop across the meter;

d) cleanliness and lubricating properties of the liquid;

e) flow rate;

f) liquid temperature;

g) condition of proving equipment;

h) foreign material lodged in the meter or flow conditioner;

j) changes in inlet fluid velocity profile or swirl.

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 turbine 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 shall 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 low end of the flow rate range the meter factor curve tends to become less linear than is the case in the medium and

1) The details of calculating meter factors and bills of lading when using meter readings to which meter factors have to be applied, 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.

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higher flow rate ranges (see annex A, figure 2, and applications A and B). If a reliable plot of meter factor versus flow rate has been developed it is safe to select the meter factor value from that curve, although if a proving system is permanently installed it is still preferable to re-prove the meter and to apply the value so computed. If changes in flow rate exceed the lower or upper limit of the acceptable linearity (see annex A, figure 2) then the meter should be proved at the operating rate.

5.3.2 Variations in viscosity

For an individual turbine meter, it may be possible to develop a single empirical equation or plot of meter factor as a function of viscosity. However this cannot be done for turbine meters as a class.

Since turbine meters are viscosity sensitive, and since viscosity changes with the temperature of hydrocarbon liquids, particularly those liquids of higher relative density, the response of a turbine meter to a change in temperature cannot be assigned solely to thermal variations of the liquid.

On the other hand, for liquids of lower relative density such as gasoline whose viscosity remains essentially unchanged with changes in temperature, meter factor valves likewise remain virtually unchanged. A mathematically based adjustment to meter factors for hydrocarbons as a class, or for turbine meters in more viscous hydrocarbons and all crude oils, is not recommended. Mathematical corrections shall be applied only to individual meters when they are being operated within the range of conditions for which they have been proved. It is advisable to prove the meter under conditions which closely approximate those in operation.

5.3.3 Variations in temperature

In addition to the effects of change in viscosity (see 5.3.2) caused by changes in temperature of the liquid, significant variations in temperature can also affect meter performance by causing changes in the physical dimensions of the meter and in the apparent volume measured by the meter because of thermal expansion or contraction of the liquid. The extent of liquid expansion or contraction may be calculated using approved tables or formulae. Accepted corrections may be applied for changes in physical dimensions of the meter, but other possible effects such as changes in the mechanical tolerance and blade angle, could depend on the individual meter, and may not be capable of correction for turbine meters as a class. For highest accuracy the meter should be proved in the range of operating conditions.

5.3.4 Variations in pressure

A variation in the pressure of the liquid being metered from that which existed at the time of proving will result in a change in the relative volume of the liquid due to its compressibility. A change in the physical dimensions of the meter, arising from expansion or contraction of its housing under pressure will also occur. Accepted correction tables for both effects may be used, but potential error increases as the magnitude of the difference between the proving and operating conditions increases. For highest accuracy, the meter should be proved in the range of operating conditions.

5.3.5 Correction to a base or reference temperature

Considerable meter error may be introduced into the measurement of a hydrocarbon liquid, unless the volume metered is reduced to a standard condition of base or reference temperature and base or reference pressure. It is recommended that appropriate corrections be made to minimize this error whenever the measurement circumstance warrants such adjustment.[1)]

6 Operation and maintenance of metering systems

6.1 General

This clause covers recommended operating and maintenance practices for turbine 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 turbine meter depends on the conditions of the meter, the proving system, the frequency of meter proving and the variations, if any, between operating and proving conditions. All equipment shall be selected, operated and maintained in such a manner as to achieve the desired accuracy which may be established by policy, mutual consent of the parties or, in certain countries, the appropriate regulations.

6.2.2 Turbine meters shall be operated within the specified flow range and the operating conditions which produce the desired accuracy (see annex B). They shall be operated with the necessary ancillary equipment. It must also be recognized that turbine meters should not be used to make deliveries less than a minimal quantity below which random errors may defeat required accuracy.

6.2.3 If a turbine meter is used to measure reversible flow, meter factors shall be obtained for each direction of flow. Usually protective devices must be located on both sides of the meter.

6.2.4 Definite procedures both for 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) operation of stand-by or spare meters;

1) The correction factors will be specified in a future International Standard.

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c) minimum and maximum meter flow rates and other operating conditions such as pressure and temperature;

d) instructions for applying pressure and temperature correction factors;

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

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

g) instructions in the use of control charts and the action to be taken when the meter factor exceeds the established acceptable limits;

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

j) instructions covering reporting the breakage of any seals if fitted;

k) instructions in the use of all 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 frequency of meter proving and re-proving when changes of flow rate or other variables 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 mean meter factor.

