NOVEL METHODS OF TESTING FOR MEASUREMENT OF NATURAL GAS AND HYDROGEN MIXTURES

D3.2

Report on validation of new or modified test protocols and test methods

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TECHNICAL REFERENCES

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0	16/01/2026	First release	INIG
1	03/02/2026	Review and supplementing the missing information	NaTran, FBK
2	07/02/2026	Reviewing changes and comments from partners and correcting the text of the report	INIG
3	09/02/2026	Reviewing of the report and supplementing information	INRIM, Cesame
4	23/02/2026	Reviewing of the report and supplementing information	INIG, Enagás
5	13/05/2026	Minor corrections and final review	INIG

TABLE OF CONTENT

ACRONYMS AND SYMBOLS

DSO	Distribution System Operator
E_n	Index calculated in accordance with ISO/IEC 17043:2023
H2NG	Hydrogen added natural gas (hydrogen content in natural gas from 0 to 100%)
ILC	Interlaboratory comparison
MUT	Meter under test
Q_{min}	Minimum Flow Rate
Q_{max}	Maximum Flow Rate
RPD	relative % deviation
SoA	State of Art
TDLAS	Tunable Diode Laser Absorption Spectroscopy
TSO	Transmission System Operator
U_{Lab}	Expanded uncertainty calculated for the given Participant's laboratory
U_{ref}	Expanded uncertainty of determining the result of the reference Laboratory or uncertainty of the reference value
UUT	Unit Under Test
x	Laboratory result
X	Reference Laboratory result or comparison reference value (CRV)
Z	Compression factor

1. INTRODUCTION AND EXECUTIVE SUMMARY

The WP3 will focus on obtaining experimental validation to update existing research protocols and standards for measuring the quality and quantity of hydrogen and H2NG blends, addressing identified gaps. An experimental and rigorous approach is necessary before introducing new protocols or standards for measuring the quantity and quality of H2NG mixtures. The first objective of WP3 is to validate and confirm the possibility of using new testing protocols and methods to evaluate the performance of measurement equipment for H2NG mixtures.

Task 3.2 is responsible for the experimental validation of new and/or modified test protocols and methods. The methodology validation activity is carried out on the devices selected in Task 2.1. Where possible, interlaboratory comparisons (ILCs) will be used. Once validated, the methodologies are implemented in Task 3.3 for conducting testing activities. The cooperation of several research laboratories within the Consortium, along with partners involved in developing or modifying existing research methods, will ensure the achievement of the expected goals.

2. METHODOLOGY

This Report summarizes the activities conducted during Task 3.2 and has been edited in accordance with the following steps:

1. Analyzing the findings from WP2 related to specified test equipment. This analysis is crucial for selecting representative samples for interlaboratory comparisons.
2. Reviewing the findings from Task 3.1 concerning the preparation of test benches for testing, the research capabilities of individual partners/laboratories involved in Task 3.3 and analyzing the defined research procedures in Task 3.1. This analysis is vital for identifying suitable laboratories where ILCs will be conducted as part of the validation process.
3. Determining, for each type of measuring devices planned in the project, laboratories where ILC tests will be carried out.
4. Selecting appropriate samples for ILC tests and specifying the validation method for each type of measuring device.
5. Defining the experimental validation plan.
6. Presentation of calibration results included in experimental validations.
7. Analysis of calibration results and evaluation of comparison results.

3. EXPERIMENTAL VALIDATION OF NEW AND/OR MODIFIED TEST PROTOCOLS AND METHODS

Task 3.2 is responsible for the experimental validation of new and/or modified test protocols and methods. The methodology validation activity will be carried out on the devices selected in Task 2.1.

Test method validation is the process of providing objective evidence to confirm the suitability of a validated test method for its intended use. During validation, parameters characterizing the efficiency of the research method are examined - the validation tests and checks carried out allow us to learn about the capabilities and limitations of the measurement method. By definition, EN ISO/IEC 17025 [1] validation is the confirmation, by examination and provision of objective evidence, that specific requirements for a specifically intended task have been met. In other words, validation is a process that aims to confirm the reliability of the method used, i.e., it is intended to answer the question of whether the method used is correct and whether the obtained test results are reliable. Validation also means the process of confirming that the selected methods meet the requirements for their use and that they are able to detect the tested factor with appropriate precision and accuracy. It is recommended that the techniques used to determine the performance of the method should be one of the following or a combination thereof: calibration using reference standards or reference materials; comparison of results obtained by other methods; interlaboratory comparisons; systematic assessment of factors influencing the result; assessment of the uncertainty of results based on scientific understanding of the theoretical basis of the method and practical experience.

