

Fiscal measurement systems for hydrocarbon gas

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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 Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.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) and Federation of Norwegian Manufacturing Industries (TBL).

NORSOK standards are administered and published by Standards Norway.

Annexes A and B are normative. Annexes C and D are informative.

Introduction

This revision 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 metering industry still needs this NORSOK standard to be effective as a system standard for design and procurement. The structure from the 1998 version has been kept and the main changes are related to the following topics:

- 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;
- technical performance for on-line gas chromatograph when used in allocation and when used for gas density calculation is clarified and also shown in a detailed calculation example.

This update have been carried out by the NORSOK expert group Eg IM 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 gas. 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 and guidelines of the standards referenced below.

2.1 Normative references

AGA 7,	<i>Measurement of gas by turbine meters - AGA Transmission Measurement Committee Report No. 7.</i>
AGA 8,	<i>Compressibility factors of Natural Gas and other related hydrocarbon gases, AGA Transmission Measurement Committee Report No. 8.</i>
AGA 9,	<i>Measurement of Gas by Multipath Ultrasonic Meters; AGA Transmission Measurement Committee Report No. 9.</i>
AGA 10,	<i>Speed of sound in Natural Gas and Other Related Hydrocarbon Gases</i>
AGA 11,	<i>Measurement of Natural Gas by Coriolis Meter</i>
AGA 2001,	<i>A model for estimation of the ultrasonic acoustic noise level emitted by pressure regulating valves and its influence on ultrasonic flowmeters</i>
ASTM D1945,	<i>Analysis of natural gas by gas chromatography</i>
BIPM et.al. *)	<i>Guide to the Expression of Uncertainty in Measurements (GUM)</i>
IEC 60751,	<i>Industrial Platinum Resistance Thermometer sensors</i>
IP PMM Part VII,	<i>Continuous Density Measurement</i>
ISO 1000,	<i>SI units and recommendations for use of their multiples and of certain other units</i>
ISO 5024,	<i>Measurement - Standard reference conditions</i>
ISO 5167-1,	<i>Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full - Part 1: General principles and requirements</i>
ISO 5167-2,	<i>Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full - Part 2: Orifice plates</i>
ISO 5167-3,	<i>Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full - Part 3: Nozzles and Venturi nozzles</i>
ISO 5167-4,	<i>Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full - Part 4: Venturi tubes</i>
ISO 6551,	<i>Petroleum Liquids and Gases - Fidelity and Security of Dynamic Measurement - Cabled Transmissions of Electric and/or Electric Pulsed Data</i>
ISO 6976,	<i>Natural gas - Calculation of calorific values, density, relative density and Wobbe index from composition</i>
ISO 9000-3,	<i>Guidelines for the application of the ISO 9001 to the development, supply and maintenance of software</i>
ISO 9951,	<i>Measurement of gas flow in closed conduits - Turbine meters</i>
ISO 10715,	<i>Natural Gas Sampling Guidelines</i>
ISO 10790,	<i>Measurement of fluid in closed conduits - Guidance to the selection, installation and use of Coriolis meters (mass flow, density and volume flow measurement)</i>
ISO 12213-1,	<i>Natural gas - Calculation of compression factor – Part 1: Introduction and guidelines</i>
ISO 12213-2,	<i>Natural gas - Calculation of compression factor – Part 2: Calculation using molar-composition analysis</i>
ISO TR 9464,	<i>Guide to the use of ISO 5167</i>
NFOGM 2003,	<i>Handbook of uncertainty calculations; Ultrasonic fiscal gas metering stations</i>
NFOGM 2001,	<i>Handbook of uncertainty calculations, Fiscal orifice gas and turbine metering stations</i>

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

2.2 Informative references

ISO 6974-1,	<i>Natural gas - Determination of composition with defined uncertainty by gas chromatography - Part 1: Guidelines for tailored analysis</i>
ISO 6974-2,	<i>Natural gas - Determination of composition with defined uncertainty by gas chromatography - Part 2: Measuring-system characteristics and statistics for processing of data</i>
ISO 6974-3,	<i>Natural gas - Determination of composition with defined uncertainty by gas chromatography - Part 3: Determination of hydrogen, helium, oxygen, nitrogen, carbon dioxide and hydrocarbons up to C8 using two packed columns</i>

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

carrier gas

gas used to transport sample through the columns, normally helium, hydrogen or mixture of helium and hydrogen

3.1.5

column

tubes inside the temperature controlled oven of the OGC packed with material suitable for separating the components of natural gas when flowing the sample through using carrier gas

3.1.6

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.

3.1.7

group of component

group of components with so low concentrations that their measurement as individual would be difficult or require excessive time

NOTE Hydrocarbons heavier than pentanes (denoted as C6+) is example of such a group.

3.1.8

may

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

3.1.9**online gas chromatograph (OGC) calibration**

determination of the response of the detector for a given component with known concentration given on the certificate of the calibration gas or comparing the reading from OGC with values given on the certificate of the WGM

NOTE The gas chromatograph is fed continuously and automatically with process gas.

3.1.10**quantity**

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

3.1.11**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

3.1.12**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 Symbols

U_{CXi} is the expanded uncertainty of X_i in the WGM ($k = 2$). Expressed in mole percentage.

U_{LXi} is the expanded uncertainty of X_i , due to lack of linearity of OGC ($k = 2$). Determined from linearity test of OGC and expressed in mole percentage.

U_{RXi} is the expanded uncertainty of X_i , due to lack of repeatability of OGC ($k = 2$). Determined from stability test of OGC and expressed in mole percentage.

U_{Xi} is the total expanded uncertainty of X_i determined by OGC ($k = 2$). Expressed in mole percentage.

X_i is the concentration of component i expressed in mole percentage.

3.3 Abbreviations

AGA	American Gas Association
ANSI	American National Standards Institute
ASME	The American Society of Mechanical Engineers
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
EN	European Standard
FAT	factory acceptance test
GCV	gross calorific value
GRP	glass reinforced plastics
ID	internal pipe diameter
IEC	International Electrotechnical Commission
IFCC	International Federation of Clinical Chemistry
IP PMM	Institute of Petroleum, Petroleum Measurement Manual
ISO	International Organization for Standardization
IUPAC	International Union of Pure Applied Chemistry
IUPAP	International Union of Pure Applied Physics
NFOGM	Norwegian Society for Oil and Gas Measurement
NPD	Norwegian Petroleum Directorate
OD	outer pipe diameter
OGC	on-line gas chromatograph

OIML	International Organization of Legal Metrology
P&ID	process and instrument diagram
Pt-100	platinum resistance thermometer
RAM	read access memory
SAS	safety and automation system
SI	System Internationale
USM	ultrasonic meter
VDU	visual display unit
WGM	working gas mixture

NOTE WGM is also called calibration gas, used for regular calibration of the OGC. Normally prepared by gravimetric method and supplied with a certificate listing the concentrations of all component and the uncertainty of the concentrations.

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 gas include all systems for

- sales and allocation measurement of gas,
- measurement of fuel and flare gas,
- sampling,
- gas chromatograph.

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

The standard reference condition shall be 15 °C, 1,01325 bara, see ISO 5024.

The normal reference condition is defined as 0 °C, 1,01325 bara.

For calculation of gross calorific value (superior) and Wobbe index the standard reference condition shall be used in addition to combustion temperature of 25 °C and metering temperature of 15 °C.

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

Table 1 specifies normally applied uncertainty limits.

Table 1 - Measurement system uncertainty limits

MEASUREMENT SYSTEM	UNCERTAINTY LIMITS (Expanded uncertainty with a coverage factor $k = 2$)	CLASS
Sales and allocation measurement	$\pm 1,0$ % of mass ^a	Class A
Fuel gas measurement	$\pm 1,8$ % of standard volume	Class B
Flare gas measurement	$\pm 5,0$ % of standard volume	Class C
Simplified measurement system for gas	$\pm xx$ % of standard volume ^b	Class D
^a The uncertainty is given in mass, but other units may be requested (project specific) e.g. standard volume, energy etc.		
^b 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 documents:

- "Guide to the Expression of Uncertainty in Measurement (GUM)", (BIPM et. al.);
- a practical implementation is shown in handbooks of uncertainty calculation (including spreadsheet), issued by CMR, NPD and NFOGM (NFOGM 2001 and NFOGM 2003).

4.3 Sampling and analysis equipment

Automatic sampling or analysis equipment shall be installed. For dry gas, on-line gas chromatography shall be used if suitable for the process. Automatic sampling or analysis equipment is not required for fuel and flare metering systems.

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 traceable measured and certified to international/national standards. The material constants shall be documented. Implemented constants shall be available for verification, see 5.2.4.15.

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 gas flow rates and accumulated quantities. Where applicable, approval by the national authorities is required for the measurement system.

5.1.2 Products/services

The quality of the gas to be measured shall be evaluated. To obtain the required measurement uncertainty, single-phase condition is required.

5.1.3 Equipment/schematic

The measurement system shall consist of

- a mechanical part, including the flow meter,
- an instrument part,
- a computer part performing calculations for quantity, reporting and control functions. The computer part shall be dedicated computer(s). However, the supervisory computer may be a dedicated part of 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 gas 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 systems, listed in 5.1.4.2.

NOTE NPD regulation requires one spare meter run for a multi-run sales gas metering station.

5.1.4.2 Uncertainty

Class A system.

5.1.4.3 Lifetime

The lifetime is application specific.

5.1.4.4 Availability

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

5.1.5 Process/ambient conditions

See 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 5.2.4.3.

It shall be possible to measure the gas flow and accumulate even if the supervisory computer fails completely.

It shall be possible to operate all valves locally.

The gas flow measurement function shall not be affected during regular calibration of the field instruments or if a field instrument of any type fails.

5.1.6.2 Measurement systems with multiple meter runs

In automatic mode, the measurement system shall control opening and closing of meter runs that are in service mode, as required by the amount of gas flow being measured.

The meter runs inlet valves shall have remotely operated electrical actuators. These shall not be part of the automatic operation.

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

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, it should be easy access to 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 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 (m/s). For differential pressure device equivalent Re-number range will apply.

Densitometer cables shall be equipped with quick connectors for easy retrofit.

The computer part shall be designed so that during calibration the quantities shall be registered separately and independently of measured quantities. 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 that requires 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 transducer 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 input/output system, i.e. no average.

5.1.7.4 Isolation and sectioning

It shall be possible to maintain and inspect the mechanical part of the system, including internal surface of the meter run, without dismantling the manifolds (or similar).

5.1.7.5 Thermal insulation

The insulation/heat trace 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 and downstream length of pipe shall be installed. If the measurement system has an inlet manifold, it shall be in the same plane as the meter tubes

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

NOTE A model for estimation of the ultrasonic acoustic noise level emitted by pressureregulating valves and its influence on ultrasonic flowmeters" MARCEL J.M. VERMEULEN, GEEUWKE DE BOER and JIM BOWEN, Paper was presented during the AGA Operations Conference (Washington) in year 2001

The metering system shall not be installed in locations where any liquid may be accumulated.

5.1.9 Interface requirements

The computer part shall be interfaced to

- SAS (if dedicated computer),
- sampling system and/or on-line gas chromatograph,
- production database and allocation systems (information management system).

The remaining interfaces, if any, are application specific, e.g. water dew point, hydrocarbon dew point, hydrogen sulphide (H₂S).

5.1.10 Testing and commissioning requirements

The testing and commissioning requirements 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

5.2.2.1 Sizing

The measurement system shall be designed to measure any expected flow rate within 80 % of maximum capacity.

5.2.2.2 Meter run pressure setting/equalising

Each meter run shall have

- a connection to flare for depressurizing the meter run,
- a connection for nitrogen purging,
- a small bore by-pass across the inlet or outlet valve for pressure setting/equalizing the meter run.

5.2.2.3 Meter runs and header design

Meter run and header design shall ensure adequately developed flow profile at the flow meter. This can be achieved when the cross sectional area of inlet manifold is, as a minimum equal to the area of the meter runs in operation. For large measurement stations, placing the inlet pipe in the centre of the manifold may reduce the inlet manifold diameter. This is valid unless it is verified and documented that the flow meter is not influenced by the layout of the meter runs and header in such a way that the overall uncertainty requirements are exceeded.

Orifice:

The orifice meter runs shall be designed in accordance with ISO 5167-1 and ISO 5167-2.