6.3 Meter maintenance

6.3.1 Meters shall be maintained in accordance with the manufacturer's 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. Certain internal parts may be cleaned and oiled, but tungsten carbide bearing surfaces should be cleaned but not oiled.

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

6.3.3 Totalizer components and temperature and pressure instruments and/or transmitter should be periodically checked.

6.4 Meter factor control charts

6.4.1 A meter factor control chart is any suitable 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 are essentially plots of successive meter factor values along the abscissa at the appropriate ordinate value and between limiting abscissa representing $\bar{X} \pm 1\sigma$, $\bar{X} \pm 2\sigma$, $\bar{X} \pm 3\sigma$, where σ is the standard deviation of the meter factor obtained from a set of proving runs and $\bar{X}$ is the mean value of all these values. Such a chart should be maintained for each product, or grade of crude oil over a 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 trouble, but not the nature of the trouble. When measurement trouble is encountered, a systematic checking of the measurement system is recommended. The following components of the measurement system should be considered, although not necessarily in the listed order :

a) all valves affecting meter proving;

b) strainers, filters, air and water separators;

c) pulse counters, coil preamplifiers, signal transmission system, power supply, and all read-out devices;

d) moving parts and bearing surfaces of the turbine meter;

e) other parts of the meter and meter run;

f) detector switches in a pipe prover, or ancillary equipment in a tank prover;

g) displacer in a pipe prover;

h) pressure, temperature, and density sensing devices.

See annex B for three decision charts designed to aid in diagnosing malfunction in turbine metering systems.

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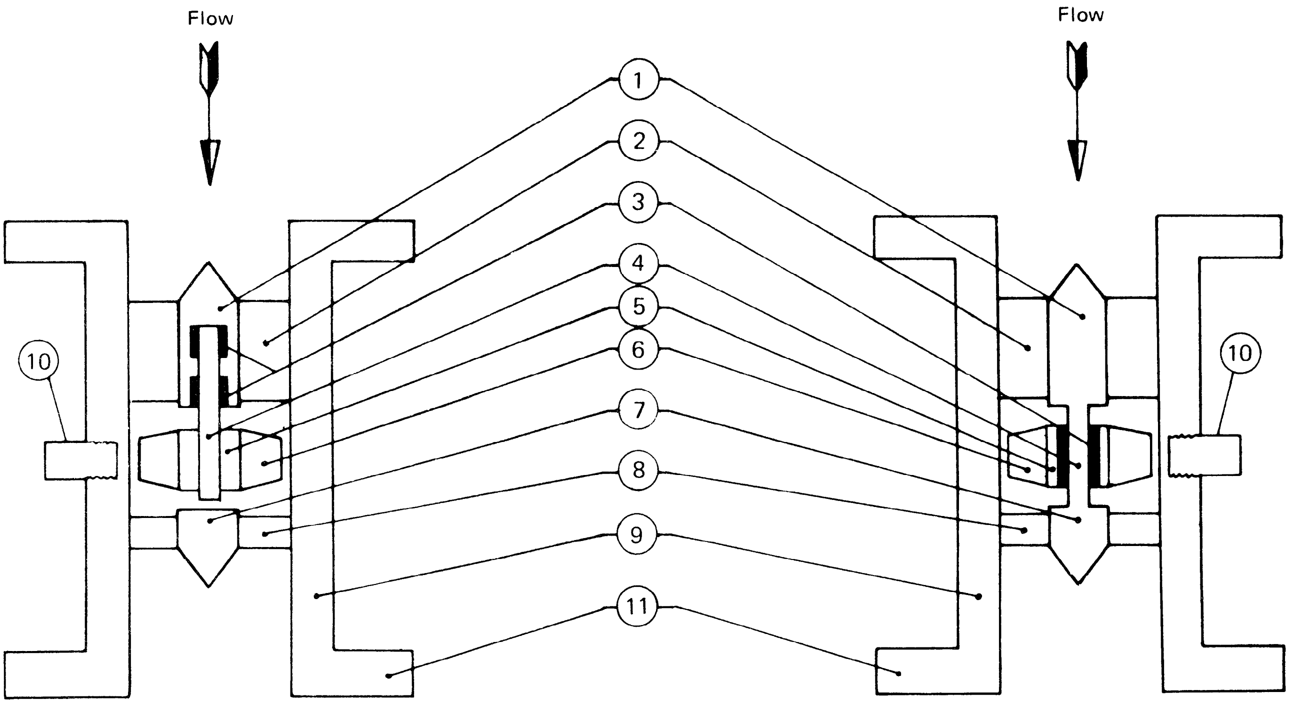
Annex A

Turbine meters — Parts and characteristics

(Forms part of the standard)

This annex provides illustrative descriptions of turbine meter performance characteristics, accessory read-out instrumentation possibilities, recommended flow straightener assembly, meter accuracy curve, and names of turbine meter parts (see figures 1 to 6).

