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Gas infrastructure — Gas measuring systems — Functional requirements

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National foreword

This British Standard is the UK implementation of EN 1776:2015. It supersedes BS EN 1776:1999 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GSE/33/-/5, Gas Measurement (Revision of EN 1776).

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Contents

European foreword

This document (EN 1776:2015) has been prepared by Technical Committee CEN/TC 234 “Gas infrastructure”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2016, and conflicting national standards shall be withdrawn at the latest by June 2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 1776:1998.

This document has been prepared under the mandate M/017 given to CEN by the European Commission and the European Free Trade Association.

This version of the standard comprises a major revision of EN 1776:1998. The scope of the standard is expanded and now includes also gas measuring systems in light industry, commercial as well as residental use. For this purpose the document has been restructured and amended.

This European Standard has in part been developed in response to the work of the European Standards Organisations (CEN/CENELEC/ETSI) under the Commission Mandate M/441. The standard should be read in conjunction with CEN/CLC/ETSI TR 50572, *Functional Reference Architecture for Communications in Smart Metering Systems* and EN 16314, *Gas meters – Additional functionalities* (often referred to as a smart gas meter).

Directive 2009/73/EC concerning common rules for the internal market in natural gas and the related Regulation (EC) No 715/2009 on conditions for access to the natural gas transmission networks also aim at technical safety (security) including technical reliability of the European gas system. These aspects are also in the scope of CEN/TC 234 standardization. In this respect CEN/TC 234 evaluated the indicated EU legislation and amended this technical standard accordingly, where required and appropriate.

This European Standard covers the environmental aspects relevant to the design, construction, operation, and maintenance and commissioning/decommissioning of gas measuring systems, where appropriate, in accordance with CEN Guide 4 and CEN/TR 16388.

In preparing this European Standard, a basic understanding of gas infrastructure by the user has been assumed.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This European Standard specifies different classes of measuring systems, each having their own specific requirements.

By nature, a measuring system is an aggregate of several components. In this European Standard, it is assumed that each component is in full compliance with applicable CEN or ISO standards, if any.

This European Standard allows the user to choose between different accuracy classes of measuring systems, the choice of which can be justified on economic grounds.

1 Scope

This European Standard specifies functional requirements for the design, construction, testing, commissioning/decommissioning, operation, maintenance and, where appropriate, calibration, together with suitable documented provisions for all new gas measuring systems and any major changes of existing systems.

This European Standard also specifies accuracy classes of measuring systems and thresholds applicable to these classes. Demonstration of compliance is achieved through the selection, installation and operation of appropriate measurement instruments, together with suitable documented provisions for calculations. Examples of demonstration of compliance are provided for each accuracy class; however, they are not prescriptive solutions.

This European Standard is applicable for gases of the 2nd family as classified in EN 437. It is also applicable for treated non-conventional combustible gases complying with EN 437 and for which a detailed technical evaluation of the functional requirements (such as injected biomethane) is performed ensuring there are no other constituents or properties of the gases that can affect the metrological and physical integrity of the measuring systems.

This European Standard can also be used as a guideline for 1st and 3rd family gases as classified in EN 437; however additional considerations should be taken with regard to the different constituents and physical characteristics of the gas family.

This European Standard is not applicable for raw or sour gases.

This European Standard is not applicable for gas measurement in CNG filling station.

This European Standard gives guidelines when designing, installing and operating gas meters with additional functionalities (smart gas meters).

Communication protocols and interfaces for gas meters and remote reading of gas meters are outside the scope of this European Standard and are covered by the appropriate parts of EN 13757, which provide a number of protocols for meter communications. Supervisory control and data acquisition protocols (SCADA) are also not covered by this European Standard.

Unless otherwise specified all pressures used in this European Standard are gauge pressures.

For associated pressure regulating systems the requirements of EN 12186 and/or EN 12279 apply.

For requirements on design, housing, lay-out, materials for components, construction, ventilation, venting and overall safety of gas measuring systems within the scope of this European Standard, EN 15001, EN 12186, EN 12279 and/or EN 1775 apply additionally, where relevant.

This European Standard specifies common basic principles for gas infrastructure. Users of this European Standard should be aware that more detailed national standards and/or codes of practice may exist in the CEN member countries.

This European Standard is intended to be applied in association with these national standards and/or codes of practice setting out the above mentioned basic principles.

In the event of conflicts in terms of more restrictive requirements in national legislation/regulation with the requirements of this European Standard, national legislation/regulation takes precedence as illustrated in CEN/TR 13737-1 and CEN/TR 13737-2.

CEN/TR 13737 (all parts) gives:

— clarification of all legislation/regulations applicable in a member state;

— if appropriate, more restrictive national requirements;

— a national contact point for the latest information.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1359, *Gas meters — Diaphragm gas meters*

EN 1594, *Gas infrastructure — Pipelines for maximum operating pressure over 16 bar — Functional requirements*

EN 1775, *Gas supply — Gas pipework for buildings — Maximum operating pressure less than or equal to 5 bar — Functional recommendations*

EN 12186, *Gas infrastructure — Gas pressure regulating stations for transmission and distribution — Functional requirements*

EN 12261, *Gas meters — Turbine gas meters*

EN 12279, *Gas supply systems — Gas pressure regulating installations on service lines — Functional requirements*

EN 12327, *Gas infrastructure — Pressure testing, commissioning and decommissioning procedures — Functional requirements*

EN 12405-1, *Gas meters — Conversion devices — Part 1: Volume conversion*

EN 12405-2, *Gas meters — Conversion devices — Part 2: Energy conversion*

EN 12405-3, *Gas meters — Conversion devices — Part 3:Flow computers*

EN 12480, *Gas meters — Rotary displacement gas meters*

EN 13463-1, *Non-electrical equipment for use in potentially explosive atmospheres — Part 1: Basic method and requirements*

EN 15001-1, *Gas Infrastructure — Gas installation pipework with an operating pressure greater than 0,5 bar for industrial installations and greater than 5 bar for industrial and non-industrial installations — Part 1: Detailed functional requirements for design, materials, construction, inspection and testing*

EN 15001-2, *Gas infrastructure — Gas installation pipework with an operating pressure greater than 0,5 bar for industrial installations and greater than 5 bar for industrial and non-industrial installations — Part 2: Detailed functional requirements for commissioning, operation and maintenance*

EN 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres (IEC 60079-10-1)*

EN 60079-14, *Explosive atmospheres — Part 14: Electrical installations design, selection and erection (IEC 60079-14)*

EN 60079-17, *Explosive atmospheres — Part 17: Electrical installations inspection and maintenance (IEC 60079-17)*

EN 61000 (all parts), *Electromagnetic compatibility (EMC)*

EN ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements (ISO 5167-1)*

EN ISO 5167-2, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 2: Orifice plates (ISO 5167-2)*

EN ISO 6141, *Gas analysis — Contents of certificates for calibration gas mixtures (ISO 6141)*

EN ISO 6142-1, *Gas analysis — Preparation of calibration gas mixtures — Part 1: Gravimetric method for Class I mixtures (ISO 6142-1)*

EN ISO 6143, *Gas analysis — Comparison methods for determining and checking the composition of calibration gas mixtures (ISO 6143)*

EN ISO 6975, *Natural gas — Extended analysis — Gas-chromatographic method (ISO 6975)*

EN ISO 10715, *Natural gas — Sampling guidelines (ISO 10715)*

EN ISO 10723, *Natural gas — Performance evaluation for analytical systems (ISO 10723)*

EN ISO 12213-1, *Natural gas — Calculation of compression factor — Part 1: Introduction and guidelines (ISO 12213-1)*

EN ISO 15970, *Natural gas — Measurement of properties — Volumetric properties: density, pressure, temperature and compression factor (ISO 15970)*

ISO 2186, *Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements*

ISO 10790, *Measurement of fluid flow in closed conduits — Guidance to the selection, installation and use of Coriolis flowmeters (mass flow, density and volume flow measurements)*

ISO 17089-1, *Measurement of fluid flow in closed conduits — Ultrasonic meters for gas — Part 1: Meters for custody transfer and allocation measurement*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
accuracy of measurement
closeness of the agreement between the result of a measurement and a true value of the measurand

3.2
additional components
elements or devices, required to ensure correct measurement or intended to facilitate the measuring operations, or which could in anyway affect the measurement

EXAMPLE Additional components can be

a) filter;

b) flow conditioning device;

c) branch or by-pass line;

d) valves;

e) pressure reduction devices located upstream or downstream of the meter;

f) sampling systems;

g) piping.

3.3
authorized person

person who is appointed to fulfil a given task on gas measuring systems

3.4
availability

probability, at any time, that the measuring system, or a measuring instrument forming a part of the measuring system, is functioning according to specifications

3.5
base conditions

specified conditions to which the measured quantities of gas are converted

Note 1 to entry: Operating and base conditions relate to the volume of gas to be measured or indicated only and should not be confused with “rated operating conditions” and “reference conditions” which refer to influence quantities.

3.6
bias

systematic difference between the true value of measurand and its determined value

3.7
calorific value determination device

CVDD

measuring instrument for obtaining the calorific value of gas

3.8
competent person

person who is qualified, trained and experienced to perform activities to gas measuring systems

3.9
compression factor

Z

ratio of the volume of an arbitrary mass of gas, at a specified pressure and temperature to the volume of the same mass of gas under the same conditions as calculated from the ideal-gas law

Note 1 to entry: The compression factor (Z) indicates the extent to which gas deviates from ideal gas behaviour.

3.10
conversion device

3.10.1
conversion device

device that converts a quantity at metering conditions to a quantity to base conditions or energy

3.10.2
energy conversion device
device which calculates, integrates and displays energy using quantity at base conditions and the calorific value and/or the gas composition

3.10.3
volume conversion device
device that converts the quantity measured at measuring conditions into a quantity at base conditions

3.11
custody transfer
change in responsibility for the conveyance of gas, this may or may not involve a change of ownership of the gas

3.12
documented provisions
provisions established by the operator of a gas measuring system in order to give confidence that operations are performed according to metrological expectations

3.13
drift
slow change of a metrological characteristic of a measuring instrument

3.14
energy determination
quantitative determination of the amount of energy of a quantity of gas based either on measurement or calculation using measured values or attributed values

3.15
fail-safe
characteristic of a device to go to a safe operating condition when a failure occurs

3.16
gas measuring installation
complete set of measuring instruments and additional components assembled to carry out specified measurements

3.17
gas measuring station
measuring station consists of one or more gas measuring installation(s) and includes its housing, compound, the inlet and outlet pipework as far as the isolating valves

Note 1 to entry: Measuring station does not normally apply for gas measuring installation for residential and commercial use, even if there is housing.

3.18
gas measuring system
consists of a gas measuring installation, documented provisions and where appropriate a gas measuring station

3.19
gas measuring system operator
natural or legal person who is responsible for the operation and maintenance of the measuring system

Note 1 to entry: The gas measuring system operator is referred to be the operator.

3.20
gas meter
instrument designed to measure, memorise and display the quantity of gas (volume or mass) that has passed it

3.21
gross calorific value
GCV
amount of heat, determined on molar, mass or volume basis, which would be released by the complete combustion in air of a specified quantity of gas, in such a way that the pressure at which the reaction takes place remains constant, and all the products of combustion are returned to the same specified temperature as that of the reactants, all of these products being in the gaseous state except for water formed by combustion, which is condensed to the liquid state at this specified temperature

Note 1 to entry: GGCV is often referred to as H_s in other standards.

3.22
hazardous area
area in which an explosive or flammable gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment

[SOURCE: EN 60079-10-1:2009]

3.23
housing
cabinet or meter compound external to the building

3.24
installation effect
difference in performance of the measuring instrument between the calibration conditions and actual conditions of use

Note 1 to entry: This difference can be caused by different flow conditions due to velocity profile, perturbations, or by different working regimes (pulsation, intermittent flow, alternating flow, vibrations, etc.).

3.25
maximum permissible error
MPE
extreme absolute value of error permitted by specification

Note 1 to entry: Conformity with an MPE is based on calibration results for individual instruments and on statistical methods for measuring systems.

3.26
measuring conditions
conditions of the gas at which the quantity is measured at the point of measurement (temperature and pressure of the measured gas)

3.27
measuring instrument
device intended to be used for measurements, alone or in conjunction with supplementary device(s)

EXAMPLE Gas meter, calorific value determination device.

3.28
metering temperature
absolute gas temperature to which the indicated quantity of gas is related

3.29
pressure

3.29.1
absolute pressure
pressure of the gas measured with the reference to an absolute vacuum

3.29.2
gauge pressure
difference between the absolute pressure of the gas and the atmospheric pressure at the place and time of the measuring

3.29.3
design pressure
DP
pressure on which design calculations are based

Note 1 to entry: A part of a measuring installation designed for a design pressure DP can comprise components designed for a different maximum allowable pressure PS.

3.29.4
maximum incidental pressure
MIP
maximum pressure which a system can experience for a short time, limited by the safety device(s)

3.29.5
maximum operating pressure
MOP
maximum pressure at which a system can be operated continuously under normal operating conditions

Note 1 to entry: Normal operating conditions are: no fault in any device or stream.

3.29.6
metering pressure
$\boldsymbol{P}_{\mathrm{m}}$
absolute pressure at which the volume of gas is measured

3.29.7
temporary operating pressure
TOP
pressure at which a system can be operated temporarily under control of the regulating device(s)

3.30
representative calorific value
individual calorific value or a combination of calorific values that is considered to be, according to the constitution of the measuring system, the most appropriate calorific value to be associated with the metered quantity in order to calculate the energy

3.31
responsible person
person who is responsible for design, construction, commissioning, operation and maintenance of the measuring installation and/or system

3.32
sensor
instrument for measuring certain measurands which are characteristic of the gas (temperature, pressure, calorific value, etc.)

3.33
smart meter
meter with additional functionalities one of which is data communication

3.34
stability
ability of a measuring system, or a measuring instrument, to perform its functions for a specified period of time

3.35
stripped gas
natural gas from which large amounts of easily liquefiable components have been removed

3.36
traceability
property of the result of a measurement or a value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties

3.37
uncertainty
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

[SOURCE: ISO/IEC Guide 98-3]

4 General requirements

4.1 General

When considering the design, construction, operation and maintenance of a gas measuring system, the requirements of the relevant national authority shall be taken into account.

All parties involved shall exchange all appropriate information to ensure effective design, installation, commissioning and operation of the measuring system.

4.2 Safety and environment

The gas measuring system shall be designed and constructed such that it operates in a safe manner. The owner/operator shall have safety procedures describing how the installation including the housing is managed.

Safety is a management responsibility which requires that all personnel involved in design, installation, testing, commissioning, operation and maintenance of the gas measuring system shall be competent and have adequate safety training. The management shall ensure that all areas of responsibility are clearly defined.

During normal operation, the gas measuring system shall comply with locally established environmental noise limits.

The owner/operator of the measuring system shall make information available to the consumer or the person responsible for the property of any risks associated with the system.

EXAMPLE Instructions stating the precautions to be taken if the smell of gas persists.

NOTE 1 For further guidance, see EN 1775.

NOTE 2 This may be achieved by the affixing of appropriate warning notices.

All works shall be conducted in accordance with national health, safety and environmental legislation.

4.3 Quality system for gas measuring system

The operator shall have a quality system and use it to manage the measurement system for its entire lifetime.

The quality system shall be applied to the complete gas measuring system including all activities undertaken for the purpose of energy determination in accordance with this European Standard. Reference should be made to ISO 10012 and/or EN ISO 9000- series of standards or to equivalent quality system standards.

This quality system shall also include the gas measuring installation which shall be applied to the design, construction and testing activities in accordance with this European Standard also considering the requirements for commissioning, operation and maintenance.

NOTE 1 National regulations may constitute compliance with the requirement for a quality system.

NOTE 2 National regulations may require that some inspection and testing of the measuring accuracy have to be witnessed and accepted by an authorized and competent person.

5 Basic requirements for measuring systems

5.1 General

The output of the gas measuring system is energy (kWh or MJ), that is the product of gas volume at base conditions or mass and gross calorific value.

NOTE Differing physical principles are used to determine gas volume or mass passing through the meter. The most commonly used techniques are mentioned in this European Standard. Other methods can be used.

Involved parties shall ensure that the method of energy determination is traceable, reliable and satisfies the basic gas and energy measurement requirements such as accuracy, security as well as economic criteria.

The chosen method shall deliver a calorific value with accuracy in line at least with legal requirements. The method shall be sufficiently accurate to reduce random and systematic errors to such a level that contractual obligations are fulfilled and that it can be justified on technical or economic considerations. Energy determination shall be based on measured or attributed values of gas composition of the gas passing through the gas meter. The quantity of gas is the volume at base condition or it's mass. The equations for calculating the volume or mass into energy are given in Annex C.

Possible methods for determining the quantities of energy are described in EN ISO 15112 and EN 12405-2.

5.2 Approach to energy measurement

When designing an energy measuring system the following two steps should be undertaken:

a) classification of measuring system according to its accuracy class (see 5.3)

NOTE 1 The introduction of accuracy classes serves two main purposes. Firstly, it offers a means of ensuring minimum accuracy requirements are met (i.e. appropriate accuracy of measurement is employed). Secondly, it permits installation of a cost-effective measuring system (i.e. not at excessive cost).

b) identification of separate modules of the measuring system (see 5.4)

NOTE 2 Each module performs a specific function within the global energy measurement process. Each module could be either an instrument (e.g. a meter or a calorific value determining device) or a calculation or functional process (e.g. assignment of a calorific value, or conversion of quantity of gas to energy using a representative calorific value).

The methodology how to combine the modular accuracies to derive overall accuracy is given in Clause 6 and Annex E.

NOTE 3 A number of examples are offered in Annex E for clarification of the approach set out in this clause. However, these examples are informative and cannot be taken as evidence that any particular equipment or provisions meet a particular accuracy requirement.

5.3 Classification of the measuring system

5.3.1 General

The accuracy class of the measurement system shall be defined as an expanded uncertainty on energy determination over the billing period:

a) Class A gas measuring system with an in-service uncertainty less than or equal to 1,2 %.

b) Class B gas measuring system with an in-service uncertainty greater than 1,2 % and less than or equal to 2,5 %.

c) Class C gas measuring system with an in-service uncertainty greater than 2,5 % and less than or equal to 3,5 %.

d) Class D gas measuring system with an in-service uncertainty greater than 3,5 % and less than or equal to 8,0 %.

Based on the four accuracy Classes A to D, the responsible person shall choose the most appropriate class for the measuring system under consideration.

The choice shall be based at least on:

- type of installation;

EXAMPLE 1 Location on the gas network, etc.

NOTE Typical locations of gas measuring installations are given in Annex G.

- capacity of the installation;

EXAMPLE 2 Flow rate or annual volume.

- measuring instrument MPE required;

EXAMPLE 3 Legislative, regulatory requirements or economic considerations.

- gas pressure and temperature (and hence the value of the compression factor);
- economic considerations;
- quality of the gas.

See EN ISO 15112 for further details on energy determination.

Accurate and reliable energy determination can be undertaken by using the various modules a) to f) described in 5.4 below.

5.3.2 Minimum requirements Class A and Class B

For Class A and Class B gas measuring installations, the pressure (P), temperature (T), compression factor (Z) conversion (PTZ conversion) shall be carried out from the on-line pressure, temperature measurements.

Minimum requirements in Class A gas measuring installation:

a) The on-line gas composition shall be measured by at least one local CVDD and which is used for the PTZ conversion and the energy determination.

b) Depending on the capacity of the gas measuring installation a second CVDD and duplicated gas meters in series and/or pressure and temperature conversion shall be considered. Parties shall define criteria for deciding whether duplicate measurement in series is needed. When duplicated instruments are installed, the average value between the two systems should be used for energy determination.

