

NORSOK STANDARD

**FISCAL MEASUREMENT SYSTEMS FOR
HYDROCARBON LIQUID**

I-105
Rev. 2, June 1998

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FOREWORD

NORSOK (The competitive standing of the Norwegian offshore sector) is the industry initiative to add value, reduce cost and lead time and eliminate unnecessary activities in offshore field developments and operations.

The NORSOK standards are developed by the Norwegian petroleum industry as a part of the NORSOK initiative and supported by OLF (The Norwegian Oil Industry Association) and TBL (Federation of Norwegian Engineering Industries). NORSOK standards are administered and issued by NTS (Norwegian Technology Standards Institution).

The purpose of NORSOK standards is to contribute to meet the NORSOK goals, e.g. by replacing individual oil company specifications and other industry guidelines and documents for use in existing and future petroleum industry developments.

The NORSOK standards make extensive references to international standards. Where relevant, the contents of a NORSOK standard will be used to provide input to the international standardisation process. Subject to implementation into international standards, the NORSOK standard will be withdrawn.

Annex A and B are normative. Annexes C, D and E are informative.

INTRODUCTION

This standard is a replacement of the previous NORSOK standards with respect to fiscal measurement systems for hydrocarbon liquid: I-CR-100 Fiscal measurements systems, I-SR-100 Automatic oil sampler, I-SR-105 Fiscal metering for crude oil and condensate, all revision 1, January 1995. This new standard has been subject to a total change in contents and structure.

The NORSOK standards for instrumentation shall be read in conjunction with this standard for supplementary requirements. However, if there are any inconsistency in relevant NORSOK standards, priority shall be given to this standard, Fiscal measurement systems for hydrocarbon liquid, I-105.

1 SCOPE

This standard describes the functional and technical requirements for fiscal measurement systems for liquid hydrocarbons. Further the standard provides criteria for selection of such systems or main components thereof.

2 NORMATIVE REFERENCES

The following standards include provisions which, through reference in this text, constitute provisions of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be provided if it can be shown that they meet or exceed the requirements of the standards referenced below.

API MPMS	Manual of petroleum measurement standard, chap. 4, 5, 11-13.
API MPMS, clause 8.2	Automatic sampling of petroleum and petroleum products.
API MPMS, clause 10.9	(corresponds to IP 386/90)
ASTM-D-4928-89	(corresponds to IP 386/90)
BIPM, et.al.*)	OIML P17, Guide to the expression of Uncertainty in Measurements.
ECMA-TR25	OSI sub-network interconnection scenarios permitted within the framework of ISO-OSI ref. model.
EN 60751	Industrial Platinum Resistance Thermometer sensors
IP 386/90	Determination of water content of crude oil - Coulometric Karl Fischer method
IP PMP No. 2	Guidelines for users of Petroleum Measurement Tables
IP PMM Part VII	Continuous Density Measurement
ISO 1000	SI units and recommendations for use of their multiples and of certain other units.
ISO 3170	Petroleum Liquids - Manual Sampling
ISO 3171	Petroleum Liquids - Automatic pipeline sampling.
ISO IEC 3309	Telecommunication and information; exchange between systems; high level datalink control (HDLC) procedure; frame structure.
ISO 5024	Measurement - Standard reference conditions
ISO 5167-1	Measurement of fluid flow by means of pressure differential devices – Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full
ISO 6551	Petroleum Liquids and Gases - Fidelity and Security of Dynamic Measurement - Cabled Transmissions of Electric and/or Electric Pulsed Data.
ISO 7278 Part 3	Liquid hydrocarbons - Dynamic measurement - Proving systems for volumetric meters"
ISO 9000-3	Guidelines for the application of the ISO 9001 to the development, supply and maintenance of software.
ISO 10723	Performance evaluation of on line analytical systems
NORSOK Z-010	Electrical, Instrumentation & Telecommunication installation

*) On behalf of BIPM, IEC, IFCC, ISO, IUPAC, IUPAP and OIML

3 DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

Allocation	Distribution of sold/produced quantities of hydrocarbons between licensees and owner companies.
Conventional system	A measurement system for oil/condensate with multiple meter runs and prover unit.
Fiscal quantity	Measured quantity of hydrocarbons used for sale, custody transfer, ownership allocation or calculation of royalty or tax. Note: The term "fiscal " refers to the function of the measurement system, not its level of measurement uncertainty.
ID	Internal pipe diameter.
Informative references	Shall mean informative in the application of NORSOK standards.
In-line	Total main pipe volume shall flow through the in-line unit.
May	Verbal form used to indicate a course of action permissible within the limits of the standard.
Normative references	Shall mean normative (a requirement) in the application of NORSOK standards.
Prover unit	Conventional pipe prover, master meter or other applicable method to calibrate the flow element.
Quantity	Measure of the hydrocarbon medium, by volume, mass or energy
Shall	Verbal form used to indicate requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted, unless accepted by all involved parties.
Should	Verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required.

3.2 Abbreviations

ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BIPM	International bureau of Weight and Measure
CEN	The European Committee for Standardization
ECMA	European Association for Standardizing Information and Communication Systems
EN	European Norm
FAT	Factory Acceptance Test
IEC	International Electrotechnical Commission
IFCC	International Federation of Clinical Chemistry
IP	Institute of Petroleum
IP PMP	Institute of Petroleum, Petroleum Measurement Paper
IP PMM	Institute of Petroleum, Petroleum Measurement Manual
ISO	International Organization for Standardization
IUPAC	International Union of Pure and Applied Chemistry
IUPAP	International Union of Pure and Applied Physics
LPG	Liquified Petroleum Gas
MPMS	Manual of Petroleum Measurement Standard

NPD	Norwegian Petroleum Directorate
NTS	Norwegian Technology Standards Institution.
OIML	International Organisation of Legal Metrology
OLF	The Norwegian Oil Industry Association.
OSI	Open system interconnections
PD meter	Positive Displacement meter
Pt-100	Platinum resistance thermometer
SAS	Safety and Automation System
TBL	Federation of Norwegian Engineering Industries.
VDU	Visual Display Unit

4 GENERAL REQUIREMENTS

4.1 General

The measurement system which fulfils the functional and technical requirements and has the lowest life cycle cost shall be selected.

Fiscal measurement systems for hydrocarbon liquid include all systems for:

- Fiscal measurement of liquid
- Water in oil measurement
- Sampling

All systems shall give readings and reporting in SI-units according to ISO 1000, except for pressure where the unit bar shall be used and for dynamic viscosity where the unit mPa·s shall be used.

The standard reference condition shall be 15,0 °C, 1,01325 bar absolute, ref. ISO 5024. LPG measurement could use other reference conditions in accordance with recognized standards.

For system concepts with no system specific requirements in this NORSOK standard, the design shall to the greatest possible extent, be based on (in order of priority):

- International standards, preferably ISO or CEN.
- The manufacturer's recommendations.

4.2 Uncertainty

Uncertainty limit (expanded uncertainty with a coverage factor $k=2$) for the fiscal oil measurement system shall be $\pm 0,30$ % of standard volume.

Any other uncertainty limit may be applicable for fiscal measurement systems if validated by a cost-benefit analysis performed and accepted by the operator (see Annex C).

The uncertainty figures shall be calculated for each component and accumulated for the total system in accordance with the following reference document: Guide to the Expression of Uncertainty in Measurement.

4.3 Sampling equipment

Automatic sampling equipment shall be installed. For determination of water content in oil, a continuous water-in-oil monitor shall be considered as alternative to automatic sampling and subsequent laboratory analysis. Sampling systems, however, may be needed for other analyses such as density, salt, sediments, composition analysis, and samples to be delivered to the customer etc. Such other use of the sampler shall be taken into consideration.

Manual sampling point shall also be installed.

4.4 Calibration

All instruments and field variables used for fiscal calculations or comparison with fiscal figures shall be traceably calibrated by an accredited laboratory to international/national standards.

All geometrical dimensions used in fiscal calculations shall be traceably measured and certified to international/national standards.

4.5 Computer design

The vendor shall develop a functional specification for the computer part. This document shall clearly specify all functions and features e.g. the applied algorithms, the sequences of the system, operator responses and error handling.

5 SALES AND ALLOCATION MEASUREMENT

5.1 Functional Requirements

5.1.1 General

The measurement system shall measure crude oil or condensate flow rates and accumulated quantities and control an automatic oil sampler system. Where applicable, approval by the national authorities is required.

5.1.2 Products/Services

Maximum pressure loss across the measurement station (Incl. in- and outlet headers) shall be 2,0 bar, with no meter calibration in progress and 2,5 bar, with meter calibration in progress.

Single liquid phase shall be maintained across the measurement station. For turbine meters the minimum back-pressure shall be in accordance with API MPMS chap. 5.3.4.3.

5.1.3 Equipment/Schematic

The measurement system shall consist of:

- a mechanical part including the flow meter and prover unit,
- an instrument part,
- a computer part performing calculation of quantities, reporting and system control functions.

The computer part shall be dedicated computer(s). However, the supervisory computer part may be a dedicated part of the SAS.

A compact design is encouraged to reduce space requirements and weight.

5.1.4 Performance

5.1.4.1 Capacity

The measurement system shall be capable of measuring the full range of planned quantities of hydrocarbon liquid through the measurement system. The flow rate in each meter run shall not exceed limits, which result from the total uncertainty limits for the measurement system, listed in subclause 5.1.4.2.