There are two types of tests in the project, i.e. performance and aging tests. Considering the specificity of the research planned in the project, it can be noted that most measurement methods are based on standardized methods with modifications to accommodate different gas mixtures as the medium. Aging tests focus on maintaining specific conditions, e.g. pressure and an appropriate gas mixture. For this reason, aging tests do not require validation, but only confirmation that the conditions established in D2.2 have been maintained. Only tests related to determining the accuracy of the instruments require validation. This is crucial for assessing the impact of applied test methodologies. Due to the limited number of laboratories involved in the tests, ILCs will be utilized wherever possible.

3.1 Devices intended for the testing campaign in T3.3

Below, in clauses 3.1.1 to 3.1.7, based on THOTH2 D2.2 Report on "*Methodology and test protocols (Testing protocols will be provided to WP3 as an input for testing)*", the selected devices for testing in the T3.3 campaign are presented. The devices were chosen based on the SoA for TSO and DSO, and representative devices from these categories were then selected to validate the measurement methods through ILCs.

Due to the fact that not all the test samples selected in WP2 could be obtained from THOTH2 Partners and manufacturers, several devices were replaced with others, but of the same technology (which was marked in Table 1 to Table 5 as "substitute").

3.1.1 Gas meters

Table 1 and Table 2 present gas meters used by TSO and DSO, respectively, that were selected and delivered for testing. From these gas meters, objects for ILC tests were chosen in Chapter 3.3.

Table 1. Gas meters from TSO delivered for testing

Rotary	Turbine	Ultrasonic
G100 Sample 20	G160 Sample 22	DN300 Sample 14
G250 Sample 21	G650 Sample 23	DN100 Sample 16
G100 Sample 18	G160 Sample 24	DN300 Sample 15
G250 Sample 19	G650 Sample 25	

Table 2. Gas meters from DSO delivered for testing

Diaphragm	Thermal Mass	Ultrasonic
G40 Sample 8	G4 Sample 10	G4 Sample 3
G65 Sample 9	G25 Sample 11	G6 Sample 4
G4 (T conversion) Sample 5		G4 Sample 1
G6 (T conversion) Sample 6		G6 Sample 2
G10 (PT conversion) Sample 7		

3.1.2 Pressure transmitters

Table 3 shows the pressure transducers used by TSO and DSO, that were selected for testing. From these pressure transducers, objects for ILC tests were chosen in Section 3.3.

Table 3. Pressure transducers delivered for testing

Gauge/Absolute
Device 1 (piezoresistive)
Device 2 (resonant)
Device 3 (resonant)
Device 4 (resonant)
Device 5 (resonant)
Device 6 (piezoresistive)
Device 7 (piezoresistive)

3.1.3 Temperature transmitters

THOTH2 partners have agreed that, based on the installation conditions of the temperature sensors and their operating principle, the hydrogen content has no influence on their correct operation. Therefore, no experimental tests are planned for temperature transmitters, and validations are deemed unnecessary.

3.1.4 Volume conversion devices - Calculation of compression factor

The impact of hydrogen on volume conversion devices (flow computers) is considered in two aspects, i.e. regarding the resistance of pressure transducers (discussed in a separate clause), and concerning the accuracy of the method for converting the compression factor, Z for hydrogen content above the method range.

Based on the State of the Art (SoA) outlined in Deliverable report D1.1, operators typically use volume converters with algorithms compliant with SGERG-88 according to EN ISO 12213-3 [2] and AGA8-92DC according to EN ISO 12213-2 [3] for converting to base conditions. For such algorithms, THOTH2 partners have agreed that the tests will testing will involve computer calculations (simulations) using these algorithms, compared to reference methods dedicated to calculating gases with higher hydrogen content.

Furthermore, Enagás, one of the partners, will conduct volume conversion accuracy tests using the flow computer. These tests will include evaluating Performance according to AGA8-92DC, Performance for SGERG-88, and Performance for Hydrogen gas (H_2).

3.1.5 Gas quality measuring devices (gas chromatographs)

Based on the analysis conducted within WP2, the consortium partners have decided to exclude gas analyzers from the scope of the THOTH2 project research. Instead, it has been agreed to focus on water dew point analyzers. The currently used gas analyzers by TSOs and DSOs are not designed to measure hydrogen content in gas and therefore are inherently unsuitable for measuring H2NG blends. For this reason, investigating them in this context has been deemed unnecessary.

