

Fiscal measurement systems for hydrocarbon liquid

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Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are, as far as possible, intended to replace oil company specifications and serve as references in the authorities' regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary to fill the broad needs of the Norwegian petroleum industry. Where relevant, NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable for most standards work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published with support by The Norwegian Oil Industry Association (OLF), The Federation of Norwegian Industry, Norwegian Shipowners' Association and The Petroleum Safety Authority Norway.

NORSOK standards are administered and published by Standards Norway.

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

Introduction

This edition replaces the version from 1998. The basis for this NORSOK standard has been the version from 1998 combined with general industry experience over the last years. The structure from the 1998 version has been kept and the main changes are related to the following topics:

- included statistical method for meter proving;
- included reference to last version of relevant standards and included reference to new relevant standards;
- modifications of the technical and functional requirements;
- improved clarification of technical requirements;
- included reference to standard for Coriolis meter.

The revision has been carried out by NORSOK expert group EG IM "Metering" with members from end users (oil companies), authorities, contractors, consultants and metering system vendors.

1 Scope

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

2 Normative and informative references

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

2.1 Normative references

ANSI/ASME,	Performance Test Code 19.3
API MPMS, Chap. 4,	Proving Systems
API MPMS, Chap. 4.3,	Small volume provers
API MPMS, Chap. 4.8,	Operation of proving systems
API MPMS, Chap. 5,	Metering
API MPMS, Chap. 5.2,	Measurement of Liquid Hydrocarbons by Displacement Meters
API MPMS, Chap. 5.3,	Measurement of Liquid Hydrocarbons by Turbine Meters
API MPMS, Chap. 5.8,	Measurement of Liquid Hydrocarbons by Ultrasonic Flow meters Using Transit Time Technology
API MPMS, Chap. 8.3,	Standard Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products
API MPMS, Chap. 10.9,	Standard Test Methods for Water in Crude Oils by Coulometric Karl Fischer Titration (corresponds to IP 386/99)
API MPMS, Chap. 11,	Volume Correction Factors
API MPMS, Chap. 11.2.2,	Compressibility Factors for Hydrocarbons
API MPMS, Chap. 12,	Calculation of Petroleum Quantities
API MPMS, Chap. 20,	Allocation Measurement
BIPM, et.al.*),	OIML P17, Guide to the expression of Uncertainty in Measurements
IEC 60751,	Industrial Platinum Resistance Thermometer sensors
IP 386/99,	Determination of water content of crude oil - Coulometric Karl Fischer method
	NOTE See also ASTM-D-4928-00 which corresponds to IP 386/99.
IP PMM Part VII,	Density. Section 2. Continuous Density Measurement
ISO 1000,	SI units and recommendations for use of their multiples and of certain other units
ISO 3171,	Petroleum Liquids - Automatic pipeline sampling
ISO 5024,	Measurement - Standard reference conditions
ISO 6551,	Petroleum Liquids and Gases - Fidelity and Security of Dynamic Measurement - Cabled Transmissions of Electric and/or Electric Pulsed Data
ISO 7278-3,	Liquid hydrocarbons - Dynamic measurement - Proving systems for volumetric meters - Part 3: Pulse Interpolation Techniques
ISO 9000-3,	Guidelines for the application of the ISO 9001 to the development, supply and maintenance of software
ISO 10337,	(corresponds to IP 386/99)
ISO 10790,	Measurement of fluid flow in closed conduits — Guidance to the selection, installation and use of Coriolis meters (mass flow, density and volume flow measurements)
ISO/TR 9464,	Guide to the use of ISO 5167
NFOGM 2001,	Handbook of uncertainty calculations, Fiscal orifice gas and turbine metering stations
NFOGM 2005,	Handbook water fraction metering
NORSOK I-001,	Field instrumentation
NPD Regulations,	Regulations relating to measurement of petroleum for fiscal purposes and for calculation of CO ₂ -tax