Note: NPD regulation requires one spare meter run for a multi-run metering station.

5.1.4.2 Uncertainty

The uncertainty limit shall be $\pm 0,30$ % (expanded uncertainty with a coverage factor $k=2$) of standard volume.

5.1.4.3 Lifetime

The lifetime is application specific.

5.1.4.4 Availability

The measurement system shall be designed for continuous measurement of all expected flow rates.

5.1.5 Process/Ambient Conditions

Ref. to process data sheet (project specific).

5.1.6 Operational Requirements

5.1.6.1 General

The measurement system shall be operated from the computer part. The measurement system shall also be operable from SAS.

It shall be possible to measure the oil flow, operate the system and perform proving even if the supervisory computer fails completely.

The system shall automatically perform all line/ valve control for meter runs that are in service mode, as required during normal operation and during the proving phase. There shall also be a manual mode for such operations.

The meter run inlet valves and the prover/master meter outlet valve shall only be manually operated.

It shall be possible to operate all valves locally.

The closing of the last open meter run shall only be possible in manual mode.

During normal operation the proving sequence shall be automatically started and performed on specified deviation criteria (e.g. flow rate deviation, density deviation, time since last proving). It shall be possible to start the proving sequence manually while in automatic mode and to disable the automatic mode. It shall also be possible to perform a proving sequence for one trial manually in a step-by-step manner.

Continuity in measurement of the oil flow shall be maintained during regular calibration of the field instruments and whenever a field instrument of any type fails.

5.1.6.2 Tanker loading measurement system

In automatic mode the different phases in a loading sequence such as start-up, loading, topping off and termination shall be pre-programmed in the computer. The computer shall automatically calculate and set the sampling rate when given the size of the oil batch.

The measurement system shall apply batch retroactive K-factor for the first meter calibration during the batch. Electronic batch totals shall be incremented or decremented immediately upon determination of the retroactive K-factor. Any non-resettable counters that can not be decremented shall have separate decrement-registers (reset to zero at start of batch) to be incremented to zero before counting continues in non-resettable counters.

When no batch is in progress, any flow passing through the measurement system shall be accumulated in non-resettable non-batch totals.

5.1.7 Maintenance Requirements

5.1.7.1 General

The field instrumentation should be chosen to ensure long maintenance and calibration intervals.

The maintenance requirements for automated condition based maintenance in Annex A shall apply. In addition, it should be easy to retrofit the instruments and flow elements for maintenance.

5.1.7.2 Calibration

Locations where checking and calibration take place shall be protected against environmental influences and vibrations such that the requirements given in this standard can be fulfilled.

It shall be possible to calibrate all instruments and separate components in the electronic loop either without moving them from their permanent installations and without disconnecting any cables, or by using transmitters fitted with quick connectors (for removal for calibration/ maintenance). An exception to this will be a flow meter that requires off-line calibration.

If it is impossible to calibrate the meter at the relevant process conditions, the meter shall at least be calibrated for the specified flow velocity range.

Density meter cables shall be equipped with quick connectors for easy retrofit.

There shall be connections for in-situ calibration of the prover unit.

The computer part shall be designed so that during calibration the amounts shall be registered separately and independently of measured amounts.

In calibration mode, the flow time shall be registered and displayed by the flow computer/computer system.

5.1.7.3 Maintenance

It shall be easy access to any part requiring regular calibration and maintenance. Facilities to ease the calibration shall be included in the system or offered as an option.

It shall be possible to maintain the mechanical part of the system without dismantling the manifolds (or similar).

The software shall provide means of calling up live transmitter values (one at a time) onto the operator workstation for purpose of calibration. The input shall be displayed in engineering units. Input shall be displayed on VDU with the same time period as read by the I/O system i.e. no average.

5.1.7.4 Isolation and Sectioning

It shall be possible to isolate the prover unit for uninterrupted metering during calibration.

5.1.7.5 Thermal Insulation

The insulation/heat tracing shall be removable for test and field calibration of instruments in the measurement system.

5.1.8 Layout Requirements

Bypassing of the measurement system is not permitted.

Sufficient upstream lengths of pipe shall be installed, including space to allow for necessary filters, strainers and flow conditioners.

Ultrasonic flow meters shall not be installed in the vicinity of pressure reduction systems (valves etc.), which may affect the signals.

5.1.9 Interface Requirements

Computer part interfaces:

- If dedicated computer: SAS.
- Sampling system.
- Production database and allocation systems.

5.1.10 Testing and Commissioning Requirements

The testing and commissioning requirements given in Annex B shall apply.

5.2 Technical requirements

5.2.1 General

The requirements below are only relevant if the specified component is part of the measurement concept.

5.2.2 Mechanical part, exclusive prover unit

5.2.2.1 Sizing

The measurement system shall be designed to measure any expected flow rate with the meters operating within:

- 80 % for continuous metering
- 90 % for batch metering

of their standard range (not extended).

5.2.2.2 Meter runs

The design shall be according to API MPMS Chap. 5. Only symmetrical reducers/expanders shall be used between meter run strainer and flow meter.

5.2.2.3 Flow meter designs

The linearity shall be better than:

- 0,50 % (band) for 1:10 turndown using 1 mPa·s water.
- 0,50 % (band) for maximum stated turndown on product.
- 0,30 % (band) for optimal stated turndown on product.

The repeatability shall be better than 0,040 % (band) within linear range on water and product (5 successive repeats). A statistical method may be used. (Student-t at 95% confidence level)

The flow meter shall have a minimum turndown ratio of 1:10.

Turbine and PD meters:

Turbine meters shall be according to API MPMS Chap. 5.3. The rotor shaft shall be supported upstream and downstream of rotor. The rotor shall be hydrodynamically balanced between the supports.

PD meters shall be according to API MPMS Chap. 5.2.

There shall be dual pulse train with direct transmission of flow meter pulses to the computer part. The pulse integrity shall be to ISO 6551, grade A, or equivalent.

Ultrasonic meters:

The number of paths for ultrasonic meters shall be determined by required uncertainty limit.

All geometric dimensions of the ultrasonic flow meter that affect the measurement result shall be measured and certified using traceable equipment, at known temperatures. The material constants shall be available for corrections.

The meter shall be designed and installed so that any accumulation in the form of gas or solid particles in the vicinity of the transducers is avoided.

The meter shall, either by its own design or by necessary piping arrangements always be available for necessary maintenance.

For the meter run, the minimum straight upstream length shall be 10 ID. The minimum straight downstream length shall be 3 ID. Flow conditioner of a recognized standard shall be installed, unless it is verified that the ultrasonic meter is not influenced by the layout of the piping upstream or downstream, in such a way that the overall uncertainty requirements are exceeded.

Ultrasonic meters may be used bidirectionally. In this case both ends of the meter shall be considered as upstream, and thermowells shall be placed outside the 10 ID on either ends.

Gaskets between meter run and pipe section shall not protrude into the meter run.

Other types of meters:

Project specific.

5.2.2.4 Block valves

The block valves critical for meter calibration and calibration of prover unit, shall be of double-block-and-bleed type, shall have no contact with sealing during operation, and shall have positive shut-off (dual expanding seals).

Other types of valves may be considered for the stream inlet valves.

The leakage control shall be by automatic or manual monitoring of block valves. There shall be automatic monitoring of the flow diverter valve in the prover unit.

The valves for stream control and meter calibration control shall have automatically operated actuators with failsafe “stay in position”. Flow direction shall be clearly stated on valve bodies.

Electrical positioner shall be used for remote control, in addition to limit switches for on or off positions. Any flying leads shall be protected with a flexible conduit.

Valves for non-critical applications (stream inlet/prover outlet) may be manually operated.

5.2.2.5 Flow control

The flow control shall not influence the production/total flow through the measurement system. There shall be active flow control to achieve stable flow at target value prior to start of calibration run. The flow control shall also achieve stable flow at target value during calibration, for meter run under calibration. There shall be no active flow control during calibration trials.

The flow control valve shall be located downstream of flow meter/calibrated volume combination.

Flow control valves shall move to open position on power supply failure or signal failure.

5.2.2.6 Relief valves

The relief valves shall not be located between the flow meter and exit of calibration unit to ensure the integrity of the calibration volume.

5.2.2.7 Drain and vent systems

The system shall have:

- Closed drain and vent system, each with single connection at system limit.
- Double block-and-bleed valve arrangement with spectacle blind in drain and vent lines.

5.2.2.8 Thermal Insulation

If exposed to ambient conditions, the meter runs including temperature, density, sampling system etc. may be thermally insulated and/or heat traced.

The ultrasonic flow meter with associated meter tube should be thermally insulated upstream and downstream including temperature measurement point, in order to reduce temperature gradients.

5.2.3 Mechanical part, prover unit

5.2.3.1 General

The capacity of the prover unit shall correspond to the maximum of flow meter standard range.

3 blinded connections with block valves shall be installed to enable serial and parallel calibration of the prover unit. The prover unit shall be calibrated before delivery from the manufacturer.

If exposed to ambient conditions, the prover unit including temperature etc. may be thermally insulated and/or heat traced.

5.2.3.2 Conventional Pipe Prover

The prover shall be bi-directional or unidirectional, according to API MPMS Chap. 4. Interpolation may be used to achieve 0,01% pulse resolution. The prover shall have 4 distinct, calibrated volumes with two detector switches at either end.

