ENGINEERING STANDARD

FOR

MEASUREMENT OF LIQUID HYDROCARBONS

(CUSTODY TRANSFER)

THIRD EDITION

MARCH 2020

FOREWORD

The Iranian Petroleum Standards (IPS) reflect the views of the Iranian Ministry of Petroleum and are intended for use in the oil and gas production facilities, oil refineries, chemical and petrochemical plants, gas handling and processing installations and other such facilities.

IPS are based on internationally acceptable standards and include selections from the items stipulated in the referenced standards. They are also supplemented by additional requirements and/or modifications based on the experience acquired by the Iranian Petroleum Industry and the local market availability. The options which are not specified in the text of the standards are itemized in data sheet/s, so that, the user can select his appropriate preferences therein.

The IPS standards are therefore expected to be sufficiently flexible so that the users can adapt these standards to their requirements. However, they may not cover every requirement of each project. For such cases, an addendum to IPS Standard shall be prepared by the user which elaborates the particular requirements of the user. This addendum together with the relevant IPS shall form the job specification for the specific project or work.

The IPS is reviewed and up-dated approximately every five years. Each standards are subject to amendment or withdrawal, if required, thus the latest edition of IPS shall be applicable

The users of IPS are therefore requested to send their views and comments, including any addendum prepared for particular cases to the following address. These comments and recommendations will be reviewed by the relevant technical committee and in case of approval will be incorporated in the next revision of the standard.

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GENERAL DEFINITIONS

Throughout this Standard the following definitions shall apply.

COMPANY :

Refers to one of the related and/or affiliated companies of the Iranian Ministry of Petroleum such as National Iranian Oil Company, National Iranian Gas Company, National Petrochemical Company and National Iranian Oil Refinery And Distribution Company.

PURCHASER :

Means the “Company" where this standard is a part of direct purchaser order by the “Company”, and the “Contractor” where this Standard is a part of contract document.

VENDOR AND SUPPLIER:

Refers to firm or person who will supply and/or fabricate the equipment or material.

CONTRACTOR:

Refers to the persons, firm or company whose tender has been accepted by the company.

EXECUTOR :

Executor is the party which carries out all or part of construction and/or commissioning for the project.

INSPECTOR :

The Inspector referred to in this Standard is a person/persons or a body appointed in writing by the company for the inspection of fabrication and installation work.

SHALL:

Is used where a provision is mandatory.

SHOULD:

Is used where a provision is advisory only.

WILL:

Is normally used in connection with the action by the “Company” rather than by a contractor, supplier or vendor.

MAY:

Is used where a provision is completely discretionary.

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APPENDICES:

0. INTRODUCTION

This Engineering Standard is concerned with the measurement of liquid hydrocarbons custody transfers by means of meters. Two principal types of meters which are mostly used, positive displacement meters and turbine meters are covered.

1. SCOPE

This Engineering Standard Specification covers the minimum requirement for proper engineering specification, installation, selection, operation and maintenance of meter station designed for dynamic measurement of liquid hydrocarbons with acceptable accuracy, safety, reliability, maintainability and quality control. The application criteria for turbine and positive displacement meters together with considerations regarding the liquid to be measured are also covered in this Standard. This standard does not apply to the measurement of two-phase fluids.

Note 1:

This is a revised version of this standard, which is issued as revision (1)-2005. Revision (0)-1997 of the said standard specification is withdrawn.

Note 2:

This is a revised version of this standard, which is issued as revision (2)-2012. Revision (1)-2005 of the said standard specification is withdrawn.

Note 3:

This is a revised version of this standard, which is issued as revision (3)-2020. Revision (2)-2012 of the said standard specification is withdrawn.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the company and the vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

API (AMERICAN PETROLEUM INSTITUTE)

RP-551	"Process Measurement Instrumentation"
RP-500	"Classification of Areas for Electrical Installation in Petroleum Refineries"
Chapter 1	"Manual of Petroleum Measurement Standards "Vocabulary""
Chapter 3.1A	"Method of Gauging Petroleum and Petroleum Products"
Chapter 3.1B	"MPMS Standard Practice for Level Measurement of Liquid Hydrocarbon in Stationary Tanks by Automatic Tank Gauging"
Chapter 4	"Manual of Petroleum Measurement Standards "Proving Systems""
	Section 1- "Introduction"
	Section 2- "Displacement Provers"
	Section 3- "Small Volume Prover"
	Section 4- "Tank Provers"
	Section 7- "Field-Standard Test Measures"
Chapter 5	"Manual of Petroleum Measurement Standards-Metering"
	Section 1- "General Consideration for Measurement by Meters"

Section 2- "Measurement of Liquid Hydrocarbons by Positive Displacement Meters"

Section 3- "Measurement of Liquid Hydrocarbons by Turbine Meters"

Section 4- "Accessory Equipment for Liquid Meters"

Section 5- "Fidelity and Security of Flow Measurement Pulsed-Data Transmission Systems"

Section 6- "Measurement of Liquid Hydrocarbons by Coriolis Meters"

Section 8- "Measurement of Liquid Hydrocarbons by Ultrasonic Flow Meters Using Transit Time Technology"

Chapter 6	"Manual of Petroleum Measurement Standards "Metering Assembly""
Chapter 7	"Manual of Petroleum Measurement Standards "Temperature Determination""
Chapter 8	"Manual of Petroleum Measurement Standards "Sampling""
Chapter 12.2.1-5	"Manual of petroleum Measurement Standards "Calculation of Petroleum Quantities""
Chapter 13.1-2	"Manual of Petroleum Measurement Standards "Application of Statistical Methods""
MPMS 21.1, 21.2	"Flow Computers"

BSI (BRITISH STANDARDS INSTITUTE)

BS 6169	"Methods for Volumetric Measurement of Liquid Hydrocarbons"
	Part 1- "Displacement Meter Systems (Other than Dispensing Pumps)"
	Part 2- "Turbine Meter Systems"
BS EN ISO 6551	"Fidelity and Security of Dynamic Measurement of Petroleum Liquids and Gases in Cabled Transmission as Electric and/or Electronic Data"

ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

ISO 2715	"Liquid Hydrocarbons-Volumetric Measurement by Turbine Meter Systems"
ISO 2714	"Liquid Hydrocarbons-Volumetric Measurement by Positive Displacement Meter Systems Other than Dispensing Pumps"
BS EN ISO 6551	"Petroleum Liquid and Gases-Fidelity and Security of Dynamic Measurement Cabled Transmission of Electric and/or Electronic Pulsed Data"
ISO 10790	Measurement of fluid flow in closed conduits — Guidance to the selection, installation and use of Coriolis flowmeters (mass flow, density and volume flow measurements)

IP (THE INSTITUTE OF PETROLEUM)

Part 9	"Positive Displacement Meters"
Sec. 1	

IP 205/71	"Automatic Tank Gauging"
IP 202/73	"Tank Calibration, Section 3"

ISA (INSTRUMENT SOCIETY OF AMERICA)

RP 31.1	"Specification, Installation, and Calibration of Turbine Flow Meters"
5.1	"Instrumentation Symbols and Identification"
RP 12.01.01	"Electrical Instruments in Hazardous Atmospheres"
S 12.10	"Area Classification in Hazardous Dust Location"
S 12.11	"Electrical Instruments in Hazardous Dust Locations"
S 18.1	"Announciator Sequences and Specifications"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-E-IN-110	"Engineering Standard for Pressure Instrument"
IPS-E-IN-120	"Engineering Standard for Temperature Instrument"
IPS-E-IN-130	"Engineering Standard for Flow Instrument"
IPS-E-IN-140	"Engineering Standard for Level Instrument"

3. TERMS AND DEFINITIONS

3.1 Accessory Equipment

Accessory equipment is any device that enhances the utility of a measurement system

4. UNITS

This standard is based on international system of units (SI), as per IPS-E-GN-100, except where otherwise specified.

5. GENERAL CONSIDERATION FOR MEASUREMENT BY METERS

5.1 Field of Application

The field of application of this engineering Standard is the volume and mass measurement of liquid crude oils and refined products, which are normally in the liquid phase at atmospheric pressure and ambient temperature.

This Standard is also concerned with the metering of hydrocarbons which can be made and kept liquid by maintaining the proper pressure and temperature.

The metering of two-phase fluids will not be covered in this Standard.

5.2 Guidelines for Selecting the Type of Meter

The custody transfer metering of petroleum liquids shall be done with high performance versions of Positive Displacement (P.D) Meters, Turbine Meters, Ultrasonic (Transit time differential method) or Coriolis meters.

Although factors such as pressure, flow rate and fluid contamination may influence the type of meter selected, viscosity and flow rate should be considered first.

The viscosity of the liquid affects whether a positive displacement meter or turbine meter will provide the best overall accuracy for a particular custody transfer application. Fig. 1 provides a guide line for P.D and turbine meter selection as a function of viscosity and flow rate.

5.2.1 Selecting positive displacement meters

The following strengths and weaknesses shall be considered when selecting positive displacement meters.

Positive displacement meters have the following strengths:

a) Accuracy.

b) Capability to measure viscous liquids.

c) Capability to function without external power.

d) Operation near-zero flow rate.

e) Simplicity of design and operation.

Positive displacement meters have the following weaknesses:

a) Flow surges may damage the meter.

b) High cost of large meters.

c) Susceptibility to corrosion and erosion.

d) Higher maintenance requirement.

e) High pressure drop.

5.2.2 Selecting turbine meters

The following strengths and weaknesses shall be considered when selecting the turbine meter.

Turbine meters have the following strengths:

a) Accuracy.

b) Wide flow range.

c) Small size and weight.

d) Wide temperature and pressure range.

Turbine meters have the following weaknesses:

a) Flow conditioning is required.

b) Back pressure control is needed to prevent cavitation.

c) Inability to meter high-viscosity liquids.

d) Sensitivity to viscosity changes at high viscosities.

e) Higher maintenance requirement.

5.2.3 Selecting ultrasonic meters

The following strengths and weaknesses shall be considered when selecting ultrasonic meters.

Ultrasonic meters have the following strengths:

a) Have no moving parts and don't require frequent recalibration and maintenance.

b) The flowmeter does not alter the flow properties during measurement and causes little or no pressure drop.

c) The presence of large amount of gas or solid contents may temporary blind the meter, but not damage it.

d) Wide flow range

e) Multi-path ultrasonic flowmeters do not require reproving when the fluid properties change. Since the medium density is the same in both directions, the differential transient time measurement is not affected by density changes to the flowing liquid.

Ultrasonic meters have the following weaknesses:

a) It is not suitable for dirty liquids

b) It is necessary to use the straightener in upstream of the meter

5.2.4 Selecting the coriolis meters

The following strengths and weaknesses shall be considered when selecting the coriolis meter.

Coriolis meters have the following strengths:

a) Since mass is independent of other physical parameters, as well as the ambient conditions in which the measurement is made, therefore the measurement is essentially unaffected by changes in temperature, pressure, density, viscosity and flow profile.

b) Along with mass flow and temperature, measures the fluid density allowing it to accurately calculate the volumetric flow

c) No rotating parts and low maintenance

d) High accuracy

Coriolis meters have the following weaknesses:

a) High pressure drops

b) High initial costs

c) Limited sizes

5.3 Accuracy Class

Taking into consideration their field of application, accuracy of measuring systems and flow meters shall be better than 0.25% and 0.15%, respectively.

5.4 Design Considerations

The design of meter installations shall take into account the following considerations:

a) The installation shall be capable of satisfying the required performance characteristics for the application between the maximum and minimum flow rates, at the maximum operating pressure, and over the temperature range and liquid types to be measured. If necessary, the installation should include protective devices that keep the operation of the meter within design limits.

b) The installation should ensure a maximum, dependable operating life. Strainers, filters, air/vapor eliminators, or other protective devices may be provided upstream of the meter to remove solids and/or gases that could cause meter damage, premature meter wear and/or measurement error.

A differential pressure gauge shall be used to determine when the filter or strainer should be cleaned.

c) The installation shall maintain adequate pressure on the liquid in the metering system at all temperatures to ensure that the fluid being measured will be in the liquid state at all times.

d) The installation should provide for proving each meter and should be capable of duplicating normal operating conditions at the time of proving.

e) The installation should ensure, where necessary, appropriate flow conditioning both upstream and downstream of the meter or bank of meters.

f) The installation should comply with all applicable regulations and codes.

g) Factors which should be considered at the design stage are listed in Table 1. These parameters are not in order of importance, but are for general guidance only.

h) Effects of any contaminants on the meter and the quantity, size, particle distribution and type of foreign matter, including abrasive particles, water and vapor which may be carried in the stream. These may influence the size of straining, filtering and vapor or water separation equipment from the point of flow rate capacity and pressure drop.

i) The class and type of piping connections and materials and dimensions of the equipment to be used.

j) The space required for meter station and the proving facility.

k) The method by which a meter in a bank of meters can be put on or taken off line as the total rate changes and the method by which the meter can be proved at its normal operating rate.

l) The type, method and frequency of proving.

m) Maintenance methods and cost, spare parts required.

n) The adjusting method for meter registration. A means where by 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 is obtained.

o) Type of indicating or recording devices required and the standard units of volume in which read-out is required.

p) The need for accessory equipment, such as totalizers, pulsers, additive injection apparatus, combinators, and devices for controlling delivery of a predetermined quantity. When meter-driven mechanical accessory devices are used, caution must be taken to limit the total torque applied to the metering element .Consideration should also be given to using electrical transmitter on the meter, and to having various functions operated electrically there from.

q) The types of readout and printout devices or systems to be used, signal preamplification (see API MPMS Chapter 5.4)

r) The fidelity and security of pulse-data transmission systems (see API MPMS Chapter 5.5).

s) For availability of measuring system, at least one standby meter run should be considered.

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

u) 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 design criteria.

TABLE 1 - FACTORS AFFECTING THE SELECTION OF METER TYPE

Item	Category	Items for consideration
1	Performance considerations	Desired level of overall performance Desired level of linearity Desired level of repeatability/reproducibility Range of operating flowrates Type of flow (unidirectional or bidirectional, reversible, continuous, intermittent or fluctuating of the fluid) Maximum pressure drop allowed Response time Output characteristics
2	Installation considerations	Pipe work orientation Line size Provision of ancillaries Presence of pulsation/vibration Location access for servicing Electrical power and connection requirements Operating service continuous/intermittent
3	Liquid property considerations	Pressure range Temperature and viscosity range Lubricity Compressibility effects Liquid abrasiveness Corrosive nature and toxicity Vapor pressure and presence of other phases
4	Environmental considerations	Ambient temperature effects Effect of humidity Electrical interference Presence of hazardous atmospheres External corrosive effects

5.5 Valves

5.5.1 The flow or pressure control valves on the meter run should be capable of rapid, smooth opening and closing to prevent shocks and surges. Other valves particularly those between the meter or meters and prover such as the stream diversion valves, drain and vent valves require leakproof shut-off, which may be provided by a double block-and-bleed valve with telltale bleed or by another similarly effective method of verifying shut-off integrity.

5.5.2. In general, all valves, especially spring-loaded or self-closing valves, should be designed so that they will not admit air when they are subjected to hydraulic shock (hammering) or vacuum conditions.

5.5.3 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, e.g. block and bleed valve.

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

5.5.5 A flow-limiting device, such as a flow rate control valve or a restricting orifice, should preferably be installed downstream of the meter and prover. The device should be selected or adjusted so that sufficient pressure will be maintained to prevent vaporization. An alarm may be desirable to signal that flow rates have fallen below the design minimum. If a pressure-reducing device, or other restrictive device (e.g., check valve, isolating butterfly valve, etc.) is used on the inlet side of the meter, it shall be installed as far upstream of the meter as possible. The device shall be installed so that sufficient pressure will be maintained on the outlet side of the meter installation to prevent any vaporization of the metered liquid.

Also minimum differential pressure must be maintained across the meter.

5.5.6 A back-pressure valve may be required to maintain the pressure on the meter and the prover above the fluid vapor pressure. In general, displacement meters do not accelerate fluid velocity and are not normally subject to the resulting pressure reduction that can cause vaporization (cavitation) in other types of meters.

5.5.7 If a bypass is permitted around a meter or a battery of meters, it shall be provided with a blind and positive shutoff double block-and-bleed valve with a telltale bleed. The bypass line could be used only under permission of all authorized parties.

5.6 Piping

5.6.2.1 Each meter shall be installed in such a manner as to prevent passage of air or vapor through it. If needed, air/vapor elimination equipment shall be installed as close as possible to the upstream side of the meter. The vent lines on air/vapor eliminators shall be of adequate size. The safety of the venting system should be given special design consideration.

Air eliminators can not vent when they are operating bellow atmospheric pressure, and under adverse conditions; they may even draw air into the system. A tight closing check valve in the vent line will prevent air from being drawn into the system under these conditions.

5.6.2.2 A bank of meters connected in parallel is recommended 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.

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

5.6.2.4 Meter installation requires that protective devices be installed to remove from the liquid abrasives or other entrained particles that could stop the metering mechanism or cause premature wear. Strainers, filters, sediment traps, settling tanks, water separators, a combination of these items, or any other suitable devices should be used. They should be properly sized and installed so that they do not adversely affect the operation of the meter. Monitoring devices shall be installed to determine when the protective device needs to be cleaned.

5.6.2.5 Meters and meter piping shall be protected from pressure pulsation and excessive surges as well as excessive pressure caused by thermal expansion of the liquid. This may require the installation of surge tanks, an expansion chamber, relief valves, pressure limiting valves or other protective devices. When 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.

5.6.2.6 Any condition which may cause the release of vapor from the liquid shall be avoided by proper design and by operation of the meter within the flow range specified by the Manufacturer. The release of vapor can be minimized or eliminated by maintaining sufficient back pressure down stream of the meter. This can be achieved by installing the appropriate type of back pressure, throttling the reducing valve downstream of the meter. The required back pressure may be recommended by Manufacturer.

5.6.2.7 Meters and piping shall be installed so that accidental drainage or vaporization of liquid is avoided. The piping shall have no unvented high points or pockets where air or vapor may accumulate and be carried through the meter by the added turbulence that results from increased flow rate. The installation shall prevent air from being introduced into the system through leaky valves, piping, glands of pumps, shafts, separators, connecting lines and so forth.

5.6.2.8 A means of measuring temperature shall beprovided to enable correction of thermal effects on the stream or meter. The capability to obtain the stream temperature inside the meter body is desirable. Some displacement meters and double case turbine meters allow for installation of a temperature-measuring device in the meter body. However, this is impractical with most other types of meters because of the way they are constructed or because of the type of temperature-measuring device that is selected. If it is impractical to mount the temperature-measuring device in the meter, the device should be installed either immediately downstream (preferable, especially for turbine meters) or upstream of the meter run. Where several meters are operated in parallel on a common stream, one temperature- measuring device in the total stream, located sufficiently close to the meter inlets or outlets, is acceptable if the stream temperatures at each meter and at the sensing location agree within the tolerance specified in API MPMS Chapter 7.

Test thermowell(s) should be provided downstream of each meter, or downstream of all the meter runs, to verify that the stream temperatures are identical and the upstream temperature is representative of the temperature at the meters.

5.6.2.9 Where determination of meter pressure is required, a set of pressure gauge, recorder or transmitter of suitable range and accuracy shall be installed near the inlet or outlet of each meter. Near the inlet is acceptable for displacement and Coriolis meters.

5.6.2.10 A heat traced manifold that maintains a heavy hydrocarbon in liquid state shall be designed to meet the followings:

a) An excessively high temperature can not occur.

b) The temperature can not fall bellow the level at which the viscosity of the liquid becomes too great for the displacement meter at the required flow rates.

c) Temperature control is especially important when the meter is not operating. The meter manufacturer should be consulted about high and low limits for viscosity and temperature.

5.6.2.11 Piping shall be designed to prevent the loss or gain of liquid between the meter and the prover during proving.

5.6.2.12 Lines from meter to the prover shall be installed in a manner to minimize the possibility of air or vapor being trapped. Manual bleed valves should be installed at high points so that air or vapor can be drawn off before proving. The distance between the meter and its prover shall be minimized. The diameter of the connecting lines shall be large enough to prevent a significant decrease in flow rate during proving. In bank of meter stations, throttling valves may be installed downstream of the meters to regulate flow through the prover while each meter is being proved.

5.6.2.13 Special consideration should be given to the location of each meter, its accessory equipment, and its piping manifold to minimize the mixing of dissimilar liquids

5.7 Meter Performance

Meter performance is defined by how well a metering system produces, or can be made to produce, accurate measurements.

