Gasunie Technical Standard

Design Specification Systems

OSS-20-E

Functional requirements for fiscal metering systems

External

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N.V. Nederlandse Gasunie

Gasunie Technical Standard

Design Specification Systems
OSS-20-E

Functional requirements for fiscal metering systems

This specification is drawn up by the Gasunie department
"Gasunie Transport Services; Assets - Assetbeleid en uitvoering"
(Gasunie Transport Services; Assets - Asset policy and execution)

Issued by Gasunie department "Document Support".

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FOREWORD

This specification supersedes OSM-20-E, version 2.

OSM-20-E ("Functional requirements for fiscal metering systems") is a function specification and is therefore converted from Design Specification Instrumentation (OSM) to Design Specification Systems (OSS).

The content of this version has not changed from the previous version of OSM-20-E, version 2, 04-02-2019.

CONTENTS

1. SCOPE AND APPLICATION

1.1 Scope

This specification applies to fiscal metering systems of parties connected to the gas network of Gasunie Transport Services (GTS). These parties are: producers, storage and LNG operators and Transmission System Operators (TSOs) at border points.

1.2 Application

Natural gas in the Netherlands is transported between entry and exit points. At these points accountable measurements are needed for billing purposes. There is a set of minimum requirements that newly build or renovated metering systems of parties connected to the GTS network shall comply with, before the metering system can be used for the purpose of custody transfer of gas.

This document describes the minimum requirements to which the measuring equipment, calibration equipment, calibration materials, calibration procedures, and maintenance procedures shall comply. These requirements include the accompanying allowed uncertainty and data handling.
Final details concerning above-mentioned items shall be agreed upon by the Gasunie department "Gasunie Transport Services; Metering & Allocation" and established in the Metering Manual.

2. REFERENCES

This specification is subject to the requirements of the documents mentioned in this clause.
If the documents in this specification are mentioned with a date, this specific edition is applicable.

OIML R137	Gas meters Part 1: Requirements
Network Code	ENTSOG Network Code Interoperability and Data Exchange Rules
Invoedvoorwaarden	ACM - Codes energie Invoedvoorwaarden Gas - LNB

2.1 Gasunie specifications

Reference is made in this specification to the following Gasunie specifications:

MSM-44-E	Offline fiscal data delivery to Gasunie Transport Services
MSM-15-E	Near-real-time data delivery to Gasunie Transport Services for energy data and quality data.

2.2 Standards

Reference is made in this specification to the standards[1] mentioned in this sub clause. Any supplements and errata notices are also applicable.

ISO 7870-1	Control charts; part 1: General guidelines
ISO 7870-4	Control charts; part 4: Cumulative sum charts.
NEN-EN 1776	Gas infrastructure - Gas measuring systems - Functional requirements.
NEN-EN 12261	Gas meters - Turbine gas meters.
NEN-EN 12405-1	Gas meters - Conversion devices - Part 1: Volume conversion.
NEN-EN 12405-2	Gas meters - Conversion devices - Part 2: Energy conversion.
NEN-EN 12405-3	Gas meters - Conversion devices - Part 3: Flow computer.
NEN-EN-ISO 6974-1	Natural gas - Determination of composition and associated uncertainty by gas chromatography - Part 1: General guidelines and calculation of composition.
NEN-EN-ISO 6974-2	Natural gas - Determination of composition and associated uncertainty by gas chromatography - Part 2: Uncertainty calculations.

[1] Applicable for all NEN-EN standards: Depending on the country where the standard will be applied, DIN-EN or BS EN, for example, shall be chosen.

NEN-EN-ISO 6974-3	Natural gas - Determination of composition with defined uncertainty by gas chromatography - Part 3: Determination of hydrogen, helium, oxygen, nitrogen, carbon dioxide and hydrocarbons up to C8 using two packed columns.
NEN-EN-ISO 6974-4	Natural gas - Determination of composition with defined uncertainty by gas chromatography - Part 4: Determination of nitrogen, carbon dioxide and C1 to C5 and C6+ hydrocarbons for a laboratory and on-line measuring system using two columns.
NEN-EN-ISO 6974-5	Natural gas - Determination of composition and associated uncertainty by gas chromatography - Part 5: Isothermal method for nitrogen, carbon dioxide, C1 to C5 hydrocarbons and C6+ hydrocarbons.
NEN-EN-ISO 6974-6	Natural gas - Determination of composition with defined uncertainty by gas chromatography - Part 6: Determination of hydrogen, helium, oxygen, nitrogen, carbon dioxide and C1 to C8 hydrocarbons using three capillary columns.
NEN-EN-ISO 6976	Natural gas - Calculation of calorific values, density, relative density and Wobbe indices from composition.
NEN-EN-ISO 10715	Natural gas -- Sampling guide lines.
NEN-EN-ISO 10723	Natural gas - Performance evaluation for analytical systems.
NEN-EN-ISO 12213-1	Natural gas – Calculation of compression factor; Part 1: Introduction and guidelines.
NEN-EN-ISO 12213-2	Natural gas – Calculation of compression factor; Part 2: Calculation using molar-composition analysis.
NEN-EN-ISO 12213-3	Natural gas – Calculation of compression factor; Part 3: Calculation using physical properties.
NEN-EN-ISO/IEC 17025	General requirements for the competence of testing and calibration laboratories.
NEN-ISO 17089-1	Measurement of fluid flow in closed conduits - Ultrasonic meters for gas; part 1: Meters for custody transfer and allocation measurement.