The prover shall be equipped with:

- Quick opening cover on displacer home chamber.
- Specially designed flanges in pre-run/calibrated section.
- The inner surface, rubber sealings, lining of prover, etc. shall be of a material that is compatible with and can withstand the oil flowing through.

4-way valve of large size should have a hydraulic actuator.

The design shall minimise dynamic forces during diverter valve operation.

The uncertainty limits are: $\pm 0,04$ % of calibrated volume (expanded uncertainty with a coverage factor $k=2$).

The repeatability shall be within: 0,020 % (band) for 5 successive repeats

5.2.3.3 Compact Prover

The prover shall be design according to API MPMS Chap. 4.3.

The uncertainty limits are: $\pm 0,04$ % of calibrated volume (expanded uncertainty with a coverage factor $k=2$).

The repeatability shall be within: 0,020 % (band) for 5 successive repeats.

5.2.3.4 Master Meter

Same requirements shall apply as in clause 5.2.2.3 Flow meter designs.

5.2.4 Instrument Part

5.2.4.1 Location of sensors

Pressure and temperature shall be measured in each of the meter runs. When metering oil, the pressure and temperature shall also be measured at the inlet and outlet of the prover unit. Density shall be measured by at least two densitometers in the metering station. The density measurement device shall be installed so that representative measurements are achieved. Pressure and temperature shall be measured as close as possible to the density measurement.

5.2.4.2 Instrument panel and supplies

Field instrument cable entry shall be metric threads. The electrical supply for field instrumentation used for fiscal measurement systems shall be powered from the instrument panels. The instrument panels shall be supplied from UPS. All flow passing a fiscal measurement system shall be measured. The power supplies to the measurement system shall be designed for this operation philosophy.

5.2.4.3 Signal Types

For measurement systems instrument field bus/digital communication shall be entirely implemented i.e. so it can be utilised for diagnostic purposes. All transmitters shall be of smart type where available.

5.2.4.4 Stability for smart transmitters

For smart pressure transmitters the stability shall be equal or better than $\pm 0,1\%$ of upper range limit for 12 months. For smart temperature transmitters the stability shall be equal or better than $\pm 0,1\text{ }^{\circ}\text{C}$ for 24 months.

5.2.4.5 Temperature loop

For fiscal measurement applications the smart temperature transmitter and Pt-100 element should be two separate devices where the temperature transmitter shall be installed in an instrument enclosure connected to the Pt-100 element via a 4-wire system. Alternatively, the Pt-100 element and temperature transmitter may be installed as one unit where the temperature transmitter is head mounted onto the Pt-100 element (4- or 3-wire system).

The Pt-100 element should as a minimum be in accordance to EN 60751 tolerance A.

The temperature transmitter and Pt-100 element shall be calibrated as one system where the Pt-100 element's curve-fitted variables shall be downloaded to the temperature transmitter before final accredited calibration. The loop uncertainty shall be better than $\pm 0,15\text{ }^{\circ}\text{C}$ (expanded uncertainty with a coverage factor $k=2$).

5.2.4.6 Thermowells

For fiscal measurement systems, thermowells for pressure class below class 2500 shall be of threaded/screwed type.

All thermowells shall at least be inserted $1/3$ ID into the pipe, but less than $1/2$ ID.

A reference thermowell shall be installed within 2 ID of the primary thermowell.

Thermowells shall be installed in 10 - 2 o'clock position to allow for liquid filling of the well.

The design shall avoid vibration to flow meter maximum extended range. The vibration calculation shall be done for normal flow rate in addition to 10% increased flow rate with respect to maximum flow rate. Ref. ANSI/ASME Performance Test Code 19.3 - 1974, section 8-19 thermowells.

Thermowells inner diameter suitable for elements of 6 mm should be used.

Thermowells shall be mounted in such a manner that the temperature element can be installed and removed from the well for maintenance reasons.

5.2.4.7 Density

Continuous measurement of density is required.

There shall be automatic selection of best available measured or fallback value for density.

The design shall be in accordance with IP PMM Part VII.

The density shall be measured by the vibrating element technique. Density calculation and calibration shall be in accordance with company practice. The density shall be corrected to the conditions at the fiscal measurement point.

There shall be direct transmission of densitometer pulses/frequency signal to the computer part or via smart communication. Reference is made to subclause 5.2.4.3 Signal types.

Uncertainty: $\pm 0,30$ % of measured value, for complete density circuit, including drift between calibrations (expanded uncertainty with a coverage factor $k=2$).
Specified uncertainty: $\pm 0,50$ kg/m³ or better for densitometer (expanded uncertainty with a coverage factor $k=2$).
Specified repeatability: $\pm 0,02$ % or better for densitometer.

5.2.4.8 Ultrasonic Flow Meter

For the ultrasonic flow meter, critical parameters relating to electronics and transducers shall be determined. It shall be possible to verify the quality of the electric signal, which represents the acoustic pulse, by automatic monitoring procedures in the instrument or by connecting external test equipment.

The transducers shall be identified by serial number or similar to identify their location in the meter body. A dedicated certificate stating critical parameters shall be attached.

5.2.4.9 Differential pressure for leakage control

Such devices may be installed across strainers and block valve cavities. Reference is made to design requirements in Norsok standard I-001.

5.2.4.10 Local Indicators

Where local indicators are required, local indicators on the smart transmitters can be used as alternative to local gauges.

5.2.4.11 Local pressure indication

For meter tubes/runs, which require pressure or depressurisation system for maintenance purposes, a local indication of pressure shall be installed on the high-pressure side.

5.2.4.12 Instrument ball valve

For fiscal measurement applications, ball valve manifold block or an assembly of discrete components ball valves shall be applied (3/5-valve). Final valve arrangement shall be installed in instrument enclosure and be service friendly. In general, the valves shall not be less than 9 mm bore, however the equaliser valves and test valve can be 4 mm bore. The test port shall be equipped with quick connector.

5.2.4.13 Instrument tubing

For fiscal measurement systems the instrument impulse tubing shall not be less than 9 mm ID. The tubing length should be kept as short as possible.

The slope of the impulse lines should be no less than 1:12. All instrument tubing shall be installed so that “gas traps” are avoided.

5.2.4.14 Enclosures

Enclosures shall be used for stream pressure and temperature transmitters. The type shall be fire retardant Glassflake Reinforced Polyester (GRP). If the instruments are installed in exposed area enclosure shall be insulated, heated and temperature controlled.

For by-pass densitometer a clamp on type fire retardant GRP enclosures should be utilised.

5.2.4.15 Displacer detector switches

Displacer detector switches shall use direct EEx d wiring.

5.2.5 Computer Part

5.2.5.1 General

The computer part shall consist of a sufficient number of computers performing the functions specified below, VDUs, printers for reporting, and a communication system for transferring signals to other systems.

5.2.5.2 Computer Design

The software for calculation of fiscal quantities shall be stored in a secure and resident manner.

Reference is made to ISO 9000-3.

Version number shall identify the present software program version(s). Change of version number shall be implemented every time permanent program data is altered. It shall be possible to determine the present program version directly from VDU and/or printouts.

The update time shall be less than 2 seconds for the VDU update and the resolution shall be sufficient to verify the requirement for calculation accuracy. Any displayed values shall be presented by 8 significant digits if necessary. This shall be valid in the normal range of any parameter and $\pm 10\%$ of this value.

Change of fiscal day for continuous measurement systems will be project specific e.g. 00:00 or 06:00 each day.

The flow computers shall be equipped with battery supported RAM, certified EEx ia, to safeguard warm start after minimum 1 year power off.

Pulse integrity handling shall be according to ISO 6551, level A.

Pulse interpolation to meet requirement for 0,01% volume resolution during meter calibration, according to ISO 7278, Part 3.

Input signals:

Signals from prover unit displacer detectors shall be read as interrupts. Signals from all instruments in one meter run shall be read during 1 second, except for temperature and density, which may be read every 5 seconds. Signals from duplicated instruments shall be read within 0,5 second. A/D conversion shall be by 14 bits minimum. The system shall accept any manual input necessary to perform calculations mentioned below for any measured value. The manual input values shall be verifiable without rounding off or truncation of digits.

Output signals:

D/A conversion for fiscal purposes shall be by 14 bits minimum.

5.2.5.3 Process operator interface

The process operator interface shall as a minimum comprise:

- Graphic user interface.
- Meter run control.
- Batch control (batch measurement systems).
- Meter calibration control.
- Security control of operator entered parameters.

The graphic user interface shall include a simplified P&ID with process variables and valve status. It shall be possible to operate all valves from the graphics.

5.2.5.4 Computer system interface

The computer system (supervisory) interface shall as a minimum comprise:

- Graphic user interface.
- Meter run control.
- Batch control (batch measurement systems).
- Meter calibration control.
- Security control of operator entered parameters.
- System monitoring.
- Trouble shooting.
- Software updates.
- Tape drive and / or CD-ROM.

The graphic user interface shall include a simplified P&ID with process variables and valve status. It shall be possible to operate all valves from the graphics.

5.2.5.5 Calculations

The computer shall calculate flow rates and accumulated quantities for

- i) actual volume flow,
- ii) standard volume flow and
- iii) mass flow.

All calculations shall be performed to full computer accuracy. (No additional truncation or rounding.)

The interval between each cycle for computation of instantaneous flow shall be less than 10 seconds.