The overall performance of measurement by a meter depends on the condition of the meter and its accessories, the temperature and pressure corrections, the proving system, the frequency of proving, and the variations between operating and proving conditions. The inherent accuracy of a meter is often published in the manufacturer’s specification, and may be expressed as repeatability and/or linearity. In other words, accuracy is based on how repeatable and how linear the meter can stay within the manufacturer’s performance specifications. Manufacturers’ specifications are based on meter operation within recommended flow ranges, within a narrow range of pressures, temperatures, and fluid viscosities. For custody transfer applications, meters with the highest inherent accuracy should be used and should be proved on site. The meters should operate within the manufacturer’s specifications.

Meter factors must be determined when commissioning a meter.

The variables which may affect the meter factor are shown in Table 2:

TABLE 2 - PARAMETERS AFFECTING METER PERFORMANCE

	PD Meter	Turbine Meter	Ultrasonic Meter	Coriolis Meter
Specific gravity/Density	✓	✓	✓	✓
Flow rate	✓	✓	✓	✓
Liquid viscosity	✓	✓	✓	✓
Liquid temperature	✓	✓	✓	✓
Fluid Liquid pressure	✓	✓	✓	✓
Cleanliness of the liquid	✓	✓	—	—
Change in measuring-element clearances due to wear or damage which affects the slippage	✓	—	—	—
pressure drop through the meter	✓	—	—	✓
Malfunctions in the proving system				
lubricating qualities of the liquid	✓	✓	—	—
Mechanical clearances or blade geometry due to wear or damage.	—	✓	—	—
Changes in piping, valves, or valve positions that affect fluid profile.	—	✓	—	—
Conditions of the prover.	—	✓	—	—
Foreign material lodged in the meter, strainer or flow-conditioning element	—	✓	—	—

5.7.1 Meter readout adjustment methods

Either of two methods of meter readout adjustment may be used, depending on the meter's intended application and anticipated operating conditions.

5.7.1.1 Direct volume readout method

With the first method the readout is adjusted until the change in meter reading during a proving equals or nearly equals the volume measured in the prover. It is then sealed to provide security against unauthorized adjustment.Adjusted meters are most frequently used on retail delivery trucks and on truck and rail-car loading racks, where it is desirable to have direct-reading meters without having to apply mathematical corrections to the reading.

An adjusted or direct-reading meter is correct only for the liquid and the flow conditions at which it was proved.

5.7.1.2 Meter factor method

With the second method of meter readout adjustment, the meter readout is not adjusted, and 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 indicated by the meter. For subsequent metering operations, the actual throughput or measured volume is determined by multiplying the volume indicated by the meter by the meter factor. When direct reading is not required, the use of a meter factor is preferred for several reasons: It is difficult or impossible to adjust a meter calibrator mechanism to register with the same resolution that is achieved when a meter factor is determined. In addition, adjustment generally requires one or more reprovings to confirm the accuracy of the adjustment. In applications where the meter is to be used with several different liquids or under several different sets of operating conditions, a different meter factor can be determined for each liquid and for each operating condition. An adjusted or direct registration is valid for only the one liquid and the one flow rate for which it was adjusted.

5.7.2 Causes of variations in meter factors

The variables that have the greatest effect on the meter factor are flow rate, viscosity, temperature, and foreign material (for example, paraffin in the liquid).

If a meter is proved and operated on liquids with inherently identical properties, under the same conditions as in service, the highest level of accuracy may be expected. If there are changes in one or more of the liquid properties or in the operating conditions between the proving and the operating cycle, then a change in meter factor may result, and a new meter factor must be determined.

5.8 Meter Specification

The following specifications are recommended for flow meters used in custody transfer:

Linearity: ±0.15% or better, over the linearity flow range.

Repeatability: According to Table 3

Number of Proving Runs, n	Moving (Variable) Range Limit
3	0.0002
4	0.0003
5	0.0005
6	0.0006
7	0.0008
8	0.0009
9	0.001
10	0.0012
11	0.0013
12	0.0014
13	0.0015
14	0.0016
15	0.0017
16	0.0018
17	0.0019
18	0.002
19	0.0021

5.8.1 Base condition correction

A calculated temperature and pressure correction based on the volume weighted average temperature and pressure of the delivery, may be used to correct indicated volume to a volume at a base or reference temperature and pressure.

5.9 Safety

5.9.1 General

The flowmeter should not be used at conditions, which are outside the flowmeter's specification. Flowmeters also should conform to any necessary hazardous area classifications. The following additional safety considerations should be made.

5.9.2 Hydrostatic pressure test

The wetted parts of the fully assembled flowmeter sensor should be hydrostatically tested in accordance with the appropriate standard.

5.9.3 Mechanical stress

The flowmeter shall be designed to withstand all loads originating from temperature, pressure, and pipe vibration. Meters shall be designed and installed so that they will not be subjected to undue stress, strain or vibration. Provision shall be made to minimize meter distortion caused by piping expansion and contraction.

5.9.4 Erosion

Fluids containing solid particles or cavitation can cause erosion of the flowmeter during flow. The effect of erosion is dependent on flowmeter size and geometry, particle size, abrasives, and velocity. Erosion should be assessed for each type of use of the flowmeter.

5.9.5 Corrosion

Corrosion, including galvanic corrosion, of the wetted materials can adversely affect the operating lifetime of the flowmeter, pipe, and flanges. The construction material of the flowmeter should be selected to be compatible with process fluids and cleaning fluids. Special attention should be given to corrosion and galvanic effects in no-flow or empty-pipe conditions. Corrosion also affects the flowmeter's performance. All process-wetted materials should be specified.

5.9.6 Area classification

The regulations for electrical equipment in hazardous areas shall be considered when there is a possibility of a hazardous atmosphere being present at the meter station.

5.10 Cavitation Prevention

Any condition that tends to contribute to vaporization or cavitations of the liquid stream should be avoided by system design and by operating the meter within its specified flow range. Vaporization or cavitation can be minimized or eliminated by maintaining sufficient pressure in and immediately downstream of the meter. The numerical value of the minimum back pressure at the outlet of the meter may be calculated with the following expression, which has been commonly used. The calculated back pressure has proven to be adequate in most applications, and it may be conservative for some situations.

$$Pb = 2\Delta p + 1.25pe$$

Where:

Pb = minimum back pressure, pounds per square inch gauge (psig),

Δp = pressure drop through the meter at the maximum operating flow rate for the liquid being

measured, pounds per square inch (psi),

pe = equilibrium vapor pressure of the liquid at the operating temperature, pounds per square inch absolute (psia), (gauge pressure plus atmospheric pressure).

6. MEASUREMENT OF LIQUID HYDROCARBONS BY POSITIVE DISPLACEMENT METERS

6.1 Introduction

In principle, a positive displacement meter is a flow measuring device that separates a liquid into discrete volumes and counts the separated volumes. The registered volume of the displaced meter must be compared with a known volume that has been determined by proving.

6.2 Principle of Operation

P.D meters repeatedly entrap a known quantity of fluid as it passes through the meter. When the numbers of times the fluid is entrapped is known, the quantity of fluid that has passed through the flow meter is also known.

In practice, this type of meter senses the entrapped fluid by generating pulses, each of which represents a fraction of the known quantity entrapped.

6.3 Types of Positive Displacement Meters

6.3.1 Helical gear positive displacement meters

Two radially-pitched helical gears are used to continually entrap liquid as it passes through the meter causing the rotors to rotate in the longitudinal plane. Flow through the meter is proportional to the rotational speed of the gears.

6.3.1.1 Helical gear meter shall be applicable to non-abrasive lubricious liquids. Slippage can pose a problem in low viscosity applications, especially if there is any wear of machined parts, so most applications are on high viscosity liquids.

6.3.1.2 This type of P.D meter is somewhat tolerant of dirt, as there are few passages that are easily plugged, but is susceptible to overspeed and bearing damage.

6.3.1.3 Volumetric flows can be measured with an accuracy ranges from approximately 0.2 to 0.4 percent rate, depending on the application and the meter design. Non viscous flows shall be measured less accurately than viscous flows due to errors caused by increased slippage through the meter at low viscosities.

6.3.2 Oscillating piston positive displacement meters

A cylindrical measurement chamber with a partition plate separating the inlet from the outlet port is used.

The motion of the piston is transmitted to a magnet assembly that is used to drive a meter magnet external to the flow stream. It can also be used to drive a register or a transmitter.

As the meter entraps a fixed quantity of liquid each time the meter is rotated, the rate of flow is proportional to the rotational velocity of piston.

6.3.2.1 Oscillating piston meters shall be used on viscous liquid service where turndown is not of great Importance. This meter is somewhat tolerant of dirt, there are few easily plugged passages, but large or abrasive solids can be compressed between the piston and the meter body, thereby distorting the piston.

6.3.2.2 This type of meter can measure volumetric flows with an accuracy of up to approximately ±0.5 percent rate, depending on the application. Non viscous flows shall be measured less accurately due to errors caused by increased slippage through the meter at low viscosities.

6.3.2.3 The maximum flow through oscillating piston meters shall be a function of usage. These meters generally have different flow ratings for continuous and intermittent services. Turndown ratio in an intermittent liquid application may be typically 5:1 to 6:1. In continuous application, the maximum turndown can be as low as 3:1 to 4:1.

6.3.2.4 This design shall be applicable to clean non-abrasive liquids. Slippage can pose a problem in low viscosity applications, especially if there is any wear of machined parts; therefore, most applications shall be on higher viscosity liquids.

6.3.3 Oval gear positive displacement meters

The differential pressure across the meter causes forces to be exerted on a pair of oval gears, often called rotors, causing them to rotate.

As the upstream pressure is greater than the downstream pressure, the force exerted on the upstream end of the lower face of upper rotor is greater than on the downstream end. This tends to make upper rotate in clockwise direction and lower rotor in a counter clock wise direction.

6.3.3.1 This meter can measure volumetric flows with an accuracy that ranges from approximately ±0.25 to 1 percent rate, depending on the application and meter design. Non viscous flows shall be measured less accurately due to errors caused by increase slippage through the meter at low viscosities.

6.3.3.2 The maximum flow through this P.D meter shall be dependent upon lubricity and viscosity of the liquid.

Turndown in an intermittent lubricious liquid application can be as high as 20:1. The same meter in an intermittent non-lubricious liquid application may have a maximum turndown of 4:1. In continuous operation, the turndown is further reduced to approximately 3:1.

6.3.3.3 Oval gear meters shall be applicable to non-abrasive lubricious liquids with viscosities from approximately 0.2 CP to 500.000 CP. Slippage can pose a problem in low viscosity applications, especially if there is any wear of machined parts. Therefore, most applications shall be on higher viscosity liquids.

6.3.4 Rotary positive displacement meters

Rotary positive displacement meters converts the entrapment of liquid into a rotational velocity proportional to the flow through the meter.

As the meter entraps a fixed quantity of liquid each time the meter is rotated, the flow is proportional to the rotational velocity of one of the rotating parts.

6.3.4.1 Rotary flow meters shall be used on liquid service where accuracy is of importance but turndown is not. These meters shall be applicable to clean non-abrasive liquids.

6.3.4.2 This design can measure volumetric flows with an accuracy that ranges from approximately ±0.1 to 0.2 percent rate, depending on the application. Nonviscous flows shall be measured less accurately than viscous flow due to errors caused by increased slippage through the meter at low viscosity service.

6.4 Design Consideration

All types of displacement meter stations shall meet the section 4.4 requirements.

6.5 Selection of Displacement Meter and Ancillary Equipment

6.5.1 Consideration of Table 1 requirements, shall be given to, and Manufacturer consulted, regarding selection of the meter and its ancillary equipment.

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

6.5.3 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.

6.5.4 Automatic pressure lubrication for nonlubricating or dirty liquids.

6.6 Installation Design Considerations

Meters shall be installed according to the Manufacturer's instructions and shall not be subjected to undue piping strain and vibration. Flow conditioning is not required for displacement meters. (Fig. 2)

6.6.1 Piping

6.6.1.1 Each meter shall be installed in such a manner as to prevent passage of air or vapor through it. If needed, air/vapor elimination equipment shall be installed as close as possible to the upstream side of the meter. The vent lines on air/vapor eliminators shall be of adequate size. The safety of the venting system should be given special design consideration.

Air eliminators can not vent when they are operating bellow atmospheric pressure, and under adverse conditions; they may even draw air into the system. A tight closing check valve in the vent line will prevent air from being drawn into the system under these conditions.

6.6.1.2 A bank of meters connected in parallel is recommended 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.

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

6.6.1.4 Meter installation requires that protective devices be installed to remove from the liquid abrasives or other entrained particles that could stop the metering mechanism or cause premature wear. Strainers, filters, sediment traps, setting tanks, water separators, a combination of these items, or any other suitable devices can be used. They should be properly sized and installed so that they do not adversely affect the operation of the meter. Monitoring devices shall be installed to determine when the protective device needs to be cleaned.

6.6.1.5 Meters and meter piping shall be protected from pressure pulsation and excessive surges as well as excessive pressure caused by thermal expansion of the liquid. This may require the installation of surge tanks, an expansion chamber, relief valves, pressure limiting valves or other protective devices. When 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.

6.6.1.6 Any condition which may cause the release of vapor from the liquid shall be avoided by proper design and by operation of the meter within the flow range specified by the Manufacturer. The release of vapor can be minimized or eliminated by maintaining sufficient back pressure down stream of the meter. This can be achieved by installing the appropriate type of back pressure, throttling the reducing valve downstream of the meter. The required back pressure may be recommended by Manufacturer.

6.6.1.7 Meters and piping shall be installed so that accidental drainage or vaporization of liquid is avoided. The piping shall have no unvented high points or pockets where air or vapor may accumulate and be carried through the meter by the added turbulence that results from increased flow rate. The installation shall prevent air from being introduced into the system through leaky valves, piping, glands of pumps, shafts, separators, connecting lines and so forth.

6.6.1.8 A means of measuring temperature shall be provided to enable correction of thermal effects on the stream or meter. The capability to obtain the stream temperature inside the meter body is desirable. Some displacement meters and double case turbine meters allow for installation of a temperature-measuring device in the meter body. However, this is impractical with most other types of meters because of the way they are constructed or because of the type of temperature-measuring device that is selected. If it is impractical to mount the temperature-measuring device in the meter, the device should be installed either immediately downstream (preferable, especially for turbine meters) or upstream of the meter run. Where several meters are operated in parallel on a common stream, one temperature-measuring device in the total stream, located sufficiently close to the meter inlets or outlets, is acceptable if the stream temperatures at each meter and at the sensing location agree within the tolerance specified in API MPMS Chapter 7.

Test thermowell(s) should be provided downstream of each meter, or downstream of all the meter runs, to verify that the stream temperatures are identical and the upstream temperature is representative of the temperature at the meters.

6.6.1.9 When placing a new meter in service, means should be provided to protect the meter from damage and malfunction arising from over-speeding or the influence of foreign matter such as thread cuttings, pipe debris, weld spatter, or similar material arising from the construction. Means of accomplishing mechanical protection are the use of a temporary by-pass, temporary spool pieces, or the installation of a protective device upstream to collect the debris.

Over-speeding can damage either the bearing, or the measuring element, unless care is exercised during start-up. The line should be filled slowly by allowing line pressure to rise slowly with the downstream valve being closed. Any gas that is present should be vented. Once the pressure is stable, the downstream valve can be opened slowly to allow flow to start.

6.7 Meter readout adjustment methods

Either of two methods of meter readout adjustment may be used, depending on the meter's intended application and anticipated operating conditions.

6.7.1 Direct volume readout method

With the first method the readout is adjusted until the change in meter reading during a proving equals or nearly equals the volume measured in the prover. It is then sealed to provide security against unauthorized adjustment.Adjusted meters are most frequently used on retail delivery trucks and on truck and rail-car loading racks, where it is desirable to have direct-reading meters without having to apply mathematical corrections to the reading.

An adjusted or direct-reading meter is correct only for the liquid and the flow conditions at which it was proved.

6.7.2 Meter factor method

With the second method of meter readout adjustment, the meter readout is not adjusted, and 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 indicated by the meter. For subsequent metering operations, the actual throughput or measured volume is determined by multiplying the volume indicated by the meter by the meter factor5.7.1.3 When direct reading is not required, the use of a meter factor is preferred for several reasons: It is difficult or impossible to adjust a meter calibrator mechanism to register with the same resolution that is achieved when a meter factor is determined. In addition, adjustment generally requires one or more reprovings to confirm the accuracy of the adjustment. In applications where the meter is to be used with several different liquids or under several different sets of operating conditions, a different meter factor can be determined for each liquid and for each operating condition. An adjusted or direct registration is valid for only the one liquid and the one flow rate for which it was adjusted.

6.8 Causes of variations in meter factors

The variables that have the greatest effect on the meter factor are flow rate, viscosity, temperature, and foreign material (for example, paraffin in the liquid).

If a meter is proved and operated on liquids with inherently identical properties, under the same conditions as in service, the highest level of accuracy may be expected. If there are changes in one or more of the liquid properties or in the operating conditions between the proving and the operating cycle, then a change in meter factor may result, and a near meter factor must be determined.

6.8.1 Variation in flow rate

Meter factor varies with flow rate. At the lower end of the range of flow rates, the meter-factor curve may become less reliable and less consistent than it is at the middle and higher rates. However, a meter shall be used within its linearity range.

If a change in total flow rate occurs in a bank of two, three, or more displacement meters installed in parallel, the usual procedure is to avoid overranging 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.

6.8.2 Variation in viscosity

The meter factor of a displacement meter is affected by changes in viscosity that result in variable slippage. The meter factor accounts for the rate of slippage only if the slippage rate is constant.

Viscosity may vary as a result of changes in the liquids to be measured or as a result of changes in temperature that occur without any change in the liquid. The meter shall be reproved if the grade of liquid changes or if a significant viscosity change occurs.

6.8.3 Variation in temperature

In addition to affecting the viscosity of the liquid, changes in liquid temperature, have other important effects on meter performance, as reflected in the meter factor.

The mechanical clearances of the displacement meter may be affected by temperature. Higher temperature may partially vaporize the liquid, cause two-phase flow, which will severely impair measurement performance.

6.8.3.1 As the temperature of the liquid in the meter and in the prover are not usually the same, both volumes shall be corrected to a volume at a base or reference temperature so that a correct meter factor can be obtained. Petroleum measurement tables referred to in API MPMS Chapter 11.1 and 12.2.3 should be used for such corrections.

6.8.3.2 Either an automatic temperature compensator or a manually calculated temperature correction based on the observed temperature of the delivery may be used to correct registered volume to a volume at a base or reference temperature.

6.8.4 Variation in pressure

6.8.4.1 If the pressure of the liquid when it is metered varies from the pressure that existed during proving, the relative volume of the liquid will change as a result of its compressibility. The potential for error increases in the proportion to the magnitude of the difference between the proving and the operating conditions.

For greatest accuracy, the meter shall be proved at the operating conditions.

6.8.4.2 The physical dimension of the meter will also change as a result of the expansion or contraction of its housing under pressure. The use of double case meters prevents this problem.

6.8.5 Appendix A will show the specification data sheets used for ordering positive displacement meter.

7. MEASUREMENT OF LIQUID HYDROCARBONS BY TURBINE METERS

7.1 Introduction

Turbine flow meters have been widely accepted as a proven technology that is applicable for measuring flow with high accuracy. Turbine flow meters can be superior to other technologies in the turbulent flow regime.

7.2 Principles of Operation

A turbine meter, being an inferential type of volumetric flow meter, is actually sensing flow velocity by measuring the rotational velocity of a bladed rotor. The flowing liquid causes the rotor to move with a tangential velocity proportional to the average stream velocity (which is true if the drag on the rotor—mechanical and viscous—is negligible). The average stream velocity is assumed to be proportional to the volumetric flow rate (which is true if the cross-sectional flow area through the rotor remains constant). (Fig. 3) The movement of the rotor can be detected mechanically, optically or electrically and is registered on a read-out.

Conventional turbine meters have typically been used in low viscosity refined products, with limited use in moderate to high viscosity crude oil due to performance limitations. The capillary seal positive displacement meter has been the choice for custody transfer measurement of moderate to high viscosity crude oil, providing good measurement but at a high total cost of ownership.

The Dual Bladed Helical Turbine Meter is designed for the measurement applications which have typically been divided between conventional turbine meters and positive displacement meters. This uniquely designed turbine flow meter provides highly accurate custody transfer measurement in applications ranging from very low viscosity products such as LPG's, to heavy crude oil.

