TECHNICAL SPECIFICATION

TURBINE FISCAL METERING SYSTEMS FOR LIQUID HYDROCARBON

DEP 32.32.00.11-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This is a new DEP which defines the minimum requirements for turbine metering systems (including in-situ proving equipment) for the measurement of the quantity and the quality of liquid hydrocarbons passing through an accounting facility such as at the inlet or outlet of an oil pipeline or at a ship loading station.

This DEP only covers metering systems that use turbine meters. Other methods (e.g. Pd meters, Coriolis, vortex) may be considered, but they are not covered by this DEP.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this DEP is confined to companies forming part of or managed by the Royal Dutch/Shell Group, and to Contractors nominated by them (i.e. the distribution code is "C", as defined in DEP 00.00.05.05-Gen.).

This DEP is primarily intended for use in oil and gas production facilities, but may also be used in oil refineries, chemical plants, gas plants and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.4 ABBREVIATIONS

BS&W	-	Base Sediment and Water
CCR	-	Central Control Room
DCS	-	Distributed Control System
IP	-	Institute of Petroleum
LCR	-	Local Control Room
MESC	-	Materials and Equipment Standards and Code
RTD	-	Resistance Temperature Detection Element
SCADA	-	Supervisory Control and Data Acquisition System

1.5 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (9).

1.6 ORDER OF PRECEDENCE

In case of conflict between documents relating to the enquiry/order, the following priority of documents shall apply:

1. National or legal codes or regulations
2. The Purchase Order
3. The Requisition
4. This DEP
5. Other Shell, industry, national and international standards referenced herein.

Any conflict of requirements which cannot be resolved by the above order of precedence shall be referred to the Principal for resolution.

2. MANUFACTURER'S RESPONSIBILITY

The Manufacturer's scope of work shall include design, fabrication, inspection, testing, supply of documentation and the delivery of complete liquid metering systems.

The Manufacturer shall assume full system responsibility. This means that the Manufacturer shall ensure the operability, accuracy and quality of all components including those of the Manufacturer's sub-suppliers and, in addition, conformance to authority and code requirements.

Equipment offered by the Manufacturer shall be in accordance with the Principal's Preferred Vendor List for Instrumentation and Computers. Equipment shall be proven and shall comply with the relevant codes.

The Manufacturer's design shall recognise that simplicity, and consequently minimisation of field installation work, is of prime importance. The design shall also provide ease of access to all components, maximise maintainability and include facilities to contain (and properly dispose of) liquid spills resulting from operational assembling and draining activities.

The Manufacturer shall prepare a detailed specification for the microprocessor instrumentation and for programming software. Where applicable, the Manufacturer shall be required to liaise with the main data acquisition system Supplier, to be advised by the Principal, to arrange data link and protocol necessary for monitoring of the metering system.

The Manufacturer shall, at all stages, inform the Principal immediately if there is doubt on the specified requirements. The Manufacturer shall not proceed with any such aspects of the work until he has received the necessary confirmation, in writing, from the Principal.

3. METERING SYSTEM DESIGN

3.1 GENERAL

The metering system shall be considered as two major sub-systems. These are:
i) the field mounted skid including the sampling and proving equipment, and
ii) the computing facility in the CCR, LCR or local equipment room for calculation, read out and control.

The metering system shall provide measurement accuracy for accounting purposes as required by this DEP for mass and volumetric quantities and the flow rates of the liquid hydrocarbon together with its temperature, pressure, density, and water content prior to delivery into downstream systems. It shall incorporate sufficient parallel meter runs to enable the maximum and minimum flow rates to be measured at the specified accuracy, with one complete spare meter run.

Fiscal metering installations are usually subject to approval by local authorities. This normally covers approval of the design through to final installation. Discussions with the authorities should commence at the earliest possible stage and be continuous, in order to gain acceptance of the metering philosophy and to simplify final approval of the installation.

The skid package will be subject to the location's prevailing environmental conditions as specified in the Requisition. The skid shall include all pipework manifolds, metering streams, valves, instruments and fittings. It shall be supplied as a fully piped, cabled and instrumented package.

Operational experience has shown that the maximum differential pressure across the complete metering system should be less than 2.0 bar.

A typical flow scheme for a fiscal metering station is contained in Appendix 1 of this DEP.

3.2 INLET HEADER

The inlet header should incorporate the following:
- Pressure transmitter and pressure gauge.
- Temperature transmitter and thermowell.
- Temperature indicator and thermowell.
- Sampling stream for the specified analyser systems (including density). Alternatively, the sampling stream may be located downstream of the meters.

3.3 METERING RUN

Parallel metering runs should be provided, each fitted with the following:
- Inlet valve.
- Strainer.
- Flow straighteners.
- Turbine flowmeter, complete with dual pick-ups and pre-amplifiers.
- Temperature transmitter and thermowell.
- Pressure transmitter and pressure gauge.
- Temperature indicator and thermowell.
- Stream flow control valve.
- Outlet valves, one to isolate the stream and one to divert to the prover loop.
- Thermal relief valves.

3.4 METER PROVER

Uni- or bi-directional mechanical displacement meter provers, generally as defined in API Manual of Petroleum Measurement Standards, Chapter 4 are currently applied. However, should compact proving devices be accepted by the fiscal authorities these may be applied if approved by the Principal.

For offshore applications, where space and weight are important considerations, either the bi-directional or compact prover will provide the smaller and lighter solution for a given meter capacity.

3.5 MICROCOMPUTER BASED MONITORING AND CONTROL SYSTEM

Metering and meter proving shall be managed by a microcomputer system. This system shall be installed in the CCR, LCR or local equipment room. Normally, separate microcomputers should be dedicated to each of the metering runs, to the station and to prover control. However, the functionality of the microcomputers may be combined into one or more computers if it can be demonstrated that the required reliability, availability and redundancy standards will be met. Such an arrangement will often be subject to approval by local authorities.