Where the interval between the calculations extends over several updates of input data, the mean value of input data shall be used in the computations.

Algorithm and truncation/rounding errors for computations in the computer part shall be less than $\pm 0,001$ %. This requirement shall be verifiable.

The computer part shall include electronic means for storing accumulated fiscal quantities for each meter run and the total measurement system. These figures shall also be stored in back-up files. The figures shall be stored for the time period that is regarded as necessary. The files shall be secured in such a way that they can not be zeroed or altered unless a special security method is followed.

When calculating oil volume all correction factors C_{tlm} , C_{plm} , C_{tsp} , C_{psp} , C_{tlp} and C_{plp} , according to API MPMS Chap. 11 and 12 shall be implemented. The compressibility factors shall be calculated according to API MPMS Chap. 11.2.1.

The correction factors C_{tsm} and C_{psm} should also be implemented. The accuracy of C_{tsm} and C_{psm} should be evaluated before implementation.

$$C_{tsm} = (1 + E_h \cdot (T_m - T_r))^2 \cdot (1 + E_r \cdot (T_m - T_r))$$

where

T_m = Temperature at the meter

T_r = Standard reference temperature

E_h = linear temperature expansion coefficient of the meter housing

E_r = linear temperature expansion coefficient of the meter rotor

$$C_{psm} = 1 + (P_m - P_r) \cdot Y$$

where

P_m = Pressure at the meter

P_r = Standard reference pressure

$$Y = (2-e) \cdot 2R / \{ E \cdot [1 - AT/\pi R^2] \cdot 2t \}$$

where

e = Poisson ratio

R = Radius of the meter housing

E = Elasticity module

AT = Area of rotor

t = Thickness of meter housing

The combination of the correction factors shall be according to API MPMS Chap. 12. Calculation of standard density from measured density and calculation of operating density from standard density, using the correction factors above, shall be implemented. The parameters in the calculation of each correction factor shall be user selectable.

Calculation of all required values for reports and VDU shall be implemented.

That is for continuous measurement systems (pipelines):

- hourly and daily totals and maintenance mode totals,
- average flow rates,
- average flow-weighted by volume K-factors and process values.

That is for batch measurement systems (tanker loading):

- batch totals, non-batch totals and maintenance mode totals,
- average flow rates,
- average K-factors and process values, all average values shall be flow-weighted by volume.

The resolution on the VDU shall be sufficient to verify the requirements for calculation accuracy.

5.2.5.6 Check

Comparisons shall be implemented between duplicated instruments measuring the same process value. Comparisons shall also be implemented between instruments measuring the same process value in different meter runs. Comparisons shall be based on values averaged over a moving time window to be operator selectable between wide intervals (that is from 1 second to 10 minutes).

Facilities shall be included to enable user verification of functions, parameters and accuracy for input values, calculated values and output values.

Auto selection of back-up density in the event of a densitometer failure.

Ultrasonic check:

All parameters relevant for verifying the condition of the meter shall be included in the self-check or user verification of the meter. The computer shall be prepared for zero flow point check of the transducers, e.g. by using an external test cell.

5.2.5.7 Alarms

The alarm system shall raise alarms, print out alarms and/or save alarms to external file, if any comparison check exceeds operator selected limits or if any measured value is outside predetermined limits or in case of indication of instrument failure, computer failure or failure in valve operation.

The alarm system shall be designed in a flexible way, fulfilling as a minimum the following requirements:

- For all alarms it shall be possible, under password/key-switch protection,
 - to suppress or enable the alarm and
 - apply time delay for filtering purposes.
- A list of all suppressed alarms shall be available on screen and printer and external file.
- Grouping of alarms shall be considered in order to reduce the number of alarms to a minimum.
- Hardware and software watchdog alarm shall be implemented.

5.2.5.8 Events

The system shall log all events as a result of system or operator action to external file and printer.

The events shall include manually entered parameters on the computer part that may be changed by an operator.

5.2.5.9 Reporting of data for continuous measurement system

The computer shall generate quantity reports containing as a minimum:

- current flow rates and process values,
- all totals, and
- average K-factors and process values, all average values shall be flow-weighted by volume.

Reports for the following intervals shall be available: current status (no average values), hourly and daily.

The computer shall provide proving reports. All correction factors applied in the calculation and all data required for manual checks of the calculated correction factors shall be included in the report.

The reports above shall be printed automatically but it shall also be possible to suppress the printing of the reports. The reports shall also on request be shown on VDU. When fixed values or fallback values are used instead of the live signals sometime during the report interval, this shall be visually identified on the print out and on the VDU.

The reported data shall be for each meter run and with totals for the measurement system.

If the reporting computer is down across change of hour or day, the quantities thus not reported for the expected time period shall be automatically recovered and reported with the first report that is generated when the computer comes back in service.

Printing of measurement reports shall be on a separate fast laser printer.

Trend curves shall be available on VDU and printers as well as in tabular form, showing values representing measured and calculated flow and process values, for user selectable time periods (that is from one hour to 62 days). The displayed values shall represent the measured and calculated values for a time interval adapted to the selected time period, using data reduction. For each measured and calculated value, the data reduction shall as a minimum produce the minimum, maximum, current and average values for the time interval. For the last hour the time interval shall be maximum 10 seconds. There shall be continuous updating of a live trend curve for the last hour, for all values. Zoom facilities shall be available in both x and y direction. Screen dump facility shall be available.

5.2.5.10 Reporting of data for batch measurement system

The computer shall generate quantity reports containing as a minimum:

- current flow rates and process values,
- all totals, and
- average flow-weighted by volume K-factors and process values.

Reports for the following intervals shall be available: accumulated quantity from start of batch, hourly and total batch.

The other requirements are the same as for continuous measurement system (see subclause 5.2.5.9).

5.2.5.11 Storing of data for continuous measurement system

1-hourly reports to be stored to computer file for 62 days, daily reports for 1 year, calibration reports for 1 year.

Only reports for successful meter calibration to be stored.

All measured and calculated values averaged over the moving time windows shall be stored in computer file for 62 days.

Alarm and event reports to be stored to computer file for 10 days.

5.2.5.12 Storing of data for batch measurement system

1-hourly reports to be stored to computer file for 62 batches, batch reports for 400 batches, calibration reports for 400 batches.

Only reports for successful meter calibration to be stored.

All measured and calculated values averaged over the moving time windows shall be stored in computer file for 62 batches.

Alarm and event reports to be stored to computer file for 10 batches.

5.2.5.13 Availability

The computer part shall have fault tolerant design to maintain fiscal measurement, calculations and file storage during error conditions.

The computer part shall be designed in such a way that maximum oil flow can be measured even if a single failure occurs within any level of the computer part.

The availability of the fiscal computer system shall be documented and better than 99.5% availability.

The ultrasonic flow meter shall be designed such that measurements of acceptable quality can be achieved when one transducer pair is out of service.

5.2.5.14 Network Protection/Security

If the flow computers or supervisory computer(s) are connected to a network appropriate security and protection shall be applied, i.e. only dedicated computers shall have access to the measurement computers. Network communication shall utilise a protocol where protection and security is a part of the protocol. Recognised standards are ISO IEC 3309 and ECMA-TR25 or equivalent.

The computer system shall in addition include an efficient security system using system features, utilities and hardware.

Self check and self diagnostics at cold start, warm start and continuously during normal operation

The algorithms and fixed parameters important for accurate computation of fiscal quantities shall be secured in a way that makes direct access impossible, unless an established security routine is followed. There shall be protection against unauthorised data entry by password or key switch. The selection of automatic or manual operation shall be protected by password or key switch.

5.2.5.15 Expandability

For future computer expandability a maximum limit at maximum load to the following computer parts shall be:

- The software, including programs and data shall not occupy more than maximum 50% of the computer memory at any time.
- No more than 50% of the computer disk capacity shall be utilised.
- The system, application and communication software shall require less than 50% of the CPU capacity.
- Input data from the field must be equipped to handle 25% extra points.
- The system must be able to handle 25% extra flow per station or flow computers.

5.2.5.16 Time Synchronisation

A secure handling of daylight saving time and time through day, month and year shall be included.

The fiscal measurement computer system shall be synchronised from a Radio Clock, either directly or via the SAS system.

The system shall operate correct i.e. calculate and report correct regardless of change in day, month, year, decade etc.

5.2.5.17 Downloading of Constants and Ranges

Last versions of constants and ranges are to be downloaded to the flow computer upon initiation, restart or on operator request. In addition, it shall be possible in a secure manner, to download single constants or ranges to the flow computer. Some data consisting of several data items must be downloaded as complete data sets. This applies to e.g. densitometer constants.

The supervisory computer must verify that the flow computer has received the current value. The value downloaded must be shown together with the value read back from the flow computer.

All values to be changed shall be stored to disk on supervisory computer.

It shall be possible to request a configuration/parameter report at any time.

5.2.5.18 Automatic restart

The system must be capable of orderly shutdown in the event of a total power failure or major transient. Restart after power failure shall be automatic and shall include restart for all features, devices and programs including correct time from a radio clock, or a battery backed up calendar clock.

5.2.5.19 Background Compilation and Execute Capability

The system may have the capability for program compilation and execution in a background mode without disturbing the continuous functions operating in the foreground. It must be possible to build, replace, and initiate foreground tasks without interrupting other system functions.