Ultrasonic:

The ultrasonic meter runs shall be designed in accordance with AGA 9 with the following clarifications:

- 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 15 ID. The minimum straight downstream length shall be 3 ID. Flow conditioner of a recognized standard shall be installed. If it is documented that the ultrasonic meter is not influenced by the layout of the piping upstream in such a way that the overall uncertainty requirements are exceeded other designs based on computerized flow modelling can be allowed.
- Ultrasonic meters may be used bi-directionally. In this case both ends of the meter shall be considered as upstream.

Coriolis:

Upstream piping configuration may affect the gas velocity profile entering a coriolis sensor. The upstream piping configuration will have to be based on an evaluation of recent test results for similar type of meters.

5.2.2.4 Flow meter designs

Orifice meters:

The orifice meter shall be designed in accordance with ISO 5167-1 and ISO 5167-2. Orifice plate carrier of single chamber type shall be applied.

Ultrasonic meters

The ultrasonic meter shall be designed in accordance with AGA 9 with the following clarifications:

- the number of paths for ultrasonic meters shall be determined by required uncertainty limit. In order for the ultrasonic meter to be accepted and considered to be of acceptable quality the maximum deviation from the reference during flow calibration shall be less than $\pm 1,5 \%$. The linearity shall be better than $1,0 \%$ (band) and the repeatability shall be better than $\pm 0,2 \%$. These requirements are applicable after application of factory zero flow point calibration but before application of any correction factors, for flow velocities above $1,5 \text{ m/s}$,
- the meter shall be designed and installed such that any accumulation in the form of liquid or solid particles in the vicinity of the transducers is avoided,
- 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 AGA 11, and ISO 10790, Annex E.

Other types of meters:

Project specific.

5.2.2.5 Block valves

The meter run inlet and outlet valves shall be of double block and bleed type. The valves shall be equipped with a body vent and the leakage control shall be automatic or manual monitored.

Outlet on/off valves at multiple meter runs shall be equipped with remotely 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.

5.2.2.6 Vent systems

The system shall have vent system with single connection at system limit. Double block and bleed valve arrangement in the vent lines.

5.2.2.7 Thermal insulation

The meter including critical flanges and downstream spool, temperature measurement point, density, OGC, sampling system etc. shall be thermally insulated and/or heat traced.

There shall be no heat tracing of meter runs between flow meter and temperature measurement nor on the density tubings.

5.2.3 Instrument part

5.2.3.1 General

Pressure and temperature shall be measured in each meter run. Density shall be measured or calculated based on input from OGC. Density determination shall be duplicated, either by two densitometers, one OGC and one densitometer, or dual OGC.

5.2.3.2 Location of sensors

Pressure: When ultrasonic meters are utilised, pressure shall be measured at the USM body or downstream the flow meter.

Temperature: Temperature shall be measured downstream of the flow meter.

Density: If densitometers are used, the density measurement device shall be installed so that representative measurements are achieved. Pressure and temperature measurement shall be measured as close as possible to the density measurement.

When orifice meters are utilised the upstream flange tap position shall be used for pressure measurement and the density shall be measured or calculated to the upstream flange tap condition.

5.2.3.3 Instrument panel and supplies

Field instrument cable entry shall be metric threads. The electrical supply for field instrumentation used for fiscal measurement systems including the computer system, shall be powered from instrument panels supplied from uninterrupted power supply.

5.2.3.4 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.

5.2.3.5 Stability for smart transmitters

For smart pressure and smart differential 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 $\pm 0,1$ °C for 24 months.

5.2.3.6 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-wire or 3-wire system).

The Pt-100 element should as a minimum be in accordance with EN 60751, tolerance Class 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 calibration, see 4.4. The total uncertainty for the temperature loop shall be better than $\pm 0,15$ °C.

5.2.3.7 Thermowells

All thermowells shall at least be inserted $1/3$ ID into the pipe, but less than $1/2$ ID. Further details and principles are given in ISO/TR 9464, 12.3.4. A second thermowell shall be installed within 2 ID of the primary thermowell.

For horizontal pipes thermowells shall be installed in clock position between 10 and 2 to allow for liquid filling of the well. For vertical pipes thermowells shall be installed to allow for liquid filling of the well.

The design shall avoid critical vibration in the thermowell. The vibration calculation shall be done for 20 % above maximum design flow rate, see ANSI/ASME Performance Test Code 19.3 - 1974, Chap. 1, 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.

5.2.3.8 Direct density measurement

The gas shall at the density measurement point be in a measurable form i.e. well above the hydrocarbon dew point. The density shall be measured by the vibrating element technique and according to IP PMM Part VII. Density calculation and calibration shall be in accordance with company practice. The density shall be corrected to the conditions at the fiscal measurement point.

The transducer pulse/frequency signal shall direct or via smart communication be transmitted to the computer, see 5.2.3.4. If the density is of the by-pass type, temperature compensation shall be applied.

The uncertainty (expanded uncertainty with a coverage factor $k = 2$) of the complete density circuit, including drift between calibrations shall not exceed $\pm 0,30$ % of measured value.

The measured density shall be compared against a calculated density.

5.2.3.9 Calculated density

Calculated density shall be by AGA 8, detailed characterization method, or ISO 12213-1 and ISO 12213-2. For special applications, other methods may be considered. When an OGC is a part of the fiscal measurement system, composition data from this unit shall automatically be used in the standard and line/operating density calculation. However, if online compositional data is not available, operator entered composition data shall be used.

5.2.3.10 Ultrasonic flow meter

For the ultrasonic flow meter, critical parameters relating to electronics and transducers shall be documented. 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 marked by serial number or similar to identify their location in the meter body etc. A dedicated certificate stating critical parameters shall be attached.

5.2.3.11 Differential pressure transmitter

Smart differential pressure transmitters for orifice measurement systems shall be installed in parallel for mutual surveillance, i.e. if the duty transmitter fails the hot stand-by shall be used automatically until the duty transmitter is repaired.

5.2.3.12 Local indicators

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

5.2.3.13 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.

5.2.3.14 Instrument ball valves

For fiscal measurement applications, ball valve manifold block or an assembly of 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 be full bore with respect to instrument impulse tubing. However, the equaliser-, test-valves and tubing (typically $\frac{1}{4}$ in) may be reduced bore. The test port shall be equipped with quick connector.

5.2.3.15 Instrument tubing

For fiscal measurement systems the instrument impulse tubing shall not be less than 12,7 mm ($\frac{1}{2}$ in) OD. 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 "liquid traps" are avoided.

Instrument tubing for differential pressure transmitters should be kept symmetrical with respect to pipe/instrument interface, where tubing diameter changes and isolation valves are installed.

5.2.3.16 Enclosures

Enclosures shall be used for stream differential pressure, pressure and temperature transmitters. The type shall be fire retardant GRP or equivalent. If the instruments are installed in exposed area, enclosure shall be insulated, heated and temperature controlled.

For densitometers a clamp on enclosure, type fire retardant GRP or equivalent, shall be utilised.

5.2.4 Computer part

5.2.4.1 General

The computer part shall consist of a sufficient number of computers performing the functions specified in 5.2.4.2 to 5.2.4.16, VDUs, printers for reporting, and communication possibilities for transferring signals to other systems.

This subclause specifies the requirements for "A Class" system.

5.2.4.2 Computer design

The software for calculation of fiscal quantities shall be stored in a secure manner, see 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 s for the VDU update and the resolution shall be sufficient to verify the requirement for calculation accuracy. Any displayed value shall be presented by eight 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 will be project specific, e.g. 00:00 or 06:00 each day.

The flow computers shall be equipped with battery supported RAM, this shall ensure safe warm start after 1 year power off.

Input signals:

Signals from all instruments in one meter run shall be read during 1 s, except for temperature and density, which shall be read at least every 5 s. Analogue to digital conversion shall be by 14 bits minimum. The system shall accept any manual inputs 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:

Digital to analogue conversion for fiscal purposes shall be by 14 bits minimum.

5.2.4.3 Process operator interface

The process operator interface shall as a minimum comprise

- graphic user interface,
- meter run control,
- security control of operator entered parameters,
- alarm handling.

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.

5.2.4.4 Measurement computer system

The computer system functions and interface shall as a minimum comprise

- graphic user interface,
- meter run control,
- security control of operator entered parameters,
- alarm and event handling,

- 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.

5.2.4.5 Calculations

The computer shall calculate flow rates and accumulated quantities for

- a) actual volume flow,
- b) standard volume flow,
- c) mass flow, energy flow (application specific).

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 s.

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

For ISO 5167 (all parts) calculation, the average values for density and differential pressure shall be calculated from square roots of the field values.

The iteration procedure shall ensure that a new iteration of flow coefficient is carried out if the difference between the two last flow coefficient computations exceeds ten to the power of minus five (0,00001).

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 (non resetable counter function). The figures shall be stored for the time period that is regarded as necessary. The files/records shall be secured in such a way that they can not be zeroed or altered unless a special procedure is followed.

The computer part shall be capable of calculating the following figures based on the compositional data normalised values X_i :

- compressibility factor at reference condition according to ISO 6976;
- gross calorific value (superior) according to ISO 6976 and 4.1;
- Wobbe-index according to ISO 6976 and 4.1;
- relative density (real/ideal) according to ISO 6976;
- density at reference condition according to ISO 6976.

It shall be possible to enter the project specific relevant properties of the C6+ fraction in the computer part.

The following calculated values shall as a minimum be available for reports and VDU:

- hourly and daily totals and maintenance mode totals;
- average flow rates;
- average process values, all average values shall be flow-weighted by mass.

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

5.2.4.6 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 s to 10 min).

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

Back-up density shall be automatically selected in the event of failure in the main method for density determination.

Ultrasonic meter check:

All parameters relevant for verifying the condition of the meter shall be included in the self-check or be available for manual verification of the meter. Speed of sound calculation shall be according to AGA 10.

5.2.4.7 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,
 - 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 alarms shall be implemented.

5.2.4.8 Events

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

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

5.2.4.9 Reporting of data

The computer shall generate quantity reports containing as a minimum

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

Reports for the following intervals shall be available:

- current status (no average values);
- hourly;
- daily.

The reports shall also contain gas quality parameters as measured by on-line equipment or manually entered, e.g. GCV, Wobbe-index and gas composition.

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, station total and non resetable totals.

If the reporting computer is out of service during 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 1 h 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 s. 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.

5.2.4.10 Storing of data

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

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 at least 30 days.

5.2.4.11 Availability

The computer 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 gas flow can be measured even if failures occur within any level of the computer part.

The availability of the fiscal computer system shall be documented and better than 99,5 % availability.

5.2.4.12 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.

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

Self-check and self-diagnostics shall be done during normal operation and at cold and warm start up.

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.

5.2.4.13 Spare capacity

For future extension the following requirements are valid:

- the software, including programs and data, shall not occupy more than a 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/output rack shall have 25 % spare;
- the flow computer rack shall have 25 % spare.

5.2.4.14 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.

5.2.4.15 Downloading of constants and ranges

Last versions of constants and ranges are to be downloaded to the flow computer upon start-up, 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 shall be downloaded as complete data sets. This applies to e.g. densitometer constants.

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

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

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

5.2.4.16 Automatic restart

The system shall be capable of an 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.

6 Fuel gas measurement

6.1 Functional requirements

6.1.1 General

The measurement system shall measure gas flow rates and accumulated quantities. Where applicable, approval by the national authorities is required for the measurement system.

6.1.2 Products/services

See 5.1.2.

6.1.3 Equipment/schematic

The measurement system shall consist of

- a mechanical part (including the flow meter),
- an instrument part,
- a computer part performing calculations for quantity, reporting and control functions. The computer part shall be dedicated computer(s). However, the supervisory computer may be a dedicated part of SAS or shared with the sales or allocation measurement system.

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

The measurement method shall be by ultrasonic meter, orifice meter or turbine meter.

6.1.4 Performance

6.1.4.1 Capacity

See 5.1.4.1.

6.1.4.2 Uncertainty

Class B system.

6.1.4.3 Lifetime

See 5.1.4.3.

6.1.4.4 Availability

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

6.1.5 Process/ambient conditions

See 5.1.5.

6.1.6 Operational requirements**6.1.6.1 General**

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

It shall be possible to measure the gas flow and accumulate even if the supervisory computer fails completely.

It shall be possible to operate all valves locally.

Continuous measurement of the gas flow shall be maintained during regular calibration of the field instruments and instrument fails.

For single meter run configuration, it shall be possible to route the gas stream through a by pass line for inspection and maintenance of the fuel meter run. When the system is in this bypass mode, flow calculations shall continue based on average flow rate in a user selectable time periods (that is from 1 min to 1 h) prior to opening to by pass (manual override).