Conventional multi-bladed turbine meters perform in their most linear range when operated at Reynolds numbers (Re) above 30,000. Two-bladed helical turbine meters perform in their most linear range when operated well within the turbulent flow regime (i.e., above 10,000 Re).

7.3 Design Consideration

Turbine metering installation shall comply with the following requirements.

7.4 Selection of Turbine Meters and Accessory Equipment

Consideration shall be given to, and the Manufacturer consulted regarding, the following when selecting a meter and its ancillary equipment:

1) At the low end of the flow rate range the meter factor curve may become less linear and less repeatable than it is at the medium and higher rates (Fig. 5)

7.5 Installation Design Considerations

7.5.1 Flow conditioning

7.5.1.1 The performance of turbine meters is affected by swirl and non-uniform velocity profiles that are induced by upstream and downstream piping configurations, valves, strainers, pumps, fittings, joint misalignment, protruding gaskets, welding projections, or other obstructions. Flow conditioning shall be used to overcome the adverse effects of swirl and non-uniform velocity profiles on turbine meter performance.

7.5.1.2 Flow conditioning typically requires the use of a combination of straight pipe and flow conditioning elements that are inserted in the meter run upstream (and downstream, if flow through the meter is bidirectional) of the turbine meter (Fig. 7)

7.5.1.3 When only straight pipe is used for flow conditioning, the liquid shear, or internal friction between the liquid and the pipe wall, shall be sufficient to accomplish the required flow conditioning. Appendix A of API MPMS 5.3 should be referred to for guidance in applying the technique.

Experience has shown that in many installations, pipe lengths of 20 meter-bore diameters upstream of the meter and 5 meter-bore diameters downstream of the meter provide effective conditioning. For other special situations refer to Flow conditioning subclause of API MPMS chapter 5.3.

7.5.2 Piping

7.5.2.1 A working basis for the design of a turbine-meter assembly and its related equipment is shown in schematic diagram of (Fig. 6).

7.5.2.2 A thermometer, or a thermometer well that permits the use of a temperature-measuring device, shall be installed in or near the inlet or outlet of a meter run so that metered stream temperatures can be determined. The device shall not be installed upstream within the flow-conditioning sections or downstream closer than the Manufacturer’s recommended position. If temperature compensators are used, a suitable means of checking the operation of the compensators is required.

7.5.2.3 Meter run shall be constructed in a way to have no velocity component other than the direction of flow.

7.6 Meter Performance

Meter performance is defined by how well a metering system produces, or can be made to produce, accurate measurements.

7.6.1 Meter factor

Meter factors shall be determined by proving the meter under conditions of rate, viscosity, temperature, density, and pressure similar to those that exist during intended operation. Meter performance curves can be developed from a set of proving results. The curve in (Fig. 5) is called a linearity curve.

7.6.1.1 Variable conditions which may affect meter factor values are:

- **a)** Flow rate.
- **b)** Viscosity of the liquid.
- **c)** Temperature of the liquid.
- **d)** Density of the liquid (specific gravity).
- **e)** Line pressure and pressure drop across the meter.
- **f)** Cleanliness and lubricating properties of the liquid.
- **g)** Changes in mechanical clearances or blade geometry due to wear or damage.
- **h)** Changes in piping, valves, or valve positions that affect fluid profile.
- **i)** Conditions of the prover.
- **j)** Changes in inlet fluid velocity profile.

7.6.2 Causes of variations in meter factor

Many factors can change the performance of a turbine meter.

Some factors, such as entrance of foreign matter into the meter, can be remedied only be eliminating the cause. Other factors, such as the build up of deposits in the meter, depend on the characteristics of the liquid being measured; these factors must be overcome by properly designing and operating the meter system.

The independent variables which have the greatest effect on the meter factor are flow rate, viscosity, temperature, pressure, lubricity properties and foreign matter (such as paraffin in liquid).

7.6.3 Meter specifications

Appendix A-2 will show the specification data sheet used for ordering turbine meter.

8. MEASUREMENT OF LIQUID HYDROCARBONS BY ULTRASONOC (TRANSIT TIME DIFFERENTIAL METHOD)

8.1 Introduction

Ultrasonic meters are inferential meters that derive the liquid flow rate by measuring the transit times of high-frequency sound pulses. Transit times are measured from sound pulses traveling diagonally across the pipe, downstream with the flow and upstream against the liquid flow. The difference in these transit times is related to the average liquid flow velocity along multiple acoustic paths. Numerical calculation techniques are then used to compute the average axial liquid flow velocity and the liquid volume flow rate at line conditions through the meter.

8.2. Principles of measurement

The ultrasonic transit-time flowmeter is a sampling device that measures discrete path velocities using one or more pairs of transducers. Each pair of transducers is located a known distance, lp, apart such that one is upstream of the other (see Figure 1). The upstream and downstream transducers send and receive pulses of ultrasound alternately, referred to as contra-propagating transmission, and the times of arrival are used in the calculation of average axial velocity, v. At any given instant, the difference between the apparent speed of sound in a moving liquid and the speed of sound in that same liquid at rest is directly proportional to the instantaneous velocity of the liquid. As a consequence, a measure of the average axial velocity of the liquid along a path can be obtained by transmitting an ultrasonic signal along the path in both directions and subsequently measuring the transit time difference.

The volume flowrate of a liquid flowing in a completely filled closed conduit is defined as the average velocity of the liquid over a cross-section multiplied by the area of the cross-section. Thus, by measuring the average velocity of a liquid along one or more ultrasonic paths (i.e. lines, not the area) and combining the measurements with knowledge of the cross-sectional area and the velocity profile over the cross-section, it is possible to obtain an estimate of the volume flowrate of the liquid in the conduit.

Several techniques can be used to obtain a measure of the average effective speed of propagation of an ultrasonic signal in a moving liquid in order to determine the average axial flow velocity along an ultrasonic path line. However, the normal technique applied in modern UFMs is the direct time differential technique.

The basis of this technique is the measurement of the transit time of ultrasonic signals as they propagate between a transmitter and a receiver. The velocity of propagation of the ultrasonic signal is the sum of the speed of sound, c, and the flow velocity in the direction of propagation.

For arithmetic calculation see ISO 12242.

8.3 Design Considerations

8.3.1 A working basis for the design of a ultrasonic flow meter assembly and its related equipment is shown in schematic diagram of (Fig. 8).

8.3.2 Transit time UFMs typically do not require the use of strainers since they have no mechanical moving parts that could be adversely affected by debris. Strainers may be required to protect associated equipment, including meter provers or pumps or to provide a means of keeping flow conditioners free of debris.

8.3.3 If air or vapor is present in the flowing stream, eliminators shall be provided to minimize measurement error (see Figure 8).

8.3.4 The meter run design shall ensure that each meter is liquid filled under all operating conditions. Placement of the meter(s) at high points in the system shall be avoided. UFMs may be installed in any position or plane. However, care shall be taken to ensure that the acoustic transducers are not located on the top or bottom of the pipe to minimize the effects of air or sediment. The meter's installation orientation should be in accordance with the manufacturers' recommendation.

8.3.5 Steps shall be taken to minimize the amount of water in the fluid being measured. Depending on the flow regime, the acoustic properties of the oil, the water droplet size and distribution, and the amount of water, UFMs may become less accurate because paths may become inoperable. Due to the number of possible variables, a specific % water limitation cannot be given. Consult the UFM Manufacturer for guidance on this limit. The meter diagnostics may be useful in understanding the performance of the meter.

8.3.6 For liquids with vapor pressure greater than atmospheric pressure, a backpressure greater than 20 psi above the liquid vapor pressure at operating conditions is sufficient.

9. MEASUREMENT OF LIQUID HYDROCARBONS BY CORIOLIS METER

9.1 Principle of Operation

Coriolis meters measure mass flow rate and density. A Coriolis meter consists of a sensor and a transmitter. A typical Coriolis sensor has one or two tubes through which the fluid flows. The tube or tubes are made to vibrate at their natural or harmonic frequencies by means of an electromagnetic driving mechanism. The flowing fluid generates a Coriolis force that is directly proportional to the mass flow rate of the fluid.

The magnitude of the Coriolis force can be detected and converted to a mass flow rate. The Coriolis transmitter powers the sensor, processes the output from the sensor in response to mass flow, and generates signals for accessory equipment representative of that flow rate. A Coriolis meter may also be configured to indicate volumetric flow rate. In this case, the frequency of the oscillating tube or tubes is measured and used to determine the density of the fluid. The density is determined in a similar manner as other types of vibrating tube density meters and is independent of the mass flow rate determination.

The volumetric flow rate may be determined by dividing the mass flow rate by the measured density at flowing conditions. Throughout this document, both mass and volume measurements are referred to. Proving methods will vary depending upon the coilfiguration of the Coriolis meter.

9.2 Types of Coriolis Meters

9.2.1 U-Shaped coriolis meters

U-Shaped Coriolis meters are the traditionally recognised coriolis meters and they have the ability to handle high pressure applications.

9.2.2 Triangular-tube coriolis meters

Triangular-tube Coriolis meters have the ability to handle large flow volumes at low pressure drops.

9.2.3 Micro-bend tube coriolis meters

Micro-Bend tube Coriolis meters with compact tube arrangement have a significantly smaller radius than traditional U-tube design Coriolis meters and therefore benefit from reduced space requirements and a reduced pressure drop.

9.3 Design Consideration

9.3.1 Tube housing design

The tube housing should be designed primarily to protect the flow sensor from deleterious effects from its surrounding environment (dirt, condensation, and mechanical interference) which might interfere with operation. If the vibrating tube(s) of the Coriolis flowmeter were to fail, the housing containing the tube(s) would be exposed to the process fluid and conditions which could possibly cause housing failure.

During operation, one of the main safety concerns is the possibility of a tube fracture occurring. If this occurs, there are two main safety issues:

a. The pressure within the flow sensor housing may exceed the design limits, possibly causing the housing to rupture.

b. Fluids that are toxic, corrosive, flammable, or volatile may be hazardous to operating/maintenance personnel and/or the environment.

To help mitigate the hazards associated with a tube failure, additional or optional equipment provided by the meter manufacturer or the user may need to be considered such as:

a. Flow sensor housings constructed as a pressure-containing vessel, designed to contain fluid under pressure to a specified pressure limit.

b. Burst disks, pressure relief valves and drains, or vents on the housing, to relieve pressure inside the housing and allow fluids released due to a tube fracture to be directed away from the flow sensor to an area less hazardous to operating/maintenance personnel.

9.3.2 Density and viscosity

Density and viscosity may have a minor effect on measurements of mass flow. Consequently, compensation is not normally necessary. However, for some designs and sizes of meters, density and/or viscosity changes can induce an offset in the flowmeter output at zero flow and/or a change in the flowmeter calibration factor. The offset can be eliminated by performing a zero adjustment at operating conditions.

9.3.3 Temperature

Temperature changes affect the flow calibration factor due to temperature related material properties and compensation is necessary. Compensation for this effect is usually performed by the transmitter using the measured tube temperature. However, large differences in temperature between the oscillating tube(s) and the ambient temperature can cause errors in the temperature compensation. The use of insulation materials can minimize these effects. Temperature variations can also induce an offset in the flowmeter output at zero flow.

9.3.4 Pressure

Pressure may have a minor effect on measurements of mass flow and compensation is not normally necessary. However, for some designs and sizes of flow meters, pressure changes can affect the flow calibration factor and, in this case, compensation is necessary. Pressure changes can also induce an offset in the flowmeter output at zero flow. This effect can be eliminated by performing a zero adjustment at the process pressure.

9.4 Installation Design Considerations

The installation arrangement design enables measurement to meet the user's requirements. Some applications might need strainers or filters, and other applications might need air and/or vapour eliminators.

Coriolis flowmeters are regularly placed in the mainstream of the flow but can also be placed in a bypass arrangement for density measurements.

10. ACCESSORY EQUIPMENT FOR LIQUID METERS

This chapter is intended to be a guide for the selection and application of accessory equipment that is used with liquid hydrocarbon meters to obtain accurate measurements and possible maximum service life.

10.1 Definitions

10.2 Selecting Accessory Equipment for Meters

Accessory devices should be selected so that trouble will not arise from the following:

a) Environment

Local climate extremes should be evaluated, and the installation should be protected accordingly. Electrical safety factors (including the hazardous area classification), electromagnetic and radio frequency interference, weatherproofing, fungus-proofing, and corrosion should be considered.

b) Maintenance

Easy access should be provided for maintenance, and spare parts that have been recommended by the Manufacturer should be obtained.

c) Compatibility

The read out device or register shall be compatible with the meter and its transmission system.

d) Installation

All equipment must be installed and operated according to the manufacturer's recommendations and must conform to all applicable regulations and codes.

10.2.1 Shaft driven (mechanical) accessories

A variety of shaft-driven accessories should be applied to positive displacement meters and sometimes to turbine meters. A mechanical linkage, usually a gear train, transmits force and motion from the rotation measurement element to the exterior of the meter, where the accessories are attached.

Care should be exercised in selecting the number and type of accessories so that excessive torque, which can overload the meter, is avoided. Some of the accessory devices are discussed here.

10.2.1.1 Adjuster (calibrator)

A mechanical meter adjuster, or calibrator, changes the drive-system gear ratio between the volume-sensing portion of the meter and the primary register. The calibrator should adjust the register so that it shows the direct reading of the volume passed through the meter. Adjusters may be gear changing, friction driven, or clutch driven, depending on the design, the adjustment range may cover from 1 to 10 percent of throughput.

Different types of adjusters are capable of handling different torque loads. Friction-driven and clutch-driven adjusters show decreased sensitivity and repeatability when torque is increased. Increased torque reduces life in all types of adjusters. If adjustment to a unity meter factor is not required, the adjusting device should be omitted from the meter, and a direct drive shaft to the register should be installed.

10.2.1.2 Registers

A shaft-driven primary register should be attached directly to the meter. The primary register should display the selected units of measurement, and displays fractions of these units, if required. A primary register may be a totalizer only or totalizer with a separate nonresetable register. A primary register should be secured and sealed to the meter to prevent tampering.

10.2.1.3 Printer

A shaft-driven primary printer may accompany a primary register. The primary printer should record on a measurement ticket the amount of the liquid that is delivered. The ticket shall be printed in standard units of measurement, and in decimal fractions of these units, if required.

10.2.1.4 Temperature compensator

A temperature compensator is a variable-ratio mechanism located in the meter’s drive train. It should have a temperature sensor that works with the variable-ratio mechanism to correct the flowing volume to standard reference temperature.

The temperature compensator must be set for the appropriate thermal coefficient of expansion of the liquid hydrocarbon that is measured.

The location of the temperature compensator in relation to primary or other accessory readout devices depends on which of the devices are to be compensated and which are to remain uncompensated. Where practical, mechanical temperature compensators should be avoided. Temperature compensation is best achieved by approved electronic methods within the flow computer.

10.2.1.5 Pulse generator

A pulse generator provides pulses in a quantity that is directly proportional to meter throughput. Pulsing devices can have various types of output signal, including switch closures, square-wave signals, and sine-wave signals. The devices can also have various frequency outputs.

10.2.1.6 Preset device

A preset device can be preset for any quantity of meter throughput. At the preselected quantity, the device shall stop the flow of liquid or shall perform desired functions automatically. It may or may not be an indicating device.

10.2.1.7 Combinator

A combinator accepts two or more simultaneous input frequencies and displays their total.

10.2.2 Pulse-Driven (electronic) accessories

A variety of pulse-driven accessories can be used with both positive displacement and turbine meters. The pulses generated by high-resolution pulse generators for positive displacement meters and the inherent pulse generated by most turbine meters represent discrete units of volume and can be used to provide input signals to the other read out devices.

10.2.2.1 Electronic adjuster (calibrator or scaler)

An electronic adjuster, also called a factoring center, manipulates the pulse signal to achieve a unity meter factor for direct reading of volume. The device is generally capable of being calibrated to one part in 10,000.

10.2.2.2 Read-out

An electrically driven primary read-out indicates quantities in the desired standard units of measurement. It also indicates decimal fractions of these units, if required. The accuracy of the read-out depends on system resolution, which is proportional to the number of pulses per unit quantity.

Electromechanical registers are limited in speed. Their adequacy should therefore be considered before a decision is made about installation. Electronic readouts are not limited in speed, but they depend on electrical power for proper performance. During power failure, standby power is needed to verify and retain meter registration if a mechanical means is not available.

10.2.2.3 Printer

The two common ones include electromechanical mechanisms in the final stages The first type is designed so that each adjacent digit advances the next digit into position as it would in a mechanical readout. This type of printer is simple, inexpensive and widely used, but it has limited speed and longevity.

The second type of printer includes individual digit modules that remain in a rest position until they are called on to print the throughput volume that is stored in a memory. This type of printer has high resolutions, high speed, and exceptional longevity.

10.2.2.4 Flow computer

Many types of electronic flow computers are available that accept meter output signals, and other sensor signals, to calculate volume or mass flow quantities as required. Flow computers display, transmit, and print data (by appropriate ports and protocols) that can be used for operational or custody transfer purposes. A flow computer can be designed for a single meter run or a bank of meters.

In addition to meter signals, some flow computers accept signals from pressure, temperature, and density devices that allow the calculation of gross and net flow rates and totals.

The flow computer should have provisions to accurately calibrate input or output signals. Security measures should be provided to prevent unauthorized access and alteration of the flow computer memory or user configuration. Security may be hardware, such as key locks or switches, or software passwords.

Also, the flow computer should have means of internal processor and circuit error checking to ensure the integrity of calculated results.

Their capabilities shall include real-time compensation for meter factor, pressure, temperature, density, scaling of signals, transmission, and display of data.

10.2.2.5 Preset counter

A preset counter is a totalizing counter that actuates a contact closure when the measured volume equals a value that was preselected on a manually adjustable counter.

10.2.2.6 Proving counter

A proving counter is a high-resolution digital-pulse totalizer that provides a display of the accumulated high-frequency pulsed output from the meter. Pulse totalizers shall be started and stopped with an on/off gating circuit that is operated from the prover's mounted detectors. The prover sphere detector switches identify the passing of a calibrated quantity of fluid The totalizer may be an electromechanical counter or an electronic counter. If the counter is attached to a small volume prover, as described in API MPMS Chapter 4.2, the device will constitute a sophisticated electronic system that has the capability to quantify fractions of a pulse cycle, using the pulse interpolation techniques discussed in API MPMS Chapter 4.6.

10.2.2.7 Flow rate indicator

A flow rate indicator converts an input signal to a visual display of flow rate in the desired units. The device is used for general operational information and to monitor system flow rate during meter proving.

10.2.2.8 Frequency converter

A frequency converter should convert an input frequency, or a pulse train, to a proportional analog signal for retransmission to other devices, such as recorders or controllers that require analog input signals.

10.2.2.9 Stepper drive

A stepper drive converts a frequency input to an acceptable form for driving a stepper motor. The stepper motor then rotates at a speed that is proportional to the input frequency. The device shall be used to drive various mechanical devices that require a rotary input (for example, counters, ticket printers, and compensators).

10.2.2.10 Temperature compensator

A temperature compensator should be able to combine an input signal from a volume meter and an input from a temperature sensor to provide a corrected output to standard reference temperature, 60ºF, 15ºC, or 20ºC.

10.2.2.11 Combinator

A combinator shall accept two or more simultaneous input frequencies and display their total.

10.2.2.12 Performance compensator

A performance compensator is generally used on multi viscosity turbine meters to compensate for the effect of viscosity on the meter performance curve. This device is microprocessor- based and uses meter factor vs. velocity/viscosity curve to compensate for viscosity change. Each meter has a unique meter factor vs. velocity/viscosity curve plotted over a specific flow and viscosity range. Product viscosity must be input for each product metered.

10.2.2.13 Pulse resolution enhancer

A pulse resolution enhancer may be used on relatively low K-factor turbine meters (e.g., dual helical type turbine meters) to enhance the resolution of the output pulse train. The device precisely measures the time period of each input pulse from the turbine meter. One such commonly used device assumes that the next incoming pulse will have the same time period as the average time period of the two previous incoming pulses. It then generates (with an insignificant time delay) the programmed number of additional pulses (e.g., 10), equally spaced over the projected time period of the next pulse. By doing this for each pulse produced by the turbine meter, it legitimately increases the resolution (i.e., frequency) of the turbine meter pulse train.

10.2.2.14 Dual chronometry pulse interpolator

This device can be used to obtain the proving resolution needed when the number of meter pulses per proving run is less the 10,000. It has two precise digital timers. One measures the precise duration of the proving run (i.e., time between detector switches). The other measures the time from the first meter pulse after the first detector switch signal to the first pulse after the second detector switch signal. The ratio of these two times allows calculation of the fraction of a meter pulse to be added to the number of whole meter pulses measured between detector switches.