6 WATER IN OIL MEASUREMENT

6.1 Functional requirements

6.1.1 General

The water-in-oil meter shall automatically and continuously measure the percent of produced water by volume in a crude flow at line conditions. In addition the percent of produced water shall be calculated by volume at standard condition and on mass basis.

6.1.2 Products/services

Not applicable.

6.1.3 Equipment/schematic

The meter should be installed in-line to assure a good measurement of the water-in-oil. The measurement shall be continuous and the response time of the measured values should be maximum one second.

6.1.4 Performance

6.1.4.1 Capacity

The water-in-oil meter shall perform within the required uncertainty limits for the full turndown ratio of the measurement station.

6.1.4.2 Uncertainty

The uncertainty limits are (expanded uncertainty with a coverage factor $k = 2$):

- $\pm 0,05$ % volume absolute from 0 to 1 % volume water content.
- $\pm 5,0$ % of reading above 1 % volume water content.

The repeatability shall be better than 0,50 % (band) above 0,01 % volume water content (5 successive repeats).

Acceptable uncertainty limits for the most critical parameters influencing the water-in-oil measurement shall be determined, reference is made to subclause 4.2.

6.1.4.3 Lifetime

Project specific.

6.1.4.4 Availability

The system shall be designed for continuous measurement or calculations of all expected flow rates.

6.1.5 Process/Ambient conditions

The water-in-oil meter shall automatically compensate for changes in process and/or ambient conditions influencing the accuracy of the meter, reference is made to process data sheet (project specific). For conversion calculations from flowing conditions to reference conditions, see Annex D.

6.1.6 Operational Requirements

A digital link should be available for configuration and calibration purposes of the water-in-oil meter.

6.1.7 Maintenance requirements**6.1.7.1 Maintenance**

- It shall be easy access to any part requiring regular calibration and maintenance. Facilities to ease the calibration shall be included in the system or offered as an option.
- It shall be possible to maintain the mechanical part of the system without dismantling the manifolds (or similar).
- The software shall provide means of calling up live transmitter values (one at a time) onto the operator workstation for purpose of calibration. The input shall be displayed in engineering units. Input to be scanned on screen with same time period as read by the I/o system i.e. no average.

6.1.7.2 Isolation and sectioning

It shall be possible to isolate unit for uninterrupted metering during maintenance.

6.1.7.3 Layout requirements

Piping arrangement shall allow bypassing the in-line water-in-oil meter.

The water-in-oil meter should be located as close as possible to the fiscal measurement station.

Water-in-oil meters may alternatively be installed in each meter run, downstream of the primary measuring device.

The water-in-oil meter shall only be mounted in locations where there is a sufficiently well mixed flow-regime for the type of meter in use.

Vertical mounting will help to ensure adequate mixing. It should be assured that the meter is installed where the fluid velocity is sufficient. A static mixer may be installed upstream of the water-in-oil meter to ensure good mixing.

6.1.8 Interface requirements

Computer part interface to supervisory oil metering computer or alternatively via flow computer.

6.1.9 Testing and commissioning requirements

FAT (Factory Acceptance Test) to be carried out before ex work delivery. FAT to include functional test and verification of calculation accuracy.

6.2 Technical requirements

6.2.1 Mechanical part

Water-in-oil meters with no moving parts are preferred.

6.2.2 Instrument part

The output values from the water-in-oil meter shall be available as either a 4-20 mA signal, frequency signal and/or via digital communication.

6.2.3 Computer part

For an example of water-in-oil calculations see Annex D.

Version number shall identify the present software program version(s). Change of version number shall be implemented every time permanent program data is altered. It shall be possible to determine the present program version directly from VDU and/or printouts.

Facilities shall be included to enable user verification of functions, parameters and accuracy for input values, calculated values and output values.

The computer shall be prepared for check of sensor calibration against reference fluids.

7 OIL SAMPLER SYSTEMS

7.1 Functional requirements

7.1.1 General

The system shall collect and store a representative oil sample at line conditions, allowing it to be transported to the laboratory for repeatable analysis. The system shall be mounted close to the pipeline and collect samples over a specific sample period (e.g. a day, a week, a month or for a batch) unattended. Adequate mixing equipment shall, if deemed necessary be installed upstream of the sampling probe.

The measurement system shall control the automatic oil sampler system:

- provide a flow proportional by volume pacing signal (and a fallback signal),
- monitor the sample volume collected and status of the sampling system.

In addition, there shall be a manual sample point, where the manual sampling probe shall be installed such that a representative sample of the process fluid can be collected. Adequate mixing equipment shall, if deemed necessary be installed upstream of the sampling probe. However, if an auto-sampler is included in the measurement system the manual sampling may be taken from the same probe.

7.1.2 Products/Services

Not applicable.

7.1.3 Equipment/schematic

The system shall be designed in accordance with ISO 3171. Optionally the amendments and supplements to ISO 3171 as specified in Annex E shall be adhered to (project specific).

The sample equipment shall be contained in cabinet(s) except for:

- The probe- or in-line extractor
- Piping from/to the mainline
- The back-pressure system
- Static in-line mixer (if applicable)
- Pump (project specific)

The cabinet(s) shall be located as close as possible to the sampling point.

The cabinet(s) shall be insulated and heated to keep temperature of the fluid in the sampling system at least 10 °C above the wax appearance (if applicable) or pour point temperature, whichever is the highest. This shall, if necessary, be achieved by using heat tracing and insulation of the piping and sample receiver. The heating shall be adjustable.

The manual sample point shall be equipped with flushing facilities and a cabinet with required valves and quick connectors in addition to an arrangement where the sample cylinder can be placed during spot sampling.

7.1.4 Performance**7.1.4.1 Capacity**

Receiver size to allow for 10000 grabs per sample period within 80% of filling range. Grab size shall be minimum 1 ml. For batch loading number of grabs per sample may be limited by maximum sampling frequency.

7.1.4.2 Uncertainty

Reference is made to ISO 3171.

7.1.4.3 Lifetime

Project specific.

7.1.4.4 Availability

The system shall be designed for continuous measurement or calculations of all expected flow rates.

7.1.5 Process/Ambient Conditions

Project specific on data sheets.

7.1.6 Operational Requirements

- The control function shall be done from a dedicated controller, SAS or a metering system.
- There shall be continuous monitoring in the control unit of the sample volume collected and of maximum filling alarm.

7.1.7 Maintenance Requirements

There shall be easy access in cabinet(s) to all main components and valves.

7.1.8 Isolation and sectioning

It shall be possible to isolate the system from the main process.

7.1.9 Layout Requirements

The sampling system should be located as close as possible to the fiscal measurement station.

7.1.10 Interface Requirements

The system shall be able to communicate with:

- the pacing device
- controlling device (if metering computer or SAS)
- SAS (if the system has dedicated computer)

7.1.11 Testing and commissioning Requirements

The following Factory Acceptance Tests shall be done:

- The test in ISO 3171, sect 15,3 f).
- Verification of the efficiency of mixing according to ISO 3171, sect. 12.3.
- Flow test to check that a known sample (with max water) is coming through to the receiver.

7.2 Technical requirements

None. Optionally Annex E shall apply.

ANNEX A REQUIREMENTS FOR AUTOMATED CONDITION BASED MAINTENANCE (NORMATIVE)

A.1 General

The fiscal measurement station shall be designed for fully automated condition based maintenance. This includes the ability to automatically verify the current condition of all measured field tags that are of importance to the integrity of the fiscal measurement station. These field tags are typically pressure, temperature, density, differential pressure, flow values (turbine meter k-factor, ultrasonic meter values), level in sampling container (compared to calculated level) etc.

This verification of current condition shall preferably be carried out using calibrated reference meters. The condition based monitoring may however also be carried out using duplicated equipment or by any other relevant method.

Where possible comparative monitoring of parallel meter runs shall be carried out, i.e. when two or more meter runs are operating concurrently.

A.2 Software requirements

The software shall be prepared for easy and reliable verification of the accuracy of each independent program routine and totalization. The computer under test must measure the duration of the accuracy tests, when the duration of the accuracy tests is influencing the estimated values.

The measured field tags and parameters indicating the condition of each field tag i.e. deviations from reference values, shall be stored and trended graphically. Additionally, a current condition report shall be generated at predefined times or on demand. The current condition report shall include comparisons against predefined limits of deviation for each parameter, and a written alarm shall be given in the report, if any limit is exceeded. Generally, a verification of current condition shall not include any manual interference with the measurement equipment or computers. The current condition report may be combined with the report of the daily status of the measurement system. The fiscal measurement reports shall not be combined with the current condition report.

In a turbine meter station with prover, a function for automatic turbine meter calibration combined with statistical evaluation of previous K-factors, shall be implemented. It shall be possible for a new K-factor to be automatically accepted by comparison with the statistical K-factor (e.g. average of the last 30 accepted K-factors) and predefined limits for acceptance. Manual acceptance shall be invoked if the new K-factor exceed acceptance limits. It shall be possible to select a mode where a fixed K-factor is used in stead of the statistical K-factor.

ANNEX B TESTING AND COMMISSIONING (NORMATIVE)

B.1 Necessary tests

B.1.1 General

This annex outlines the minimum test requirements for fiscal measurement systems.

The Supplier shall not present any item for inspection and testing until he has completed his own inspection and testing. The purchaser reserves the right to perform any checking as deemed necessary.

A written record is to be made of all tests and results and copies made available to the purchaser if required.