6.1.6.2 Measurement systems with multiple meter runs

See 5.1.6.2.

6.1.7 Maintenance requirements**6.1.7.1 General**

See 5.1.7.1.

6.1.7.2 Calibration

See 5.1.7.2.

6.1.7.3 Maintenance

See 5.1.7.3.

6.1.7.4 Isolation and sectioning

See 5.1.7.4.

6.1.7.5 Thermal insulation

See 5.1.7.5.

6.1.8 Layout requirements

Sufficient upstream and downstream length of pipe shall be installed.

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

6.1.9 Interface requirements

Computer part interfaces:

- if dedicated computer: SAS;
- sampling system and/or on-line gas chromatograph;

- production database and allocation systems.

6.1.10 Testing and commissioning requirements

The testing and commissioning requirements in Annex B shall apply.

6.1.11 Special consideration for fuel gas system

Orifice meter should be preferred to gas turbine meter unless the cost of long upstream meter run lengths for the orifice meter outweighs the cost of annual flow calibrations at operating conditions of the gas turbine meter, and the cost of one spare gas turbine meter (in stores).

A gas turbine meter should be preferred if the flow range of the fuel stream requires frequent changes of orifice plates during regular operation. Ultrasonic meters should also be evaluated for this application.

For every small fuel gas streams, in particular non-fuel streams withdrawn from the fuel distribution system downstream of the main fuel metering system, the following methods should be considered:

- for small gas streams in temporary use or withdrawn manually at intervals: no meter, just estimation;
- for continuous streams smaller than specified by ISO 5167 (all parts) and AGA 7, one of the following methods shall be used:
 - small, full bore, gas turbine meters, designed to manufacturer's standard (minimum 6 mm);
 - integral orifice meters (smaller than 12 mm);
 - other suitable type of small flow meter with equivalent accuracy.

6.2 Technical requirements

6.2.1 General

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

6.2.2 Mechanical part

6.2.2.1 Sizing

See 5.2.2.1.

6.2.2.2 Meter run pressure setting/equalising

See 5.2.2.2.

6.2.2.3 Meter runs and header design

See 5.2.2.3.

6.2.2.4 Flow meter designs

Orifice meters:

The orifice meter shall be designed in accordance with ISO 5167-1 and ISO 5167-2.

Orifice plate carrier of single chamber type shall be applied.

Ultrasonic meters:

The ultrasonic meter shall be designed in accordance with AGA9 with the following clarifications:

The ultrasonic meters shall have minimum two paths.

In order for the ultrasonic meter to be accepted and considered to be of acceptable quality the maximum deviation from the reference during flow calibration shall be less than $\pm 2,0$ %. The linearity shall be better than 1,5 % (band) and the repeatability shall be better than $\pm 0,50$ %. These requirements are applicable after application of factory zero flow point calibration but before application of any correction factors, for flow velocities above 1,5 m/s.

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

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

Gas turbine meters:

Turbine meters shall have minimum straight upstream and downstream meter tube lengths according to AGA 7, ISO 9951 or manufacturer's requirements, whichever is the most stringent. Turbine flow meter shall be high quality meters of full profile, axial type, designed specifically for gas flow measurement. Design shall be according to AGA 7, Figure 1, (not Figure 1A).

Other types of meters:

Project specific.

6.2.2.5 Block valves

The meter run inlet and outlet valves shall be of double block and bleed type. The valve balls shall be trunnion mounted, with independent upstream and downstream seals and firesafe. The valve shall be equipped with a body vent and the leakage control shall be automatic or manual monitored.

For single meter run the bypass valve shall be equipped with limit switches, which shall trigger the bypass calculation routine. The bypass valve shall include a body vent and the leakage control shall be automatic or manual monitored.

Outlet on/off valves at multiple meter runs shall have remotely operated actuators with failsafe "stay in position". Flow direction shall be clearly stated on valve bodies.

Remotely operated electrical actuator may be used for control, in addition to limit switches for on or off positions. Any flying leads shall be protected with a flexible conduit.

6.2.2.6 Vent systems

See 5.2.2.6.

6.2.2.7 Thermal insulation

See 5.2.2.7.

6.2.3 Instrument part

6.2.3.1 Location of sensors

See 5.2.3.2.

6.2.3.2 Instrument panel and supplies

See 5.2.3.3.

6.2.3.3 Signal types

See 5.2.3.4.

6.2.3.4 Stability for smart transmitters

See 5.2.3.5.

6.2.3.5 Temperature loop

See 5.2.3.6.

6.2.3.6 Thermowells

See 5.2.3.7.

6.2.3.7 Density

Density shall be calculated by AGA 8 latest revision, detailed characterization method or ISO 12213-2, based on representative gas composition data. If the gas composition data is not available from an on-line system and the gas composition varies significantly the density should be measured.

6.2.3.8 Ultrasonic flow meter

See 5.2.3.10.

6.2.3.9 Differential pressure transmitter

See 5.2.3.11.

6.2.3.10 Local indicators

See 5.2.3.12.

6.2.3.11 Local pressure indication

See 5.2.3.13.

6.2.3.12 Instrument ball valves

See 5.2.3.14.

6.2.3.13 Instrument tubing

See 5.2.3.15.

6.2.3.14 Enclosures

See 5.2.3.16.

6.2.4 Computer part**6.2.4.1 General**

See 5.2.4.1.

6.2.4.2 Computer design

See 5.2.4.2.

6.2.4.3 Process operator interface

See 5.2.4.3.

6.2.4.4 Computer system interface

See 5.2.4.4.

6.2.4.5 Calculations

See 5.2.4.5

6.2.4.6 Check

See 5.2.4.6.

6.2.4.7 Error handling

Error detection and error correction functions in accordance to ISO 6551, section 3, level A, shall be applied in the flow computer whenever a measurement system with gas turbine meters are selected.

6.2.4.8 Alarms

See 5.2.4.7.

6.2.4.9 Events

See 5.2.4.8.

6.2.4.10 Reporting of data

See 5.2.4.9.

6.2.4.11 Storing of data

See 5.2.4.10.

6.2.4.12 Availability

See 5.2.4.11.

6.2.4.13 Network protection/security

See 5.2.4.12.

6.2.4.14 Spare capacity

See 5.2.4.13.

6.2.4.15 Time synchronisation

See 5.2.4.14.

6.2.4.16 Downloading of constants and ranges

See 5.2.4.15.

6.2.4.17 Automatic restart

See 5.2.4.16.

7 Flare gas measurement**7.1 Functional requirements****7.1.1 General**

The system shall measure flow rate and accumulate quantities of flare gas, in Sm^3 , in accordance with governmental regulations. The calculation can either be done in a dedicated flow computer or in SAS.

7.1.2 Products/services

Not applicable.

7.1.3 Equipment/schematic

The measurement method should be by an ultrasonic transit time flow meter (USM). Various differential pressure methods should be evaluated in order to extend the operating range for the USM.

The system may share supervisory computer with other measurement systems or use part of the SAS.

7.1.4 Performance**7.1.4.1 Capacity**

The measurement system shall be capable of measuring the design rate of gas through the measurement system.

7.1.4.2 Uncertainty

Class C system.

7.1.4.3 Lifetime

See 5.1.4.3.

7.1.4.4 Availability

The regularity for the flare measurement system shall be 98 %.

7.1.5 Process/ambient conditions

See 5.1.5.

7.1.6 Operational requirements

For flare measurement systems with dedicated computer, there shall as a minimum be regular transmission to SAS of

- standard volume flow rate and totals,
- actual volume flow rate,
- pressure and temperature,
- mass (application specific).

The system shall provide access and space for maintenance and calibration.

When calibration or maintenance takes place, the computer calculation shall be based on manual field inputs.

7.1.7 Maintenance requirements**7.1.7.1 Meter verification**

The stream computers shall have calibration mode.

7.1.7.2 Isolation and sectioning

Not applicable.

7.1.8 Layout requirements

Minimum distances to upstream and downstream disturbance are 20 ID and 8 ID respectively, when using USM.

7.1.9 Interface requirements

Computer part interfaces:

- if dedicated computer: SAS;
- production database and allocation systems.

7.1.10 Testing and commissioning requirements

Before being put into operation, the ultrasonic flare gas meter shall be checked to verify velocity of sound and zero flow point. Deviation limits for the various parameters shall be determined prior to or as soon as possible, after the meter is put into service.

7.2 Technical requirements**7.2.1 Mechanical part**

All geometric dimensions of the ultrasonic flow meter which affect the measurement result shall be measured using traceable equipment, at known temperatures. The meter shall be designed and installed so that any accumulation of impurities in the vicinity of the transducers is avoided, or can be drained/flushed out without interrupting the operation.

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

7.2.2 Instrument part

Critical parameters related to electronics and transducers shall be determined. A dedicated certificate stating critical parameters shall be attached.

The static pressure shall be measured by a bara sensor.

See 5.2.3.4, 5.2.3.5, 5.2.3.6, 5.3.3.7, 5.2.3.10, 5.2.3.14 and 5.2.3.15.

7.2.3 Computer part

The computer part shall consist of a computer performing the functions specified below, a VDU, a printer for reporting, and a communication system for transferring signals to other systems:

- facilities shall be included to enable user verification of functions, parameters and accuracy for input, calculated and output values;
- during the operational phase, the parameters relevant to verify the condition of the meter shall be checked. If an alarm mode so indicates, the necessary verification and corrections shall be done;
- the computer shall raise and log alarms if any comparison checks exceed operator selected limits, if any measured value is outside predetermined limits, and in case of indications of instrument failure or computer failure;
- the computer shall report daily totals;
- change of fiscal day will be project specific, e.g. 00:00 or 06:00 each day.

The flow computers shall be equipped with battery supported RAM, this shall ensure safe warm start after minimum 1 year power off.

Algorithm and truncation/rounding errors for computations in the computer part shall be less than $\pm 0,01$ %. This requirement shall be verifiable.

8 Gas samplers systems

8.1 Functional requirements

8.1.1 General

The system shall collect and store a representative gas sample at line conditions, allowing it to be transported to the laboratory for analysis. The system shall be mounted as close as possible to the pipeline to collect samples over a sample period, unattended. The system shall be in accordance with ISO 10715. The distance to the nearest upstream disturbance, shall be at least 20 ID.

The measurement system shall control an automatic gas sampler system, i.e.

- provide a flow proportional by mass pacing signal (and a fall back signal) and
- 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 gas can be collected. The distance to the nearest upstream disturbance, shall be at least 20 ID. However, if an auto-sampler or OGC sampling probe is included in the measurement system, the manual sampling may be taken from the same probe.

8.1.2 Products/services

Single phase natural gas.

8.1.3 Equipment/schematic

The system consists of a probe, a by-pass loop, two sample pumps, a computer timing system and two sample receivers (collection cylinders) for sample transportation.

The sample equipment shall be contained in a cabinet with exception for

- the probe,
- tubing to/from the mainline,
- the back-pressure system.

The cabinet shall be located as close as possible to the sample point.

The cabinet shall be insulated, and if necessary, heated to keep the temperature well above the condensation temperature, minimum +10 °C. The heating shall be adjustable.

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

8.1.4 Performance

8.1.4.1 General

ISO 10715 describes the performance requirements for a fiscal sampling system.

8.1.4.2 Availability

The availability for the system is satisfactory when 8.1.3 is followed.

8.1.5 Process/ambient conditions

The sampling cabinet including the tubing shall be kept under sufficient protected environment, i.e. providing necessary protection against cold, heat, rain, wind etc.

8.1.6 Operational requirements

The control function shall be done from a dedicated controller, SAS or a measurement system. There shall be monitoring of maximum filling with adjustable alarm setting. In addition the measurement system shall provide a flow proportional pacing signal and monitor the sample volume collected and status of the sampling system.

8.1.7 Maintenance requirements

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

8.1.8 Isolating and sectioning

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

8.1.9 Layout requirements

ISO 10715 describes the layout requirements for a fiscal sampling system.

8.1.10 Interface requirements

The system shall be controlled and monitored from the measurement computer or SAS.

8.2 Technical requirements

8.2.1 Initial selection of automatic probe location

The sample point shall be chosen to provide a representative sample of the flowing gas in the pipe.

The sampling point shall be installed at least 20 diameters downstream of the nearest bend or restriction on a horizontal pipe. The probe shall be installed between clock position 10 and 2.

8.2.2 Design considerations for sampling systems

ISO 10715 describes the design considerations for a fiscal sampling system.

8.2.3 Probe design

The probe shall be designed and installed according to ISO 10715. The design shall avoid critical vibration in the probe. The vibration calculation shall be done for 20 % above maximum design flow rate.