Control of the metering station, selection of metering runs to suit production profiles, equal distribution of flow between streams and initiation of flow meter calibration, shall be executed from the CCR or LCR. This includes measurement and logging of pressures, temperatures, cumulative volumes, water content and density.

In view of the redundancy of the metering streams to obtain maximum production, it is not considered necessary to provide redundancy in the individual metering stream computers. Failure of a microcomputer should, therefore, be easily rectified by replacing it with a plug-in spare unit.

Where a data link is required between the metering package and a SCADA or DCS system, the Manufacturer shall allow for the effort and liaison with Principal and the SCADA or DCS Supplier to develop the necessary software system which will enable the required amount of information to be addressed from the SCADA or DCS system.

All necessary controls, monitoring, printer and display facilities shall be supplied as part of the metering system.

The input signal conditioning and analogue-to-digital conversion of the microcomputer system shall be specified to have an overall uncertainty of less than 0.025%. The metering station measurement uncertainty due to computation and digital output of calculated quantities shall be less than 0.001%.

The system shall not suffer from radio frequency noise interference. The power and frequency of portable radios are as follows:

Frequency:	27 MHZ, 160 MHZ, 460 Mhz
Antenna Power:	27 MHz at 20 cm approx. 70 volts/metre
	160 MHz at 20 cm approx. 10 volts/metre
	460 MHz at 20 cm approx. 60 volts/metre

The system shall be supported from an uninterruptible electrical power supply and have provision for retaining for at least 31 days volatile memory data and the integrated flow totals in the event of a power supply failure.

The signal connections between the metering skids and the microcomputer system are summarised in Appendix 2. The display, transfer and utilisation of data and calculated values are shown in Appendix 3.

The following features shall be included in the metering system to minimise the probability of undetected corruption:

- Analogue signals shall have alarm settings just above and below the nominal zero and full-scale values.
- Manually entered data and configuration changes shall be protected by a key lock or other suitable security device.
- Any alarm, log-on or parameter changes shall be logged in an "Event Log" to provide a complete audit trail.

3.6 UTILITIES

The electrical power supply requirements shall be in accordance with DEP 33.64.10.10-Gen.

Instrument air, if required, shall be clean, dry and oil free. Air pressure will normally be 7 bar (ga), with a minimum pressure of 4 bar (ga) and a maximum of 8 bar (ga).

4. TECHNICAL REQUIREMENTS - FIELD MOUNTED COMPONENTS

4.1 SKID, STRUCTURAL AND BASEPLATE

The configuration of the metering skid shall meet the requirements of, and be within the dimensional constraints given in, the Requisition. The Manufacturer shall propose a design within these constraints that combines compactness with compliance to quoted standards and codes and ensures maintainability of equipment.

The effect of weight for offshore platforms is of paramount importance and design consideration shall be given to minimising the weight of equipment as far as possible without degrading safety performance or efficiency. The mass of equipment and its centre of its gravity in relation to plan and elevation shall be given by the Manufacturer for all assembled skid units.

The metering skid shall be of all welded steel construction with a rigid base. The baseplate shall be adequately supported. Lifting facilities shall be provided as part of the skid and these shall permit lifting of the complete assembly without causing permanent deformation or damage to the skid or to any of the equipment mounted on the skid.

Structural integrity of the skid shall not be reliant on any equipment fixed to it.

A drip-pan shall be provided over the entire skid base, inclined so that it drains to a single point, which shall be designated as a hazardous drain. The drain shall be terminated in a 2" rated ANSI/ASME B16.3 150 lb flange for connection and continuation by the Principal. Vents and drains shall be provided at all high and low points in the piping system, with the low point drains manifolded to the baseplate edge. Visual indication shall be provided at each drain to detect for liquid discharge.

4.2 PIPING AND VALVES

Piping design shall comply with DEP 31.38.01.10-Gen. and DEP 31.38.01.11-Gen. For EP applications the design shall also comply with EP 55000-21 (noting the minimum mandatory isolation requirements).

Process inlet and outlet piping connection locations shall be in accordance with the schematic drawings included with the Requisition.

The metering skid shall have a common inlet header and a common outlet header to ensure uniform measuring conditions at all meter streams.

Any section of pipe that may be blocked in by closing valves shall be fitted with thermal relief valves, piped to the drain system. Valves shall be full nozzle, direct spring loaded type, with connections to suit piping design.

Spool pieces shall be provided to replace the turbine meters during hydrotest, installation and precommissioning. The spools shall be to the piping standard for the skid and be provided complete with gaskets.

The installation of parallel meter runs between common inlet and outlet headers causes the following mechanical problems, which shall be addressed by the Manufacturer in the design:

- Differential thermal expansion between flowing and non-flowing meter runs can cause high stress levels. These shall be calculated in the overall system stress calculations.
- The removal of components for inspection and maintenance from isolated meter runs is made difficult by system stiffness. The Manufacturer shall propose a method to facilitate component removal. The method should be approved by the Principal.

The meter run outlet and the prover inlet and outlet valves shall be in accordance with the API Manual of Petroleum Measurement Standards, Section 4.

The meter run inlet and outlet and the prover inlet and outlet valves shall be fitted with open and closed position switches for remote indication, and a valve leakage detection alarm.

The meter run inlet and outlet and the prover inlet and outlet valves shall be fitted with manual, electric or pneumatic actuators.

Electric actuators (if fitted) shall be furnished with interposing relays to the control circuit of the three-phase motor. Actuator motors shall be of the cage induction type with integral starters incorporating stall protection, limit switches and anti-condensation heaters.

4.3 INSTRUMENT AND ELECTRICAL

All field mounted electrical/electronic instruments installed in hazardous areas shall be certified for use in such locations. The selection and installation of the types of protection for electrical equipment installed in hazardous areas shall be as defined in publication IEC 79-14. Certification by recognised test houses shall be obtained.