The objective of the acceptance tests will be to assure that the systems meets the functional and technical requirements described in this document. Supplier shall prepare acceptance test procedures for factory and offshore acceptance tests, which shall demonstrate that all specifications of this document and subsequent functional design document are met. Purchaser will review and comment, as necessary, to arrive at a mutually agreeable acceptance test procedure prior to start of testing.

The equipment shall undergo a factory acceptance test prior to shipping. Personnel from purchaser will normally witness the test and decide if the equipment has performed satisfactorily. Any problems found shall be corrected by the Supplier, who shall demonstrate that any discrepancies have been corrected prior to shipment.

The supplier shall at each test, as a minimum demonstrate the following:

- The capability and proper operation of the hardware and software.
- The equipment's ability to meet all functional and technical requirements described in this document.
- That all the expandability requirements are included.
- That the communications software and hardware work properly.
- Satellite communication, if applicable.
- The operation of the graphics package.
- That all counters, registers, internal switches, etc. will be reset at the correct hour (project specific) each day, in such a way that no data is lost and there is no effect on the accuracy of calculations made following the turn-over.
- That no data will be lost/changed if switching over to a standby system (project specific).

- That all calculations are correct.
- Interface/total functional test to the SAS-system including displays, alarms, operator interactions etc.

B.1.2 Supplier internal system test

This test shall be performed as described above. There shall be an arrangement to simulate all field signals into the system and indicating or metering instruments to monitor the output signals of the system. This test must be documented as described in FAT procedure, and completed before the next test is performed.

B.1.3 Purchasers factory acceptance test

This test shall be performed as described above for all systems. The test shall be arranged as follows:

- The test will start with a review of supplier's documentation of the following:
 - All software is tested and is free of patches
 - All hardware modules have been tested in accordance with recognised industrial standards, with regard to susceptibility to environmental conditions, such as variations in signal and supply voltages.
 - Result of supplier's test as per above procedure.
- The purchaser will then perform the test on his own, assisted by supplier's personnel as required.
- During the test purchaser may also introduce some reasonable additional tests to check that the system operates accurately under normal or abnormal operating conditions.

This test must be completed before the next test is performed.

B.1.4 Site/yard acceptance test

Verification of system after power-up, full load test. Integrated test with SAS. Operating manuals must be available for this test.

B.1.5 Offshore/commissioning verification test

A simplified version of the FAT will be performed again after the equipment has been shipped offshore.

Field instruments i.e. secondary instruments shall prior to start up, be traceably re-calibrated by an accredited laboratory to international/national standards before the instruments are taken into service.

Ultrasonic meter:

After being pressurised, before being put into operation, the ultrasonic flow meter shall be checked to verify velocity of sound and zero flow point for each individual sound path. The supplier shall determine deviation limits for the various parameters, before the meter is put into service.

The equipment will be accepted as operational after all required functions have been demonstrated and proven to be in actual operation.

B.2 Test of individual components

B.2.1 Test Equipment

All test equipment shall be of standard and precision which is appropriate to the tests to be performed, with calibration certificates from an accredited laboratory.

B.2.2 Inspection and testing of Field Instruments

Procedure for calibration shall be sent purchaser for review and acceptance. Purchaser will witness these calibrations (3 weeks notice required before verification).

Turbine, PD and ultrasonic flow meters shall be individually calibrated at a laboratory, which is traceable to international/national standards at process conditions (velocity of flow, pressure and temperature), as similar to the operational conditions as possible. The effect of variations in temperature and pressure shall be determined. The calibration factor shall be determined. The meters shall be identified, and a certificate shall be issued. For the ultrasonic flow meter, the zero flow point correction shall be determined.

The turbine, PD and ultrasonic flow meters shall initially be traceably calibrated using product of viscosity similar to process fluid to verify the repeatability and linearity requirements in subclause 5.2.2.3. The calibration shall be carried out at the highest and at the lowest part of the working range, and at three points distributed between the minimum and maximum values. Five repeats shall be made for each point.

If it is impossible to calibrate the turbine, PD or ultrasonic meter at the relevant process conditions, the meter shall at least be calibrated for the specified flow velocity range.

When calibrating the prover unit, if the first five consecutive trials are outside a band of 0,020 % of the average volume, it is acceptable to carry out three additional trials. If the spread is still outside of 0,020 % of the average volume, fault finding shall be undertaken, before the calibration sequence is restarted.

An inspection/test shall take place when the measurement skids have been fully completed in all details and prior to purchaser's factory acceptance test. The inspection/test will as a minimum comprise:

- Check that all instruments are installed in such a way that they will give correct measurement and easy calibration.
- Review of calibration certificates for field instruments. Recent calibration certificates for all instruments within the skids shall be available. The purchaser may require some or all of the instruments to be check calibrated at this test.

This inspection/test will be witnessed/made by the purchaser.

B.3 Other Instrument Equipment tests

Instrument panels which form part of the total measurement package shall undergo the functional tests as stated in the approved supplier test procedure.

The complete panels with all the equipment installed and connected, shall be tested for electric continuity, insulation and earth, and shall be heat soak tested as mutually agreed.

The supplier shall, before shipment, visually inspect, calibrate where necessary, and functionally test all instruments that are included in the package instrumentation system. This shall apply whether instruments are mounted on the package, mounted but disconnected for shipment, or shipped loose for installation at the module construction yard or offshore.

Spool pieces shall be provided for all in line instruments that will have to be removed for flushing, pre-commissioning or commissioning tasks.

B.4 Total system test. Liquid function test, for liquid hydrocarbon system that includes prover

This test shall be performed when the tests of the various components have been successfully completed.

Complete functional test:

- Two meter streams selected at random shall be flow tested simultaneously, one stream metering, and one stream on prove, up to the maximum linear capacity of each meter.
- Pressure loss tests i.e. at proving on line maximum flow rate. Fast response recorder to be available to check pressure loss. Pressure loss measured on water to be converted to pressure loss at oil flow at operation conditions.
- Test that oil filled parts in the system will be kept above the waxing point temperature (Heat tracing/insulation test).

B.5 Preservation

The entire fiscal measurement system shall be protected against corrosion and other damages during export shipment and storage. Supplier shall propose methods/procedures/conditions of warranty for period from FAT to start up operation.

ANNEX C SYSTEM SELECTION CRITERIA (INFORMATIVE)

C.1 Alternative cost/benefit analysis of metering concepts

The cost of using a concept with high accuracy (concept A) may be unreasonable in relation to the monetary value of the additional measurement uncertainty of a less accurate/less expensive concept (concept B). The selection of metering concept shall be based on one of the two alternative cost/benefit analyses given below.

C.1.1 For metering systems for main fields and sales metering

An analysis shall be performed to quantify:

- a) The measurement uncertainty of concept A and B
- b) The potential monetary loss from the additional measurement uncertainty, by using concept B instead of concept A, during the lifetime of the installation.
- c) The total cost savings, by using concept B instead of concept A, during the lifetime of the installation.
- d) The cost saving in c) minus the potential monetary loss in b).

The key parameter is this analysis for decision making, is the value in d).

All monetary values above shall be calculated as net present values of investment and operating cost.

C.1.2 For metering systems for satellite fields with tie-in and processing on existing field platforms

An analysis shall be performed to quantify:

- a) The monetary value of 1 % reduction in measurement uncertainty for oil and gas based on difference in ownership between satellite field owners and existing field owners, during the lifetime of the installation. (Assuming for example that owners are willing to use 0,25 NOK maximum to reduce measurement uncertainty by 1,0 NOK)
- b) The uncertainty of the well-test concept for oil and gas (No measurement).
- c) A matrix (table) showing the monetary value of reducing measurement uncertainty from the well-test concept towards 0 % measurement uncertainty for oil and gas.

The key parameter is this analysis for decision making, is the total cost of using a metering system with a specified measurement uncertainty, compared to the monetary value of the corresponding reduction in measurement uncertainty from the no measurement case for oil and gas, during the lifetime of the installation.

All monetary values above shall be calculated as net present values of investment and operating cost. A calculation to be performed for each field owner including all field owners shares.

ANNEX D WATER IN OIL CALCULATIONS (INFORMATIVE)**D.1 General**

This appendix describes the calculations for water in oil measurement.

No numbers in the calculations in the flow computer are rounded or truncated.

D.2 Abbreviations

Meas - Measured value. Signal read from a sensor and first scaled to appropriate unit.

Comp - Value computed by the system.

CP - Changeable parameter. Parameter that will have an initial value, for example from a certificate, and that may be changed at routine.

Const - Constant value. May only be changed by editing and recompiling source code.

