BS EN 12405-3:2015

BSI Standards Publication

Gas meters — Conversion devices

Part 3: Flow computer

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National foreword

This British Standard is the UK implementation of EN 12405-3:2015.

The UK participation in its preparation was entrusted to Technical Committee GSE/25, Gas Meters.

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

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Gaszähler - Umwerter - Teil 3: Flowcomputer

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Contents

Page

European foreword

This document (EN 12405-3:2015) has been prepared by Technical Committee CEN/TC 237 “Gas meters”, the secretariat of which is held by BSI.

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of an identical text or by endorsement, at the latest by June 2016, and conflicting national standards shall be withdrawn at the latest by June 2016.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.

EN 12405 consists of the following parts:

— Part 1: Volume conversion (and its amendments EN 12405-1:2005/A1:2006 and EN 12405-1:2005+A2:2010 to allow the harmonization of the standard with the Measuring Instruments Directive 2004/22/EC);

— Part 2: Energy conversion;

— Part 3: flow computer (this European Standard).

In the preparation of this European Standard, the content of OIML Publication, “Recommendation 140 – measuring systems for gaseous fuel”, has been taken into account.

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

A high accuracy volume conversion device can be needed depending of the intended use. EN 12405-3 is established in order to meet severe requirements concerning accuracy and related functions.

For the purpose of this European Standard, functions are described, although these functions can be physically located in different components (e.g. calibration curve programmed in the measuring equipment itself or in the calculator).

Four main categories of functions are described to achieve data processing:

— Sensor signal Acquisition functions: to process signals from physical quantity provided by sensors and transducers to measurands;

— Sensor functions: to convert measurands to correct measurements, mostly based upon calibration results and filtering procedures;

— Metering functions: to calculate derived values such as volume, calorific value, compression factor etc. based upon international standards and formulas and to take care of the supervision and monitoring for the purpose of high accuracy and substitution values;

— Long Term Data Storage functions: to keep all relevant information necessary to construct or reconstruct calculated values:

  — for later legally relevant purposes (e.g. the conclusion of a commercial transaction);

  — for back up of the relevant data.

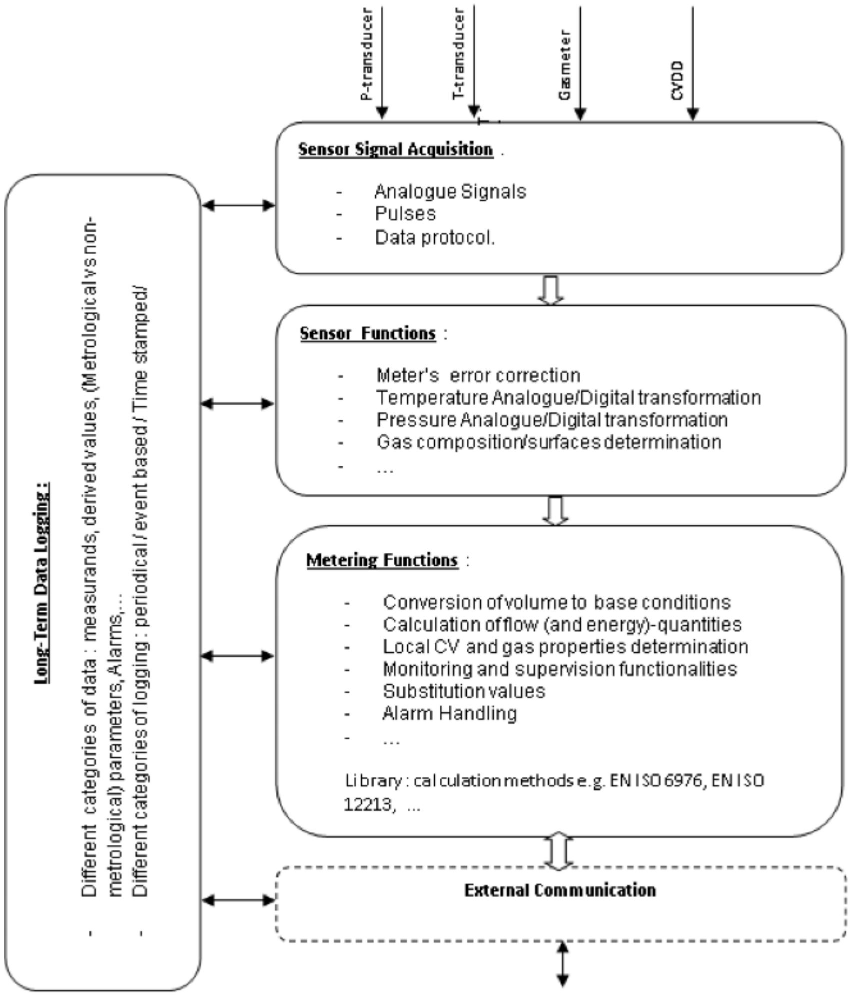


Figure 1 — Description of the functionalities of the flow computer calculator

Modular and global approaches

In the modular approach, the flow computer is an assembly of separate associated measuring instruments and a calculator, which are verified separately. Each instrument is verified according to its testing procedure, using the indication available on the calculator or on the associated measuring instrument itself. In this case, the indication shall correspond to the indication of that measuring instrument, which is directly performing volume conversion. The verification of the functions consists in verifying the calculation concerning each characteristic quantity of the gas and/or the calculation for the volume conversion.

In case of external communication, sufficient resolution of required data is ensured during data transmission.

The associated measuring instruments are validated for or with a type calculator in order to ensure the interoperability of the association.

CVDD is covered in EN 12405-2.

In the global approach, the flow computer is tested as a package including the calculator and its associated measuring instruments and functions.

The testing procedures are given in Annex A.

1 Scope

Part 3 of this European Standard specifies the requirements and tests for the construction, performance, safety and conformity of flow computers (FCs) used to meet the metrological and technical requirements of a high accuracy volume conversion device.

They are used to determine volume of fuel gases, including those of the first and second families according to EN 437.

For the purpose of this European Standard, only flow computers that are intended to operate with ultrasonic meters according to ISO 17089-1 or gas turbine meters conforming to EN 12261 are considered.

For the purpose of this European Standard only classification classes E2 and M1 are considered for the flow computer calculator.

FCs are equipped with external separate transducers for pressure and temperature which may be approved separately.

The provisions concerning pressure and temperature transducers are given in Annex B and C.

Requirements and tests are given for energy calculator in EN 12405-2.

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 437, *Test gases — Test pressures — Appliance categories*

EN 1776, *Gas supply systems — Natural gas measuring stations — Functional requirements*

EN 12261, *Gas meters — Turbine gas meters*

EN 12405-1:2005+A2:2010, *Gas meters — Conversion devices — Part 1: Volume conversion*

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

EN 55011, *Industrial, scientific and medical equipment — Radio-frequency disturbance characteristics — Limits and methods of measurement (CISPR 11, modified)*

EN 60068-2-1, *Environmental testing — Part 2-1: Tests — Test A: Cold (IEC 60068-2-1)*

EN 60068-2-2, *Environmental testing — Part 2-2: Tests — Test B: Dry heat (IEC 60068-2-2)*

EN 60068-2-30, *Environmental testing — Part 2-30: Tests — Test Db: Damp heat, cyclic (12 h + 12 h cycle) (IEC 60068-2-30)*

EN 60068-2-31, *Environmental testing — Part 2-31: Tests — Test Ec: Rough handling shocks, primarily for equipment-type specimens (IEC 60068-2-31)*

EN 60068-2-64, *Environmental testing — Part 2-64: Tests — Test Fh: Vibration, broadband random and guidance (IEC 60068-2-64)*

EN 60068-2-78, *Environmental testing — Part 2-78: Tests — Test Cab: Damp heat, steady state (IEC 60068-2-78)*

EN 60068-3-1, *Environmental testing — Part 3-1: Supporting documentation and guidance — Cold and dry heat tests (IEC 60068-3-1)*

EN 60079-0, *Explosive atmospheres — Part 0: Equipment — General requirements (IEC 60079-0)*

EN 60079-7, *Explosive atmospheres — Part 7: Equipment protection by increased safety "e" (IEC 60079-7)*

EN 60079-11, *Explosive atmospheres — Part 11: Equipment protection by intrinsic safety “i” (IEC 60079-11)*

EN 60079-25, *Explosive atmospheres — Part 25: Intrinsically safe electrical systems (IEC 60079-25)*

EN 60529, *Degrees of protection provided by enclosures (IP Code) (IEC 60529)*

EN 60751, *Industrial platinum resistance thermometers and platinum temperature sensors (IEC 60751)*

EN 60947-5-6, *Low-voltage switchgear and controlgear — Part 5-6: Control circuit devices and switching elements — DC interface for proximity sensors and switching amplifiers (NAMUR) (IEC 60947-5-6)*

EN 60950-1, *Information technology equipment — Safety — Part 1: General requirements (IEC 60950-1)*

EN 61000-4-1, *Electromagnetic compatibility (EMC) — Part 4-1: Testing and measurement techniques — Overview of IEC 61000-4 series (IEC 61000-4-1)*

EN 61000-4-2, *Electromagnetic compatibility (EMC) — Part 4-2: Testing and measurement techniques — Electrostatic discharge immunity test (IEC 61000-4-2)*

EN 61000-4-3, *Electromagnetic compatibility (EMC) — Part 4-3: Testing and measurement techniques — Radiated, radio-frequency, electromagnetic field immunity test (IEC 61000-4-3)*

EN 61000-4-4, *Electromagnetic compatibility (EMC) — Part 4-4: Testing and measurement techniques — Electrical fast transient/burst immunity test (IEC 61000-4-4)*

EN 61000-4-5, *Electromagnetic compatibility (EMC) — Part 4-5: Testing and measurement techniques — Surge immunity test (IEC 61000-4-5)*

EN 61000-4-6, *Electromagnetic compatibility (EMC) — Part 4-6: Testing and measurement techniques — Section 6: Immunity to conducted disturbances, induced by radio-frequency fields (IEC 61000-4-6)*

EN 61000-4-8, *Electromagnetic compatibility (EMC) — Part 4-8: Testing and measurement techniques — Power frequency magnetic field immunity test (IEC 61000-4-8)*

EN 61000-4-11, *Electromagnetic compatibility (EMC) — Part 4-11: Testing and measurement techniques — Voltage dips, short interruptions and voltage variations immunity tests (IEC 61000-4-11)*

EN 61000-4-29, *Electromagnetic compatibility (EMC) — Part 4-29: Testing and measurement techniques — Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests (IEC 61000-4-29)*

EN 62054-21, *Electricity metering (a.c.) —Tariff and load control — Part 21: Particular requirements for time switches (IEC 62054-21)*

EN 62262, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code) (IEC 62262)*

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

EN ISO 12213-2:2009, *Natural gas — Calculation of compression factor — Part 2: Calculation using molar-composition analysis (ISO 12213-2:2006)*

EN ISO 12213-3:2009, *Natural gas — Calculation of compression factor — Part 3: Calculation using physical properties (ISO 12213-3:2006)*

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

IEC 61520, *Metal thermowells for thermometer sensors — Functional dimensions*

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

ISO/IEC/IEEE 60559, *Information technology — Microprocessor Systems — Floating-Point arithmetic*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1
absolute pressure
value of the pressure of the gas relative to vacuum

3.1.2
associated measuring instrument
instrument for measuring certain quantities which are characteristic of the gas, e.g. temperature, pressure, or calorific value, whose indications are used by the calculator with a view to making a correction and/or a conversion

Note 1 to entry: For the purpose of this European Standard, when dealing with the ECD in modular approach, the VCD and CVDD are considered as associated measuring instrument.

3.1.3
base conditions
fixed conditions used to express the volume of gas independently of the measurement conditions and the superior calorific value

Note 1 to entry: The pressure base for both volumetric metering and combustion is always 1,01325 bar. The temperature is specified.

EXAMPLE Temperature of 273,15 K and absolute pressure of 1,013 25 bar or temperature of 288,15 K and absolute pressure of 1,013 25 bar.

3.1.4
calculator
electronic device that receives the output signals from measuring and data acquisition systems, e.g. associated gas meter or transducers, and processes them

3.1.5
calorific value determining device
CVDD
associated measuring instrument for determining the calorific value of gas

Note 1 to entry: For the purpose of this European Standard, the CVDD is described as a gas chromatograph (GC) because of the needs of using the gas composition for checks and calculations.

3.1.6
compression factor
parameter which indicates the deviation from the ideal gas

3.1.7
conversion factor
factor equal to the volume at base conditions divided by the corrected volume, or if there is no gas meter error correction, equal to the volume at base conditions divided by the volume at measurement conditions

3.1.8
conventional true value
value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose

3.1.9
corrected volume
volume at measurement conditions corrected for the error curve of the gas meter

3.1.10
correction
value added algebraically to the uncorrected result of a measurement to correct the systematic error

3.1.11
correction factor
numerical factor by which the measured volume is multiplied to correct it to compensate the error curve of the gas meter

3.1.12
display
element or assembly of elements of the indicating device on which the results of measurement and memorized values are displayed

3.1.13
disturbance
influence quantity having a value within the limits specified but outside the specified rated operating conditions of the measuring instrument

Note 1 to entry: An influence quantity is a disturbance if the rated operating conditions for that influence quantity are not specified.

3.1.14
durability
ability of an instrument to maintain its performance characteristics over a specified period of use

3.1.15
energy conversion device
ECD
energy conversion device calculates, integrates and displays energy using volume at base conditions and the calorific value or the gas composition

3.1.16
environmental class
class referring to climatic, i.e. ambient temperature and humidity, mechanical and electromagnetic conditions

3.1.17
error of conversion
difference between the conversion factor C displayed by a conversion device and the conventional true value of the conversation factor C_{CT} expressed as a percentage of the conventional true value of the conversion factor

3.1.18
error of indication
indication of a measuring instrument minus the (conventional) true value of the corresponding input quantity

3.1.19
flow computer
FC
high accuracy gas-volume conversion device associating measuring instruments with a calculator integrating data processing and monitoring functions

Note 1 to entry: More information on functions can be found in the introduction.

3.1.20
gas-volume conversion device
VCD
device that computes, integrates and indicates the volume increments measured by a gas meter if it were operating at base conditions, using as inputs the volume at measurement conditions as measured by the gas meter, and other parameters such as gas temperature, pressure and gas composition

Note 1 to entry: The conversion device can also compensate for the error curve of a gas meter and associated measuring transducers.

Note 2 to entry: The deviation from the ideal gas law can be compensated by the compression factor.

3.1.21
gauge pressure
value of the pressure of the gas relative to the ambient atmospheric pressure

3.1.22
global approach
approach ensuring that the performances of the conversion device are verified and approved with a completely integrated package including the calculation, the associated measuring instruments and other functions

3.1.23
HF
high frequency pulse generator in accordance with EN 60947-5-6

Note 1 to entry: If the meter is fitted with a high frequency output, the high frequency signal at Q_{max} is in the range of 0,3 kHz to 5 kHz.

3.1.24
indicating device
part of a measuring instrument that displays an indication i.e. alphanumeric string

3.1.25
influence factor
influence quantity having a value within the specified rated operating conditions of the measuring instrument

3.1.26
influence quantity
quantity that is not a measurand but that affects the result of the measurement (e.g. ambient temperature)

3.1.27
maximum operating pressure
MOP
maximum pressure at which a system can be operated continuously under normal conditions

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

3.1.28
maximum permissible error
MPE
extreme value of the measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument or measuring system

Note 1 to entry: Generally the two extreme values are taken together and are termed “maximum permissible errors” or “limit of error”.

Note 2 to entry: The term “tolerance” should not be used to designate “maximum permissible error”.

3.1.29
measurand
particular quantity subject to measurement

3.1.30
measurement conditions
conditions of the gas, the volume of which is measured at the point of measurement (e.g. the temperature and the pressure of the gas)

3.1.31
measuring interval
time interval in which a consumption of gas is determined by the meter

Note 1 to entry: To each measuring interval belongs a single value.

3.1.32
measuring transducer
transducer device, used in measurement, that provides an output quantity having a specified relation to the quantity

3.1.33
measuring or working range
all of the measurand values within which the measuring device error is supposed to be included, between specific limits

Note 1 to entry: The URL (Upper Range Limit) sets the device's measurement uncertainty. It may be understood to be the full range.