8.2.4 Sample collection pump

There shall be two parallel sample collection pumps, which shall be self-purging and be designed to operate under line conditions. The grab size volume shall be adjustable in the range 0,5 ml to 1,5 ml (by e.g. different cup sizes).

The sample collection pumps shall be located above and as close to the probe as is practically and possible. Filters, drip pots, screens, regulators and such conditioning equipment shall not be placed between the probe and the sampler.

8.2.5 Sampler controller

The controller shall provide a flow proportional by weight sampling signal with a time proportional back-up possibility.

8.2.6 Sample receiver

The sample receiver shall be designed as follows:

- there shall be two parallel sample receivers;
- the filling of the two sample receivers shall have a maximum deviation of $\pm 5\%$;
- heat tracing and insulation shall be provided to keep the temperature minimum $10\text{ }^{\circ}\text{C}$ above the condensation temperature;
- the receivers shall be of the floating piston type with back-pressure of an inert gas;
- the receivers shall be portable (maximum weight 150 N including transportation container with normal size 1000 ml);
- the receivers shall be equipped with a local piston position indicator and a limit switch for maximum filling.

8.2.7 Tubing and valves

The tubing and valves shall be designed as follows:

- the tubing shall slope downwards from the sample pump to the sample receiver;
- the temperature in all parts of the sample lines/tubing and sample receivers shall be kept at a temperature minimum $10\text{ }^{\circ}\text{C}$ above the hydrocarbon dew point temperature;
- the instrument valves for the sampling system shall be of type full-bore ball valves;
- the sample tubing from/to the main pipe should have a slope of at least 1:12 to avoid liquid traps.

8.2.8 Back-pressure system

There shall be a back-pressure system with inert gas (argon or helium). This shall include a booster facility. The back-pressure volume shall be at least five times larger than the receiver volume and of a size so that the pressure increase caused by 100 % sample filling is less than 10 bar.

9 Gas chromatograph

9.1 Functional requirements

9.1.1 General

The purpose of an OGC is to give continuous quantitative composition analysis of natural gas from a process stream.

The analysis is normally limited to the following main components and concentrations:

Components	Concentration range in mole %
Nitrogen	0 to 15
Carbon dioxide	0 to 10
Methane	60 to 100
Ethane	0 to 15
Propane	0 to 5
Iso-butane	0 to 1

Normal-butane	0 to 1
Iso-pentane	0 to 1
Normal-pentane	0 to 1
Hexane's and heavier	0 to 1

The ranges shall be restricted to the operational needs for each project.

The OGC shall quantify the concentrations of the main components in the gas composition, for the purpose of gas accounting, calculation of calorific value and reference density in fiscal applications. The gas composition shall also be used for check of gas quality conformity with gas quality specifications defined by commercial gas agreements, and as a base for calculation of the operating density. The calculation of the operating density will normally be handled by the flow computers using live input values of the gas composition from the gas chromatograph.

Calculation of flow weighted average composition will normally be handled by the fiscal measurement computer system. The concentration given in mole % shall be converted to mass % for such calculations.

The analytical results shall be traceable regarding sample point, time and date, calibration gas cylinder, calibration table, and time of last calibration.

Recognized method for gas chromatograph analysis is ASTM D1945. Informative references are given in ISO 6974-1 to ISO 6974-3.

9.1.2 Products/services

Single phase natural gas.

9.1.3 Equipment/schematic

9.1.3.1 General

The system shall consist of the sample handling system, the analytical unit, the computer unit, and the calibration equipment.

9.1.3.2 Sample handling system

The sample handling system shall ensure that the sample to the OGC is representative for the process stream and suitable for the OGC. Recommendations as specified in this NORSOK standard, by the analyser, supplier and in the ISO 10715, shall be followed.

The shortest practical sampling route between sampling point and analyser should be selected. Calculation of the transport time from sample point to the gas chromatograph shall be presented. The effect that the sum of the transport time and the analysis cycle time could have on daily average analysis shall be evaluated.

Spot sampling connection shall be provided, see 8.1.

9.1.3.3 Analytical unit

The analytical unit shall separate all components sufficiently from each other so all components present in the process gas are detected with sufficient accuracy. Special care shall be taken to check that the separation between nitrogen/carbon dioxide and methane and between hexane and n-pentane are handled by the gas chromatograph in such a way that the requirements given in 9.1.4 are fulfilled.

The hexane's and heavier fraction (C6+) may include components from 2,2-dimethylbutane (neo-hexane) and upwards in an increasing order of boiling point.

9.1.3.4 Computer unit

The computer unit shall control the chromatograph. Program software, interfaces and protocol should be robust with special consideration concerning automatic regeneration of all control and communicational functions after the event of a general power failure.

The software shall be able to perform statistical tracking of analyser performance.

Criteria for accepting the results from the calibration sequence shall be implemented. Total un-normalised mol % shall be within certain limits. It should be possible to set individual limits for each component. All limits shall be possible to be set by operator.

The computer unit shall have the option of selecting an automatic benchmark and/or an automatic calibration performed between a certain number of analysis, or executed at selected calendar dates or weekdays, or at a specified time during the day.

It shall be possible to enter the relevant response factor of the C6+ fraction in the computer unit.

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

9.1.3.5 Calibration equipment

The calibration gas(es) (WGM) shall be permanently connected to the analytical unit. The system shall have a valve arrangement that provides the possibility of automatic selection of gas samples from the process gas and the WGM(s). Selection (manual/automatic) of WGM(s) shall be possible from the central control unit.

9.1.4 Performance

9.1.4.1 Uncertainty

Uncertainty of the concentration of component i, for the purposes given in this subclause, shall be reported and calculated in mole % and not as relative percentage uncertainty, U_{RelXi} .

The relation between uncertainty in mole % and relative percentage uncertainty is:

$$U_{Xi} = U_{RelXi} \times X_i / 100 \%$$

An example of processing data from a performance test is described in detail in Annex D.

Calibration gas

Each of the components in the calibration gases (WGMs) used for either acceptance tests, commissioning or during operation shall have the following documented uncertainty limits (expanded uncertainty with a coverage factor $k=2$):

Component range (mole %)	Certified uncertainty (mol %) U_{CXi}	Blending tolerance (mol %)
0,1 to 0,25	$0,05 \times X_i$	$0,05 \times X_i$
0,25 to 1	$0,01 \times X_i$	$0,03 \times X_i$
1 to 10	$0,005 \times X_i$	$0,03 \times X_i$
10 to 50	$0,002 \times X_i$	$0,03 \times X_i$
50 to 100	$0,002 \times X_i$	$0,02 \times X_i$

Repeatability

The repeatability of the OGC shall be tested in accordance with B.3.3.4 and shall be within the following limits:

Component range (mole %)	Standard deviation (mole %) $U_{RXi} / 2$
0 to 25	0,02
25 to 100	0,05

Expanded uncertainty ($k = 2$) of X_i due to lack of repeatability, U_{RXi} , is standard deviation multiplied by 2.

Linearity:

The linearity of each component shall be tested in accordance with B.3.3.5.

The uncertainty due to lack of linearity shall be determined from the maximum difference between the three test points for each component.

Expanded uncertainty due to linearity, U_{LXi} , is determined as this maximum difference divided by $3^{0,5}$ (see Guide to the Expression and Uncertainty in Measurements (GUM)); rectangular distribution assumption).

Total expanded uncertainty:

Total expanded uncertainty ($k=2$) of X_i is calculated as follows:

$$U_{Xi} = (U_{RXi}^2 + U_{CXi}^2 + U_{LXi}^2)^{0,5}$$

U_{Xi} shall be expressed in mol %

Gross calorific value:

The resulting uncertainty in gross calorific value, U_{HS} , shall be less than 0,30 % of the gross calorific value, H_S , when applying the following equation:

$$U_{HS} = [\sum (H_S - H_{Si})^2 \times (U_{Xi}/100)^2]^{0,5}$$

where H_{Si} is the gross calorific value on volumetric basis for each component found in ISO 6976. H_S shall be taken as the mean value of the three test gases.

Density:

When the composition is used for density calculation, the resulting uncertainty of each component, U_{Xi} , shall be such that the uncertainty in density, U_ρ , shall be less than 0,30 % of the density, ρ , for the working range of X_i , when applying the following equation:

$$U_\rho = 2 \cdot \left\{ \sum_{i=1}^n [S_{\rho, Xi}^2(p, T, X_i) \cdot \left(\frac{U_{Xi}}{2}\right)^2] + S_{\rho, p}^2(p, T, X_i) \cdot u_p^2 + S_{\rho, T}^2(p, T, X_i) \cdot u_T^2 + u_{\rho, Z}^2 \right\}^{0,5}$$

where

$S_{\rho, Xi}(p, T, X_i)$ is sensitivity coefficient of ρ with regard to component X_i for given pressure, p , temperature, and X .

$$S_{\rho, Xi}(p, T, X_i) = (\rho(p, T, X_1, \dots, X_i + \Delta X_i, \dots, X_n) - \rho(p, T, X_1, \dots, X_i, \dots, X_n)) / \Delta X_i$$

$S_{\rho, p}(p, T, X_i)$ is sensitivity coefficient of ρ with regard to p for given p , T and X .

$$S_{\rho, p}(p, T, X_i) = (\rho(p + \Delta p, T, X_1, \dots, X_i, \dots, X_n) - \rho(p, T, X_1, \dots, X_i, \dots, X_n)) / \Delta p$$

u_p is standard uncertainty of pressure measurement in the actual project.

$S_{\rho, T}(p, T, X_i)$ is sensitivity coefficient of ρ with regard to T for given p , T and X .

$$S_{\rho, T}(p, T, X_i) = (\rho(p, T + \Delta T, X_1, \dots, X_i, \dots, X_n) - \rho(p, T, X_1, \dots, X_i, \dots, X_n)) / \Delta T$$

u_T is standard uncertainty of temperature measurement in the actual project.

$u_{\rho, Z}$ is standard uncertainty of density due to uncertainty in calculation model for compressibility, Z .

$$u_{\rho, Z} = \rho(p, T, X_1, \dots, X_i, \dots, X_n) u_Z$$

u_Z is the relative standard uncertainty of the calculation model for Z .

ρ shall be taken as the density at given pressure and temperature using the normalised mean values of X_i for the three test gases.

Note that ΔX_i , Δp and ΔT shall be small, in the order of the respective uncertainties of X_i , p and T or less.

Working range of X_i is project specific.

Note that the requirement of U_{X_i} will normally be stricter for fulfilling the requirement for density uncertainty than for fulfilling the requirement for uncertainty of gross calorific value and gas composition for allocation purposes.

Fiscal gas composition:

For the purpose of gas composition used for allocation of mass per component, the resulting uncertainty of each component, U_{X_i} , shall be so that the uncertainty of the components or group of components being part of the allocation procedure shall not exceed the following limits for the working range of X_i , unless there are project specific requirements:

Component range [mass %]	U_{X_i} (mol%) ($k = 2$)
0,5 to 20	$0,15 \times MW/MW_i$
20 to 50	$0,30 \times MW/MW_i$
50 to 100	$0,60 \times MW/MW_i$

where

MW is the mole weight for the composition in question

MW_i is the mole weight for component i

Working range of X_i shall be specified by the project.

For the purpose of determination of the concentration of a specified component, the required uncertainty of this component is project specific.

9.1.4.2 Availability and reliability

The system shall be designed for continuous operation and for low downtime in case of maintenance, repair etc. For class A systems, when automatic sampling system is not installed, there shall at least be two independent OGC analytical systems installed. To increase the reliability of the results it should be possible to check the results from the OGC by other independent means. Such means may be another OGC installed in parallel, analytical equipment installed at other locations with which it is possible to compare the results, equipment measuring properties, which are dependent on the gas composition. Possible type of equipment for the latter check could be densitometers and ultrasonic flow meters reporting the velocity of sound.

9.1.5 Process/ambient conditions

The OGC should be kept under sufficient controlled environment, i.e. providing necessary protection against cold, heat, rain, wind etc.

Line pressure variations shall not affect the sample flow rate and pressure of the sample gas to the analyser.

9.1.6 Maintenance requirements

Care shall be taken to allow for simple quick maintenance of filters and valves and for proper choice of filter media. If necessary, spare filters shall be installed. All fittings shall be accessible for maintenance or replacement.

9.2 Technical requirements

9.2.1 Sample handling system

The sample handling system shall collect a representative gas sample.

The transport time through the sample handling system shall be less than 2 min.