10.2.3 Interface connections to pulse driven accessories

Interface connections are the connections between the meter and its driven equipment.

10.2.3.1 Shielded cable

Acceptable pulse transmission length of shielded twisted-pair of conductor between volumetric meter and related electronic equipment if a signal of ample strength (≥100 millivolts peak to peak) transmitted shall be 300 meters.

Shielding shall be grounded at the receiving end only to prevent ground loop effects. The cables should be routed so that proximity to sources of electrical interference is avoided.

10.2.3.2 Preamplifiers

A preamplifier should be used to shape the meter output pulse and increase the signal to noise ratio. If a pulse carrying cable equal to or greater than the maximum distance recommended by the manufacturer of the pulse generator or receiver is required, a preamplifier should be used. The preamplifier should always be located at the meter (the source of the signal) so that the original low-level signals will be amplified and increased to a satisfactory level.

10.2.4 Installing considerations for pulse-driven accessories

10.2.4.1 A system that transmits data consists of at least three components: a meter (pulse producer), a transmission line (pulse carrier), and a receiver/readout device (pulse counter and display). These three components shall be compatible, and each component must meet the specifications recommended by the manufacturers of the meter and accessory equipment.

10.2.4.2 Great care should be exercised in effectively isolating the meter system from external electrical influences. To minimize unwanted noise, all instrument grounding should be connected and separate from other, non-instrument grounding networks. Shielding the transmission cables of meter and prover detectors is essential.

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

10.2.4.4 The electrical output signal of a turbine meter may be considered to be a train of electrical pulses. The following types of devices that produce electrical signals shall be used with turbine meters:

a) Inductance system

In this system, the rotating element of the turbine meter employs permanent magnets that may be embedded in the hub or the blade tips or attached to the rotor shaft or to a ring driven by the rotor.

Regardless of the design, magnetic flux from a moving magnet induces a voltage in a pickup coil that is located near the magnetic field.

b) Variable reluctance system

In this system, a fixed, permanent magnet is centered inside the pick up coil housing so that a variation in magnetic flux results from the passage of a highly permeable, magnetic rotor material near the pick up coil.

c) Photoelectric system

In this system, a beam of light is interrupted by the blades of the rotor or by elements of a member that is driven by the rotor so that a pulsed signal output is developed.

d) Magnetic reed-switch system

In this system, the contacts of a reed switch are opened and closed by magnets embedded in the rotor or in a rotating part of the turbine meter. The switch action interrupts a constant input so that a pulsed signal output is produced.

10.2.4.5 The following pulse characteristics influence proper operation of the meter system:

a. Amplitude.

Any receiving device that is connected to a pulse producer, or meter, shall be sensitive enough to operate when the pulse amplitudes are generated over the rated flow range.

b. Frequency.

The receiving device shall be able to cope with the maximum output frequency of the pulse producer, or meter, when it reaches its highest expected flow rate.

c. Width.

After shaping, the duration of every pulse generated by the pulse producer, or meter, shall be long enough to be detected and counted by the receiving device.

d. Shape.

A sine-wave output shall not be used, without pre amplification and shaping, to operate a receiving device that requires a square-wave input.

10.2.4.6 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 should be maintained by :

a) Minimize the length of the signal transmission cable (s).;

b) Avoid coiling excess signal transmission cable to minimize impedance;

c) Using the technically compatible signal transmission cable as recommended by the equipment manufacturer;

d) Introducing a signal preamplifiers into the transmission system at the turbine meter, if transmission distance dictate so;

e) Ensuring that supply voltages to preamplifiers and constant amplitude pulse generating systems are of proper magnitude and do not exceed the minimum 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) Minimize the number of terminations or connections

i) Replace components that give a weakened signal as a result of deterioration. meter output so that flow rate can be indicated. Since signals may have a relatively low power level, installation conditions shall be suitable for low power level signals. The recommendations described in this section do not apply to all meters; they are related only to systems that have low power level signals.

10.2.5 Protection/control equipment conditioners

Protection/control equipment Conditioners is used with meters to ensure the most accurate and reliable performance. This includes, but not limited, to flow control, pressure control, and removal of unwanted foreign material, such as dirt, water, or gas.

10.2.5.1 Strainers

Foreign material, such as rust, scale, welding beads, slag, sand, and gravel, may damage a meter system or may adversely affect its performance. A strainer is usually installed upstream of the meter as a protective device. It includes a basket or barrier (usually made of perforated sheet, metal cloth, or screen) that stops and collects foreign material before it enters the meter. The strainer design and mesh size should be designed according to the needs of the meter system and the overall system on which meter is installed. Meter and strainer manufacturers should be consulted regarding design criteria. A maintenance program should be followed for inspection/ cleaning strainer baskets. The purpose of the strainer is defeated if the screen/basket becomes loaded to the point of rupturing. A differential pressure gauge shall be used to indicate the differential pressure across the strainer. The differential pressure will be in proportion to the amount of foreign material that has accumulated. Based on this information, major problems caused by foreign materials can be avoided. If the flow cannot be stopped for strainer maintenance, dual strainers should be used. Strainers are also available that are cleaned through periodic back washing to a sump or other disposal facility.

10.2.5.2 Air/vapor eliminators

Air or vapor in a flowing stream will be measured as liquid and will result in an error in the indicated quantity. Large quantities of air or vapor, such as those that may exist in an empty piping system, can result in over speeding and damage to a rotating meter. Under these conditions, air elimination equipment shall be used.

Selecting the size and type of air eliminator for an installation requires that careful consideration be given to piping and other equipment and to the operating details of the system. These details should include the maximum possible quantity of air or vapor, the type of liquid being handled (with particular reference to its viscosity and foaming characteristics), the size and length of piping, the type and location of the pumps, and the rate of flow. The piping downstream of the eliminators must remain filled with liquid to prevent air or vapor from being measured along with the liquid. This may require the installation of a control valve downstream of the meter that will automatically throttle or stop the liquid flow when air/vapor is being vended.

10.2.5.3 Control of flow

Most installations include a manually or power-operated valve for starting, controlling and stopping the flow of liquid. In general, power-operated valves should open and close slowly to prevent flow pressure surges.

To avoid over speeding a meter, it may be necessary to include a control valve that will limit the maximum rate of flow to the rated maximum of the meter.

In multi-meter installations, a control valve should be used downstream of each meter to balance flow when one or more meters are taken off line or when proving would take place.

If it is necessary to prevent the flow of liquid from reversing direction, a valve that allows flow in only one direction should be used.

A minimum back pressure must be maintained to prevent liquid from vaporizing or flashing. This may require the use of a back-pressure controller and a control valve that can maintain the require back pressure under any line pressure.

If a meter is equipped with a counter that can be preset for delivering a particular volume, the on/off valve is usually controlled by the counter so that the flow can be stopped at the proper time. The preset counter may be linked to the valve by mechanical, electrical or other means. Pressure-reducing valves are commonly employed in pipelines to reduce pressure to a level that is suitable to meter or station man folding. Care must be exercised to ensure that pressure is not reduced enough for vaporization to occur. It is not good practice to throttle immediately upstream of a flow meter since this may create flow disturbances and cause measurement error.

10.2.6 Fluid property monitoring instrumentation

Some conditions and properties of liquid hydrocarbons have a greater affect on measurement accuracy than do others; monitors may therefore be desirable to assess the temperature, pressure, density, and viscosity of the flowing liquid.

The accuracy and resolution of thermometers, temperature recorders, pressure gages, pressure recorders, and hydrometers used in a measurement system should be appropriate for the meter needs and scale of operation.

Since metering requires the highest accuracy possible, the equipment should allow for precise reading and should be checked or calibrated frequently.

11. FIDELITY AND SECURITY OF FLOW MEASUREMENT PULSED-DATA TRANSMISSION SYSTEMS

11.1 Introduction

The purpose of this publication is to serve as a guide for the selection, operation, and maintenance of various types of pulsed-data, cabled transmission systems for fluid metering systems to provide the desired level of fidelity and security of transmitted flow pulse data. This publication does not endorse or advocate the preferential use of any specific type of equipment or systems, nor is it intended to restrict future development of such equipment.

11.2 Field of Application

The recommendations set forth are concerned only with the fidelity and security of pulsed-data, cabled transmission systems between a flow meter or flow meter transducer and a remote totalizer and/or a flow computer.

The different levels of security that can be applied to transmission systems, criteria and recommendations for the design, installation, use, and maintenance of the relevant equipment are described in this publication. The levels of security

are designated E to A from the lowest to the highest order of security, respectively.

11.3 Definitions

11.3.1 Fidelity

The exactitude with which the primary indication reproduces the inherent precision of the measurement.

11.3.2 Noise

Unwanted signals which may impair fidelity, and which occur for periods exceeding 0.2 second.

11.3.3 Transients

Disturbances having a duration of 0.2 Sec. or less.

11.3.4 Methods of comparison

As used in level A through D, is the determination of the fidelity of primary indication by use of redundant, alternate, or secondary source to verify the desired level of security.

11.3.5 Unrevealed error

Any lack of fidelity outside the prescribed limits of error, including errors caused by functional failure and by external influence.

11.3.6 scaler: is an electronic device that accepts flow pulses representing arbitrary volume or mass increments and outputs flow pulses scaled to represent more useful volume or mass increments, 1 pulse per barrel for example.

11.4 Levels of Security

Five levels of security may be identified and considered, of which level E shall be used as a minimum acceptable level.

Other levels shall be selected according to project requirements.

11.4.1 Level E

Error reduction at Level E is achieved solely by correctly installed apparatus of good quality. This is a straightforward totalizer system. Figure 9 illustrates a simple system with no built-in provisions for error monitoring. Only good quality components and subunits, correctly installed, will lead to confidence in the security of the system. The use of a preamplifier transmitter to drive the transmission line is considered beneficial for the majority of applications, as is the provision of signal conditioning. The system, though simple, does not differ in hardware quality from more secure systems that use the same elements.

11.4.2 Level D

A level D system consists of manual error monitoring at specified intervals by methods of comparison. This level of security is intended to give protection against functional errors and failures and is a method of verification by manual action. Figure 10 illustrates a simple system with means of making a periodic manual assessment of security. The read-out can be visually checked against an independent totalizing system. The secondary read-out may be permanent or temporary, local or remote. Manual comparison made during a periodic check will monitor the integrity of the transmission and totalizer elements. It may be less convenient than provisions of Level C, as the system may have to be stopped for readings to be taken. Overall security is mainly inferred from the performance during the error monitoring period

11.4.3 Level C

This level of security consists of automatic error monitoring and error indication at specified intervals by methods of comparison. A level C is intended to give protection against functional errors and failures and this may be achieved by design methods, The time intervals for error monitoring may be subject to revision in the light of experience gained. Figure 11 illustrates a dual transmission system with a dual pulse comparator of simple designIf the pulses delivered become numerical out of step, warning will be given by the comparator (differential counter). Level C security will be defeated by other disturbances dealt with by higher level security systems. For example, simultaneous interference superimposed on both channels will not be detected because a numerical difference between channels is not caused. It is intended that this type of error monitoring be carried out periodically; the monitoring equipment may thus be shared with other metering systems. Level C security is inferred from the results obtained during the monitoring period.

11.4.4 Level B

Level B consists of continuous monitoring, error indication, and alarm signaling by methods of comparison. This level of security is intended to give warning of transients and other spurious influences, in addition to functional errors and failures. Figure 12 illustrates a dual transmission system with dual pulse comparator in which the pulse trains are continuously monitored for number, frequency, phase, and sequence and any irregularity is indicated. Simultaneous interfering pulses must be detected and indicated. Alarm is given if pulses are lost or gained on either channel.

11.4.5 Level A

Level A consists of continuous verification and correction by methods of comparison. This level is intended to give protection against transients and other spurious influences, in addition to functional errors and failures. Figure 13 illustrates a dual transmission system protected against both dynamic faults arising from monitoring the duplicated pulses and by static testing the electrical integrity of the transmission circuits. The system should still operate as a Level E system if one of the transmission channels fails.

An incidental advantage of level A is its ability to detect some mechanical faults in the transducer.

Simultaneous pulses caused by symmetrical interference are automatically rejected and do not influence the system. Other than a complete failure of one of the transmission channels, no attempt is made to automatically compensate for lost or gained pulses on either transmission channel.

Alarm will be given in all circumstance when impaired pulses are received by the comparator. It may be desirable to provide redundancy in one or all of the elements of the system.

11.5 System Design Considerations

11.5.1 General design criteria

The most important consideration is to prevent the occurrence of spurious pulses rather than rely upon the provision of verification circuitry to provide protection against the results of false measurement. The design approach shall, therefore, take into account the noise environment. Poorly designed units and inadequate regard for noise pick-up can seriously influence the performance of the equipment. Low-level high-impedance signals become attenuated by line losses, and the overall signal-to-noise ratio can further be impaired by the greater probability of noise in longer lines. A secure and reliable pulsed-data transmission system will be achieved most readily by concentrating on the elimination of error sensitive elements. Addition of dual circuits or other techniques aimed at increasing security will guard against influences that are beyond the control of the designer. As a precaution, suppliers of signal processing equipment should be advised of radio frequencies used in close proximity so radio frequency interference immunity can be investigated.

11.5.2 Totalizers

11.5.2.1 Primary totalizer

It is basic to security requirements that the value of the totalizer count can not be impaired during delivery. The use of a nonresetable counter is mandatory for revenue accounting systems and is recommended for all other primary systems and is recommended for all other non-custody and check meter systems. In custody transfer electronic flow measurement systems, the primary totalizer is contained in the Tertiary device. It shall be non-resettable during normal delivery operations, but can be reset by authorized personnel for the purposes of maintenance or commissioning of equipment.

11.5.2.2 Secondary indication

Where it is acceptable, ancillary devices need not have as high a degree of security as the primary indication.

However, such devices should be given basic approval as part of an overall approval and should be compatible with it. Representative secondary indicators include a counter directly driven by a flow meter, an electromechanical counter, or an electronic counter equipped with a standby battery.

11.5.3 Signal pre-amplifiers

A signal pre-amplifier should be introduced into the transmission system at the transducer, if transmission distance or manufacturers' requirements so dictate.

11.5.4 Standby power supply

Where a power interruption could result in a significant error in measurement, provision for an uninterruptible power supply should be considered.

11.5.5 Test requirements

Careful consideration should be given to the form of tests to be applied to the hardware and software for fidelity and security purposes. The tests should take into account the major environmental hazards that experience shows are likely to be encountered on site.

11.5.6 General precautions

The gain and frequency response of the system elements should be restricted to that required by the application.

Sensitivity controls on pre-amplifiers, scalers, and others shall not be capable of unauthorized adjustment. The totalized pulse counts existing at the time of any power failure shall be retained. Cable pairs and the instrument input circuit shall be protected from excessive transient voltages or currents as well as electrical storms.

11.6 Installation Design Considerations

11.6.1 Signal amplitude

The following points should be observed so that the signal amplitude from the transducer to the receiver can be maintained at a high level.

11.6.1.1 The installation recommendation specified by the manufacturers should be carefully followed, whilst complying fully with statutory requirements and/or codes of safety.

11.6.1.2 The length of transmission lines from the meter to the read-out equipment shall be held to a minimum the appropriate signal transmission cables shall be used.

11.6.1.3 Proper impedance matching shall be ensured.

11.6.1.4 The supply voltages to pre-amplifiers should be checked to ensure they are of proper magnitude and do not exceed noise or ripple maximums as specified by equipment manufacturer.

11.6.2 Signal-to-noise ratio

The following points should be observed so that the signal-to-noise ratio can be optimized.

11.6.2.1 Only shielded transmission cables of the proper material, size, and number of conductors shall be used. Individual twisted shielded pairs afford the maximum protection against noise. Helical lay cables are acceptable for many installations. Parallel lay cables should be avoided. The shield of transmission cable should be grounded at one point only, to prevent formation of ground loops. A continuous run of transmission cables should be used whenever possible. Where joints are unavoidable, continuity of the shield shall be assured. Joints should be encapsulated to maintain the electrical specification and security of the cable. When multi-read-out devices are used and wired in parallel, Shielded cables should be used for connecting wiring.

11.6.2.2 The data transmission lines should not share a conduit with anything other than shielded cables or cables from direct current temperature sensors. If the maximum electrical power carried by any one transmission cable is ten or more times greater than the minimum power carried by any flowmeter signal data transmission cable, separate conduits should be provided. In the event that separate conduits are not feasible, additional cable shielding should be incorporated and circuits tested to verify necessary fidelity of signals. Data transmission cables should not be run in parallel with power cables. When this is not possible the cables should be sufficiently spaced to prevent interference or be adequately shielded. If it is necessary for transmission cables and power cables to cross, this should be at right angles whenever possible.

11.6.2.3 When transmission cables are run in ducts or inside control cabinet, every attempt should be made to keep the shielded cable bundle intact and separate from other conductors.

All spare transmission cables and conductors that run in a conduit with an active transmission line should have the shield and conductors grounded at the same single point as the active line

11.6.2.4 The grouping of cables to intrinsically safe devices with other current-carrying cables requires special consideration in hazardous areas, and governing regulations shall be followed.

11.6.2.5 Several methods of attenuating noise may be used, for example, band-pass filters and isolating transformers.

11.7 Typical sources of error

Typical sources of error which should be taken into consideration are as follows:

1) Electromagnetic interference

2) Transients

3) Power supply variations and/or interruption

4) Inadequate signal level as a result of line loss

5) Common-mode noise induced in cabling

6) Series-mode noise induced in cabling

7) Noise introduced from ground loops problems

8) Excessive gain and frequency response of the system elements.

9) Spurious signals induced from other meters sharing the same multicore cable.

10) Short circuit or open circuit of conductor pair or short circuit of either conductor to ground or shield.

11) Bad connections, temperature variations and extremes, vibration shock, and adverse environmental conditions.

12. PROVING SYSTEM

In a custody transfer liquid metering station, some methods shall be provided to calibrate the meter. This shall be done by comparing the meter reading with a known volume of liquid which is accurately measured. The purpose of proving a meter is to determine its meter factor which by definition is a number obtained by dividing the actual quantity(volume/mass) of liquid that passes through a meter by the volume indicated or registered by the meter.

12.1 Definition of Terms

12.1.1 Proving: In the petroleum industry, the term proving is used to refer to the testing of liquid petroleum meters.

12.1.2 Prover calibration: is the procedure used to determine the volume of a prover.

12.1.3 A prover pass: is one movement of the displacer between the detectors in a prover.

12.1.4 A prover round trip: is the result of the forward and reverse passes in a bidirectional prover.

12.1.5 A meter prover: is a vessel of known volume utilized as a volumetric reference standard for the calibration of meters in liquid petroleum service.

12.2 Proving and Meter Factor

The purpose of proving a meter is to determine its meter factor. Therefore, obtaining a meter factor is the first step in calculating the Net Standard volume of a receipt or delivery of petroleum products.

12.2.1 General consideration

A meter that requires flow conditioning, should be proved with its normal flow-conditioning sections at the expected operating rates of flow under the pressure and temperature at which it will operate with the liquid to be measured. A meter that is used to measure several different liquids should be proved with each liquid.

Meter proving must be performed with a high degree of accuracy, Thorough inspections of provers and their components should be made routinely to ensure the reproducibility of proving results.

12.3 Conventional Pipe Prover

Conventional pipe provers should be used as volume standards for proving liquid meters that generate at least 10,000 unaltered pulses during a proving run. The reference volume (the volume between detectors) switches required for a pipe prover depends on factors such as the resolution of the proving register, the repeatability of the detector, switches and the repeatability of the proving system as a whole.

12.3.1 Pipe prover systems

All types of pipe prover system operate on the common principle of the repeatable displacement of a known volume of liquid from a calibrated section of pipe between two signaling detectors. Displacement is achieved by means of slightly oversized sphere or piston that is driven along the pipe by the liquid stream being metered. The corresponding metered volume is simultaneously determined. A meter that is being proved on a continuous-flow basis shall be connected at the time of proof to a counter that can be instantly started or stopped by the signaling detectors. The counter shall be an electronic pulse counter. The counter is started and stopped when the displacing device actuates the two detectors at the ends of the calibrated section. The two types of continuous-flow pipe provers shall be normally used as unidirectional and bidirectional. Other types of provers are in use based on special requirement.