3.1.34
modular approach
approach in which the performances of the associated measuring instruments and the calculator, in which data from the associated devices are processed, are verified and approved separately

Note 1 to entry: The conditions for the matching of the associated measurement instruments are verified appropriately.

3.1.35
overload of pressure
maximum pressure to which the transducer may be submitted without durable alteration of its metrological characteristics: it is set in accordance with the maximum allowable pressure

3.1.36
precision
closeness of agreement between indication obtained by replicate measurements on the same or similar objects under specified conditions

3.1.37
rated operating conditions
values for the measurement and influence quantities making up the normal working conditions of an instrument

3.1.38
reference conditions
set of reference values or reference ranges of influence factors prescribe for testing the performances of a measuring system or a device or for inter comparisons of the results of measurements

3.1.39
repeatability
measurement precision under a set of repeatable conditions of measurement

3.1.40
Reynolds number
Re
dimensionless parameter expressing the ratio between the inertia and viscous forces

Note 1 to entry: Reynolds number is expressed in the meter upstream pipe

$$Re_i = \frac{w_i \, DN \, \rho_i}{\mu_i} = \frac{4 \, Q_i \, \rho_i}{\pi \, \mu_i \, DN} \qquad (1)$$

3.1.41
secured communication
communication, physical or not, between elements of a measuring system ensuring that information transferred from one of these elements to another one may not be tampered with by the user, by external influences or by fault of the system

Note 1 to entry: This is ensured by providing sealing devices and/or checking facilities.

Note 2 to entry: WELMEC Guide 7.2 provides guidance with application of MID for software-equipped measuring instruments.

3.1.42
sensor
element of a measuring system that is directly affected by a phenomenon, body, or substance carrying a quantity to be measured

3.1.43
setting of clock
adjustment of the clock by a time difference which is larger than a certain limit

3.1.44
signal
message made up of data or information that enables the data or information to be conveyed from one apparatus to another

Note 1 to entry: It may take many forms broadly classed as analogue or digital.

Examples are shown in Table 1

Table 1 — Electronic interface descriptions

Measurand representation as:	Example	Transmission between devices	Conversion
Proportional quantity, analogue signals Analogue value	Voltage Current Frequency	Analogue	Analogue-to-digital conversion
Proportional quantity, digital signals Pulses	NAMUR-Sensor Reed-Contact	Digital	Counting
Coded (Binary) Data protocol	HART- Protocol Modbus - Protocol	Coded (e.g. digital)	Decoding

3.1.45
superior calorific value
gross calorific value
amount of heat 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: In the following parts of this standard, the term calorific value (CV) is used to mean superior calorific value.

Note 2 to entry: The condensation heat and combustion heat depend directly upon the temperature and pressure; consequently the energy at base conditions is considered. The temperature to which the products of combustion are returned, need not necessarily be the same value upon which the volume conversion is calculated. The standard base conditions of temperature, pressure and humidity (state of saturation) to be used for measurements and calculations carried out on natural gases, natural-gas substitutes and similar fluids in the gaseous state are in accordance to EN ISO 13443.

3.1.46
synchronization of clock
adjustment of the clock by a time difference which is smaller than a certain limit

3.1.47
time interval
interval in which the measurement of gas quantities is determined

3.1.48
uncertainty (of measurement)
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

3.1.49
volume
volume without specifying whether it is a corrected volume at measurement conditions or an uncorrected volume at measurement conditions

3.2 Symbols and subscripts

The symbols and subscripts used in this European Standard are listed in Table 2.

Table 2 — Symbols

Symbols	Represented quantity	Units
V	volume	m^3
C	conversion factor	-
C_f	correction factor	-
C_c	calculator conversion	-
C_{CT}	conventional true value of the conversion factor	-
Co	line coefficient	-
D	pipe diameter	m
Q	volumetric flow rate	m^3/h
$F(Q)$	correction functions for flow rate	-
$F(Re)$	correction function for Reynolds number	-
H_S	superior calorific value	MJ/kg, MJ/m^3, kWh/kg or kWh/m^3
imp	volumetric pulse at measurement conditions	-
P_{op}	actual working pressure of the meter at the line	bar or MPa
P_{test}	pressure of the meter flow calibration at laboratory, fixed in the calibration certificate	bar or MPa

P_{min}	minimum absolute gas pressure	bar or MPa
P_{max}	maximum absolute gas pressure	bar or MPa
Q_1	minimum flow rate, at P_{test}, fixed in the calibration certificate (for one or two P_{test})	m^3/h
Q_n	maximum flow rate, at P_{test}, fixed in the calibration certificate (for one or two P_{test})	m^3/h
Q_{min}	minimum meter flow rate, fixed by the manufacturer	m^3/h
Q_{max}	maximum meter flow rate, fixed by the manufacturer	m^3/h
Re	Reynolds number	-
Re_1	minimum Reynolds number at P_{test}, obtained for Q_1	-
Re_n	minimum Reynolds number at P_{test}, obtained for Q_n	-
Re_{op}	Reynolds number calculated at operating conditions	-
p	absolute pressure at measurement conditions	bar or MPa
T	absolute temperature at measurement conditions	K
t	ambient temperature	°C
Z	compression factor of the gas at measurement conditio	-
U_{nom}	nominal supply voltage	V
e	error on the measurement	%
e_c	total conversion factor error	%
e_f	error on the calculation of conversion factor	%
e_p	error on the pressure measurement	%
e_t	error on the temperature measurement	%
n	number of impulse	-
f_{nom}	nominal supply frequency	Hz
w	gas velocity	m/s
ΔV	volume increment	m^3
δ	continuous function of the meter error	%
ρ	density of the gas	kg/m^3
μ	dynamic gas viscosity	Pa.s
Subscripts		
m	measurement conditions	
i	test point (from a calibration bench)	
corr	corrected	
amb	ambient	
b	base conditions	
CT	conventional true value	
OP	operating condition	
min	minimum	
max	maximum	
n	number of time intervals	
τ	time interval	

3.3 Abbreviations

CV	Calorific Value
CVDD	Calorific Value Determination Device
DN	Nominal Diameter
GC	Gas Chromatograph
FC	Flow Computer
GTM	Gas turbine meter
MOP	Maximum operating pressure
MPE	Maximum Permissible Error
USM	Ultra sonic meter
VCD	Volume Conversion Device

3.4 Environmental classification for flow computers

3.4.1 Climatic conditions

Climatic conditions depend on the temperature and humidity. Appropriate ranges are defined in 5.2.

3.4.2 Mechanical conditions

Class M1: this class applies to instruments used in locations with vibration and shocks of low significance, e.g. for instruments fastened to light supporting structures subject to negligible vibrations and shocks transmitted from local blasting or pile-driving activities, slamming doors, etc.

Class M2: this class applies to instruments used in locations with significant or high levels of vibration and shock, e.g. transmitted from machines and passing vehicles in the vicinity or adjacent to heavy machines, conveyor belts, etc.

3.4.3 Electrical and Electromagnetic conditions

Class E1: this class applies to instruments used in locations with electromagnetic disturbances corresponding to those likely to be found in residential, commercial and light industrial buildings.

Class E2: this class applies to instruments used in locations with electromagnetic disturbances corresponding to those likely to be found in industrial buildings.

4 Principle of measurement

4.1 General

The volume conversion performed by a FC is always a function of pressure, temperature and deviation from the ideal gas law, based upon a live calculation using pressure, temperature and gas composition.

The source of information for volume and flow rate can be of different types of technologies (HF pulse emitter, serial link communication, etc…). It shall be specified by the manufacturer.

The compression factor calculation shall be carried out according to EN ISO 12213-2 or EN ISO 12213-3. The CV calculation shall be carried out according to EN ISO 6976.

The general principles for calculation are the following:

$$V_m = \sum_{i=\tau_1}^{\tau_n} V_{m,i} \tag{2}$$

where

V_m is the incremented volume at measurement conditions;

$V_{m,i}$ is the volume increment at measurement conditions;

τ is the summation time period (time interval).

$$V_{corr} = \sum_{i=\tau_1}^{\tau_n} \left[C_f . V_{m,i} \right] \tag{3}$$

where

V_{corr} is the incremented corrected volume at measurement conditions;

C_f is the correction factor according to flow rate or Reynolds number. It is described as *F(Q)* or *F(Re)* in the document (see 4.2.2.4).

$$V_b = \sum_{i=\tau_1}^{\tau_n} \left[C \; . V_{corr,i} \right] \tag{4}$$

where

V_b is the incremented volume at base conditions;

C is the conversion factor given by the relationship:

$$C = \frac{p}{p_b} \frac{T_b}{T} \frac{Z_b}{Z} \tag{5}$$

For energy determination, see EN 12405-2.

In order to obtain a high accuracy device, the device has a number of correction- and monitoring functions.

The conversion factor shall be recalculated at time intervals not exceeding 30 s. The FC calculator should be able to treat a sampling of input measurements (*P, T*) at time intervals not exceeding 5 s.

4.2 Correction functions

4.2.1 General

The purpose of error correction is the significant reduction of the systematic errors. The FC shall provide correction at least for the following quantities:

— pressure,

— temperature,

— volume at measuring conditions.

Attention should be paid to the volume correction that could be already included in the flow rate calibration of the gas meter.

The requirements and testing of meter error correction are described in Annex D.

4.2.2 Correction of the volume at measurement conditions

4.2.2.1 General requirements

The correction of the meter measurement errors shall be carried out by devices receiving signals (volume conversion devices, FCs etc.) and shall refer to the indicated volumetric flow rates or volume increments.

The calculator shall include an error correction. The application of the error correction of the meter remains optional.

The error correction shall be applied only for the meter generating HF pulses and/or digital coded signals. For HF pulses, the correction shall only be applied if the gas meter produces at least 10 pulses per second at Q_{min}. For digital coded signals, the correction shall only be applied if:

a) the data resolution is sufficient by application of at least 32 bits floating point format according to ISO/IEC/IEEE 60559, and

b) the update period is performed at least every second, and

c) the transfer rates on serial interfaces are at least 4 800 bits per second.

The gas meter errors shall be obtained from test calibration results (or test points) and treated as a set of data for the calculator. They shall be used for the determination of a continuous error function $\delta(Q)$ or $\delta(Re)$ applied in error correction procedure.

Calibration of the gas meters (pressure and type of the gas used) shall be done on the basis of its intended use and according to EN 12261 for turbine gas meters or according to ISO 17089-1 for USM. For the application of an error correction, the turbine meter behaviour shall fulfil the preconditions described in EN 12261.

During a gas meter calibration, the errors of the gas meter are determined at calibration points, e.g. for arbitrary calibration point “i” the error is defined as:

$$e_i = 100\ (Q_i - Q_{iCT}) / Q_{iCT} \qquad (6)$$

where

e_i	error of gas meter [%], determined as a function of the flow rate Q_i;
Q_i	volumetric flow rate [m^3/h] at flowrate “i” – the indication of the gas meter;
Q_{iCT}	conventionally true value of volumetric flow rate at “i” (determined on the basis of measurements of the calibration facility reference flow meter).

4.2.2.2 Gas meter error curve $e(Q_i)$

The errors of the tested meter shall be determined at a minimum of 6 values of flow rates according to EN 12261 for turbine meters or ISO 17089-1 for ultrasonic meters. The distribution of errors is described as a function $e(Qi)$.

Other parameters, like pressure, can significantly affect the meter error curve. By using error curve expressed as $e(Re_i)$, (called as the “Reynolds calibration”) the gas velocity, density and viscosity are taken into account.

The Reynolds number calibration can be developed on a basis of a calibration results $e(Q_i)$ obtained for one or more values of calibration pressure. The number of calibrations performed in various pressure values depends on the gas meter foreseen line pressure range. The number of the pressure calibrations needed is specified in EN 12261 and ISO 17089-1.

In this transformation, composition of gas, pressure and temperature values measured during calibration shall be taken into account.

The Reynolds number for each calibration point Q_i shall be calculated according to the following formulae:

$$Re_i = w_i \, DN \, \rho_i / \mu_i \text{ [dimensionless]} \tag{7}$$

where

w gas velocity at the gas meter inlet cross section [m/s]

$$w_i = Q_i / A \tag{8}$$

where

Q_i volumetric flow rate through the gas meter at point ”i” [m^3/s]

$A = \pi \, DN^2/4$ gas meter cross section area [m^2]

where

DN nominal diameter of the gas meter upstream pipe [m]

The Re_i number expressed as a function of flow rate Q_i equals to (after substitutions):

$$Re_i = 4 \, Q_i \, \rho_i / \pi \, D_N \, \mu_i \tag{9}$$

where

ρ_i density of the gas used in calibration, [kg/m^3]
at each calibration point “i”.

μ_i dynamic gas viscosity [Pa.s]
at each calibration point “i”.

For more information on viscosity calculation, see [11] and [12] in bibliography.

4.2.2.3 Gas meter definite and continuous error function *δ(Q)* or *δ(Re)*

The errors specified at the calibration points $\delta(Q_i)$ or $\delta(Re_i)$ shall be used to determine an approximate error curve of the errors between the points.

The definite and continuous error function $\delta(Q)$ or $\delta(Re)$ can be determined by:

— a linear interpolation (straight lines between neighbouring points), or

— a polynomial approximation defined by a set of coefficients or calculated by FC based upon the calibration points.

In case the calibration of the meter has been performed for more than one test pressure value, an approximation function shall be applied.

As a criterion of matching the approximation function, the requirement of the “least square fit” should be applied.

NOTE See OIML R137 for more information.

The error function $\delta(Q)$ or $\delta(Re)$ shall be declared by the manufacturer of the calculator, during initial configuration, and indicated by the calculator.

4.2.2.4 Correction procedure of the gas meter errors

The correction of errors of the measured flow rates being in limits of application (see 4.2.2.5) shall be carried out according to the following formulae:

$$Q_{corr} = Q\ F(Re)\ [\mathrm{m^3/h}] \tag{10}$$

or

$$Q_{corr} = Q\ F(Q)\ [\mathrm{m^3/h}] \tag{11}$$

where

Q_{corr} corrected volumetric flow rate [$\mathrm{m^3/h}$]

Q uncorrected volumetric flow rate, calculated from:

$$Q = n\ k\ [\mathrm{m^3/h}] \tag{12}$$

where

n the number of impulses received from the gas meter over time [$\mathrm{h^{-1}}$]

k - weight of one impulse [$\mathrm{m^3}$]

The correction of errors of the measured volume increments, shall be carried out according to formulae:

$$\Delta V_{corr} = \Delta V\ F(Re)\ [\mathrm{m^3}] \tag{13}$$

or

$$\Delta V_{corr} = \Delta V\ F(Q)\ [\mathrm{m^3}] \tag{14}$$

where

ΔV_{corr} corrected increment of volume [$\mathrm{m^3}$]

ΔV uncorrected increment of volume [$\mathrm{m^3}$]

$$\Delta V = n\ k\ [\mathrm{m^3}] \tag{15}$$

where

n number of impulses received from gas meter, usually in short period of time, in which the flow rate can be treated as unchangeable and its average value is equal to "Q"

k as above

$F(Re)$, or $F(Q)$ correction factor, as below

The correction factor $F(Re)$ is determined as:

$$F(Re) = 100/(\delta(Re) + 100) \tag{16}$$

where

$\delta(Re)$ error calculated for current value of Reynolds number

The *Re* number value shall be calculated for currently measured flow rate Q (calculated according to Formula (12), and currently determined gas density and viscosity (for currently measured gas composition, pressure and temperature). The formulae used to calculate current value of *Re* number are specified as Formula (7) or Formula (9).

The correction factor $F(Q)$ is determined as:

$$F(Q) = 100/(\delta(Q) + 100) \tag{17}$$

where

$F(Q)$ – correction factor calculated for currently measured flow rate Q

$\delta(Q)$ – error calculated for currently measured flow rate Q

4.2.2.5 Limits of error correction application

The area where the error correction can be applied (flowrate, Reynolds number, pressure) shall be defined. The FC shall control the error correction limits.

Outside this area, the error correction should not be applied (correction factor is 1 or the last correction). No correction shall be applied above Q_{max} and below Q_{min}.

An extrapolation within this area may be applied under conditions that can be found in Annex E.

4.2.3 Temperature and pressure correction of USM body dimension

During flow calibration (see ISO 17089-1), all systematic errors are brought down to zero by determining and then applying the meter flow calibration factor. From that moment onwards, the meter's reference conditions of pressure and temperature are those as encountered during the dynamic calibration.