All electrical equipment shall be weatherproof to IP 56 as defined in IEC 529. Junction boxes, cable racking and tray work shall be AISI 316L stainless steel.

The Manufacturer shall provide and install all electrical cabling for connection of the various components of both the metering skid and the computing facilities. Interconnecting cables between the two shall be specified by the Manufacturer for supply by the Principal.

Earthing of the system shall be the Manufacturer's responsibility and electrical equipment shall be bonded together to form a continuous low impedance path to earth. Each skid shall be provided with two diagonally opposite earth bosses in accordance with Shell Standard Drawing S 68.004. Special electronic/computer earthing requirements shall be as specified in DEP 32.37.20.10-Gen.

Signals from the skid shall be segregated according to the various voltage levels and types that exist. The segregation shall be in accordance with DEP 32.37.20.10-Gen.

Field equipment and cabling in areas which are not protected by either earthed steel structures or dedicated lightning conductors shall be provided with lightning protection as detailed in DEP 32.37.20.10-Gen.

4.4 TURBINE METERS

Turbine meters shall be selected to conform to the following requirements:

Linearity of each meter shall be better than ± 0.25% over a 10:1 flow range at the specified operating viscosity. The meters shall be calibrated initially on water by an independent authority. Viscosity performance shall be established when the meters are in operation.

The repeatability under stable conditions shall be better than ± 0.05% of the mean pulse count. This shall be checked for several different flow rates within the specified 10:1 range, on both water and fluid of the relevant viscosity. The former checks shall be carried out at Manufacturer's works during system test and the latter during location tests.

The turbine meters shall be provided with meter tubes and flow straighteners as necessary, in accordance with ISO 2715. Minimum upstream and downstream run lengths shall be 10D and 5D respectively, where D is the inside diameter of the run.

Two pick-up heads shall be provided for the checking of pulse integrity. The design shall permit changing of pick-up coils without removal of turbine meter from the meter run. The connections shall permit sealing to the satisfaction of the appropriate authority.

The meter calibration factor for each turbine meter shall be determined initially by tests carried out by the Manufacturer and entered manually into each respective meter stream microcomputer.

4.5 STRAINERS

The strainers shall be provided with the following:

- Single basket stainless steel material with a mesh insert size as recommended by the turbine meter Manufacturer.
- Flanged davit closure for easy removal and replacement of basket.
- Flanged vent and drain connections.

4.6 FLOW STRAIGHTENERS

Flow straighteners shall be designed and fabricated in accordance with ISO 2715.

4.7 FLOW CONTROL VALVES

The metering stream flow control valves should be pneumatically operated valves to control the proving flow from minimum to maximum conditions and to avoid hydraulic shock during start-up and shut-downs.

A side-mounted de-clutchable handwheel should be provided for manual operation.

The equipment Manufacturer shall perform sizing calculations, in accordance with IEC 534-2.

4.8 TEMPERATURE MEASUREMENT

For temperature measurement, electrical resistance thermometry shall be used. The measurement transducer shall be a Pt 100 Platinum RTD, 100 ohm at 0 °C, alpha coefficient 0.00385 ohm/ohm/ °C as defined in IEC 751. Tolerance class A shall be applied.

Resistance thermometers shall be interrogated directly by the relevant microcomputers utilising the four-wire technique. Typically the temperature span will be 0 °C to 100 °C; however, narrower spans shall be applied where operating temperature stability permits.

The RTDs shall be mounted in flanged thermowells to enable replacement without depressuring or draining the system. A test thermowell shall be installed adjacent to the RTDs to allow a temperature check during commissioning and at periodic meter station inspections. The two thermowells shall be installed on different radial axes to minimise vibration fatigue of the downstream well by vortex shedding from its upstream partner.

Thermowells shall be provided for all temperature applications, in accordance with (4.2).

Test thermowells shall be provided with bores suitable for the insertion of mercury-in-glass high accuracy thermometers.

The Manufacturer shall provide two mercury-in-glass precision thermometers for calibration check purposes. Thermometers shall be certified with an accuracy better than 0.1 °C.

4.9 PRESSURE MEASUREMENT

Pressure and differential pressure transmitters should be of the "Smart" type with an analogue 4-20 mA output signal. They shall be in accordance with DEP 32.31.00.32-Gen. Digital signal transmission based on proprietary communication protocols should not be used as equipment from different Manufacturers may not be able to be mixed/interchanged. Application of digital communication requires the written agreement of the Principal.

Local pressure gauges shall be of the Bourdon tube type with a 100 mm minimum diameter, in accordance with MESC No. 60.35/001.

4.10 DENSITY MEASUREMENT

The Manufacturer shall provide a dual parallel densitometer system. The signal of both transducers shall be compared for transducer health monitoring. A deviation of 0.5-1.0 kg/m^3 (this value shall be specified by the Principal) between the two measurements shall initiate an alarm.

A representative slip stream shall be taken from and returned to the metering station header through the two vibrating tube type density transducers.

The physical installation and calibration verification requirements are detailed in IP Petroleum Measurement Manual, Part VII, Section 2.

4.11 BS&W MEASUREMENT

Two BS&W systems are specified in the Requisition. The systems shall be operated on a duty-standby basis with the station microcomputer providing changeover on receipt of a system fault output. If this measurement is not used for net oil computations, but as an operating guide only, then one BS&W meter will suffice.

Sensor range shall be 0-5% water in oil with an accuracy of ±0.2% absolute.

Correction of oil quantity to allow for water content shall normally be a retroactive accounting procedure using the results of the sample analysis (4.12).

The output of each water-in-oil measurement instrument shall be a 4-20 mA analogue signal.

NOTE: This measurement is normally only required on crude oil applications.