In addition to the pictorial information presented, these illustrations provide a recommendation for standardized terminology and data presentation. The intention of such a standardization is to simplify communication between designers, operators and manufacturers.



1 Upstream stator
2 Upstream stator supports
3 Bearings
4 Shaft
5 Rotor hub
6 Rotor blade
7 Downstream stator
8 Downstream stator supports
9 Meter housing
10 Pick-up
11 End connections

Figure 1 — Names of typical turbine meter parts

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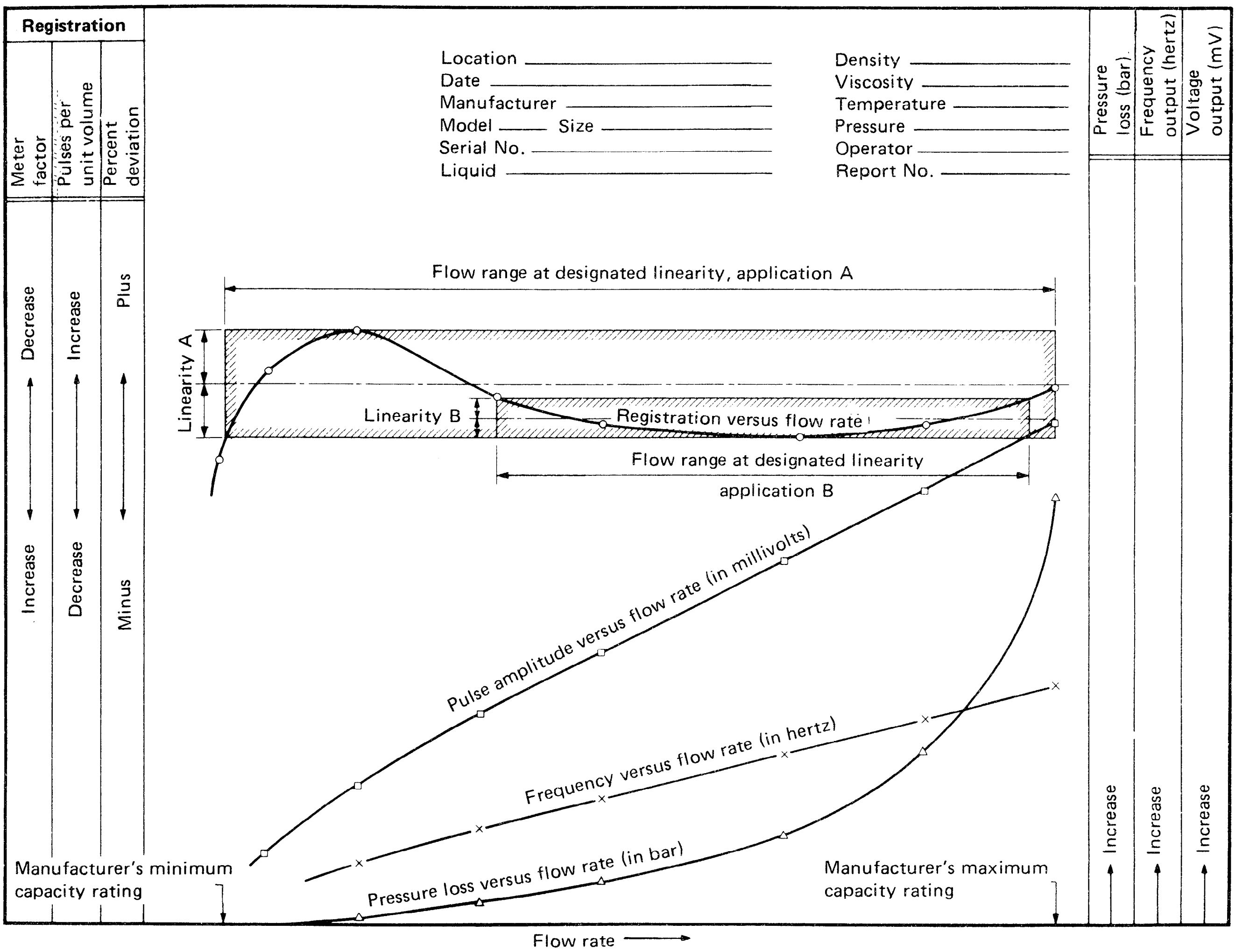

NOTE — The meter characteristic curves shown are to be considered as illustrative only and shall not be construed as representing the likely performance of any given model or size of turbine meter.