12.3.1.1 Unidirectional provers

A unidirectional prover is shown in Figure 14. It uses a sphere displacer and sphere interchange. The sphere interchange is for receiving, holding, and launching the sphere. After falling through the interchange, the sphere enters the flowing stream of liquid and is swept around the loop of pipe. At the end of its pass, the sphere enters the sphere transfer valve, where it lies until the next proving pass. The calibrated base volume of the prover is the one-way volume between the detector switches.

12.3.1.2 Bidirectional provers

Bidirectional provers can use either a sphere or a piston as a displacer (Figure 15, 16). Spheres are more commonly used because they will go around bends, and the prover can be built in the form of a compact loop, as in the example shown in Figure 15.

A four-way valve is normally used to reverse the flow through the prover. The sphere in Figure 15 is shown in the position that it occupies at the end of a proving run. The sphere will start to travel on its return pass when the four-way valve begins to reverse the flow, but it will not reach its full speed until the movement of the four-way valve is complete.

The main body of the prover shall be a straight piece of pipe, but it may be countered or folded to fit in a limited space or to make it more readily mobile. An elastomer spheroid shall be used as the displacer in the folded or countered type; a piston or sphere may be used in the straight-pipe type.

12.3.2 Performance requirements of pipe prover

12.3.2.1 Calibration repeatability for prover volume

When the prover volume is calibrated, the results, after correction, of two or more consecutive runs shall lie within 0.02 percent (0.01 percent of the average) to determine the prover volume.

12.3.2.2 Valve seating

The sphere interchange in a unidirectional prover or the flowdiverter valve or valves in a bidirectional prover shall be fully seated and sealed before the displacer actuates the first detector. These and any other valves whose leakage can affect the accuracy of proving, shall be provided with some means of demonstrating during the proving run that they are leak free.

12.3.3 Equipment

12.3.3.1 Temperature measurement

Temperature stabilization is normally accomplished by continuously circulating liquid through the prover section with or without insulation. When provers are installed above ground, thermal insulation shall be applied for temperature stabilization.

Temperature measurement sensors shall be of suitable range and accuracy and shall be installed at the inlet and outlet of the prover. All electronic temperature devices should be provided with displays that provide a resolution of 0.1°C or 0.1°F or better.

12.3.3.2 Pressure measurement

Pressure-measurement devices of suitable range and accuracy shall be used at suitable locations to measure pressure at the meter and the prover.

12.3.3.3 Displacing devices

One type of displacing device commonly used in pipe provers is the elastomer sphere hydrostatically filled with liquid under pressure.
Excessive over-inflation normally has no significant effect on the calibration results since a prover sphere that is sealing at 3% oversize, will not show any additional benefits by inflating it to 6% oversize.

Insufficient expansion of the sphere can lead to leakage past the sphere and consequently to measurement error.

Care must be exercised to ensure that no air remains inside the sphere. The displacer shall be as impervious as possible to the operating liquids. The liquid used to fill the sphere shall have a freezing point below any expected temperatures. Water or water-ethyleneglycol mixtures shall be used. Another commonly used displacer is the cylindrical piston with suitable seals.

12.3.3.4 Valves

All valves used in pipe prover systems that can provide or contribute to a bypass of liquid around the prover or to leakage between the prover and meter shall be of the double block-and bleed type and with a provision made for seal verification.

Full positioning of the flow-reversing valve or valves in a bidirectional prover or the interchange valve in a unidirectional prover must be accomplished before the displacer is allowed to actuate the first detector. The distance before first detector, commonly called prerun, depends on valve operation time and the velocity of the displacer. Methods used to shorten this prerun, such as faster operation of the valve or delay of the displacer launching, require that caution be exercised in the design so that hydraulic shock or additional undesired pressure drop is not introduced. If more than one flow-directing valve is used, all valves should be arranged by linkage or another means to prevent shock caused by an incorrect sequence of operation.

12.3.3.5 Detectors

Detection devices shall detect the position of the displacer within specified tolerance. The most common type of detector is the mechanically actuated electrical switch. Other types include the electronic proximity switch and the induction pick up may be used if they provide satisfactory repeatability. The repeatability with which the detector in a prover can signal the position of the displacer shall be ascertained as accurately as possible.

12.3.3.6 Peripheral equipment

A meter pulse generator shall be provided for transmission of flow data and shall provide electrical pulses with satisfactory characteristics for the type of proving counter used. The device should generate a sufficient number of pulses per unit volume to provide the required discrimination.

12.3.3.7 Proving counter

An electronic pulse counter shall be used in meter proving because of the ease and accuracy by which it can count high-frequency pulses. The pulse-counting devices shall be equipped with an electronic start/stop switching circuit that is actuated by the pipe prover’s detectors.

12.3.3.8 Sphere interchange

The sphere interchange valve which is used on unidirectional pipe prover is a device for transferring the sphere from the downstream end of the proving section to the upstream end. Sphere interchange may be accomplished with several different combinations of valves or other devices to minimize bypass flow through the interchange during the sphere transfer process. A verifiable leaktight valve seal is essential before the sphere reaches the first detector switch of the proving section.

12.3.3.9 Flow reversal valve

A single multiport valve should be used for reversing the direction of the displacer. All valves shall be leak free and allow continuous flow through the meter.

A method of checking for seal leakage during a proving pass shall be provided for all valves. The valve size and actuator shall be selected to minimize hydraulic shock.

12.3.3.10 Drains and vents

Because air and vapor are compressible, their presence in the system during the calibration may be a contributing cause to poor repeatability. Vent valves are used to remove all air or vapor present in the system before and after calibration runs. Vent valves shall be visually inspected between passes to insure there is no leakage. Drain valves shall be visually inspected between passes to insure there is no leakage. If visual indication is not possible, the valves shall be isolated and/or blinded. If vents and drains are being considered for waterdraw connections, their location should ensure that all the water used in the calibration will be circulated through the entire proving system. This is necessary to maintain constant temperature in the calibration water.

12.3.4 Design of pipe provers

12.3.4.1 General consideration

From a study of the application, intended use and space limitations, the following should be established:

- **a)** If the prover is stationary, determine:
  - **1)** whether it will be dedicated (on line) or used as part of central system
  - **2)** whether it will be kept in service continuously or isolated from the metered stream when it is not being used to prove a meter.
  - **3)** What portions of a stationary prover are desired below ground?
  - **4)** What foundation and/or support requirements are needed.
- **b)** If the prover is mobile, determine:
  - **1)** Whether leveling devices are required.
  - **2)** Hose compatibility with liquids.
  - **3)** Whether hoses or arms are required.
- **c)** The ranges of temperature and pressure that will be encountered.
- **d)** The maximum and minimum flow rates expected.
- **e)** The flow rate stability.
- **f)** The maximum allowable pressure drop across the prover.
- **g)** The physical properties of the fluids to be handled.
- **h)** The degree of automation to be incorporated in proving operation.

i) The disposal requirements for the fluid.

j) Available utilities.

k) Volume requirements of the prover.

l) Whether or not pulse interpolation will be used.

12.3.4.2. Minimum number of meter pulses

In order to design a prover the first requirement is to determine the number of meter pulses that must be accumulated to meet the desired accuracy requirement (± 0.01%). To determine the required meter pulses, refer to section 4.3.2 of API MPMS 4.2.

12.3.4.3. Volume

For a prover , the minimum volume of the calibrated prover pass (between detector switches) is:

$$V_p \geq \frac{N_m}{k}$$

Where:

Vp = volume of prover pass, barrels,

Nm = number of meter pulses during a prover pass, in pulses,

k = K factor for meter, pulses per barrel.

For more information refer to section 4.3.3 of API MPMS 4.2.

12.3.4.4 Displacer velocity

The maximum velocity of a displacer shall be established to prevent damage to the displacer and the detectors. Most designers agree that 3 meters per second is a typical design specification for unidirectional provers, where as velocities up to 1.5 meters per second are typical in bidirectional provers. For piston displacers, a maximum velocity of 3ft/sec. – 5 ft/sec. is recommended, depending on the design. Higher velocities may be possible if the design incorporates a means of limiting mechanical and hydraulic shock as the displacer completes its pass. Minimum displacer velocity must also be considered, especially for proving meters in a liquid that has little or no lubricating ability, such as gasoline that contains high proportions of aromatics or liquefied petroleum gas. Provided that acceptable performance can be assured, no arbitrary limit is imposed on velocity. The displacer should move at a uniform velocity between detectors. At low velocities when the lubricating ability is poor, the sealing friction is high, and/or the prover surface is rough, the displacer may chatter.

12.3.4.5 Design accuracy requirements

12.3.4.5.1 General consideration

The ultimate requirement for a prover is that it proves meters accurately; however accuracy can not be established directly because it depends on the repeatability of the meter, the accuracy of the instrumentation, and the uncertainty of the prover base volume. The accuracy of any prover/meter combination can be determined by carrying out a series of repeated measurements under carefully controlled conditions and analyzing the results statistically. For method of calculation refer to API MPMS 4.2 Appendix C. The minimum linear distance between detector switches depends on the detector's ability to repeatedly locate the displacer. The total uncertainty of the detectors and displacer at the 95% confidence level shall be limited to ± 0.01% of the length of the calibrated section.

12.3.4.5.2 Replacing the detectors

When the worn or damaged parts of a detector are replaced, care shall be taken to ensure that neither the detector's actuating depth nor its electrical switch components are altered to the extent that the prover volume is changed. This is especially true for unidirectional provers because changes in detector actuation are not compensated for round trip displacer travel as they are in bidirectional provers. If replacement of a detector changes the volume of the prover, recalibration is required.

12.3.4.5.3 Counter resolution

The resolution of a digital counter is unity. The indicated pulse count therefore has a 1 pulse uncertainty for a pass between detectors. For example, to limit the pulse uncertainty to ±1 pulse during, a prover pass, at least 10,000 pulses would have to be collected during a single pass. This uncertainty is represented mathematically as follows:

$$a(N_m) = \frac{\pm 1\,\text{pulse}}{N_m} \times 100\%$$

Where:

$a(N_m)$ = potential error of the recorded pulse count during a prover pass, ± % pulse,.

N_m = number of whole meter pulses collected during a prover pass.

Calibrating the flow meters (especially dual bladed helical turbine meters) requires using the pulse interpolation method described in the API Manual of Petroleum Measurement Standards (Chapter 4 Section 6). It would not be practical to build a prover with sufficient volume to generate 10,000 pulses. The reason for using this method for proving the helical turbine meter is because the meter provides fewer pulses per unit volume than traditional turbine meters.

12.3.4.4.4 Pulse generation

Prover volumes can be reduced by increasing the pulse-generation rate of the meters to be proved.

Care must be taken when gear-driven pulse generators are used on displacement meters to obtain very high pulse generation rates, since mechanical problems such as back lash, drive-shaft torsion, and cyclic variations can cause irregular pulse generation.

12.3.5 Calibration of pipe provers

The base volume of a unidirectional prover is the calibrated volume between detectors corrected to standard temperature and pressure conditions. The base volume of a bidirectional prover is expressed as the sum of the calibrated volumes between detectors in two consecutive one-way passes in opposite directions, each corrected to standard temperature and pressure conditions. The base prover volume is determined with three or more consecutive calibration runs that repeat within a range of 0.02%.

Periodic recalibration of the prover is also required.

In theory the various methods of calibration described below are equally valid. However, in practice there may, be some definite commercial and technical advantages in the use of one or other of these methods for a particular situation.

a) Water-draw Methods

The waterdraw method of prover calibration is based on the drawing of water from a displacement prover into field standard test measures. For open tank provers, the waterdraw method may use either the drawing of water from the tank prover into the field standard test measures or alternatively by filling of the tank prover from the test measures. For more information refer to standard API MPMS 4.9.2. (Refer to Fig. 17, 18 & 19)

b) Master Meter

The master meter shall not have been calibrated by another master meter. A volumetric master meter is proven utilizing a volumetric tank or displacement prover (Refer to Fig. 21)

c) Gravimetric Method

For displacement type provers, the water representing the prover volume is displaced into a container located on aweigh scale. For open tank provers, the Gravimetric Method may use either the drawing of water from the tank prover into the container or alternatively by filling of the tank prover from the container. The weight of the displaced water is then determined and corrected for the effect of air buoyancy to determine mass. The mass obtained shall then be divided by the density of the water at the prover conditions of temperature and pressure to obtain the volume of water displaced. Corrections for temperature and pressure of the prover metal shall then be applied to this volume to determine the volume of the prover at reference conditions for any given calibration run. The prover base volume is the average of a set of runs that meet the repeatability criteria.

12.4 Small Volume Prover Systems

These provers accumulate less than 10,000 whole, unaltered meter pulses between detectors during one pass of the piston displacer, and therefore require pulse interpolation. Optical detector switches used with these provers are externally mounted from the flow media and are able to indicate the position of the displacer with a high degree of precision. As a result of this precision it is possible to have a very short distance between detector switches. The calibrated base volume of this prover is normally much smaller than sphere type unidirectional and bidirectional provers, typically having a maximum calibrated volume of 200 gallons. Since the small volume of these provers may not allow for the accumulation of 10,000 whole, unaltered pulses, the prover electronics must provide means for pulse interpolation.

The small volume prover may be used in many applications in which pipe provers or tank provers are commonly used. Small volume provers may be stationary or portable.

12.5 Volumetric Tank Prover

12.5.1 Closed tank provers

All components of the tank prover installation, including connecting piping, valves, and manifolds, shall be in accordance with applicable pressure codes.

Once a closed tank prover is on stream, it becomes part of the pressure system. Provisions should be made for expansion and contraction, vibration, reaction to pressure surges, and other process conditions. Consideration should be given to the installation of valving to isolate the tank prover from line pressure when the system is not in use or during maintenance.

All closed tank provers should be equipped with vent and drain connections.

Provisions should be made for the disposal of liquids and/or vapors that are drained or vented from the tank prover. The disposal may be accomplished by pumping liquids or vapors back into the system or by diverting them to a collecting point.

Blind flanges or valve connections should be provided on either side of a double block-and-bleed valve in the tank prover piping system. These connections can serve as locations for proving portable meters or as a means of calibrating the tank prover by the master-meter or waterdraw method.

12.5.2 Atmospheric tank provers

An atmospheric tank prover is a volumetric vessel with an upper neck, upper sight glass, upper scale, and an upper and lower cone usually separated by a cylindrical section. Different types are identified by the way in which their bottom "zero" is defined. Atmospheric tank provers are described below:

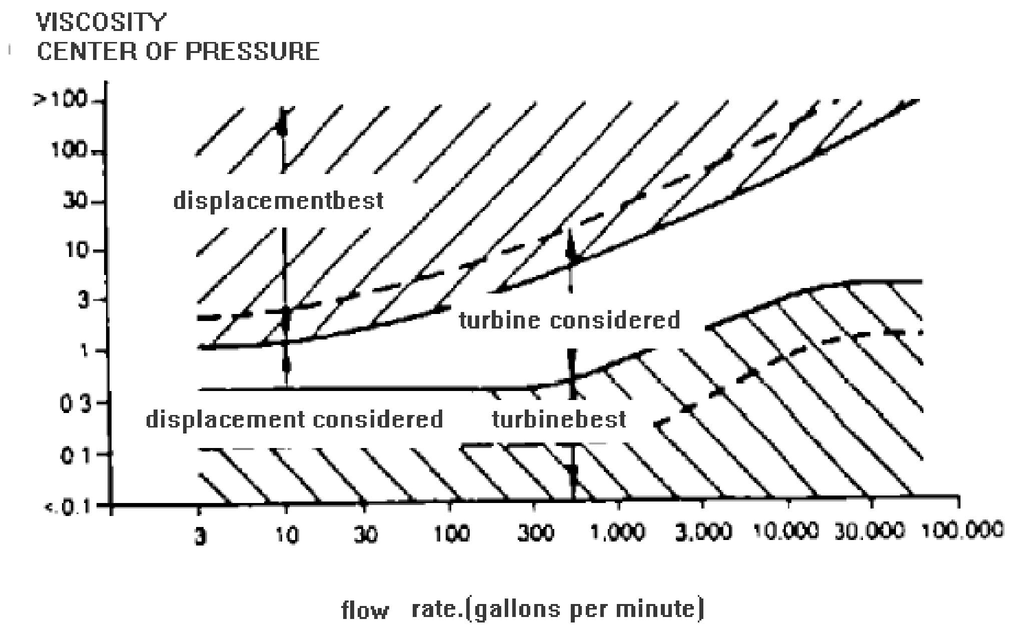
- **Bottom-weir type:** This prover has a bottom neck beneath the lower cone. The bottom neck may or may not have a sight glass and scale, but in any case it has a fixed bottom “zero” defined by the weir.
- **Dry-bottom type:** This prover usually does NOT have a bottom neck under the lower cone. The closed bottom drain valve defines the bottom “zero” just as on a field standard test measure.
- **Wet-bottom type:** This prover has a bottom neck beneath the lower cone. The bottom neck always has a sight glass and scale. The bottom “zero” is defined by the “zero” on the scale. In practice, readings above and below the “zero” in the lower neck are common.

13. AUTOMATIC SAMPLING SYSTEMS

A typical automatic sampling system consists of stream conditioning upstream of the sampling location, a device to physically extract a grab from the flowing stream, a flow measurement device for flow proportioning, a means to control the total volume of sample extracted, a sample receiver to collect and store the grabs a nd depending on the system, a sample receiver /mixing system. Unique properties of the petroleum or petroleum product(s) being sampled may require the individual components or the entire system to be insulated and/or heated.

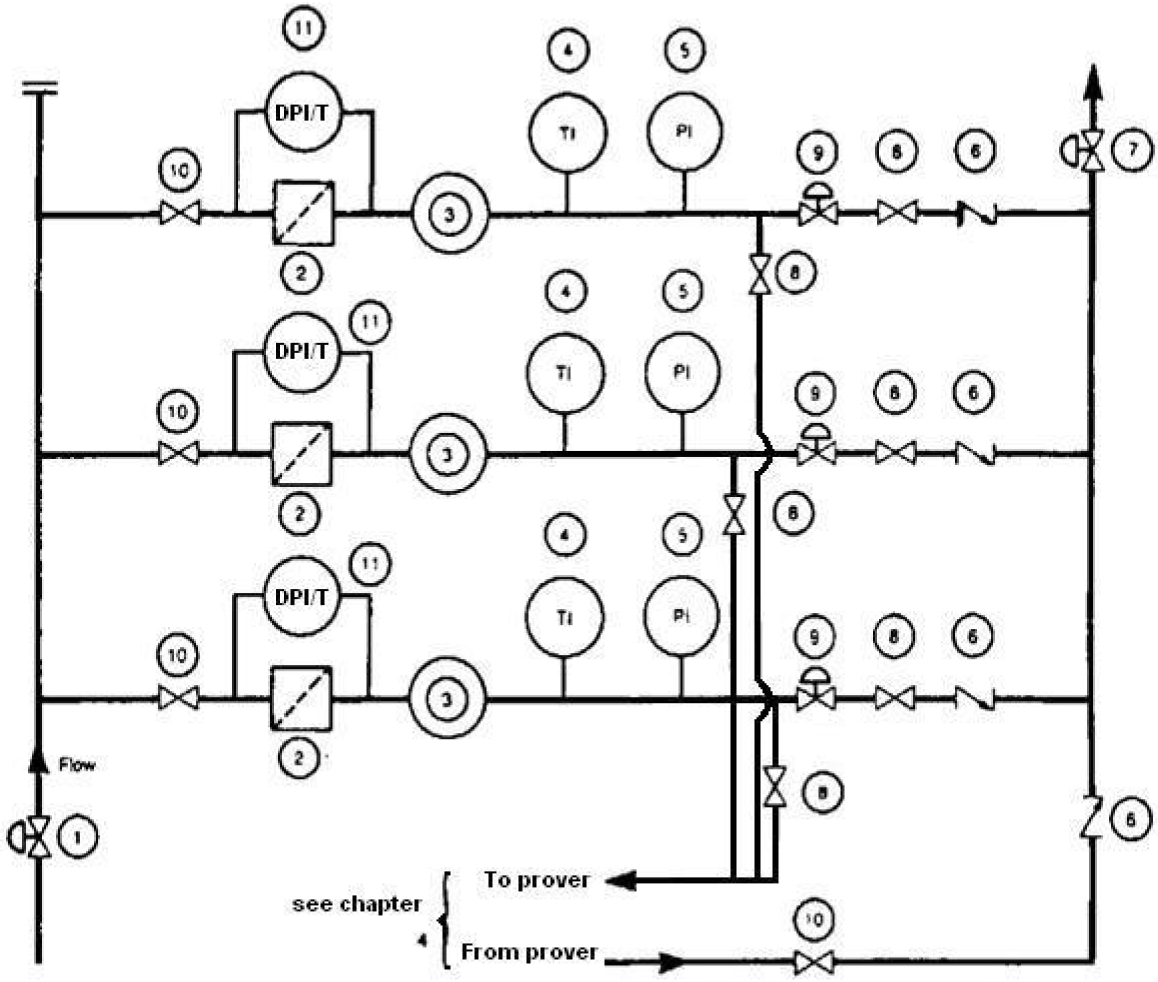
Grabs must be taken in proportion to flow. However, if the flow rate, during the total parcel delivery (week, month, etc.) varies less than ±10 percent from the average flow rate, a representative sample may be obtained by the time proportional control of the grabs.