Minimum requirements for Class B gas measuring installation are:

c) This class of installation shall have installed a volume conversion device using pressure and temperature measurements. Depending on the metering pressure compression factor (Z) should be determined on-site or attributed as a fixed factor.

d) Calorific value shall be determined using one of the following methods:

   1) continuous sampling on site;

   2) periodical sampling on site;

   3) determined remotely;

   4) attributed fixed factors in accordance with documented provisions.

e) The PTZ-conversion is assumed to be carried out most of the time from a declared fixed gas composition, so basically no CVDD is installed in the gas measuring installation. The determination of energy can be performed locally or remotely and is carried out from this same declared GCV or from an on line CVDD.

When no CVDD is installed in the gas measuring installation the PTZ conversion is carried out from a declared fixed gas composition.

For both determination of energy and PTZ conversion the same GCV and/or gas composition shall be used. Exceptions may be possible in the following cases:

- economical reason, minimum capacity requirements;

- in the case of two or more sources of supply with different gas qualities, either a CVDD shall be installed or documented provisions shall provide a representative gas quality.

Corrections should be made retrospectively between the declared fixed gas composition and assessed actual composition.

5.3.3 Minimum requirements Class C and Class D

The attributed gross calorific value (GCV) for that charging area should be calculated by using the method contained within the documented provisions. The GCV should be averaged over a pre-determined time period (daily, monthly or annually).

If an area is supplied by more than one entry point, a flow weighted average GCV should be calculated from gas flows at each entry point. Different approaches on this subject are given in EN ISO 15112.

For temperature, pressure and compressibility reference is made to 6.6.

5.4 Gas measuring system modules

When considering a measuring system individual modules shall be identified. Examples are given in Annex E.

When combining the modules of the measuring system they all shall be under the same base conditions.

NOTE At the individual module level, the error associated with the module can depend on the value of one or more input parameters, e.g. error in volume at metering conditions and/or error in calorific value of a CVDD.

Some of these modules can be assumed, attributed or derived whilst others are measured in accordance with 5.3.

Consideration should be given to the following essential gas measuring system modules:

a) gas volume/mass: this measurement is at measuring conditions.

b) gas pressure: the absolute pressure within the meter is required for conversion of the volume measured to the same base condition. Gas pressure can be measured on site (gauge or absolute) or attributed.

c) gas temperature: the absolute temperature within the meter is required for conversion of the volume measured. This can be measured on site or attributed.

d) compression factor: for low metering pressures the compression factor has no significant influence and can therefore be attributed the value of 1. Depending on the measuring system accuracy required, for higher pressure systems, the compression factor is based on measurement and/or calculated.

e) representative gross calorific value: It can be expressed in mass or in volume using the same base conditions. For installations of Class C and Class D it is derived by using documented provisions.

f) density: this value is needed to convert the calorific value in volume to the calorific value in mass or vice versa.

6 Energy Determination

6.1 General

When designing a gas measuring system it shall be ensured that the calorific value is determined at the measuring installation or upstream on the network.

If the gas composition and calorific value are not determined at the gas measuring installation, the CVD shall be installed in appropriate location of the network to be representative for the gas passing through the gas measuring installation. The positioning of the sampling points of a CVDD shall be representative of the gas passing through the meter runs.

The method used to determine the GCV by the measuring system shall be included within the documented provisions.

For a Class A system, the GCV shall be determined at the measuring installation.

For a Class B system, an assessment shall be made on how representative the actual calorific value is of the gas composition passing through the measuring installation.

For a Class C system or Class D system attributed values for the gross calorific value shall be used, as described in the documented provisions. The gross calorific value shall be measured in different locations to provide a representative sample at the gas measuring installation. The tolerance in attributed calorific values shall comply with national requirements or company specifications.

Accuracy characteristics of the selected instruments shall be sufficient to allow the energy determination in measuring system, as defined by national requirements.

For the chosen accuracy class no error in energy shall exceed the MPE for the specified accuracy class over the operational range for the measuring system (flow rates, compositions, etc.).

Energy determination shall be carried out using one of the methods described in 6.3 to 6.7.

NOTE For the overall measuring system, the error in energy for the measuring system depends upon all of the input parameters that affect the errors arising from each module of the measuring system. A measuring system therefore shows a distribution of errors in energy from a combination of distributions of errors arising within the individual modules.

6.2 Requirements for measurements used in energy determination

6.2.1 Base conditions

All parties should employ the same base conditions when comparing measurements of volume, calorific value and energy. Factors for conversion between different base conditions are provided in EN ISO 13443.

6.2.2 Flow measurement

The involved parties shall ensure that the method used for determining gas volume flow rate or mass flow rate

- is traceable and reliable;

- satisfies the basic gas and energy measurement requirements, such as safety and economics;

- meets the accuracy requirements of the selected class.

Meters based on different physical principles can be used. The most commonly-used techniques are included in 7.6.3 and Annex A.

6.2.3 Gross calorific value (GCV)

6.2.3.1 General considerations

The GCV of the gas shall be determined by measurement or by attribution of an appropriate representative value.

NOTE 1 The measurement techniques can be divided into three groups:

- based on composition measurement according to EN ISO 6976;
- based on combustion calorimetry according to EN ISO 15796;
- correlative techniques (limited range and accuracy).

When determining GCV based on composition, the existence of components not determined by the chosen analytical technique should be taken into account.

Where GCV measurement by a local CVDD is not economically justified, the GCV shall be calculated based on one or more measurements at representative points on the pipeline.

NOTE 2 Among these kinds of calculations, the gas quality tracking system is a special assignment method for the calculation of gas qualities at any time and at any place in a pipeline or a grid, by means of a grid simulation or a state reconstruction based on gas qualities measured at all supplying points on the pipeline. See EN ISO 15112.

The accuracy of the GCV determination shall be sufficient to ensure that the overall accuracy of the measuring system is within the MPE of the selected accuracy class.

6.2.3.2 Calorific value determination device (CVDD)

The accuracy of the CVDD shall be determined.

NOTE 1 CVDDs can generally be characterized into three types:

- those in which calorific value is determined by measurement using non-separative means and for which guidance on selection and operation is provided in ISO 15971;
- those in which calorific value is determined by calculation using EN ISO 6976 from a gas composition measured using a suitable separative technique, such as gas chromatography;
- those in which calorific value is determined from correlations of calorific value with other properties (such as speed of sound, thermal conductivity, dielectric permittivity, carbon dioxide content, hydrocarbon content) that are measured by suitable means.

NOTE 2 GCV determination can be subject to national legal requirements and controls, which may specify a particular technique or instrument and the manner of its operation.

Gas chromatographs should be set up to carry out analysis according to EN ISO 6974 (all parts). The operating conditions for the gas chromatographs shall be based on a performance evaluation complying with EN ISO 10723.

When assessing the accuracy of a CVDD at least the following factors shall be taken into account:

a) sampling and conditioning;

b) speed of response of CVDD;

c) uncertainty on the composition of any working calibration gas;

d) in case of separative techniques presence of components not analysed;

e) absence of contamination;

f) linearity of the instrument over the composition range;

g) ambient conditions;

h) low limit detection.

NOTE 3 The areas associated with non-linearity of the CVDD can be reduced by requiring the calibration gas to be close to the expected composition of the gas sampled from the line, or by using a multi-point calibration.

NOTE 4 In the case of gas chromatographs, areas associated with non-linearity can be determined by performance evaluation according to EN ISO 10723.

When constituents not detected by the CVDD are present at a significant level, adequate corrective calculation shall be carried out according to EN ISO 6975. The traceability of the calibration gas shall be established.

Limits shall be set on the total un-normalized molar concentrations for a gas chromatography analysis. Data acceptance criteria shall be set at values which are within or equal to any legal metrology or contractual limits.

6.3 Calculation method of energy using assigned GCV and P, T, Z values

The actual volume shall be converted to volume at base conditions using attributed T, P and Z. The totalized volume shall be converted to energy using an attributed GCV.

6.4 Calculation method of energy using an on-site CVDD and on-site PTZ-Conversion

The actual flow-rate shall be converted to flow-rate at base conditions using a measured T, P and Z (PTZ-conversion) and then shall be converted to energy flow by multiplication by a live GCV. Energy shall be totalized, typically using a flow computer. Z shall be calculated from live T, P and gas composition.

6.5 Calculation method of energy using an assigned GCV and PTZ-conversion

The actual flow-rate shall be converted to flow-rate at base conditions using a measured T, P and Z (PTZ -conversion) and then shall be totalized. The totalized volume shall be converted to energy using an attributed calorific value. Z shall be calculated from live T and live P assuming a defined gas composition.

6.6 Calculation method of energy using PT-Conversion and assigned GCV and Z value

The actual flow-rate shall be converted to flow-rate at base conditions using a measured T and P (PT-conversion) and then shall be totalized using an assigned Z. The totalized volume shall be converted to energy using an attributed GCV.

6.7 Calculation method of energy using T-Conversion and assigned GCV, and P, Z values

The actual flow-rate shall be converted to flow-rate at base conditions using a measured T and then totalized using assigned P and Z values. The assigned P value should take into account the altitude, lock-up pressure zone as well as the accuracy class of the pressure regulator and the supply pressure when appropriate. The totalized volume is then converted to energy using an attributed GCV.

NOTE Lock–up pressure zone and accuracy class are specified in EN 334.

6.8 Gas temperature conversion

In order to convert volume at operating conditios to base conditions, the gas temperature shall be measured at a location that ensures that it is representative of the temperature of the gas being metered.

Recommendations for temperature measurement are provided in EN ISO 15970 or in the relevant parts of EN 12405.

6.9 Gas pressure conversion

In order to convert pressure at operating conditios to base conditions, the pressure shall be measured at a location that ensures that it is representative of the pressure of the gas being metered.

Recommendations for pressure measurement are provided in EN ISO 15970, or the relevant parts of EN 12405

6.10 Compressibility conversion

When volume at operating conditions is converted to base conditions, using a Z calculated for the gas at operating conditions, the calculation shall be performed in accordance with EN ISO 12213-1.

When the gas is fed on-line to a gas chromatograph and at high pressure for (re-vaporized) LNG and stripped gases EN ISO 12213-2 should be applied

When only the GCV, relative density, hydrogen and carbon dioxide content are known, together with the relevant pressures and temperatures EN ISO 12213-3 should be applied.

NOTE The EN ISO 12213-3 is only applicable for a limited range of physical characteristics.

6.11 PTZ-conversion

Conversion techniques used shall have proven accuracy and shall be suitable for the measuring conditions (see 7.10).

NOTE P, T and Z can be determined simultaneously by a single device

6.12 Uncertainty of energy determination

The uncertainty in energy determination should be assessed according to:

- ISO/IEC Guide 98-1 and ISO/IEC Guide 98-3,
- ISO/IEC Guide 98-3 Supplement 1 and 2,
- ISO/IEC Guide 98-4 or ISO 5168,
- JCGM 106,
- JCGM 107.

NOTE 1 The text of the ISO/IEC Guide 98- series equates to JCGM 100 series (JCGM = Joint Committee for Guides in Metrology); JCGM 105, JCGM 106 and JCGM 107 are in preparation to be transferred into the series of ISO/IEC Guide 98.

Bias should be identified and reduced to acceptable levels.

NOTE 2 In some applications it can be appropriate to do so by specifying a maximum permissible bias.

NOTE 3 Using the series of ISO/IEC Guide 98-3 and ISO/IEC Guide 98-1 and JCGM 105 and JCGM 107 the bias can be taken into account by enlarging the “uncertainty” attributed to the result, instead of applying it to the reported result of a measurement.

The assessment of the conformity of the metrological performance of a measuring system is carried out according to ISO/IEC Guide 98-4, “Uncertainty of measurement – Part 4: Role of measurement uncertainty in conformity assessment”. Annex D indicates how such conformity assessment can be carried out in the context of an energy measurement system.

Annex E provides some examples of conformity assessments.

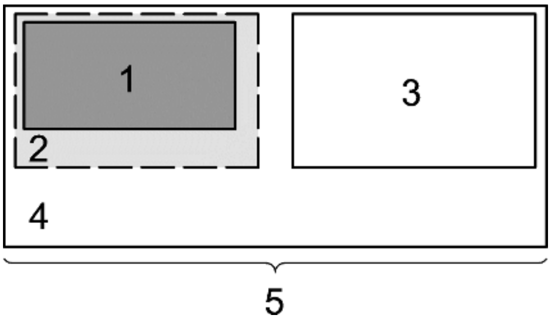
7 Design of gas measuring system

7.1 General

A gas measuring system shall comprise:

- a gas measuring installation;
- documented provisions; and
- where appropriate, a gas measuring station.

Figure 1 illustrates a typical gas measuring system.



Key

1 gas measuring installation
2 gas measuring station
3 documented provisions
4 gas measuring system
5 output: energy

Figure 1 — Illustration of gas measuring system

The accuracy requirement for the system (i.e. the maximum permissible error) shall be determined applying 5.3. The system shall then be designed in such a way that the required accuracy is achieved by validating against 6.12 and confirming it meets the requirements for the selected class.

When requested, the achieved accuracy of the system shall be available to involved parties to demonstrate compliance with the selected class.

Annex D provides a general approach to demonstrating compliance in accordance with 6.12.

The gas measuring installation should be located in a building, a compound, a cabinet or a shelter. Unless it unduly affects their integrity, operation, or accuracy some higher capacity gas measuring installations may also be installed in open air.

When selecting the location, the advice of the manufacturer and operator of the installation shall be sought.

7.2 Safety provision

7.2.1 General

When designing a gas measuring system, safety provisions shall be integrated to ensure its safe access, egress, construction, operation, inspection and maintenance and located such that risk and nuisance to the environment and its operation are kept within acceptable limits.

The designer of the gas measuring installation and station shall ensure that proper care is taken to prevent noise generated hazards.

The gas measuring installation and station shall have at least one inlet valve to allow it to be safely isolated and to undertake any maintenance. For higher accuracy installations an outlet valve should be fitted.

As part of the design of the installation and station the electrical safety shall be considered. All electrical installations shall comply with the applicable European Standards.

7.2.2 Hazardous area classification

The possible hazardous area in any housing, station and installation shall be assessed and classified according to EN 60079-10-1.

For any non-electrical equipment with its own potential ignition source reference shall be made to EN 13463-1.

A risk assessment should be made according to EN 1127-1.

Any electrical installation in a hazardous area shall comply with 8.6.

7.3 Housing

All meter housings shall be well ventilated and be adequate in size, layout and design to undertake all installation, commissioning and maintenance requirements.

The design of a measuring station, including the layout, housing and materials for the housing, shall comply with the relevant requirements of EN 12186, EN 12279 or EN 15001, where applicable.

For measuring installations without pressure regulation the most relevant standards shall be chosen depending on inlet pressure and capacity.

7.4 Gas measuring station

A measuring station shall comprise:

- a measuring installation (see 7.6);
- additional components (see 7.13, 7.16 and following);
- where appropriate a housing (see 7.3).

Any additional components shall be installed in accordance with the installation requirements and shall not adversely affect the measurement results.

7.5 External influences

The performance of the gas measuring installation and housing when used in its specified operating conditions shall not be adversely affected by any expected external influences, such as but not limited to:

- mechanical influences;
- electromagnetic influences;
- weather conditions, ambient temperature;
- humidity.

7.6 Gas measuring installation

7.6.1 General

The design of the installation varies according to its required accuracy.

The measuring installation shall comprise a gas meter and one or more of the following components:

a) conversion device;

b) change-over equipment to select the appropriate number of meter runs to meet the actual load of the station;

c) CVDD;

d) valves, pipes, gaskets and joints;

e) lagging for thermal insulation and noise reduction;

f) filters and separators;

g) electrical installation, lightning protection, earthing;

h) detection systems such as gas and/or fire detection (see also EN 60079-29-1, EN 15001-1);

i) communication;

j) others.

A gas measuring installation can be connected with other gas installations.

EXAMPLE 1 As part of a pressure regulating installation.

Any additional connected installation or equipment shall not adversely affect the integrity of the gas measuring installation or its measurement.

EXAMPLE 2 Connected installations can be gas pressure regulating installations, gas drying facilities, odorization injection equipment.

The gas measuring installation shall be designed such that the correct functioning is ensured for all specified pressure and temperature ranges as well as, where appropriate, impurities present in the gas.

The specified pressure and temperature range shall cover at least MOP, TOP, MIP, minimal pressure at the inlet of the installation, $T_{\min}$, $T_{\max}$ and ambient temperature.

The design shall also take into account environmental factors such as vibrations, pulsation and noise.

The design shall ensure appropriate access/egress for inspection, removal or replacement of the gas meter.

In case of an emergency, it shall be possible to shut down the installation safely.

The capacity and the correct functioning of the installation shall be based on the minimum and maximum values for:

a) volume or mass flow rate;

b) gas temperature;

c) velocity of gas in the meter run;

d) metering pressure;

e) acceptable pressure loss;

f) range of constituents (composition of the gas);

g) contaminants in the gas;

h) internal diameter of the connection of the gas meter (to avoid steps in diameters and subsequent flow disturbances).

All pressure containing components of the gas measuring installation shall withstand the strength test pressure. The strength test pressure is derived from the design pressure (DP) of the upstream system.

NOTE 1 See EN 12007 (all parts) and EN 1594 for further information on this subject.

The technology selected for the gas measuring installation shall be sufficiently accurate to reduce random and systematic errors to such a level that contractual or legal obligations are fulfilled and that can be justified on technical and economic reasons.

The gas measuring installation should be installed as close as possible to the point where the change of responsibility takes place to avoid unmeasured gas.

For unidirectional gas measuring installation possible unwanted reverse flow during operation should be avoided for example by installing a non-return valve. The installed valve shall not be adversely affect the gas measurement and should be installed in accordance with the manufacturer's instructions.

Where the gas measuring installation incorporates more than one meter run, each run shall have its own upstream and downstream means of isolation.

Where in-service verification of the measuring instrument(s) is required, appropriate provisions shall be made.

EXAMPLE 3 Appropriate provisions can be:

- multiple measuring stream;
- spool for the installation of a temporary reference meter;
- the use of meters with (self-) diagnostics capability;
- two meters in series for online comparison.

In case of multiple measuring stream of the same size and each with a single gas meter, it is recommended that parallel lines can be temporarily reconfigured in series.

NOTE 2 Also known as z-configuration.

The primary measuring values shall be safeguarded for a stated minimum duration of time. If the safeguarding relies on electrical power, provision shall be taken to prevent electrical power failure, voltage fluctuation or overload (lightning strike).

EXAMPLE 4 Use mechanical index, no-break power for the whole installation, battery powered flow meters.

Where appropriate, the gas measuring installation shall take into account the European Standards EN 12186, EN 15001 and EN 12279 when considering:

a) valves, pipes, gaskets and joints;

b) lagging for thermal insulation and noise reduction;

c) filters and separators;

d) electrical installation, equipotential bonding, lightning protection, earthing;

e) detection systems such as gas and/or fire detection (see also EN 60079-29-1, EN 15001-1).

Provisions shall be taken to ensure stability of all equipment during operations, e.g. supports.

7.6.2 Continuity of supply

Continuity of supply is not normally necessary for a Class D installation. However for other installations it may be considered if cessation of the gas supply can cause a safety hazard, or risk to life or significant risk to property (see 7.12.1 and 7.13).

When continuity of supply is deemed to be essential the following should be considered:

a) additional meter run (n+1 meter runs, where n is the number of meter runs needed for the design capacity);

b) incorporate a bypass.

7.6.3 Gas meters

The meter shall be selected so that it will operate correctly and safely under all operating conditions. Annex A gives guidelines on the selection of meters.

Any gas meter shall meet the national metrological and safety requirements of the country where the meter is installed. Gas meters shall conform to relevant European Standards, where available.

Gas meters installed under the scope of this European Standard shall comply with European standards where available. Examples are given in Annex A.

When selecting a meter, consideration shall be given to the required:

- flow rate (expected minimum and maximum);
- direction of flow;
- accuracy class;
- pressure rating (P_{max});
- pressure loss across the meter at the installation’s designed flow rate;
- suitability for the installation pipework configuration;
- resistance to fluctuations of the flow rate;
- any pressure absorption limitations;
- turndown ratio ($Q_{\text{min}}/Q_{\text{max}}$).