In general, the pressure and temperature during calibration will be different from those encountered under operating conditions. Any subsequent change in temperature or pressure will alter the physical dimensions of the meter and, if not corrected for, will introduce a systematic flow measurement error.

The error of the meter due to change in temperature or pressure, shall be corrected by mathematical equations as described in ISO 17089-1.

4.2.4 Temperature and pressure measurement correction for conversion

The calculator shall be able to take the calibration results of the temperature and pressure transducers into account before the application of the conversion functions (e.g. Resistance at 0°C for Pt100Ω as in EN 60751), as far as they are not taken into account by the transducer itself. The installation should be carried out following the guidelines of the manufacturer and corresponding standards (e.g. EN ISO 15970).

5 Rated operating conditions

5.1 Specified field of measurement

5.1.1 General

The field of measurement of the complete instrument shall be specified by the manufacturer.

5.1.2 Specified measurement range for gas pressure

The transducer shall be calibrated over the measuring range which shall be at least:

$$\frac{p_{max}}{p_{min}} > 2 \qquad (18)$$

where

p_{max} and p_{min} are defined in 8.10

5.1.3 Specified measurement range for gas temperature

The manufacturer shall specify the measuring range according to the following:

— normal range: −25 °C to +55 °C;

— limited range: a minimum range of 40 °C anywhere between the limits of the normal range;

— extended range: to be specified by the manufacturer.

5.1.4 Gas characteristics

Fuel gases of the first and second families according to EN 437.

The manufacturer shall indicate the:

— gas family or group;

— maximum operating pressure.

5.1.5 Base conditions

The manufacturer shall specify the base conditions, or range of base conditions for converted quantities, and they shall be indicated by the calculator.

5.2 Environmental conditions

5.2.1 Ambient temperature range

The manufacturer shall specify the ambient temperature range of the FC with a minimum temperature range of 50 °C for the climatic environment, and the minimum temperature limit being either −40 °C, −25 °C, −10 °C or 5 °C, and the maximum temperature limit being either 30 °C, 40 °C, 55 °C or 70 °C.

5.2.2 Humidity range

The instrument shall operate in a relative humidity range of at least 10 % to 93 %.

The manufacturer shall indicate whether the instrument is designed for condensing or non-condensing humidity as well as the location specifications for the instrument.

If designed for non-condensing humidity, the device shall meet the requirements of the test in A.4.

If designed for condensing humidity, the device shall meet the requirements of the test in A.5.

5.3 Power supply

The manufacturer shall specify the nominal value of the AC supply and/or the limits of DC supply.

The limits of AC/DC supply shall be compatible with customers' requirements. The limits of AC supply shall be compatible with the electricity supply of country of destination.

6 Construction requirements

6.1 General

6.1.1 All the constituent elements of a FC shall be constructed of materials having appropriate quality to resist the various forms of degradation which may occur under normal operating conditions as specified by the manufacturer. A FC shall, in all circumstances, withstand the influence factors and disturbances defined in 8.5.

6.1.2 All the constituent elements of a FC shall be designed in such a way that it does not degrade the accuracy of the measurement of the gas meter with which it is associated.

6.1.3 Any interfaces and connections fitted within the conversion device allowing the connection of complementary devices shall not corrupt the metrological behaviour of the conversion device.

6.1.4 The interconnections and any interfaces between the calculator of the FC and the transducers are integral parts of the conversion device.

The manufacturer shall specify the length and characteristics of the interconnections and of any interfaces where these may affect the accuracy of measurement of the FC.

6.1.5 Equipment used in hazardous areas shall meet the electrical requirements specified in the appropriate standards: EN 60079-0, EN 60079-1, EN 60079-2, EN 60079-5, EN 60079-6, EN 60079-7, EN 60079-11 and EN 60079-25.

6.1.6 All the constituent elements of a conversion device shall be constructed in such a way that the compatibility of electromagnetic disturbances conforms the requirements specified in EN 55011.

6.2 Sealing

The FC shall be secured to prevent access without evidence that this has occurred to parts, software, parameters or settings that are critical for its metrological characteristics or that could influence the metrological performance.

The FC shall be constructed to prevent access without evidence that it has occurred that the metrological relevant registers shall be reset during use or that devices or supply equipments shall be disconnected, when this influences the metrological performance of the FC.

Interfaces need not be secured if the FC cannot be influenced in any inadmissible way by the connection to it of another device, by any feature of the connected device itself or by any remote device that communicates with it.

For the purpose of this European Standard, it is recommended to work with electronic sealing when applicable.

Security by sealing shall be applied to the following specific provisions:

— inscriptions;

— interfaces (in- and outputs) for legal purposes;

— connection between different parts of the FC not integrated in one housing;

— connection to the legally relevant indicating device;

— connection between P- and T device with conversion device;

— legal part of software;

— software / parameter settings for example but not limited to: configuration of registers, gas composition and parameters for compressibility calculation, setting of correction devices (curve fitting…), programmed pulse factor, etc.

The metrological relevant parts shall be secured inside the housing.

The evidence shall be permanently visible damage to the conversion device or its protective seals, or set an alarm which shall be memorized in the event register. The seals shall be visibly fixed, and easily accessible.

Electronic seals shall comply with the following requirements:

— access shall only be obtained by using a password or a code that can be updated or by using a specific device;

— the last intervention, at least, shall be registered in the memory, including date and time of intervention, the new check sum and a specific code to identify the intervention;

— it shall be possible to have access to the intervention(s) registered in the memory.

If the given inputs may be dismantled or replaced, all connections and interfaces between the calculator and transducers or meter should be protected by separate seals to avoid the breaking of the main metrological seal in case of component replacement. Access to parameters which take part in the determination of the measured results or to the measured results themselves shall not be possible through the disconnected points, except if the conditions given in this paragraph are fulfilled.

The parameters used in the processing of the measurements, or intended to identify the constituent parts of the FC, shall be incapable of being changed except by a person authorized to make such changes. Those parameters shall be verifiable individually or by checksum of the parameter set applied.

The FC shall compute, by means of a deterministic procedure, a fixed-size bit string (data checksum) from all metrological relevant parameters. The purpose is to detect intentional or unintentional alterations that may have been introduced in the FC parameter set during a given period.

The hash function used to compute the data checksum would ideally make infeasible to modify the parameter set without altering the data checksum or to find two different parameter sets that produce the same data checksum.

The checksum shall be shown on a local display or retrieved by the configuration software tool of the FC.

The permission to alter the parameter set shall be restricted by password, regardless of the means used (local keypad or software tool). Additionally, the permission to alter part of or the whole parameter set *may* be restrained by a hardware lock. In that case, the access to the hardware lock shall be protected by a metrological seal.

If the FC is provided with a configuration software tool, the latter shall be able to produce a plain text report listing all metrological relevant parameters and their values, as well as the data checksum.

In parallel, the FC shall compute a hardware checksum for the purpose of detecting replacement, subtraction or addition of the main electronic components or boards. The hardware checksum shall be computed from the serial numbers of the components.

Any change of the parameters shall:

— either entail the breaking of the FC 's seals;

— or be recorded by the FC, together with an identifier specific to the person making the change and the date of the change.

6.3 Time measuring functions

6.3.1 Clock

The FC shall incorporate a clock.

For the accuracy of the clock, the requirements of EN 62054-21 for crystal controlled time switches apply.

The clock shall be settable via user interface and communication interface and external synchronization shall be possible via a communication interface. For the synchronization, the requirements of EN 62054-21 apply.

If the time of the clock deviates by more than 10 s from legal time, the clock shall be synchronized immediately after recognition. This can be done on site by the competent person via the user interface or a communication interface or it can be done automatically via a communication interface.

As the FC is read remotely on a regularly base, the clock shall be synchronized sufficiently often to ensure that the deviation from legal time is not greater than 10 s.

Synchronization is allowed only once during a measuring interval.

If the time of the clock in the FC deviates by more than 30 s from legal time, a setting of the clock shall be carried out.

Setting of the clock – manually or via interfaces – in which the adjustment exceeds 30 s shall be handled by the software, e.g. by changing a protected parameter. Information about setting of the clock e.g. in an audit trail shall be available as long as the affected measurement values are available in the memory of the auxiliary device.

NOTE It is not necessary to save the information about all time settings until the following verification or inspection of the instrument if the memory of the instrument does not contain the relevant interval data anymore.

The clock shall be provided with a standby power source (e.g. back-up battery) if it is supplied by mains. The design of the back-up power supply shall guarantee a deviation from legal time which is within the limits for time synchronization during the specified capacity of the stand-by power source.

After having resumed normal operation (for instance after power failure) the FC shall recognize whether the stand-by power source was sufficient for maintaining the clock accuracy. If not, this event shall be handled as specified in this clause.

6.3.2 Time interval

The measurement data calculated values or any relevant parameters shall consist of a fixed number of results per day, depending on the chosen measuring interval, e.g. 24 time intervals of 1 h per day.

The raster of measuring intervals shall be synchronous to the legal time and the requirements of EN 62054-21 for time switches with digital displays apply. For a measuring interval of 15 min, this recommendation is fulfilled if each forth interval starts at the beginning of a full hour.

The nominal value of the measuring interval is a legally relevant parameter. A change of the measuring interval remotely may be possible if registered in an audit trail (log book) and if the traceability of all interval values is still given for a billing period.

The interval values shall be stored in a non-volatile memory related to the measuring interval.

These interval values shall be accessible by user interface (display) and communication interface related to the measuring interval, for an appropriate time period, in order to allow an appeal in respect to the billing.

NOTE An appropriate access time can be realized by an appropriate memory depth of the non-volatile memory.

The time frame of the measuring intervals (i.e. the number of intervals per day) shall be preserved in spite of synchronizing or setting of the clock. Intervals skipped because of setting of the clock shall be marked invalid.

The measurement value of the current interval during setting of time shall be marked invalid.

The design of the interval functionality shall guarantee that the sum of interval values will be equal to the main register.

Due to different resolutions of interval registers and main index, it could be that fractional parts are taken into the next period. This may lead to an inequality which should be not more than the last fractional part of the last interval value (or the main index respectively).

6.4 Casings

Casings shall meet the requirements concerning the safety of the equipment as specified in EN 60950-1 and mechanical impact as specified in EN 62262.

The casings of all the constituent elements of a conversion device shall have an ingress protection index (IP), specified in EN 60529, complying with the installation conditions specified by the manufacturer.

Any part of the conversion device designed for outdoor use and not intended to be installed in a weather proof housing shall be at least in accordance with the severity level IP 65, specified in EN 60529.

6.5 Indications

6.5.1 General

6.5.1.1 The calculator shall be fitted with an indicating device that indicates:

— the incremented volume at base conditions Vb;

— the incremented volume at measurement conditions Vm;

— the incremented corrected volume Vc if applicable;

— the alarms' indications as defined in 6.7;

— the totalized energy;

— the time of the measurement.

6.5.1.2 Additionally, the following information shall be indicated by a method described in 6.5.1.3:

— the base conditions in the form:

  — Tb = …. K;

  — pb = …. bar";

— the conversion factor C;

— the compression factor Z if applicable;

— the parameter values measured by the transducers (e.g. pressure p in bar, temperature t in °C);

— the correction factor Cf if applicable;

— the error correction function δ(Q) or δ(Re) if applicable;

— alarm(s) indication(s) additional to those defined in 6.7 if applicable;

— the entered data which affect the metrological result;

— gas properties used in Z computation if applicable;

— the reference to the method by which the compression factor is calculated or the constant, if applicable;

— the serial number of the transducers as appropriate;

— the upper and the lower limits of the specified measuring range of the temperature transducer in K or °C and the gauge or absolute pressure, in bar, of the pressure transducer as appropriate;

— the value of one volumetric pulse at measurement conditions in the form:

  — 1 imp $\widehat{=}$ … m^3 (or dm^3); or

  — 1 m^3 (or dm^3) $\widehat{=}$ … imp;

— the parameters for gas meter error correction curve if applicable;

— the indication of the end of life of the battery, if applicable;

— the software version.

It shall also be possible, at the time of the control operations described in Annex A, to display the values of the conversion factor and of the various quantities measured or calculated.

6.5.1.3 The information shown in 6.5.1.2 shall be indicated either on:

— the indicating device of the FC;

— a permanently attached information plate with indelible markings;

— an external attached indicating device;

— a combination of the above.

6.5.1.4 The volume at base conditions or energy shall be preferentially displayed.

6.5.1.5 It shall be possible to indicate the interval values, the time of the clock and all legally important parameters on a legally controlled device. This indication shall be part of the instrument.

The time shall be provided by the instrument in such a way that transformation to legal local time can be easily accomplished (e.g. indication of UTC).

The time since the beginning of an interval or the rest of the interval shall be indicated as well as the measurand (consumption) since the beginning of a time interval. This value shall be available remotely if an appropriate interface is available.

6.5.1.6 The method by which the quantities described in 6.5.1.2 may be displayed on the indicating device of FC shall take one of the following forms:

— by means of direct operator input (e.g. the depression of push buttons, whereby each quantity may be selected by sequential operator inputs or combination of operator inputs. Each operator input shall select the current value of the quantity. If after 255 s there has been no operator input, the display shall revert to showing the volume at base conditions, or to visualizing V_b by a simple operation (e.g. the depression of a push button);

— by means of automatic and sequential scrolling through the quantities that may be continuous, or initiated by an operator input. In this case the display shall show each parameter for 5 s and the volume at base conditions shall be shown every 15 s.

6.5.1.7 The identification and the unit of each quantity or parameter that can be indicated shall be clearly shown next to or upon the display unit of the calculator.

EXAMPLE Volume at base conditions, V_b, …m^3.

6.5.1.8 The scale interval of the display of the volume at base conditions shall be of the form 10^n units of volume. The value of the scale interval shall be clearly stated in the vicinity where the volume at base conditions is displayed.

6.5.1.9 The indicating device shall have at least 8 significant digits.

6.5.2 Electronic indicating device

6.5.2.1 The device indicating the volume at base conditions shall be provided with means for checking to ensure that the display is operating correctly.

6.5.2.2 The minimum height of the numerals for the display of converted volume V_b shall be 4 mm and the minimum width shall be 2,4 mm.

6.5.2.3 It shall be possible to read the index clearly and correctly, within an angle of 15° from normal to the window.

6.5.2.4 When all the digits of the indicating device are not used for the indication of the volume, every unused digit to the left of the significant digit shall indicate zero.

6.6 Inputs for volume conversion

The FC shall be able to process input signals from the associated gas meter representing the volume at metering conditions.

In case pulse signals are used, the inputs of the FC shall respond to every pulse sent by the associated gas meter.

The manufacturer shall specify the signal inputs characteristics of the FC and the interfaces between the calculator of the FC and the transducers shall be specified in terms of all parameters that may influence that measurement.

Meters can often be subject to considerable periods of time where there is no gas flow. During such periods, conventional HF pulse outputs will, in effect, be operating at 0 Hz. Conversely, at maximum throughput, a typical meter's HF output up to 5 kHz or higher. Any pulse input circuitry in a FC will have to be capable of dealing with such frequency ranges.

6.7 Alarms in flow computer

6.7.1 Detection of defective operation situations

The FC shall be capable of detecting:

— if any of the measured or calculated values is outside the specified measurement ranges;

— if the instrument operates outside the limits of validity of the computing algorithm;

— if any of the electrical signals are outside the range of the input(s) of the calculator.

Alarms can be raised by specific monitoring functions as described in 6.8.

As long as such a defective operation is detected by the FC, any further increase of the volume at base conditions shall not be permitted. The increment can continue in a separate register. The recording of volume at measurement conditions and, if applicable, the corrected volume shall continue to operate.

The resetting of the cleared alarm shall be possible only if the cause of the alarm has been eliminated.

6.7.2 Handling of volumes during maintenance

If the FC is capable of estimating the amount of gas passed through the installation during the duration of the maintenance, provision shall be taken to prevent the confusion between estimated values and the calculated volume at base conditions.

Substitute values shall be memorized/indicated separately.

EXAMPLE Stored in a different memory from the one specified in 6.7.3.

6.7.3 Memorization of metrological data

The information specified in 6.5.1.2 shall be memorized at least at last clock hour and retained during an interruption, of any kind, computation shall resume with the values retained at the moment of an interruption.

The memory shall be able to retain all the specified data for up to six months.