Figure 2 — Turbine meter characteristics

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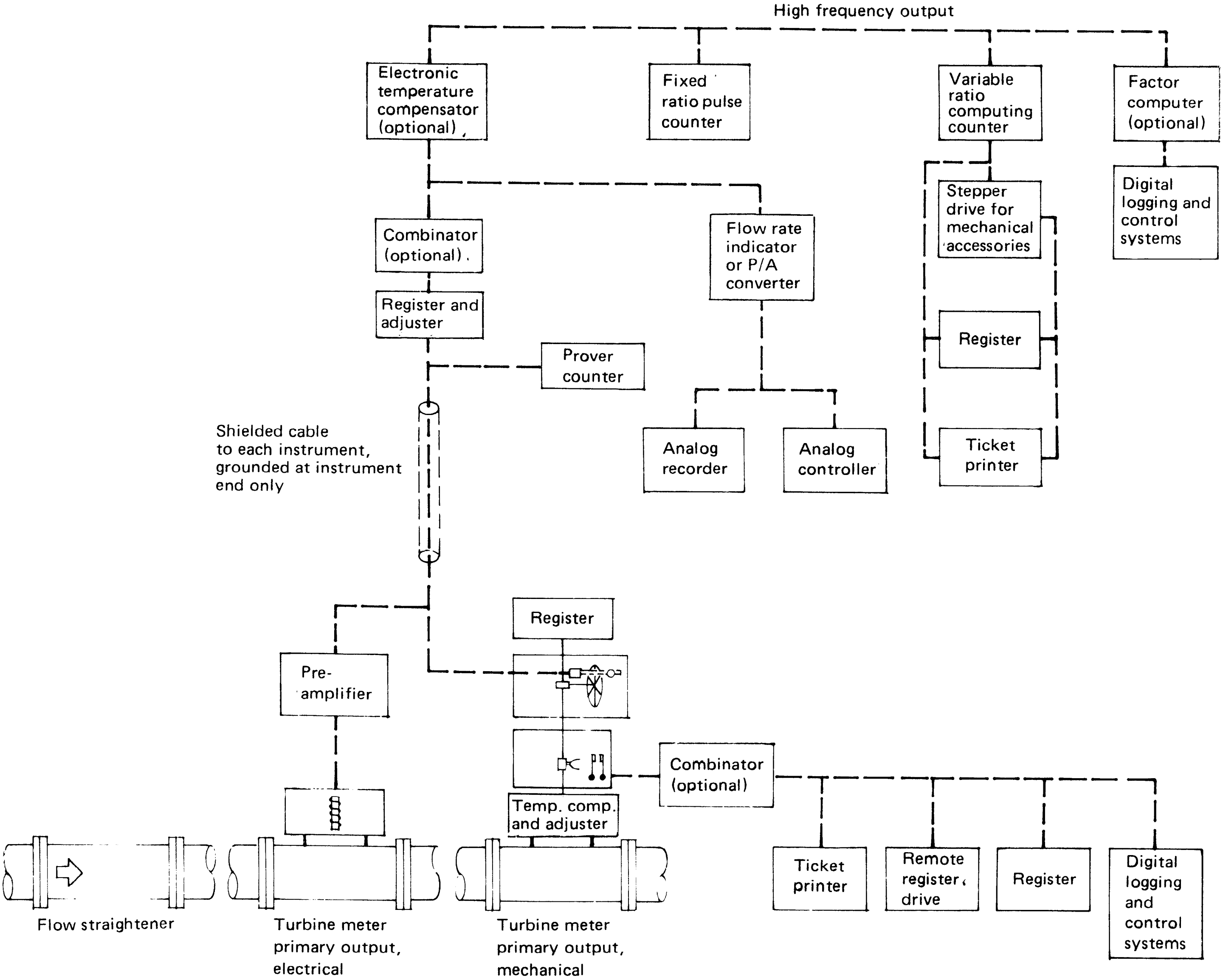