The effective turndown ratio ($Q_{\text{min}}/Q_{\text{max}}$).of the gas measuring installation could be affected by oversizing which can influence the meter’s accuracy.

Furthermore for some meter types, when calibration and operating conditions are different, correction should be considered in order to take into account the effect of gas pressure and temperature on the gas meter.

7.6.4 Gas meters with additional functionalities

The gas meter may be designed with additional functionalities according to EN 16314:

a) Functionality 1: remote reading of metrological register(s) and provision to designated market organizations;

b) Functionality 2: two-way communication between the metering system and designated market organization(s);

c) Functionality 3: to support advanced tariffing and payment systems;

d) Functionality 4: to allow remote disablement and enablement of supply and flow/power limitation;

e) Functionality 5: to provide secure communication enabling the meter to export metrological data for display and potential analysis to the end consumer or a third party designated by the end consumer;

f) Functionality 6: to provide information via web portal/gateway to an in-home/building display or auxiliary equipment.

Additional functionalities can be provided by attaching an additional functionality device to the meter or by directly incorporating these functionalities into the meter. Meters can be provided with devices such as; pulse transmitters, serial or wireless interface for transmission of measured quantity to other equipment such as totalizers, recorders or communication equipment.

Transmitter range and pulse significance shall be suitable for the application.

7.6.5 Gas meter with remotely operated valve

For a meter with a maximum flow rate of less or equal than 10 m^3/h incorporating a gas valve the following shall apply.

a) The valve shall not be capable of opening without direct manual intervention at the meter, or after a check that no uncontrolled gas can be released.

b) The valve opening procedure shall either:

    1) via a notice place on the meter, instruct the local operator how activate the valve to prevent an uncontrolled release of gas; or

    2) incorporate a check for an uncontrolled release of gas. There shall be automatic closure of the valve or no opening of the valve when release of gas is not safe; or

    3) a combination of 1) and 2).

The valve covered by this clause shall not be used for permanent isolation. It shall not be formally regarded as a thermal or safety shut off valve.

Valves within meters shall comply with national requirements.

Due to the significant risks associated with it, restoration shall be undertaken in a safe manner. The method used to activate a valve shall be secure to prevent communication errors or malicious interference causing unintended operation.

Where two meters are installed in series, the first meter shall not have an integral gas valve.

NOTE Further information on the design of gas valves integral to the meter is given in EN 16314.

7.7 Calorific value determination system

7.7.1 General

The calorific value determination system that is installed in the measuring installation shall comprise the following components:

a) a gas sampling system;

b) an equipment for measurement (direct or indirect) and calculation;

c) a provision for calibration;

d) a data handling system;

e) for gas chromatograph: a carrier gas system.

NOTE The overall measuring system accuracy requirements will determine the type and specified accuracy of the CVDD.

7.7.2 Sampling

Sampling shall be in accordance with EN ISO 10715. Particular attention shall be given to:

- preconditioning system for reducing the delay time of the sampled gas;
- conditioning system which includes heating and filtering of the sampled gas;
- venting system.

On-line measuring instruments require continuous direct sampling.

With off-line measuring instruments the following sampling techniques can be used depending on the fluctuation of composition, properties and required accuracy:

a) periodical spot sampling;

b) incremental sampling, which accumulates gas samples into one composite sample.

7.7.3 Provisions for calibration

Cylinders of gas used for checking and calibration or gas characteristics measurements shall be stored and operated within their specified temperature range.

Any dedicated connection between the cylinder and the measuring instrument shall include the necessary pressure reduction according to the CVDD manufacturer’s instructions. When necessary, heating shall be applied to prevent condensation of constituents of the gas mixture.

7.8 Gas pressure measurement

7.8.1 General

Pressure sensors and their installation shall comply with EN ISO 15970.

In order to ensure accurate measuring, care shall be given to the design of the installation of pressure sensors to avoid mechanical vibrations and presence of liquid inside the sensing line.

Field maintenance, checking and recalibration require the possibility to isolate the sensor from the line with a valve without the need to shut down the whole installation and to apply a reference test pressure. Any valve in the sensing line should be capable of being sealed in the appropriate position to prevent unauthorized operation.

The pressure sensor shall be connected to the pressure tapping on the gas meter, if available. They shall be fitted and connected in accordance with the manufacturer instructions. During calibration of the gas meter at the calibration facility the same pressure tapping shall be used.

The pressure connections for differential pressure sensors should be separated from all other pressure connections.

7.8.2 Gas pressure measurement Class A and Class B

Pressure can be measured with absolute pressure sensor or gauge pressure transmitters.

For Class A, in order to avoid the introduction of errors caused by variations in atmospheric pressure, a transmitter of absolute pressure shall be used. Nevertheless, a gauge pressure transmitter may be used, if combined with atmospheric pressure sensor.

For Class B, if gauge pressure sensors are used, it should be considered whether a barometric pressure transmitter or a fixed value for the atmospheric pressure is applied. When a fixed atmospheric pressure is applied,s the extra measuring uncertainty as a consequence should be taken into account. Every pressure sensor shall have its own continuous sensing line and shall not be combined with any other additional component.

The heights differences between the sensing point and the sensor shall be as small as possible to avoid any significant effect of gravity on the pressure measurement.

7.8.3 Gas pressure determination Class C and Class D

Documented provisions shall include how the absolute metering pressure (P_m) is determined.

Any pressure value used in these documented provisions should be derived from using a combination of the following:

a) set point of the upstream pressure regulator including its accuracy and flow rate range;

b) average absolute/atmospheric pressure;

c) altitude of the location of gas measuring installation; or

d) a volume conversion device.

7.9 Gas temperature measurement

Temperature transducers and their installation shall comply with EN 12405-1 or EN ISO 15970.

The gas temperature shall not adversely affect the performance of the gas meter and shall be kept within the operating range of the measuring instruments.

The thermowells set in the meter body should be used where available, if required.

If thermowells are used, they should protrude into the pipework by about one third of the nominal bore where the pipe is normally DN 50 and above. On diameter pipes larger than 300 mm and/or where resonant vibrations of the thermowell are known to be a possible problem, the design of the thermowell can restrict the depth of insertion. For further details, see ISO/TR 9464 and ISO 17089-1.

Whenever a thermowell is installed, consideration should be given to fit in a spare thermowell for use during field-verification, at an angle of at least 30° to the primary thermowell to avoid resonance and mutual influence.

Thermowells shall not introduce any flow perturbations that influence the measurement accuracy. The thermowell shall be positioned according to the standards on the relevant gas meters and/or manufacturer's instructions. For meters used for bidirectional applications, the flow perturbations shall be taken into account by calibrating the gas meter together with the thermowells correctly positioned.

In order to ensure that the measured temperature at the thermowell is the same as that of the gas passing through the meter, it can be necessary to insulate the external part of the thermowell and the pipework for a suitable distance downstream and upstream of the meter.

NOTE The necessity to do so depends on the expected differences in gas and ambient temperature in a specific measuring station and on the desired accuracy.

Where attribute values are used for metering temperature (T), the documented provisions should be derived from a representative analysis of gas temperatures.

7.10 Conversion device

7.10.1 General

Conversion devices shall comply with the appropriate part of EN 12405.

Conversion devices shall be directly connected to measuring instruments, when used for pressure and temperature, and where appropriate CVDD. Any interfaces and connections fitted within the conversion device allowing connection of complementary devices shall not corrupt the metrological behaviour of the device.

When different conversion devices are combined care shall be taken to ensure all calculations used are consistent.

In some cases it can be sufficient to use a fixed value within the conversion devices for temperature, pressure and gas composition for conversion (see Annex C). These values shall be included in the documented provisions.

7.10.2 Energy conversion device

Energy conversion devices shall meet the requirements of EN 12405-2 and shall be installed in accordance with manufacturer´s instructions.

7.10.3 Volume conversion device

Volume conversion devices shall meet the requirements of EN 12405-1 or EN 12405-3 and shall be installed in accordance with manufacturer´s instructions.

7.10.4 Temperature conversion device

Temperature conversion devices are also covered by EN 12405-1. Some meters included temperature conversion with in the meter, e.g. diaphragm meter according to EN 1359.

7.11 Compression factor

For Class A the compression factor shall be calculated with live pressure, temperature and gas composition as the input.

For Class B and Class C depending on the metering pressure, the compression factor should be calculated with live pressure, temperature and a representative gas composition.

NOTE When calculating the compression factor, for higher pressures and variations of the gas composition and properties it is important to obtain accurate determination of the gas composition.

For low metering pressures and for Class D in general, fixed factors for compressibility can be used.

7.12 Pipework requirements

7.12.1 For Class A and Class B measuring installation

In order to obtain acceptable velocity profile reference shall be made to all manufacturer's instructions. The following should be taken into account:

a) the required upstream and downstream pipe section and the gas meter should have the same nominal diameter. Whether a flow conditioner is recommended or not, the gas meter manufacturer has to provide evidence of what minimum pipe lengths are required;

b) any valve located just at the beginning of the required upstream straight pipe of the meter section should be of a full bore type;

c) if a pressure regulator or a regulating valve is installed upstream of a meter, precautions should be taken with respect to the sensitivity of the meter for noise and flow perturbation;

d) where appropriate, the use of pipe fittings or equipment should not produce significantly asymmetric velocity profiles and/or swirls;

e) for Class A, the meter run should be thermally protected to minimize the influence of ambient temperature on velocity profile particularly at low flow rates.

In order to avoid noise, vibrations and/or erosion problems; the internal diameter of the pipework of the gas measuring installation shall be calculated for gas velocities, which shall not exceed 20 m/s in the pipework.

NOTE 1 In the meter gas velocity can be higher.

NOTE 2 Additional guidance on gas meters' characteristics is given in Annex A.

7.12.2 For Class C and Class D measuring installation

For Class C and Class D, pipework installation shall meet the requirements given in EN 15001 or EN 1775, as appropriate.

7.13 Valves

7.13.1 General

Any valve shall be suitable for its intended use. Where the meter or any additional component could be damaged through excessive flow rates (during commission and re-commissioning) a slow opening valve or a small commissioning valve shall be used. All valves selected shall provide, when closed, internal gas tightness seal. Valves shall comply with a European Standard where applicable.

7.13.2 By-pass

The by-pass shall not affect the measurement result.

In normal conditions of use, any by-pass valve shall be closed, gas tight and sealed.

For high pressure applications a double block and bleed valve or a special valve arrangement with a similar checking facility should be used.

A by-pass should not be fitted where gas flow interruption is acceptable (see also 7.6.2).

A by-pass shall not be used during normal operation of the gas measuring installation.

It shall be possible to determine whether the by-pass is in the open or closed position. Clear indication of the direction of operation for opening or closing the valve shall be given.

7.14 Parallel meter runs

Where a gas measuring installation incorporates more than one meter run, each run shall have its own upstream and downstream isolation valves.

Meter runs of different sizes within the same measuring installation shall not be used simultaneously if this will cause overspeeding of any gas meters.

Appropriate to the application, the number of parallel meter runs should be such that the maximum flow rate can be measured with one meter out of service whilst the rest of the meters operate within their specifications.

If there is a meter run for series connection this shall tie into the main runs upstream and downstream of the required upstream and downstream straight length of the meter.

When a meter run is not in operation, it shall be isolated such that the measuring system does not register any flow.

7.15 Pulsations and vibrations

7.15.1 General

Pulsations and/or vibrations shall not affect the gas measuring results beyond agreed tolerances. These phenomena shall be taken into account.

When designing a measuring installation the effects of pulsation shall be checked. The following components can have an influence on the gas meter:

a) compressors, especially piston-type compressors;

b) piping layout generating resonances and/or

c) pressure regulators;

d) flow regulating valve.

The influence of pulsations can be reduced by various measures:

e) increasing the distance between the meter and the pulsation source;

f) using suitable pulsation dampers;

g) isolating the gas meter; or

h) choosing less sensitive technologies.

EXAMPLE Tees, flow conditioners, change of diameters.

The sensitivity characteristics of the installed gas meter shall be taken into account with view to pulsation frequency, noise and others.

Vibrations can arise:

- when the mechanical natural frequency of the pipe system is equal or very close to the excitation frequency caused by components as mentioned,
- by the gas meters themselves, or
- by flow induced pulsations.

To prevent or minimize vibration effects on the gas meter, appropriate calculations for the whole gas measuring should be done, at design stage.

7.15.2 Pulsating effects related to specific flow meter types:

7.15.2.1 Turbine meter

A turbine meter should not be used to measure flows which are rapidly pulsating, nor should they be used where total metered gas flow is on/off, unless the on-time is greater than 30 min. The positioning of any compressor is critical to ensure that the measuring installation is not adversely affected by pulsations.

7.15.2.2 Rotary displacement meter

A rotary meter should not be used where any connected gas appliance has very rapid starting and stopping ramp rates. The positioning of any compressor is critical to ensure that the measuring installation is not adversely affected by pulsations.

7.15.2.3 Ultrasonic meter (non-domestic)

An ultrasonic meter (non-domestic) shall not be used where they are influenced by noise generated from pressure regulators, compressors or valves, etc., without sufficient noise damping.

7.16 Filter

Dust, borne solids and/or fluids should not influence the results of measurement, therefore, where required, suitable filters and/or separators should be fitted upstream of the meter.

7.17 Gas conditioning, hydrate protection

If pressure reduction or flow control cause hydrate or ice formation which affects the operation of the measuring installation, a pre-heater shall be fitted or other suitable means shall be employed.

If any pre-heating is applied care shall be taken that the measurement results remain within their accuracy limits.

NOTE Further information concerning pre-heating is given in EN 12186.

7.18 Duplication of measuring instruments

Depending on size and accuracy requirements of the gas measuring installation and in order to increase the availability, the reliability and the confirmation of the results from measurement, measuring instruments should be duplicated and should operate independently.

EXAMPLE Double calculation for orifice meter, dual configuration ultrasonic meter or series connection for meters can be adopted.

The criteria to duplicate measuring instruments shall be agreed upon between the involved parties.

7.19 Venting

When considering the intentional release of gas to the atmosphere, venting or purging, the requirements of EN 1775, EN 12186 or EN 15001, whichever is applicable, shall be complied with.

Venting of gas to the atmosphere shall be kept to a minimum during all phases of the life of a gas measuring installation, from design to decommissioning.

7.20 Ventilation

When the gas measuring installation is located in a housing, ventilation shall be adequate to ensure any minor escape of gas and does not built up to an explosive limit.

Ventilation shall meet the requirements given in EN 1775, EN 12186, EN 12279 or/and EN 15001, whichever is applicable.

7.21 Odorants and/or additives

The addition of odorants and/or other additives used for gas treatment, e.g. for drying of the gas, shall not affect the performance and accuracy of the gas measuring installation. If odorants are injected at the same installation, the injection point should be located downstream the meter runs.

7.22 Electromagnetic compatibility (EMC)

The electrical and electronic sub-systems, the instruments and equipment used at the measuring installation shall comply with the requirements for electromagnetic emission and immunity stated in the applicable standards of the EN 61000 series.

It shall be ensured that electromagnetic effects do not adversely affect the metrological and operational performance of the measuring installation.

NOTE European Directive 2004/108/EC for EMC (electrical and electronic sub-systems and instruments) is applicable.

7.23 Documented provisions

7.23.1 General

Documented provisions shall be established and shall provide clear, transparent, objective and traceable calculations of the amount of energy delivered by the measuring system.

The provisions shall include the following, where applicable:

a) a clear description of which input parameters are required and how these values are used to calculate the energy delivered by the measuring system so that a competent person can reproduce the results;

b) a clear description of the uncertainty calculations;

c) objective and traceable values for all input parameters not directly given by the measurement instrument readings and which attributed values are used and how these values are obtained;

d) a description of the general layout of the gas measuring installation and which readings/values are used for energy calculation;

e) sufficient records of all measuring data and relevant parameters for the specified/required period of time, to enable to reproduce the calculations;

f) a description of how to deal with missing or rejected instrument readings and include a procedure describing how energy will be recalculated in case of error;

g) a procedure for the estimation of to determine the gas quantities delivered of the gas consumption, to be used when the meter has failed.

7.23.2 Data handling (Security)

Within these provisions, data handling shall at least have the following functionalities:

- acquisition of data;
- storage;
- monitoring;
- reporting;
- verification and corrections.

Furthermore, the data handling shall provide procedures:

- for approval of the measuring data from the gas measuring installation(s); and
- for parameters for the determination of the accountable energy amounts.

Data handling can have additional parts and/or functionalities:

a) system and/or procedures for the determination of energy with respect to gas measuring installations without local gas quality determination;

b) recording of all actions and incidents relevant to the performance of the measuring system.

The data transmission shall not compromise the integrity and completeness of the measuring data.

When measuring data, programs or commands are transmitted from the measuring installation to another location or vice versa, for further processing or storage, the transmission shall be done by secure and tamper-proof methods or channels.

Only contracted data shall be transmitted and the data shall only be shared with the contracted parties.

Precautions shall be taken to ensure that any commands received shall not put the installation into an unsafe mode or cause hidden/unrecognized errors in the measuring system, even in the case of incomplete, interrupted or corrupted communication.

Any data conversion during or immediately before or after data transmission (e.g. upgrading, completion) shall be transparent and traceable and shall be described in the documented provisions.

8 Construction of a gas measuring installation

8.1 General

Construction, mechanical integrity and safety of a gas measuring installation shall comply with the requirements of EN 12186, EN 12279, EN 15001, EN 1594 and/or EN 1775, as applicable.

For meter housing associated with installation, reference shall be made to EN 12279 or EN 12186, as applicable.

Meters and the associated measuring instruments shall be handled with care because they are precision devices. They shall be stored in a clean and dry condition, taking due regard of the manufacturer's recommendations on storage and handling. The meter inlet and outlet connections shall be protected to prevent ingress of foreign material and moisture and shall remain protected until installation of the meter.

If required by regulation or contract, each measuring instrument shall be accompanied by a test and calibration certificate. It shall be confirmed that all components are suitable for the foreseen operational conditions to which they could be subjected.

All measuring instruments and additional components shall be installed in accordance with national regulations and/or manufacturer's installation, operation and maintenance manual.

The installation of measuring instruments, used for/in determination of energy, shall allow indexes and displays to be easily read. Relevant markings on additional components should also be clearly readable.

Prior to installation all relevant metrological seals shall be visually inspected to ensure they are present and not damaged.

Any tapping used for metrological input shall not be used for any other purposes. Any tapping and internal weld shall be such that the impact on the flow profile upstream does not influence the accuracy of the meter. .

Alignment of pipework and the correct placement of gaskets during construction are essential to avoid flow disturbances, especially in meter runs.

Gas pipework shall be installed and supported in such a manner to avoid undue stress being placed upon any measuring instruments and additional components. Any temporary commissioning filters/strainer should be positioned upstream of mechanical gas meters in accordance with manufacturer's instructions. It shall be ensured that all swarf and debris have been removed from the pipework.

Low points in any sensing line or sampling line shall be avoided so that liquid or dirt cannot collect in them and cause false pressure readings.

8.2 Specific requirements for thermowells

To ensure a representative gas temperature measurement, any thermowell shall be protected against the ingress of water and be provided with the correct amount of heat conducting material at the sensor tip.

8.3 Specific requirements for (differential) pressure transducers

The pressure should be taken from the assigned meter pressure tapping.

NOTE This point is usually marked with P_m.

Any connection shall be according to ISO 2186 and to the manufacturer's specifications.

Mechanical stress shall not be applied to the sensor by the installation or by the sensing lines.

8.4 Specific requirements for sampling systems for CVDD's

The sampling system shall be connected to the designated sampling point.

NOTE Further information can be found in EN ISO 10715.

8.5 Corrosion protection

All components of the measuring installation shall be resistant to or protected against external corrosion.

NOTE Further information can be found in EN 15001 and EN 1775.