4.12 SAMPLER

A 'grab' type sampler and collection system shall be fitted to the inlet manifold of the metering pipework. It shall act on impulses from the station microcomputer and collect a flow rate proportional sample whose composition is representative of the total fluid flowing through the metering station.

The requirements for sample extraction and collection are defined in the IP Petroleum Measurement Manual, Part VI, Section 1.

The system shall be fitted with a console mounted indicator and a voltage free contact output to verify that pulses have transferred to the sampler solenoid valve.

The sampler shall operate at constant pressure.

4.13 METER PROVER

The meter prover shall be equipped with a quick opening closure for sphere removal.

The number of meter pulses generated over calibrated volume shall be not less than 10,000 pulses and resolution of the detector and sphere system shall be compatible with this requirement. The sphere velocity shall not exceed 3 m/s. The length between detector switches (or round trip length for bi-directional provers) shall be at least 10,000 times the detector repeatability. The prover connection shall be downstream of the turbine meters.

The prover shall have two dual detector switches at each end of the calibrated volume in order to prevent the loss of the prover function in case of a faulty detector switch. The detector should be designed such that the contacting head of the detector protrudes far enough into the prover pipe to ensure switching takes place at all flow rates during calibration and normal operation. Detectors and switches shall be suitably weatherproofed for their environment.

In the case of mechanical switches, each sphere detector shall have a dedicated micro-switch. The actuation of each detector shall be set during manufacture so that should it be necessary to replace a detector during service there will be a negligible change in prover calibrated volume such that the accuracy of the prover will not be affected.

Connections shall be provided on the prover loop to facilitate recalibration with a portable master prover equipped with a master meter.

4.13.1 Four-way valve

The four-way flow diverter valve in a bi-directional prover shall be in accordance with the API Manual of Petroleum Measurement Standards, Chapter 4.

4.13.2 Freedom from shock

When the prover is operating at its maximum design flow rate the sphere shall come to rest safely at the end of its travel, without shock.

4.13.3 Prover internal coating

The internal coating of the prover shall have a uniform bore, durable and smooth surface. The vendor shall provide full details of the coating, surface preparation, method of surface preparation, method of application, maximum allowable fluid temperature and method of repair. Porosity and explosive decompression of the lining shall also be avoided.

4.13.4 Guide bars/tees

Careful consideration shall be given to the design of guide bars or tees to avoid damage to spheres.

5. TECHNICAL REQUIREMENTS - MONITORING AND CONTROL SYSTEM

5.1 STREAM MICROCOMPUTER

Each stream microcomputer shall have as a minimum the following facilities:
- Alphanumeric displays providing interface to operator.
- Alarm/indicators for status information.
- Keyboard for data entry commands etc.

Each stream microcomputer shall, as a minimum, perform the following functions and where necessary display relevant data:
- Receive dual pulse inputs from the associated turbine meter and carry out pulse security checking in accordance with IP Petroleum Measurement Manual, Part XIII, Section 1.
- Introduce the meter calibration factor in pulses per volume unit (often referred to as the meter K-factor), entered either manually or downloaded from the data base.
- Calculate gross volume through the meter.
- Receive input signals from the associated pressure, temperature and density transmitters.
- Calculate the stream mass flow, utilising gross volume flow and density.
- Compensate gross stream volume for the effect of pressure and temperature, to obtain net stream reporting volumes at 15 °C and 1.01325 bar absolute.
- Transmit, via the data bus, on demand from the station microcomputer, selected measured and calculated variables.
- Display all measured and calculated variables.
- Output alarm messages to the station microcomputer for logging and control.
- Permanently display the totalised mass quantity with sufficient digits to accumulate three months' maximum flow without roll-over.
- Display on demand the totalised daily mass flow (reset to zero daily).
- Watchdog timer to monitor internal circuits and to signal to the station microcomputer, via hard wiring, when a fault is detected. This shall enable the station microcomputer to deduce when a stream microcomputer data link is faulty and enable it to take the appropriate action (i.e. shutdown a stream when the microcomputer is faulty, or alarm when the data link is faulty).
- Operate in a fully automatic mode with the station microcomputer.
- Operate in a manual mode with the operator manually launching the sphere when the station microcomputer is out of service.
- Store in memory the applicable tables detailed in ASTM D1250 (or the appropriate formula and procedures), for use in compensating gross volume during normal throughput flow.
- Generate an alarm when flow counting is detected but the meter stream is not selected (i.e. off-line).
- Downloading of meter calibration factors should be time stamped. The stream microcomputer should also hold the previous meter calibration factor used.

5.2 STATION MICROCOMPUTER

The station microcomputer shall act as the prime interface for metering, entry and display of data. The station microcomputer shall have as a minimum the following facilities:
- Alphanumeric display of all data, control requests, alarm, etc.
- Keyboard for data entry commands, etc.
- Alarm indication facility.

The station microcomputer shall, as a minimum, perform the following functions and where necessary display the relevant data:

- Form a data base of selected alarms, measured and calculated variables, obtained via the data bus from the stream measurement microcomputers, or directly from the station common signals.
- Compile station data in an agreed format and feed this to a dedicated printer either at specified times or on demand from the operator.
- Receive and act on keyboard commands from the operator.
- When required by the specification, interface with the SCADA or DCS system via a serial data link using a protocol agreed between the Manufacturer and the SCADA or DCS

system Supplier for the two-way interchange of data.
- Display valve status and selected parameters.
- Display an index of all the commands and functions available to the operator.
- Permanently display meter station mass flow with sufficient digits to accumulate three months' maximum design flow without roll-over.
- Display on demand the station daily totalised mass flow.
- Proportional flow control of the sampler.

NOTE: All functions shall be interractive and the system shall have the capacity for utilising a question and answer type of dialogue through the keyboard and the alphanumeric display.