3. DEFINITIONS, ABBREVIATIONS AND SYMBOLS

3.1 Definitions

In this specification the following definitions are applicable:

Measuring installation	An installation comprising all the equipment including the inlet and outlet pipework as far as the isolating valves and any structure within which the equipment is housed, used for gas measurement and energy determination in custody transfer.
Metering system	A system encloses all components at the measuring installation and the corresponding (remote) data handling systems, needed for the determination of energy amounts for billing purposes or controlling of other contract parameters.
Flow measuring system	A system comprising of a gas flow meter including the equipment necessary for converting the flow at operational conditions to a flow at normal conditions.
Data handling	The handling of measuring data needed for on-line allocation and off-line allocation. *Note:* *Telemetry data (GTS dispatching centre) and other operational data is not included.*
Connected party	The party to which the metering system connected to the GTS network, belongs and who is responsible for the metering system.
Accountable data	The approved measuring and allocation data, which the connected party has sent to GTS, after it has been verified, corrected (if required) and approved.

Note:
The definitions in this specification comply with the ISO/CEI GUIDE 99 (see documentation 1).

3.2 Abbreviations

In this specification the following abbreviations are applicable:

BIPM	International bureau for Weight and Measures
CUSUM	Cumulated Sum (of systematic errors)
FC	Flow conditioner
GC	Gas Chromatograph
GCA	Grid Connection Agreement
GTS	Gasunie Transport Services
ISO	International Standardisation Organisation
LNG	Liquified Natural Gas
MID	Measuring Instruments Directive
MPD	Maximum Permissible Deviation
MPE	Maximum Permissible Error
OIML	International Organisation for Legal Metrology
P&ID	Piping and instrumentation diagram

PFD	Process flow diagram
SL	Significance Level
SOS	Speed of Sound
TM	Turbine gas meter
TSO	Transmission System Operator
US	Ultrasonic
USM	Ultrasonic gas meter
VIM	International vocabulary of metrology
VPN	Virtual Private Network
XML	Extensible Mark-up Language

3.3 Symbols

In this specification the following symbols are applicable:

Symbol	Description	Unit
E	Energy	kWh
f	influencing factor	1
$H_{s,\mathrm{n}}$	Superior Heating value under normal conditions[2]	kWh/m^3 (n)
k	threshold value	1
V_n	normalised volume	m^3 (n)
V	Actual volume (under operational conditions)	m^3
V_c	Actual volume corrected for the error curve of the gas meter	m^3
P	Absolute pressure	bar (abs)
s	Standard deviation	1
S^+	cusum quantity for the detection of persistent deviations with a positive sign	1
S^-	cusum quantity for the detection of persistent deviations with the negative sign	1
SL_comp	Significance Level of a component of the measuring system	1
SL_system	Significance Level of the measuring system	1
T	Thermodynamic temperature	K
pc	Period of calibration	1
t	Temperature	°C
Z	Compression factor	1
Z_n	Compression factor at normalised conditions	1

[2] The reference conditions for volume shall be 0 °C and 1,01325 bar (abs). For superior heating value and energy the default combustion reference temperature shall be 25 °C.

4. REQUIREMENTS

4.1 Total metering system

A total metering system connected to the GTS network shall comply with the international accepted standards and the national legislation for energy determination. The connected party shall inform GTS about the design of a newly build or renovated measuring installation by sending in due time the P&IDs and PFDs. GTS will respond to these documents within a month. The construction work on the measuring installation shall be started only after GTS has authorised the design. The metering manual shall be drawn up by the connected party. Employing of the metering system will take place after the metering manual is signed by the connected party and GTS.

The metering system and its operation shall meet the following requirements:

- The owner of the metering system has the responsibility to make the accountable measurements compliant with the applicable (legal) requirements ("Network Code" or "Invoedvoorwaarden") and the latest international standards. The total metering system shall comply with the requirements and the recommendations of NEN-EN 1776.
- The overall uncertainty on energy shall not exceed 0,75%. (For the definition and an example of the overall uncertainty as used by GTS reference is made to annex A)
- The owner of the metering system shall prove that the operational uncertainty is within limits by using an uncertainty model.
- The measuring policy shall assure that systematic errors, regardless of the sign of the deviation, are actively reduced using agreed procedures in accordance with ISO 7870-1 and ISO 7870-4 (see annex B).
- When a systematic error is found in the energy determination over a period of time (e.g. caused by incorrect settings or deviations of instruments outside the agreed limits), the system shall be capable to deliver all the required data to calculate the deviated amount of energy (for the purpose to be presented to GTS and to be settled with the concerned parties).
- All measurements shall be traceable to international (reference) standards (BIPM; NEN-EN-ISO/IEC 17025).
- For the calculation of the volume and energy conversion factor the pressure, temperature and gas composition shall be used, measured at the measuring installation, on positions representative for the gas passing the gas meter.
- The degree of transparency on data, quality assurance and instrument maintenance shall be agreed upon and shall be established in a Metering manual. This Metering manual consist among others of:
  - the calibration procedures for pressure and temperature transmitters, gas meter, gas chromatograph and flow computer, including tolerances and actions;
  - the quality control, periodical and overall check, at which all instruments are calibrated using reference materials, measuring reference instruments and/or certified calibration facilities;
  - used reference materials and performance registration (Quality Assurance);
  - the data handling including verifications, corrections and final approval of the measuring data;

- all parameters of the metering system fully transparent to GTS.