8.6 Electrical equipment in hazardous area

If a hazardous area is classified at the place of installation, any electrical equipment shall be suitable for the classified zone and be designed, selected and fitted in accordance with EN 60079-14 and manufacturer‘s instructions.

9 Testing of the gas measuring installation/station

9.1 Strength and tightness test

9.1.1 General

Strength and tightness tests shall be carried out according to EN 1775, EN 12327, EN 12186 or EN 15001, whichever is applicable.

9.1.2 Test report

A test report shall be compiled and retained, containing the following information as a minimum:

a) the identity of the authorized person responsible for the test;

b) the date of the test;

c) the names of the owner and of the installer/contractor of the gas measuring installation/station;

d) identification of the section to which the test relates;

e) the design pressure;

f) the strength and tightness test pressures reached during testing and the time for which this pressure was maintained;

g) the test medium;

h) a reference to the testing procedure;

i) the test results.

The test report shall be retained until the gas measuring installation /station is taken out of service or has been re-tested and new test report has been filed.

Reference is made to Annex F.

9.2 Purging

After a satisfactory tightness test the whole installation shall be purged to gas in accordance with EN 12327.

10 Pre-commissioning and commissioning of the gas measuring installation

10.1 General

Some gas measuring installations consist of complex mechanical and electronic equipment which shall be properly commissioned to ensure that it meets its design specification in operational service.

Verification shall be carried out in accordance with national requirements and/or the manufacturer's installation, operation and maintenance manuals.

10.2 Pre-commissioning checks

10.2.1 General

Any specific pre-commissioning checks, including verifications, defined by the manufacturer and/or required according to EN 15001, EN 12327 or EN 12186, whichever is applicable, shall be undertaken.

Pre-commissioning checks shall be completed before the gas measuring installation is commissioned.

It shall be verified that the installation has been successfully pressure tested, purged and sufficiently dried.

The installation shall be inspected visually to ensure that it is complete, undamaged (incl. seals), correctly aligned and in accordance with the design. In particular the automatic and manual isolation and vent valves shall be checked to ensure safe and reliable operation.

Certificates for all measuring instruments (meter, conversion device, etc.) and for all electrical systems shall be available, as appropriate.

Cabling in hazardous areas shall be checked to ensure that they comply with the appropriate standards, manufacturer's requirements and national requirements.

10.2.2 Electrical or electronic system

Installed electrical or electronic systems shall be checked in whether it is in accordance with EN 60079-17.

10.3 Commissioning and re-commissioning

10.3.1 General

When commissioning or re-commissioning, the installation shall be pressurized and the performance of the complete measuring installation and its correct functioning in the system shall be verified. Care shall be taken when opening the valves to ensure that the meter is not subjected to excessive pressure differentials or subjected to over-speeding. This is particularly important when pressurizing large downstream pipework volumes through turbine and rotary displacement meters.

Before commencing any tests or verification on equipment located in temperature controlled areas, the tested equipment shall be left in an energized state for sufficient time for the temperature to stabilize.

10.3.2 Gas meters

10.3.2.1 General

A check shall be carried out to ensure that the instructions and requirements given in the manufacturer's operation, installation and maintenance manuals are applied correctly.

EXAMPLE Lubricating oil, pressure difference, etc.

Where applicable, all output signals from the meter shall be checked against the meter index (mechanical or electronic).

Visual inspection of the meter and its associated inlet and outlet pipework shall be carried out.

Temporary commissioning filters/strainer should be positioned upstream of mechanical gas meters.

10.3.2.2 Non-domestic ultrasonic meters

A check shall be made to ensure that there is a zero reading (no counting below low-flow cut off) on each chord when the meter is isolated from any flow; see ISO 17089-1 where requirements on field tests are described.

The non-domestic ultrasonic meter can be connected to the volume conversion device (VCD) with a digital/analogue or pulse signal. When the signal used for the meter at the calibration facility is different from the signal used at the gas measuring installation, it should be checked that the flow rates given by both signals are the same.

NOTE 1 This can occur if the calibration facility uses the pulse output and on-site the serial port is used or vice versa.

During commissioning and re-commissioning a check should be undertaken to monitor the performance of the non-domestic ultrasonic meter in accordance with ISO 17089-1. If the ultrasonic meter has diagnostic tools it is recommended to bring those into service. There are two main parameters:

a) speed of sound;

b) velocity profile.

The speed of sound of each chord shall be compared with the computation results based on the analysis of the gas composition and operational conditions. This check shall be used to verify the performance of the metering installation.

A comparison should be undertaken between the velocity profile in the meter at the calibration facility with the profile given on site and shall ensure that the profile on site is within the specifications.

NOTE 2 These checks can also be performed continuously by the measuring installation (see Clause 11).

10.3.2.3 Orifice plate meter

The orifice plate shall be examined to ensure that it complies with EN ISO 5167-1 or EN ISO 5167-2 and no damage has occurred during its installation.

It shall be verified if formulae and discharge coefficients used for the computation of volumes based on pressure differential are correctly entered into the volume conversion devices according to the EN ISO 5167-1 or EN ISO 5167-2 standard.

10.3.2.4 Coriolis meter

A zero adjustment test shall be undertaken in accordance with ISO 10790. If needed, any adjustment procedure shall be performed.

The effects of the upstream and downstream pipework and vibrations on the meter’s performance shall be checked.

10.3.3 Instrumentation

10.3.3.1 General

Any sensors and all additional components forming a measuring chain shall be verified as a single unit. Prior to the verification, a check shall be undertaken to ensure components are undamaged and correctly connected.

EXAMPLE These can include interfaces, signal convertors, power supply units, including cabling and other electronic equipment, the display, monitor, recorder or printer, etc.

All verification results shall be recorded at the time of verification including all relevant prevailing operating conditions.

A check shall be undertaken to ensure that all instrumentation contributing to the end results of measurement have been calibrated with traceability to a national or international standard.

10.3.3.2 Conversion device

A check shall be carried out to ensure that the relevant constants and formulae have been properly configured into the conversion device in accordance with the agreed specifications/national requirements and that it performs all calculations correctly.

10.3.3.3 Full functional test

Following the verification and calibration of the instrumentation, a full functional test shall be carried out on the gas measuring installation.

NOTE This test confirms the overall working of the installation including the sensors, the alarms, the signal transmission, the analogue to digital conversion and the flow computation and checks if the results of the conversion are correct.

10.3.4 Initial comparison check

When measurement is duplicated the difference between all used measurement instruments and calculations to determine energy shall be within the agreed limits.

10.4 Acceptance, documentation and hand-over

The responsible person for the system shall ensure that the owner of the system accepts the gas measuring system and is provided with sufficient written documentation concerning commissioning and re-commissioning in form of a technical file. This shall be appropriate for the size and complexity of the system in order that the system can be used and maintained by the user in a safe condition.

Any technical file shall confirm at least the following that:

a) successful commissioning of the installation has been undertaken;

b) all technical documentation, including drawings, all operational manuals, type approval, calibration and material certificates, etc., have been handed over;

EXAMPLE Also includes information on type of meter installed, index reading, meter serial number, etc.

c) all appropriate safety warning notices have been displayed;

d) equipotential bonding of metal structure have been verified;

e) where appropriate, explosion protection documentation, including any classification of hazardous areas are available;

f) if applicable, any deviation between the design drawings and the as built condition is acceptable.

NOTE Acceptance, documentation and hand-over can be subject to contracts between involved parties.

For further details on documentation and records, see Annex F.

10.5 Post-commissioning checks

Any post-commissioning check (running test) should be in accordance with or as close as possible to the test and calibration procedures of the measuring installation. It should be carried out after a specified period of time following to the commencement of operation to ensure that it is still within the specifications.

Any temporary commissioning filters/strainer should be removed.

The verification and calibration procedures after commissioning shall be undertaken with the gas in operating condition and according to EN 15001-1 and EN 15001-2.

11 Operation and maintenance

11.1 General

Operation and maintenance procedures shall ensure that the gas measuring installation continues to operate within its agreed MPE and the gas measuring system operates within its agreed accuracy (see 5.3). All persons actively involved in the operation and maintenance of the measuring station shall be identified and their duties and responsibilities shall be fully documented.

After the gas measuring installation has been commissioned, its integrity and performance shall be maintained. The operator of the measuring system shall prepare, maintain and retain auditable procedures for its operation and maintenance.

Inspection, verification and calibration shall be carried out to a set procedure to ensure that the gas measuring system performs within the required accuracy and maintains a high level of reliability. The frequency of inspection/calibration should be based on:

- the required system uncertainty;
- the measuring installation performance; and
- any changes in the operational conditions.

Inspection and maintenance of certified electrical equipment shall be carried out in accordance with legal requirements and the manufacturer's instructions.

The integrity and ventilation of the housing shall be checked to ensure that it has not deteriorated and access and egress are still appropriate.

The pipework and all additional components shall be checked to ensure their integrity is maintained.

The meter run and, where applicable, any by-pass valve and any associated filters shall be checked for correct functioning.

Flow rates and operating pressures should be checked periodically to ensure that the measuring installation, including the secondary instrumentation, is operating within the design constraints.

The assumptions used for the fix factors should be periodically verified.

All settings of the instruments shall be checked periodically to ensure that their values are consistent with those in the documented provisions.

If duplicated measurement is used, the difference between the measurement results shall be checked against their performance specification. Corrective actions shall be taken when this difference is outside the performance specification.

Where a meter by-pass is installed, it shall be secured and sealed in the closed position. Sealing is optional, if the meter installation is in a locked housing with restricted access.

A check shall be undertaken to ensure a notice is still fitted adjacent to the valve giving the necessary instructions on when and how to operate the by-bass valve.

If unwanted reverse flow or phantom flows is detected in a gas measuring installation, corrective action should be taken. Any corrective action shall be documented and the concerned original values, before correction, shall be recorded.

Any significant change to the gas measuring installation shall be recorded.

Following calibration or verification of the sensor and the CVDD, it shall be checked that the total error of the sensor or CVDD measurement pertaining to normal volume and energy is within acceptable limit such that the measuring installation is operating within its agreed MPE and the gas measuring system operates within its agreed accuracy.

The results of inspection, verification and calibration shall be documented.

11.2 Reference equipment

For off-site calibrations, measuring instruments and sensors which comprise the gas measuring installation and which are relevant to the accuracy of measurement, shall be calibrated against references traceable to international standards. Off-site-calibrations should be undertaken at a facility accredited by the national authority according to EN ISO/IEC 17025.

For on-site verification, reference equipment used should have an uncertainty of measurement of less than or equal to:

$$U_{\mathrm{ref}} \leq 1/3\ \mathrm{MPE}_{\mathrm{instrument}}$$

Where the above is not achievable apply the following formula:

$$MPE \geq \sqrt{U_{\mathrm{ref}}{}^2 + U_{\mathrm{Maes.}}{}^2}$$

NOTE In some countries accuracy of the reference equipment is subject to national regulation.

11.3 Gas meters

11.3.1 General

Reference should be made to the manufacturer’s installation, operation and maintenance manual for any specific checks or adjustments required to maintain the meter uncertainty within the specification.

Any inspection of a gas meter shall check for signs of faulty operation.

EXAMPLE Excessive noise, irregular movement of the index, water ingress and for evidence of corrosion or other damage.

If there is any doubt about the performance of the meter, the causes shall be investigated. If necessary, the meter should be removed from the pipework for an internal inspection. If the performance of the meter remains in doubt, it shall be replaced.

Where meters require periodic lubrication this shall be undertaken in accordance with the manufacturer’s installation, operation and maintenance manual.

When electrical pulse outputs from a gas meter are in use, these shall be compared periodically against the meter index and against each other.

The meter should be calibrated at conditions representative of the expected operating conditions. Provisions given in EN 12261, EN 12480 and ISO 17089-1 shall be applied. If the field conditions differ significantly from the calibration condition it shall be taken into account in uncertainty calculations.

Off-site-calibrations should be undertaken at a facility accredited by the national authority according to EN ISO/IEC 17025.

For high accuracy gas meter calibration, the facility should have a recognized and known uncertainty.

NOTE Details on the concept of a common harmonized European cubic meter for natural gas can be found in the bibliography [33].

11.3.2 Rotary displacement meters

If the performance of a rotary displacement meter is in doubt a different pressure check can be undertaken. If significant increase in the differential pressure is identified this can indicate the existence of a mechanical fault.

11.3.3 Turbine meters

If the performance of the turbine meter is in doubt it should be subject to internal inspection and, where necessary, a spin down test.

NOTE For the internal inspection and spin down test usually a removal of the meter from the pipework is required.

Attention shall be given to:

- proper installation;
- deposits;
- wear or damages on the meter pipe wall;
- the inlet hub;
- the flow conditioner; and
- the turbine wheel.

The spin down test should be carried out in draught free environment. Comparison of measured spin down times with the manufacturers’ values for a new meter gives a good guide to the condition of the bearings of the meter.

11.3.4 Vortex meters

When the performance of a vortex gas meter is in doubt it shall be removed from the pipework for internal inspection.

Attention shall be given to:

- proper installation;
- deposits;
- wear or damages on the meter pipe wall;
- wear and damages on the edge sharpness of the bluff body.

NOTE Often failures are caused by the sensors (thermistors) which could defect the vortex.

11.3.5 Ultrasonic meters

When available diagnostic results from the meter’s diagnostic tools should be checked on a regular basis and compared with the results obtained during commissioning. Further information can be obtained from ISO 17089-1 and the manufacturer’s documentation.

If there is a CVDD onsite then an on-line comparison of the speed of sound in the gas is recommended.

11.3.6 Orifice Meters

When examining the meter, the influence of the condition of the inner wall of the meter and of the upstream pipe on the meters performance shall be considered.

The orifice plates, the orifice carriers and the associated pipework shall be examined periodically according to EN ISO 5167-1.

For orifice plates attention shall be given specifically to:

- bore diameter;
- edge sharpness;
- plate flatness;
- dirt and debris particularly on the upstream face.

For the carrier and associated pipework special attention shall be given to:

- the upstream pipe is free from dirt, debris, damage and deterioration;
- the condition of the orifice carrier seals is satisfactorily;
- the plate bore is concentric with the carrier and upstream pipe.

If significant damage or deterioration has been found this shall be repaired and it shall be checked that all parts again comply with EN ISO 5167-1.

11.4 Conversion devices

The conversion device shall be examined and verified in accordance with contractual obligations and the manufacturer's installation, operation and maintenance manual. Changes of parameters shall be tested and well documented.

Detailed requirements are given in the specific parts of this European Standard (see 7.10).

The periodic verification shall determine whether that the advance in the conversion device uncorrected volume register is consistent with the meter's index and that the conversion results are within the agreed accuracy limits. It shall also be checked that the calculation of the conversion factors are according to the specification.

11.5 Calorific value determination device

The calorific value measuring systems shall be operated and maintained to meet the agreed accuracy.

The performance of the CVDD-System shall be regularly checked for the following:

- integrity of the sampling lines;
- gas being sampled at the correct temperature;
- cleanliness of any filter and replacement, if necessary;
- adequacy of sampling flow;
- validity of the calibration gas certificate;
- the composition of the calibration gas correctly feeding the CVDD-System;

- the CVDD remains within specified uncertainties.

Calibration gases shall be prepared according to EN ISO 6142-1 or EN ISO 6143 or certified according to EN ISO 6141.

A verification gas sampled from the line and analysed in a calibration laboratory shall be used to ensure the CVDD is accurate over the full gas composition.

11.6 Sensors

All measuring sensor shall be checked to ensure that they all function within their acceptance limits. If any malfunction is noticed, corrective action shall be taken.

The verification of sensors shall be performed under representative operational conditions.

The verification can be done at the working point or at several points over the measuring range. If adjustment is undertaken to bring the instrument within the acceptance limit, at least 3 measurements divided over the measuring range and at the normal operating conditions shall be performed to determine the adjustment.

The result of the verification of a sensor measurement compared to the reference measurement should be within the acceptance limit to ensure that the MPE is not exceeded.

11.7 Calibration/verification and maintenance records

The calibration/verification and maintenance data shall be stored and made available to demonstrate that the performance of the gas measuring installation(s) remains within its accuracy limits. All relevant documentation and records shall be retained in accordance with contractual agreement and/or relevant national requirements.

The documents and records of maintenance, verification, calibration should comprise:

- calibration reports of pressure and temperature sensor(s),
- calibration and test-gas analyses of the gas chromatographs,
- calibration certificates of the gas meter(s),
- a list of relevant events and actions at the gas measuring installation with regards to the energy determination process (‘logbook’).

Additionally for the control of Classes A and B the following functionalities should be part of the documentation system:

- procedures for quality control and data analysis for long term effects;
- central registration of all vital settings of the instruments and computers at the gas measuring installation.

For further information, see Annex F.

12 Decommissioning

Decommissioning of the installation shall be carried out in accordance with EN 12186, EN 1775 and EN 12327, as applicable.

When an installation is taken out of service for a long period it should be decommissioned, disconnected from the gas infrastructure and the ends sealed.

Annex A
(informative)

Guideline for the selection of meters

Table A.1 provides an outline of characteristics of commonly used gas meters. It is not intended to be used as a definitive list, but as guidance to meter selection. It should not be treated as exhaustive, as new technology is constantly being developed. Reference should always be made to manufactures' instructions.

