ANNEX 6

FISCAL METERING MANUAL

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1 General description

1.1 Introduction

This document describes the metering principles and the quality assurance and control (QA/QC) methods for all exit connection points between the Transport System operated by Hynetwork Services (HNS) and all connected parties where HNS is operator of the metering station. The descriptions are generic and not station specific.

The aim and the output of fiscal measurement systems is a set of fiscal energy values, which is the basis for:
(a) invoicing purposes;
(b) energy settlements for users of the hydrogen production system as well as users of the HNS Transport System;
(c) balancing purposes for the HNS Transport System and its shippers.

This metering manual reflects the minimum requirements regarding the design, maintenance and quality control of the metering stations:
(a) any deviation from these requirements will be documented;
(b) international and industry standards will be used as reference and guidance, unless otherwise stated, the latest version always applies.

This metering manual reflects the quality assurance process with respect to the management and maintenance of the fiscal measurement facilities operated by HNS.

1.2 Policy

HNS endeavors to perform all measurements and all maintenance with the purpose of:
(a) fiscal measurement uncertainty <1.0% for energy on a monthly basis, and <2.0% for energy on an hourly basis;
(b) avoid errors;
(c) actively search for any systematic errors and remove them once one is found;
(d) comply with international standards of measurements;
(e) be traceable to international (physical) standards;
(f) provide transparency;
(g) deliver all required data within the appointed time frame.

The design of the measuring installation in combination with the procedures of operation are in accordance with EN 1776 "Natural gas measuring stations – Functional Requirements" [1], and the GTS_OSS-20A-E – *Functional requirements for fiscal and non-fiscal metering systems; Hydrogen network*.

2 Definitions

The scope of the definitions used is only for this document.

2.1 Statistical terminology

The statistical terms used in this metering manual shall be in accordance with the definitions used in "International vocabulary of basic and general terms in metrology" [2].

Calibration: A 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 of a reference material, and the corresponding values realized by standards. Note: Neither "check" nor "inspection" are qualified as "calibration".

Adjustment: Operation of bringing a measuring instrument into a state of performance suitable for its use. Note: "Calibration" does not include "adjustment".

2.2 Gas technology related definitions

"Standard Reference Conditions":
Standard Reference Conditions are defined as a temperature of 288.15 K (15 °C) and an absolute pressure of 101.325 kPa (1.01325 bar). The index "S" indicates these Standard Reference Conditions.

"Volume":
The volume (V) of Gas is given in m^3. All volumes in this document are related to a certain period of time (e.g. 15', hour, day, month); when no period of time is specified, "generally speaking" is meant.

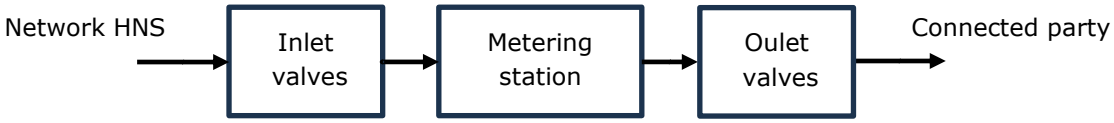
"Superior Calorific value":
The superior calorific value, H_s (S), will be referred to as calorific value. Its unit is kWh/m^3. In ISO 6976 notation: H_s (S) = H_s {15 °C, V(15 °C; 101,325 Pa)} [3].

"Measuring capacity":
Refers to the quantity of Gas that can be technically measured by the equipment described in Article 3.1.

3 Description of the measuring station

3.1 General description

An HNS exit station contains the following main components.



The metering station consists of several meter runs, with one additional run provided as a spare (n+1) configuration.
If required, a single, smaller meter run may be installed to accommodate seasonal capacity (e.g., summer). Redundancy configuration (n+1) will not be applied for this smaller meter run.

Every meter run consists of the following components:
(a) double block and bleed inlet valves;
(b) nitrogen injection point to allow purging and which can also be used for temporary quality measurement;
(c) dust filter;
(d) flow meter including a flow straightener;
(e) pressure-, temperature transmitter and flow computer;
(f) pressure safety valve (not for open-pipe layout);
(g) PCV pressure regulation (not for open-pipe layout);
(h) double block and bleed outlet valves.

3.2 Station documentation

All activities performed by HNS shall be documented, including the date and the nature of the activity work.

The results of the calibrations are made available by HNS.