5.3 PROVER MICROCOMPUTER

The prover microcomputer shall perform the following functions:
- To receive a 'prove initiate' command, which may be automatic, semi-automatic, manual or a combination of these.
- To check that the rates of change of prover temperature and pressure are within preset limits.
- To count raw unscaled meter pulses between detector switch operations for one prover stroke.
- To correct the prover volume to operating conditions of temperature and pressure.
- To calculate the meter calibration factor (the 'K' factor) in pulses per volume unit, in accordance with API Manual of Petroleum Measurement Standards, Chapter 4.
- To automatically conduct a series of proving runs, terminating when five consecutive runs provide results which have a spread of less than 0.05%.
- To queue future proof runs at the operator's discretion.
- To transfer data to the station microcomputer via serial data highways.
- To control the meter run flow control valve and monitor the prover isolation valves and position switches.
- Display four-way valve leakage alarm.
- Generate and print validation report.

The prover microcomputer shall be similar to the units described in (5.1). The prover microcomputer shall be responsible for computing the meter calibration factor using average temperature and pressure. This shall be achieved by counting raw meter pulses from the individual station microcomputer between detector switch operations. The microcomputer shall provide all necessary prover sequence control.

The proving function shall be controlled from the station microcomputer via the prover microcomputer. The 'prove initiate' command shall be transmitted to the skid equipment when the following parameters are stabilised and accepted:
- prover inlet and outlet temperature;
- prover pressure;
- prover inlet and meter run outlet isolation valve seal status;
- proving flow rate.

The selection of a meter for proving shall set up an automatic sequence of valve control procedures. Valve seal integrity shall be monitored throughout.

If the first 5 consecutive meter proving runs are not within the required accuracy, an alarm should be raised to alert the operator. Should the meter fail to achieve the required performance after 10 consecutive meter proving runs, the proving sequence shall be aborted. The system should then wait for an operator command on whether or not to resume the next proving run in the queue. All calculations and reports shall be generated in the usual way for aborted runs, but they shall be annotated to indicate a failed prover run.

Should any of the prover monitored parameters exceed pre-determined limits, then the proving run shall be automatically aborted, an alarm generated and the calculation discarded.

On completion of a proving sequence, the revised meter factor shall be displayed. Provided that it is satisfactory, the new meter calibration factor shall then be downloaded to the relevant line microcomputer, automatically initiated by a command from the operator. It shall be possible to perform this function manually if required. Should preset limits of the meter calibration factor be exceeded then an alarm shall be initiated.

The prover microcomputer shall be provided with a resettable high speed totaliser, with a minimum of eight digits, for the accumulation of meter pulses. Resolution shall be ± 1 pulse.

The following inputs shall be provided:
- position detector switch signals;
- inlet and outlet temperature;
- prover pressure;
- prover four-way diverter valve position status;
- valve seal status on prover inlet and meter run outlet isolation valves;
- serial data link from stream and station microcomputers;
- unscaled meter pulses from each individual stream meter via the stream microcomputer.

The following outputs shall be provided:
- serial data link to station and stream microcomputer;
- stream control valve;
- inlet temperature;
- outlet temperature;
- prover pressure.

6. INSPECTION AND TESTING

6.1 GENERAL

In addition to the provision for testing and inspection stated in the terms and conditions of purchase, the Manufacturer shall give the Principal adequate notice of his intention to carry out tests so that arrangements can be made to witness the event.

The appropriate authority may wish to approve the equipment design and witness calibration tests. This requirement will be stated in the Requisition.

In the purchase order the Principal shall indicate whether or not he wishes to perform inspection during fabrication. If so, the Principal shall indicate the scope of his inspection, which typically may include:

- To ensure dimensional compliance with the flow metering design.
- To ensure that the performance of instrumentation meets specification accuracy.
- To ensure that the computing system fulfils the functional performance requirements, including immunity from external interference sources.
- To ensure that the basic skid and piping fabrication meets structural and piping code requirements.
- To ensure that the electrical/electronic installation complies with electrical safety requirements and that components to be used in hazardous areas have recognised certification.

6.2 INSPECTION FOR COMPLIANCE WITH METERING DESIGN

Metering tubes shall be inspected before incorporation into the pipework fabrication to ensure compliance with the requirements of ISO 2715, in particular the dimensions of the upstream flow conditioning section and of the downstream section, including the locations of the thermowells and pressure tappings.

The turbine meter Manufacturer shall be required to provide a calibration certificate for each meter. Where possible, the calibration fluid should have a similar viscosity to the specified operating liquid. Where this cannot be achieved calibration using water, together with the Manufacturer's prediction of performance on the operating liquid, shall be performed.

The meter prover shall be calibrated at the Manufacturer's premises by an independent calibration company. The calibration should be witnessed by the appropriate authority and recorded on a formal certificate.

The instruments detailed in (4.4, 4.7, 4.8, 4.9, 4.10 and 4.11) shall be inspected and tested in accordance with DEP 62.10.09.11-Gen.

6.3 INSPECTION AND TESTING ON SKID STRUCTURAL AND PIPING SYSTEMS

All materials used in fabricating the process pressure retaining system, e.g. pipework, valves, fittings, etc., shall have relevant mill certificates, casting melt certificates, etc., in accordance with the applicable MESC specification.

Prior to commencement of fabrication, the welder(s) for the process piping fabrication shall be certified to the requirement of the piping design specification.

During fabrication, welds shall be inspected as defined in DEP 31.38.01.31-Gen. Records shall be kept and witnessed as appropriate.

Hydrostatic pressure tests shall be performed in accordance with ANSI/ASME B31.3 and DEP 31.38.01.31-Gen. Specifically, the entire pipework system shall be maintained at maximum rated pressure, for the recommended time, following removal of turbine meters and replacement by pipe spools. A certified chart record of temperature and pressure shall be produced covering the duration of the test.

All flanges and swing elbows shall be capable of being opened without pipe spring or malfunction. The Principal may require the Manufacturer to open joints for spot checks.