The sampling probe shall be installed so that a representative sample of the gas can be collected. The distance to the nearest upstream disturbance, shall be at least 20 ID.

Conditioning equipment is required to reduce pressure to a level suitable for the analyser.

Adequate protective filtering and coalescer have to be installed after the pressure reduction system to remove dirt and liquid entrainments if such contamination will be present.

The temperature in all parts of the sample lines including sample conditioning equipment shall be kept at a temperature minimum 10 °C above the hydrocarbon dew point temperature. The dew point temperature shall be calculated by well recognised methods for every pressure level in the system. The temperature and pressure at critical points in the sampling system shall be indicated.

Slope of at least 1:12 should be maintained along the sample line from the probe to the pressure reduction system in order to avoid liquid traps.

The sampling probe should be designed so it is possible to be retracted under operating pressure by method accepted by the operator.

All manually controlled shut off valves in the cabinets shall have a proper open/close indication.

Waste samples from the analyser shall be vented via a separate vent line specially designed in order to minimize influence from ambient conditions. Waste bypass gas from the cabinets can be vented to a common vent system.

9.2.2 Analytical unit

The time required for a full analysis cycle shall be less than 10 min.

The oven temperature shall be controlled to obtain required stability and accuracy of the analysis. It should be possible to check the temperature at any time.

The chromatograph shall use carrier gas in accordance with requirement given by the application. Pressure and flow rate of carrier gas shall be controlled with sufficient accuracy. Necessary equipment for safe operation in case of failure in carrier gas supply shall be installed if applicable.

The chromatograph shall use thermal conductivity detector or equivalent.

NOTE Thermal conductivity detector is the most commonly used detector to measure the main components in natural gas.

9.2.3 Computer unit

Communications between the analytical unit and the computer unit should be according to the vendor's standard protocol.

The following functions shall all be available for the operator and should also be available from the supervisory computer:

- start and stop the analysis cycle;
- change the alarm limits;
- acknowledge alarms;
- define and/or read component table, retention time retention time tolerance, response factor and valve switching;
- sequence, calibration frequency and WGM concentration;
- password protected program modifications;
- define and/or read time, peak height, peak area, peak start time, peak end time (for each component) and total area;
- select override analysis.

The computer unit shall have functions that give an alarm and inhibit the use of calibration tables containing response factors that are outside pre-set limits of acceptable values. The response factors for those

components not present in the calibration gas shall either be manually entered or automatically calculated by using a mathematical relation to other components, i.e. calculate response factors for the hexane plus fraction from the response of pentanes or butanes.

The chromatograms should be displayed in real time and also stored digitally with the possibility of later visual inspection. Start and stop of peak integration event marks and electronic baseline should be possible. Hard copies shall be available.

A main report to the main network shall contain names of components, normalised mole % of each component rounded to the nearest 0,001 %.

A quality control report for printouts and electronic transmission should contain information about retention time, peak height, peak width, peak area, response factor, and mole % before and after normalisation.

A control function in the software should give alarm if one or more components are missing from the report or that the sum of non-normalised values are outside pre-set limits. This alarm shall inhibit the transmission of potential erroneous results onto the main computer network.

The following requirements for displaying items should be considered:

- alarm status;
- historical analysis data for a single component in chart form;
- historical analysis data in report format, average, maximum and minimum values for each component and calculated values;
- the last measured concentration value for each component and calculated values;
- real time chromatogram and valve status.

Alarm generation shall be standardized.

Communication with the main metering computer should be via serial data link.

9.2.4 Calibration equipment

The calibration gas bottles cabinet shall be electrically heated to prevent condensation. It should be possible to enter, store and change the composition of the calibration gas. The vendor of the WGM shall provide relevant documentation for the uncertainty calculations.

Annex A (Normative)

Requirements for automated condition based maintenance

A.1 General

The fiscal measurement systems 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 system. These field tags are typically pressure, temperature, density, differential pressure, flow values (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 in operation.

A.2 Software requirements

The software shall be prepared for easy and reliable verification of the accuracy of the measured field tags.

Parameters indicating the condition of each field tag (i.e. deviations from reference values or other deviations) shall be stored and trended graphically. Additionally, a current condition reports shall be generated at predefined times or on demand. The current condition reports shall include comparisons against predefined limits of deviation for each parameter. Generally, a verification of current condition shall be automatic. The current condition reports may be combined with the reports of the daily status of the measurement system.

Annex B (Normative) Testing and commissioning

B.1 Scope

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

B.2 System test requirements

B.2.1 General

The supplier shall not present any item for inspection and testing until he has completed his own inspection or 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 NORSOK standard. The supplier shall prepare acceptance test procedures for factory and offshore acceptance tests, which shall demonstrate that all specifications of this NORSOK standard and subsequent functional design documents 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 NORSOK standard;
- that all the spare 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.2.2 Supplier internal system test

This test shall be performed as described in B.1. 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 shall be documented as described in FAT procedure, and completed before the next test is performed.

B.2.3 Purchasers factory acceptance test (FAT)

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 suppliers 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;
 - 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 shall be completed before the next test is performed.

B.2.4 Site/yard acceptance test

Such a test typically includes verification of system after power-up, full load test and integrated test with SAS. Operating manuals shall be available for this test

B.2.5 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 calibrated by an accredited laboratory to international/national standards before the instruments are taken into service.

Ultrasonic meter for gas:

After being pressurised, but 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.3 Test of individual components

B.3.1 Test equipment

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

B.3.2 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).

For Class C systems and Class D systems, flow meters shall be tested as mutually agreed.

For Class A systems and Class B systems, turbine 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 and ultrasonic flow meter shall be tested in the upper and lower part of the range, and at three points distributed between the maximum and minimum values. Five repeats shall be made for each point. Relevant performance criteria are given in 5.2.2.4 and 6.2.2.4. The calibration factor, which derives from the calibration, shall always be used.

If it is impossible to calibrate the turbine or ultrasonic meter at process conditions the calibration shall aim to achieve the specified flow velocity range.

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

- 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 checked calibrated at this test.

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

B.3.3 Inspection and testing of OGC

B.3.3.1 General

In addition to checks and verification of leakage testing, tagging, workmanship etc., the tests listed below should be performed to check the gas chromatograph system's functions.

B.3.3.2 Functional acceptance test procedures

The tests in B.3.3.3 to B.3.3.10 should be performed to check the gas chromatograph system's functions.

B.3.3.3 Ability to separate components

A gas sample containing all components present in the actual process gas shall be applied to the sample inlet of the gas chromatograph. The associated chromatograms for five consecutive runs shall be evaluated.

B.3.3.4 Stability test

Apply calibration gas with hydrocarbon components up to C5 and nitrogen and carbon dioxide to the sample inlet of the gas chromatograph and analyse continuously for 48 h. Check on the printouts of normalised values that the precision is within the requirements given in 9.1.4.1.

B.3.3.5 Linearity test

Three different certified calibration gases containing all components present in the actual process gas up to normal hexane (exclusive H₂S, water, neo-pentane, etc) should successively be applied for 10 consecutive cycles to the inlet of the gas chromatograph. One of the calibration gases shall be close to the normal sample gas composition. In the two other gases the components shall be so balanced that the working range of X_i are covered.

The calibration gases shall have the accuracy defined in 9.1.4.1.

Evaluation of the linearity test should be performed on normalised results.

B.3.3.6 Calculation test

The calculation of the relevant gas properties performed by the computer part of the gas chromatography like gross calorific value, real standard density, Wobbe index etc. shall be checked for three different gas compositions. The compositions are entered into the computer. The calculations shall be checked against reference calculations to be within $\pm 0,001$ % of specified value.

B.3.3.7 Auto-calibration function

The function automatic calibration shall be checked by connecting a gas sample to the process gas inlet and a calibration gas to the calibration gas inlet. Calibration interval and number of consecutive calibration runs (for example three) shall be entered. With this configuration the chromatograph should run for minimum 24 h allowing for at least four calibration runs. It should be checked that the calibration reports and the updating of the response factors are according to specifications. Included in the test shall also be a check of the criteria for accepting the response factor found during the calibration.

B.3.3.8 Output signals

The output signals, analogue, digital or serial links should be checked for correct information.

B.3.3.9 Alarm and event messages

Any alarm situation shall be simulated and it should be checked that the corresponding alarms are set and presented according to specifications, e.g. on flashing lights, on displays, on printers, on the serial communications etc.

B.3.3.10 System test

Apply reference gas to the inlet of the sampling system which shall include preconditioning and conditioning cabinets as close as possible to normal operating temperature and at a minimum, medium and maximum operating pressure for 10 analysing cycles at each pressure. The readings of normalised values shall not depend on the pressure and the reading of the normalised values shall be within the required repeatability.

B.4 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, which 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.5 Preservation

The entire fiscal metering 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

(Informative)

System selection criteria

C.1 General

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.2 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 in 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.3 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,

EXAMPLE Assuming 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 in 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 (Informative) Example of performance calculation of online gas chromatograph (OGC) result

D.1 General

In this annex an example of how to calculate uncertainties of an OGC after completion of a test of the OGC in accordance with 9.1.4.1 is given. Where it is referred to GCV on volumetric basis (unit: kJ/Sm³), reference metering temperature is 15 °C and combustion reference temperature is 25 °C.

D.2 Repeatability

The repeatability of the OGC is found by testing in accordance with B.3.3.4, i.e. a continuous test for 48 h.

Table D.1 shows example of a record from such a test. During the test period from 02.07.2002 at 10:59 to 04.07.2002 at 12:01, a total of 577 analyses were run with a cycle time of approximately 5 min. Note that a large part of data is deleted in Table D.1 for layout reasons.

For each component the standard deviation is calculated and shown in the second last row in Table D.1. Expanded uncertainty ($k=2$) of X_i due to lack of repeatability, U_{RXi} , is standard deviation multiplied by 2. U_{RXi} is shown in the last row of Table D.1.

D.3 Calibration gases

Each of the components in the calibration gases (WGMs) used for either acceptance tests, commissioning or during operation shall have the documented uncertainty equal to or below the limits given in 9.1.4.1.

The uncertainties shall be given on certificates for the individual calibration gas together with its composition. Table D.2 shows one example of information on three calibration gases used for a test of a gas chromatograph. The values of GCV are calculated in accordance with ISO 6976.

For each calibration gas, #1, #2 and #3, U_{CXi} is listed. In the following calculation of total uncertainty, the average uncertainty from the three calibration gases for each component is used.

D.4 Linearity

The linearity of each component shall be tested in accordance with B.3.3.5, i.e. by using three different certified calibration gases. Each of the three calibration gases should successively be applied for 10 consecutive cycles of the gas chromatograph.

The calibration gases in this example are those listed in Table D.2.

The results from such a test are shown in Table D.3.

For each calibration gas and for each component, the deviation between the value in the certificate and the average of 10 OGC readings is calculated. These deviations are shown in the last column in Table D.3.

The expanded uncertainty ($k=2$) of X_i due to lack of linearity, U_{LXi} , is determined by dividing the maximum difference between the three test points by the square root of 3, see Table D.4. The maximum difference between the three test points is called "linearity band". The division by square root of three converts "linearity band" to an uncertainty term in accordance with the "Guide to the Expression and Uncertainty in Measurements (GUM)".

The result from the linearity test can be visualised graphically as shown in Figure D.1 for the component CO₂.

D.5 Adding up uncertainties for each component

Total expanded uncertainty ($k = 2$) of X_i , U_{Xi} , is calculated as follows:

$$U_{xi} = [U_{RXi}^2 + U_{CXi}^2 + U_{LXi}^2]^{0,5}$$

The result of this summation and calculation is shown in Table D.5.

D.6 Uncertainty of calorific value

The uncertainty in gross calorific value, U_{Hs} , shall be calculated by applying the following equation:

$$U_{Hs} = [\sum (H_s - H_{Si})^2 \times (U_{xi}/100)^2]^{0,5}$$

where

H_{Si} is the gross calorific value on volumetric basis for each component found in the ISO 6976.

H_s shall be taken as the mean value of the three test gases.

Calculation results, which are based on test results, are shown in detail in Table D.6.

The end result shows in this case an expanded uncertainty of 0,08 % of H_s , which is well below the required limit of 0,30 %.