After the rejection and/or removal of a measuring station or its components, HNS shall retain the corresponding calibration certificates for a minimum of seven years.

3.3 Measurement availability

The gas quality, pressure and temperature measurement signals shall have an availability of 99.0% per year. The availability of the fiscal metering system >99.0%. One event shall not exceed 24 hours.

3.4 Volume/mass and energy measurement

3.4.1 Volume at operating conditions

For determining the volume under operational conditions, every meter run is fitted with an ultrasonic (US) flow meter.

The range of the flow meter (Q_{min} and Q_{max}) will meet the expected flow of the meter run.

The ultrasonic flow meter shall be installed in accordance with the manufacturer's instructions. The manufacturer must provide documented evidence demonstrating that the

flow meter meets the required performance criteria, with or without a flow conditioner, for the specified pipe length.

The ultrasonic flow meter shall have MID (Measuring Instruments Directive) approval and shall be protected against unauthorized access. All meter parameters and associated calibration certificate(s) shall be properly documented.

The flow meter including the flow straightener and upstream pipe length will be calibrated with hydrogen at a calibration facility accredited according to NEN-EN-ISO/IEC 17025 for hydrogen.

Calibration curve correction or Reynolds correction shall be applied to the flow meter to minimize systematic errors, using the physical reference points established during calibration.

Pressure and temperature correction shall be performed when calibration conditions differ from operational conditions. These corrections shall be implemented within the flow computer.

3.4.2 Volume and mass at standard reference conditions and energy

Volumes at operational conditions will be converted to volumes at standard reference conditions (288.15 K and 1.01325 bar (abs)) and to mass with the density calculated with ISO 6976. Volume conversion is performed continuously in a flow computer by using live inputs of absolute pressure (P), temperature (T) and calculated compression factor (Z). The compression factor (Z) is calculated using the GERG2008 equation of state with a fixed 100% hydrogen composition. Also, the energy calculation is based on a fixed 100% hydrogen composition.

If the purity at an exit is below 99.98%, the compression factor shall be corrected based on the actual gas composition. This correction will not be executed by the local flow computer but will be applied with the HNS central systems.

Every flow computer has MID approval and will register the following counters:
(a) actual uncorrected volume [m^3];
(b) actual corrected volume [m^3] (m^3 corrected for pressure/temperature and the calibration curve);
(c) volume at standard reference conditions [m^3 (S)] (based on 100% hydrogen);
(d) net energy [kWh] (based on 100% hydrogen).

All inputs to the flow computer, including the flow meter, temperature and pressure transmitters, are digital (serial) to eliminate additional uncertainty associated by transmission techniques.

3.5 Calorific value measurement

The gas composition is calculated based on the gas quality measured and the entry stations of the HNS network, and simulation of the gas flowing through the network. This calculated gas composition is used, if applicable, for the correction for the compressibility calculation factor (Z) and the recalculation of energy.

Both corrections will be performed at least on an hourly basis.

4 Uncertainty model and CUSUM

All measurement stations of HNS shall have a maximum uncertainty of 1% on monthly basis and a maximum uncertainty of 2% on hourly basis. To guarantee these uncertainties an uncertainty model is used based on determining the best values for thresholds, correction levels and maximum permissible errors and is derived from the known uncertainties of the measuring instruments and reference instruments. The uncertainties have various origins, and a proper analysis of the following aspects has been carried out:
(a) equipment accuracy;
(b) equipment stability (short term and long term);
(c) environmental influences (temperature/pressure sensitivity);
(d) calibration equipment specification;
(e) calibration method;
(f) calculation methods, assumptions and uncertainties;
(g) application range (pressure, temperatures, gas quality).

Appendix 1 specifies the uncertainties of the reference equipment.

The influence factor (f) is determined by analyzing the effect of change in pressure and temperature on the pTz energy determination for different gas compositions. The influence factor for temperature is -0.979 and pressure is 0.969.

4.1 Uncertainty calculations

Uncertainty calculations for HNS exit stations, derived from the metering system outlined in Chapter 3, are presented in Table 4.1.1.