D.3 Variable names used in Water-in-oil calculations

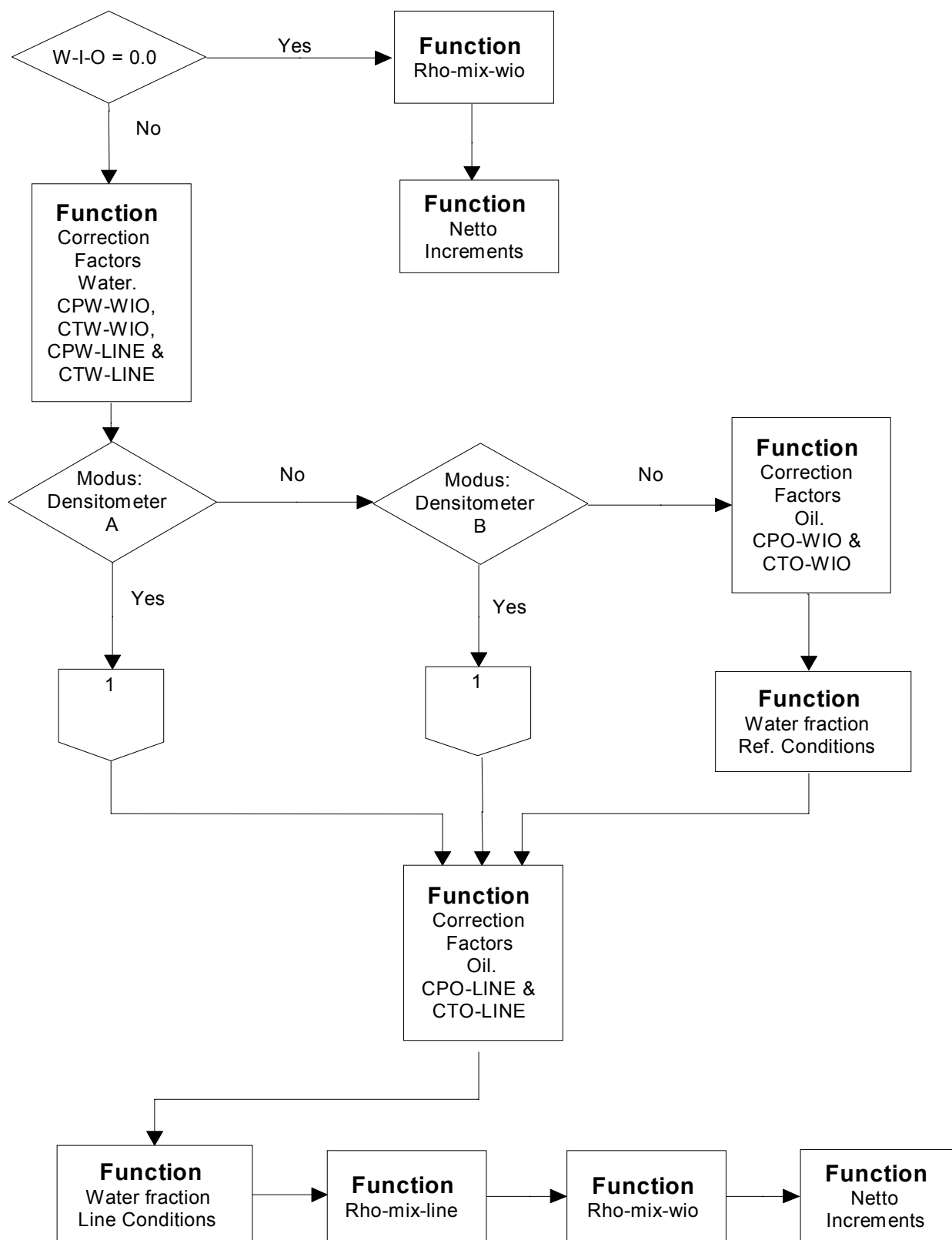
This section describes the variable names used in equations and algorithms.

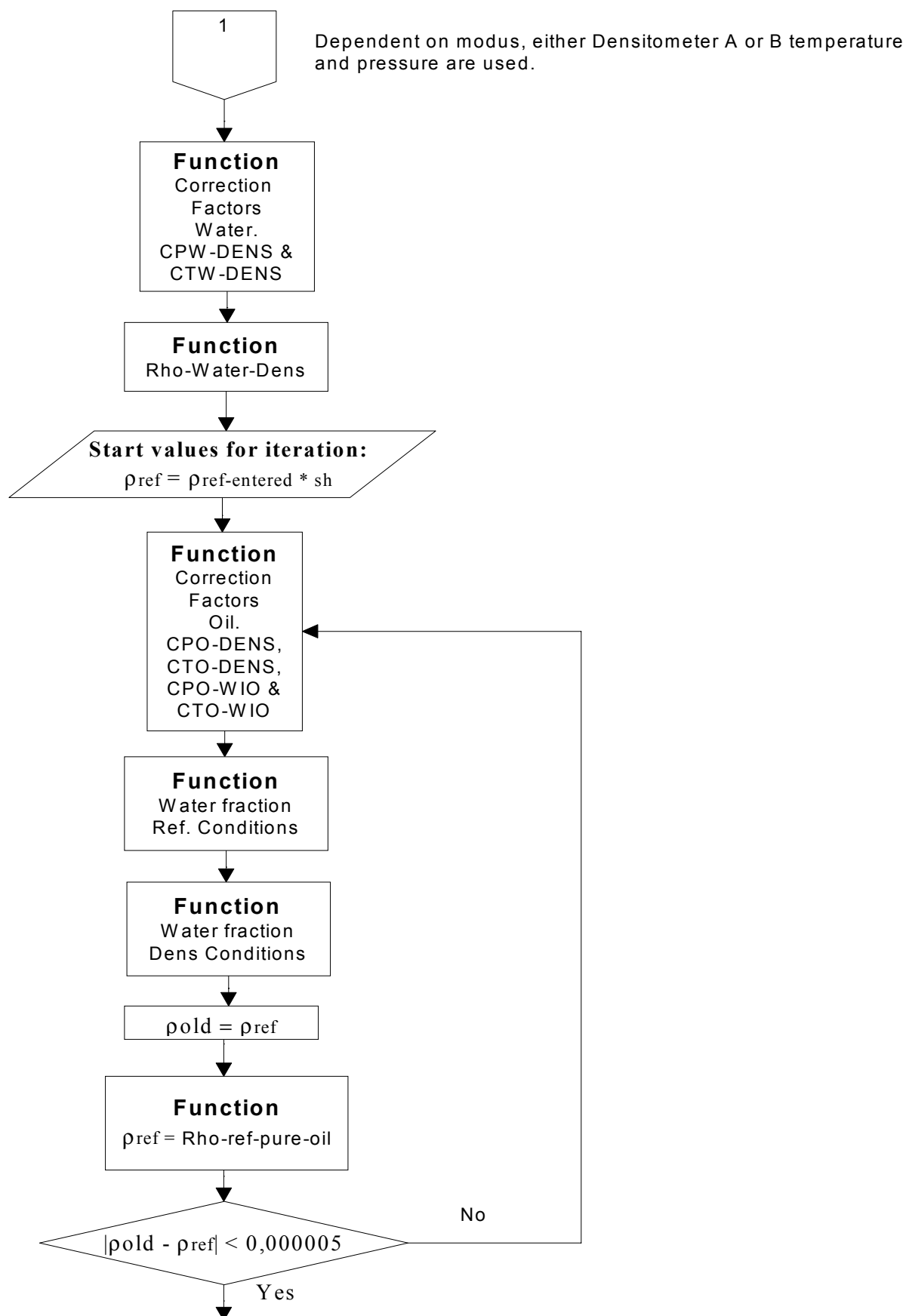
The column “Source” indicates whether a variable is a constant, a measured process value, an operator-entered value or a calculated value. Some variables may have more than one possible source depending on selected process instrumentation and calculation algorithms.

Name	Units	Description	Source
ρ	[kg/m ³]	Operating density, line density	Comp
$\rho_{\text{calc-w}}$	[kg/m ³]	Calculated reference density for water	Comp
ρ_{dens}	[kg/m ³]	Calculated density from densitometer (at densitometer conditions)	Comp
$\rho_{\text{mix-line}}$	[kg/ m ³]	Line density, mix of oil and water	Comp
$\rho_{\text{mix-wio}}$	[kg/ m ³]	Density at water in oil conditions of oil and water	Comp
ρ_{ref}	[kg/Sm ³]	Density at reference conditions	Comp, CP
$\rho_{\text{ref-o-pure}}$	[kg/Sm ³]	Reference density for pure oil	Comp
$\rho_{\text{ref-water}}$	[kg/Sm ³]	Reference density for pure water	CP
ρ_{waterD}	[kg/m ³]	Density for water at densitometer conditions	Comp

Name	Units	Description	Source
pref- entered	[kg/Sm ³]	Density at reference conditions, operator entered	CP
Cpod	[-]	Correction factor for the effect of pressure on the oil at the densitometer	Comp
Cpol	[-]	Correction factor for the effect of pressure on the oil at line conditions	Comp
Cpow	[-]	Correction factor for the effect of pressure on the oil at water in oil analyser	Comp
Cpwd	[-]	Correction factor for the effect of pressure on the water at the densitometer	Comp
Cpwl	[-]	Correction factor for the effect of pressure on the water at line conditions	Comp
Cpww	[-]	Correction factor for the effect of pressure on the water at water to oil analyser	Comp
Ctod	[-]	Correction factor for the effect of temperature on the oil at the densitometer	Comp
Ctol	[-]	Correction factor for the effect of temperature on the oil at line conditions	Comp
Ctow	[-]	Correction factor for the effect of temperature on the oil at the water in oil analyser	Comp
Ctwd	[-]	Correction factor for the effect of temperature on the water at the densitometer	Comp
Ctwl	[-]	Correction factor for the effect of temperature on water at line conditions	Comp
Ctww	[-]	Correction factor for the effect of temperature on the water at the water to line analyser	Comp
Imnet	[kg]	Net mass increment	Comp
Imw	[kg]	Water increment	Comp
Iv	[m ³]	Volume increment	Comp
Ivrnet	[S m ³]	Net volume increment at reference condition	Comp

Name	Units	Description	Source
P	[bar g]	Pressure	Meas
sh	[-]	Shrinkage factor	CP
T	[°C]	Temperature	Meas
Tref	[°C]	Reference temperature	CP
Wd	[-]	Water in oil volume ratio at the densitometer	Comp
Wl	[-]	Water in oil volume ratio at line condition	Comp
Wr	[-]	Water in oil volume ratio at reference condition	Comp
Ww	[-]	Water in oil volume ratio at water in oil analyser	Comp

D.4 Algorithm for Water-in-oil calculations**D.4.1 Flow chart for Water-in-oil calculation**



D.4.2 Correction Factors for Water

The functions and routines described in this clause deals with the correction factors for temperature and pressure effects on water density.