After an interruption or a failure and the restoration of values retained at the moment of interruption or failure, the conversion device shall be capable of restarting automatically.

6.7.4 Handling of alarms

Operation of alarms shall be tested in accordance with A.16.

6.8 Specific monitoring functions performed by flow computer

6.8.1 General

Specific monitoring functions performed by the FC ensure correct and timely operation of the volume conversion process with respect to the associated measuring instruments.

Application of the monitoring functions depends on the availability and configuration of measuring equipment.

The following Table 3 indicates which functions are mandatory or optional in the FC in relation to the inputs from an associated measuring instrument type.

Table 3 — Mandatory/optional functions

Clause	Monitoring function	Associated measuring instrument	Mandatory/optional	Comment
6.8.2.1.2	Discrepancy of pulse source	Turbine meter	Mandatory	
6.8.2.1.3	Total Failure of pulse source	Turbine meter	Mandatory	
6.8.2.2	Pulse-encoder comparison	Turbine meter	Optional	
6.8.3.1	USM data (Health check)	USM	Optional	Can be performed by separate software
6.8.3.2	Timeout check	USM	Mandatory	
6.8.4.1	Verifying analysis data	GC	Mandatory	
6.8.4.2	GC-GC comparison	GC	Mandatory	
6.8.4.3	Timeout check	GC	Mandatory	
6.8.5.1	Verifying measurements	P and T	Mandatory	Check of the used range
6.8.5.2	Timeout check for transducers	P and T	Mandatory	
6.8.5.3	Cross check of measurements	P and T	Optional	
6.8.6	Verification of c (self-check)	Flow-Computer	Mandatory	
6.8.7.1	Meter-Meter comparison (serial)	Flow-Computer	Optional	Can be performed off-line
6.8.7.2	Meter-Meter comparison (Z-configuration)	Flow-Computer	Optional	Can be performed off-line
6.8.7.3	Meter-Meter comparison (parallel operation)	Flow-Computer	Optional	Can be performed off-line
6.8.8.1	SOS comparison between USM and GC	Gas Quality	Mandatory	

The principle of the timeout checks is specified as followed, where, device means USM or GC.

In the case the device is connected via a protocol channel to the FC, the FC checks the reception of the required data frame according to the mode of operations and set up of the communication parameters.

The mode of operation defines whether the communication from the device to the FC is solicited or not as defined for the 2 following main cases:

— The device sends on a regular basic a data stream with a generic construction, depending of its configuration.

— The device answers to a command or a set of commands from the FC.

The FC raises an alarm if the required data frame is not received correctly according to the communication set up. Main parameters taken in account for checking/control are (none exhaustive list):

— number of attempts/retries,

— interval data frame,

— delay of response to a command.

NOTE In case, the transmitted data contain legally relevant information which are used to present or process the measurement results in the FC then the data set is in accordance with Welmec 7.2 guidance (bibliography):

— measurement value(s) with correct resolution,

— the legally correct unit of measure,

— the time and date of the measurement (if applicable),

— identification of the instrument if applicable (data transmission).

6.8.2 Turbine Meter health check (Mechanical meter)

6.8.2.1 Pulse – pulse comparison/Volume Comparison

6.8.2.1.1 General

The notion "Pulse Comparison" dates back to the early days of flow computing when pulse counting was performed by specially designed channels. If two pulses sources were generated by one flow meter, with the same pulse rate but with a phase difference, it was relatively easy to measure the phase difference and generate an alarm if it was too high. Pulse comparison on the hardware base is an appropriate method but the two pulse sources have to have the same frequency. Another method is volume comparison, i.e. compare the volumes counted on the base of two different pulse sources. The pulses shall have different pulse rates (i.e. low and high frequency) and the primary signals can be electrically different.

The volume comparison is done with two special volume indexes each of them assigned to a different pulse source. At the beginning of the comparison both indexes are reset to zero. Thereafter, the indexes start incrementing volumes. In order not to overrun the maximal size of the index the indexes again are set to zero after one of them has reached a maximum magnitude (e.g. a volume equivalent to 100 h * Q_{max}). The volume comparison detects the failures as described in 6.8.2.1.2 and 6.8.2.1.3.

6.8.2.1.2 Detection of Discrepancy of pulse source

While the indexes are increasing, the FC checks the deviation between the indexes. If one of the indexes is lagging behind by a certain amount, it is considered faulty and the other pulse source takes over to further increase the custody transfer index. An alarm "Deficiency of pulse source" is generated and processed according to the alarm handling rules and protocols. The permissible deviation between both indexes shall be user adjustable and defined in a way that an absent pulse source does not lead to failure detection. The deviation allowed shall be a user definable parameter of the FC: e.g. a proven value from practical experience is a volume accumulated during 180 s at Q_{max}, which allows for a quick detection of a failure and prevents a false alarm.

6.8.2.1.3 Detection of Total Failure of pulse source

The definition of a second deviation level is to be applied as criteria for a total failure of a pulse source.

If the deviation between the two indexes reaches this second deviation level, the pulse source which is lagging behind is considered to exhibit a total failure and an alarm “Total failure of pulse source” is generated and processed according to the alarm handling rules and protocols. The permissible deviation between both indexes shall be user adjustable. A value for the volume as 1 h * Q_{max} has shown good results.

6.8.2.2 Pulse – Encoder comparison

Modern flow meters are often equipped with an electronic index device that performs the pulse counting and volume index incrementation by itself. The main custody transfer index is located in the electronic index device and the FC only receives a copy of it and calculates from it the volume at base conditions. The transfer of data between the electronic index and the FC is performed on base of a digital protocol with the required integrity checks of the transferred data.

Flow meters are also able to generated pulses which can be used to make a comparison between the electronically transferred data and those counted on base of a pulse. Compared to the “Volume comparison” described before it does not make any difference if both volume registers are made up in the same FC or one of the registers is transferred from the electronic index. Thus, the same methods explained in 6.8.2.1.1 and 6.8.2.1.2 apply also here. In addition, a total Failure of the electronic index device is also given if the digital data link is interrupted or the transferred data is defective. The methods to detect a faulty data transfer of the electronic index is device dependent.

6.8.3 USM health check (meter integrity check)

6.8.3.1 Verifying USM data

USMs shall calculate the operational flow and volume by an algorithm and an associated hardware which is unique to each manufacturer and model. In regards to a FC, an USM is some sort of electronic indicator that shall transmit the following information:

— Volume index under operating conditions (V).

— Flow rate under operating conditions (Q).

— Error warning which indicates a faulty operation.

— Volume index under operating conditions during error occurrence.

— Performance analysis. This signifies that the meter is operating correctly, e.g. all acoustic paths are working properly or the signal noise ratio is below a critical level.

— Further information which are designed specifically and used to assess the operating quality of the USM.

— Measured Speed of Sound (MSOS). The USM measures the speed of sound under operating conditions permanently.

This list is not exhaustive and most USM deliver at least the first three items above. ISO 17089-1 describes the general feature of a USM. The data transfer is primarily done by a digital link with a set of dedicated protocols, but there are still USM devices in use with pulse generators. The FC typically shall be adapted to the data link and contents of a specific USM.

If the USM indicates an error, the FC shall handle the error in the same way as with turbine meter. For this reason the FC shall perform a timeout check.

If the USM offers an error index automatically, the FC shall use it instead of generating another error index.

The information “Performance analysis” and “Further information” typically are not evaluated by the FC. But the FC shall pass on these data to the external communication system. In many countries this capability is important as for metrological reasons as the USM is connected exclusively to the FC and the additional information can only be accessed through the FC.

The FC shall carry out the comparison of the measured and theoretical speeds of sound. The FC gets the Measured Speed of Sound (MSOS) from the USM and compares it to the Theoretical Speed of Sound (TSOS). In order to calculate the TSOS, FC shall use AGA10 [13] or other appropriate methods and shall record the actual gas composition, pressure and temperature at the meter. This requires a link to an online GC. If the FC detects a deviation higher than the set limit, it shall set off a warning but not an alarm. Moreover, the FC shall need a filtering function and not indicate a SOS deviation at the first occurrence.

NOTE Due to the delay of the GC, a sudden change in gas composition could lead to a false assessment.

6.8.3.2 Timeout check

In the case the USM is connected via a protocol channel to the FC, the FC shall monitor the incoming data frames. Normally, 1 data frame per second is received by the FC. Whenever the time for 10 frames elapses and no correct data frame is received, the FC shall indicate an alarm from this device (see 6.7.4).

6.8.4 Gas analysis devices health check

6.8.4.1 Verifying analysis data

The FC shall be able to check:

— status register (error bits);

— sum up of the gas composition (normalization);

— min/max values of all components;

— verification of the provided gross calorific value (EN ISO 6976) and compressibility;

— deviation between several connected GCs.

6.8.4.2 GC-GC comparison

When several GCs are used, their values shall be compared.

A preset parameter shall characterize an acceptable deviation for the compared gross calorific value.

In case of exceeding the acceptable deviation calculated by the comparison, then:

— in case of two operating GCs:

  — the trigged parameter is a metrological one;

  — a metrological alarm shall be raised and stored;

— in case of three operating GCs:

  — a warning shall be indicated and stored;

— calculations are carried out with the values from a two GCs still in operation.

In each case, traceability shall be given by individual storages of gas analysis values for recalculation.

6.8.4.3 Timeout check

In case the GC is connected via a protocol channel to the FC, the FC is monitoring the incoming data frames. Normally 1 data frame per second is received by the FC. Whenever the time for 10 frames elapses and no correct data frame is received the FC will indicate an alarm for this device.

6.8.5 *p*-T transducer health check

6.8.5.1 Verifying measurements

The data of the connected pressure and temperature transducers shall be checked within the FC against their min/max ranges. Therefore a min/max value for every transducer shall be provided within the FC. The FC itself checks the incoming values against these limits and shall indicate an alarm if the limits are exceeded.

6.8.5.2 Timeout check for transducers

In the case the transducers are connected via a data communication protocol to the FC, the FC is monitoring the incoming data frames. Normally 1 data frame per second is received by the FC. Whenever the time for 10 frames elapses and no correct data frame is received, the FC shall indicate an alarm for this device.

6.8.5.3 Cross check of measurements

A cross check of pressure and temperature values on the same line or between corresponding lines in case the same operating conditions should be applied.

A preset parameter characterizes an acceptable deviation, taking into account also a tolerance from measuring time interval to the next measuring time interval.

In case of exceeding the acceptable deviation by comparison of the corresponding values, a warning should be indicated and stored.

6.8.6 Self check of the *Z* algorithm

The FC shall check the calculation of the *Z* algorithm due to wrong input values (min/max *p*, *T*, gas components, heating value, density) to detect outliers on *Z* calculation.

6.8.7 Volume comparison

6.8.7.1 Meter – Meter comparison (serial meter connection)

In large gas metering stations, two meters are often installed in series to measure the same gas flow. Two meters arranged in this way give high availability. It is recommended to set up a permanent meter to meter comparison to be able to detect malfunction of one of the meters. Instead of matching the measured volume at operational conditions, the different pressures and temperatures should be taken into account when the converted volume at base conditions of both meters is calculated. A comparison based on mass or energy is also applicable. Normally, every FC is connected to one meter, but in some cases the data of two meters are processed by one FC. When two FCs are installed, only one of them should compare the data of the two meters. In this case, data are exchanged between the two FCs via a digital data link.

The comparison should be done for a fixed converted volume or time period, which is user definable.

The comparison can be started up manually or automatically. The following criteria should be used for a reliable comparison:

— Two FCs use the same compression factor algorithm and the same gas composition.

— The comparison should be stopped if the flow rate of one of the two meters falls below a certain value, which is fixed by the user. If the flow rate exceeds the set value again, a new comparison starts. It is recommended to define the flow threshold in base conditions when the comparison is made between the same quantities. A definition of the threshold in flow under operational conditions is also possible and can lead to different data of both meters. In general, the application of a flow threshold prevents the meters to operate far below Q_{min}.

The comparison should be stopped immediately if one of the FCs or the connection between the FCs is disturbed. For this reason, time out checks are carried out on the FC.

6.8.7.2 Meter – Meter comparison via Z-switching

There are stations where two parallel meters of the same size are installed for reason of redundancy. A Z-shaped pipe connection gives the opportunity to set both meters in line temporarily and run a meter comparison test. This situation can be traced back to the one discussed in 6.8.7.1 with the exception that the comparison should be performed manually, i.e. the valve is switched in a way that the flow is passing through both meters and the comparison task should be initiated manually at that FC performing the test. Another aspect is that the flow through both meters should be established for some time (e.g. 30 min) before the test is started in order to allow the temperature to settle in the formerly not operating meter.

Attention shall be given to the data processing of the custody transfer. As the flow is passing through two meters which only are set in line temporarily, there is the danger of a double count. The FC temporarily switched in line can have for example a provision either to prevent the metrological relevant counter from incrementing during the test or to mark the volume passed as not accountable in the associated data storing module.

6.8.7.3 Meter – Meter comparison via parallel operation

A cross check of the line coefficient variations between corresponding lines in case of the same operating conditions can be applied. The line coefficient can be calculated on integrated volume at base conditions over a period of time (hourly, daily, etc.) using the following formula:

$$Co_{ij} = \frac{V_l \, N_l}{V_{tot}} \tag{19}$$

where

Co_{ij}	is the line coefficient
V_l	is the volume transited via the line, l, in question
N	is the number of lines in operation
V_{tot}	is the volume transited by all lines in operation

Then a preset parameter characterizes an acceptable deviation, taking into account also a tolerance from measuring time interval to the next measuring time interval.

In case of exceeding the acceptable deviation by comparison of the corresponding values, a warning shall be indicated and stored.

6.8.8 Gas quality comparison

6.8.8.1 Speed of sound comparison between USM and GC

In case the flow meter is an USM, according to ISO 17089-1, there is a specific operational diagnostic that the FC should implement.

When the gas composition, temperature and absolute pressure are measured, the theoretical speed of sound (TSOS) can be calculated and compared to the measured value (MSOS) by the USM. The monitoring of the Speed of Sound in the gas flowing in the line through the measurement system is an excellent tool to monitor not only the USM, but also the other components of the system, such as the gas chromatograph and the pressure and temperature transducers.

The FC should include a communication port with serial interface, to connect to the USM with an appropriate protocol and continuously receive the values of averaged Speed of Sound (MSOS).

The FC should implement a Speed of Sound calculation method based on an equation of state, the AGA Report No.10, GERG 2004 and GERG 2008 (see bibliography) or other recognized standards for calculation SOS, to obtain the TSOS.

The FC should perform a continuous comparison between MSOS and TSOS and calculate a deviation:

$$d_{SOS} = [(MSOS - TSOS) / TSOS] * 100 \qquad (20)$$

This calculated value should be shown in the FC display.

An alarm should be programmable in case the deviation exceeds a preset value in the setup/configuration. The possible origin of the problem rising the alarm is detailed in ISO 17089-1.

6.9 Cut-off function

A low flow cut-off function shall be provided that sets the flow rate value to zero when the indicated flow rate is below a minimum value.

NOTE Setting the value to zero at low flow can cause problems if the USM output is used to control valve settings.

The low-flow cut-off shall be switched off for all tests if:

— the meter is working within the calibration range;

— the test cell, containing electronics and transducers, is set up for no-flow conditions; or

— when verifying that the meter displays values at zero when no gas is flowing through the meter.

6.10 Long-term data storage

6.10.1 General

Long-term storage for sets of data shall be accessible by the FC. This function may be integrated in or separated from the FC.

The measurement data stored shall contain all relevant information necessary to construct or reconstruct calculated values:

— for later legally relevant purposes (e.g. the conclusion of a commercial transaction);

— for back up of the relevant data.

All information necessary for legal and metrological calculations shall be stored together with the measurement values.

As a minimum requirement a data set or combinations of data sets consist of information, which allows to associate the data origin and to identify unambiguously stored information in their context when having been processed and stored.

In addition appropriate measures for protection are to be selected, if integrity and/or authenticity and/or confidentiality are required according security policy, taking into account different applications for data sets stored.

The application software for data storage according to the requirement of separation of legally relevant software and non-legally relevant software may be constructed:

— only for this measuring function (built-for-purpose),

— or to support the entire system of the FC.

For the purpose of this function, the WELMEC 7.2 Software guide (bibliography) shall be taken into account.