Table A.1 — Guidelines for the selection of meters

Applicable factors/Gas meter type	Rotary displacement meters	Turbine meters	Diaphragm meter	Ultrasonic meters for non-domestic use	Domestic ultrasonic meters	Vortex meter	Orifice meter	Coriolis meter	Thermal mass meter
Product standard	EN 12480	EN 12261	EN 1359	ISO 17089-1	EN 14236	ISO 12764	EN ISO 5167 (all parts)	ISO 10790	(not available at the time of writing)
Gas density at operating conditions	Unaffected over specified density range	Measuring range will increase with higher density	No influence as maximum working pressure ≤ 500 mbar	Low density can cause drop out	Unaffected over specified density range	Measuring range will increase with higher density	Flow range depends on density, as Δp depends on massflow	Generally used for medium and higher densities	No influence as maximum working pressure ≤ 500 mbar
Gas borne solids	Possible blockage of the rotors.	Blades may be damaged and freedom of rotation may be affected.	Normally unaffected.	Deposits with impact on internal geometry/ measure-ment	Normally unaffected.	Deposits and bluff body abrasion possible.	Deposits and abrasion possible.	Deposits and abrasion possible.	Deposits and abrasion possible.
Filter	Filter recommended/see manual for position	Filter recommended/see manual for position	Normally not required	Normally not required	Normally not required	Filter recommended/see manual for position	Filter recommended /see manual for position	Filter recommended/see manual for position	Filter recommended/ see manual for position

Applicable factors/Gas meter type	**Rotary displacement meters**	**Turbine meters**	**Diaphragm meter**	**Ultrasonic meters for non-domestic use**	**Domestic ultrasonic meters**	**Vortex meter**	**Orifice meter**	**Coriolis meter**	**Thermal mass meter**
Orientation	Normally for both horizontal and vertical mounting	Normally for both horizontal and vertical mounting	The meter has to be in the vertical plain and level	Normally for both horizontal and vertical mounting	The meter has to be in the vertical plain and level but can be fitted horizontally if manufacturer's instructions allow	Normally for both horizontal and vertical mounting	Normally for both horizontal and vertical mounting	Normally for both horizontal and vertical mounting	Normally for both horizontal and vertical mounting. Correct installation is important.
Electrically power requirement	No need as long as mechanical index	No need as long as mechanical index	No need as long as mechanical index	Yes	Yes	Yes	Yes	Yes	Yes
Pressure absorption (using air)	Low	Medium	Low	None	Low	Medium	High	High	Low
	typically 2–5 mbar	max 25 mbar	Typically 2–4 mbar	negligible	< 2 mbar	max 20 mbar	200 …500 mbar	high	For $Q_{\max}$ 6 m^3/h $\leq$ 2 mbar
Rapid pressure and flow variations	max permitted rate 350 mbar/s	max permitted rate 350 mbar/s	Insignificant	Depending on the frequency	Depending on the frequency	Rapid pressure variations may cause damage.	Rapid pressure variations may cause damage.		
		Rapid flow variations cause measure errors; particularly rapid flow reductions cause overreading							
Pulsating flow	May cause measuring failure	May cause measuring failure	Measurement unaffected	Measurement unaffected (as long as the measuring rate is high enough)	Measurement unaffected (as long as the measuring rate is high enough)	May cause measuring failure	May cause measuring failure	May cause measuring failure	Measurement unaffected

Applicable factors/Gas meter type	**Rotary displacement meters**	**Turbine meters**	**Diaphragm meter**	**Ultrasonic meters for non-domestic use**	**Domestic ultrasonic meters**	**Vortex meter**	**Orifice meter**	**Coriolis meter**	**Thermal mass meter**
Environmental sensitivity	May be sensitive to high frequency pulsation (or their harmonics)	May be sensitive to high frequency pulsation (or their harmonics)	Measurement unaffected	May be sensitive to fluid borne ultrasonic noise when its frequencies are close to the meter working frequencies	Measurement unaffected	May be sensitive to fluid borne vortexes	May be sensitive to high frequency pulsation (or their harmonics)	May be sensitive to high frequency pulsation (or their harmonics)	Measurement unaffected
Typical turn down ratios inside the permitted limit of error	20:1 to 160:1	20:1 to 30:1	150:1	20:1 to 30:1	150:1	20:1 to 30:1	5:1 to 10:1	(not known)	150:1
	Turn down ratio will increase with higher density	Turn down ratio will increase with higher density							
Overload	Overload possible for a short time, according standard	Overload possible for a short time, according standard	Overload possible for a short time, according standard	Overload possible.	Overload possible.	Overload possible.	Overload possible.	(not known)	Overload possible.
Increase of the nominal capacity	Increase in maximum flow needs larger meters or additional streams or higher pressure.	Increase in maximum flow needs larger meters or additional streams or higher pressure.	Increase in maximum flow needs larger meters or additional streams.	Increase in maximum flow needs larger meters or additional streams or higher pressure.	Increase in maximum flow needs larger meters or additional streams or higher pressure.	Increase in maximum flow needs larger meters or additional streams or higher pressure.	Increase in maximum flow needs larger meters or additional streams or higher pressure.	Increase in maximum flow needs larger meters or additional streams or higher pressure.	Increase in maximum flow needs larger meters or additional streams.
Meter failure	Meter failure can interrupt the gas flow.	No effect on the continuity in gas supplying	Meter failure can interrupt the gas flow.	No effect on the continuity in gas supplying	No effect on the continuity in gas supplying	No effect on the continuity in gas supplying	No effect on the continuity in gas supplying	No effect on the continuity in gas supplying	No effect on the continuity in gas supplying

Applicable factors/Gas meter type	**Rotary displacement meters**	**Turbine meters**	**Diaphragm meter**	**Ultrasonic meters for non-domestic use**	**Domestic ultrasonic meters**	**Vortex meter**	**Orifice meter**	**Coriolis meter**	**Thermal mass meter**
Maintenance requirements	Replacement and checking of oil level as per Manufacturer's instructions	Maintenance free or lubrication as per Manufacturer's instructions	Not recommended	Minimized when equipped with smart self-diagnostic means	Periodical replacement battery required	Not recommended	Recommended particularly for orifice plate	Minimized when equipped with smart self-diagnostic means	Periodical replacement battery required
Emitted noise	Can be noisy	Can be noisy at high flow rates and/or high pressure	can be noisy	can be noisy	no noise	can be noisy	Can be noisy	can be noisy	no noise
Internal vibration	At certain flow rates the meter's natural resonance can cause vibration within connected pipework	Not an issue	Not an issue	Not an issue	Not an issue	Not an issue	Not an issue	Not known	Not an issue
Environmental impact	Disposal of oil or any mounted electronic components	Disposal of oil or any mounted electronic components	Disposal of battery and electronic components	Disposal of electronic components	Disposal of battery and electronic components	Disposal of electronic components	Disposal of electronic components	Disposal of electronic components	Disposal of electronic components
Space required for the meter and its upstream/ downstream pipework	No special requirements	Length of upstream/ downstream straight pipework as per the results of type test declared by the manufacturer. It is necessary to consider if high or low flow perturbation occurs	No special requirements	Length of upstream/ downstream straight pipework as per the results of type test declared by the manufac-turer.	No special requirements	Length of upstream/ downstream straight pipework as per the results of type test declared by the manufacture	Length of upstream/ downstream straight pipework as per the relevant standard and the manufacturer's instructions	No special requirements	No special requirements

Applicable factors/Gas meter type	Rotary displacement meters	Turbine meters	Diaphragm meter	Ultrasonic meters for non-domestic use	Domestic ultrasonic meters	Vortex meter	Orifice meter	Coriolis meter	Thermal mass meter
Typical pipework length — upstream DN	0	2–10	0	10	0	20	from 2,5 to 80 depends on beta ratio, type of pressure differential device and on additional uncertainty	0	0
Typical pipework length — downstream DN	0	1	0	3–5	0	5	from 2 to 8 depends on beta ratio, type of pressure differential device and on additional uncertainty		

Annex B
(informative)

Sensor test procedures

B.1 Differential pressure sensors

B.1.1 General

Differential pressure sensors should be tested in one of the following ways:

a) high static pressure testing;

b) "Footprint testing";

c) atmospheric calibration.

The method chosen is dependent upon the static pressure at which the measurement is undertaken, the location of the measuring installation and the availability of the specific test equipment.

B.1.2 High static pressure testing

Each differential pressure sensor should be tested in situ using a certified pneumatic deadweight tester or another calibration instrument with a certified uncertainty of at least 1/3 of the uncertainty of the particular sensor. The differential pressure sensor should be pressurized to the same pressure as the measuring line under normal operating conditions.

Corrections should be made to the stamped weight-pieces of the deadweight tester to take account of the effects of local gravity and temperature, if this varies significantly from the calibration temperature at which the deadweight tester was calibrated.

If there is a difference in level between the sensor and the deadweight tester a buoyancy correction factor should also be applied.

The output of the differential pressure sensor should be observed and recorded with both rising and falling pressure at three or more nominal points over its working range. The differential pressure sensor should be over-ranged to 110 % of its working range in between the rising and falling tests.

Zero and span adjustments can be made to bring the sensor centrally within the agreed tolerance.

B.1.3 "Footprint testing"

For "Footprint testing" the differential pressure sensors first should be tested and adjusted at high static pressure at an accredited calibration laboratory on the same basis as described in B.1.2. A further calibration is then carried out at ambient pressure and another test record ("the Footprint") is generated.

At the measuring installation, each differential pressure sensor should be tested in situ using a certified deadweight tester connected to the high pressure port with the low pressure port open to atmosphere.

After the above tests have been completed a zero check should be undertaken at the operating static pressure.

The recorded results of measurement from the above tests should then be compared with those on the "Footprint" generated in the above mentioned laboratory. If they are not within the permitted tolerance, the differential pressure sensor should be returned to the laboratory for calibration and adjustment.

B.1.4 Atmospheric calibration

As an alternative to B.1 and B.2 the differential pressure sensors can be tested at atmospheric pressure only. Each differential pressure sensor should be tested in situ using a certified deadweight tester connected to the high pressure port with the low pressure port open to atmosphere.

Attention should be paid to the fact that differential pressure sensors tend to be sensitive to transfer from ambient pressure to operating pressure. Correction for the systematic shift of the output, inherent to this way of calibration, might be required.

If the recorded results of measurement are not within the permitted tolerance, then the sensor should be replaced. Alternatively adjustment of the zero and span can be undertaken to bring it within tolerance, if this is permitted by the documented provisions.

B.2 Pressure sensors

The result of a measurement at each point should be within the permitted tolerance. If this is not the case then the pressure sensor should be replaced. Alternatively, span and zero adjustment can be undertaken to bring the instrument within the permitted tolerance, if this is permitted by the documented provisions.

B.3 Temperature sensors

B.3.1 Platinum resistance thermometers (PRTs)

The linearity of a platinum resistance thermometer sensor is inherent in its design and construction and is not subject to drift or ageing. Therefore, calibration of this sensor needs only to be carried out at one point in its operating range.

If there is no test thermowell in the meter run, the PRT should be removed from its thermowell and placed in an insulated beaker containing a fluid of a known temperature together with a calibrated reference thermometer device. When the reading on the thermometer has stabilized, the same procedure as below should be followed.

If a test thermowell has been provided in the meter run, a calibrated reference thermometer device should be placed into it. When the thermometer reading has stabilized it, should be compared with the temperature reading displayed by the conversion device. If the comparison is within the agreed limits the results of measurement should be recorded on the test record sheet. Where the reading is outside the agreed limits the element should be changed.

B.3.2 Other temperature sensors

For other semiconductor based temperature sensors it is recommended to carry out the tests at two points on the operating range as they can be subject to ageing and drift. In this case the device should be removed from the thermowell and placed, together with a calibrated thermometer device, in an insulated beaker containing, initially, melting ice and then oil at ambient temperature. The procedure in B.3.1 should then be followed. Alternatively temperature calibrators can be used to create and maintain the necessary temperatures.

B.4 Density sensors

B.4.1 Density sensors for operating conditions

B.4.1.1 General

Density sensors should be tested in one of the following ways:

a) vacuum test;

b) nitrogen/methane test;

c) calculation method.

The method chosen depends upon the other secondary instrumentation installed on site and the availability of the appropriate test equipment.

If the instrument is outside the agreed limits, it should be removed for recalibration.

B.4.1.2 Vacuum test

The density sensor should be isolated from the process. It should be connected to a vacuum pump and evacuated to an absolute pressure of 1,3 mbar or less.

The temperature of the density sensor should be measured using a calibrated thermometer device inserted into a thermowell adjacent to the density sensor or by its own temperature device, if one is fitted.

When stability has been achieved, the output time period of the density sensor should be measured using a calibrated stop-watch. The measured time period and the vacuum point time period (taken from the density sensor calibration certificate) should be within the agreed limits. These limits include an uncertainty for the density sensor, and an uncertainty for the temperature shift.

B.4.1.3 Nitrogen/Methane test

A supply of high purity nitrogen/methane with a certified quality is connected to the density sensor and a reference pressure using a deadweight tester is applied. Once stable conditions exist, the applied pressure, density sensor temperature and displayed periodic time should be recorded.

The N_2/CH_4 density for the pressure and temperature recorded should then be calculated and compared with the density sensor reading. The difference should be within the limits stated in the documented provisions.

B.4.1.4 Calculation method

In gas measuring installations where the gas composition is reasonably stable and can be determined by a CVDD the density sensor should be checked by the following method:

a) Before commencing the tests it should be ensured that the density sensor has been in operation for a period sufficient in order to stabilize the temperature of the sample gas.

b) When stable conditions have been attained the measured operating density is compared with a computed reference operating density. The difference between both density values should not exceed the agreed limits.

c) The instantaneous reference value of the operating density should be computed from the following data:

    1) the results of measurement of gas pressure and temperature;

2) the compression factor Z calculated on the basis of the gas analysis in accordance with the formulae in EN ISO 12213-1, EN ISO 12213-2 and EN ISO 12213-3.

B.4.2 Density sensors for base conditions

The density sensor for base conditions should be calibrated in accordance with the procedures in the documented provisions and the manufacturer's instructions.

The density sensor for base conditions should be calibrated at two points by introducing, sequentially, two gases of known base density into the sample chamber. The purity and base density of the test gases should be defined according to applicable standards. Calibration constants should be calculated in accordance with the manufacturer's instructions.

The values of displayed base density should not differ from the reference base density values by more than the permitted tolerance.

Annex C
(informative)

Set of formulae to calculate volume or mass to energy

C.1 General

This clause provides the set of formulae normally used to calculate the gas quantity by

- volume at base conditions;
- mass; or
- energy.

It should be noted that the measurement is volume V in m^3 at operating conditions. This clause uses the symbols given in Table C.1.

Table C.1 — Symbols

Symbol	**Represented quantity**	**Unit**
ρ	Gas density at metering conditions	kg/m^3
ρ_b	Gas density at base conditions	kg/m^3
E	Energy	kWh or MJ
GCV_m or $H_{s,m}$	Gross calorific value at base conditions, based on mass	MJ/kg or kWh/kg
GCV_v or $H_{s,v}$	Gross calorific value at base conditions, based on volume	MJ/m^3 or kWh/m^3
M	Mass	kg
M_m	Molar mass	kg/mol
P	Metering pressure (absolute pressure at metering conditions)	Pa or bar
P_b	Base pressure (absolute pressure at base conditions)	Pa or bar
R	Universal gas constant	kJ/(kmol × K)
T	Metering temperature	K
T_b	Base temperature	K
V	Volume at metering conditions	m^3
V_b	Volume at base conditions	m^3(b)
z	Compression factor of the gas at metering conditions	-
z_b	Compression factor at base conditions	-
b	Base conditions	

C.2 Calculation of volume

The volume at base conditions V_b is calculated by:

$$V_b = V \times \frac{\rho}{\rho_b} \qquad (\text{m}^3) \qquad (\text{C.1})$$

Alternatively, by calculating the density ρ at operating conditions by:

$$\rho = \frac{P \times M_\mathrm{m}}{T \times Z \times R} \qquad (\mathrm{kg/m^3}) \qquad (C.2)$$

the conversion formula becomes:

$$V_\mathrm{b} = V \frac{P \times T_\mathrm{b} \times Z_\mathrm{b}}{P_\mathrm{b} \times T \times Z} \qquad (\mathrm{m^3}) \qquad (C.3)$$

C.3 Calculation of mass

The mass m is calculated by:

$$m = V \times \rho \qquad (\mathrm{kg}) \qquad (C.4)$$

or when again the density at metering conditions from Formula (C.2) is inserted:

$$M = V \frac{P \times M_\mathrm{m}}{T \times Z \times R} \qquad (\mathrm{kg}) \qquad (C.5)$$

C.4 Calculation of energy

The energy E can be calculated by multiplication with the gross calorific value GCV either via the volume or via the mass.

In case of volume based calculation the formula becomes:

$$E = V_\mathrm{b} \times GCV_\mathrm{v} \qquad (\mathrm{kWh\ or\ MJ}) \qquad (C.6)$$

where V_b results either from Formula (C.1) or from Formula (C.3).

When based on mass the formula becomes:

$$E = M \times GCV_\mathrm{m} \qquad (\mathrm{kWh\ or\ MJ}) \qquad (C.7)$$

Annex D
(informative)

Comformity assessment for the energy determination

D.1 Introduction

ISO/IEC Guide 98-4 and JCGM 106 provide guidance and procedures for assessing the conformity of an item (entity, object or system) with specified requirements. The procedures can be used where the following conditions exist (JCGM 106):

- the item is distinguished by a single scalar quantity, or characteristic, defined to a level of detail sufficient to be reasonably represented by an essentially unique true value;
- an interval of permissible true values of the characteristic is specified by one or two tolerance limits;
- the characteristic can be measured and the measurement result expressed in a manner consistent with the principles of the GUM, so that
- knowledge of the true value of the characteristic can be reasonably described by (a) a probability distribution function (PDF), (b) a distribution function, (c) numerical approximation to such functions, or (d) a best estimate, together with a coverage interval and an associated coverage probability.

The procedure for assessment of conformity comprises a sequence of three operations (JCGM 106):

- measure the characteristic of interest;
- compare the measured value of the characteristic with specified acceptance criteria;
- decide on a subsequent action.

D.2 Measurement Systems

In the context of a measurement system the characteristic is its error of indication, E, and the requirements are expressed as a maximum permissible error $E_{\max}$. The error of indication must therefore lie in the interval $[-E_{\max}, E_{\max}]$.

For measurement systems, JCGM 106 also introduces the term measurement capability index (JCGM 106) as follows:

A measurement system is assigned a probability distribution function PDF $h(\eta_m|\eta)$ that characterizes its possible outputs η_m assuming a known input $Y = \eta$/Eingabe $Y = \eta$. For a system corrected, by suitable calibrations, for all systematic errors, the estimate $E = (Y_m)$ is equal to η with an associated standard uncertainty $u_m = \sqrt{V(Y_m)}$, where $V\,(Y_m)$ is the variance of Y_m.

The measurement capability index C_m is defined as:

$$c_m = \frac{T}{4u_m} = \frac{E_{\max}}{U}$$

Where T is the tolerance and is equal to 2 $E_{\max}$ and $U = 2u_m$.

If the knowledge of Y is characterized by a normal PDF, the coverage probability for the interval $[y - 2u_m], y + 2u_m]$ is approximately 95 %.

Conformity of a system with the requirement is therefore indicated by a value of C_m of 1 or more.

D.3 Energy Measurement Systems

For the energy measurement systems described in this European Standard, the three operations of JCGM are as applied follows:

a) Measurement of the characteristic of interest. The energy measurement system is assigned a PDF that characterizes the global error in energy. The PDF is assigned by combination of PDFs that characterize the errors arising from the individual modules that comprise the overall measurement system.

b) Comparison of the measured value of the characteristic of interest with the specified acceptance criteria. This is readily achieved by calculating the measurement capability index of the energy measurement system, C_m.

c) Decision on the subsequent action. If C_m is equal to 1 or more, then the measurement system is deemed to be compliant with the requirement.

In some circumstances it is not practical to correct for all systematic errors and the PDF is characterized by a non-zero mean. In general it is desirable that an energy measurement system is designed such that mean error is close to zero and it can be appropriate to specify an additional requirement regarding the mean, e.g. as a maximum (absolute) mean error.

Annex E
(informative)

Specific national examples of the assessment of conformityof the metrological performance of a gas measuring system

E.1 Introduction

These specific national examples are intended to demonstrate possible approaches of assessment of overall performance of a metering system. The following examples are specific to the countries to which they apply.

In these examples the contributions to mean error and uncertainty in mean error from both measurement instruments and from assumptions/calculations are combined to give an overall measurement system performance. Appropriate documentary provisions to support the justification and explanations accompanying the examples are assumed to have been made available for inspection by appropriate authority, where necessary.

Summary of overall accuracy of the specific national examples provided:

Table E.1 — Summary of overall accuracy of the examples provided

Example	Short description	Mean error ± uncertainty ($k = 2$)	Class
1	Diaphragm meter; meter pressure regulated at 21 mbar; fixed factor volume conversion; charging area CV.	−0,4 % ± 7,4 % = max 7,8 % in-service accuracy	D
2	Rotary displacement meter; meter pressure regulated at 21 mbar; fixed factor volume conversion; charging area CV.	−0,4 % ± 6,9 % = max 7,3 % in-service accuracy	D
3	Rotary displacement meter; meter pressure regulated at 2 bar; site-specific (altitude) fixed factor volume conversion; charging area CV.	−0,4 % ± 5,2 % = max 5,6 % in-service accuracy	D
4	Rotary displacement meter; meter pressure regulated at 2 bar; Type 2 PTZ volume conversion; charging area CV.	−0,1 % ± 3,0 % = max 3,1 % in-service accuracy	C
5	Rotary displacement meter; meter pressure regulated at 2 bar; Type 1 PTZ volume conversion; charging area CV.	−0,1 % ± 3,0 % = max 2,8 % in-service accuracy	C
6	Ultrasonic meter + Turbine meter; meter pressure unregulated above 55 bar; volume conversion using a flow computer; CV measured at site.	0 % ± 0,75 % = max 0,75 % in-service accuracy	A
7	Turbine meter; meter pressure regulated at 8 bar; volume conversion using a flow computer; charging area CV.	0 % ± 1,0 % = max 1,0 % in-service accuracy	A

E.2 Example 1

An energy determination system operating in the UK employs a diaphragm meter operating at a pressure of 21 mbar, which is controlled by a pressure regulator of accuracy class AC10 located upstream of the meter.