- The required availability for the measuring installation is 99,9%. This can be achieved by using redundancy in the installation (e.g.: n+1 meter runs, where n runs are needed for the maximum flow capacity, double gas chromatograph systems, No-break power). Gas shall only flow if the measuring installation is available and is functioning within specifications.
- For large volumes (> 250 million m^3 (n) per year per meter run) a double flow measuring system with two flow meters in series of different measuring principles (different manufacture and/or type) and separate pressure and temperature measurement shall be used. The same applies for the gas quality measurement, where double gas chromatographs shall be used for the total measuring installation, including separate sample conditioning system, separate carrier gas, separate calibration gas and separate reference gas.
- In case of a double flow measuring system the energy determination shall be based on the average value of both measurements.
- A double measuring system shall be equipped with on-line comparison between the gas chromatographs ($H_{s,n}$) and gas meters (V_n) with relevant alarms on the calculated deviations.

  Note:
  See annex C for the examples for the configuration of the meter runs.

4.2 Flow measurement

The flow measurement shall meet the following requirements:

- The equipment used shall have an MID approval. The gas meter shall be protected against unauthorised access by means of sealing and the parameters of the meter and the calibration certificate(s) shall be well documented.
- An upstream flow conditioner shall be used; the same flow conditioner and the same upstream pipe of the gas meter shall be used during calibration. The installation of and the distance between the flow conditioner shall be accordance with the manufacturer instructions and NEN-EN 12261 (turbine gas meters) or NEN-ISO 17089-1 (ultrasonic gas meters). The manufacturer of the gas meter shall have documented evidence that the gas meter has a good performance with the flow conditioner at the chosen distance. If a flow conditioner is not used, the owner shall provide proof that there is no installation effect on the flow measurement.
- Flow meters shall be protected against pollution or dirt.
- Active interpretation of diagnostic data of a gas meter shall be used if present, for example a comparison of Speed of Sound (SOS) when using an US meter: SOS derived from the gas chromatograph data versus SOS measured by the ultrasonic meter or, when using a turbine gas meter, a second independent read-out (e.g. optoelectronically read-out of the mechanical index).
- The meter run shall be thermally insulated from ambient temperature.
- Calibration curve correction for the gas meter shall be applied to minimise systematic errors using the physical reference points of the calibration.

- Initially the as found recalibration of the gas meter shall be done at least every 5 years. This interval can be exceeded to 8 years under the following conditions:
  - A double flow measuring system with two flow meters in series;
  - Online comparison of the normalised volume;
  - The shift of the meter error curve over a period of at least 5 years is within 0,3 %.

- Every gas meter in the installation shall have an individual calibration certificate and the calibration shall be performed complying to the following requirements:
  - Calibration of the gas meters will be performed at an internationally recognised calibration site that is accredited by the national council of accreditation in accordance with NEN-EN-ISO/IEC 17025 and holds the Harmonised European Gas Cubic Meter for natural gas as realised by PTB, NMI-VSL and BNM (the national metrological institutes of the Netherlands, Germany and France). The owner shall inform GTS at which facility the gas meters will be calibrated. At least 1 month in advance the owner will inform GTS when the gas meters will be calibrated.
  - The conditions at flow calibration shall resemble the conditions during operation (natural gas under operational pressure and temperature). All parameters that can adversely affect the performance of the meter shall be considered: wall roughness (coating), temperature, diameters steps, protrusions, bends, flow conditioners and the like. All generally recognised differences between the conditions at flow calibration and conditions during operation shall be eliminated if these differences result in a significant shift of (part of) the calibration curve. Therefore the gas meter, the relevant upstream piping and the flow conditioner shall be calibrated as a package.
  - Calibration at least at 6 flow set points conform the OIML requirements (R137) (Q_{min}, 10 %, 25 %, 40 %, 70 % and 100 % of Q_{max}).
  - Bi-directionally used gas meters are to be calibrated bi-directionally which results in the appropriate certificates for each direction.
  - It is preferable that the gas meters are adjusted such that the weighted average deviation is as close as possible to zero.
  - After adjustment, the gas meter deviations at all the calibrated flow points shall be less than the maximum permissible deviation (MPD) specified in table 1.
    Note: These deviations are still without curve corrections.
  - Linearity and steepness of the curve: The errors in the flow rate range between 0,25 Q_{max} and Q_{max} shall be within a band of 0,3 %.