6.10.2 Categories of data to be stored

Data to be stored can be differentiated by the following categories:

— measurement data (e.g. volume, pressure and temperature);

— derived (calculated) legal and metrological / non-metrological relevant values;

— metrological / non-metrological relevant parameters (e.g. topological data);

— event and status (e.g. alarms);

— identification data (e.g. measuring point identifier);

— cryptographic data (e.g. keys and initialisation vectors).

Measurement data, calculated values, parameters, events and status shall be parts of fiscal data sets stored with correlation capability.

The system shall indicate clearly the data stored during alarm conditions to allow the operator to exclude or take them into account. For this issue, the status and event storage should be relevant. The external system should be able to validate the content of the stored data.

The data stored should be accessible on request and shall be transmitted via communication interface of the FC to facilitate an equivalent indication as for legal and metrological relevant data required.

6.10.3 Triggers and methods for storage

Triggers to store sets of data can be:

— clock based (periodical storage);

— event based (e.g. alarm occurrence, threshold value passed);

— on-demand (e.g. local or remote operator activation).

The data storage function shall then perform promptly storage of data sets, when the measurement data and calculation results acc. the incremented measurements are concluded.

The system of storage data may use two different methods to operate long-term data storage:

— circular buffer (with superseding the oldest data set with the most recent);

— non-circular buffer[1] (stopping when max. number of entries reached).

Data storage may contain periodically stored data, event based (status) or on-demand data or combination of all.

All data storage shall provide the capability to trace sequential arrangement of storage entries in order of appearance by time information or other criteria (e.g. time stamps, sequential order numbers).

NOTE The minimum period for storing measurement data is beyond the scope of this standard.

Frequent event of the same type should be filtered to avoid the filling of the memory.

6.10.4 Clock-time stamps

Traceability of stored data can be supported by time stamp information derived from a clock (see 6.3).

This time stamp consists as a minimum of the date and time information, where it should apply Universal Time Coordinated (UTC) to accomplish the transformation to legal local time in a generic way.

The accuracy for the periodical storage and time stamping shall be suitable for its intended use.

Data shall be stored by attaching an automatic time stamp on creation.

6.10.5 Security (physical, electronic and software)

The basic requirement for data storage is completeness of data set as intended to be stored.

Additional protection according to the security policy of the operating organization may include the following major security services as specific to data categories and/or sets of data:

— integrity;

— authenticity;

— confidentiality.

The storage shall be part of the metrological necessary hardware.

Protection measures shall be supported by functions for availability, access control, and authorization (physical or electronic seals, coded access):

a) Stored data shall be protected against accidental and unintentional changes. To detect data changes due to physical effects (e.g. electrostatic discharges), a checksum or signature should be calculated over the entire data set and inserted into the data set to be stored. Measures can be differentiated according to the risk classification in WELMEC 7.2 (see [16]) for integrated or removable storage.

b) The measurement data stored shall be protected against intentional changes while in use, transfer (inside the FC) or storage. The memory (a built-for-purpose measuring instrument or shared with other functions) may be physically removable.

Deletion of stored data should be restricted to authorized parties.

[1] Applied for fiscal audit trail acc. WELMEC 7.2

Connection (Insertion) and usage of a removable storage should be checked against misuse (e.g. memory from a different device or full memory).

The software used for verifying measurement data sets stored (retrieval of stored data) should display or print the data, check the data for changes, and warn if a change has occurred. Data that are detected as having been corrupted should not be used.

6.10.6 Error handling

Performing the function of data storage several situations may generate an error, which is to be made available for information and appropriate reaction.

By definition the amount of storage place for data storage will be split into different sections for specific data stored according configuration. The manufacturer shall indicate the sections, their corresponding numbers of entries applicable and the methods, in which the data storages are operated (circular buffer, non-circular buffer).

Based on this during operation it shall generate (as a minimum):

— a warning, when a data log filling level reaches a limit (related to the max, number of entries);

— an operational alarm, when a non-circular buffer reaches the maximum number of entries;

— an operational alarm, when a storage section is not available for the storage function.

The following reactions are dedicated to error situations listed:

— Temporary non-availability of storage

  As the measurements are cumulative, the register may be read out and transmitted to the storage at a later time when the storage is available again.

— Power supply failure

  The memory has to be retained during power supply failure.

NOTE Functionality to retrieve data stored by other than the originating source is outside the scope.

6.10.7 Long term data storage – Security audit

For security audit of the data storage, the construction details, the configuration of data sets stored and the security policy including sealing should be taken into account for definition of a risk class according to WELMEC 7.2 Software Guide (see [16]).

Based on this risk class, the specific requirements with corresponding validation procedures are to be performed.

The data listed in 6.5.1 shall be stored.

For a set of data, the minimum information is:

— identification of data origin (e.g. generating instrument, measuring point);

— identifier of stored information;

— information (values of measurement or calculation, status);

— measurement unit and resolution of value, if applicable;

— quality of value (minimum marking: a valid or invalid information);

— time stamp / sequential order number.

For a set of data or a combination of sets, additional data for protection are always generated:

— integrity check information;

— signature for authentication of data origin;

— or can be generated:

— encryption of contents for confidentiality.

The FC shall be capable of recording and storing as a minimum the following events:

— clearing of stored data;

— fault event (e.g. alarm);

— corruption of database;

— activation of firmware upgrade;

— resetting and clearing of database;

— power supply loss;

— setting of the clock;

— perceived tamper events e.g. fraud attempts.

7 Installation requirements

7.1 General

The installation requirements shall be as specified in EN 1776.

The calculator and the associated transducers shall be installed in a manner appropriate to the conditions necessary for their effective use. The installation and the presence of the conversion device shall not affect the measurement of volume at measurement conditions by the gas meter with which it is associated.

The calculator and the transducers shall only be used in climatic conditions that are in accordance with the specified environmental classes.

Transducers shall be designed to be installed in the open air and be exposed to foul weather and to the effects of an industrial environment. They shall be used in the ambient conditions (humidity, temperature…) limits defined by the manufacturer. The temperature of the gas also varies in the rated operating conditions. The equipment and procedures required to meet the entire specifications shall be included in the equipment supply (for example, heated casing to overcome ambient temperatures, maintenance procedures, etc.).

The compatibility of the output of the gas meter and the input of the FC shall be verified. In addition it shall be verified that the display (converted and unconverted readings) shall have at least a sufficient number of numerals to ensure that the volume passed during 8 000 h at the meter's flow rate of Q_{max}

(and at the maximum likely conversion factor) does not return all of the numerals to their original position.

The installation in hazardous or potentially hazardous areas shall be done in conformity with EN 60079-0, EN 60079-1, EN 60079-2, EN 60079-5, EN 60079-6, EN 60079-7, EN 60079-11 and EN 60079-25.

The connections of transducers shall be done in accordance with the manufacturers' requirements.

In order to guarantee metrological performances in case of large ambient thermal variations, the transducer shall either be:

— thermally insulated, so as to guarantee a near-constant operating temperature, which is as close as possible to the calibration temperature;

— or temperature-compensated, for which cowling with lagging or cladding should be added, without heat treatment, to obtain equivalent performances.

For large-scale metering, application of both types of treatment is recommended.

7.2 Calculator

The manufacturer shall specify if the FC calculator can be installed indoor or outdoor and its relevant environment classes.

7.3 Temperature transducer

The temperature transducer shall be installed in an environment classes E2 and M2.

The purpose of the temperature transducer is to measure the gas temperature at measurement conditions.

Temperature probes shall be installed on thermo wells, in accordance with the standard IEC 61520. Their connections shall be protected in an IP65 insulated box or better.

Temperature transducers and their installation shall comply with EN 1776, EN 12405-1 or EN ISO 15970. It shall be possible to verify, on site, the temperature transducer (for example equipped with a second thermowell).

7.4 Pressure transducer

The pressure transducer shall be installed in an environment classes E2 and M2.

Pressure transducers and their installation shall comply with EN 1776, EN 12405-1 or EN ISO 15970. It shall be possible to verify, on site, the pressure transducer (for example equipped with a stainless steel multichannel manifold).

The pressure transducer shall be connected to the pressure tapping (marked p_m) of the gas meter, if available. They shall be fitted and connected in accordance with the manufacturer instructions.

Transducers may be chosen for measurement of gauge or absolute pressure, in accordance with 4.2 in EN 12405-1. In order to avoid the introduction of errors caused by variations in atmospheric pressure, a transducer of absolute pressure shall be used. If a gauge pressure transducer is used, then it shall be used in combination with an atmospheric pressure transducer.

8 Performance

8.1 Reference conditions

1) The reference conditions are the following: ambient temperature: 20 °C ± 3 °C and the actual temperature shall not change by more than ± 1 °C during a test;

2) Ambient relative humidity: 60 % ± 15 % and this relative humidity shall not change by more than 10 % during a test;

3) AC mains powered equipment:

    a. supply voltage nominal values;

    b. supply frequency nominal values;

4) DC mains powered equipment:

    a. supply voltage nominal values;

These reference conditions are used for the tests described in appropriate annexes.

8.2 Rated operating conditions

See Clause 5.

8.3 Maximum permissible errors

8.3.1 General

For FC, the maximum permissible errors (*MPE*) expressed as relative values, applicable to the various indications or the various separated elements, shall be as specified in Table 4.

The error of the gas meter is not taken into account.

Table 4 — Maximum permissible errors for FC

Indication or element	Reference conditions	Rated operating conditions
Main indication (e_c) for volume conversion	± 0,3 %	± 0,5 %
Calculator (e_f)	± 0,1 %	± 0,1 %
Temperature (e_t)	± 0,1 %	± 0,2 %
Pressure (e_p)	± 0,1 %	± 0,2 %

According to the regulations in force, the metrological control may concern:

— in the modular approach, the errors of the constituent elements: calculator, temperature transducer and pressure transducer and then the errors of e_f, e_t and e_p based on respective outputs shall be compared to the *MPE* indicated in Table 4, or

— in the global approach, the error of main indication shall be compared to the *MPE* indicated in Table 4.

The *MPE*s related to the calculator are to be considered only when it is subjected to a separate control.

8.3.2 Global approach: error of main indication

The percentage error e_c on the main indication is defined by the equation:

$$e_c = \frac{(C - C_{CT})}{C_{CT}} \times 100 \quad (21)$$

The allowed error is given by:

$$e_c \le MPE \quad (22)$$

8.3.3 Modular approach: specific errors for a FC

Specific errors exist for each component part of a FC (i.e. calculator, pressure transducer and temperature transducer). These errors are defined by the relationships:

$$e_f = \frac{(C_c - C_{CT})}{C_{CT}} \times 100 \quad (23)$$

$$e_p = \frac{(p - p_{CT})}{p_{CT}} \times 100 \quad (24)$$

$$e_t = \frac{(T - T_{CT})}{T_{CT}} \times 100 \quad (25)$$

The values of e_f, e_p and e_t shall be verified during the accuracy test defined in A.2.

The allowed combined error is given by:

$$|e_c| = |e_f| + |e_p| + |e_t| \le MPE \quad (26)$$

The requirements related to the accuracy of the main indication shall be met.

8.4 Conditions of matching the constituent elements of a FC

The matching of the constituent elements of a FC shall comply with the following requirements:

a) each of all the elements shall be approved and verified separately;

b) the complete assembly shall be subjected to a verification concerning:

- the configuration;
- the data and signals transmission;
- the maximum error of the FC, which shall be within the *MPE* of the main indication according to Table 4;

c) the rated operating conditions of the assembly shall be deemed as being equal to the common part of the measure ranges of each of the constituent elements of the conversion device;

d) the transducers shall be mounted under the conditions specified in the type approval certificate, and according to the manufacturer's instructions;

e) if a transducer is capable of generating and transmitting an alarm to the calculator, the conversion device shall handle this as an alarm.

8.5 Influence factors

Ambient temperature (dry heat and cold): test defined in A.3;

— damp heat, steady-state: test defined in A.4;

— cyclic damp heat: test defined in A.5;

— electrical power variations: test defined in A.6;

— effects of vibrations: test defined in A.12;

— effects of shocks: test defined in A.13.

The relevant requirements are given in Table 5 and Table 6.

8.6 Disturbances

— Short time power reductions, for mains powered equipment: test defined in A.7;

— electrical bursts: test defined in A.8;

— electromagnetic susceptibility: test defined in A.9;

— electrostatic discharges: test defined in A.10;

— overload of pressure: test defined in A.11;

— overload of pressure (mechanical): test defined in A.14;

— short time DC power variations: test defined in A.18;

— surges on supply lines and/or signal lines: test defined in A.19;

— power frequency magnetic field: test defined in A.20.

The relevant requirements are given in Table 5 and Table 6.

8.7 Durability

After a period of use corresponding to an accelerated ageing, as defined in A.15, the relevant requirement shall be as given in Table 5 and Table 6.

8.8 Repeatability

The application of the same measurand under the same conditions of measurement shall result in the close agreement of 6 successive measurements (see A.17).

The test shall be carried out with one gas during the accuracy test, at p_{min} and T (see Table A.1).

The difference between the measurement results shall meet the requirement given in Table 5 and Table 6.

8.9 Reliability

A measuring instrument shall be designed to reduce as far as possible the effect of a defect that would lead to an inaccurate measurement result, unless the presence of such a defect is obvious.

8.10 Adjustment and calibration of the transducers

The pressure transducers shall be calibrated on their pressure measuring ranges in order to improve their metrological performances.

For pressure measurements, the measuring range (P_{min}. and P_{max}.) shall be chosen and adjusted in such a way that it includes the predictable values of the quantity to be measured.

The transducers shall be calibrated with traceability to a national or international standard before installation on site. To prevent unexpected transport effects, an on-site verification shall be carried out.

Their sensors and all combined components such as interfaces, signal convertors, power supply units, including cabling and other electronic equipment forming a measuring chain should be verified as a unit.

It should be possible to perform an adjustment on a FC for a transducer on site, if this is allowed by national rules for initial verification and if the necessary method and means are available. The adjustment on site of transducers should be performed with working standards, having traceability to national or international standards. The expanded uncertainty (k = 2) associated with the standards used and their implementation shall be less than one third of the applicable *MPE* (Table 3).

During this initial verification on site, it is possible to make either:

— a one point adjustment, at usual working pressure for a pressure transducer and at testing temperature for a temperature transducer, in order to minimize the error at this pressure, or

— a two or multiple points adjustment, with at least testing maximal and minimal working pressure for a pressure transducer, and the specified upper and lower limits of temperature range for a temperature transducer.

This field adjustment of a transducer is possible only at ambient temperature for a pressure transducer, thus it should not have a significant corrective action on original calibration of sensor, to avoid impacts on the behaviour of the transducer in the complete temperature range. For this reason, no adjustment should be made for transducers which are found outside the metrological acceptance criteria, during the verification.

The adjustment on site of transducers should be performed with working standards, having traceability to a national or international standard.

A 3 way valve should give the possibility to test the pressure transducer, without stopping the gas delivery or venting the meter.

9 Tests of conformity

9.1 Verification of the construction requirements

The conformity tests shall be carried out according to the tests procedures presented in Tables 5 and 6, and the appropriate annexes. The test procedures describe:

— alarms operation,

— accuracy tests under reference conditions,

— performance tests under environmental influences (i.e. influence and disturbance tests as described in 8.5 and 8.6),

— metrological performance tests for transducers.

Construction requirements, as stated in Clause 6, are verified on one sample in accordance with the specifications given in A.1.

9.2 Verification of the performance requirements

9.2.1 Test conditions

The device shall meet the requirements specified in Tables 5 and 6.