Instrument and/or parameter	**Maximum uncertainty calibrated (SL)[1]**	**Maximum acceptable deviation (AL)[2]**	**Maximum Permissible Error (MPE)[2 3]**	**Influencing factor (f)[4]**	**(MPE*f)²**
Flow meter	0.2%	0.5%	0.7%	1.00	0.49000
Absolute pressure	0.10%	0.40%	0.50%	0.969	0.23523
Temperature	0.04% (0.12 K)	0.15% (0.45 K)	0.19% (0.57 K)	-0.979	0.03467
Z/Zn method (k-factor)	0.1%		0.1%	1.00	0.01000
Energy hydrogen	0.1%	0.3%	0.4%	1.00	0.16000
Energy (E)	0.247%	0.717%	0.964%		
Energy without base volume	0.26%	0.52%	0.66%		

Table 4.1.1: Uncertainty calculations pTz

[1] Maximum uncertainty calibrated: An estimate characterizing the range of values (at a 95% probability level) within which the true value of a measurement lies at the time of calibration, based upon the calibration uncertainty during the calibration against the reference instrument, including the initial uncertainty and repeatability of the process instrument.
[2] Values are related to the maximum acceptable deviation of the instrument during operation. When exceeded the instrument will be adjusted.
[3] These maximum acceptable deviation limits ensure that the uncertainty in the energy remains within 1.0%.
[4] The influence factor quantifies the impact of a given parameter on the energy calculation.

4.2 CUSUM

To avoid persistent one-sided deviations a CUSUM technique will be applied (see ISO 7870). Table 4.2.1 shows the CUSUM threshold and action limits for pressure and temperature instruments.

Instrument and/or parameter	CUSUM threshold	CUSUM action limit
Temperature value in flow computer	0.04 K	0.25 K
Pressure value in flow computer	0.03%	0.2%

Table 4.2.1: CUSUM limits

Two CUSUM's will be determined for all measurements of pressure, temperature, calorific value and density called $S^+(..)$ and $S^-(..)$.
S^+ is the CUSUM for the detection of persistent deviations with a positive sign.
S^- is the CUSUM for the detection of persistent deviations with a negative sign.

All CUSUM's will be updated after the periodically calibration (see Article 6.2) with the latest determined deviations.

Formula 4.2.1: CUSUM plus deviation:

$$S_t^+ = max(0, S_{t-1}^+ + (\Delta_t - k))$$

Formula 4.2.2: CUSUM minus deviation:

$$S_t^- = max(0, S_{t-1}^- - (\Delta_t + k))$$

Where:

S^+_t is the S^+ CUSUM in month "t"
S^-_t is the S^- CUSUM in month "t"
S^+_{t-1} is S^+_t in the month before
S^-_{t-1} is S^-_t in the month before
Δ_t is the relative deviation of the instrument in month "t", either with a positive sign or with negative sign.
k is the threshold; values are listed in Table 4.2.1 (column "CUSUM threshold").

If S^+ or S^- exceeds the action limit listed in Table 4.2.1 the instrument will be treated according to Chapter 6.

After recalibration or replacement of the instrument its S^+ and S^- values will be set to 0.

5 Data handling

5.1 Data acquisition and data handling

The flow computer records four counter readings per meter run every 5 minutes and every hour: the US meter (C_V_{gm}), the non-converted amount of gas (C_V_b), the converted quantity of gas (C_V_n) and the energy (C_E).

The central IT systems of HNS read out these counters every 5 minutes, including error messages by a telemetry-unit. When the data is processed, a set of verifications is performed. Depending on these verifications and error messages the data will be automatically or manually corrected.

All data will be kept in the central IT systems for at least seven years, including audit trails of the corrections.

Time synchronization is provided by the telemetry-unit.

5.2 Error handling

All metering station alarms are transmitted to HNS via the telemetry unit. Each alarm shall be acknowledged and addressed within 24 hours and resolved whenever feasible. If a fault cannot be resolved immediately, the system will switch to the spare meter run. The faulty meter run will be repaired within 5 working days.

5.3 Telemetry

The online measurement signals and the counters of the flow computer(s) are read out according to Article 5.1.

6 Quality assurance

6.1 Introduction

All instruments including the flow computer and US meter will have MID approval and are provided with seals to prevent unauthorized access.

The calibrations of the US meters and the reference equipment used (see Appendix 1) are calibrated at an ISO 17025 accredited calibration facility.

All maintenance documentation, certificates, validations and calibration results are stored in the central IT systems for a minimum of seven years.

HNS annually reports on the performance of its metering systems. This report covers the entire population of measuring stations and does not focus on individual systems. Individual calibration and validation results can be retrieved via the Business Partner Portal.