6.4 INSPECTION FOR ELECTRICAL SAFETY

Safety documentation for the selected type of protection for the installed electrical instruments shall be compiled for scrutiny and to ensure that any certificate conditional requirements have been incorporated in the installation.

All wiring shall be tested for insulation resistance, earth fault and earth continuity. To prevent damage to low voltage equipment, the instrument equipment shall be disconnected at both ends of the cable before these tests are carried out and re-connected prior to the functional tests.

All terminations, glands, junction boxes and other electrical and electronic equipment enclosures on the skid shall be inspected for correct application, assembly and closure.

6.5 MASS AND VOLUME FLOW COMPUTATION SYSTEM

6.5.1 Functional tests

A detailed test programme to confirm compliance with the design requirement shall be developed by the Manufacturer for approval by the Principal. These tests shall include but not be limited to the following:

- Functional and performance check of all analogue and frequency measured variable conversions into digital values.
- Confirmation of correct flowrate computation and quantity integration operations with simulated measurement inputs.
- Confirmation of correct output signals to the totalisers, analogue indicators or recorders and to SCADA or DCS systems.
- Confirmation of correct generation of operating function alarms, e.g. high flowrate, etc.
- Confirmation of computer system alarms.
- Confirmation of event logging and reports.
- Demonstration of immunity of the system to radio interference in accordance with (3.5).
- Demonstration of series and common mode noise rejection in accordance with (3.5).
- Demonstration of short circuit protection of inputs and outputs. A representative sample of inputs and outputs shall be subjected to sustained short circuit, to ensure that devices can survive both a fleeting and a sustained short circuit.
- Demonstration that malfunction of an input/output channel shall not cause failure of any other input/output channel.
- Demonstration that signal isolation between input or output channels shall be clearly defined.
- Demonstration of auto start-up and recovery after power failure.
- Functional check of a representative sample of spare parts by inserting these into the main equipment and performing tests described above.
- Functional check of Manufacturer/Supplier supplied tools and test equipment with the main equipment.

NOTE: The tests are to be made over the full ambient temperature range to demonstrate compliance, statistically, with design criteria.

6.5.2 Heat soak tests

The system shall be operated by the Manufacturer in its final on-site configuration for a minimum period of 200 hours. A minimum of 10% of digital inputs, 10% of digital outputs and all analogue inputs and outputs shall be simulated for this period, with simulation equipment provided by the Manufacturer.

All deliverable equipment used in the system shall be subjected to an elevated temperature of 45 °C (typical) for 100 hours during the demonstration period. The system environment shall be cycled between 45 °C and the site ambient temperature at 12 hour intervals, until the 100 hour elevated temperature period is completed.

During the heat-soak test, the system equipment shall be fully energised. Fully-loaded operating conditions shall be simulated at 24 hour intervals by demanding reports, selecting displays, exercising calculations and sending and requesting data over communication channels.

If a component failure occurs all tests shall be repeated after the replacement of the faulty component, unless otherwise agreed by Principal. This ensures that all essential components are subjected to the specified minimum testing.

6.5.3 Dynamic tests

A specific programme of dynamic tests shall be agreed between the Manufacturer and the Principal. The programme shall include but not be limited to the following tests:

- Verification that meter run and meter prover selection valves operate correctly, that the valves seal and correctly signal the valve positions.
- Verification that the meter stream flow control valves function correctly and that flow balance between meter runs is achieved.
- Verification that the measurement data presented at the operator's interface to the microcomputer is correct and that commands given at the interface are executed correctly.
- Verification that alarms are initiated at appropriate measurement conditions.
- Demonstration of all event, alarm and routine log formats.

6.6 FUNCTIONAL TESTING OF THE COMPLETE METERING SYSTEM

The wet functional test shall demonstrate that all the sub-systems, already tested in isolation, operate successfully as an integrated system under actual flowing liquid conditions.

The Manufacturer shall assemble the complete metering system for a functional test. The assembly shall include a suitable pump or pumps, a liquid break tank and additional temporary pipework to allow inhibited water to be circulated through the system. The pump(s) and temporary facilities shall be capable of achieving a variable flowrate up to at least twice the capacity of a single meter run. All measurement transducers shall be installed and connected by temporary cables to the microcomputers and all control output signals from the microcomputers to selection valves, control valves, etc., shall be connected and commissioned.

All aspects of system software, including any required data link protocol, shall be tested during the system functional test to ensure correct operation. This testing shall include connecting the system to a device that simulates the full DCS/SCADA etc. to ensure correct reflection of metering data on the DCS/SCADA system. (Such a device may need to be provided by the DCS/SCADA supplier).

After satisfactory completion of the functional tests, the test liquid shall be drained off and the piping system dried, e.g. by blowing through with warm dry compessed air.

It should be noted that the water quality to be used for functional testing depends on the material(s) from which the equipment is manufactured.

The special water and drying requirements to be met are the same as for "Hydrostatic Pressure Test" as specified in DEP 31.38.01.31-Gen.

6.7 BS&W MEASUREMENT, DENSITY MEASUREMENT AND SAMPLERS

Section 6.1, 6.3 and 6.4 also apply to these systems.

These systems should be tested as part of the functional test described in Section 6.6. Where this is not possible, a Site Acceptance Test shall be developed by the Manufacturer. This shall include a functional test of each system, including any interface with the main metering skid and its microcomputers.

7. PRESERVATION AND PREPARATION FOR SHIPMENT

7.1 PRESERVATION

Full consideration shall be given to the need for long-term preservation of the skid and metering electronics after testing has been completed. The Manufacturer shall furnish recommendations for long-term preservation (18 months) at a designated site for the periods prior to installation and after installation float-out for an offshore installation.

7.2 PREPARATION FOR SHIPMENT

All packing shall be in accordance with BS 1133.

The Manufacturer shall provide a complete packing and handling specification to cover both skid and electronic panels.