Table 5 — List of relevant tests for calculator

	Equipment performance			**Environmental conditions**		
Clause	**Tests**	**Acceptance criteria**	**Timing**	**Test procedure**	**Severity level Class O (outdoor)**	**Severity level Class I (indoor)**
A.2	Accuracy	*MPE*	D	PR1	NA	NA
A.3	Ambient temperature	*MPE*	D	PR2	SL 3, 4	SL 2
A.4	Damp heat, steady-state	*MPE*	BDA	PR3	SL2	SL1
A.5	Cyclic damp heat	*MPE*	BA	PR3	SL2	SL1
A.6	Electrical power variation	*MPE*	BD	PR3	E2/SL2	E2/SL2
A.7	Short time AC power reductions	$\Delta e < MPE$	BD	PR4	E2/SL2	E2/SL2
A.8	Electrical bursts	$\Delta e < MPE$	BD	PR4	E2/SL3	E2/SL3
A.9	Electromagnetic susceptibility	$\Delta e < MPE$	BD	PR4	E2/SL3	E2/SL3
A.10	Electrostatic discharges	$\Delta e < MPE$	BD	PR4	E2/SL3	E2/SL3
A.12	Random vibrations	MPE	BA	PR3	M2/SL1	NA
A.13	Shocks	$\Delta e < MPE$	BA	PR4	M2/SL1	NA
A.15	Durability	$\Delta e < 0{,}5\ MPE$	BA	PR2	see specifications	see specifications
A.16	Alarms operation	operable	D	PR4	NA	NA
A.17	Repeatability	$\Delta e < MPE/3$	D	PR2	NA	NA
A.18	Short time DC power variations	$\Delta e \le MPE$	BD	PR4	E2/SL1	E2/SL1
A.19	Surges on supply lines and/or	$\Delta e \le MPE$	BA	PR4	E2/SL3	E2/SL3
A.20	Power frequency magnetic field	$\Delta e \le MPE$	BD	PR4	E2/SL5	E2/SL5

Test procedure: PR1, PR2, PR3, PR4 (See Annex A)

Timing: B: Before, D: During, A: After

Δe: error during over time

For the acceptance criteria, Δe needs to be compared with *MPE* given in Tables 2 and 3.

M - mechanical class

E - electromagnetic environmental class

SL - severity level for tests (see OIML D11 and appropriate IEC standards)

NA: not applicable

Table 6 — List of relevant tests for transducers

Equipment performance				Environmental conditions	
Clause	**Tests**	**Acceptance criteria**	**Timing**	**Test procedure**	**Severity level Class O (outdoor)**
A.2	Accuracy	*MPE*	D	PR1	NA
A.3	Ambient temperature	*MPE*	D	PR2	SL 3, 4
A.4	Damp heat, steady-state	*MPE*	BDA	PR3	SL2
A.5	Cyclic damp heat	*MPE*	BA	PR3	SL2
A.6	Electrical power variation	*MPE*	BD	PR3	E2/SL2
A.7	Short time AC power reductions	$\Delta e < MPE$	BD	PR4	E2/SL2
A.8	Electrical bursts	$\Delta e < MPE$	BD	PR4	E2/SL3
A.9	Electromagnetic susceptibility	$\Delta e < MPE$	BD	PR4	E2/SL3
A.10	Electrostatic discharges	$\Delta e < MPE$	BD	PR4	E2/SL3
A.11	Overload of pressure	$\Delta e < MPE$	BA	PR5	NA
A.12	Random vibrations	MPE	BA	PR3	M2/SL1
A.13	Shocks	$\Delta e < MPE$	BA	PR4	M2/SL1
A.14	Overload of pressure (mechanical)	operable	A	PR4	NA
A.15	Durability	$\Delta e < 0{,}5\ MPE$	BA	PR2	see specifications
A.16	Alarms operation	operable	D	PR4	NA
A.17	Repeatability	$\Delta e < MPE/3$	D	PR2	NA
A.18	Short time DC power variations	$\Delta e \le MPE$	BD	PR4	E2/SL1
A.19	Surges on supply lines and/or signal lines	$\Delta e \le MPE$	BA	PR4	E2/SL3
A.20	Power frequency magnetic field	$\Delta e \le MPE$	BD	PR4	E2/SL5
Test procedure: PR1, PR2, PR3, PR4 (See Annex A)					
Timing: B: Before, D: During, A: After					
Δe: error during timing For the acceptance criteria, Δe needs to be compared with *MPE* given in Table 2 and 3.					

The tests shall be performed using reference instruments traceable to national or international calibration standards. The uncertainties shall be determined, including those arising from their use, and shall not exceed one fifth of the maximum permissible errors.

The conventional true value of the compression factor shall be computed according to EN ISO 12213-3 or outside the limits of this method, with the methods described in EN ISO 12213-2. When used with first family gases, it is necessary to check this against a first family gas calculation method.

Following the type approval of a FC, any modification(s) to the device shall be validated with tests relevant to the modification(s). A complete set of tests per modification is not required.

9.2.2 Samples of FC required for testing

As a FC is composed of separate elements, each element is tested separately.

For each constituent of the conversion device (pressure or temperature transducer, temperature sensor, calculator), the specifications regarding the number of test samples and the recommended test sequence are given in the corresponding annexes (see B.5.3, C.5.3).

The calculator is considered as an element with only one variant; the requirements in Table 5 are applicable, with the exception of the testing concerning the overload of pressure which is not performed on the calculator (A.11).

For pressure and temperature transducers, “variant” refers to each different transducer, from different suppliers and/or different types. The number of samples applicable to the testing procedure shall be adapted in accordance with the characteristics of the different types of transducers or in accordance with 9.2.2 of EN 12405-1:2005+A2:2010.

10 Marking

Each conversion device shall be marked with the following information in legible characters which are permanently visible:

a) type approval mark and number;

b) identification mark or name of the manufacturer;

c) serial number of the instrument and the year of manufacture;

d) hazardous area classification of the FC, if applicable;

e) *MPE* at reference conditions.

The following indications shall also either be marked or be listed on the packaging and in the documentation:

f) base conditions in the form:

— T_b = ... K;

— p_b = ... bar;

g) extreme temperatures of the environmental class in the form:

— $t_{amb,max}$ = ... °C;

— $t_{amb,min}$ = ... °C;

h) the pressure range is according to the concerning parts certificate. If restrictions are beside, then the extreme gas pressures in the form:

— p_{max} = ... bar;

— p_{min} = ... bar;

or the maximum measuring range for pressure in the form

— $p_{max} / p_{min} \leq$ .... ;

i) the pressure range is according to the concerning parts certificate. If restrictions are beside, then the extreme gas temperatures in the form:

— T_{max} = ... °C;

— T_{min} = ... °C;

j) IP code;

k) this standard including the year of publication.

11 Installation and operating instructions

The device shall be accompanied by information in written form or electronic format in a language acceptable by the user.

Each device, or group of devices, shall be delivered with installation, operation and maintenance manuals which are easily understandable, giving appropriate instructions on:

— name and address of manufacturer;

— rated operating conditions;

— mechanical and electromagnetic environment classes;

— upper and lower temperature limit, whether condensation is possible or not;

— whether the device is suitable for use outdoors or not;

— instructions for installation, maintenance, repairs, permissible adjustments;

— estimated period of time over which the metrological characteristics of the device are maintained;

— instructions for correct operation and any special conditions of use;

— conditions for compatibility with interfaces, sub-assemblies or measuring instruments.

Groups of identical measuring instruments used in the same location or used for utility measurement do not necessarily require individual instruction manuals.

Annex A
(normative)

Type test

A.1 General conditions

A.1.1 General

The constituent elements of a FC shall be operating during all the tests. When the FC includes an error curve correction of the associated gas meter, the correction factor shall be fixed to 1 for all the tests. The meter error correction procedure shall be tested independently according to Annex D.

The input signal, which represents the volume at measurement conditions and comes from the meter with which the FC is associated, shall be simulated in accordance with the requirements of 6.6.

This volume shall be simulated so that it represents the greater of 1 000 pulses or 1 000 times the value of the least significant digit of the volume at measurement conditions. Nevertheless, for disturbance tests, this value can be increased according to the duration of the test.

For the accuracy tests, the values of p_{max}, T_{max} and p_{min}, T_{min} shall be approximated values, respectively by lower values and upper values, or the level defined for activate the alarm shall be increase to prevent the activation of the alarms, except for the specific alarm tests.

When test procedures require a test at reference conditions before the application of the influence factors or disturbances, the test under reference conditions performed at the end of the previous test can be used for that purpose.

The length of the connection cables shall be the length specified by the manufacturer. If the maximum length specified is more than 3 m, a minimum length of 3 m can be used.

The subclauses named "Reference to documents" (e.g. A.4.2, A.5.2,…) describe the applicable standards for environmental testing.

A.1.2 Additional conditions specific to FC

In addition to the specifications given in A.1.1, the constituent elements of a FC shall be tested separately as follows:

— the transducers are tested according their respective specifications given in Annexes B and C;

— the calculator is tested according this annex, with the following particular restrictions:

  — the overload tests according A.11 and A.14 are not carried out on the calculator;

  — for all tests performed, pressure and temperature values are simulated by signal inputs. The signals shall be generated using reference instruments traceable to national or international calibration standards. The uncertainties shall be determined, including those arising from their use, and shall not exceed one fifth of the maximum permissible errors.

A.1.3 Test procedures

A.1.3.1 Test procedure 1 (PR1*)*

A.1.3.1.1 Test conditions

This test procedure is applicable for the accuracy test. It is performed under reference conditions as defined in 8.1.

For the compression factor calculation, three gas compositions specified as Gas 1, Gas 3 and Gas 6 in Annex C of EN ISO 12213-2:2009 and Annex C of EN ISO 12213-3:2009 shall be used.

A.1.3.1.2 Performance of the test

A.1.3.1.2.1 General

The test consists in the determination of the error of the FC at the specified points. The error is determined on the conversion factor or on the volume at base conditions as described below.

A.1.3.1.2.2 Volume conversion

The accuracy test has to be performed at each point of Table A.1 and according to the methodical arrangement (1 to 15). In addition, the error shall be calculated on V_b for the point 8 of Table A.1. For all the other points, the error can be determined for the conversion factor *C*.

Table A.1

	p_{min}	p_2	p_3	p_4	p_{max}
T_{min}	**1 ⇒**	**2 ⇒**	**3 ⇒**	**4 ⇒**	**5 ⇓**
T	**⇓ 10**	**⇐ 9**	**⇐ 8**	**⇐ 7**	**⇐ 6**
T_{max}	**11 ⇒**	**12 ⇒**	**13 ⇒**	**14 ⇒**	**15**

where

$$T \approx \frac{T_{max} + T_{min}}{2}$$

$$p_2 \approx \frac{3p_{min} + p_{max}}{4}$$

$$p_3 \approx \frac{p_{min} + p_{max}}{2}$$

$$p_4 \approx \frac{3p_{max} + p_{min}}{4}$$

The set point of temperature and pressure shall be within ± 4 % of the calculated value.

A.1.3.2 Test procedure 2 (PR2)

The test procedure PR2 corresponds to the test procedure PR1, but carried out with one gas composition, the one for which the results of the test in A.2 are the worst, at reference conditions or rated operating conditions depending on the test.

A.1.3.3 Test procedure 3 (PR3)

The test procedure 3 is the same as procedure 2 but it has to be applied on a limited number of points (see Table A.2).

Table A.2

	p_{min}	p_{max}
T_{min}	**1 ⇒**	**2 ⇓**
T_{max}	**4 ⇐**	**⇐ 3**

The error shall be calculated on the volume at base conditions for the point 3 of Table A.2. For all the other points, the error can be determined for the conversion factor *C*.

A.1.3.4 Test procedure 4 (PR4)

The test procedure 4 is the same as procedure 2 but it has to be applied on one single point, to be chosen inside the specified field of measurement of the conversion device.

At this point the error shall be calculated on the volume at base conditions.

A.1.3.5 Test procedure 5 (PR5)

The test procedure 5 is the same as procedure 2 but has to be applied on five points (see Table A.3), corresponding to the points 6 to 10 of Table A.1. The error is determined only for the conversion factor *C*.

Table A.3

	p_{min}	p_2	p_3	p_4	p_{max}
T	**5**	**⇐ 4**	**⇐ 3**	**⇐ 2**	**⇐ 1**

A.1.4 Verification of the construction requirements

The verification of the construction requirements given in 6.1 to 6.5 is carried out by visual inspection, measurements and all relevant checks which assess conformity to the required specifications.

The compliance to 6.7 is verified through the test defined in A.16.

A.2 Accuracy tests under reference conditions

A.2.1 Objective

The objective is to verify that the instrument conforms to maximum permissible errors specified in this European Standard under reference conditions.

A.2.2 Reference to documents

Not applicable.

A.2.3 Procedure

The test procedure is the PR1 as defined in A.1.3.1.

A.2.4 Acceptance criteria

All functions shall operate as designed.

At each test point and each measurement the error shall be within the maximum permissible errors specified in 8.3 for reference conditions.

A.3 Effect of ambient temperature

A.3.1 Objective

The objective is to verify that the instrument conforms to specifications of this European Standard under conditions of ambient temperature (dry heat and cold).

A.3.2 Reference to documents

EN 60068-2-1.

EN 60068-2-2.

EN 60068-3-1.

A.3.3 Procedure

The test procedure is the PR2 as defined in A.1.3.2.

The value of the ambient temperature shall be the upper and the lower values of the environmental class as defined in 5.2.1.

A.3.4 Acceptance criteria

All functions shall operate as designed.

At each test point and each measurement the error shall be within the maximum permissible errors specified in 8.3 in the column “rated operating conditions” of Table 4, as appropriate.

A.4 Effect of damp heat, steady-state test

A.4.1 Objective

The objective is to verify that the instrument conforms to the specifications of this European Standard under conditions of high humidity and constant temperature.

A.4.2 Reference to documents

EN 60068-2-78.

A.4.3 Procedure

The test procedure is the PR3 as defined in A.1.3.3.

The test consists of an exposure to a constant temperature equal to the upper temperature of the environmental class and to a constant relative humidity of 85 % for 2 days.

The performance of the test shall be so that no condensation of water occurs on the FC.

The test procedure PR3 shall be performed three times:

— at reference conditions, before the increase of temperature;

— at the end of the upper temperature phase;

— at reference conditions, after the decrease of temperature.

A.4.4 Acceptance criteria

All functions shall operate as designed.

At each test point and each measurement, before, during and after the test, the error shall be within the maximum permissible errors specified in 8.3 for reference conditions and for rated operating conditions respectively.

A.5 Effect of damp heat, cyclic test

A.5.1 Objective

The objective is to verify that the instrument conforms to the specifications of this European Standard under conditions of cyclic damp heat.

A.5.2 Reference to documents

EN 60068-2-30.

A.5.3 Procedure

The test procedure is the PR4 as defined in A.1.3.4.

The test consists of an exposure to cyclic temperature variation between temperature at reference conditions and the upper temperature of the environmental class. During the temperature change and the low temperature phases, the humidity shall be maintained above 95 % and during the upper temperature phases, the humidity shall be maintained above 93 %.

Condensation should occur on the equipment under test during the temperature rise.

The conversion device is non-operational when the influence factor is applied.

The tests shall be performed 2 times:

— at reference conditions, before the cyclic variations;

— at reference conditions, after the cyclic variations.

A.5.4 Acceptance criteria

All functions shall operate as designed.

At each test point and each measurement, before and after the test, the error shall be within the maximum permissible errors specified in 8.3 for reference conditions.

A.6 Electrical power variation

A.6.1 Objective

The objective is to verify the compliance with the provisions of this European Standard under conditions of varying AC mains power supply, varying DC power supply.

A.6.2 Reference to documents

EN 61000-4-1 for mains power supply. Check if IEC TR 61000-2-1 and EN 61000-2-2 are needed.

A.6.3 Procedure

The test procedure is the PR3 as defined in A.1.3.3.

The test consists of exposure to power variation while the FC operates.

For AC power supply the test is performed at 4 conditions of the mains supply, according to the methodical arrangement of Table A.4 (1 to 4).

Table A.4

Condition	Frequency	Voltage
1	f_{nom}	1,10 U_{nom}
2	f_{nom}	0,85 U_{nom}
3	1,02 f_{nom}	U_{nom}
4	0,98 f_{nom}	U_{nom}

For DC power supply the voltage shall be fixed at the minimum and maximum value specified by the equipment manufacturer.

A.6.4 Acceptance criteria

All functions shall operate as designed.

At each test point and each measurement the error shall be within the maximum permissible errors specified in 8.3 for rated operating conditions.

A.7 Short time power reductions

A.7.1 Objective

The objective is to verify the compliance with the provisions of this European Standard under conditions of short time power reductions.

A.7.2 Reference to documents

EN 61000-4-11.

A.7.3 Procedure

The test procedure is the PR4 as defined in A.1.3.4.

Before the application of the disturbance, the error shall be determined.

During the test, the mains voltage shall vary as defined in the above standard. For each variation, the error shall be determined.

A.7.4 Acceptance criteria

All functions shall operate as designed.

The error determined before the application of the disturbance shall be within the *MPE* at reference conditions.