3.1.6 Water Dew Point Analyzers

Table 4 shows water dew point analyzers used by TSO and DSO, that were selected for testing, from which the objects for ILC tests were chosen in Chapter 3.3.

Table 4. List of possible UUTs selected for the trace-water instruments tests in Task 3.3

UUT Sample	Technology	UUT OWNER
Device 1	TDLAS	SNAM
Device 2	Ceramic Metal-Oxide Moisture Sensor	GAZ-SYSTEM
Device 3	Ceramic Moisture Sensor	GAZ-SYSTEM
Device 4	Aluminum oxide technology sensors	INRIM
Device 5	Aluminum oxide technology sensors	INRIM
Device 6	Capacitive-based sensor prototypes	Manufacturer

3.1.7 Leak detectors

Table 5 shows leak detectors used for TSO and DSO, that were selected for testing, from which objects for ILC testing were chosen in Section 3.3.

Table 5. Leak detectors delivered for testing in Task 3.3

Model	Technology
Device 1	Catalytic sensor
Device 2	IR + Catalytic sensor
Device 3	Catalytic + electrochemical sensors
Device 4	Semiconductor + catalytic + thermal conductivity sensors
Device 5	Infrared sensors

3.2 Available infrastructures for testing campaign

Below, based on current information from THOTH2 working and monthly meetings, and documents published on SharePoint, including deliverable D3.1, the research capabilities of individual partners for testing specific types of devices are presented. A detailed description of the measuring equipment is presented in report D3.1.

3.2.1 Gas meters

Tables 6 and Table 7 present the measurement capabilities of individual laboratories for planned calibration measurements of gas meters used by TSO and DSO using various gases, respectively. This data was used to select participants for the ILC tests outlined in Section 3.3. Partners who will be involved in the testing for specific gases in Task 3.3 are highlighted in bold within the tables.

Table 6. Calibration capability for TSO gas meters selected for testing in Task 3.3

Capability to perform calibration / Medium (at working pressure)		
H2NG and 100% H_2	**Dry air**	**Natural gas**
DNV up to 35 bar and 500 m^3/h	**CESAME** 1 ÷ 40/50 barg and 5 ÷ 50 000 Nm^3/h; Up to DN 400 Critical flow sonic nozzle: uncertainties about 0.21% (k=2)	**Enagás** 3 ÷ 50 barg and 10 ÷ 10 000 m^3/h accredited range: 16 to 50 barg DN50 to DN600 Turbine meters working standards CMC 0.23 ÷ 0.26 %
		NaTran 1 ÷ 30 barg and 0,1 ÷ 2 000 Nm^3/h Critical flow sonic nozzle: CMC 0.25% (k=2) 1 ÷ 30 barg and 10 ÷ 10 000 Nm^3/h Critical flow sonic nozzle: CMC 0.3% (k=2)
		GAS SYSTEM 8 to 54 barg and 8 ÷ 6 000 m^3/h) DN50 to DN400 Rotary and turbine meters working standards CMC 0.22 ÷ 0.29 %

Table 7. Calibration capability for DSO gas meters selected for testing in Task 3.3

Capability to perform calibration / Medium (at atmospheric pressure)			
25% H2NG	**100% H_2**	**Air**	**Natural Gas**
INIG 0.04 ÷ 100 m^3/h at 25 mbarg Reference wet drum and rotary meters CMC 0.22 ÷ 0.27 %	**INIG** 0.04 ÷ 18 m^3/h at 25 mbarg Reference wet drum and rotary meters CMC 0.22 ÷ 0.27 %	INIG 0.016 ÷ 1000 m^3/h at 25 mbarg Reference wet drum, rotary and turbine meters CMC 0.23 ÷ 0.50 %	**INIG** 0.016 ÷ 100 m^3/h at 25 mbarg Reference wet drum and rotary meters CMC 0.22 ÷ 0.29 %
			NaTran 0.1 ÷ 2 000 Nm^3/h (BMC) 10 ÷ 10 000 Nm^3/h (PLAT)

3.2.2 Pressure transmitters

Table 8 presents the measurement capabilities of individual laboratories for planned calibration measurements of pressure transducers used by TSO and DSO. This data was used to select participants for the ILC tests outlined in Section 3.3.