D.7 Uncertainty of calculated density based on composition, pressure and temperature

D.7.1 General

The uncertainty of the calculated operating density, U_ρ , shall be calculated by applying the following equation:

$$U_\rho = 2 \cdot \left\{ \sum_{i=1}^n [S_{\rho, Xi}^2(p, T, X_i) \cdot \left(\frac{U_{Xi}}{2}\right)^2] + S_{\rho, p}^2(p, T, X_i) \cdot u_p^2 + S_{\rho, T}^2(p, T, X_i) \cdot u_T^2 + u_{\rho, Z}^2 \right\}^{0,5}$$

The calculation of the sensitivity coefficients will be explained below. The uncertainty of pressure and temperature are normally taken from the instrumentation performance or data sheet, uncertainty of Z is taken from a standard (e.g. ISO 12213-2) and the uncertainties of the individual components are those calculated from the tests, i.e. from D.7 (Table D.5).

Table D.7 shows detailed results of the calculations necessary to find the uncertainty of operating density. The first row shows pressure, temperature and composition for which the density and its uncertainty shall be calculated. Pressure and temperature are normally typical operating conditions and the composition will normally be in the middle of the working range, often equal to calibration gas #2, see Table D.2.

This example is for pressure of 150 bar, temperature 50 °C and composition equal to calibration gas #2. In this example, the method described in ISO 12213-2 is used to calculate the density. Other methods may be used to calculate density, sensitivities etc.

The sensitivity for the variables is found by sequentially changing the variables one by one by a small amount and see what effect it has on the density. Examples are given in D.7.2 to D.7.6.

D.7.2 Effect of pressure, row 2 in Table D.7

The effect of pressure is found by calculating the effect of changing pressure by + 0,05 bar:

$$\begin{aligned} S_{\rho, p} &= [\rho(150 \text{ bar} + 0,05 \text{ bar}, 50^\circ\text{C}, C_1, C_2, \dots, CO_2) - \rho(150 \text{ bar}, 50^\circ\text{C}, C_1, C_2, \dots, CO_2)] / 0,05 \text{ bar} \\ &= (146,9981 \text{ kg/m}^3 - 146,9465 \text{ kg/m}^3) / 0,05 \text{ bar} = 1,031 \text{ kg/m}^3/\text{bar} \end{aligned}$$

Given an expanded uncertainty ($k = 2$) of pressure, U_p , of 0,2 bar, the standard uncertainty, u_p , is 0,1 bar. The term $S_{\rho, p}^2 \cdot u_p^2$ then becomes 0,0106 (kg/m³)² as shown at the end of row 2 in Table D.7.

D.7.3 Effect of temperature, row 3 in Table D.7

The effect of temperature is found by calculating the effect of changing temperature by +0,1 °C:

$$S_{\rho,T} = [\rho(150 \text{ bar}, 50 \text{ °C} + 0,1 \text{ °C}, C1, C2, \dots, CO_2) - \rho(150 \text{ bar}, 50 \text{ °C}, C1, C2, \dots, CO_2)] / 0,1 \text{ °C}$$

$$= (146,8483 \text{ kg/m}^3 - 146,9465 \text{ kg/m}^3) / 0,1 \text{ °C} = -0,982 \text{ kg/m}^3/\text{°C}$$

Given an expanded uncertainty ($k = 2$) of temperature, U_T , of 0,2 °C, the standard uncertainty, u_T , is 0,1 °C. The term $S_{\rho,T}^2 \cdot u_T^2$ then becomes 0,0096 (kg/m³)² as shown at the end of row 3 in Table D.7.

D.7.4 Effect of C1 (methane), row 4 in Table D.7

The effect of methane is found by calculating the effect of changing concentration by +0,04 mole %:

$$S_{\rho,C1} = [\rho(150 \text{ bar}, 50 \text{ °C}, (82,16 + 0,04), C2, \dots, CO_2) - \rho(150 \text{ bar}, 50 \text{ °C}, 82,16, C2, \dots, CO_2)] / 0,04 \text{ mole \%}$$

$$= (146,9258 \text{ kg/m}^3 - 146,9465 \text{ kg/m}^3) / 0,04 \text{ mole \%} = -0,516 \text{ kg/m}^3/\text{mole \% of C1.}$$

The expanded uncertainty ($k = 2$) of C1, U_{C1} , is calculated from the test as described in D.7 and shown in Table D.5 to be 0,1862 mole %, the standard uncertainty, $u_{C1} = U_{C1}/2$, is 0,0931 mole %. The term $S_{\rho,C1}^2 \cdot u_{C1}^2$ then becomes 0,0023 (kg/m³)² as shown at the end of row 4 in Table D.7.

D.7.5 Effect of components other than C1, row 5 to row 13 in Table D.7

The sensitivities and effects of the other components are calculated similar to calculation of $S_{\rho,C1}$ and the effect of C1. The calculations for the other components are found in row 5 to row 13 in Table D.7.

By studying the column for term $S_{\rho,Xi}^2 \cdot u_{Xi}^2$ the component(s) giving the highest contribution to the uncertainty of operating density can be found.

D.7.6 Effect of compressibility factor Z, row 14 in Table D.7

$u_{\rho,Z}$ is standard uncertainty of density due to uncertainty in calculation model for compressibility, Z.

$$u_{\rho,Z} = \rho(p, T, X_1, X_i, \dots, X_n) \cdot u_Z$$

u_Z is the relative standard uncertainty of the calculation model for Z.

In this example, ρ is 146,9465 kg/m³, the expanded uncertainty ($k = 2$) of Z, u_Z , is taken from information in ISO 12213-2 where it is given as 0,1 %, the standard uncertainty, U_Z , is therefore 0,05 %.

The term $u_{\rho,Z}^2$ then becomes $(146,9465 \text{ kg/m}^3 \times 0,0005)^2 = 0,0054 \text{ (kg/m}^3)^2$ as shown at the end of row 14 in Table D.7.

D.7.7 Uncertainty of density due to uncertainty of composition, pressure and temperature

By applying the equation for U_ρ using the numbers obtained as described in D.7.2 to D.7.5, a total expanded uncertainty of ρ ($k = 2$) at the given conditions is calculated to 0,3783 kg/m³ as shown in Table D.7. This is equal to 0,26 % of 146,95 kg/m³ which is below the required limit of 0,30 %.

It should be noted that for other pressures and temperatures, the uncertainty of calculated density may not be acceptable (i.e. uncertainty above 0,30 %) even though the uncertainty of the composition is the same. The following table reflects that point.

Pressure		Temperature		Density		
Value (bar)	Uncertainty (bar)	Value (°C)	Uncertainty (°C)	Value (kg/m³)	Uncertainty (kg/m³)	Uncertainty (%)
150	0,20	50	0,20	146,95	0,38	0,26
150	0,20	10	0,20	203,95	0,62	0,30
100	0,20	50	0,20	93,33	0,29	0,31
100	0,20	10	0,20	127,56	0,50	0,39
100	0,10	50	0,20	93,33	0,22	0,23
100	0,10	10	0,20	127,56	0,41	0,32
60	0,20	50	0,20	52,08	0,22	0,41
60	0,20	10	0,20	65,65	0,31	0,47
60	0,10	50	0,20	52,08	0,13	0,26
60	0,10	10	0,20	65,65	0,20	0,30

This table shows that despite the uncertainty of the composition results in an uncertainty of 0,08 % of GCV which is well below the limit of 0,30 % for this parameter, the uncertainty in operating density can in many cases be above the limit of 0,30 %, depending on operating conditions as well as uncertainty of pressure and temperature.

Uncertainty of density for various pressures and temperatures and for various uncertainties of pressures and temperature when composition uncertainty is as given in Table D.5.

D.8 Fiscal gas composition

For the purpose of gas composition used for allocation of mass per component, the resulting uncertainty of each component, U_{xi} , shall be so that the uncertainty of the components or group of components being part of the allocation procedure shall not exceed the following limits for the working range of X_i , unless there are project specific requirements:

Component range [mass %]	U_{xi} (mol%) ($k = 2$)
0,5 to 20	$0,15 \times MW/MW_i$
20 to 50	$0,30 \times MW/MW_i$
50 to 100	$0,60 \times MW/MW_i$

where

MW is the mole weight for the composition in question

MW_i is the mole weight for component i

To check if the found uncertainties are within the required limit, the actual gas composition in mole % shall first be converted to composition in mass %. This is done by the following equation:

$$Y_i = X_i \cdot MW_i / MW$$

where

Y_i is mass % of component i

In Table D.8, results of calculations and comparisons for the example used in this annex are shown.

The last column in Table D.8 is the ratio of found uncertainty to the required uncertainty. As long as this number is one or below, the requirement is fulfilled. In this case, all components passed the test.

D.9 Presentation

In a complete test report according to NORSOK tables similar to Table D.1 to Table D.8 should be presented together with a conclusion after Table D.1, Table D.2, Table D.6, Table D.7 and Table D.8 whether or not test results are acceptable.

Table D.1 could alternatively be replaced by a diagram together with values for average, standard deviation and U_{RXi} . Table D.4 could be supported by diagrams similar to that in Figure D.1.

Table D.1 - Example of results from a stability test in accordance with B.6.3.4.