Volume is converted to volume at base conditions of 15 °C and 1 013,25 mbar using a fixed factor of 1,022 64; this value is required by the UK Gas (Calculation of Thermal Energy) Regulations.

Conversion to energy is carried out by use of a billing CV calculated from the average of each of the daily charging area calorific values determined over the charging period. The daily charging area calorific values are calculated from the net daily energy flows and net daily volume flows into the charging area (the daily "Flow-Weighted Average CV"- FWACV).

Table E.2 — Example 1

	Property	**Units**	**Value**	**True value**	**Assigned PDF**				**Line**
					mean	mean, %	u_m	u_m, %	
Volume measurement	**Volume metered**	**m³**	**100,00**	**100,00**	**0,00**	**0,000 %**		**1,5000 %**	1
Volume conversion	atmospheric pressure	mbar	1 013,25	1 015,20	-	-	24,43	-	2
	meter pressure	mbar	21,00	21,00	-	-	1,05	-	3
	altitude	m	67,50	67,16	-	-	54,55	-	4
	altitude correction factor	mbar/m	−0,120 208	−0,120 208	-	-	-0,001 2	-	5
	pressure (combined)	mbar	1 026,14	1 028,13	−1,990 9	−0,194 %	25,31	2,461 9 %	6
	temperature	K	285,35	285,05	0,300 0	0,105 %	5,60	1,964 6 %	7
	Z_b/Z	-	1,000 0	1,000 184	0,000 2	0,018 %	0,000 004 9	0,000 5 %	8
	fixed factor	-	1,022 654 755	1,025 905 981	-	-	-	-	9
	volume conversion factor	**-**	**1,022 640 000**	**1,025 905 981**	**−0,003 3**	**−0,318 %**	**-**	**3,149 7 %**	10
Energy conversion	CV variation	MJ/m³	39,50	39,50	0	-	0,5	1,265 8 %	11
	area FWACV	MJ/m³	39,50	39,50	0	-	-	0,074 6 %	12
	truncation of area CV	MJ/m³	39,50	39,55	-0,05	-	0,029	0,073 4 %	13
	energy conversion	**MJ/m³**	**39,50**	**39,55**	**−0,050**	**−0,126 %**	**-**	**1,270 1 %**	14
Overall	energy	MJ	4 039,43	4 057,46	−18,03	−0,444 %	-	3,712 7 %	15
Accuracy in determined energy: −0,4 % ± 7,4 % (k = 2)									16

Table E.3 — Explanation and justification of Example 1

Line	Explanation and justification
1	Unconverted volumetric flow rate using a diaphragm meter can generally be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0,75 % if compliant with EN 1359 (excluding meters compliant with EN 1359:1998, Annex B. The meter is assumed to have been selected to operate between 0,1 $Q_{\max}$ and $Q_{\max}$, so $u(V) = 1{,}5/k = \pm\ 0{,}75$ %, assuming a value of $k = 2$. The meter is assumed to not be maintained and calibrated so meter drift is assumed in accordance with the endurance/in-service requirements of EN 1359:1998, Table 2, so $u(e(V)) = 3/k = \pm\ 1{,}5$ %, assuming a value of $k = 2$.
2	The correction factor in the Regulations assumes an atmospheric pressure of 1 013,25 mbar. For the UK mean monthly atmospheric pressure between 1987 and 1996 was estimated to be described by a distribution with mean 1 015,20 mbar and a standard deviation of 24,43 mbar, so the mean error in atmospheric pressure is taken to be −1,95 mbar, with a standard uncertainty of 24,43 mbar.
3	The correction factor in the Regulations assumes a meter pressure of 21 mbar. The variation of meter inlet pressure for a pressure regulator of accuracy class AC10 is taken to be 10 % of the gauge pressure $\pm\ (0{,}1 \times 21)/k = 1{,}05$ mbar, assuming a value of $k = 2$.
4	The correction factor in the Regulations is based on a nominal altitude of 66 m above sea level. In practice the correction factor is based on the use of an altitude adjustment to pressure of −8,114 mbar. This value is derived from table in part 1 the Regulations (height above sea level band > 65,0 m ≤ 67,5 m), which in turn is derived from an altitude of 67,5 m in the formula that was in use by British Gas prior to the Regulations coming into force: pressure deduction = altitude in metres × 0,120 208 The value 0,120 208 is the altitude correction factor. For the UK mean altitude was estimated in 1998 to be described by a distribution with mean 67,16 m and a standard deviation of 54,55 m, so the mean error in altitude is taken to be +0,34 m, with a standard uncertainty of 54,55 m.
5	The value of altitude correction factor (0,120 208 mbar/m) was in use by British Gas prior to the Regulations coming into force. This value is assumed to have zero mean error and standard uncertainty 0,001 2 mbar/m (1 %).
6	Pressure based on the assumptions in the Regulations detailed in lines 2 to 5 above is calculated to be 1 026,4 mbar. The mean (true) pressure estimated as detailed in lines 2 to 5 above is calculated to be 1 028,13 mbar. This results in a mean error of −1,99 mbar. The standard uncertainty in mean error in metering pressure is calculated to be 25,31 mbar from the estimates of standard uncertainty of the input sources identified in lines 2 to 5 using the formula: $u(P) = \sqrt{\left[(P_{\mathrm{atm}})^2 + (P_{\mathrm{meter}})^2 + (u(A) \cdot ACF)^2 + (u(ACF) \cdot A)^2\right]}$ This formula is derived formally in Annex A.
7	The correction factor in the Regulations assumes a gas temperature of 12,2 °C. For the UK mean monthly atmospheric pressure between 1987 and 1996 was estimated to be described by a distribution with mean 11,9 °C, with a half-range of 11,2 °C, so the mean error in gas temperature is taken to be +0,3 °C, with a standard uncertainty of $11{,}2/k = 5{,}6$ °C, assuming $k = 2$.
8	The correction factor in the Regulations assumes that non-ideality of the gas can be ignored, i.e. $Z_b/Z = 1$. Actual values of Z_b/Z were estimated for the UK based on gas composition data for 2005 at a pressure of 1 028,125 mbar and 11,9 °C (i.e. the conditions of temperature, pressure and altitude assumed in lines 6 and 7) and from this the mean error in Z_b/Z was estimated to be 0,000 184 with a standard uncertainty of 0,000 004 9.

Line	Explanation and justification
9	The value of the volume conversion factor based on the assumptions of the Regulations is calculated to be 1,022 654 755, using the formula $\text{volume conversion factor} = VCF = \left(\frac{P}{P_{\text{base}}}\right) \cdot \left(\frac{T_{\text{base}}}{T}\right) \cdot \left(\frac{Z_{\text{base}}}{Z}\right)$ Using the same formula the value of the volume conversion factor based on estimates of true value for the UK is calculated to be 1,025 905 981.
10	The actual value of volume conversion factor used in the Regulations is 1,022 64, which results in a mean error of (1,022 64 − 1,022 654 755) = −0,003 3 (rounded to 4 dp). The standard uncertainty in mean error in the volume conversion factor is estimated to be 3,148 7 % from the formula $u(bias(VCF)) = \sqrt{\left(\frac{u(P)}{P}\right)^2 + \left(\frac{u(T)}{T}\right)^2 + \left(\frac{u(Z)}{Z}\right)^2}$
11	Although the billing CV is used for consumer billing, under the Regulations a consumer can actually receive gas of CV up to 1 MJ/m^3 lower than that used for billing. The billing CV can therefore be in error (from an individual consumer's perspective) by up to 1 MJ/m^3. The mean error in actual CV is therefore assumed to be zero with a standard uncertainty of 1,0/k = 0,5 MJ/m^3, assuming k = 2.
12	The consumer is billed using a billing CV calculated from daily values of the Flow-Weighted Average CV for the charging area. The value of FWACV is assumed to be unbiased (i.e. mean error is zero) and the relative standard uncertainty in mean error is estimated to be 0,074 6 %. This is based on estimates of mean error and uncertainty in volume metering and CV determination and known values of daily average CV for all entry and exit points to a typical UK charging area.
13	The Regulations require the average billing CV to be truncated to 1 dp. Assuming that over time the digit of the 2nd decimal place of the billing CV is equally distributed between 0 and 9 suggests that truncation results in a mean error of −0,05 MJ/m^3 with standard uncertainty of $0{,}5/\sqrt{3} = 0{,}29$. The true value is therefore adjusted to 39,55 MJ/m^3.
14	The total mean error in the CV is therefore 0,05 MJ/m^3 and the standard uncertainty is calculated by adding in quadrature the relative uncertainties in lines 11-13 to obtain 1,270 1 %.
15	The determined energy, 4 039,43 MJ, is obtained by multiplying the volume, the conversion factor and the CV. The true energy is 4 057,46 MJ so the mean error is −18,03 MJ (−0,444 %). Note that the mean error can also be obtained by arithmetic addition of the relative mean error in volume, conversion factor and CV (0 % − 0,318 % − 0,126 % = 0,444 %). The standard uncertainty is obtained by adding in quadrature the relative standard uncertainties in mean error in volume, conversion factor and CV to obtain 3,712 7 %.
16	The standard uncertainty is converted to expanded uncertainty by multiplication by a coverage factor k = 2 and rounding to two significant figures. The mean error is rounded to 1 decimal place in accordance with the expanded uncertainty after rounding to two significant figures.

E.3 Example 2

An energy determination system operating in the UK employs a rotary displacement meter operating at a pressure of 21 mbar, which is controlled by a pressure regulator of accuracy class AC 10 located upstream of the meter.

Volume is converted to volume at base conditions of 15 °C and 1 013,25 mbar using a fixed factor of 1,022 64; this value is required by the UK Gas (Calculation of Thermal Energy) Regulations.

Conversion to energy is carried out by use of a billing CV calculated from the average of each of the daily charging area calorific values determined over the charging period. The daily charging area calorific values are calculated from the net daily energy flows and net daily volume flows into the charging area (the daily “Flow-Weighted Average CV” - FWACV).

Table E.4 — Example 2

	Property	Units	Value	True value	Assigned PDF				Line
					mean	mean, %	u_m	u_m, %	
Volume measurement	**volume metered**	**m³**	**100,00**	**100,00**	**0,00**	**0,000 %**	**-**	**0,500 0 %**	1
Volume conversion	**volume conversion factor**	**-**	**1,022 640 000**	**1,025 905 981**	**−0,003 3**	**−0,318 %**	**-**	**3,149 7 %**	2
Energy Conversion	**energy conversion**	**MJ/m³**	**39,50**	**39,55**	**−0,050**	**−0,126 %**	**-**	**1,270 1 %**	3
Overall	energy	MJ	4 039,43	4 057,46	−18,03	−0,444 %	-	3,432 8 %	4
Accuracy in determined energy: −0,4 % ± 6,9 % (k = 2)									5

Table E.5 — Explanation and justification of Example 2

Line	Explanation and justification
1	Unconverted volumetric flow rate using a rotary meter can generally be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0,5 %. If the meter is assumed to be compliant with EN 12480 and has been selected to operate between Q_t and Q_{max}, $u(e(V) = 1{,}0/k = \pm 0{,}5$ % assuming $k = 2$ and the weighted mean error (WME) is ± 0,4 %, so mean error is assumed to be zero. The meter is assumed to not be maintained and calibrated so meter drift is assumed in accordance with the endurance/in-service requirements of EN 12480. Drift in original error shall not be greater than one-third of 1 % = ± 0,333 %, so for an unknown (or population of) meter the mean error is assumed to be zero. The initial MPE requirements are retained because the endurance/in-service requirement of EN 12480 is that errors shall not drift outside of the original MPE.
2	The volume conversion factor is the same as that employed in Example 1 so the mean error in volume conversion factor and its standard uncertainty are identical (see line 10, Example1).
3	The calorific value is the same as that employed in Example 1 so the mean error in CV and its standard uncertainty are identical (see line 14, Example 1).
4	The determined energy, 4 039,43 MJ, is obtained by multiplying the volume, the conversion factor and the CV. The true energy is 4 057,46 MJ so the mean error is −18,03 MJ (−0,444 %). The standard uncertainty in mean error is obtained by adding in quadrature the relative standard uncertainties in mean error in volume, conversion factor and CV to obtain 3,432 8 %.
5	The standard uncertainty is converted to expanded uncertainty by multiplication by a coverage factor $k = 2$ and rounding to two significant figures. The mean error is rounded to one decimal place in accordance with the expanded uncertainty after rounding to two significant figures.

E.4 Example 3

An energy determination system operating in the UK employs a rotary displacement meter operating at a pressure of 2 bar, which is controlled by a pressure regulator of accuracy class AC1 located upstream of the meter. The energy determination system is located at an altitude of 67,16 m above sea level.

Volume is converted to volume at base conditions of 15 °C and 1 013,25 mbar using a fixed factor of calculated using a temperature conversion factor of 1,009 8, a pressure conversion factor based on the known altitude and a non-ideality conversion factor calculated using the formula given in the UK Gas (Calculation of Thermal Energy) Regulations.

Conversion to energy is carried out by use of a billing CV calculated from the average of each of the daily charging area calorific values determined over the charging period. The daily charging area calorific values are calculated from the net daily energy flows and net daily volume flows into the charging area (the daily “Flow-Weighted Average CV” - FWACV).

Table E.6 — Example 3

	Property	Units	Value	True value	Assigned PDF				Line
					mean	mean, %	u_m	u_m, %	
Volume measurement	**volume metered**	**m³**	**100,00**	**100,00**	**0,00**	**0,000 %**		**0,500 0 %**	1
Volume conversion	atmospheric pressure	mbar	1 013,25	1 015,20	-	-	24,43	-	2
	meter pressure	mbar	2 000,00	2 000,00	-	-	15,07	-	3
	altitude	m	67,50	67,16	-	-	1,25	-	4
	altitude correction factor	mbar/m	−0,120 208	−0,120 208	-	-	−0,001 2	-	5
	pressure (combined)	mbar	3 005,14	3 007,13	−1,990 9	−0,066 %	28,70	0,954 3 %	6
	pressure conversion factor	-	2,965 839	2,967 803	-	-	-	-	7
	temperature	*K*	285,35	285,05	0,300 0	0,105 %	5,60	1,964 6 %	8
	temperature conversion factor	-	1,009 813	1,010 875	-	-	-	-	9
	truncation of T conversion factor	-	1,009 8	1,010 875	-	-	-	-	10
	Z_b/Z	-	1,004 6	1,005 264	0,000 6	0,064 %	0,000 204 0	0,020 3 %	11
	volume conversion factor	**-**	**3,008 749 272**	**3,015 871 560**	**−0,007 1**	**−0,236 %**	**-**	**2,184 2 %**	12
Energy conversion	**energy conversion**	**MJ/m³**	**39,50**	**39,55**	**−0,050**	**−0,126 %**	**-**	**1,270 1 %**	13
Overall	Energy	MJ	11 884,56	11 927,77	−43,21	−0,362 %	-	2,575 7 %	14
Accuracy in determined energy: −0,4 % ± 5,2 %									15

Table E.7 — Explanation and justification of Example 3

Line	Explanation and justification
1	Unconverted volumetric flowrate using a rotary meter can generally be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0,5 %. If the meter is assumed to be compliant with EN 12480 and has been selected to operate between Q_t and Q_{max}, the standard uncertainty in mean error is taken to be $1{,}0/k$ = ± 0,5 % assuming $k = 2$. The weighted mean error (WME) is ± 0,4 %, so mean error is assumed to be zero. The meter is assumed to be regularly maintained and calibrated so meter drift is assumed to be negligible.
2	The correction factor in the Regulations assumes an atmospheric pressure of 1 013,25 mbar. For the UK mean monthly atmospheric pressure between 1987 and 1996 was estimated to be described by a distribution with mean 1 015,20 mbar and a standard deviation of 24,43 mbar, so the mean error in atmospheric pressure is taken to be −1,95 mbar, with a standard uncertainty of 24,43 mbar.
3	The correction factor in the Regulations takes account of the nominal set meter pressure. The variation of meter inlet pressure for a pressure regulator of accuracy class AC 1 is taken to be 1 % of the absolute pressure, i.e. ± $(0{,}01 \times 3\,013{,}25)/k$ = 15,07 mbar, assuming a value of $k = 2$.
4	The correction factor in the Regulations is based on values of altitude adjustment that are tabulated in intervals of 2,5 m. In practice the value of altitude adjustment is based on the highest pressure in the interval (87,5 m) and the formula that was in use by British Gas prior to the Regulations coming into force: pressure deduction = altitude in metres × 0,120 208 The value 0,120 208 is the altitude correction factor. The energy determination system is located at an altitude of 67,16 m and is assumed to be known with certainty. The uncertainty in mean error in altitude correction is therefore assumed to be half the interval in the tabulated values (2,5/2 = 1,25 m).
5	The value of altitude correction factor (0,120 208 mbar/m) was in use by British Gas prior to the Regulations coming into force. This value is assumed to have zero mean error and standard uncertainty 0,001 2 mbar/m (1 %).
6	Pressure based on the assumptions in the Regulations detailed in lines 2 to 5 above is calculated to be 3 005,14 mbar. The mean (true) pressure estimated as detailed in lines 2 to 5 above is calculated to be 3 007,13 mbar. This results in a mean error of −1,99 mbar. The standard uncertainty in mean error in metering pressure is calculated to be 28,70 mbar from the estimates of standard uncertainty of the input sources identified in lines 2 to 5 using the formula: $u(P)=\sqrt{\left[(P_{\text{atm}})^2+(P_{\text{meter}})^2+(u(A)\cdot ACF)^2+(u(ACF)\cdot A)^2\right]}$ This formula is derived formally in Annex A.
7	Pressure conversion factor is calculated from the formula $\text{Pressure conversion factor} = PCF = \left(\dfrac{P}{P_{\text{base}}}\right)$
8	The correction factor in the Regulations assumes a gas temperature of 12,2 °C. For the UK mean monthly atmospheric pressure between 1987 and 1996 was estimated to be described by a distribution with mean 11,9 °C, with a half-range of 11,2 °C, so the mean error in gas temperature is taken to be +0,3 °C, with a standard uncertainty of $11{,}2/k$ = 5,6 °C, assuming $k = 2$.
9	Temperature conversion factor is calculated from the formula $\text{Temperature conversion factor} = TCF = \left(\dfrac{T_{\text{base}}}{T}\right)$

Line	Explanation and justification
10	The Regulations require use of a temperature conversion factor of 1,009 8
11	The Regulations require that compressibility conversion factor is calculated from the formula $\frac{Z_{\mathrm{b}}}{Z} = \frac{0{,}997\,8}{1-0{,}000\,002\,26\,P}$ Actual values of Z_{b}/Z were estimated for the UK based on gas composition data for 2005 at a pressure of 3 007,13 mbar and temperature of 11,9 °C (i.e. the conditions of temperature, pressure and altitude assumed in lines 6 and 8) and from this the mean error in Z_{b}/Z was estimated to be 0,000 6 with a standard uncertainty of 0,000 204.
12	The value of the volume conversion factor based on the assumptions of the Regulations is calculated to be 3,008 749 272, using the formula $\text{Volume conversion factor} = VCF = \left(\frac{P}{P_{\mathrm{base}}}\right) \cdot \left(\frac{T_{\mathrm{base}}}{T}\right) \cdot \left(\frac{Z_{\mathrm{base}}}{Z}\right)$ Using the same formula the value of the volume conversion factor based on estimates of true value for the UK is calculated to be 3,015 871 560. Mean error in *VCF* is therefore −0,007 1 (rounded to 4 dp) or −0,236 %. The standard uncertainty in mean error in the volume conversion factor is estimated to be 2,184 2 % from the formula $u(bias(VCF)) = \left(\frac{u(P)}{P}\right)^2 + \left(\frac{u(T)}{T}\right)^2 + \left(\frac{u(Z)}{Z}\right)^2$
13	The calorific value is the same as that employed in Example 1 so the mean error in CV and its standard uncertainty are identical (see line 14, Example 1).
14	The determined energy, 11 884,56 MJ, is obtained by multiplying the volume, the conversion factor and the CV. The true energy is 11 927,77 MJ so the mean error is −43,21 MJ (−0,362 %). The standard uncertainty in mean error is obtained by adding in quadrature the relative standard uncertainties in mean error in volume, conversion factor and CV to obtain 2,575 7 %.
15	The standard uncertainty is converted to expanded uncertainty by multiplication by a coverage factor $k = 2$ and rounding to two significant figures. The mean error is rounded to 1 decimal place in accordance with the expanded uncertainty after rounding.