Table 1: Maximum Permissible Deviation (MPD) gas meters

Flow rate	**MPD %**
$Q_{\mathrm{min}} \leq Q < 0{,}2\ Q_{\mathrm{max}}$	± 1
$0{,}2\ Q_{max} \leq Q < Q_{\mathrm{max}}$	± 0,5

4.3 Volume conversion

Volumes at operational conditions shall be converted to volumes at normal conditions (273,15 K and 1,01325 bar (abs) and to energy (combustion reference temperature of 298,15 K). Volume conversion shall be performed continuously by using live inputs of absolute pressure (P), temperature (T) and compression factor (Z). The compression factor (Z) shall be calculated using NEN-EN-ISO 12213 (part 1 u/i 3) with live inputs of P, T and gas composition.

Energy conversion shall be performed using live input of the calorific value. Exception can be made in situations where the variance in the gas composition is small and prove is provided that the overall uncertainty on energy is within 0,75 %.

4.4 Flow computer, pressure and temperature transmitter

The flow computer including the pressure transmitter and temperature transmitter shall have a MID approval, and comply with NEN-EN 12405 (part 1 u/i 3). Pressure shall be measured with an absolute pressure transmitter or with a gauge pressure transmitter and an atmospheric pressure transmitter. Ambient influences such as temperature, pressure, noise, moisture, pulsations and sunlight shall be minimised.

The volume conversion shall meet the following requirements:

- It shall be demonstrated that the pressure and temperature measurement will function within the stated uncertainty of the Uncertainty Modelling Initially the calibration/verification of the pressure and temperature measurement shall be done at least every 3 months. This interval can be extended to 6 months, if the stability is demonstrated within the stated uncertainties for the pressure and temperature measurement.
- Application of z calculation is in accordance with NEN-EN-ISO 12213 (part 1 u/i 3).
- Full traceability of actions by electronic logging.
- Use of transparent logical decisions (alarm handling and low flow).
- The inputs shall be digital (serial) to eliminate additional uncertainty by transmission techniques (like analogue transmission).
- Measured volumes shall be registered using non-volatile counters.

Counters shall be installed for volume at operational conditions, volume corrected for the calibration curve, volume at normal conditions and energy. Bi-directional systems shall be equipped with the above mentioned counters for each direction.

The flow computer shall be examined and verified periodically. The flow computer shall be protected against unauthorised access by means of a password and changes of parameters shall be tested and well documented.

4.5 Fuel gas measurement (gas intake for own use)

All fuel gas shall be measured with a corresponding flow computer. The overall uncertainty on energy shall not exceed 0,75 %. Attention shall be paid to the position of the fuel gas measurement in relation to the gas chromatograph and the meter runs and to the state of the measuring installation (stand-by, flow or no flow).

4.6 Gas chromatograph

A gas chromatograph and calorific value determination shall meet the following requirements:

- Mounted in accordance with relevant standards.
- Minimization of ambient influences such as temperature, pressure, noise, moisture, pulsations, sunlight and the like.
- Authorised access only.
- The gas chromatograph shall be operated in accordance with the following points:
  - The gas chromatograph shall be used in accordance with NEN-EN-ISO 6974 (par 1 u/i 6).
  - The calculation of the physical components like calorific value, wobbe, density and relative density shall be in accordance with NEN-EN-ISO 6976. The calculation of the calorific value ($H_{s,n}$) shall be on a molar basis at 25°C.
  - The sampling system shall be provided with a fast loop in accordance with NEN-EN-ISO 10715.
  - Calculation of the calorific value ($H_{s,n}$) shall be performed with all components with an influence > 0,01 % on the calorific value. The use of the pseudo component "C6+" for higher hydrocarbons (like C6s, C7s, Benzene) is allowed only if the proportion is constant in time. This shall be demonstrated by the connected party through analysing spot samples.
  - The use of a fixed component shall be applied for unmeasured components (e.g. Helium if it is used as carrier gas) under the condition that the concentration is constant in time. This shall be demonstrated by the connected party through analysing spot samples.
  - The uncertainty of the gas chromatograph shall be demonstrated in accordance with the Performance Evaluation in accordance with NEN-EN-ISO 10723. From this evaluation a decision shall be made, in accordance to the expected gas composition range, if a multi-level calibration is necessarily.
  - The gas chromatograph shall be periodically tested by analysing a certified natural gas, which resembles the process gas. Frequency will be agreed between GTS and the owner and will be recorded in the Metering manual.
  - It shall be demonstrated that the gas chromatograph will function within the stated uncertainty of the Uncertainty Modelling (see annex A) by using a reference gas (natural gas, monthly basis) and a calibration gas (synthetic gas) to monitor calorific value, density and individual components. Frequency will be agreed upon between GTS and the owner and will be established in the Metering manual.

Recommendations for the analysis of the performance of the gas chromatograph are given in the documents "Statistical methods for quality improvement" and "Statistical process control" (see documentation 2 and 3.)