	C1 (mole %)	C2 (mole %)	C3 (mole %)	iC4 (mole %)	nC4 (mole %)	iC5 (mole %)	nC5 (mole %)	C6 (mole %)	N2 (mole %)	CO2 (mole %)	Total (mole %)
02.07.2002 10:59	82,1923	8,6056	3,4636	0,2963	0,6919	0,3964	0,2970	0,5869	0,4819	2,9882	100
02.07.2002 11:04	82,1993	8,6024	3,4618	0,2963	0,6918	0,3962	0,2971	0,5856	0,4820	2,9876	100
02.07.2002 11:09	82,1994	8,6037	3,4618	0,2966	0,6917	0,3963	0,2971	0,5846	0,4818	2,9871	100
02.07.2002 11:14	82,1984	8,6041	3,4610	0,2963	0,6917	0,3962	0,2971	0,5855	0,4819	2,9879	100
02.07.2002 11:19	82,1982	8,6024	3,4628	0,2965	0,6915	0,3963	0,2970	0,5857	0,4819	2,9877	100
02.07.2002 11:24	82,1997	8,6023	3,4614	0,2964	0,6919	0,3963	0,2971	0,5856	0,4819	2,9875	100
02.07.2002 11:29	82,1962	8,6028	3,4629	0,2966	0,6916	0,3963	0,2972	0,5856	0,4819	2,9870	100
02.07.2002 11:34	82,2002	8,6037	3,4599	0,2962	0,6917	0,3963	0,2973	0,5853	0,4818	2,9877	100
02.07.2002 11:40	82,1998	8,6039	3,4594	0,2964	0,6917	0,3963	0,2971	0,5854	0,4821	2,9879	100
02.07.2002 11:45	82,1993	8,6040	3,4608	0,2964	0,6918	0,3964	0,2974	0,5848	0,4818	2,9874	100
02.07.2002 11:50	82,1967	8,6045	3,4611	0,2965	0,6918	0,3964	0,2972	0,5860	0,4820	2,9879	100
02.07.2002 11:55	82,1983	8,6039	3,4611	0,2963	0,6918	0,3964	0,2971	0,5856	0,4818	2,9878	100
02.07.2002 12:00	82,1950	8,6050	3,4621	0,2963	0,6918	0,3963	0,2971	0,5855	0,4820	2,9879	100
02.07.2002 12:05	82,1979	8,6043	3,4603	0,2964	0,6918	0,3965	0,2973	0,5860	0,4818	2,9878	100
02.07.2002 12:10	82,1970	8,6043	3,4609	0,2962	0,6921	0,3963	0,2971	0,5863	0,4819	2,9880	100
02.07.2002 12:15	82,2002	8,6041	3,4590	0,2961	0,6919	0,3964	0,2972	0,5854	0,4818	2,9879	100
02.07.2002 12:20	82,1980	8,6063	3,4598	0,2960	0,6918	0,3962	0,2972	0,5854	0,4820	2,9874	100
02.07.2002 12:25	82,1979	8,6059	3,4594	0,2961	0,6919	0,3963	0,2972	0,5854	0,4818	2,9882	100
02.07.2002 12:30	82,1982	8,6039	3,4604	0,2962	0,6920	0,3964	0,2972	0,5855	0,4819	2,9883	100
02.07.2002 12:35	82,1987	8,6059	3,4583	0,2966	0,6917	0,3963	0,2973	0,5853	0,4819	2,9881	100
02.07.2002 12:40	82,1985	8,6051	3,4595	0,2965	0,6917	0,3964	0,2974	0,5855	0,4819	2,9875	100
02.07.2002 12:45	82,1981	8,6047	3,4594	0,2964	0,6918	0,3966	0,2974	0,5859	0,4818	2,9879	100
02.07.2002 12:50	82,1969	8,6048	3,4601	0,2962	0,6922	0,3964	0,2973	0,5859	0,4818	2,9884	100
02.07.2002 12:55	82,1953	8,6083	3,4586	0,2963	0,6913	0,3961	0,2970	0,5866	0,4820	2,9885	100
02.07.2002 13:00	82,1704	8,6152	3,4617	0,2964	0,6925	0,3962	0,2972	0,5964	0,4821	2,9918	100
02.07.2002 13:05	82,1943	8,6057	3,4605	0,2965	0,6919	0,3966	0,2973	0,5870	0,4820	2,9883	100
02.07.2002 13:11	82,1899	8,6076	3,4605	0,2964	0,6918	0,3966	0,2974	0,5887	0,4820	2,9890	100
02.07.2002 13:16	82,1989	8,6043	3,4590	0,2963	0,6920	0,3964	0,2972	0,5861	0,4817	2,9882	100
02.07.2002 13:21	82,1870	8,6097	3,4605	0,2963	0,6922	0,3965	0,2975	0,5891	0,4818	2,9893	100
02.07.2002 13:26	82,1918	8,6074	3,4611	0,2963	0,6917	0,3965	0,2972	0,5879	0,4819	2,9881	100
02.07.2002 13:31	82,1880	8,6088	3,4615	0,2964	0,6920	0,3966	0,2974	0,5885	0,4819	2,9888	100
02.07.2002 13:36	82,1940	8,6062	3,4595	0,2962	0,6920	0,3964	0,2974	0,5873	0,4822	2,9889	100
02.07.2002 13:41	82,1934	8,6063	3,4602	0,2964	0,6918	0,3965	0,2972	0,5876	0,4820	2,9885	100
04.07.2002 08:44	82,2132	8,6047	3,4333	0,2994	0,6948	0,3973	0,2974	0,5892	0,4820	2,9888	100
04.07.2002 08:49	82,2043	8,6080	3,4347	0,2992	0,6951	0,3974	0,2977	0,5926	0,4821	2,9889	100
04.07.2002 08:54	82,1994	8,6078	3,4379	0,2995	0,6952	0,3978	0,2978	0,5938	0,4821	2,9886	100
04.07.2002 08:59	82,2136	8,6026	3,4355	0,2990	0,6949	0,3976	0,2976	0,5895	0,4821	2,9875	100
04.07.2002 09:04	82,2114	8,6040	3,4352	0,2993	0,6952	0,3976	0,2977	0,5900	0,4820	2,9875	100
04.07.2002 09:09	82,2170	8,6034	3,4325	0,2995	0,6948	0,3975	0,2978	0,5883	0,4817	2,9873	100
04.07.2002 09:14	82,2151	8,6030	3,4332	0,2990	0,6950	0,3976	0,2979	0,5893	0,4822	2,9875	100
04.07.2002 09:19	82,2176	8,6030	3,4317	0,2991	0,6950	0,3975	0,2977	0,5886	0,4822	2,9875	100
04.07.2002 09:24	82,2168	8,6025	3,4326	0,2993	0,6947	0,3976	0,2979	0,5891	0,4821	2,9873	100
04.07.2002 09:29	82,2121	8,6044	3,4352	0,2993	0,6949	0,3976	0,2978	0,5894	0,4821	2,9870	100
04.07.2002 09:34	82,2176	8,6047	3,4304	0,2989	0,6948	0,3976	0,2979	0,5886	0,4820	2,9874	100
04.07.2002 09:39	82,2126	8,6051	3,4336	0,2991	0,6952	0,3977	0,2977	0,5891	0,4821	2,9876	100
04.07.2002 09:44	82,2164	8,6034	3,4314	0,2991	0,6953	0,3976	0,2978	0,5893	0,4821	2,9875	100
04.07.2002 09:49	82,2110	8,6065	3,4335	0,2992	0,6953	0,3977	0,2978	0,5896	0,4820	2,9873	100
04.07.2002 09:54	82,2142	8,6051	3,4317	0,2991	0,6951	0,3977	0,2980	0,5894	0,4821	2,9875	100
04.07.2002 10:00	82,2133	8,6036	3,4333	0,2995	0,6951	0,3977	0,2977	0,5901	0,4820	2,9876	100
04.07.2002 10:05	82,2141	8,6048	3,4310	0,2990	0,6952	0,3976	0,2979	0,5900	0,4822	2,9881	100
04.07.2002 10:10	82,2128	8,6054	3,4308	0,2994	0,6951	0,3977	0,2980	0,5903	0,4819	2,9885	100
04.07.2002 10:15	82,2116	8,6067	3,4316	0,2990	0,6953	0,3977	0,2979	0,5902	0,4820	2,9879	100
04.07.2002 10:20	82,2144	8,6050	3,4305	0,2988	0,6953	0,3976	0,2976	0,5903	0,4822	2,9882	100
04.07.2002 10:25	82,2138	8,6022	3,4337	0,2992	0,6950	0,3976	0,2977	0,5907	0,4821	2,9879	100
04.07.2002 10:30	82,2107	8,6062	3,4326	0,2991	0,6952	0,3976	0,2976	0,5909	0,4822	2,9877	100
04.07.2002 10:35	82,2129	8,6046	3,4320	0,2991	0,6953	0,3976	0,2979	0,5903	0,4821	2,9881	100
04.07.2002 10:40	82,2137	8,6035	3,4315	0,2993	0,6954	0,3979	0,2981	0,5906	0,4820	2,9879	100
04.07.2002 10:45	82,2115	8,6048	3,4327	0,2994	0,6952	0,3978	0,2979	0,5907	0,4821	2,9878	100
04.07.2002 10:50	82,2099	8,6065	3,4327	0,2992	0,6954	0,3977	0,2979	0,5904	0,4819	2,9883	100
04.07.2002 10:55	82,2080	8,6067	3,4341	0,2992	0,6950	0,3973	0,2975	0,5911	0,4823	2,9887	100
04.07.2002 11:00	82,1900	8,6106	3,4381	0,2997	0,6958	0,3979	0,2981	0,5973	0,4824	2,9900	100
04.07.2002 11:05	82,2075	8,6048	3,4364	0,2995	0,6951	0,3975	0,2979	0,5913	0,4821	2,9878	100
04.07.2002 11:10	82,1991	8,6066	3,4389	0,2996	0,6952	0,3978	0,2978	0,5942	0,4821	2,9884	100
04.07.2002 11:15	82,2028	8,6055	3,4377	0,2996	0,6949	0,3977	0,2978	0,5937	0,4821	2,9882	100
04.07.2002 11:20	82,2002	8,6064	3,4383	0,2994	0,6952	0,3978	0,2978	0,5940	0,4822	2,9885	100
04.07.2002 11:25	82,1989	8,6075	3,4372	0,2994	0,6952	0,3978	0,2979	0,5949	0,4820	2,9890	100
04.07.2002 11:30	82,1990	8,6094	3,4334	0,2992	0,6955	0,3980	0,2981	0,5955	0,4822	2,9895	100
04.07.2002 11:36	82,1962	8,6071	3,4385	0,2994	0,6956	0,3979	0,2979	0,5958	0,4821	2,9894	100
04.07.2002 11:41	82,1964	8,6090	3,4368	0,2994	0,6953	0,3978	0,2979	0,5960	0,4822	2,9892	100
04.07.2002 11:46	82,1921	8,6094	3,4395	0,2998	0,6955	0,3979	0,2980	0,5964	0,4823	2,9891	100
04.07.2002 11:51	82,1954	8,6080	3,4377	0,2997	0,6955	0,3978	0,2979	0,5964	0,4823	2,9892	100
04.07.2002 11:56	82,1966	8,6090	3,4355	0,2994	0,6956	0,3979	0,2980	0,5962	0,4824	2,9894	100
04.07.2002 12:01	82,1966	8,6098	3,4350	0,2992	0,6955	0,3979	0,2980	0,5963	0,4823	2,9894	100
Average	82,1887	8,6104	3,4488	0,2976	0,6936	0,3972	0,2978	0,5940	0,4821	2,9900	
Standard deviation	0,0130	0,0044	0,0157	0,0014	0,0015	0,0006	0,0003	0,0048	0,0002	0,0016	
U_{Rxi}	0,0259	0,0087	0,0314	0,0028	0,0030	0,0013	0,0007	0,0095	0,0004	0,0032	

Table D.2 - Example of calibration gases and their uncertainties for each component

Calibration gases										
Component	Gas # 1			Gas # 2			Gas # 3			Average of the 3 gases
	Concentration (mole %)	Relative uncertainty (k=2) U_{Relxi} (%)	Uncertainty (k=2) U_{Cxi} (%)	Concentration (mole %)	Relative uncertainty (k=2) U_{Relxi} (%)	Uncertainty (k=2) U_{Cxi} (%)	Concentration (mole %)	Relative uncertainty (k=2) U_{Relxi} (%)	Uncertainty (k=2) U_{Cxi} (%)	
C1	87,140	0,20	0,174	82,160	0,20	0,164	78,070	0,20	0,156	78,07 - 87,14
C2	5,4300	0,50	0,0272	6,6700	0,50	0,0334	7,4600	0,50	0,0373	5,43 - 7,46
C3	3,0100	0,50	0,0151	3,4200	0,50	0,0171	3,8500	0,50	0,0193	3,01 - 3,85
iC4	0,3030	1,00	0,0030	0,4100	1,00	0,0041	0,5090	1,00	0,0051	0,303 - 0,509
nC4	0,9530	1,00	0,0095	1,0800	0,50	0,0054	1,2300	0,50	0,0062	0,953 - 1,23
neoC5	0			0			0			
iC5	0,2010	1,00	0,0020	0,2430	1,00	0,0024	0,4080	1,00	0,0041	0,201 - 0,408
nC5	0,2490	1,00	0,0025	0,3030	1,00	0,0030	0,3570	1,00	0,0036	0,249 - 0,357
C6	0,3290	1,00	0,0033	0,3890	1,00	0,0039	0,4500	1,00	0,0045	0,329 - 0,45
N2	0,4250	1,00	0,0043	0,3050	1,00	0,0031	0,9960	1,00	0,0100	0,305 - 0,996
CO2	1,9600	0,50	0,010	5,0200	0,50	0,025	6,6700	0,50	0,033	1,96 - 6,67
O2	0			0			0			
GCV (kJ/Sm ³)	42 137			42 011			42 143			42 097

Table D.3 - Example of results from a linearity test in accordance with B.6.3.5

Linearity test gas # 1													
Component	From calibration gas certificate	Gas Chromatograph readings											Deviation (mol%)
	Concentration (mole %)	1. run	2.run	3.run	4.run	5.run	6.run	7.run	8.run	9.run	10.run	Average (mol%)	
C1	87,14	87,12	87,12	87,12	87,12	87,12	87,12	87,12	87,12	87,11	87,12	87,122	-0,018
C2	5,43	5,45	5,45	5,45	5,45	5,45	5,45	5,45	5,45	5,45	5,45	5,449	0,019
C3	3,01	3,01	3,01	3,01	3,01	3,01	3,01	3,01	3,01	3,01	3,01	3,010	0,000
iC4	0,303	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,3037	0,0007
nC4	0,953	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,95	0,9510	-0,0020
neo-C5	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,0000	0,0000
iC5	0,201	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,2012	0,0002
nC5	0,249	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,2493	0,0003
C6+	0,329	0,33	0,33	0,33	0,33	0,33	0,33	0,33	0,33	0,33	0,33	0,3293	0,0003
N2	0,425	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,4111	-0,0139
CO2	1,96	1,97	1,97	1,97	1,97	1,97	1,97	1,97	1,97	1,97	1,97	1,974	0,014
O2	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,000	0,000

Linearity test gas # 2													
Component	From calibration gas certificate	Gas Chromatograph readings											Deviation (mol%)
	Concentration (mole %)	1. run	2.run	3.run	4.run	5.run	6.run	7.run	8.run	9.run	10.run	Average (mol%)	
C1	82,16	82,16	82,15	82,16	82,16	82,16	82,15	82,15	82,15	82,15	82,16	82,154	-0,006
C2	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,67	6,672	0,002
C3	3,42	3,42	3,42	3,42	3,42	3,42	3,42	3,42	3,42	3,42	3,42	3,419	-0,001
iC4	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,412	0,0021
nC4	1,08	1,08	1,08	1,08	1,08	1,08	1,08	1,08	1,08	1,08	1,08	1,081	0,0006
neo-C5	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,000	0,0000
iC5	0,243	0,24	0,24	0,24	0,24	0,24	0,24	0,24	0,24	0,24	0,24	0,243	0,0003
nC5	0,303	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,304	0,0005
C6+	0,389	0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,392	0,0027
N2	0,305	0,30	0,30	0,31	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,304	-0,0009
CO2	5,02	5,02	5,02	5,02	5,02	5,02	5,02	5,02	5,02	5,02	5,02	5,020	0,000
O2	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,000	0,000