Prior to shipment, all high accuracy skid-mounted instruments and densitometers shall be removed, packed separately and shipped with the skid. Turbine meters shall be replaced with pipe spools and shipped with the skid.

The skid pipework shall be treated with Shell 'Ensis', or equivalent, and sealed for preservation purposes. Manufacturer shall provide blanking flanges as well as filling and draining facilities.

Painting of the complete assembly shall be suitable for the location and in accordance with DEP 30.48.00.31-Gen.

8. DOCUMENTATION

8.1 REQUIREMENTS

The Manufacturer shall supply the documentation in accordance with the Data Requirement Schedule of the Requisition.

In addition to the foregoing, the Manufacturer shall provide the following information:

8.2 MANUALS

During the manufacture, testing, installation and final commissioning a system dossier shall be assembled containing as a minimum:

- A narrative description of the metering function, design philosophy and operating procedures.
- Process Engineering Flow Schemes of the metering system, showing breakpoints between upstream and downstream process equipment.
- Design specifications and manufacturer documentation for the component parts of the system.
- A Computer Handbook showing the equations and routines being used.
- Calculations for flow metering system uncertainties utilising as-built dimensions and performance criteria.
- Witnessed results of computing system inspection and testing.
- Outline of prover calibration and verification methods.
- Listing of computer programs.
- Operating and maintenance manuals.
- Spare parts list as defined in DEP 70.10.90.11-Gen.

8.3 CERTIFICATES

- Use of Electrical Equipment in Hazardous Areas.
- Calibration certificates for meters and prover.

9. REFERENCES

In this DEP reference is made to the following publications:

NOTE Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Index to standard drawings	DEP 00.00.06.06-Gen.
Painting and coating for new construction projects	DEP 30.48.00.31-Gen.
Piping classes - Basis of design	DEP 31.38.01.10-Gen.
Piping - General requirements	DEP 31.38.01.11-Gen.
Shop and field fabrication of steel piping	DEP 31.38.01.31-Gen.
Instruments for measurement and control	DEP 32.31.00.32-Gen.
Instrument signal lines	DEP 32.37.20.10-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Factory inspection and testing of instruments and general instruments	DEP 62.10.09.11-Gen.
Spare parts for initial and normal operation	DEP 70.10.90.11-Gen.
Safety engineering in facilities design	EP 55000-21
Specification for pressure gauges	MESC 60.35/001

STANDARD DRAWINGS

NOTE: The latest edition of Standard Drawings can be found in DEP 00.00.06.06-Gen.

Earthing boss for steel structures, tanks, vessels, etc.	S 68.004

AMERICAN STANDARDS

Malleable iron threaded fittings classes 150 and 300	ANSI/ASME B16.3
Chemical plant and petroleum refinery piping	ANSI/ASME B31.3

Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York NY 10017
USA.

Manual of petroleum measurement standards chapter 4, proving systems, 1978	ANSI/API MPMS

Issued by:
American Petroleum Institute
1220 L Street
Northwest Washington
DC 20005

USA

Manual of petroleum measurement standards — ASTM D1250

Issued by:
American Society for Testing and Materials
1916 Race Streer
Philadelphia
Pa 19103
USA

BRITISH STANDARDS

Packaging code — BS 1133

Issued by:
British Standard Institute
Linford Wood
Milton Keynes
MK14 6LE
United Kingdom.

Petroleum Measurement Manual: — IP code
- Sampling, manual methods — Part VI, Section 1, 1986
- Density, continuous density measurement — Part VII, Section 2, 1985
- Fidelity and security of measurement data transmission systems, electric and/or electronic pulsed data cabled transmission for fluid metering systems,

Issued by:
Institute of Petroleum
61 New Cavendish S
London W1M 8AR
United Kingdom.

INTERNATIONAL STANDARDS

Electrical apparatus for explosive gas atmospheres. Part 14: Electrical installations in explosive gas atmospheres (other than mines) — IEC 79-14

Degrees of protection provided by enclosures (IP code) — IEC 529

Industrial-process control valves. Part 2: Section one - sizing equations for incompressible fluid flow under installed conditions — IEC 534-2