4.7 Data transmission and reporting

The following data and reports shall be provided by the owner of the measuring station:

- On-line data: Energy and volume counters (kWh and m^3 (n)) at 5 minutes interval using VPN per meter and flow direction. Data transmission is described in Exhibit D of the GCA (see MSM-15-E) and is available at Gasunie Transport Services.
- Accountable data at monthly basis: hourly values of accountable energy, normal volume and caloric value per meter run on monthly basis using XML formatted file transfer over IP. The requirements for sending data are described in Exhibit P of the GCA (see MSM-44-E).
- On request: all primary, hourly, data relevant to the accountable figures (e.g. V, V_c, V_n, E, P, T, $H_{s,\mathrm{n}}$, per meter) including applied corrections.
- Calibration results and agreed annual performance overview.

4.8 Reference instruments, equipment and materials

Reference materials like test and calibration gasses and calibration equipment (reference measurement instruments) shall be used to check the gas chromatograph, pressure and temperature transmitters and flow computers. Reference materials shall be periodically calibrated at a calibration facility that is accredited by the national council of accreditation in accordance with NEN-EN-ISO/IEC 17025.

Provisions shall be made for a proper connection of the references to the installation. For the reference temperature sensor a spare thermowell shall be fitted for calibration, close to the position of the primary thermowell. Care shall be taken not to install them in line, therefore it shall be mounted at an angle to the primary thermowell.

Reference materials and reference measurement equipment shall meet the following requirements:

- These shall be fit for the purpose (regarding range, uncertainty and the like).
- These shall be certified by a notified body or traceable to international standards.
- These shall have a valid calibration certificate with stated reference uncertainty and established deviations.
- The recalibration period as established by the notified body will be respected.

5. DOCUMENTATION

In this specification the following documentation is applicable:

1 ISO/CEI GUIDE 99 International vocabulary of metrology - Basic and general concepts and associated terms (VIM).

2 "Statistical methods for quality improvement" by Thomas P. Ryan, John Wiley & Sons, 1989, ISBN 0-471-84337-7.

3 "Statistical process control" by G. Barrie Wetherill and Don W. Brown, Chapman and Hill, 1991, ISBN 0-412-35700-3.

ANNEXES

A UNCERTAINTY MODELLING

A.1 Definitions

The definitions used are based on ISO/CEI GUIDE 99 International vocabulary of metrology - Basic and general concepts and associated terms (VIM) (see documentation 1).

With each term a short clarification or interpretation is given additionally.

Adjustment[1]	Operation of bringing a measuring instrument into a state of performance suitable for its use.
Calibration[2]	Set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realised by standards.
Deviation[3]	Value minus the reference value.
Error[4]	Result of the measurement minus the true value of the measurand.
Maximum Permissible Error (MPE)[5]	Extreme values of an error permitted by specifications, regulations, and the like for a given measuring instrument.
Reference standard[6]	Standard, generally having the highest metrological quality available at a given location or in a given organisation, from which measurements are derived.
Significance Level (SL)[7]	Uncertainty in the - conventional - true value.
True value[8]	Value consistent with the definition of a given particular quantity.
Uncertainty[9]	Parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonable be attributed to the measurand.

1. An adjustment shall minimise the deviation. A single point adjustment will reduce the deviation to zero, an operating range adjustment requires a weighing procedure.
2. In a calibration the difference between the measured value and the reading of the reference is determined, within a defined operating range and under specified conditions. The defined range can be a single point or a number of points.
3. A deviation is the result of a calibration. The deviation can be determined exactly, in contrast with the error. The deviation is used to judge the performance of an instrument.
4. Since the true value is not exactly known, the error can only be determined within certain confidence limits.
5. The MPE is mutually agreed between parties, either at component or overall level. Since the error cannot be determined exactly, additional agreement is necessary on how to deal with such a value.
6. The term "reference" will also be used. The reference is taken to be the instrument or system used for calibration, representing the true value with specified uncertainty. It is assumed that the reference has zero systematic error, or that the systematic error is known so it can be compensated for.
7. This term is not included in the VIM, but plays an important role in the model. The SL value is based on the uncertainty of the applied reference only.
8. This is the value that is obtained by a perfect measurement. It is not possible to determine the true value exactly. For this purpose, the "conventional true value" is sometimes introduced, having an accepted uncertainty.
9. For practical purposes, the uncertainty is taken to be twice the standard deviation of a distribution. Also, the probabilities are assumed to be normally distributed. This implies that there is a 95 % probability to remain within the uncertainty boundaries and those values are distributed symmetrically around the expectation value.