Figure 3 — Available turbine meter instrumentation

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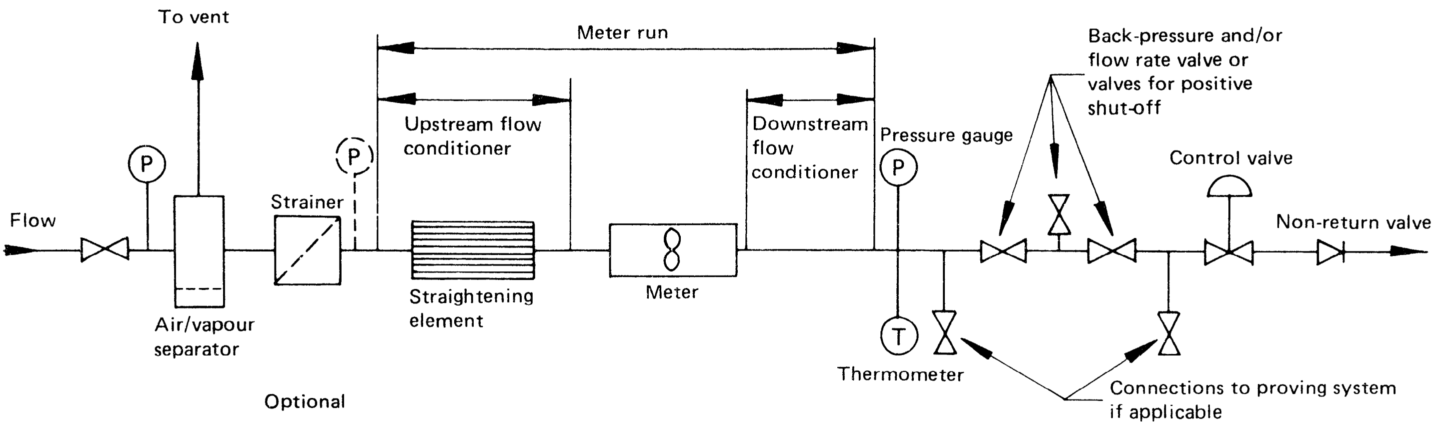
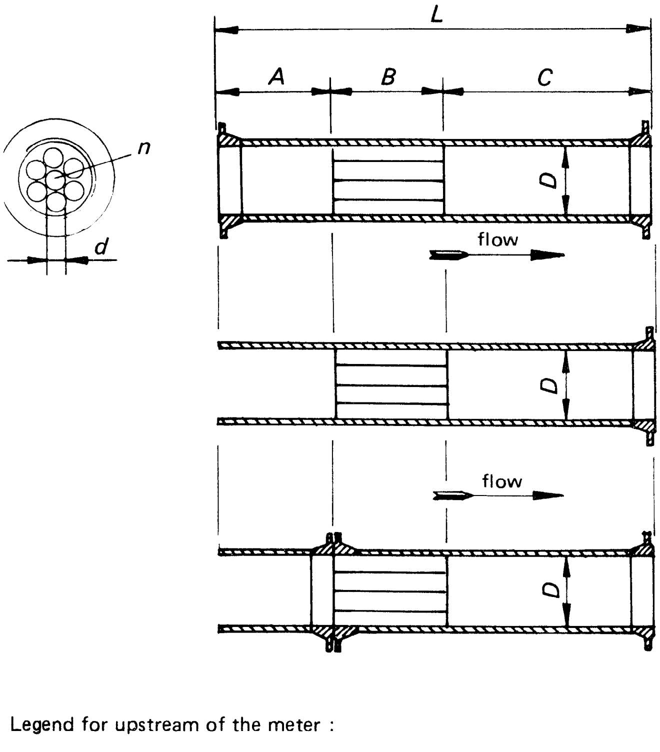


Figure 4 — Turbine meter assembly, schematic diagram

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



Legend for upstream of the meter :