6.2 Calibration and adjustment

This article describes the initial calibration and uncertainty of the instruments and electrical circuits of the measuring installation. The periodical calibrations are described in Article 6.3.

6.2.1 Calibration flow meters

General
Calibration of US meters will be performed at an internationally recognized calibration site, which is accredited by the national council of accreditation according to ISO 17025 [4] and hold the Harmonized European Cubic Meter for hydrogen as realized by PTB, NMI-VSL and LNE.

Flow meter
The gas meters will undergo an as-found calibration at a pressure matching the operational conditions. The calibration will be performed at least at 6 flow set points conform to the OIML requirements (R137-2) [5] (Q_{min}, 10%, 25%, 40%, 70% and 100% of Q_{max}). ISO 17089 [6] will be applicable for US meters.

Curve or Reynolds correction for the flow meter and pressure and temperature correction are applied according to Article 3.4.1.

6.2.2 Calibration transmitters and flow computers

Flow computer
The flow computer is periodically validated by comparing the conversion factor calculated by the flow computer and the conversion factor calculated based on the reference pressure transmitter en reference temperature transmitter. The conversion factors are compared over a certain period of time (approx. 5 minutes), and the error is determined.

Pressure transmitter
The pressure transmitter is periodically validated against a reference pressure transmitter. The reference transmitter is connected to the pressure transmitter, and the pressures under operational conditions are compared over a specific period (approx. 5 minutes) to determine the measurement error.

After adjustment, the pressure transmitter will be validated at four points across its measuring range.

Temperature transmitter
The temperature transmitter is periodically validated against a reference temperature transmitter. The reference transmitter is placed in a spare thermowell, that is placed close to the temperature transmitter of the flow computer. The temperatures under operational conditions are compared over a specific period (approx. 5 minutes) to determine the measuring error.

After adjustment, the temperature transmitter will be validated at two points; approximately 0 °C and at the upper end of the operational temperature range.

6.3 Overview of the periodical calibrations

The frequency of calibrations with reference means are shown in Table 6.3.1.

Instrument or system	**Frequency of calibration with reference means**
Flow meters	First calibration after 2 years, then every 5 years
Temperature value in flow computer	Quarterly, or at least once per year if deemed acceptable
Pressure value in flow computer	Quarterly, or at least once per year if deemed acceptable
Calibration of volume conversion	Quarterly, or at least once per year if deemed acceptable
Calibration of energy conversion.	Quarterly, or at least once per year if deemed acceptable
Reference equipment (see Appendix 1)	Every 6 months

Table 6.3.1: Example of a plan for periodic checks and calibrations

6.4 Rejection limits and actions to be taken

If during a periodic calibration, the limits in Table 4.1.1 [‘Maximum acceptable deviation (AL)’], the “CUSUM action limit” in Table 4.2.1 or the maximum acceptable deviations at periodical check of Table 6.3.1 are exceeded, the following actions must be taken:

a) Transmitters shall be calibrated and adjusted as described in Article 6.2.2.
b) In the event of a malfunction of the flow meter, the flow meter will be repaired and, if necessary, calibrated and replaced (see Article 6.2.1).

6.5 On-line comparison

If applicable, describe the online comparison of the energy and velocity of sound (VOS) measured by the US meter with the calculated VOS.

If the maximum accepted deviation is exceeded on an hourly or daily basis (see Table 6.5.1), an abnormal condition will be detected. Corrective actions shall then be taken in accordance with Article 6.2.
The online comparison is interrupted when in the relevant interval, due to an instrument failure, an alarm of any kind occurs, or when the flow is lower than Q_{min}.

Online comparison	maximum accepted difference	
Aggregation level	hourly	Daily
VOS	0.4%	0.2%

Table 6.5.1: Maximum daily checks of the maximum accepted differences between the main and backup measurements

For additional control of the US meters, an online comparison (OLC) of the measured velocity of sound (VOS) of the US meter and a calculated VOS from the GC (gas chromatograph) will be performed. No maximum acceptable deviation has been defined yet.

The VOS_{gc} will be calculated with the gas composition measured by the GC.