A.1.1 Basis assumptions

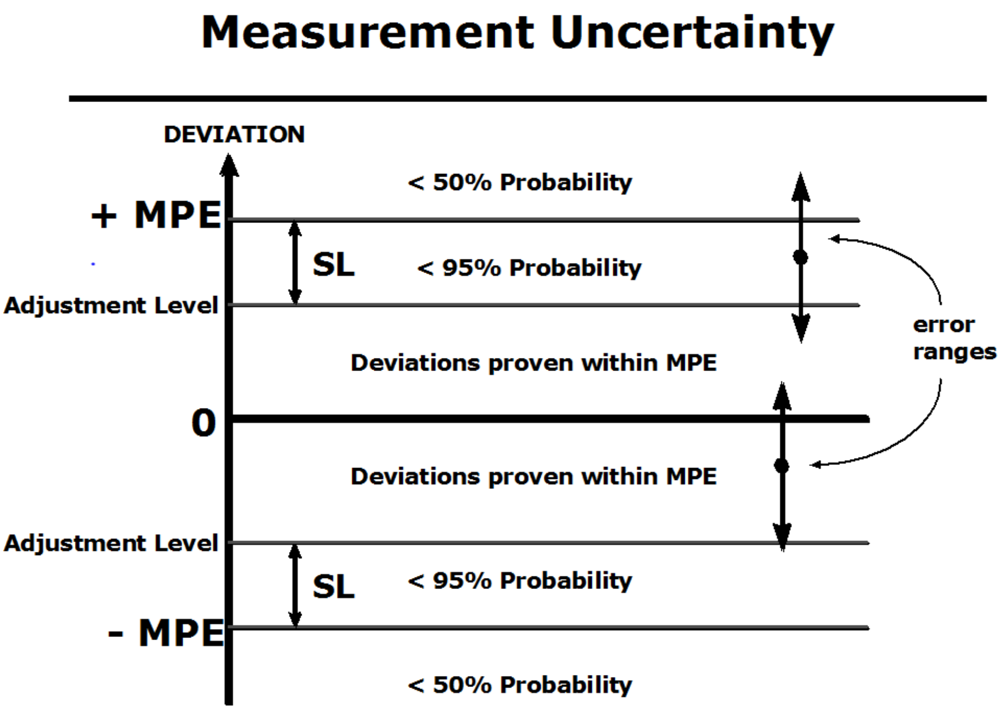
For the uncertainty modelling the following basic assumptions apply:
- Every instrument is checked on a regular basis by comparing its reading with a reference.
- The uncertainty of the reference is specified.
- Any instrument drift within the checking period will remain within specifications.
- The calibration procedure does not introduce significant uncertainties.
- Either the reference used has no systematic error, or it has a known systematic error making it possible to compensate.

A.1.2 Single instrument

A single instrument calibration results in a deviation that requires interpretation. It is supposed that a Maximum Permissible Error value has been agreed upon, and that the reference uncertainty is specified.

The interpretation of the reference uncertainty is an important aspect of the model. Its origin lies in the traceability chain leading from the primary reference (traceable to international standards) to the specific reference used. The true value is defined by this primary reference, which means that it is by definition the only reference with zero error. Every next (traceable) step in producing copies of the reference leads to an additional uncertainty. The result is that the difference between any (non-primary) reference and the true value is fixed, but unknown. Therefore it is described by a probability distribution.

The interpretation of the measured deviation is illustrated with the graph below.



Any deviation is the centre of a probability range of the actual associated error. This implies that deviations within the MPE boundaries do not automatically represent acceptable errors. As long as the absolute deviation value is much smaller than the MPE, sufficient certainty is given that the error also lies within the MPE. With larger deviation values, this certainty decreases.

At the value MPE - SL, or its opposite, the confidence level of 95 % is lost. (Strictly speaking 97,5 % for symmetry reasons.) At this stage the guarantee cannot be given anymore that the instrument operates within the Maximum Permissible Error. Therefore it shall be adjusted. This leads to the following relation between the three (absolute) values:

AdjustmentLevel = MPE-SL

Going further away from the zero level, the certainty decreases further, passing the 50 % value at the MPE level. It shall be stressed that, even in this region, it is still possible that the instrument operates within the requirements, but the probability is small.

If both the adjustment and significance levels are known, as is the case in the present situation at the export delivery points, the MPE values can be calculated for the individual components.

A.1.3 Multi component significant level

Every measuring system used for fiscal measuring consists of more components, together determining the energy throughput.
The overall significance level for the energy measurement can be determined from the individual SL values.

Since these individual values have been deduced from their own original primary reference, following different intermediate steps, it is assumed that the possible errors (fixed but unknown) have probability distributions that are not correlated. Therefore, the SL values shall be added quadratically to obtain the overall value.

Furthermore, it is recognised that the deviations in the measured energy are not always directly proportional to deviations in certain components. This is due to the applied method of energy calculation.

A typical example is the effect of calorific value deviations when using PTZ volume conversion. The direct influence is through the multiplication of normal volume and calorific value. The use of calorific value in the sGERG compression factor calculation introduces an indirect influence as well. It can be estimated that a 1 % calorific value deviation will roughly lead to a 1,25% energy deviation. This influencing factor is somewhat dependent on the actual operational situation for pressure, temperature and gas quality.

In the same way there are also influencing factors for other quantities. Gasunie Transport Services has investigated these for a wide range of operating situations and compression factor calculation methods. Table 2 gives the values for the typical situation at the high pressure delivery stations.

Table 2: Influencing factors for PTZ conversion for sGERG and high pressure

Quantity	Influencing factor
pressure	1,13
temperature	-1,55
calorific value	1,25
normal density	0,14
CO_2 concentration	0,004

In general the overall significance level can be calculated as follows:

$$SL_{system}{}^2 = \left(f_1 \times SL_{comp1}\right)^2 + \left(f_2 \times SL_{comp2}\right)^2 + \ldots..$$

where the f values represent the influencing factors.
Mathematically the influencing factors are nothing else than the partial derivatives of energy with respect to the individual quantities, calculated at the point of operation.