E.5 Example 4

An energy determination system operating in the UK employs a rotary displacement meter operating at a pressure of 2 bar, which is controlled by a pressure regulator of accuracy class AC 1 located upstream of the meter. The energy determination system is located at an altitude of 67,16 m above sea level.

Volume is converted to volume at base conditions of 15 °C and 1 013,25 mbar using a Type 2 volume conversion device compliant with EN 12405-1 that employs measured pressure and temperature with non-ideality effects accounted by a functional relationship in temperature and pressure that is appropriate to the gas being metered.

Conversion to energy is carried out by use of a billing CV calculated from the average of each of the daily charging area calorific values determined over the charging period. The daily charging area calorific values are calculated from the net daily energy flows and net daily volume flows into the charging area (the daily “Flow-Weighted Average CV” - FWACV).

Table E.8 — Example 4

	Property	**Units**	**Value**	**True value**	**Assigned PDF**				**Line**
					mean	mean, %	u_m	u_m, %	
Volume measurement	**volume metered**	**m³**	**100,00**	**100,00**	**0,00**	**0,000 %**	**-**	**0,500 0 %**	1
Volume conversion	pressure	mbar	3 005,14	3 005,14	-	-	-	-	2
	pressure conversion factor	-	2,965 839	2,965 839	0,0	0,000 %	-	0,250 0 %	3
	temperature	K	285,35	285,35	-	-	-	-	4
	temperature conversion factor	-	1,009 813	1,009 813	0,0	0,000 %	-	0,100 0 %	5
	Z_b/Z	-	1,005 0	1,005 0	0,0	0,000 %	-	0,150 0 %	6
	volume conversion factor	-	3,009 915 627	3,009 915 627	-	-	-	-	7
	volume conversion device	-	3,009 915 627	3,009 915 627	0,0	0,000 %	-	0,500 0 %	8
	volume conversion	**-**	**3,009 915 627**	**3,009 915 627**	**0,0**	**0,000 %**	**-**	**0,587 4 %**	9
Energy conversion	**energy conversion**	**MJ/m³**	**39,50**	**39,55**	**−0,050**	**−0,126 %**	**-**	**1,270 1 %**	10
Overall	energy	MJ	11 889,17	11 904,22	−15,05	−0,126 %	-	1,486 0 %	11
Accuracy in determined energy: −0,1 % ± 3,0 % (k = 2)									12

Table E.9 — Explanation and justification of Example 4

Line	Explanation and justification
1	Unconverted volumetric flow rate using a rotary meter can generally be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0,5 %. If the meter is assumed to be compliant with EN 12480 and has been selected to operate between Q_t and Q_{max}, the standard uncertainty in mean error is taken to be 1,0/k = ± 0,5 % assuming k = 2. The weighted mean error (WME) is ± 0,4 %, so mean error is assumed to be zero. The meter is assumed to be regularly maintained and calibrated so meter drift is assumed to be negligible.
2-3	For Type 2 conversion device compliant with EN 12405-1 operating at a pressure less than 21 bar a separate absolute pressure transducer is employed. The mean error and uncertainty in mean error of the transducer is therefore included separately and is taken to be 0,5/k = ± 0,25 % assuming k = 2.
4-5	For Type 2 conversion device compliant with EN 12405-1 a separate temperature transducer is employed. The mean error and uncertainty in mean error of the transducer is therefore included separately and is taken to be 0,2/k = ± 0,1 % assuming k = 2.
6-7	For Type 2 conversion device compliant with EN 12405-1 employing PTZ conversion correction for non-ideality of the gas is carried out by use of a separate calculator employing a functional relationship in temperature and pressure that is appropriate to that gas. The mean error and uncertainty in mean error of the calculator is therefore included separately and is taken to be 0,3/k = ± 0,15 % assuming k = 2.
8-9	For Type 2 conversion device compliant with EN 12405-1 the device is assumed to give zero mean error with a standard uncertainty in mean error of 1,0/k = ± 0,5 % assuming k = 2.
10	The calorific value is the same as that employed in Example 1 so the mean error in CV and its standard uncertainty are identical (see line 14, Example 1).
11	The determined energy, 11 889,17 MJ, is obtained by multiplying the volume, the conversion factor and the CV. The true energy is 11 904,22 MJ so the mean error is −15,05 MJ (−0,126 %). The standard uncertainty in mean error is obtained by adding in quadrature the relative standard uncertainties in mean error in volume, conversion factor and CV to obtain 1,365 0 %.
12	The standard uncertainty is converted to expanded uncertainty by multiplication by a coverage factor k = 2 and rounding to two significant figures. The mean error is rounded to 1 decimal place in accordance with the expanded uncertainty after rounding.

E.6 Example 5

An energy determination system operating in the UK employs a rotary displacement meter operating at a pressure of 2 bar, which is controlled by a pressure regulator of accuracy class AC 1 located upstream of the meter. The energy determination system is located at an altitude of 67,16 m above sea level.

Volume is converted to volume at base conditions of 15 °C and 1 013,25 mbar using a Type 1 volume conversion device compliant with EN 12405-1 that employs measured pressure and temperature with non-ideality effects accounted by a functional relationship in temperature and pressure that is appropriate to the gas being metered.

Conversion to energy is carried out by use of a billing CV calculated from the average of each of the daily charging area calorific values determined over the charging period. The daily charging area calorific values are calculated from the net daily energy flows and net daily volume flows into the charging area (the daily “Flow-Weighted Average CV” - FWACV).

Table E.10 — Example 5

	Property	Units	Value	True value	Assigned PDF				Line
					mean	mean, %	u_m	u_m, %	
Volume measurement	**volume metered**	**m³**	**100,00**	**100,00**	**0,00**	**0,000 %**		**0,500 0 %**	1
Volume conversion	pressure	mbar	3 005,14	3 005,14					2
	pressure conversion factor	-	2,965 839	2,965 839					3
	temperature	K	285,35	285,35					4
	temperature conversion factor	-	1,009 813	1,009 813					5
	Z_b/Z	-	1,005 0	1,005 0					6
	volume conversion factor	-	3,009 915 627	3,009 915 627					7
	volume conversion device	-	3,009 915 627	3,009 915 627	0,0	0,000 %		0,500 0 %	8
	volume conversion	**-**	**3,009 915 627**	**3,009 915 627**	**0,0**	**0,000 %**		**0,500 0 %**	9
Energy conversion	**energy conversion**	**MJ/m³**	**39,50**	**39,55**	**−0,050**	**−0,126 %**		**1,270 1 %**	10
Overall	energy	MJ	11 889,17	11 904,22	−15,05	−0,126 %		1,365 0 %	11
Accuracy in determined energy: −0,1 % ± 2,7 % (*k* = 2)									12

Table E.11 — Explanation and justification of Example 5

Line	Explanation and justification
1	Unconverted volumetric flowrate using a rotary meter can generally be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0,5 %. If the meter is assumed to be compliant with EN 12480 and has been selected to operate between Q_t and Q_{max}, the standard uncertainty in mean error is taken to be $1,0/k$ = ± 0,5 % assuming $k = 2$. The weighted mean error (WME) is ± 0,4 %, so mean error is assumed to be zero. The meter is assumed to be regularly maintained and calibrated so meter drift is assumed to be negligible.
2-3	For Type 1 conversion device compliant with EN 12405-1 operating at a pressure less than 21 bar an integral absolute pressure transducer is employed. The mean error and uncertainty in mean error of the transducer is therefore included in the overall performance of the device.
4-5	For Type 1 conversion device compliant with EN 12405-1 an integral temperature transducer is employed. The mean error and uncertainty in mean error of the transducer is therefore included in the overall performance of the device.
6-7	For Type 1 conversion device compliant with EN 12405-1 employing PTZ conversion correction for non-ideality of the gas is carried out by use of a calculator employing a functional relationship in temperature and pressure that is appropriate to that gas. The mean error and uncertainty in mean error of the calculator is therefore included in the overall performance of the device.
8-9	For Type 1 conversion device compliant with EN 12405-1 the device is assumed to give zero mean error with a standard uncertainty in mean error of $1,0/k$ = ± 0,5 % assuming $k = 2$.
10	The calorific value is the same as that employed in Example 1 so the mean error in CV and its standard uncertainty are identical (see line 14, Example 1).
11	The determined energy, 11 889,17 MJ, is obtained by multiplying the volume, the conversion factor and the CV. The true energy is 11 904,22 MJ so the mean error is −15,05 MJ (−0,126 %). The standard uncertainty in mean error is obtained by adding in quadrature the relative standard uncertainties in mean error in volume, conversion factor and CV to obtain 1,365 0 %.
12	The standard uncertainty is converted to expanded uncertainty by multiplication by a coverage factor $k = 2$ and rounding to two significant figures. The mean error is rounded to 1 decimal place in accordance with the expanded uncertainty after rounding.

E.7 Example 6

This gas measuring system for the determination of energy employs a ultrasonic meter and a turbine meter in series, operating at an unregulated pressure of 52 to 63 bar (e.g. at the border connecting gas transmission network to the Dutch Gasunie network).

Volume is converted to volume at base conditions of 0 °C and 1 013,25 mbar, using live measurements of the gas pressure, temperature and gas composition.

The stated instrument measuring uncertainties are overall numbers, where the allowed deviations found in the periodical calibrations (adjust levels) are taken into account.

Conversion to energy is carried out by use of a live measured CV. The determined energy is stored in quarterly and hourly amounts for balancing purposes and in daily and monthly amounts for charging and settlement.

Table E.12 — Example 6

	Property	Units	Value	True value	Assigned PDF				Line
					mean	mean, %	u_m	u_m, %	
Volume measurement	**volume metered**	**m³**	**100,00**	**100,00**	**0,00**	**0,000 %**	**-**	**0,150 0 %**	1
Volume conversion	atmospheric pressure	bar	1,013 25	1,013 25	0,000 0	-	0,002 0	-	2
	gauge pressure	bar	60,000 00	60,000 00	0,000 0	-	0,085 5	0,142 5 %	3
	absolute pressure	bar	61,013 25	61,013 25	0,000 0	-	0,085 5	0,142 0 %	4
	pressure analog digital conversion	-	61,013 25	61,013 25	0,000 0	-	-	0,050 0 %	5
	pressure conversion factor	-	60,215 40	60,215 40	0,000 0	-	-	0,148 8 %	6
	temperature	K	285,35	285,35	0,000 0	-	0,230 6	0,080 8 %	7
	temperature analog digital conversion	-	285,35	285,35	0,000 0	-	-	0,050 0 %	8
	temperature conversion factor	-	0,957 2	0,957 2	-	-	-	0,095 0 %	9
	Z_b/Z	-	1,129 3	1,129 3	0,000 0	-	-	0,050 0 %	10
	volume conversion factor	-	65,092 5	65,092 5	0,000 0	-	-	0,183 5 %	11
	volume conversion	**-**	**65,092 5**	**65,092 5**	**0,000 0**	**0,000 %**	**-**	**0,183 5 %**	12
Energy conversion	**energy conversion**	**MJ/m³**	**39,50**	**39,50**	**0**	**-**	**-**	**0,200 0 %**	13
Overall	energy	MJ	257 115,27	257 115,27	0,00	0,000 %	-	0,310 1 %	14
Accuracy in determined energy: 0,00 % ± 0,62 % (k = 2)									15

Table E.13 — Explanation and justification of Example 6

Line	Explanation and justification
1	Unconverted volumetric flow rate using an ultrasonic meter and a turbine meter with curve correction can generally be assumed to give zero mean error. The initial standard uncertainty of both meters after the calibration at 60 bar is 0,2/k = 0,1 % (k = 2) according to the calibration certificate of the calibration facility. The meters have been selected and assumed to operate between 0,02 $Q_{\max}$ and $Q_{\max}$ and that the installation is compliant with ISO 17089 and EN 12261. The meters are maintained and calibrated periodically (once per 4–6 yr.). In between the installation effect and drift is assumed to result in an increased standard uncertainty by 0,05 %, so in-service $u(e(\text{V}))$ = 0,3/k = ± 0,15 %, assuming a value of k = 2. If during recalibration a meter shows a shift exceeding the tolerance limit of 0,3 % compared with the previous calibration, recalculation of the wrongly measured volume and consequently the energy will be performed, in accordance with the contractual agreement with the neighbouring network operator.
2	The atmosferic pressure (barometer) is measured locally, with an initial uncertainty 1,3 mbar (certificate, 2s) and is operating with an estimated a standard uncertainty 2/k = ± 1 mbar, assuming a value of k = 2. The barometers are maintained and verified periodically on-site. The verification is performed with an reference instrument with a standard uncertainty $u(ref)$ = 2/k = 1 mbar, assuming a value of k = 2. The error of the barometer is verified against an acceptance limit of 4 mbar to guarantee that the barometer is operating within the agreed tolerance limit resulting in a standard uncertainty $u(Patm)$ = 6/ = 3 mbar, assuming a value of k = 2.
3	The effective meter pressure is measured by means of gauge pressure sensor with an intial uncertainty of 0,018 % (certificate, 2s) and with an in-service standard uncertainty 0,1/k = ± 0,05 %, assuming a value of k = 2. The pressure sensors are maintained and verified periodically on-site. The verification is performed with an reference instrument with a standard uncertainty $uP(ref)$ = 0,1/k = 0,05 %, assuming a value of k = 2. The error of the pressure sensor is verified against an acceptance limit of 0,15 % to guarantee that the pressure sensor is operating within the agreed tolerance limit resulting in a standard uncertainty $u(Pg)$ = 0,25/k = ± 0,125 %,assuming a value of k = 2. If the verification result exceeds the Acceptance Limit of 0,15 % the pressure sensor is replaced or adjusted, in accordance with the contractual agreement with the neighbouring network operator.
6	Pressure is determined by summerizing the measured gauge pressure and the measured atmospheric pressure. The standard uncertainty and in this combined metering pressure u(Pabs) = 0,25/k = ± 0,125 % Note: this is equal to the standard uncertainty of the gauge pressure in line 3, because the uncertainty in Patm is negligible at 60 bar.
7	The gas temperature in the meter pressure is measured by means of a PT100 sensor with an intial uncertainty of 0,02 K (certificate, 2s) upstream close to the meter, with an in-service standard uncertainty 0,1/k = ± 0,05 K, assuming a value of k = 2. The temperature sensors are maintained and verified periodically on-site. The verification is performed with an reference instrument with a standard uncertainty $u(T_{\text{ref}})$ = 0,1/k = 0,05 K, assuming a value of k = 2. The error of the temperature sensor is verified against an acceptance limit of 0,2 K to guarantee that the temperature sensor is operating within the agreed tolerance limit resulting in a standard uncertainty $u(T)$ = 0,3/K = ± 0,15 K If the verification result exceeds the Acceptance Limit of 0,2 K the pressure sensor is replaced or adjusted, according to the contractual agreement with the neighbouring network operator.
8	The correction factor takes into account the effect of the non-ideality of the gas, i.e. $Z_{\text{b}}/Z < 1$. Actual values of Zb/Z are determined according to ISO 12213-3, with the measured gascomposition, pressure and temperature as input. The standard uncertainty of the method is $u(Z_{\text{b}}/z)$ = 0,1/k = ± 0,05 %.

10	The value of the volume conversion factor based on the calculation, using the formula $\text{Volume conversion factor} = VCF = \left(\frac{P}{P_{\text{base}}}\right) \cdot \left(\frac{T_{\text{base}}}{T}\right) \cdot \left(\frac{Z_{\text{base}}}{Z}\right)$ The standard uncertainty in the volume conversion factor *u* (*VCF*) is calculated with the uncertainties op Pressure, Temperature and *Z*-factor. Under a pressure of 60 bar there is no linear relationship between the *Z* and the Pressure and Temperature for the ISO 12231 calculation. Therefore the sensitivity factors are taken into account, for *P* a factor 1,14 and for *T* a factor −1,6. The standard uncertainty $u(VCF)$ = $0{,}34/k = \pm 0{,}17$ % assuming a value of $k = 2$.The calculation is according to the formula: $u(VCF) = \sqrt{\left((1.14) \cdot \frac{u(P)}{P}\right)^2 + \left((-1.6) \cdot \frac{u(T)}{T}\right)^2 + \left(\frac{u(Z)}{Z}\right)^2}$
11	The gas component concentration is measured by means of a gas chromatograph on-site according to ISO 6974. The gas CV is calculated according to ISO 6976. On a yearly basis a multi-point calibration is performed for linearization purposes with an uncertainty on CV of 0,1 %/ = ± 0,05 %, assuming a value of $k = 2$. The gas chromatograph is calibrated and adjusted daily with a certified calibation gas with the main components and is verified monthly with a certified full composition testgas obtained on-site. The standard uncertainty on the CV value is $u(ref) = 0{,}2/k = 0{,}1$ %, assuming a value of $k = 2$. The verification result is tested against an acceptance limit of 0,2 %, to guarantee that the CV is determined within the agreed tolerance limit resulting in standard uncertainty $u(\text{CV}) = 0{,}4/k = \pm 0{,}4$%, assuming a value of $k = 2$. If the verification result exceeds the Acceptance Limit of 0,2 % investigation will be done and measures will be taken to bring the volume conversion within its acceptance limit.
14	The energy conversion takes place with the measured CV with an uncertainty $u(\text{CV}) = 0{,}4/k = \pm 0{,}2$ %.
15	The determined energy is obtained by multiplying the volume, the conversion factor and the CV. The uncertainties are added in quadrature resulting in an uncertainty of $u(ref) = 0{,}61/k = 0{,}31$ %, assuming a value of $k = 2$.
16	The energy is determined with a max. bias of 0,0 % ± 0,61 % The standard uncertainty is converted to expanded uncertainty by multiplication by a coverage factor $k = 2$ and rounding to two significant figures. The bias is limited by using the acceptance limits for the periodical verification and calibration results. In principal the mean bias is assumed to be zero with maximal the acceptance limit. Furtermore the bias is kept as close as possible to zero by applying long term effect analyses.

E.8 Example 7

This gas measuring system for the determination of energy employs a turbine meter, operating at an regulated pressure of 8 bar (e.g. at a Dutch city gate station),

Volume is converted to volume at base conditions of 0 °C and 1 013,25 mbar, using live measurements of the gas pressure, temperature and gas composition.

The stated instrument measuring uncertainties are overall numbers, where the allowed deviations found in the periodical calibrations (adjust levels) are taken into account.

Conversion to energy is carried out by use of a live measured CV or assigned from measurements upstream in the network. The determined energy is stored in hourly amounts for balancing purposes and in daily and monthly amounts for charging and settlement.