Table 8. Calibration capability for pressure transducers selected for testing in Task 3.3

Partners	Capability to perform calibration
INIG	Gauge: -0.98 bar ÷ 134 bar Absolute: 0.04 bar ÷ 135 bar CMC: 0.00017 ÷ 0.036 bar
Manufacturer*	Gauge: 0 bar - 350 bar Absolute: 0.12 bar – 350 bar CMC: 0.000008 ÷ 0.055 bar

** The manufacturer of the pressure transducers used in the project. It provided complete certificates from its laboratory, which has calibration accreditation.*

3.2.3 Volume conversion devices - Calculation of compression factor

Table 9 shows the possibilities of individual laboratories in relation to planned tests of volume conversion devices. This data was used to select participants for the ILC tests presented in Section 3.3.

Table 9. Calibration capability for volume conversion devices selected for testing in Task 3.3

Partners	Capability to perform tests
INIG	Tests using equations of state AGA8-92DC, SGERG-88, GERG-2008 [4]
Enagás	Tests using equations of state AGA8-92DC, SGERG-88, GERG-2008 [4]

3.2.4 Trace water sensors

Table 10 shows the measurement capabilities of individual laboratories in relation to planned tests of trace water sensors used by TSO and DSO. These data are representative of the Calibration and Measurement Capabilities (CMCs) made available to the project for testing and characterization of dewpoint sensors currently employed and to meet future needs of TSOs/DSOs.

Table 10. Calibration capability for trace water sensors selected for sensor testing in Task 3.3.

Partners	Capability to perform tests
INRIM	-75 °Cfp to +95 °Cdp @ 1050 hPa in Air or N2 up to 2 l/min; -30 °Cfp to 68 °Cdp @ approx. 1013 hPa in Air or N2 up to 20 l/min; -50 °Cfp to 95 °Cdp @ approx 1013 hPa in a chamber in Air; -100 °Cfp to -20 °Cfp @ 0.1 MPa to 0.65 MPa in N2 up to 4 l/min; -60 °Cfp to -10 °Cfp @ 0.2 MPa to 5.5 MPa in H2 up to 2 l/min.

3.2.5 Leak detectors

Table 11 shows the measurement capabilities of individual laboratories in relation to planned tests of leak detectors used by TSO and DSO. This data were used to select participants for the ILC tests presented in Section 3.3.

Table 11. Calibration capability for leak detectors selected for testing in Task 3.3

Partners	Capability to perform tests
FBK	Test with calibrated mixtures with concentrations up to 4% v/v of CH_4 and H_2. Test flow range: 1 ÷ 20K sccm, Test pressure: 0/10 bar, Test temp.: 25 °C. Possibility of implementation of setup for measurements up to 100% v/v (to be measured only concentrations out of the explosive limit).
INIG	Mixtures from 0 to 100%, with any proportion of hydrogen and methane in the mixture. Pressure range of the mixture up to 2 bar, temperature 20°C.

3.3 Selecting samples for ILC tests, comparison participants and methodology

Below, in Sections 3.3.1 to 3.3.5, the measuring devices selected for ILC tests for experimental validation purposes are presented, along with details of comparison participants and test conditions.

3.3.1 Gas meters

Table 12 presents selected gas meters for ILC tests, taking into account measurement points (measurement capabilities of all participants).

Table 12. Detailed data for ILC tests of gas meters in Task 3.2

ILC test sample	Participants	Gas medium used	Test conditions
TSO gas meters			
G250 rotary meter Sample 19	Enagás GAZ-SYSTEM CESAME	Natural gas/ Air	Errors at 1000, 700, 400, 280 ,160, 80, 20 m^3/h, min. 3 reps, Test pressure: 16 bar, Test temp.: 15 ÷ 25 °C

3.3.2 Pressure transducers

Since INIG operates in the field of accreditation and International Laboratory Accreditation Cooperation Mutual Recognition Arrangement (ILAC MRA) measurement [1], and it makes interlaboratory comparisons on an ongoing basis, the Consortium agrees to not proceed with intercomparison among THOTH2 partners and to perform calibration of the pressure transmitters only at the INIG test bench.

The INiG Laboratory conducts periodic interlaboratory comparisons as part of its accreditation, both in the field of pressure, pressure transducers and electrical quantities. The same equipment is used for these comparisons as will be used for testing within the THOTH2 project.

Table 13 presents selected pressure transducers for ILC tests, taking into account measurement points (measurement capabilities of all participants).