L = overall length of conditioning assembly = 10 *D* minimum

A = length of upstream plenum = 2 *D* to 3 *D*

B = length of tube or vane type straightening element = 2 *D* to 3 *D*

C = length of downstream plenum = 5 *D* minimum

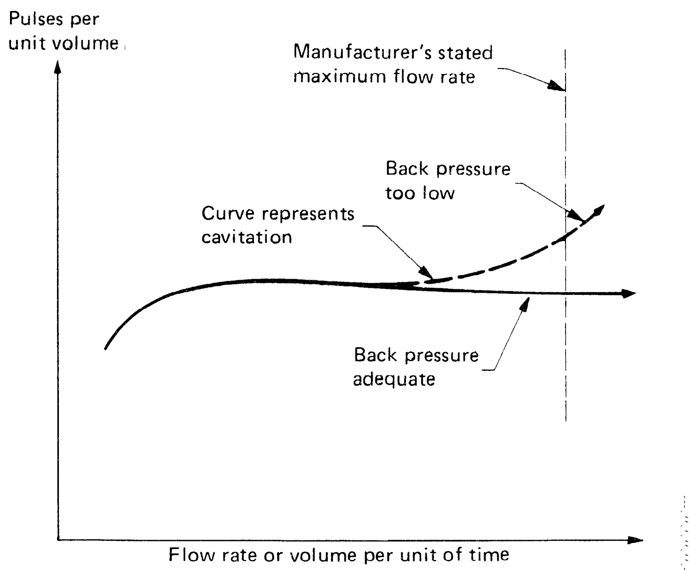
D = nominal diameter of meter

n = number of individual tubes or vanes. *n* should be at least 4

d = nominal diameter of individual tubes. *B*/*d* should be at least 10

NOTE — Downstream of the meter, use 5 *D* minimum of straight pipe.

Figure 5 — Examples of flow conditioning assemblies with straightening elements



NOTE — All curves for example only.

Figure 6 — Effects of cavitation on rotor speed

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Annex B

Trouble-shooting guide

(Forms part of the standard)

This annex is included as an aid in diagnosing malfunctions in turbine metering systems. However, it is not intended to replace a detailed and systematic checking of the measurement system.