Industrial platinum resistance thermometer sensors — IEC 751

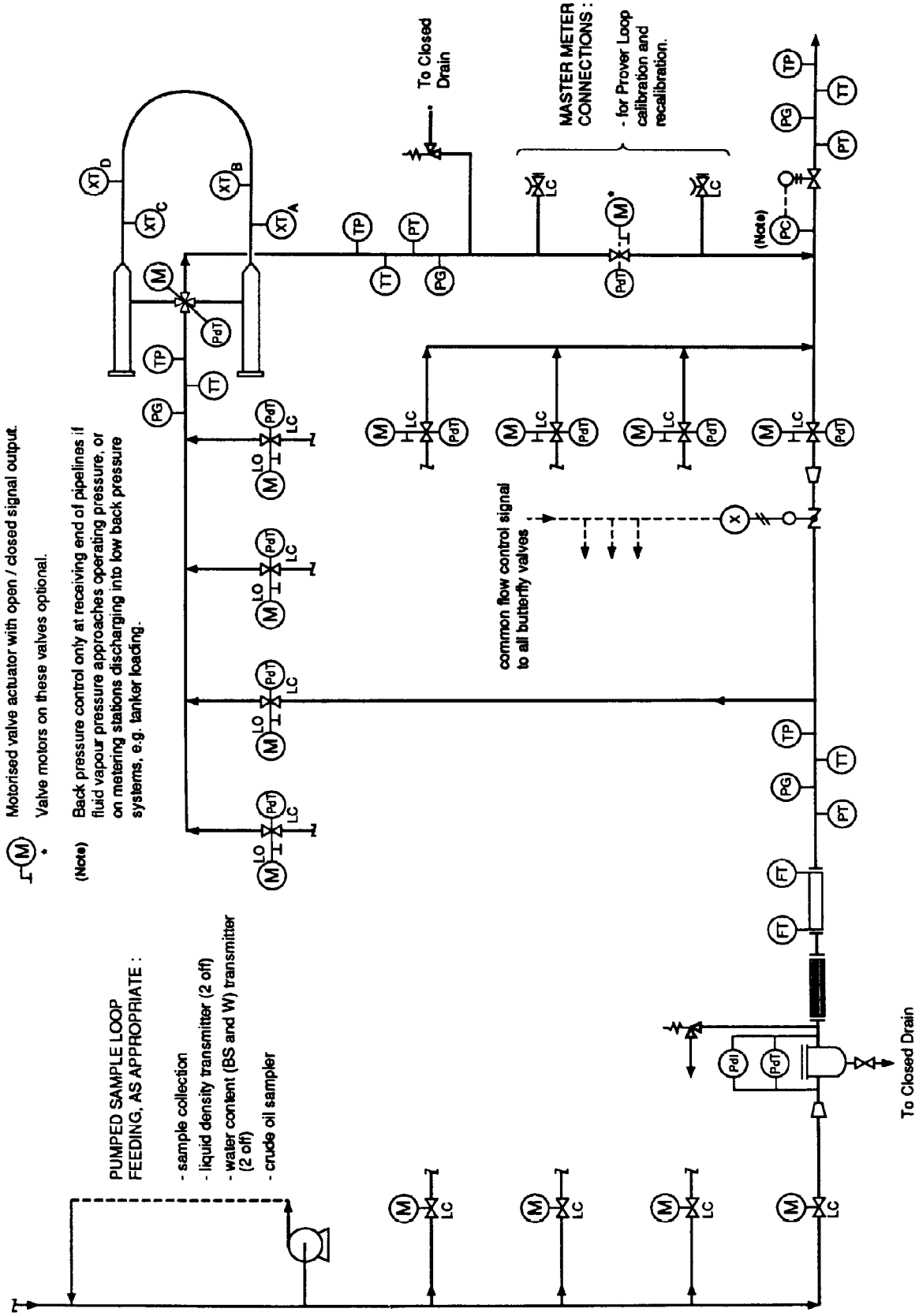
Issued by:
International Electrotechnical Commission
3 Rue de Varembé
1211-Geneva 20
Switzerland.

Liquid hydrocarbons; Volumetric measurements by turbine meter systems — ISO 2715

Issued by:
Central Secretariat of ISO
1 Rue de Varambé
1211-Geneva 20
Switzerland.

APPENDICES

APPENDIX 1 TYPICAL LIQUID HYDROCARBON FISCAL MEASUREMENT FLOW SCHEME



APPENDIX 2 FIELD SIGNAL CONNECTIONS AND TRANSFER

SIGNAL		MICRO COMPUTER		
DESCRIPTION	Type	Meter Run	Meter Prover	Station
pulse train from turbine meter (dual)	F	XX	PP	
density transducer frequency (2 off)	F	XX		XX
meter run outlet pressure	A	X	T	T
meter run outlet temperature	A	X	T	T
meter prover pressure	A	T	X	T
meter prover inlet temperature	A	T	X	T
meter prover outlet temperature	A	T	X	T
meter station inlet header pressure	A			X
water content (BS&W)	A	T		X
density transducer inlet header pressure	A			X
meter station outlet header pressure	A			X
meter station outlet header temperature	A			X
meter run outlet valve status	S	X	T	T
meter run outlet valve leakage signal	S	X	T	T
meter run proof inlet valve status	S	X	T	T
meter run proof inlet valve leakage signal	S	X	T	T
meter prover 4 way, or launch, valve status	S		X	
meter prover 4 way valve leakage signal	S		X	T
meter prover detector switches (4 off)	S		XXXX	
meter run outlet valve open/close command	S	X		
meter run proof valve open/close command	S	X		
meter run outlet butterfly valves modulated control	A		X	
meter prover 4 way (launch) valve command	S		X	
total flow proportional signal to sample system	A			X

A = Analog
F = Frequency
P = Connection only when a particular meter is in proof operation
S = Change of state (digital)
T = Data transferred from microcomputer having primary connections
X = Primary connections

APPENDIX 3 DISPLAY, TRANSFER AND UTILISATION OF DATA AND CALCULATED VALUES

DATA	MICRO COMPUTER		
	Meter Run	Meter Prover	Station
turbine meter pulse counts (dual)	S	S	
turbine meter 'k' factor	D	S	D
gross volumetric flow-rate	S	D	D
gross standard volumetric flow-rate	S	D	D
density transducer periodic time (2 off)	D or S		S
density computed (2 off)	D or S		S
meter run outlet pressure	S	D	D
meter run outlet temperature	S	D	D
mass flow-rate per meter run	S		D
accumulated volume, per meter run	S		D
accumulated mass, per meter run	S		D
total volumetric flow-rate for metering station			S
total mass flow-rate for metering station			S
accumulated volume for metering station			S
accumulated mass for metering station			S
pulse discrepancy counter, per meter run	S		D
density transducer constants (key-pad entered)	D		S
high and low flow alarms, per meter run	S		D
density deviation alarm			S
turbine meter counts per proof run (dual)		S	D
meter prover pressure		S	D
meter prover inlet temperature		S	D
meter prover outlet temperature		S	D
meter run outlet valve status (per meter run)	S	D	D
meter run proof inlet valve status (per meter run)	S	D	D
temperature and pressure correction factors for steel and liquid		S	D
meter proof initiation command	D	D	S
fluid water content (BS&W)	D		S
meter proof required alarm			S
meter run outlet valve leakage signal	S	D	D
meter run proof inlet valve leakage signal	S	D	D
meter prover 4-way valve leakage signal		S	D

S = Source of calculated data.
D = Destination of data calculated elsewhere.