The difference between the errors registered before and during the application of the disturbance shall not exceed the maximum permissible error at reference conditions as given in 8.3.

A.8 Electrical bursts

A.8.1 Objective

The objective is to verify the compliance with the provisions of this European Standard under conditions of electrical burst on mains power supply (AC or DC) and on in/out connections for signals or commands.

A.8.2 Reference to documents

EN 61000-4-4.

A.8.3 Procedure

The test procedure is the PR4 as defined in A.1.3.4.

Before the application of the disturbance, the error shall be determined.

During the application of the disturbance, the error shall then be determined.

A.8.4 Acceptance criteria

All functions shall operate as designed.

The error determined before the application of the disturbance shall be within the *MPE* at reference conditions.

The difference between the errors registered before and during the application of the perturbation shall not exceed the maximum permissible error at reference conditions as given in 8.3.

A.9 Electromagnetic susceptibility

A.9.1 Objective

The objective is to verify the compliance with the provisions of this European Standard under conditions of electromagnetic fields.

A.9.2 Reference to documents

EN 61000-4-3.

EN 61000-4-6.

A.9.3 Procedure

The test procedure is the PR4 as defined in A.1.3.4.

Before the application of the disturbance, the error shall be determined.

During the application of the disturbance, the error shall then be determined.

A.9.4 Acceptance criteria

All functions shall operate as designed.

The error determined before the application of the disturbance shall be within the *MPE* at reference conditions.

The difference between the errors registered before and during the application of the perturbation shall not exceed the maximum permissible error at reference conditions as given in 8.3.

A.10 Electrostatic discharges

A.10.1 Objective

The objective is to verify the compliance with the provisions of this European Standard under conditions of electrostatic discharges.

A.10.2 Reference to documents

EN 61000-4-2.

A.10.3 Procedure

The test includes the paint penetration method, if appropriate. For direct discharges, the air discharge shall be used where the contact discharge method cannot be applied.

The test procedure is the PR4 as defined in A.1.3.4.

Before the application of the disturbance, the error shall be determined.

During the application of the disturbance, the error shall then be determined.

A.10.4 Acceptance criteria

After the test, all functions shall operate as designed.

The error determined before the application of the disturbance shall be within the *MPE* at reference conditions.

The difference between the errors registered before and during the application of the perturbation shall not exceed the maximum permissible error at reference conditions as given in 8.3.

A.11 Overload of pressure (only for pressure transducers)

A.11.1 Objective

The objective is to verify the compliance with the provisions of this European Standard after an overload of pressure on the pressure transducer.

A.11.2 Reference to documents

No reference to European or International Standards can be given at the moment.

A.11.3 Procedure

The test procedure is the PR5 as defined in A.1.3.5.

The errors shall be determined before and after the application of the overload of pressure.

The overload of pressure is applied to the pressure transducer in the following conditions:

— value of the overload: 1,25 times the upper value of the specified measuring range of the transducer;

— duration of application: 30 min;

— relaxation time: 30 min.

A.11.4 Acceptance criteria

All functions shall operate as designed.

The difference between the errors registered before and after the application of the disturbance shall not exceed the maximum permissible error at reference conditions as given in 8.3.

A.12 Effect of vibrations

A.12.1 Objective

The objective is to verify the compliance of transducers with the provisions of this European Standard under conditions of random vibrations.

A.12.2 Reference to documents

EN 60068-2-64.

A.12.3 Procedure

The test procedure is the PR3 as defined in A.1.3.3.

The conversion device is non-operational when the influence factor is applied.

The tests shall be performed 2 times:

— at reference conditions, before the application of the vibrations;

— at reference conditions, after the application of the vibrations.

A.12.4 Acceptance criteria

All functions shall operate as designed.

At each test point and each measurement, before and after the test, the error shall be within the maximum permissible errors specified in 8.3 for reference conditions.

A.13 Effect of shocks

A.13.1 Objective

The objective is to verify the compliance of transducers with the provisions of this European standard under conditions of shocks.

A.13.2 Reference to documents

EN 60068-2-31.

A.13.3 Procedure

The test procedure is the PR4 as defined in A.1.3.4.

The tests shall be performed 2 times:

— at reference conditions, before the application of the shocks;

— at reference conditions, after the application of the shocks.

A.13.4 Acceptance criteria

After the test, all functions shall operate as designed.

At each test point and each measurement, before and after the test, the error shall be within the maximum permissible errors specified in 8.3 for reference conditions.

A.14 Overload of pressure (mechanical) (only for pressure transducer)

A.14.1 Objective

The objective is to verify that the instrument can resist to an overload of pressure without being destroyed.

A.14.2 Reference to documents

No reference to European or International Standards can be given at the moment.

A.14.3 Procedure

The test consists on exposing the pressure transducer to an overload of pressure, according Table A.5, during 15 min.

Table A.5

Maximum operating pressure of the network ***MOP*** **(bar)**	**Test pressure (bar) greater than**
$MOP > 40$	1,15 *MOP*
$16 < MOP \leq 40$	1,20 *MOP*
$5 < MOP \leq 16$	1,30 *MOP*
$2 < MOP \leq 5$	1,40 *MOP*
$0,1 < MOP \leq 2$	1,75 *MOP*
$MOP \leq 0,1$	2,50 *MOP*

A.14.4 Acceptance criteria

Following the test, a leakage test shall be performed to check that the pressure containing part of the pressure transducer has not breached.

A.15 Durability

A.15.1 Objective

The objective is to simulate an ageing of the instrument and to verify that the instrument conforms to specifications of this European Standard over a period of use.

A.15.2 Reference to documents

No reference to European or International Standards can be given at the moment.

A.15.3 Procedure

First, the test procedure PR2 shall be performed under reference conditions as specified in A.1.3.2.

Then, the FC shall be exposed to cyclic variations of ambient temperature between the minimum and the maximum temperatures of the environmental class.

The variations of ambient temperature are defined as following:

— definition of the cycle: the instrument is exposed to the maximum temperature of the environmental class during 1 week, then to the minimum temperature of the environmental class during 1 week;

— number of cycles: 2 cycles;

— total test duration: 4 weeks.

The variations between the maximum and the minimum ambient temperatures shall be performed by steps of $10\ K \cdot h^{-1}$.

After a stabilization of 24 h at reference conditions, the test procedure PR2 shall be performed again.

A.15.4 Acceptance criteria

All functions shall operate as designed.

At each test point and each measurement, the absolute value of the difference between the error before the durability test and the error after the durability test shall not exceed 0,5 of the maximum permissible error at reference conditions.

A.16 Alarms operation

A.16.1 Objective

The objective is to simulate a situation where each of the characteristic quantities of the conversion device in turn goes outside its specified field of measurement (specified measurement range) and to verify that the alarms operate in accordance with the relevant specifications of this European Standard.

A.16.2 Reference to documents

No reference to European or International Standards can be given at the moment.

A.16.3 Procedure

The test consists in reaching the set points (limits of the specified measurement ranges) by increasing then decreasing the chosen parameter, in order to verify the operation of the alarms and the correct resetting of the calculator back to its normal operation as soon as the value of the chosen parameter comes back in its declared operating range. The incrementation of the calculator shall be stopped as long as one parameter is in an alarm state and that the incrementation restarts when the cause of the alarm has been eliminated.

A.16.4 Acceptance criteria

All alarms have to be completely checked: nature, date, hours of the beginning and end of the alarm.

It is verified that the calculator is provided with a device to allow to detect and put in evidence the alarms. This alarm indication shall remain in operation till the intervention of an authorized person (code, keyboard, …).

A.17 Repeatability

A.17.1 Objective

The objective is to verify that the results of the application of the same measurand under the same conditions of measurement are in close agreement.

A.17.2 Reference to standards

No reference to European or International Standards can be given at the moment.

A.17.3 Procedure

The test consists in carrying six successive measurements with one gas during the accuracy test, at p_{min} and $T \approx \frac{T_{max} + T_{min}}{2}$.

The test procedure is the PR2 as defined in A.1.3.2.

A.17.4 Acceptance criteria

The difference between the results of six successive measurements shall not exceed one third of *MPE* at reference conditions.

A.18 Short time DC power variations

A.18.1 Objective

The objective is to verify the compliance with the provisions of this European Standard under conditions of short time DC power variations.

A.18.2 Reference to standards

EN 61000-4-29.

A.18.3 Procedure

The test procedure is the PR4 as defined in A.1.3.4.

Before the application of the disturbance, the error shall be determined.

During the test, the mains voltage shall vary as defined in the above standard. For each variation, the error shall be determined.

A.18.4 Acceptance criteria

All functions shall operate as designed.

The error determined before the application of the disturbance shall be within the *MPE* at reference conditions as given in 8.3.

The difference between the errors registered before and during the application of the disturbance shall not exceed the *MPE* at reference conditions.

A.19 Surges on supply lines and/or signal lines

A.19.1 Objective

The objective is to verify the compliance with the provisions of this European Standard under conditions of electrical surges on AC/DC main supply, signal and communication lines.

A.19.2 Reference to standards

EN 61000-4-5.

A.19.3 Procedure

The test procedure is the PR4 as defined in A.1.3.4.

Before the application of the disturbance, the error shall be determined.

During the test, the surges are applied as defined in the above standard. After the test, the error shall be determined.

A.19.4 Acceptance criteria

All functions shall operate as designed.

The error determined before the application of the disturbance shall be within the *MPE* at reference conditions as given in 8.3.

The difference between the errors registered before and after the application of the disturbance shall not exceed the *MPE* at reference conditions.

A.20 Power frequency magnetic field

A.20.1 Objective

The objective is to verify the compliance with the provisions of this European Standard under conditions of a significant influence of the power magnetic field.

A.20.2 Reference to standards

EN 61000-4-8.

A.20.3 Procedure

The test procedure is the PR4 as defined in A.1.3.4.

Before the application of the disturbance, the error shall be determined.

During the test, the power frequency magnetic field (50 Hz or 60 Hz) is generated as defined in the above standard. For each disturbance, the error shall be determined.

A.20.4 Acceptance criteria

All functions shall operate as designed.

The error determined before the application of the disturbance shall be within the *MPE* at reference conditions as given in 8.3.

The difference between the errors registered before and during the application of the disturbance shall not exceed the *MPE* at reference conditions.

Annex B
(normative)

Pressure transducers

B.1 Scope

This annex specifies the requirements and tests for the construction, performances, safety and conformity of the pressure transducers associated to FCs.

Any pressure transducer may include a correction relative to temperature.

A pressure transducer may be fitted with a setting device to adjust the specified measurement range.

B.2 Rated operating conditions

B.2.1 Specified measurement range for pressure

The measurement range of the pressure transducer shall be specified by the manufacturer, in accordance with 5.1.2.

B.2.2 Environmental class

The transducer shall comply with the requirements as per 5.2.1 and 5.2.2.

B.2.3 Power supply

The power supply conditions are those given in 5.3.

B.3 Construction requirements

B.3.1 General

The relevant requirements are those given in 6.1.

In addition, the transducer shall be sealed in such a way that the sensor element cannot be changed without breaking the sealing.

If the pressure transducer is fitted with a setting device to adjust the specified pressure range, this shall be sealed.

B.3.2 Casings

The relevant requirements are those given in 6.4.

B.3.3 Indications

B.3.3.1 General

B.3.3.1.1 If the pressure transducer is provided with an indicator, it shall indicate at least the measured gas pressure in the measurement conditions.

This indicator is not intended to be used for metrological purposes. As such, it shall bear a legend clearly visible to the user, to indicate that it is not controlled when it gives a measurement result visible to the user.

B.3.3.1.2 The identification and the unit of each value or parameter that can be indicated shall be clearly displayed next to or upon the display of the measured value.

B.3.3.1.3 The scale interval of the pressure shall be of the form 10^n units of pressure (n whole number, positive or negative). The value of the scale interval shall be clearly stated close to the main value display.

B.3.3.2 Electronic indicating device

B.3.3.2.1 The device indicating the measured pressure shall be provided with means of control to ensure that the display is operating correctly.

B.3.3.2.2 The minimum height of the numerals for the display shall be 4 mm and the minimum width 2,4 mm.

B.3.3.2.3 It shall be possible to read the index clearly and correctly within an angle of 15° from normal to the window, within the ambient temperature range.

B.3.3.2.4 When all the digits of the indicating device are not used for the indication of the pressure, every unused digit to the left of the significant digit shall indicate zero.

B.4 Performances

B.4.1 Reference conditions

Reference conditions are those given in 8.1.

B.4.2 Rated operating conditions

See B.2.

B.4.3 Maximum permissible errors

The maximum permissible errors applicable to pressure are specified in Table 4 in 8.3.1.

B.4.4 Influence factors

The influence factors are those given in 8.5.

For each influence factor, the pressure transducer shall comply with the *MPE* requirements at rated operating conditions, as given in Table 4.

B.4.5 Disturbances

Disturbances are those given in 8.6.

The difference between the errors registered before, during or after the application of the disturbance shall not exceed 0,5 *MPE* at reference conditions, as given in Table 4.

B.4.6 Durability

After a period of use corresponding to an accelerated ageing, as defined in A.15, the deviation between errors before and after ageing shall be lower than or equal to 0,5 *MPE* as given in Table 4.

B.5 Tests of conformity

B.5.1 Test conditions

The tests shall be performed using reference instruments traceable to national or international calibration standards where the uncertainties are known, including those arising from their use, and do not exceed one fifth of the maximum permissible errors.

B.5.2 Tests

The list of the relevant tests is the one given as Table 5, with the following modification: test A.2 is performed with any test gas (only one gas), at three different temperatures (T_{min}, T_{max}, $T_{at\ reference\ conditions}$).

Following the type approval, any modification to the pressure transducer shall be validated with significant tests relevant to the modification. A complete set of tests per modification is not required.

B.5.3 Sample of pressure transducers required for testing

For one presented variant of the pressure transducer, the conformity tests as per B.5.2 shall be carried out on the number of samples and following the chronology as defined in 9.2.2.

If the number of variant (N) is higher or equal to 2, the number of samples and the corresponding chronology applicable to the testing procedure should be adapted as stated in 9.2.2. Nevertheless, according to the differences from a variant to another, the testing procedure may be simplified.

Each pressure transducer tested shall comply with the performance requirements specified in B.4.

B.6 Marking

Each pressure transducer shall be permanently marked at least with the following information, in legible and visible characters:

a) the type approval mark and number (if appropriate);

b) the identification mark or name of the manufacturer;

c) the serial number of the instrument and the year of manufacture;

d) the transducer denomination;

e) the adjusted specified measurement range (pressure, temperature if appropriate);

f) the static operating rated pressure;

g) the extreme temperatures of the environmental class in the form:

— $t_{amb,max}$ = ... °C;

— $t_{amb,min}$ = ... °C ;

h) the hazardous area classification of the pressure transducer, if applicable;

i) an indication of the reference to EN 12405-3.

Annex C
(normative)

Temperature transducers

C.1 Scope

This annex specifies the requirements and tests for the construction, performances, safety and conformity of the temperature transducers associated to FCs.

A temperature transducer may be fitted with a setting device to adjust the specified measurement range.

C.2 Rated operating conditions

C.2.1 Specified measurement range for temperature

The measurement range of the temperature transducer shall be specified by the manufacturer, in accordance with 5.1.3.

C.2.2 Environmental class

The transducer shall comply with the requirements as per 5.2.1 and 5.2.2.

C.2.3 Power supply

The power supply conditions are those given in 5.3.

C.3 Construction requirements

C.3.1 General

The relevant requirements are those given in 6.1.

In addition, the transducer shall be sealed in such a way that the sensor element cannot be changed without breaking the sealing.

If the temperature transducer is fitted with a setting device to adjust the specified temperature range, this shall be sealed.

C.3.2 Casings

The relevant requirements are those given in 6.4.

C.3.3 Indications

C.3.3.1 General

C.3.3.1.1 If the temperature transducer is provided with an indicator, it shall indicate at least the measured gas temperature in the measurement conditions.

This indicator is not intended to be used for metrological purposes. As such, it shall bear a legend clearly visible to the user, to indicate that it is not controlled when it gives a measurement result visible to the user.

C.3.3.1.2 The identification and the unit of each value or parameter that can be indicated shall be clearly displayed next to or upon the display of the measured value.

C.3.3.1.3 The scale interval of the temperature shall be of the form 10^n units of temperature (n whole number, positive or negative). The value of the scale interval shall be clearly stated close to the main value display.