$OLC(\%) = [(VOS_{gc}-VOS_{us})/VOS_{gc}] * 100\%$

7 Recalculation of energy

Condition for recalculation of energy

A recalculation of invoiced energy will be made if:

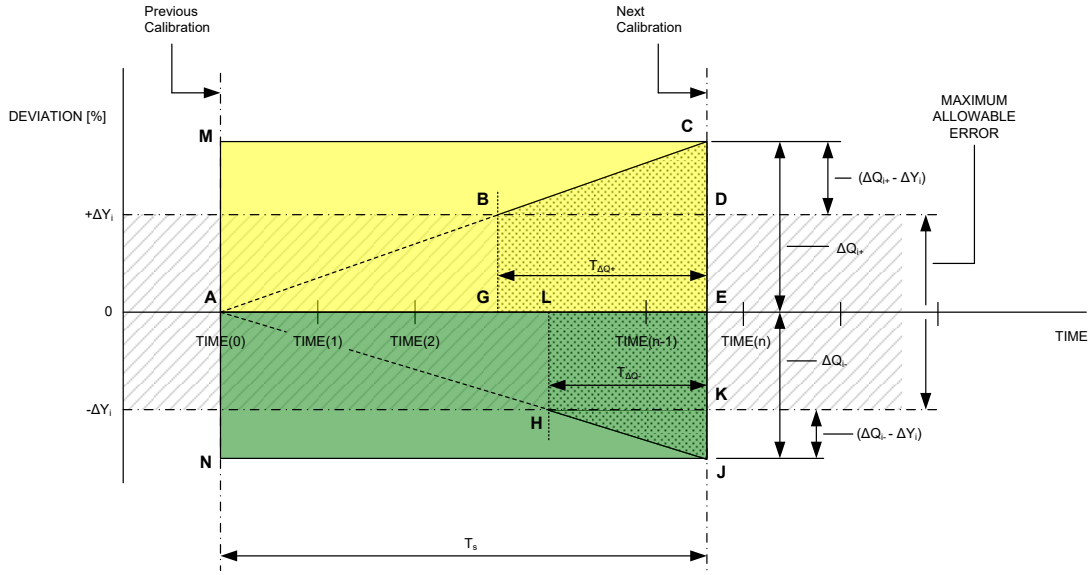
(a) the deviation of the energy conversion factor without base volume exceeds the Maximum acceptable deviation (AL; Table 4.1.1) during the periodical checks (Table 6.3.1) at the metering station or when;

(b) the shift of the flow weighted deviation of the flow meter error curve differs by more than the Maximum acceptable deviation (AL; Table 4.1.1) of the flow meter, compared with the former curve;

(c) another failure has occurred, resulting in a systematic error (e.g. wrong parameter input flow computer). In this case the recalculation limit will be zero percent (0%), which means that all systematic errors will be fully corrected.

Relevant period of time

The recalculation will be performed for the period of time since the occurrence of the failure or, when this is unknown, for a period of time estimated as follows:
A linear rise in time of the deviation (C) since the last check (A) will be assumed.
Only the time that the instrument is in operation will be taken into account.
The period of time for the measurement correction will start at the hour (G) in which the deviation exceeds the recalculation limit (B) and will be ended at the hour in which the failing instrument is taken out of service (E). The volume to be corrected in the figure below is determined by BCEG or HJEL.



Recalculation if measurements are not available

If, during the above-mentioned period or any part of it, the relevant part of the measurement is unavailable or in a failed state:

(a) recalculation for case A will be based on the determined deviation of the energy/volume conversion factor(s) and will be performed on the average of the flow meters per run on monthly or hourly totals;

(b) recalculation for case B will be based on the determined shift of the flow meter and will be performed on the average of the flow meters per run on monthly totals as far as whole months are concerned and on hourly totals otherwise;

(c) recalculation for case C will be based on the correct parameters. For systematic errors the recalculation limit is zero percent (0%).

8 Reference list

[1] NEN-EN 1776: *Gas infrastructure - Gas measuring stations – Functional requirements.*

[2] BIPM, IEC, ISO, DIN, *International Vocabulary of Basic and General Terms in Metrology*, 1993.

[3] ISO 6976: *Natural gas - Calculation of calorific value, density, relative density and Wobbe index from composition*.

[4] DIN EN ISO/IEC 17025: *General requirements for the competence of testing and calibration laboratories*.

[5] OIML R137-2: *Gas meters – Part 2: Metrological controls and performance tests*.

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

Appendix 1: Reference equipment specification

'Unimeet' reference equipment:
The 'Unimeet' is an in-house developed reference instrument capable of measuring temperature with an uncertainty of 0.1K and pressure with an uncertainty of 0.1%.