A.2 Relation between individual and overall MPE values

Any overall value for the Maximum Permissible Error shall be related to the individual MPE values. In subclause A.1.3 is stated that individual significance levels are uncorrelated, and may therefore be added quadratically. The same argument applies to the measured deviations. Therefore the overall MPE is chosen to have the same relation to the individual MPE values:

$$MPE_{system} = \sqrt{\left[\left(f1 \times MPE_{comp1}\right)^2 + \left(f2 \times MPE_{comp2}\right)^2 + \ldots.\right]}$$

From the above an adjustment level for the multi component system can be calculated in the same way as for the individual components by subtracting the system SL from the system MPE.

A.2.1 Requirement for overall MPE

An appropriate value for the maximum permissible error will be agreed between parties. The requirement then reads:

$MPE_{\text{system}} \leq MPE_{\text{required}}$

When the measurement system is engineered, this will be used as a requirement for the configuration. The instrument specifications, interpreted as MPE values, are added up as above and the resulting system value shall remain within the requirement.

Once the system is in operation, the results of periodical checks should prove the system to be within this requirement. For this purpose the overall deviation shall be calculated from the individual deviations, again making use of the energy calculation method and the influencing factors. In contrast with the SL and MPE calculation, deviations add up linearly:

$$DEV_{system} = \left(f_1 \times DEV_{comp1}\right) + \left(f_2 \times DEV_{comp2}\right) + \dots..$$

In order to give sufficient guarantee the MPE requirement is not exceeded, the calculated system deviation be subject to:

$$\left|DEV_{system}\right| \leq MPE_{required} - SL_{system}$$

where the vertical bars represent the absolute value. The right hand side acts as the system adjustment level.

If the system deviation exceeds the given limit, measures shall be taken to reduce the overall deviation within the limit by adjusting or replacing the instrument(s) causing the deviation.

Remarks:
Due to the quadratic addition of the MPE values it can occur that no individual component is outside its tolerance, but the system deviation has exceeded the overall adjustment level. In the numerical example given in subclause A.2.2 such a case is described. It shall be determined which instrument shall be adjusted. It is advised to adjust the component with the largest deviation, but left to the personnel on site to decide what is best.

Changes in MPE values can take place when an improvement of a reference can be achieved. A smaller SL value will reduce the MPE for this particular instrument, allowing for larger adjustment levels on other components. In this way investment will reduce maintenance costs and keep the quality at the same level.

Another case is that performance of a certain instrument is worse than expected. The adjustment level and thus the MPE shall be enlarged accordingly, but not without tightening the tolerance on other components.

A.2.2 Numerical example

For the large delivery stations at the Dutch borders, table 3 shows the significance and adjustment levels that have been agreed upon. In the rightmost column the MPE values have been added. The system SL values on energy and on energy without the primary measurement are calculated, making use of the influencing factors.

The MPE values for these two quantities are proposed values. It can be calculated that the system values remain within this requirement, with respective values 0,73 % and 0,61 %. The two system adjustment levels are based on MPE required and SL values.

The "energy without base volume" is important for the periodically overall check, at which all instruments are calibrated against their reference, except the turbine/US meter. For this case the "overall" value on energy shall be determined, except the primary measurement.

Table 3: Numerical example

Measured value or method	Significance level (2·s)	Adjustment level	Maximum Permissible Error
Base flow	0,3 %	0,0 % (*)	0,4 %
Pressure	0,1 %	0,15 %	0,25 %
Temperature	0,03 % (0,1 K)	0,07 % (0,2 K)	0,10 % (0,3 K)
Z/Z_n method	0,1 %	-	0,1 %
Calorific value (gas chromatograph)	0,2 %	0,2 %	0,4 %
Normal density (gas chromatograph)	0,2 %	0,2 %	0,4 %
Energy	0,50 %	0,25 %	0,75 %
Energy without base volume	0,30 %	0,35 %	0,65 %

* Gas meters are always adjusted and any remaining error shall be removed by the application of curve correction.

B LONG TERM EFFECTS, "CUSUM"

B.1 Introduction

Several methods are described to detect long term effects. One of these methods is the cumulative sum method, CUSUM. Gasunie Transport Services has adopted this method. (ISO 7870 part 1 and part 4 and documentation 1 and 2; see clause 5).

This method accumulates the realised deviations between measuring instrument and reference instrument. The long term effect is shown by a growing CUSUM value. By using an alarm limit this effect can be stopped. A threshold value is introduced to reduce the influence of random deviations. Both parameters (threshold and alarm limit) can be calculated as a function of the standard deviation of the control results.

B.1.1 Method

Threshold value:
The threshold value is the lower limit for the absolute value of the deviations which are added in the cumulative sum. A high value makes the system impassive for real problems; a low value gives to much fake alarms. In the literature is often chosen for a value of ½ to ¾ times the standard deviation.

Action limit:
This is the value where above the absolute value of the cumulative sum gives an alarm. In the literature is often chosen for a value of 3 to 5 times the standard deviation.