For more information refer to API MPMS 8.2.



SELECTION GUIDE FOR DISPLACEMENT AND TURBINE METERS

Fig. 1

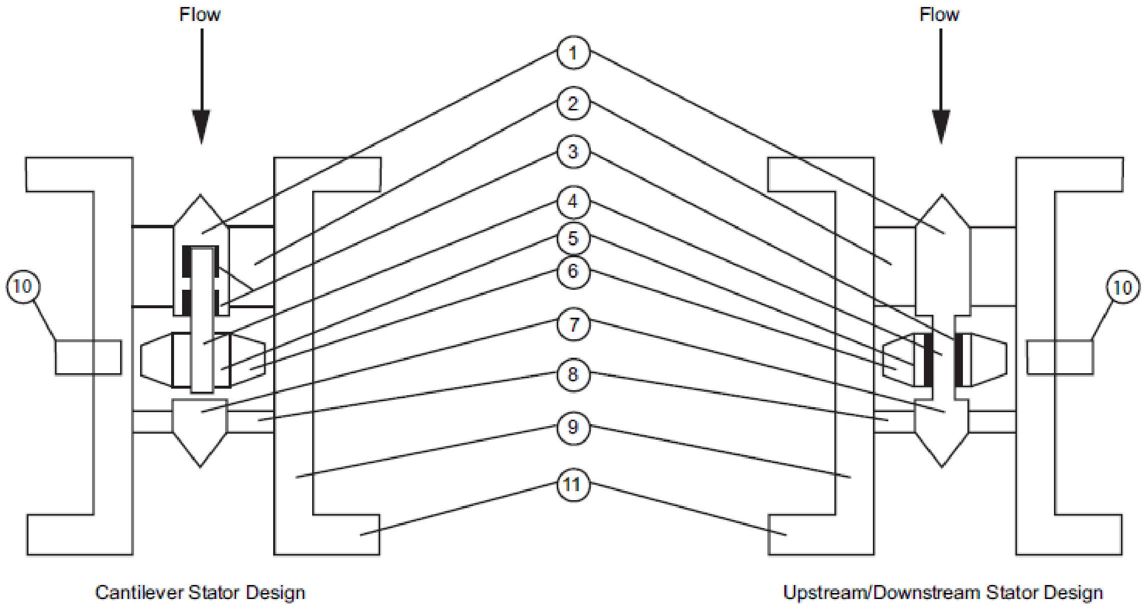


1. Pressure-reducing valve .... manual or automatic, if required.
2. Filter, strainer, and/or vapor eliminator (if required) for each meter or whole station.
3. Positive displacement meter.
4. Temperature measurement device
5. Pressure measurement device
6. Check valve, if required.
7. Control valve, if required.
8. Positive-shut-off double block-and bleed valves.
9. Flowcontrol valve, if required.
10. Block valve, if required.
11. Differential pressure device, if required.

Note: All sections of the line that may be blocked between valves shall have provisions for pressure relief (preferably not to be installed between the meter and the prover).

TYPICAL SCHEMATIC ARRANGEMENT OF METER STATION WITH THREE POSITIVE DISPLACEMENT METERS

Fig. 2



1 upstream stator

2 upstream stator supports

3 bearings

4 shaft

5 rotor hub

6 rotor blade

7 downstream stator

8 downstream stator supports

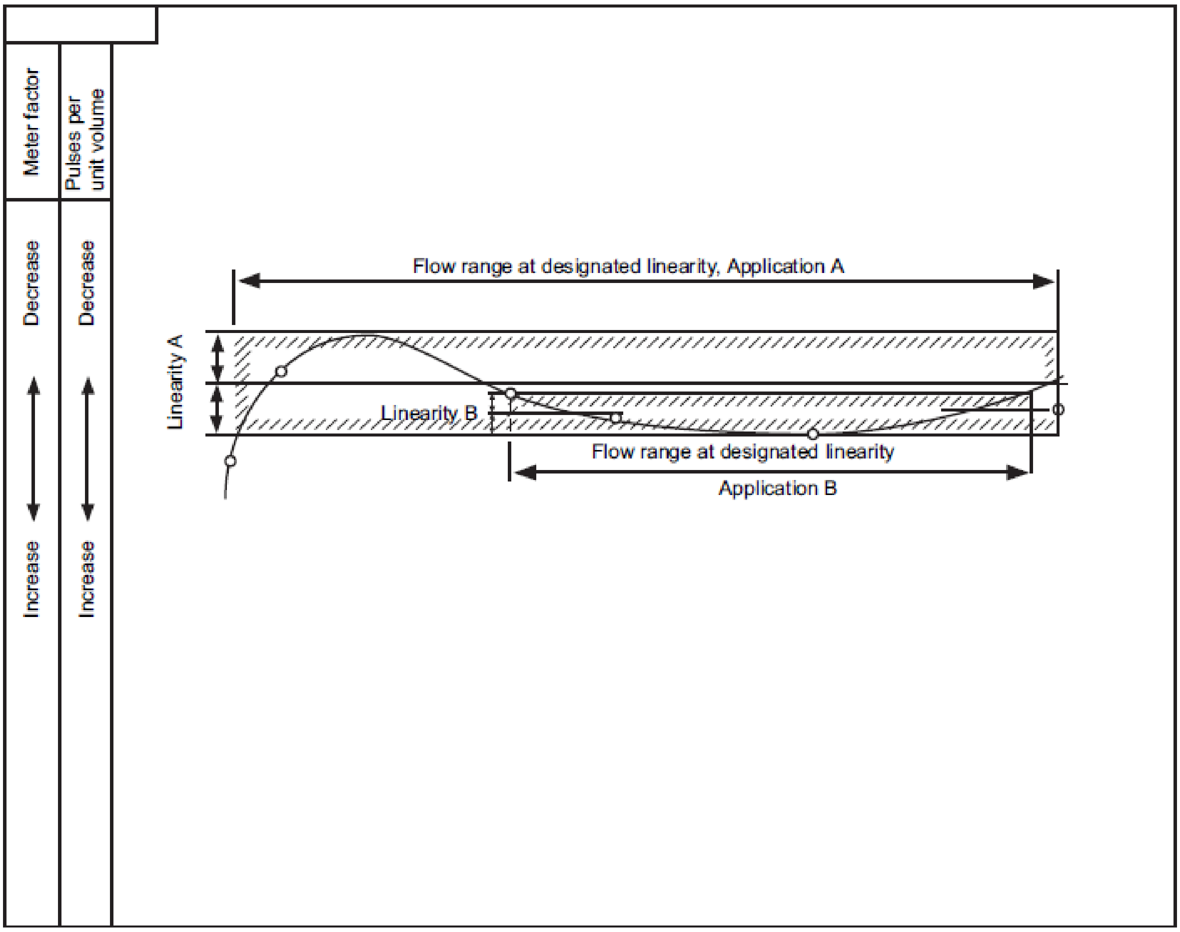
9 meter housing

10 pick up

11 end connection

NAMES OF TYPICAL TURBINE METER PARTS

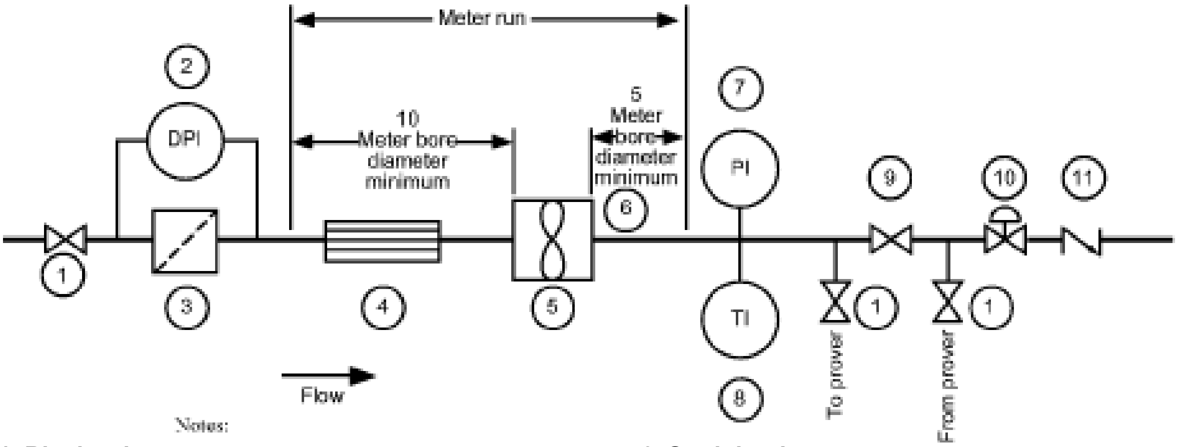
Fig. 3



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.**

TURBINE-METER PERFORMANCE CHARACTERISTICS

Fig. 4

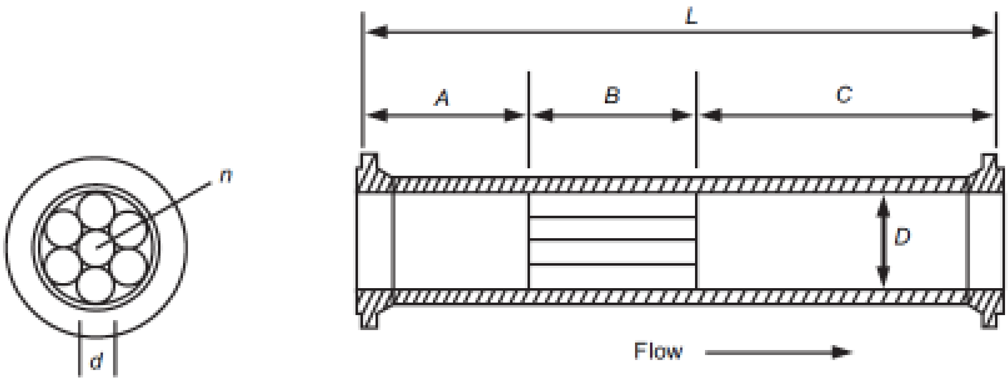


1. Block valve
2. Differential pressure device
3. Filter, strainer, and or vapor eliminator for each meter or whole station.
4. Straightener assembly per Figure 4.
5. Turbine meter
6. Straight pipe
7. Pressuremeasurement device
8. Temperature measurement device
9. Positive shut-off double block-and bleed valve.
10. Control valve
11. Check valve, if required

Note: All sections of line that may be blocked between valves shall have provisions for pressure relief (preferably not installed between the meter and the prover).

TYPICAL SCHEMATIC DIAGRAM OF A METERING RUN UTILIZING TURBINE METER

Fig. 5



Note: This figure shows assemblies installed upstream of the meter. Downstream of the meter, 5D minimum of straight pipe should be used.

L = overall length of straightener assembly ($\geq$ 10D).

A = length of upstream plenum (2D-3D).

B = length of tube or vane-type straightening element (2D-3D).

C = length of downstream plenum ($\geq$ 5D).

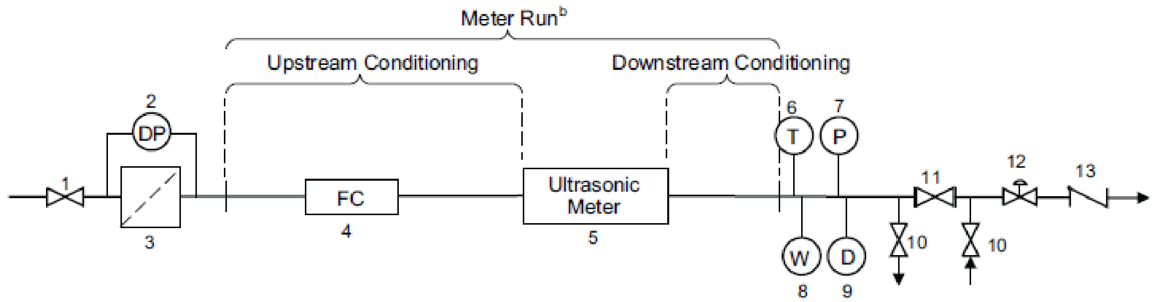
D = nominal diameter of meter.

n = number of individual tubes or vanes ($\geq$ 4).

d = nominal diameter of individual tubes (B/d $\geq$ 10).

EXAMPLE OF FLOW-CONDITIONING ASSEMBLIES WITH STRAIGHTENING ELEMENTS

Fig. 6



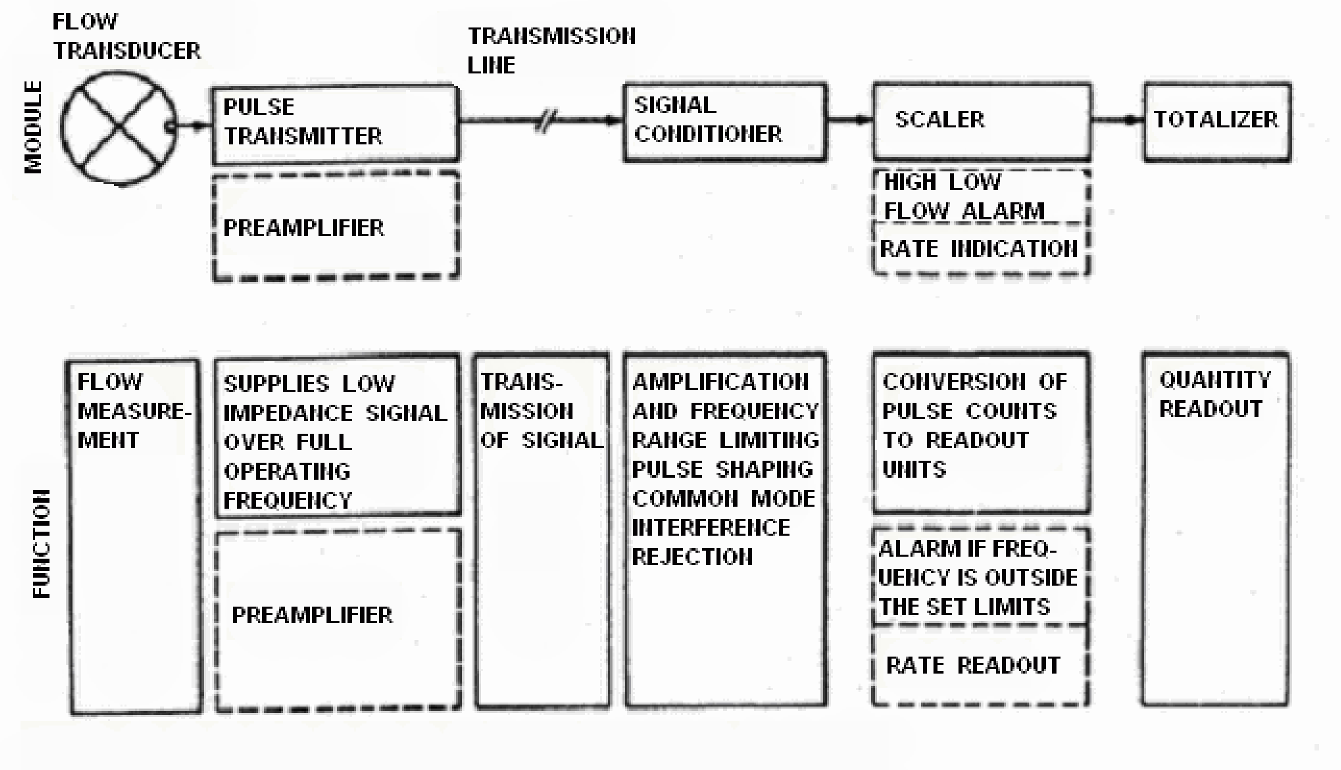
Key

1. block valve[a]
2. differential device[a]
3. strainer and/or air eliminator[a]
4. flow conditioning element[a]
5. ultrasonic flow meter
6. temperature measurement device
7. pressure measurement device
8. temperature test well
9. densitometer[a]
10. prover take-off valve
11. double block and vent valve
12. flow control valve[a]
13. check valve[a]

Note:

[a] Element may not be required.

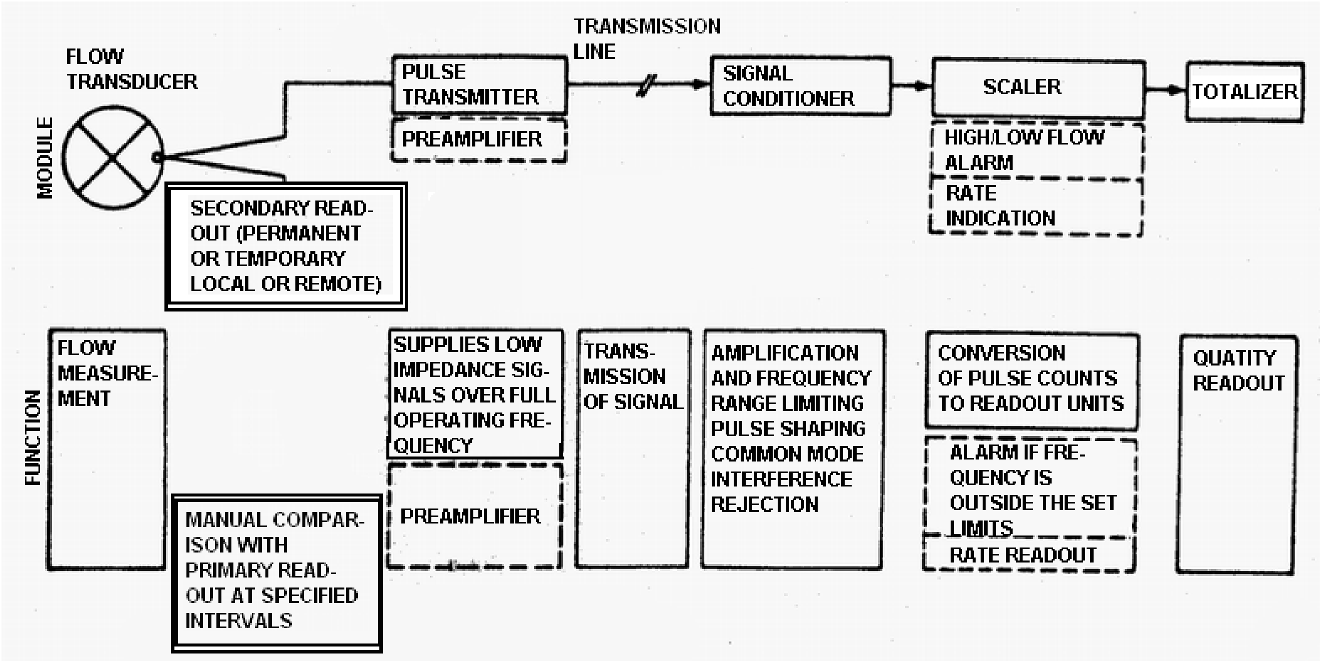
[b] See Section 7.2 of API MPMS 5.8, Flow Conditioning.