D.4.2.1 Function: Cpw

Cpw is used to correct the density of water at standard reference conditions to conditions at the water in oil analyser, line, densitometer A or densitometer B, due to difference in pressure.

The equation for Cpw is taken from ISO 8222, ISO DIS 4269-1:

$$C_{pw} = \frac{1}{(1 - F_w \cdot P)}$$

where

$$F_w = \frac{1}{(19690 + 141.8 \cdot T - 1.934 \cdot T^2 + 0.005866 \cdot T^3)}$$

D.4.2.2 Function: Ctw

Ctw is used to correct the density of water at standard reference conditions to conditions at the water in oil analyser, line, densitometer A or densitometer B, due to difference in temperature.

$$\rho = \frac{aw_0 + aw_1 \cdot T + aw_2 \cdot T^2 + aw_3 \cdot T^3 + aw_4 \cdot T^4 + aw_5 \cdot T^5}{1 + bw_1 \cdot T}$$

$$\rho_{Calc-w} = \frac{aw_0 + aw_1 \cdot T_{ref} + aw_2 \cdot T_{ref}^2 + aw_3 \cdot T_{ref}^3 + aw_4 \cdot T_{ref}^4 + aw_5 \cdot T_{ref}^5}{1 + bw_1 \cdot T_{ref}}$$

$$C_{tw} = \frac{\rho}{\rho_{Calc-w}}$$

The equation for Ctw and the values for aw0, aw1, aw2, aw3, aw4, aw5 and bw1 are found in ISO/DIS 12916, 1995.

D.4.2.3 Water density

Water density is calculated according to the following equation:

$$\rho_{water} = \rho_{ref-water} \cdot C_{pw} \cdot C_{tw}$$

D.4.3 Water fraction at Ref. conditions

Water fraction at reference conditions is calculated according to the following equation:

$$W_{ref} = \frac{1}{\left(1 + \left((1 - W_w) \cdot \frac{C_{pow} \cdot C_{tow}}{(W_w \cdot C_{pww} \cdot C_{tww})}\right)\right)}$$

D.4.4 Water fraction at Densitometer conditions

Water fraction at densitometer conditions is calculated according to the following equation:

$$W_d = \frac{1}{\left(1 + \left((1 - W_{ref}) \cdot \frac{C_{pwd} \cdot C_{twd}}{(W_{ref} \cdot C_{pod} \cdot C_{tod})}\right)\right)}$$

D.4.5 Reference density for pure oil

Pure oil reference density is calculated according to the following equation:

$$\rho_{pref} = \frac{(\rho_{dens} - (W_d \cdot \rho_{waterD})) \cdot \frac{1}{1 - W_d}}{C_{tod} \cdot C_{pod}}$$

D.4.6 Water fraction at Line conditions

Water fraction at line conditions is calculated according to the following equation:

$$W_l = \frac{1}{\left(1 + \left((1 - W_{ref}) \cdot \frac{C_{pwl} \cdot C_{twl}}{(W_{ref} \cdot C_{pol} \cdot C_{tol})}\right)\right)}$$

D.4.7 Mixed density at Line conditions

Mixed density at line conditions is calculated according to the following equation:

$$\rho_{mix-line} = (\rho_{ref-water} \cdot c_{twl} \cdot c_{pwl} \cdot W_l) + (\rho_{ref-o-pure} \cdot c_{tol} \cdot c_{pol}) \cdot (1 - W_l)$$

D.4.8 Mixed density at WIO conditions

Mixed density of water and oil at water in oil analyser conditions is calculated according to the following equation:

$$\rho_{\text{mix-wio}} = (\rho_{\text{ref-water}} \cdot C_{\text{tw}} \cdot C_{\text{pw}} \cdot W_w) + (\rho_{\text{ref-o-pure}} \cdot C_{\text{to}} \cdot C_{\text{po}}) \cdot (1 - W_w)$$

D.4.9 Net Increments

D.4.9.1 Net oil mass increment

The net oil mass increment is calculated by the following equation:

$$i_{\text{mnet}} = i_v \cdot (1 - W_l) (\rho_{\text{ref-o-pure}} \cdot C_{\text{to}} \cdot C_{\text{po}})$$

D.4.9.2 Net reference oil volume increment

The net reference oil volume increment is calculated by the following equation:

$$i_{\text{vrnet}} = \frac{i_{\text{mnet}}}{\rho_{\text{ref-o-pure}}}$$

D.4.9.3 Water increment

Water increment is calculated by the following equation:

$$I_{\text{mw}} = (i_v \cdot \rho_{\text{mix-line}}) - i_{\text{mnet}}$$

ANNEX E GUIDELINES TO IMPLEMENTATION OF ISO 3171 (INFORMATIVE)

E.1 Introduction

The automatic oil sampler system shall be designed in accordance with ISO-3171 with amendments and supplements as detailed below. Amendments and/or supplements (=Amd), more precise definition (=P= and additions (=A) to ISO 3171-88 are listed below. The headings are the same as in relevant chapters in ISO 3171. There are also some additional headings, which are indicated in the text.

The phrase "should" in ISO 3171 in connection with design requirements shall mean "shall" if not otherwise stated below.

See typical sampling systems in fig. 9, ISO 3171.

E.2 Initial selection of automatic probe location (P)

The probe shall be located close to the metering system on the same stream (flow line).

E.3 Mixing devices (P)

The need for conditioning shall be determined according to Annex A in ISO 3171.

E.4 Selection of mixing device (A)

The type of mixing device(s) shall be determined in the same priority order as the devices are described in ISO 3171, clause 5.4

E.5 Position of the sampling probe (P)

The probe (either sampling probe or sample probe with actuator, ref. ISO 3171, fig. 2) shall be installed in a horizontal position on the main pipeline.

E.6 Checking the location of the sampling probe (P)

Lab. tests shall be considered if the homogenisation according to ISO 3171, Annex A is disputable. Locate on a vertical part of the main pipeline.

E.7 Sampling probe design (P)

If by-pass loop is used the sampling probe shall be a pitot-tube type probe entry as described in ISO 3171, clause 7.2 - 7.3.

E.8 Sampler design and installation (Amd)

E.8.1 Design

- The sampling system shall be of the intermittent type (see ISO 3171, fig. 9). Both the intermittent systems (see ISO 3171 clause 8.1.1) may be selected.
- The type of system shall be determined from a cost-benefit analysis, except that the in line grab system shall be preferred when it is important with correct water content and the water content is above 1,0 volume % the conditions in ISO 3171, clause 8.2.2. are applicable.

Note: The bypass loop can in some cases be used for several purposes as measurement of density and for manual sampling.

- For bypass loop system to ensure iso-kinetic sampling the velocity in the inlet probe shall be kept within ± 10 % of the velocity in main pipe at probe entry.
- The bypass loop shall be equipped with a separate device of similar design/method as in line grab sampler (i.e. a solenoid 3-way diverter valve as separating device shall not be used) shut-off valves of full bore ball valves
- The need for a mixer immediately upstream of the separating device, to remix the by-pass-stream shall be determined according to Annex A in ISO 3171.
- The two subsystems (separating device/pump and receiver) shall be most possible independent of each other. It shall be possible to shut down one of the subsystem (e.g. for maintenance) while the other subsystem is operating (and vice versa). Each separating device/pump shall be manually operable from a panel.

E.9 Sample receivers and containers (Amd, A)

E.9.1 Sample receiver

- The receiver should be of stationary type.
- For unstabilised oil/condensate (i.e. RVP > 0,82737 bar a) a piston type sample receiver shall be used with back-pressure of an inert gas (argon or helium).
- For stabilised oil (i.e. RVP < 0,82737 bar a) a receiver with fixed volume shall be used.
- The piston type sample receiver shall be equipped with magnetic piston position indicator.
- The stationary type sample receiver shall be equipped with a mixer. The homogenising shall be according to IP 386/90, App. A

E.9.2 Sample container

- The sample container for unstabilised oil/condensate (i.e. RVP > 0,82737 bar a) shall be equipped with a homogenising unit.

E.9.3 Sampling handling

- For Newtonian fluids homogenisation by high-shear mixer or similar device should be used. For different non-Newtonian fluids one must be more careful and specific concerning shear rate(s).
- The verification of the efficiency of mixing shall be done for water content up to 5 % volume.
- The Karl Fisher method according to IP 386/90 shall be used, when applicable, for determination of water content.

E.9.4 Back-pressure system (A)

For the piston type receiver there shall be a back-pressure system including booster facility with inert gas (argon, helium or nitrogen).