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

2.2 Informative references

API MPMS, Chap. 8.2,	Automatic sampling of petroleum and petroleum products
API MPMS Chap. 13,	Statistical Aspects of Measuring and Sampling
IP PMP No. 2,	Guidelines for users of the Petroleum Measurement Tables – Computer procedure for correcting density of crude and products at line conditions to standard conditions
IP PMM Part VI,	Sampling. Section 2. Guide to Automatic Sampling of Liquid from Pipelines
IP PMM Part X,	Meter Proving. Section 1. Field Guide to Proving Meters with a Pipe Prover
IP PMM Part X,	Meter Proving. Section 3. Code of Practice for the Design, Installation and Calibration of Pipe Provers
IP PMM Part XV,	Metering Systems. Section 1. A Guide to Liquid Metering Systems
ISO 8222,	Petroleum Measurement systems - Calibration - Temperature corrections for use when calibrating volumetric proving tanks

3 Terms, definitions and abbreviations

For the purposes of this NORSOK standard, the following terms, definitions and abbreviations apply.

3.1 Terms and definitions

3.1.1

accreditation

official recognition to the effect that an organisation is operating in accordance with a documented quality assurance system and that it has demonstrated competence to carry out specified tasks

3.1.2

allocation

distribution of sold/produced quantities of hydrocarbons between licensees and owner companies

3.1.3

can

verbal form used for statements of possibility and capability, whether material, physical or casual

3.1.4

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.

3.1.5

in-line

concept where the main pipe volumes flows through the in-line unit

3.1.6

may

verbal form used to indicate a course of action permissible within the limits of this NORSOK standard

3.1.7

prover unit

conventional pipe prover, compact prover, master meter or other applicable method to calibrate the flow element

3.1.8

quantity

measure of the hydrocarbon medium, by volume, mass or energy

3.1.9

shall

verbal form used to indicate requirements strictly to be followed in order to conform to this NORSOK standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.10**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

3.1.11**standard gross volume**

oil volume at standard conditions including water

3.2 Abbreviations

A/D	analogue to digital
ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BIPM	International Bureau of Weight and Measure
CD-ROM	compact disc – read only memory
CEN	The European Committee for Standardization
CMR	Christian Michelsen Research
CPU	central processing unit
D/A	digital to analogue
EN	European Standard
FAT	factory acceptance test
GRP	glassfibre reinforced polyester
ID	internal pipe diameter
IEC	International Electrotechnical Commission
IFCC	International Federation of Clinical Chemistry
I/O	input/output
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
NFOGM	Norwegian Society for Oil and Gas Measurement
NPD	Norwegian Petroleum Directorate
OD	outer pipe diameter
OIML	International Organisation of Legal Metrology
OLF	The Norwegian Oil Industry Association.
PD meter	positive displacement meter
P&ID	piping and instrument diagram
Pt-100	platinum resistance thermometer
RAM	read access memory
RVP	reid vapour pressure
SAS	safety and automation system
SI	International System of Units
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 ° C, 1,01325 bar absolute, see 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, when standards are available, 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 gross 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. In such cases, a deviation list including the relaxed requirements from this NORSOK standard should be defined.

The uncertainty figures shall be calculated for each component and accumulated for the total system in accordance with the following reference documents:

- Guide to the Expression of Uncertainty in Measurement;
- a practical implementation is shown in Handbooks of uncertainty calculation, including spreadsheet; issued by CMR, NPD and NFOGM.

4.3 Sampling and water fraction metering 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 traceable calibrated to international/national standards. Calibration by an accredited laboratory fulfils these requirements. Test requirements prior to start-up are given in Annex B.

All geometrical dimensions used in fiscal calculations shall be traceably measured and certified to international/national standards. The material constants shall be documented. Implemented constants shall be available for verification, see 5.2.5.17.

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 other hydrocarbon liquids 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 (including 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. The operating pressure in the metering run shall be maintained sufficiently above vapor pressure.

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 in total uncertainty exceeding the uncertainty limits for the system, listed in 5.1.4.2.

NOTE NPD Regulations 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 gross volume. For water content above 0,5 %, special attention shall be made to ensure compliance with the uncertainty limits and proper performance of the measurement system.

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

Refer 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. It shall be possible to operate the measurement system from SAS, see 5.2.5.3.

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 as minimum be manually operated by electrical actuator.

It shall be possible to operate all valves locally.