Linearity test gas # 3													
Component	From calibration gas certificate	Gas Chromatograph readings											Deviation (mol%)
	Concentration (mole %)	1. run	2.run	3.run	4.run	5.run	6.run	7.run	8.run	9.run	10.run	Average (mol%)	
C1	78,07	78,19	78,20	78,20	78,19	78,19	78,20	78,20	78,19	78,19	78,20	78,195	0,125
C2	7,46	7,44	7,44	7,44	7,44	7,44	7,44	7,44	7,44	7,44	7,44	7,438	-0,022
C3	3,85	3,83	3,82	3,82	3,83	3,82	3,82	3,82	3,83	3,83	3,82	3,824	-0,026
iC4	0,509	0,51	0,51	0,51	0,51	0,51	0,51	0,51	0,51	0,51	0,51	0,506	-0,0035
nC4	1,23	1,24	1,24	1,24	1,24	1,24	1,24	1,24	1,24	1,24	1,24	1,236	0,0057
neo-C5	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,000	0,0000
iC5	0,408	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,406	-0,0015
nC5	0,357	0,36	0,36	0,36	0,36	0,36	0,36	0,36	0,36	0,36	0,36	0,358	0,0008
C6+	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,453	0,0029
N2	0,996	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,94	0,941	-0,0551
CO2	6,67	6,64	6,64	6,64	6,64	6,64	6,64	6,64	6,64	6,64	6,64	6,644	-0,026
O2	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,000	0,000

Table D.4 - Calculation of uncertainty due to lack of linearity based on test results listed in Table D.3

Linearity calculation							
Component	Gas # 1	Gas # 2	Gas # 3	Maximum difference			Uncertainty due to linearity
	Deviation (mole %)	Deviation (mole %)	Deviation (mole %)	Maximum deviation (mole %)	Minimum deviation (mole %)	Maximum difference (mole %)	Uncertainty (k=2) U_{LXi} (%)
C1	-0,018	-0,006	0,125	0,125	-0,018	0,143	0,0825
C2	0,019	0,002	-0,022	0,019	-0,022	0,041	0,0238
C3	0,000	-0,001	-0,026	0,000	-0,026	0,026	0,0147
iC4	0,001	0,002	-0,003	0,002	-0,003	0,006	0,0032
nC4	-0,002	0,001	0,006	0,006	-0,002	0,008	0,0045
neoC5	0,000	0,000	0,000	0,000	0,000	0,000	0,0000
iC5	0,000	0,000	-0,002	0,000	-0,002	0,002	0,0010
nC5	0,000	0,001	0,001	0,001	0,000	0,001	0,0003
C6+	0,000	0,003	0,003	0,003	0,000	0,003	0,0015
N2	-0,014	-0,001	-0,055	-0,001	-0,055	0,054	0,0313
CO2	0,014	0,000	-0,026	0,014	-0,026	0,040	0,0229
O2	0,000	0,000	0,000	0,000	0,000	0,000	0,0000

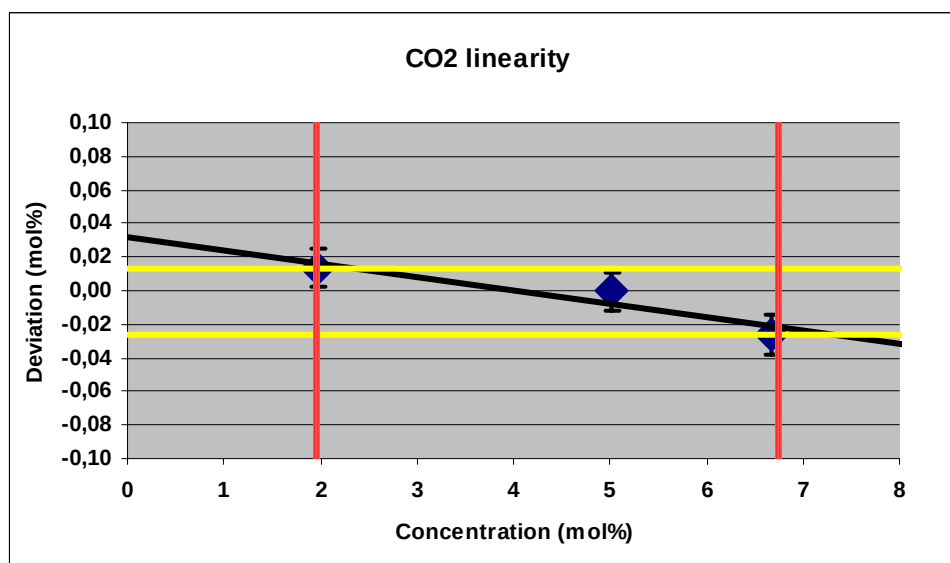


Figure D.1 - Graphical presentation of the results from the linearity test for CO₂. A linear regression line is drawn through the test points to visualise the term “linearity”. The distance between the two horizontal lines along the y-axis mark the “linearity band” which is 0,04 mol %, for the working range of CO₂ marked by the two vertical lines, i.e. from 1,96 mole % to 6,67 mole %.

Table D.5 - Summarising the uncertainties of each component due to uncertainty in the calibration gases listed in Table D.1 and repeatability and linearity based on test results listed in Table D.2, Table D.3 and Table D.4, respectively.

Calculation of uncertainty pr. component, U_{Xi}				
Component	Calibration gas	Repeatability	Linearity	Total expanded uncertainty per. component
	Uncertainty (k=2) U_{CXi} (mole %)	Uncertainty (k=2) U_{RXi} (mole %)	Uncertainty (k=2) U_{LXi} (mole %)	$U_{Xi} = (U_{RXi}^2 + U_{CXi}^2 + U_{LXi}^2)^{0,5}$ (mole %)
C1	0,1649	0,0259	0,0825	0,1862
C2	0,0326	0,0087	0,0238	0,0413
C3	0,0171	0,0314	0,0147	0,0387
iC4	0,0041	0,0028	0,0032	0,0059
nC4	0,0070	0,0030	0,0045	0,0088
neoC5				
iC5	0,0028	0,0013	0,0010	0,0033
nC5	0,0030	0,0007	0,0003	0,0031
C6+	0,0039	0,0095	0,0015	0,0104
N2	0,0058	0,0004	0,0313	0,0318
CO2	0,0228	0,0032	0,0229	0,0324
O2				

Table D.6 - Calculation of uncertainty of calorific value based on uncertainties of each component

Calculation of uncertainty of calorific value, U_{Hs}				
Component	$H_s = 42\ 097\ \text{kJ/Sm}^3$			Total expanded uncertainty per. component
	$(H_s - H_{si})^2 \times (U_{Xi}/100)^2$	$H_s - H_{si}$ (kJ/Sm ³)	H_{si} (kJ/Sm ³)	$U_{Xi} = (U_{RXi}^2 + U_{CXi}^2 + U_{LXi}^2)^{0,5}$ (mole %)
C1	68,049	4 430	37 667	0,1862
C2	97,563	-23 908	66 005	0,0413
C3	400,854	-51 757	93 854	0,0387
iC4	21,607	-79 205	121 302	0,0059
nC4	49,356	-79 591	121 688	0,0088
neoC5		-106 543	148 640	0,0000
iC5	12,342	-107 145	149 242	0,0033
nC5	11,223	-107 438	149 535	0,0031
C6+	197,593	-135 316	177 413	0,0104
N2	179,554	42 097	0	0,0318
CO2	186,566	42 097	0	0,0324
O2		42 097	0	0,0000
Sum	1224,707			
Square root of sum	35,0			
U_{Hs} (kJ/Sm ³)	35,0			
U_{Hs} (% of H_s)	0,08 %			

Table D.7 - Calculation of uncertainty of operating density based on uncertainties of each component and uncertainty of pressure, temperature and compressibility

Calculation of uncertainty of density, U_p														
Parameter to be modified	Pressure (bar)	Temperature (°C)	C1 (mole %)	C2 (mole %)	C3 (mole %)	iC4 (mole %)	nC4 (mole %)	iC5 (mole %)	nC5 (mole %)	C6+ (mole %)	N2 (mole %)	CO2 (mole %)	ρ (kg/m³)	Sensitivity, S_i
None Pressure Temperature C1 C2 C3 iC4 nC4 iC5 nC5 C6 N2 CO2 Z	150	50	82,16	6,67	3,42	0,41	1,08	0,243	0,303	0,389	0,305	5,02	146,9465	1,031 kg/m³bar
	150,05	50	82,16	6,67	3,42	0,41	1,08	0,243	0,303	0,389	0,305	5,02	146,9881	-0,982 kg/m³°C
	150	50,1	82,16	6,67	3,42	0,41	1,08	0,243	0,303	0,389	0,305	5,02	146,8483	-0,516 kg/m³mole %
	150	50	82,20	6,67	3,42	0,41	1,08	0,243	0,303	0,389	0,305	5,02	146,9258	1,337 kg/m³mole %
	150	50	82,16	6,70	3,42	0,41	1,08	0,243	0,303	0,389	0,305	5,02	146,9866	3,052 kg/m³mole %
	150	50	82,16	6,67	3,43	0,41	1,08	0,243	0,303	0,389	0,305	5,02	146,9770	4,588 kg/m³mole %
	150	50	82,16	6,67	3,42	0,415	1,08	0,243	0,303	0,389	0,305	5,02	146,9694	4,530 kg/m³mole %
	150	50	82,16	6,67	3,42	0,41	1,085	0,243	0,303	0,389	0,305	5,02	146,9691	6,010 kg/m³mole %
	150	50	82,16	6,67	3,42	0,41	1,08	0,246	0,303	0,389	0,305	5,02	146,9645	6,179 kg/m³mole %
	150	50	82,16	6,67	3,42	0,41	1,08	0,243	0,306	0,389	0,305	5,02	146,9650	8,014 kg/m³mole %
	150	50	82,16	6,67	3,42	0,41	1,08	0,243	0,303	0,392	0,305	5,02	146,9705	-0,257 kg/m³mole %
	150	50	82,16	6,67	3,42	0,41	1,08	0,243	0,303	0,389	0,315	5,02	146,9439	1,983 kg/m³mole %
	150	50	82,16	6,67	3,42	0,41	1,08	0,243	0,303	0,389	0,305	5,03	146,9663	0,0324 mole%
														0,1 %
Sum													0,0358	
Square root of sum													0,1892	
U_p (kg/m³)													0,3783	
U_p (% of ρ)													0,26 %	

Table D.8 - Comparison of found uncertainty for each component with uncertainty required for fiscal gas composition

Comparison of found U_{Xi} with required uncertainty for fiscal gas composition, U_{XiR}						
Component		Composition		U_{Xi} found from test	U_{XiR} required	U_{Xi} / U_{XiR}
	Mwi (kg/kmole)	X_i (mole %)	Y_i (mass%)	(mole %)	(mole %)	
C1	16,043	82,16	64,03	0,1862	$0,6 \times MW/MWi = 0,7699$	0,242
C2	30,07	6,67	9,744	0,0413	$0,15 \times MW/MWi = 0,1027$	0,402
C3	44,097	3,42	7,326	0,0387	$0,15 \times MW/MWi = 0,07$	0,553
iC4	58,123	0,41	1,158	0,0059	$0,15 \times MW/MWi = 0,0531$	0,111
nC4	58,123	1,08	3,049	0,0088	$0,15 \times MW/MWi = 0,0531$	0,166
neoC5	72,15	0	0		0	
iC5	72,15	0,243	0,852	0,0033	$0,15 \times MW/MWi = 0,0428$	0,077
nC5	72,15	0,303	1,062	0,0031	$0,15 \times MW/MWi = 0,0428$	0,073
C6+	86,177	0,389	1,629	0,0104	$0,15 \times MW/MWi = 0,0358$	0,290
N2	28,0135	0,305	0,415	0,0318	$0,15 \times MW/MWi = 0,1102$	0,289
CO2	44,01	5,02	10,733	0,0324	$0,15 \times MW/MWi = 0,0702$	0,462
O2	31,9988	0	0		0	
MW (kg/kmole)		20,585	20,585			