Note: The modules and functions shown in full are essential. Those shown dotted are optional

TYPICAL FUNCTIONAL ARRANGEMENT FOR A LEVEL E PULSE SECURITY SYSTEM

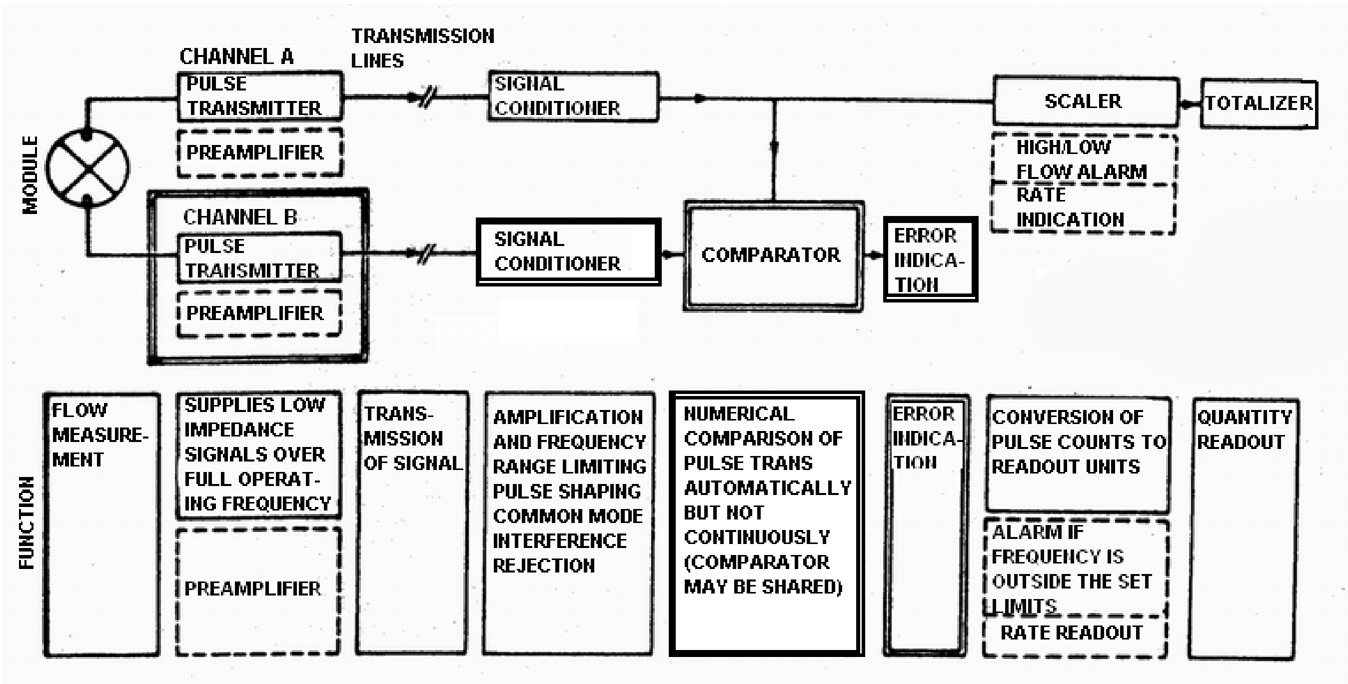
Fig. 7



Note: The modules and functions shown in full are essential. Those shown dotted are optional. The modules and functions boxed in double lines indicate the difference from Level E.

TYPICAL FUNCTIONAL ARRANGEMENT FOR A LEVEL D PULSE SECURITY SYSTEM

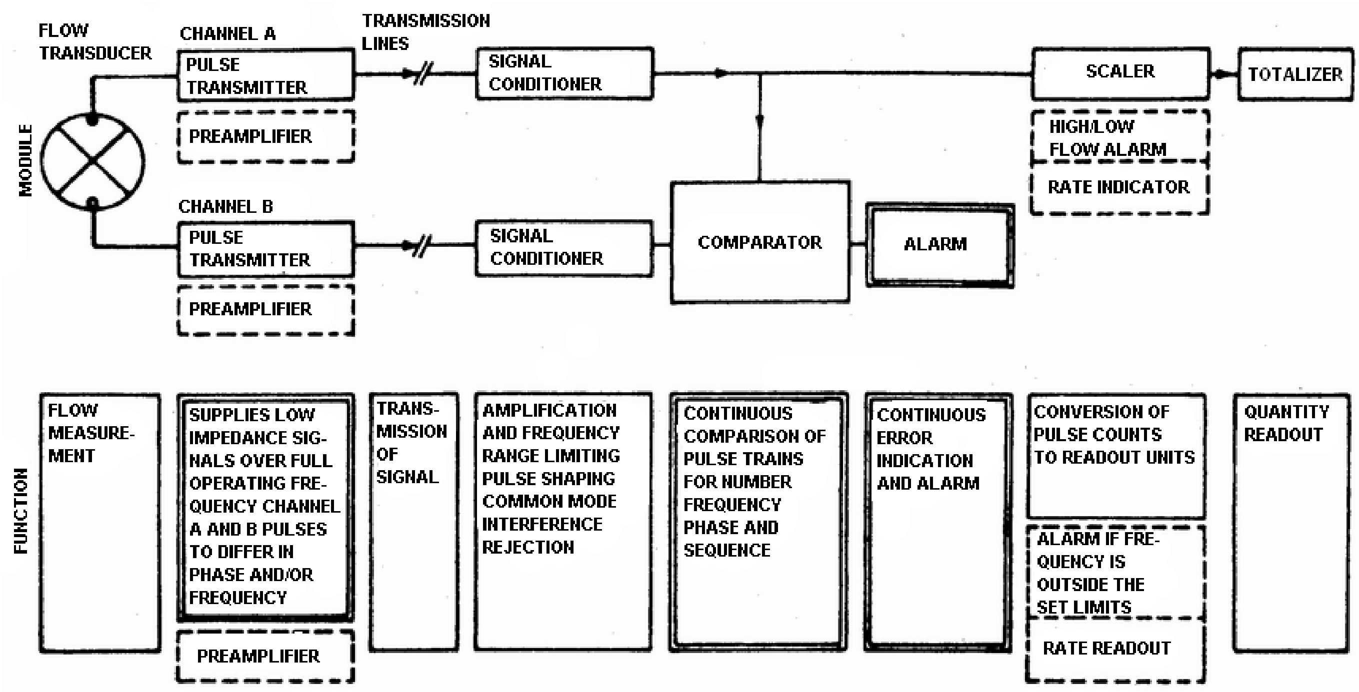
Fig. 8



Note: The modules and functions shown in full are essential. Those shown dotted are optional. The modules and functions boxed in double lines indicate the difference from Level D.

TYPICAL FUNCTIONAL ARRANGEMENT FOR A LEVE L C PULSE SECURITY SYSTEM

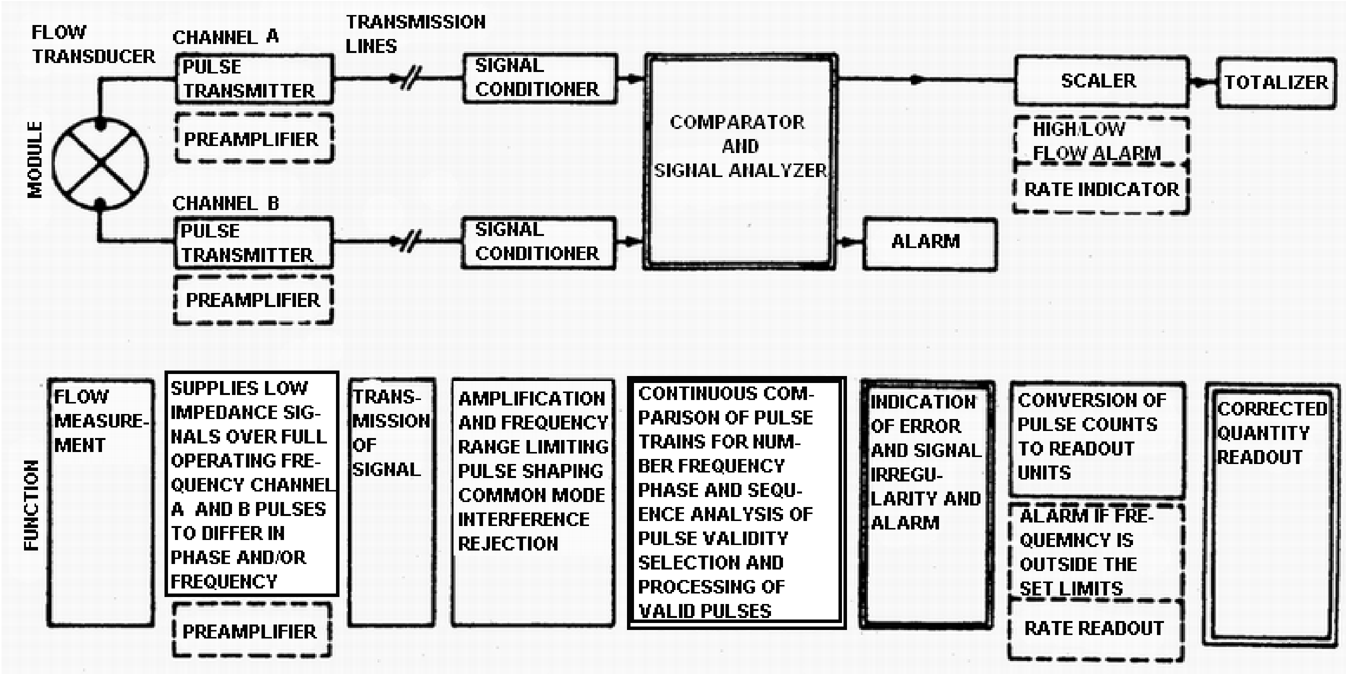
Fig. 9



Note: The modules and functions shown in full are essential. Those shown dotted are optional. The modules and functions boxed in double lines indicate the difference from Level C.

TYPICAL FUNCTIONAL ARRANGEMENT FOR A LEVEL B PULSE SECURITY SYSTEM

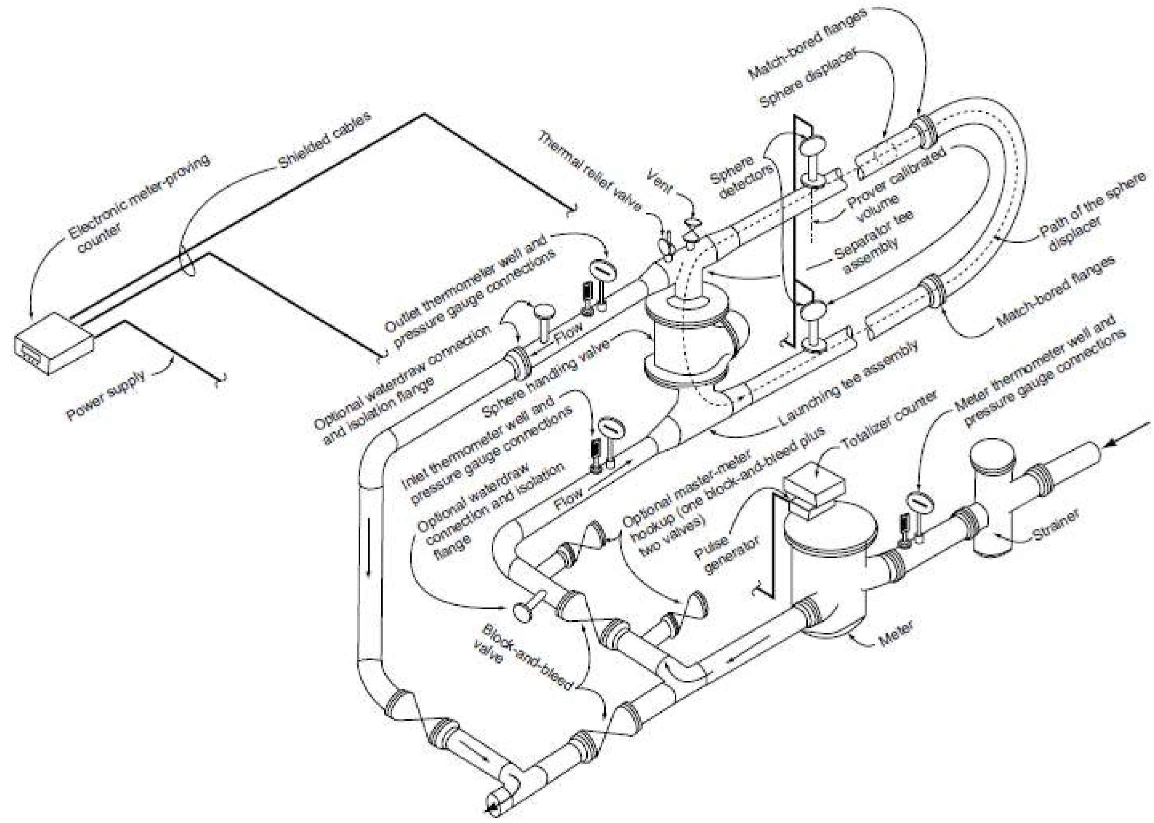
Fig. 10



Note: The modules and functions shown in full are essential. Those shown dotted are optional. The modules and functions boxed in double lines indicate the difference from Level B.

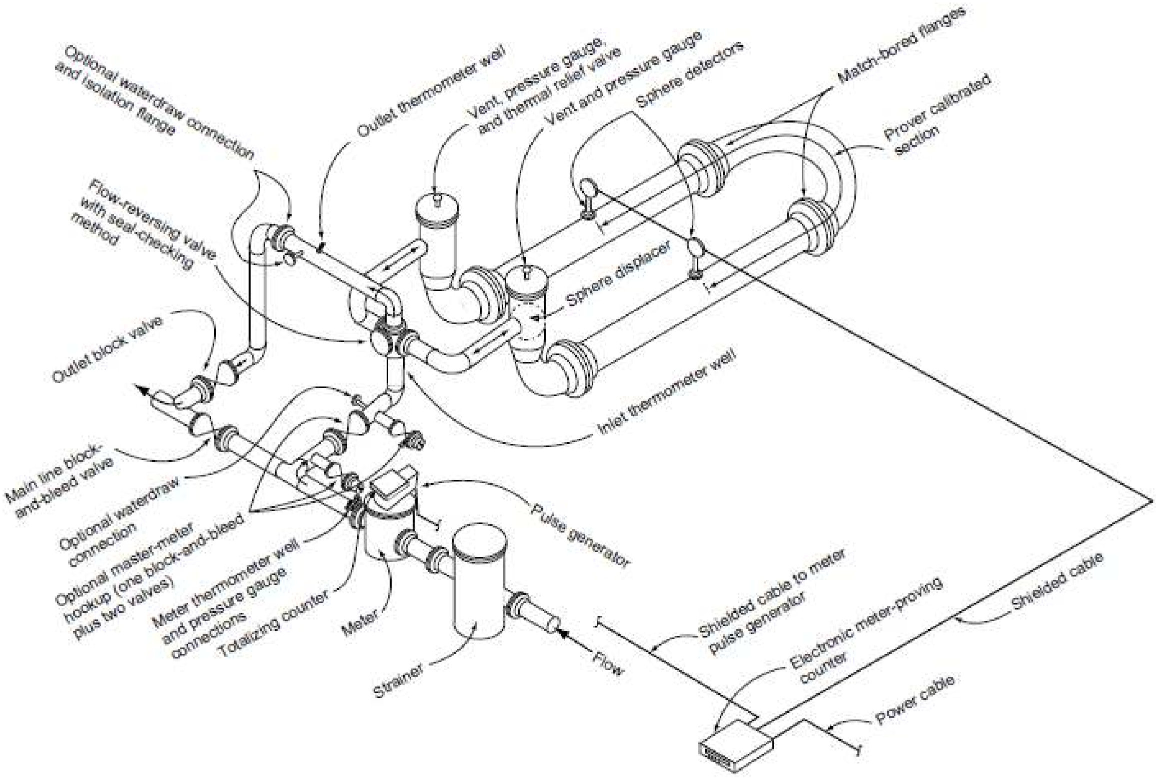
TYPICAL FUNCTIONAL ARRANGEMENT FOR A LEVEL A PULSE SECURITY SYSTEM

Fig. 11



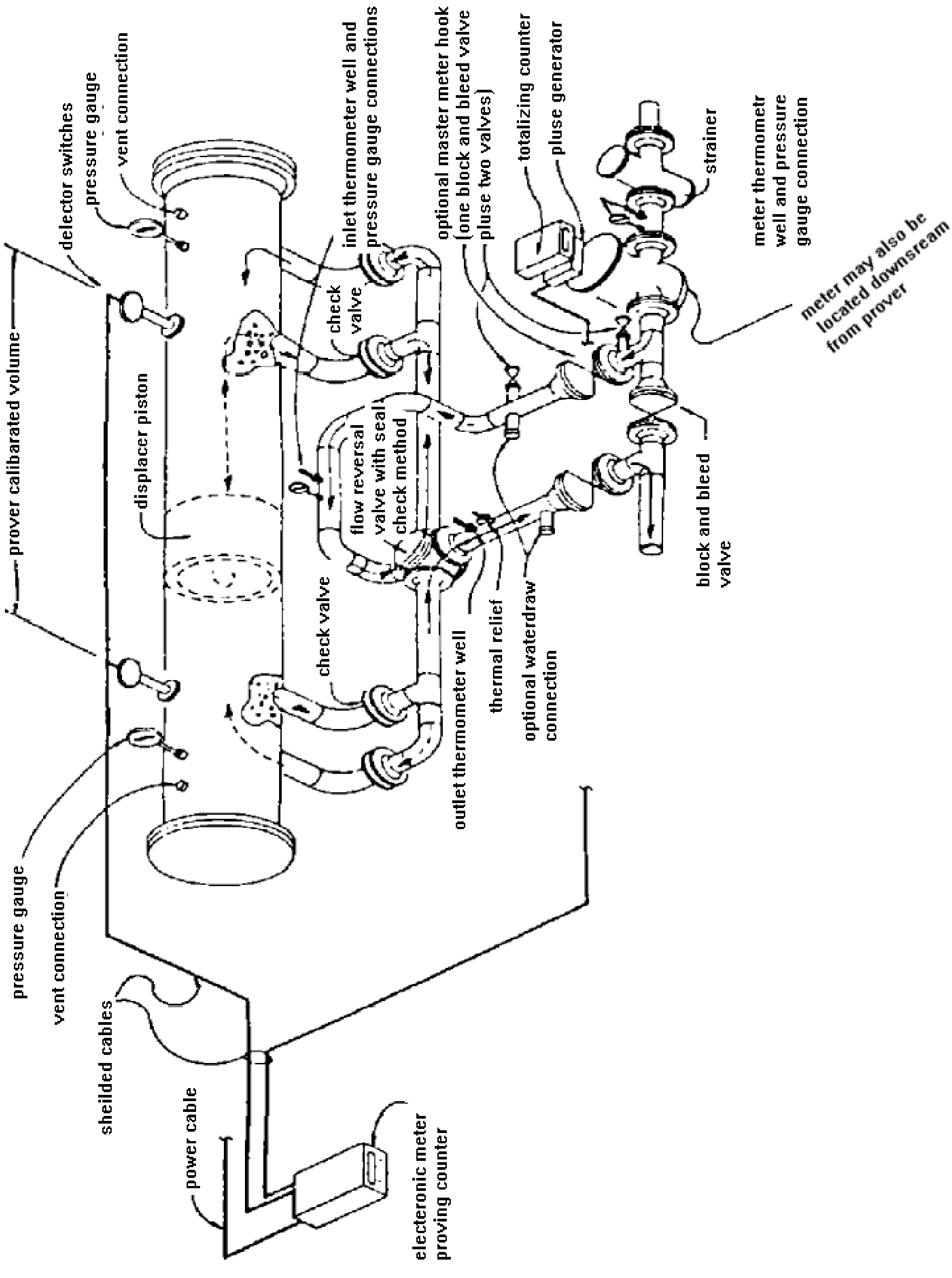
TYPICAL UNIDIRECTIONAL RETURN - TYPE PROVER SYSTEM