C.3.3.2 Electronic indicating device

C.3.3.2.1 The device indicating the measured temperature shall be provided with means of control to ensure that the display is operating correctly.

C.3.3.2.2 The minimum height of the numerals for the display shall be 4 mm and the minimum width 2,4 mm.

C.3.3.2.3 It shall be possible to read the index clearly and correctly within an angle of 15° from normal to the window, within the ambient temperature range.

C.4 Performances

C.4.1 Reference conditions

Reference conditions are those given in 8.1.

C.4.2 Rated operating conditions

See C.2.

C.4.3 Maximum permissible errors

The maximum permissible errors applicable to temperature are specified in Table 4.

C.4.4 Influence factors

The influence factors are those given in 8.5.

For each influence factor, the temperature transducer shall comply with the *MPE* requirements at rated operating conditions, as given in Table 4.

C.4.5 Disturbances

Disturbances are those given in 8.6.

The difference between the errors registered before, during or after the application of the disturbance shall not exceed 0,5 *MPE* at reference conditions, as given in Table 4.

C.4.6 Durability

After a period of use corresponding to an accelerated ageing, as defined in A.15, the deviation between errors before and after ageing shall be lower than or equal to 0,5 *MPE* as given in Table 4.

C.5 Tests of conformity

C.5.1 Test conditions

The tests shall be performed using reference instruments traceable to national or international calibration standards where the uncertainties are known, including those arising from their use, and do not exceed one fifth of the maximum permissible errors.

C.5.2 Tests

The list of the relevant tests is the one given as Table 5, with the exception of overload tests (A.11 and A.14) which are not performed on the temperature transducers.

Following the type approval, any modification to the temperature transducer shall be validated with significant tests relevant to the modification. A complete set of tests per modification is not required.

C.5.3 Sample of temperature transducers required for testing

For one presented variant of the temperature transducer, the conformity tests as per C.5.2 shall be carried out on the number of samples and following the chronology as defined in Table 6.

NOTE For the meaning of “variant”, see 9.2.2.

If the number of variant (N) is higher or equal to 2, the number of samples and the corresponding chronology applicable to the testing procedure should be adapted as stated in 9.2.2. Nevertheless, according to the differences from a variant to another, the testing procedure may be simplified.

Each temperature transducer tested shall comply with the performance requirements specified in C.4.

C.6 Marking

Each temperature transducer shall be permanently marked at least with the following information, in legible and visible characters:

a) the type approval mark and number (if appropriate);

b) the identification mark or name of the manufacturer;

c) the serial number of the instrument and the year of manufacture;

d) the transducer denomination;

e) the adjusted specified measurement range;

f) the operating rated temperature;

g) the extreme temperatures of the environmental class in the form:

— $t_{amb,max}$ = ... °C;

— $t_{amb,min}$ = ... °C ;

h) the hazardous area classification of the temperature transducer, if applicable;

i) an indication of the reference to EN 12405-3.

Annex D
(normative)

Requirements and testing of meter error correction

D.1 General

The verification of the error correction procedure implemented in FC is based on gradual verification of the successive calculation steps. It is carried out by comparison between the results obtained by the FC under the test and the adequate results obtained by reference laboratory equipment/computers. To make such verification possible, the FC manufacturer shall provide access to all parameters subjected to verification and also provide satisfactory resolution of the results/data reading.

D.2 Verification of the volumetric flow rate determination

Frequency of the impulses, which may be simulated during the verification, shall be calculated according to formula:

$$f = Q/k \ [\mathrm{h}^{-1}]$$

where

Q volumetric flow rate [m^3/h];

k gas meter weight of one impulse [m^3].

The verification shall be carried out for at least 2 values of frequency, calculated according to the above formula, for the gas meter flow rates: $Q = Q_{min}$ and $Q = Q_{max}$.

During the test, the value of frequency shall remain constant.

The impulses shall be created by a standard generator of uncertainty not higher than ± 0,01 % of the value.

The flow rate verification shall be done by a comparison of the flow rate indications of the FC under the test, with the flow rate values obtained from calculations of $Q = fxk$ for the actual frequency f generated during the tests.

The difference of the flow rate value displayed and the value calculated on the basis of generated frequency, shall not exceed 0,1 % of the value.

It is required to verify the FC behaviour when the frequency generated is lower than the frequency value adequate to Q_{min} and higher than the value adequate to Q_{max}.

The FC shall generate an alarm according to 6.7.

D.3 Verification of the gas density calculation procedure

Verification of the gas density, ρ, calculations shall be done by the comparison of the calculation results obtained by the FC under the test and by a reference laboratory computer using EN ISO 6976. Verification of the gas compressibility factor procedures shall be done according to procedures and examples of calculations included in EN ISO 12213.

The verification of the software implemented in FC under test shall be carried out for at least one set of gas composition, pressure and temperature.

The input signals of the above mentioned parameters can be created by the regularly used gas analysers and *p* and *t* transducers, or by reference laboratory apparatus simulating appropriate input signals. In both cases, it is important to note that the values of all input parameters (gas composition, pressure and temperature) displayed by FC shall be treated as an input data for reference density calculations.

Values of the density displayed by the FC under the test and by reference computer shall differ no more than 0,01 % of the reference value.

D.4 Verification of the gas viscosity calculation procedures

Verification of the gas viscosity, μ, calculation procedure shall be done by the comparison of the calculation results obtained by the FC under the test and by a reference laboratory computer. The FC under the test and the reference laboratory computer should apply the same calculation software implementing a method for the viscosity calculation (see [11] and [12]).

The verification of the software implemented in FC under the test shall be carried out for at least one gas composition, pressure and temperature.

The input signals of the above mentioned parameters can be created by the regularly used gas analysers and *p* and *t* transducers, or by reference laboratory apparatus simulating appropriate input signals. In both cases, it is important to note that the values of all input parameters (gas composition, pressure and temperature) displayed by FC shall be treated as inputs for viscosity calculations. Verification shall be done by performing gas viscosity calculations for the same input values when using reference laboratory computer.

The values of viscosity displayed by the FC under the test and by reference computer shall differ no more than 0,01 % of the reference value.

D.5 Verification of the error transposition from $e(Q_i)$ to $e(Re_i)$

As a result of a gas meter pressure calibration, the following data shall be provided:

— table of errors being a function of flow rate $e(Q_i)$, according to international standards,

— gas composition of the gas at each condition "i" used during calibration,

— temperature and pressure during each point "i" .

If the calibration is carried out at two values of pressure, the set of data specified above shall be repeated separately for each value of pressure.

The data presented above shall be used, for transposition from $e(Q_i)$ to $e(Re_i)$, according to calculation specification presented in 4.2. If the transposition from $e(Q_i)$ to $e(Re_i)$ is performed automatically by the FC under the test, then the values of Re obtained at each point "i" should be compared with adequate reference *Re* value for the same "i". The reference *Re* number values for each "i" should be calculated by reference laboratory computer with implemented reference software for the gas density and viscosity calculations.

Values of *Re*, obtained for each point "i" by the FC under the test and by the reference laboratory computer, shall not differ more than 0,01 % of the reference value.

D.6 Verification of the error function *δ(Q)* or *δ(Re)* interpolation or approximation

The verification of the interpolation or approximation of the error function *δ(Q)* or *δ(Re)* in the sections between the "i" points should be done by an inspection using a graph with of the error results obtained during the calibration together with the plots of the error function.

The error function *δ(Q)* or *δ(Re)* should not create inadequate peaks between the "i" calibration point results.

D.7 Verification of correction factor *F(Q)* or *F(Re)*, corrected flow rate and corrected volume determination

The error correction procedure implemented in FC under the test shall be tested by a comparison of at least the following output values: correction factor *F(Q)* or *F(Re)*, corrected flow rate and corrected volume, both in measuring conditions, compared to the results of the same values obtained by the reference laboratory computations.

The input values used by the reference laboratory computations shall be the same as those obtained during the FC tests. To reach this condition, the errors of A/D conversion shall be excluded. The input values shall be read with sufficient resolution.

The difference between output values obtained from FC under a test and from reference laboratory computations shall not exceed ± 0,01 %.

D.8 Verification of the activation and deactivation of error correction calculations on limits of its application

D.8.1 with error correction based on flow rate *Q* calibration

Verification of the error correction procedure implemented in the FC, shall be carried out by changing frequency of input simulating gas meter pulses.

For frequencies of pulses below and above the frequencies adequate to Q_1 and Q_n the error correction should be stopped by accepting that $F(Q) = 1$. It is recommended to verify if pressure of measurements p fulfils the following requirement:

$$0.9\ p_{test} < p < 1.1\ p_{test}$$

D.8.2 with error correction based on Re calibration

The verification of the error correction procedure based on *Re* calibration, should be carried out by changing frequency of the input signals simulating gas meter pulses in the whole range of applicable frequencies, with different pressure and temperature transducer input signals.

The pressure and temperature should be chosen arbitrary but remain constant during the test run. It is recommended to use at least one value of pressure from each of following pressure ranges: $p_{test} < P < 2\ p_{test}$ and $0,5\ p_{test} < P < p_{test}$.

For the calculation for the reference Reynolds number, the pressure and temperature values used are those displayed on the FC.

The error correction procedure shall be applied only within its application range as specified in 4.2.2.5.

Outside this range, the error correction shall be suspended by acceptance of the assumption that $F(Re) = 1$.

Annex E
(informative)

Range of application of meter error correction with functions: *e(Q)* or *e (Re)*

E.1 General

Annex E provides an outline of the application range of meter error correction. It is not intended to be used as a definitive method, only as guidance. It should not be considered as exhaustive as other statements or methods can be applied.

E.2 Range of application

In case of turbine meters, EN 12261 defines the criteria to fulfil the validity of the calibration at p_{test} i.e. “Meters meeting the requirements for Error of Indication, Linearity and Weighed Mean Error (WME) are deemed to perform within their metrological characteristics within the working pressure range $0{,}5 \times p_{test} \le p_{op} \le 2 \times p_{test}$”

Nevertheless, it is not possible to assume that the turbine error curve $\delta(Q)$, obtained during calibration at p_{test}, can be applied to correct the error at any flow rate between Q_{min} and Q_{max}, at P_{op} different of P_{test}.

The recommendations summarized in Table E.1. can also be taken into account for ultrasonic meter correction curve, unless the correction curve is included in the meter itself.

Table E.1 — Gas flow meters (turbines and ultrasonic) - error correction

CONDITIONS	RECOMMENDATION	METHOD TO APPLY
p_{op} constant = p_{test}	Flow correction curve *e(Q)*; Range $0{,}9 \times p_{test} \le p_{op} \le 1{,}1 \times p_{test}$	Within calibration range: — Polynomial adjustment; — Piecewise linearization Outside calibration range: • For $Q_{op} > Q_n$ = Error at Q_n • For $Q_{op} < Q_1$ = Error at Q_1
p_{op} variable; one or two p_{test}	Re correction curve *e(Re)*; Range $0{,}5 \times p_{test} \le p_{op} \le 2 \times p_{test}$ Range $Q_{min} \le Q_{op} \le Q_{max}$ Range $Re_1 \le Re_{op} \le Re_n$	Within calibration range: — Polynomial adjustment; — Piecewise linearization Outside calibration range: • For $Re_{op} > Re_n$ = Error at Re_n with conditions • For $Re_{op} < Re_1$ = no correction

E.3 Example for turbine meters working at p_{op} nearly constant

In Regulation and Measurement Stations (RMS), used in Delivery Points or City Gates, p_{op} is usually nearly constant and the meters should be calibrated at $p_{test} = p_{op}$. In that case correction with $\delta(Q)$ is recommended, and the range of application should be enough to cover the normal variation of pressures around P_{op}. The range $0{,}9 \times P_{test} \leq P_{op} \leq 1{,}1 \times P_{test}$ is acceptable.

Special care should be taken when the difference between p_{test} and p_{op} is higher than 10 % p_{test}. For example, if a meter is calibrated in a laboratory at p_{test} = 20 bar and the RMS has a nominal p_{op} of 16 bar, the correction with $\delta(Q)$ at that pressure is not recommended.

NOTE In RMS, p_{op} is usually limited by the maximum set pressure controlled by safety valves, to avoid high pressure downstream of the RMS (legal/regulated requirements).

For example, in RMS operating nominally at 16 bar (meters usually are calibrated at the same pressure), the maximum allowed pressure is 17,5 bar (approximately 10 % higher).

Generally, the minimum pressure does not have a fixed value. In some cases, the station has more than one measurement line, and regulating valves adjust a minimum pressure automatically.

As seen below in real-time with a turbine meter in a RMS operating within a range of 14,5 – 17,5 bar (g). The pressure range is kept by the pressure regulators:

Table E.2 — Turbine

CALIBRATION RESULTS AT P_{test} = 16 bar		
Qi (m³/h)	*Re*	Error (%)
1000	2.703E+06	−0,36
700	1.892E+06	−0,19
400	1.081E+06	−0,18
250	6.756E+05	−0,07
100	2.703E+05	0,16
50	1.351E+05	0,00

Q_{max}: 1,000 m^3/h

Q_{min}: 50 m^3/h

p_{test} 16 bar (g)

T_{test} 18 °C

DN 150

In this calibration results, $Q_1 = Q_{min}$ and $Q_n = Q_{max}$, and

$Re_n = 2{,}703 \cdot 10^6$

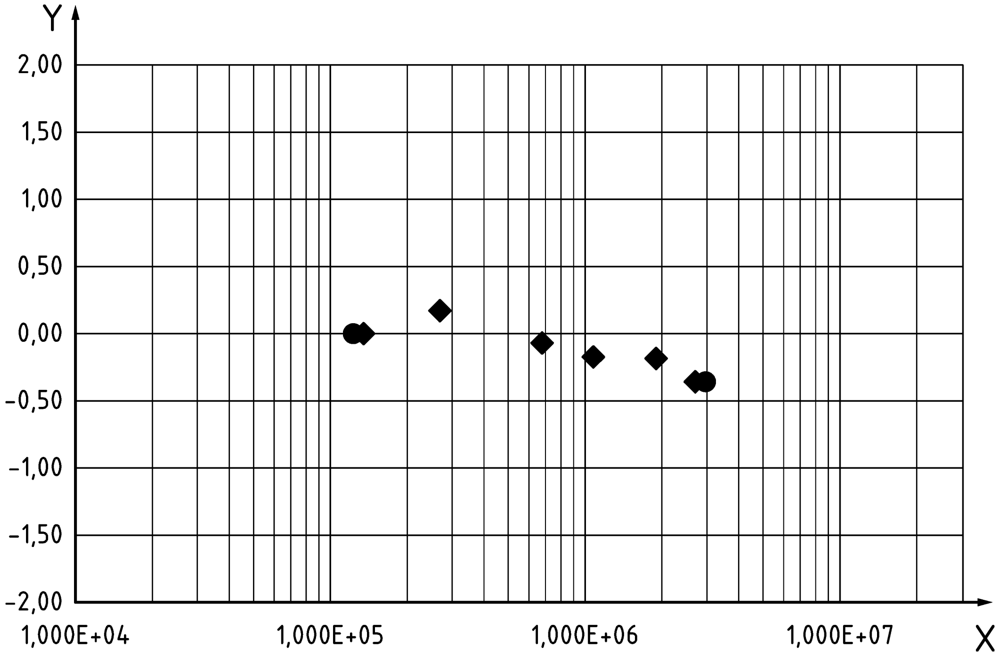
$Re_1 = 1{,}351 \cdot 10^5$

Calculations for similar gas composition (density and viscosity) and temperature, in the same range of usual operation pressures, give the following values:

Re_{op}, at Q_{max} 17,5 bar = $2{,}946 \cdot 10^6$ $> Re_n$ (9 % higher)

Re_{op}, at Q_{min} 14,5 bar = $1{,}230 \cdot 10^5$ $< Re_1$ (9 % lower)

Within the real operation range, the values of *Re* in calibration are exceeded by about 9 % but, as can be seen in Figure E.1, it is reasonable to assume that the real errors of the turbine meter over the limits are quite similar to the limit values obtained during the calibration.



Key

X: Re_{op}

Y: Error (%)

Figure E.1 —Turbine, Q_{max} 1000 m³/h (DN150), p_{test} = 16 bar

The two round points correspond to the assumed errors at extrapolated *Re* (values in Table E.2 and following data).

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