Table E.14 — Example 7

	Property	**Units**	**Value**	**True value**	**Assigned PDF**				**Line**
					mean	mean, %	u_m	u_m, %	
Volume measurement	**volume metered**	m³	100,00	100,00	0,00	0,000 %	-	0,170 0 %	1
Volume conversion	atmospheric pressure	bar	1,013 25	1,013 25	0,000 0	-	-		2
	gauge pressure	bar	8,000 00	8,000 00	0,000 0	-	-		3
	absolute pressure	bar	9,013 25	9,013 25	0,000 0	-	0,018 3	0,200 0 %	4
	pressure analog digital conversion	-	9,013 25	9,013 25	0,000 0	-	-	0,050 0 %	5
	pressure conversion factor	-	9,215 40	9,215 40	0,000 0	-	-	0,206 2 %	6
	temperature	K	285,35	285,35	0,000 0	-	0,250 0	0,087 6 %	7
	temperature analog digital conversion	-	285,35	285,35	0,000 0	-	-	0,050 0 %	8
	temperature conversion factor	-	0,957 2	0,957 2		-	-	0,100 9 %	9
	Z_b/Z	-	1,129 3	1,129 3	0,000 0	-	-	0,250 0 %	10
	volume conversion factor	-	9,615 9	9,615 9	0,000 0	-	-	0,339 4 %	11
	volume conversion	**-**	**9,615 9**	**9,615 9**	**0,000 0**	**0,000 %**	**-**	**0,339 4 %**	12
Energy conversion	**energy conversion**	**MJ/m³**	**39,50**	**39,50**	**0**	**-**	**-**	**0,200 0 %**	13
Overall	energy	MJ	37 982,64	37 982,64	0,00	0,000 %	-	0,429 0 %	14
Accuracy in determined energy: 0,00 % ± 0,86 % (k = 2)									15

Table E.15 — Explanation and justification of Example 7

Line	Explanation and justification
1	Unconverted volumetric flowrate using an ultrasonic meter and a turbine meter with curve correction can generally be assumed to give zero mean error. The initial standard uncertainty of both meters after the calibration at 60 bar is 0,2 % (2s) according to the calibration certificate of the calibration facility. The meters have been selected and assumed to operate between 0,02 $Q_{\max}$ and $Q_{\max}$ and that the installation is compliant with ISO 17089 and EN 12261, so $u(V) = 0{,}2/k = \pm\ 0{,}1\ \%$, assuming a value of $k = 2$. The meters are maintained and calibrated periodically. In between the installation effect and drift is assumed to result in an increased standard uncertainty by 0,05 %, so in-service $u(\mathrm{e(V)}) = 0{,}3/k = \pm\ 0{,}15\%$, assuming a value of $k = 2$. If as a result of recalibration a meter shows a shift exceeding the tolerance limit of 0,3 % (MPE) compared with the previous calibration, recalculation of the wrongly measured volume and consequently the energy will be performed, according to the contractual agreement with the neighbouring network operator.
2	The atmospheric pressure (barometer) is measured locally, with an initial uncertainty 1,3 mbar (cerificate, 2s) and with an estimated in-service a standard uncertainty $u(Patm) = 2/k = \pm\ 1$ mbar, assuming a value of $k = 2$. In percentage of the mean meter pressure of 60 bar $u(Patm) = 0{,}003/k = 0{,}001\ 5\ \%$. The barometers are maintained and verified periodically on-site. The verification is performed with an reference instrument with a standard uncertainty $uP(ref) = 2/k = 1$ mbar, assuming a value of $k = 2$. Taking into account that the uncertainty of the reference instrument is not significant better than the uncertainty of the process sensor, the verification result is tested against an acceptance limit of 4 mbar, to guarantee that the barometer is operating within the tolerance limit of 6 mbar (0,01 % at 60 bar).
3	The effective meter pressure is measured by means of gauge pressure sensor with an intial uncertainty of 0,018 % (certificate, 2s) and with an in-service standard uncertainty $u(T) = 0{,}1/k = \pm\ 0{,}05\ \%$, assuming a value of $k = 2$. The pressure sensors are maintained and verified periodically on-site. The verification is performed with an reference instrument with a standard uncertainty $uP(ref) = 0{,}1/k = 0{,}05\ \%$, assuming a value of $k = 2$. Taking into account that the uncertainty of the reference instrument is not significant better than the uncertainty of the process sensor, the verification result is tested against an acceptance limit of 0,1 %, to guarantee that the pressure sensor is operating within the tolerance limit for charging (MPE) of 0,15 %. If the verification result exceeds the Acceptance Limit of 0,1 % the pressure sensor is replaced or adjusted, according to the contractual agreement with the neighbouring network operator.
4	Not applicable (Patm is measured).
5	Not applicable (Id).
6	Pressure is determined by summerizing the measured gauge pressure and the measured atmospheric pressure. The standard uncertainty and in this combined metering pressure is equal to the standard uncertainty of the gauge pressure in line 3 (Unc in Patm is negligible at 60 bar)
7	The gas temperature in the meter pressure is measured by means of a PT100 sensor with an intial uncertainty of 0,02 K (certificate, 2s) upstream close to the meter, with an in-service standard uncertainty $u(Pg) = 0{,}1/k = \pm\ 0{,}05$ K, assuming a value of $k = 2$. The temperature sensors are maintained and verified periodically on-site. The verification is performed with an reference instrument with a standard uncertainty $uP(ref) = 0{,}1/k = 0{,}05$K, assuming a value of $k = 2$. Taking into account that the uncertainty of the reference instrument is not significant better than the uncertainty of the process sensor, the verification result is tested against an acceptance limit of 0,2 K, to guarantee that the pressure sensor is operating within the tolerance limit for charging (MPE) of 0,3 K. If the verification result exceeds the Acceptance Limit of 0,2 K the pressure sensor is replaced or adjusted, according to the contractual agreement with the neighbouring network operator.

8	The correction factor takes into account the effect of the non-ideality of the gas, i.e. $Z_b/Z < 1$. Actual values of Z_b/Z are determined according to ISO 12213-3, with the measured gascomposition as input. The standard uncertainty is assumed to be better than u(Zb/z) = 0,1/ = ± 0,05 %.
9	The value of the volume conversion factor based on the calculation , using the formula $\text{volume conversion factor} = VCF = \left(\frac{P}{P_{\text{base}}}\right)\cdot\left(\frac{T_{\text{base}}}{T}\right)\cdot\left(\frac{Z_{\text{base}}}{Z}\right)$ The verification results of lines 2, 3, 7 and 8 are used to calculate the error in volume conversion and tested against an Acceptance Limit of 0,25 %. If this verification result exceeds the Acceptance Limit of 0,25% investigation will be done and measures will be taken to bring the volume conversion within its acceptance limit.
10	The standard uncertainty in the volume conversion factor *u* (*VCF*) is estimated to be better than 0,25/*k* = 0,125 %, assuming *k* = 2. The calculation is according to the formula $u(bias(VCF)) = \sqrt{\left(\frac{u(P)}{P}\right)^2 + \left(\frac{u(T)}{T}\right)^2 + \left(\frac{u(Z)}{Z}\right)^2}$
11	The gas component concentrations are measured by means of an local gas chromatograph according to ISO 6974. The gas CV is calculated according to ISO 6976 with an intial uncertainty of 0,1 % (certificate of the calibration gas, 2s), with an in-service standard uncertainty *u*(*Pg*) = 0,2/*k* = ± 0,1 %, assuming a value of *k* = 2. The gas chromatographs are calibrated and ajusted daily with a certified calibation gas with main components and are verified monthly with a full composition testgas obtained on-site and certified. The test gas is certified with a standard uncertainty *uP*(*ref*) = 0,2/*k* = 0,1 %, assuming a value of *k* = 2. The verification result is tested against an Acceptance Limit of 0,2 %, to guarantee that the CV is determined within the Tolerance Limit for charging (MPE) of 0,3 %. If the verification result exceeds the Acceptance Limit of 0,2 % investigation will be done and measures will be taken to bring the volume conversion within its acceptance limit.
12	Not applicable.
13	Not applicable.
14	The verification results of lines 2, 3, 7, 8 and 11 are used to calculate the error in energy conversion factor and tested against an Acceptance Limit of 0,25 %, to guarantee that the energy determination is performed within the Tolerance Limit for charging (MPE) of 0,3 %. If this verification result exceeds the Acceptance Limit of 0,25 % investigation will be done and measures will be taken to bring the deviation of energy conversion within its acceptance limit.
15	The determined energy is obtained by multiplying the volume, the conversion factor and the CV. The uncertainties are added in quadrature resulting in an in-service uncertainty of 0,50 % (2s). The error in the energy conversion factor tested against an Acceptance Limit of 0,25 %, to guarantee that the energy determination is peformed within the Tolerance Limit for charging (MPE) of 0,75 %. If the verification result exceeds the Acceptance Limit of 0,25 % inverstigation will be done and measures will be taken to bring the deviation in energy determination within its acceptance limits.
16	The standard uncertainty is converted to expanded uncertainty by multiplication by a coverage factor *k* = 2 and rounding to two significant figures. The bias is limited by using the Acceptance Limits for the periodical verification and calibration results. In principal the bias is assumed to be maximal the acceptance limt, but kept as close as possible to zero.

Annex F
(informative)

Documentation and records

F.1Documentation

An archive should contain, but not be limited to, the following:

- all design documentation including specifications, calculations, drawings and test reports;
- comprehensive records pertaining to the installation, commissioning and subsequent operation of the measuring station;
- damage reports;
- modification and equipment replacement details;
- non-conformity reports;
- installation daily supply reports where appropriate;
- essential installation computer data base information where appropriate.

F.2Records

An archive should contain, but not be limited to, the following:

- all design documentation including specifications, calculations, drawings and test reports;
- comprehensive records pertaining to the installation, commissioning and subsequent operation of the measuring station;
- damage reports;
- modification and equipment replacement details;
- non conformity reports;
- installation daily supply reports where appropriate;
- essential installation computer data base information where appropriate.

F.3Documentation approval

All test records and maintenance reports should be signed by the person who completed the work. They should also be countersigned by the person responsible for the measuring installation and housing and where appropriate by any witness present.

Annex G
(informative)

Typical examples of positions of gas measuring installations

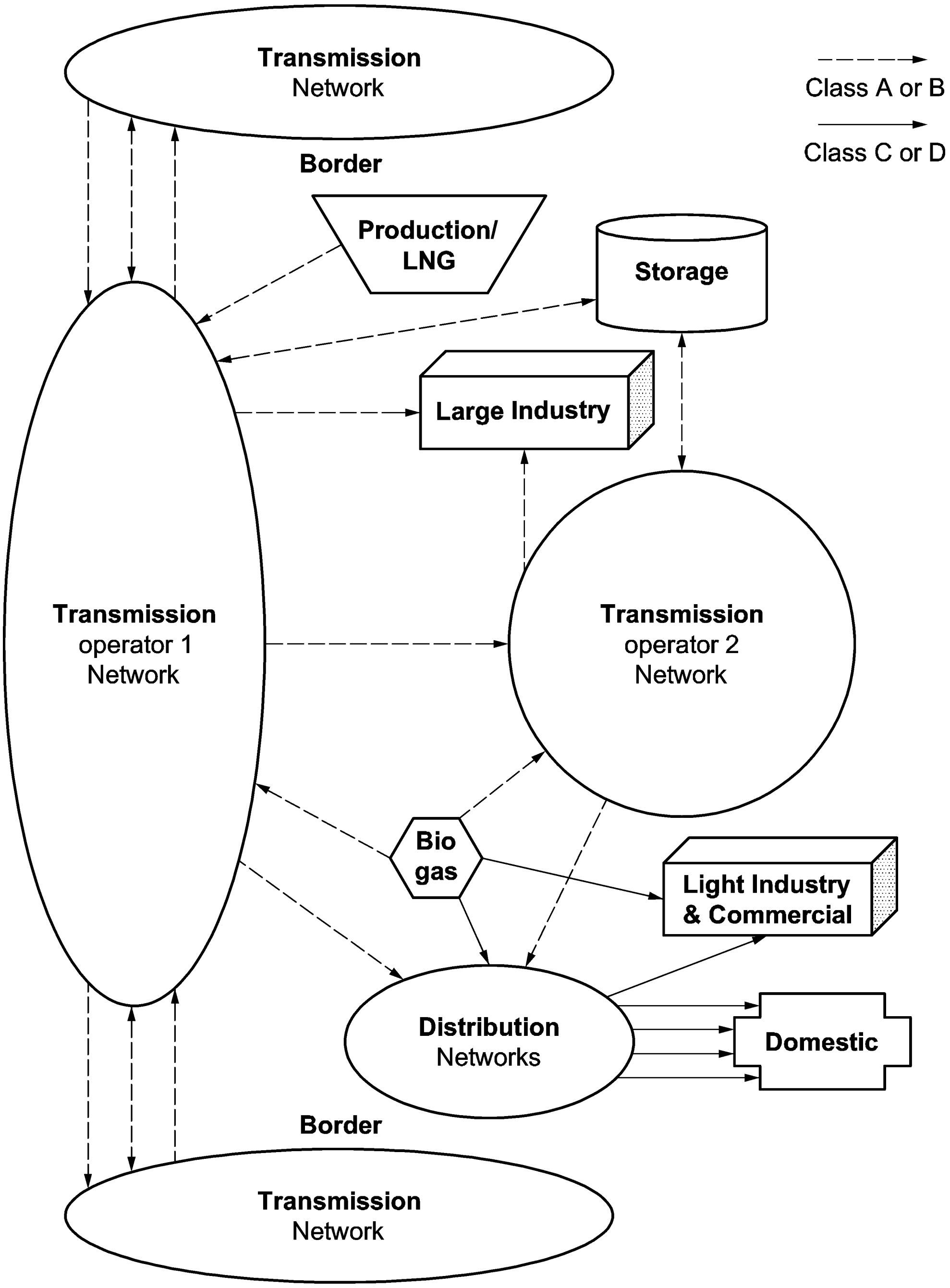


Figure G.1 — Typical examples of positions of gas measuring installations

Annex H
(informative)

Significant technical changes from the last edition of this standard, EN 1776:1998

Clause/Paragraph/Table/Figure	**Change**
General (all clauses)	Re-structuring of the document respecting the enlargement of scope; Verification of requirements and change of recommendations into requirements, where appropriate.
Clause 1 (general)	Enlargement of scope and content to include all new as well as existent and major-over-hauled measuring systems for all purposes and use (starting from domestic consumers till very large border-stations); Inclusion of documented provisions in new gas measuring systems and in major-change to systems.
Clause 1, 3rd paragraph	Inclusion of appropriate and treated non-conventional gases
Clause 1, 7th paragraph	Inclusion of metering aspects in the context of EU Mandate M/441 (smart meters).
Clause 3	Completion of terms and definitions list, especially according to enlargement of scope.
Clause 5	Clarification of the term "measuring system", giving the possibility of an output in energy (in kWh or in MJ) by using measuring instruments and/or documented provisions; Inclusion of "in-service accuracy" classification A, B, C, D, starting from higher to lower allowable accuracy ranges.
Clause 6	Clarification and elaboration of the method of calculation into energy, relevant for the in-service accuracy classes A, B, C, D.
Clause 7, Figure 1 and 7.6.4	Inclusion of illustration of a gas measuring system (Figure 1) Provision of requirements for installation and use of gas meters with additional functionalities (smart meters) in a measuring system (7.6.4)
Clause 9	Alignment of requirements with the other CEN/TC 234 standards on gas installation for strength and thightness tests before commissioning
Clauses 10 and 11	elaboration of the requirements with regard to pre-commissioning, acceptance, documentation, hand-over, post-commissioning checks, operation and maintenance
Clause 12	Integration of separate clause on de-commissioning
Annex A	Up-date of table "Guidelines for selection of meters"
Annex E	New Annex giving national examples of assessment of conformity of the metrological performance of a gas measuring system
Annex D	New Annex on Conformity assessment for the energy determination
Annex G	new Annex, giving typical examples of positions of gas measuring installations

Bibliography

[1] EN 334, *Gas pressure regulators for inlet pressures up to 100 bar*

[2] EN 437, *Test gases — Test pressures — Appliance categories*

[3] EN 1127-1, *Explosive atmospheres — Explosion prevention and protection — Part 1: Basic concepts and methodology*

[4] EN 12007-1, *Gas infrastructure — Pipelines for maximum operating pressure up to and including 16 bar — Part 1: General functional requirements*

[5] EN 12007-2, *Gas infrastructure — Pipelines for maximum operating pressure up to and including 16 bar — Part 2: Specific functional requirements for polyethylene (MOP up to and including 10 bar)*

[6] EN 12007-3, *Gas infrastructure — Pipelines for maximum operating pressure up to and including 16 bar — Part 3: Specific functional requirements for steel*

[7] EN 12007-4, *Gas infrastructure — Pipelines for maximum operating pressure up to and including 16 bar — Part 4: Specific functional requirements for renovation*

[8] EN 13757 (all parts), *Communication systems for and remote reading of meters*

[9] EN 14236, *Ultrasonic domestic gas meters*

[10] EN 16314, *Gas meters — Additional functionalities*

[11] EN 24006, *Measurement of fluid flow in closed conduits — Vocabulary and symbols (ISO 4006:1991)*

[12] EN 60079-29-1, *Explosive atmospheres — Part 29-1: Gas detectors — Performance requirements of detectors for flammable gases (IEC 60079-29-1)*

[13] EN ISO 9000, *Quality management systems — Fundamentals and vocabulary (ISO 9000)*

[14] EN ISO 9001, *Quality management systems — Requirements (ISO 9001)*

[15] EN ISO 9004, *Managing for the sustained success of an organization — A quality management approach (ISO 9004)*

[16] EN ISO 13443, *Natural gas — Standard reference conditions (ISO 13443)*

[17] EN ISO 15112, *Natural gas — Energy determination (ISO 15112)*

[18] EN ISO 15796, *Gas analysis — Investigation and treatment of analytical bias (ISO 15796)*

[19] EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025)*

[20] ISO 5168, *Measurement of fluid flow — Procedures for the evaluation of uncertainties*

[21] EN ISO 6974 (all parts), *Natural gas — Determination of hydrogen, inert gases and hydrocarbon up to C8 — Gas chromatographic method*

[22] EN ISO 6976, *Natural gas — Calculation of calorific values, density, relative density and Wobbe index from composition (ISO 6976)*

[23] EN ISO 12213-2, *Natural gas — Calculation of compression factor — Part 2: Calculation using molar-composition analysis (ISO 12213-2)*

[24] EN ISO 12213-3, *Natural gas — Calculation of compression factor — Part 3: Calculation using physical properties (ISO 12213-3)*

[25] ISO 10012, *Measurement management systems — Requirements for measurement processes and measuring equipment*

[26] ISO 15971, *Natural gas — Measurement of properties — Calorific value and Wobbe index*

[27] CEN/CLC/ETSI TR 50572, *Functional Reference Architecture for Communications in Smart Metering Systems*

[28] European Directive 2004/22/EC on measurement instruments

[29] European Directive 2004/108/EC on the approximation of laws of the Member States relating to electromagnetic compatibility (EMC) repealing Directive 89/336/EEC

[30] OIML International Vocabulary of Basic and General Terms in Metrology (IVM 2, at moment under CEN public enquiry)

[31] OIML R 140: *Measuring systems for gaseous fuel*

[32] OIML R 137-1 & 2: *Gas meters — Part 1: Metrological and technical requirements — Part 2: Metrological controls and performance tests*

[33] ISO/IEC Guide 98-1, *Uncertainty of measurement — Part 1: Introduction to the expression of uncertainty in measurement*

[34] ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

[35] ISO/IEC Guide 98-4, *Uncertainty of measurement — Part 4: Role of measurement uncertainty in conformity assessment*

[36] ISO/TR 9464, *Guidelines for the use of ISO 5167:2003*

[37] ISO 12764, *Measurement of fluid flow in closed conduits — Flowrate measurement by means of vortex shedding flowmeters inserted in circular cross-section conduits running full*[1)]

[38] JCGM 100, *Evaluation of measurement data — Guide to the expression of uncertainty in measurement*

[39] JCGM 101, *Evaluation of measurement data — Supplement 1 to the "Guide to the expression of uncertainty in measurement"*

[1)] In development.

[40] JCGM 104, *Evaluation of measurement data — An introduction to the "Guide to the expression of uncertainty in measurement"*

[41] JCGM 105, *Evaluation of measurement data — Concepts and basic principles (ISO/IEC Guide 98-2)*

[42] JCGM 106, *Evaluation of measurement data — The role of measurement uncertainty in conformity assessment*

[43] JCGM 107, *Evaluation of measurement data — Applications of the least-squares method (ISO/IEC Guide 98-5)*

[44] *Common harmonized European cubic meter for natural gas; CCM.FF-5.a; Final report on the CIPM key comparisons for natural gas at high-pressure*

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