The time needed to detect the long term effect is called "average run length" (ARL). This value is dependent of the frequency of the calibration and the time in which a systematic error may exist. In case of monthly calibrations and an action limit of 5 times the standard deviation is chosen, an error of 1 standard deviation will give an alarm after 10 months.

Two CUSUM quantities will be determined for all measurements of calorific value, line density and normal density called $S^+(..)$ and $S^-(..)$.
S^+ is the cusum quantity for the detection of persistent deviations with a positive sign.
S^- is the cusum quantity for the detection of persistent deviations with a negative sign.

All CUSUM quantities will be updated every calibration with the latest determined deviations.

$$S_{pc}^{+} = max\left[0, S_{pc-1}^{+} + (\Delta pc - k)\right]$$

$$S_{pc}^{-} = max\left[0, S_{pc-1}^{-} - (\Delta pc + k)\right]$$

where:

S_{pc}^{+}	is the S^+cusum quantity at period "*pc*"
S_{pc}^{-}	is the S^- cusum quantity at period "*pc*"
S_{pc-1}^{-}	is S_{pc}^{-} at the period before
Δpc	is the relative deviation of the instrument at period "*pc*", either with a positive sign or with negative sign.
k	is threshold value.

When S^+or S^-exceed the limit the instrument will be recalibrated.
After recalibration or replacement of the instrument its S^+ and S^- values will be set to zero.

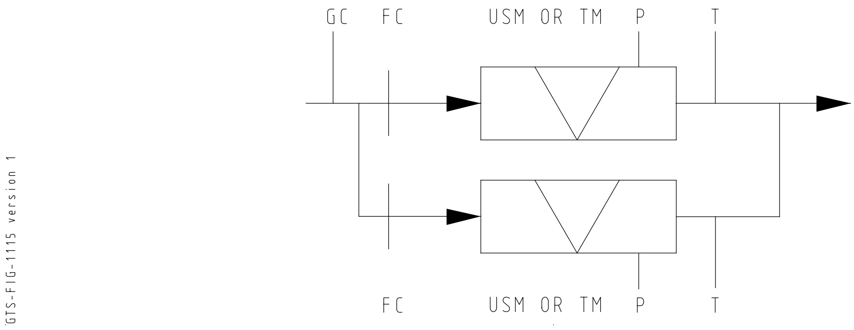
C EXAMPLES OF CONFIGURATION OF METER RUNS

C.1 Abbreviations

TM	Turbine gas meter
USM	Ultrasonic gas meter
FC	Flow conditioner
GC	Gas Chromatograph
T	Temperature
P	Pressure

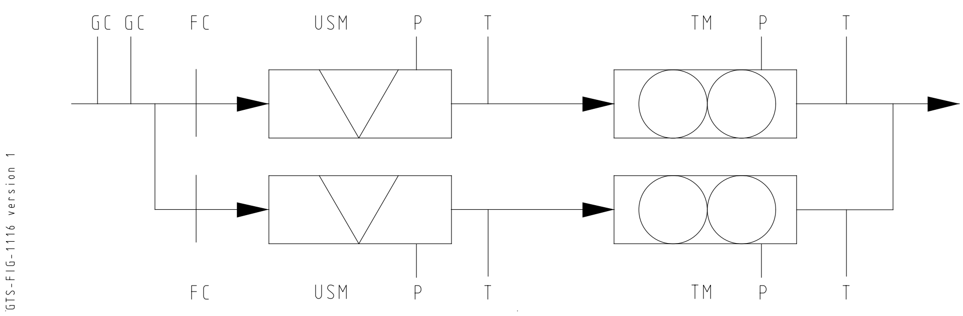
Notes:
1. all examples show the at least number of 2 meter runs (n+1 ≥ 2)
2. the number "n" and the diameter of meter runs shall be chosen, such that the minimum and maximum flow capacity is covered.

C.2 Configuration for *Q* < 250 mln m³/year (n)

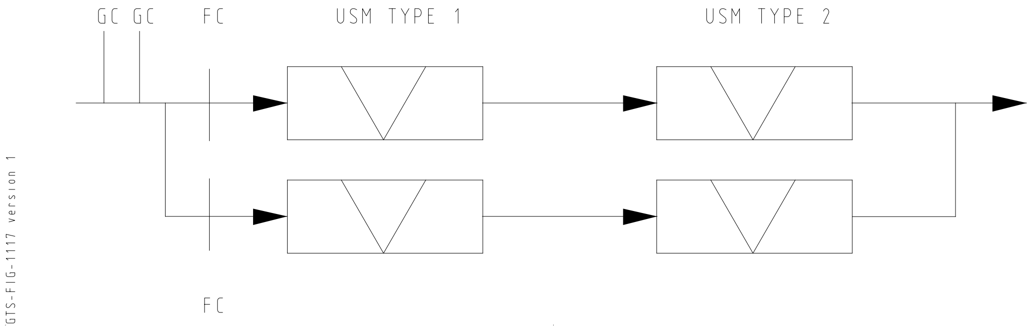


C.3 Configuration for *Q* > 250 mln m³/year (n)

C.3.1 USM and Turbine in series



C.3.2 Two USM's of different type in series (GC, P and T identical as in C.3.1)



C.4 Configuration for a bi-directional application