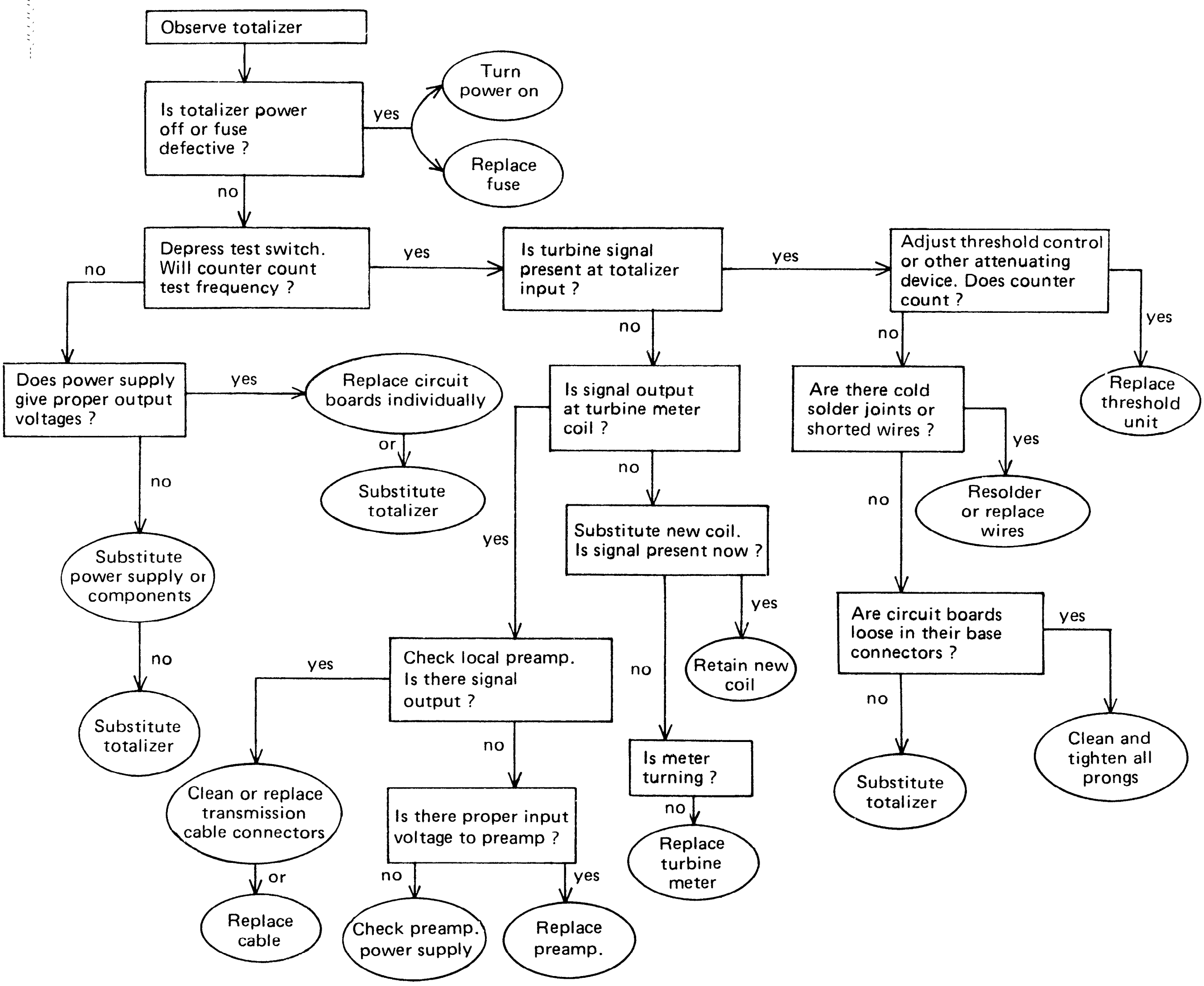

Figure 7 — Case where totalizer does not count

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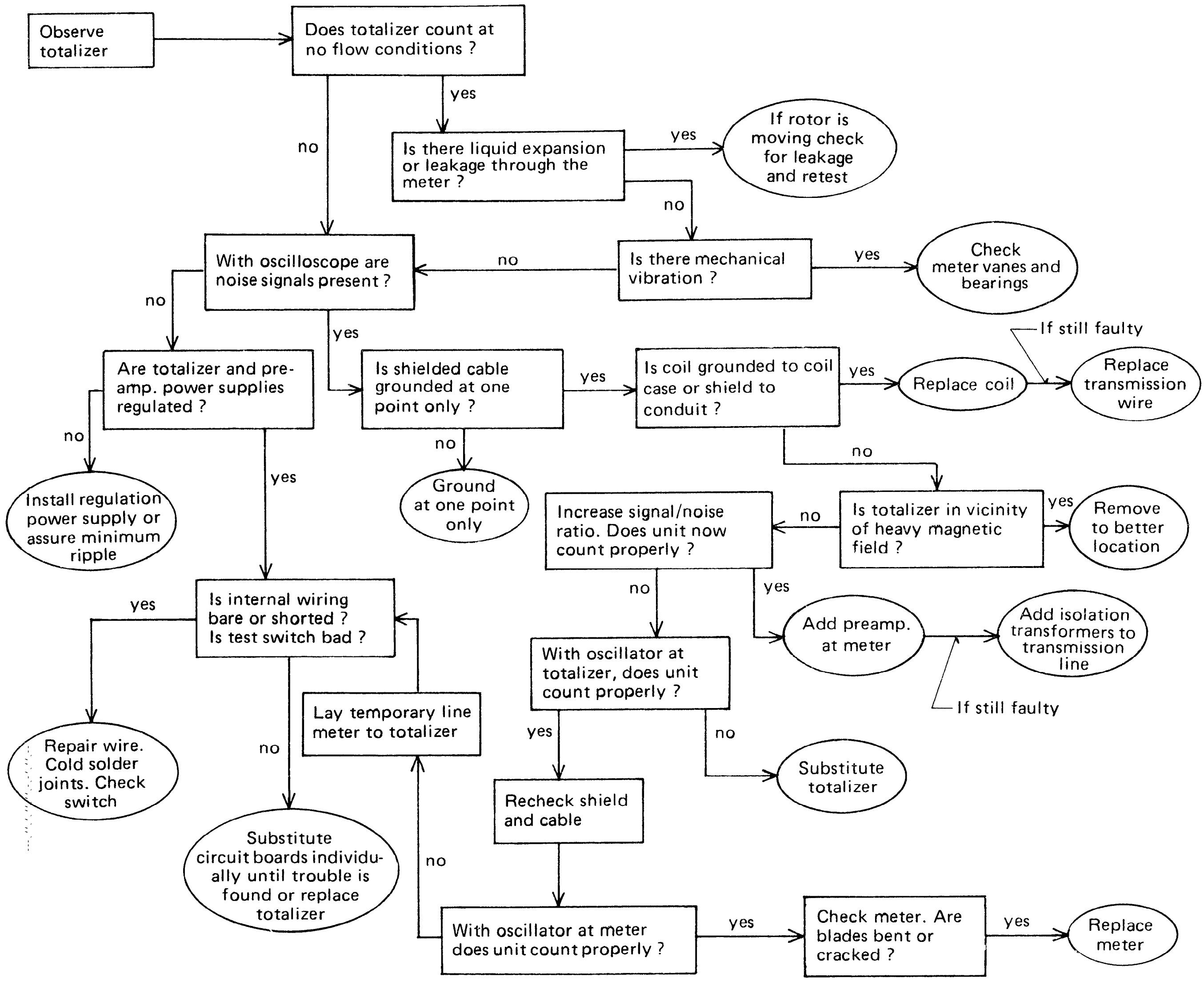