Fig. 12



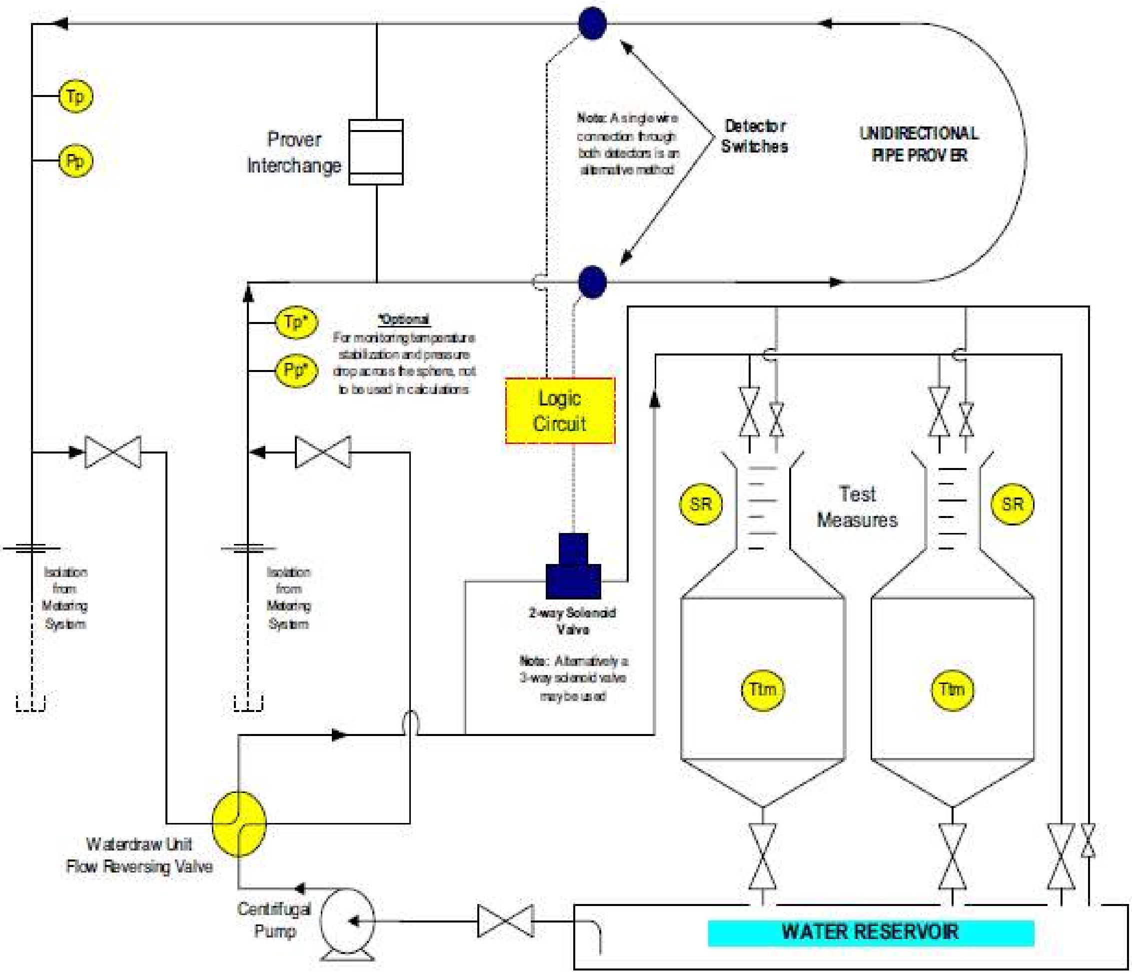
TYPICAL BI-DIRECTIONAL U - TYPE SPHERE PROVER SYSTEM

Fig. 13



TYPICAL BI-DIRECTIONAL STRAIGHT-TYPE PISTON PROVER SYSTEM

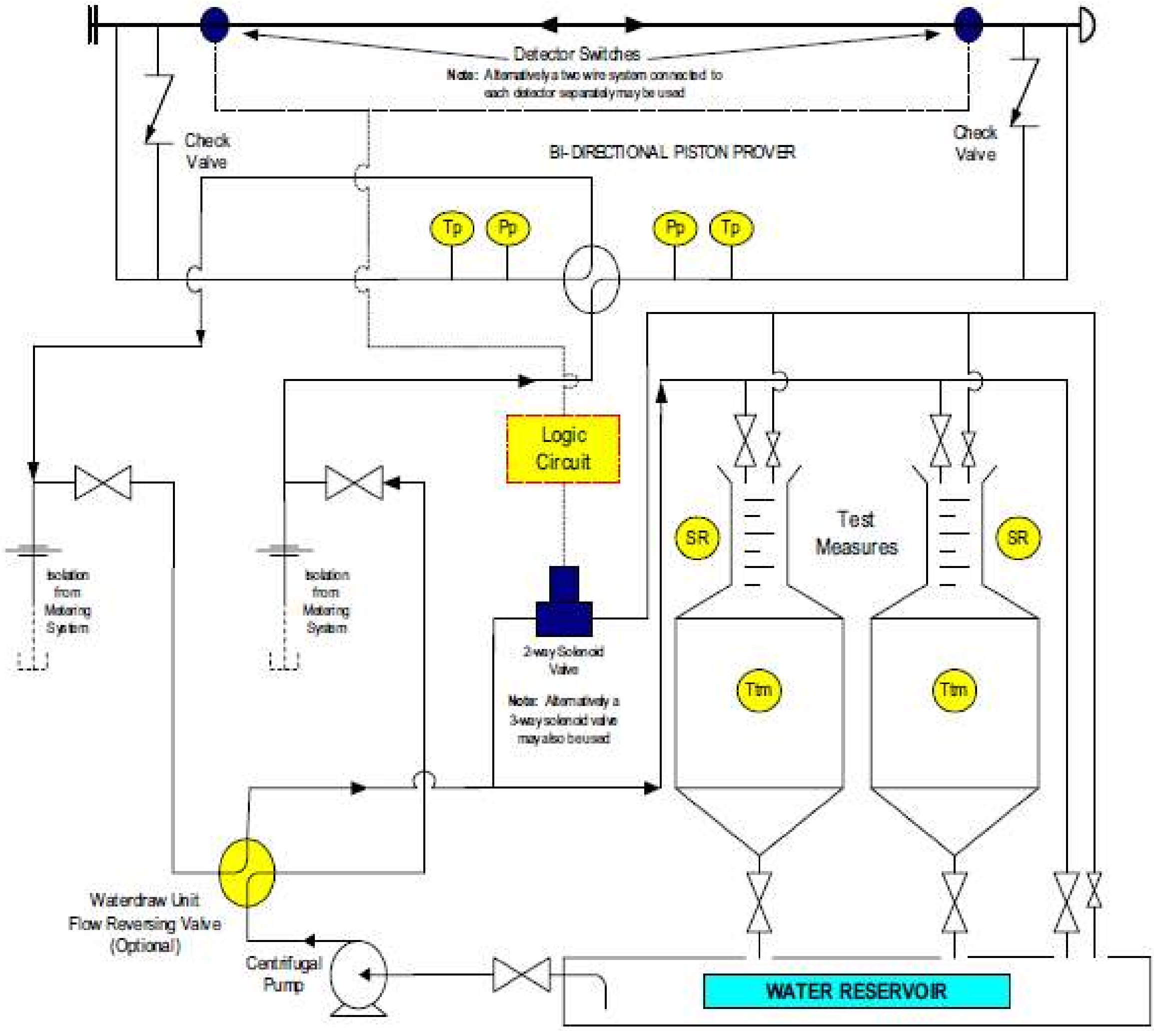
Fig. 14



SCHEMATIC DRAWING OF A TYPICAL LAYOUT FOR A WATERDRAW CALIBRATION OF A DISPLACEMENT

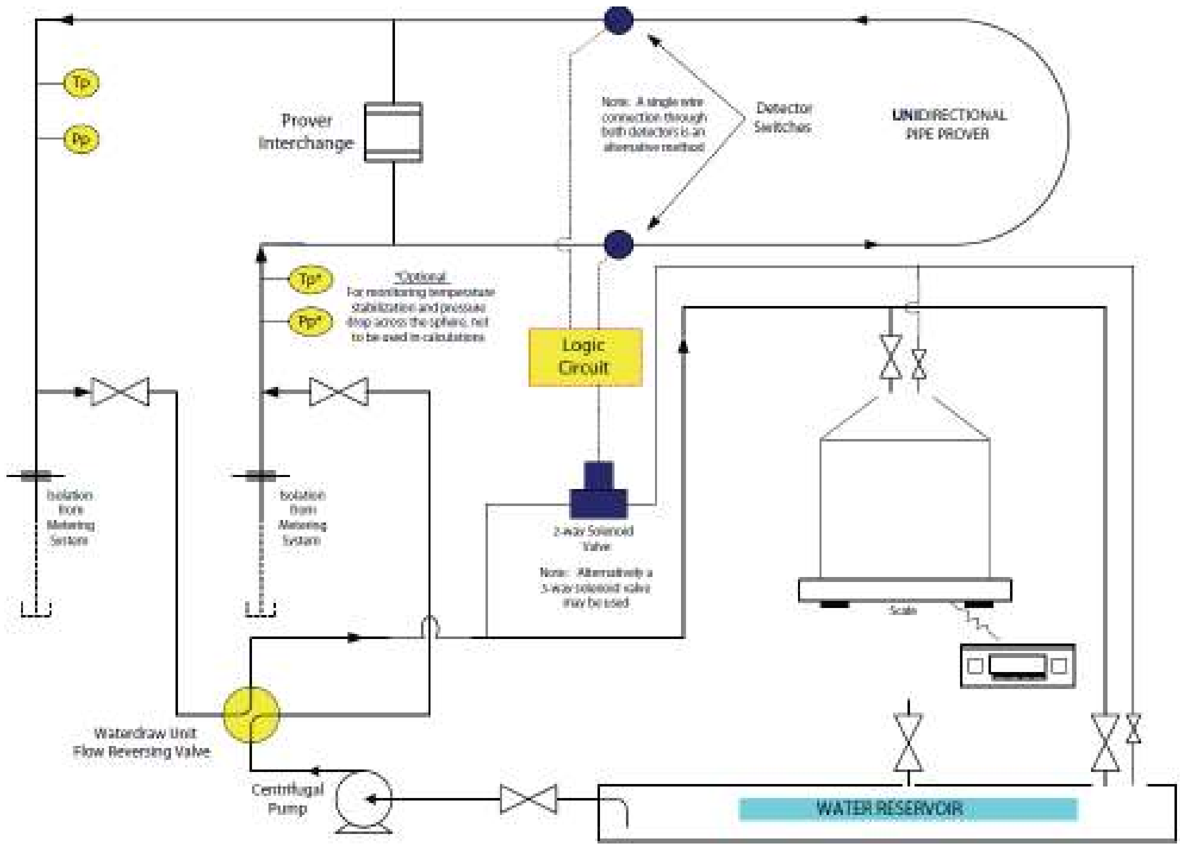
TYPE UNIDIRECTIONAL PROVER WITH A FREE DISPLACER USING TOP-FILLING TEST MEASURES

Fig. 15



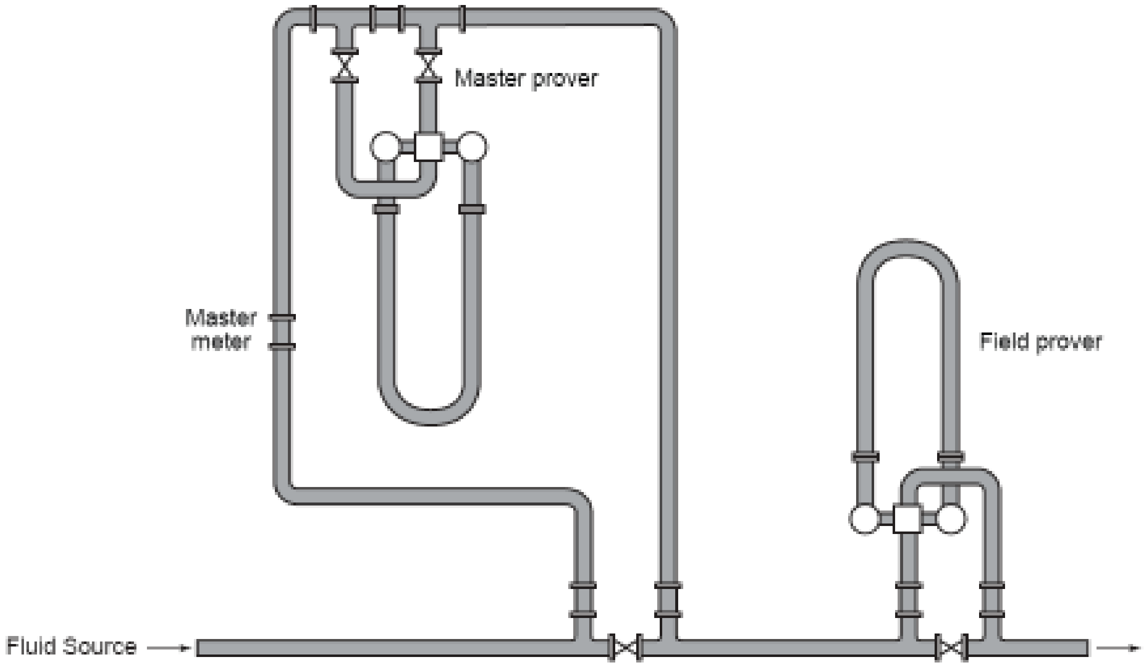
SCHEMATIC DRAWING OF A TYPICAL LAYOUT FOR A WATERDRAW CALIBRATION OF A DISPLACEMENT TYPE BI-DIRECTIONAL PROVER WITH A FREE PISTON DISPLACER AND CHECK VALVES IN THE MANIFOLD USING TOP-FILLING TEST MEASURES

Fig. 16



GRAVIMETRIC CALIBRATION OF A DISPLACEMENT TYPE UNIDIRECTIONAL PROVER WITH A FREE DISPLACER

Fig. 17



MASTER METER/MASTER PIPE PROVER METHOD

Fig. 18

APPENDICES

APPENDIX A-1

TYPICAL DATASHEET FOR POSITIVE DISPLACEMENT METERS

	POSITIVE DISPLACEMENT METERS				SHEET 1 OF 1		
					SPEC. NO.		REV.
	NO	BY	DATE	REVISION			
					CONTRACT		DATE
					REQ.	P.O.	
					BY	CHK'D	APPR.

	1	Tag Number				
	2	Service				
	3	Line No./ Vessel No.				
METER	4	Type of Element				
	5	Size				
	6	End Connections				
	7	Temp. & Press. Rating				
	8	Flow Rate Range				
	9	Totalized Units				
	10	Enclosure Class				
	11	Power Supply				
	12	Materials: Outer Housing				
	13	Main Body Cover				
	14	Rotating Element				
	15	Shaft				
	16	Blades				
	17	Bearings: Type & Material				
	18	Packing				
	19	Type of Coupling				
	20					
COUNTER	21	Register Type				
	22	Totalizer				
	23	Reset				
	24	Capacity				
	25	Set-Stop				
	26					
FLUID DATA	27	Fluid				
	28	Flow Rate:Min. / Max.				
	29	Normal Flow				
	30	Oper. Press. / Oper. Temp.				
	31	Oper. Specific Gravity				
	32	Oper. Viscosity				
	33	Coef. of Expansion				
OPTIONS	34	Flow Units				
	35	Shut-Off Valve				
	36	Switch: Single or 2-Stage				
	37	Temp. Compensator				
	38	Transmitter Type				
	39	Transmitter Output				
	40	Air Eliminator				
	41	Strainer: Size & Mesh				
	42					
	43					
	44					
	45	Manufacturer				
	46	Model Number				

Notes:

APPENDIX A-1 (continued)

POSITIVE DISPLACEMENT METERS

Instructions for ISA Form S20.25.

1. Tag No. of instrument.

2. Process service.

3. Pipe line or vessel identification.

4. Write in type of rotating element, such as, disc, piston, vane, helical, rotors, etc.

5. Show connection pipe size.

6. Specify end connections type and ANSI rating such as 300 lb R.F.

7. Specify the manufacturer’s recommended body pressure and temperature rating, such as 250 psi at 190°F.

8. Write in manufacturer’s recommended normal operating range.

9. Specify smallest totalized unit, such as "Tens of Gallons", "Pounds", "Barrels".

10. Specify enclosure electrical classification, if applicable, such as "Class 1, Group D., Div. 2", "General Purpose", etc.

11. Specify power supply, if applicable.

12. Specify materials of construction. If no preference, write in, MFR. STD. (Manufacturer’s Standard).

13-18. Specify materials of construction, if no preference, write in, Manufacturer’s Standard (MFG-STD).

19. Specify type of coupling.

20. Specify coupling such as "Magnetic", or MFR. STD.

21. Specify register type such as horizontal, vertical, inclined, inline reading, dial reading, print, etc.

22. Specify number of figures such as 6 digit, 5 digit, or 0-99, 999, etc.

23. If totalizer reset required, write in type. If reset is not required, write in "none".

24. Write in number of figures or maximum quantity (in flow units) that can be held in counter.

25. Specify by writing in "yes" if a set-stop is required to operate shut-off valve, switch, etc.

27-34. Specify fluid data as completely as possible, note at operating conditions. Be sure to note if liquid is at saturation conditions.

35. Specify by writing in "yes" if a shut-off valve is required. Valve to be manufacturer’s standard construction unless otherwise noted.

(to be continued)

APPENDIX A-1 (continued)

36. Specify by writing in "yes" if a switch is required. Two switches are required for 2-stage shut-off control.

37. Write in "yes" if manufacturer’s standard temperature compensator is required. Write in "no" if not required.

38. Specify, if transmitter is required, by writing in type such as pulse, rate of flow, etc.

39. Give transmitter output in pulse per gallon, 4-20 mA, etc.

40. Write in "yes" if air eliminator is required, otherwise write in "no".

41. Specify, if strainer is required, by writing in type such as "Y" "Basket", etc. Strainer to have same pressure and temperature rating, end connections and material as meter body unless otherwise noted.

42. Identify manufacturer’s name and model number after selection is made.

APPENDIX A-2

TYPICAL DATASHEET FOR TURBINE METERS

	TURBINE FLOWMETERS				SHEET 1 OF 1		
					SPEC. NO.		REV.
	NO	BY	DATE	REVISION			
					CONTRACT		DATE
					REQ.	P.O.	
					BY	CHK'D	APPR.

METER	1	Tag Number				
	2	Service				
	3	Meter Location				
	4	Line Size				
	5	End Connections				
	6	Body Rating				
	7	Temp. & Press. Rating				
	8	Accuracy				
	9	Linearity				
	10	K Factor, Cycles per Vol. Unit				
	11	Excitation				
	12	Materials: Body				
	13	Support				
	14	Shaft				
	15	Flanges				
	16	Rotor				
	17	Bearings: Type				
	18	Bearing Material				
	19	Max. Speed				
	20	Min. Output Voltage				
	21	Pickoff Type				
	22	Enclosure Class				
	23					
FLUID DATA	24	Fluid				
	25	Flow Rate: Min. Max.				
	26	Normal Flow				
	27	Operating Pressure				
	28	Back Pressure				
	29	Operating temp. Max. Min.				
	30	Operating Specific Gravity				
	31	Viscosity Range				
	32	Percent Solids & Type				
	33					
SECONDARY INSTR.	34	Secondary Instr. Tag No.				
	35	preamplifier				
	36	Function				
	37	Mounting				
	38	Power Supply				
	39	Scale Range				
	40	Output Range				
OPTIONS	41	Totalizer Type				
	42	compensation				
	43	Preset Counter				
	44	Enclosure Class				
	45	Strainer: Size & Mesh				
	46					
	47					
	48					
	49	Manufacturer				
	50	Meter Model No.				
	51	Secondary Instr. Model No.				

Notes:

(to be continued)

APPENDIX A-2 (continued)

TURBINE FLOWMETERS

Instructions for ISA Form S20.24.

Refer to ISA Standard S31, "Specification, Installation, and Calibration of Turbine Flowmeters"

1. Show meter tag number. Quantity is assumed to be one unless otherwise noted.

2. Refers to process service or applications.

3. Give line number or process area.

5. Specify size and style of connections, such as "1 in. NPT", "2 in. 150 lb ANSI", etc.

6. Pressure and temperature design rating required.

7. Nominal flow rating is obtained from manufacturer's data. This usually defines linear range of selected meter.

8. Turbine meter accuracy figures are in terms of percent of instantaneous flow rate.

9. Degree of linearity over nominal flow range.

10. K factor relates cycles per second to volume units. Enter this figure after selection is made.

11. Excitation modulating type only expressed as volts___ at___ hertz.

12-16. Specify materials of construction or write in "MFR STD".

17. Specify sleeve or ball bearings, or none if floating rotor design.

18. Bearing materials -- will be MFG STD if not stated otherwise.

19. Maximum speed or frequency which the meter can produce without physical damage.

21. Pickoff may be standard hi-temp., radio-frequency type (RF) or explosion proof. Minimum output voltage ____ volts peak to peak.

22. Specify electrical classification of enclosure such as General Purpose, Weather Proof, Class 1, Group D, etc.

23. Specify fluid data as indicated, using line 28 for additional item if required.

34. Give Tag No. of secondary instrument if different from meter Tag. No.

35. Pre-amplifier if used.

36. Specify function of instrument, such as rate indicator, totalizer, or batch control.

37. Flush, surface or rack.

38. Power Supply i.e., 117 V ac.

39. Applies to rate indicator.

(to be continued)

APPENDIX A-2 (continued)

40. Give output range such as "40-20 mA", 21-103 kPa (3-15 psig), etc.

41. May be used for number of digits, and to state whether counter is reset or non-reset type.

42. Specify range of compensation, if required, in pressure and/or temperature units or viscosity units.

43. Pre-set counter.

44. Specify NEMA classification of enclosure.

45. Specify strainer size and mesh size. Request Vendor’s recommendation if not known.

50. Fill in after selection is made.

51. Fill in after selection is made.

52. Fill in after selection is made.