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

It shall be possible to automatically start and perform the proving sequence based 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-reset-able 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-reset-able counters.

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

5.1.7 Maintenance requirements

5.1.7.1 General

The field instrumentation shall be selected to reduce need for maintenance and calibration activities.

The maintenance requirements for automated condition based maintenance in Annex A shall apply. In addition, there should be easy access to all 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 so that the requirements given in this NORSOK 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, 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.

Densitometer 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

There 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.

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 averaging.

5.1.7.4 Isolation and sectioning

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

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

The computer part shall be interfaced to

- SAS (if dedicated computer),
- sampling system,
- water fraction metering,
- production database and allocation systems (information management system).

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 maximum stated turndown on product (e.g. 10:1),
- 0,30 % (band) for normal operating range on product (e.g. 5:1).

The material constants shall be available for corrections.

Turbine and PD meters:

Turbine meters shall be according to API MPMS Chap. 5.3.

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

The repeatability shall be better than 0,04 % (band) within linear range on water and product when the method "5 successive repeats" is used.

The statistical method described in Annex F may be used to determine average calibration factors and evaluate the corresponding repeatability expressed as uncertainty. The maximum acceptable uncertainty band at 95 % confidence level is 0,04 %.

During operation, the repeatability shall be better than 0,05 % (band).

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

The turbine meter rotor shaft shall be supported upstream and downstream of rotor. The rotor shall be hydrodynamically balanced between the supports.

Ultrasonic meters:

Ultrasonic meters shall be according to API MPMS Chap. 5.8 with the following clarifications:

- the statistical method described in Annex F shall be used to determine average calibration factors and evaluate the corresponding repeatability expressed as uncertainty. The maximum acceptable uncertainty band at 95 % confidence level is 0,07 %;
- the number of paths for ultrasonic meters shall be determined by required uncertainty limit;
- 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, e.g. transducer replacement;
- for the meter run, the minimum straight upstream and downstream lengths shall be according to API MPMS Chapt. 5.8, clause 9.1. Strainers may be required to protect associated equipment, including meter provers or pumps. It is not recommended to install strainers upstream the meter;
- ultrasonic meters may be used bidirectionally. For installation requirements, reference is made to API MPMS Chapt. 5.8, clause 7;
- gaskets between meter run and pipe section shall not protrude into the meter run;
- the ultrasonic flow meter shall be designed such that measurements of acceptable quality can be achieved when one transducer pair is out of service.

Coriolis:

The Coriolis meter shall be designed according to API MPMS Chap. 5.6 and ISO 10790. For Coriolis meter with two parallel tubes, asymmetric distribution of flow through the meter shall be avoided.

The statistical method described in Annex F shall be used to determine average calibration factors and evaluate the corresponding repeatability expressed as uncertainty. The maximum acceptable uncertainty band at 95 % confidence level is 0,07 %.

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.

Remotely operated electrical actuator shall be used, in addition the valves shall be equipped with limit switches for open and closed position

5.2.2.5 Meter run flow control

The purpose of the meter run flow control is to achieve flow at target value during calibration of the actual meter. It 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.

Total station flow control or back pressure functions shall be by valve outside the metering system.

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 measurement point, densitometer, sampling system etc. may be thermally insulated and/or heat traced. Heating and heat trace shall be controlled in order to not affect metering performance.

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.

Three 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 measurement points etc. may be thermally insulated and/or heat traced.

Informative references are given in IP PMM Part X, Section 1 and Section 3.

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 four 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.

Four-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 0,02 % (band) when the method "5 successive repeats" is used.

The statistical method described in Annex F may be used to determine average calibrated volumes and evaluate the corresponding repeatability expressed as uncertainty. The maximum acceptable uncertainty band at 95 % confidence level is 0,02 %.

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 0,02 % (band) when the method "5 successive repeats" is used.

The statistical method described in Annex F may be used to determine average calibrated volumes and evaluate the corresponding repeatability expressed as uncertainty. The maximum acceptable uncertainty band at 95 % confidence level is 0,02 %.

5.2.3.4 Master meter

Same requirements shall apply as in 5.2.2.3.

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 supplied from uninterrupted power supply.

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.