Figure 8 — Case where totalizer counts fast (overcounts)

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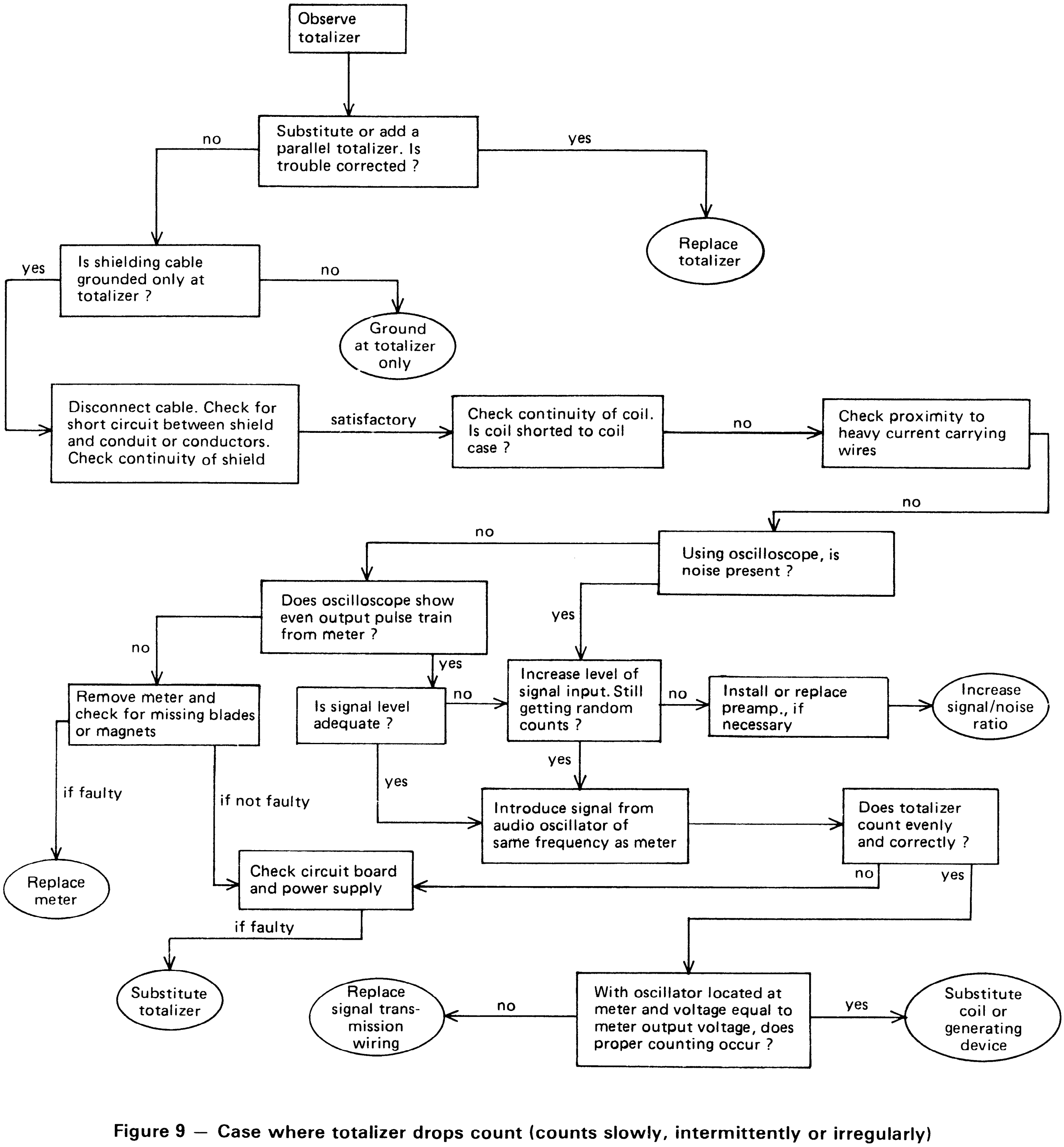

Figure 9 — Case where totalizer drops count (counts slowly, intermittently or irregularly)

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