Table 13. Detailed data for ILC tests of pressure transducers in Task 3.2

ILC test sample	Participants	Gas medium used	Test conditions
Device 6 and Device 7 (piezoresistive)	INIG Manufacturer (ILC option based on manufacturer's accredited calibration results)	Inert (N_2)	Test pressure gauge: 0, 16.2, 32.5, 48.7, 65 bar Number of series: 1 Test temp.: 15 ÷ 25 °C Reading: the current output

3.3.3 Volume conversion devices - Calculation of compression factor

For the volume conversion devices, a comparison of Z results for several datasets obtained for the SGERG-88, AGA8-92DC, and GERG-2008 methods was assumed within the range of the applicability of the methods and outside the range of the permissible hydrogen content.

Table 14 presents selected algorithms covered by ILC tests along with details of comparison participants and test conditions.

Table 14. Detailed data for ILC tests of volume conversion devices in Task 3.2

ILC test method	Participants	Gas parameters / composition
SGERG-88	Enagás INIG	Z Calculation according for gas 1 (parameters acc. to EN ISO 12213-3:2009) with 0, 5, 10, 15 % vol. H_2 @-3.15 °C; 60 bar and 56.85 °C; 60 bar
AGA8-92DC	Enagás INIG	Z Calculation according for gas 1 (composition acc. to EN ISO 12213-2:2009) with 0, 5, 10, 15, 20, 25, 30 % vol. H_2 @-3.15 °C; 60 bar and 56.85 °C; 60 bar
GERG-2008	Enagás INIG	Z Calculation according for gas 1 (composition acc. to EN ISO 12213-2:2009) with 0, 5, 10, 15, 20, 25, 30 % vol. H_2 @-3.15 °C; 60 bar and 56.85 °C; 60 bar

3.3.4 Trace water sensors

Tests of trace water sensors in the T3.3 test campaign will be carried out exclusively by the INRIM partner. It is not possible to perform ILCs in this case. Given that INRIM is the Italian National Metrology Institute, this confirms its competence and reliability of the research results.

3.3.5 Leak detectors

Table 15 shows the leak detector selected for the ILC comparisons along with the participants and comparison conditions.

Table 15. Detailed data for ILC tests of Leak detectors in Task 3.2

ILC test sample	Participants	Gas medium used	Test conditions
Device 4 (Semiconductor + catalytic + thermal conductivity)	FBK/INIG	CH_4, complement: clean air (zero gas)	Calibration curve and short-term stability tests in CH4. Test conditions are reported in the leak detector testing protocol.

4. ILC RESULTS

4.1 Gas meters ILC results

4.1.1 Gas meters ILC principles

When carrying out ILCs for method and measurement validation purposes, small interlaboratory comparisons will be carried out, following the guidelines outlined in document EA-4/21 INF:2018 [5] "Guidelines for the assessment of the appropriateness of small ILCs within the process of laboratory accreditation". A small comparison program should include the following arrangements:

- purpose and scope of interlaboratory comparison,
- quality standards,
- coordinating the program and participants,
- confidentiality,
- objects for comparison,
- measured quantity and test method,
- time frame,
- reporting of results,
- collusion and falsification of results,
- data analysis and results evaluation.

Interlaboratory comparisons included an ILC test based on the Degree of Equivalence (DoE), similar to the *E*n value calculated according to equation (1). To evaluate the results of comparisons with the reference laboratory, the E_n value can be calculated in accordance with ISO/IEC 17043:2011 [6]. Data reporting and processing as well as equivalence assessment were performed based on the DoE limit regulations of the most well-known EURAMET practices [7], [8]. For the purposes of this document, DoE will hereinafter be represented by the value *E*n.

$$E_{\mathrm{n}} = \frac{x - X}{\sqrt{{U_{\mathrm{Lab}}}^2 + {U_{\mathrm{ref}}}^2}} \tag{1}$$

where:

x- measurement result of the laboratory participating in the comparison program,
X- comparison reference value (CRV) calculated for the Participant's laboratory calibration results,
U_{Lab}- expanded uncertainty of determining the Laboratory result,
U_{ref} - expanded uncertainty of the reference value.

For comparisons among THOTH2 participants (as indicated in Table 12), each participant's calibration results were considered equivalent, and the assigned CRV value for the mean gas meter errors was determined based on the calibration results of all participating laboratories in the ILC. The assessment of equivalence between the participant's laboratory's assigned value (E_{lab1}… E_{lab3}) and the CRV reference value, i.e., "Lab-to-CRV equivalence," was performed as follows.

The assigned (reference) value was calculated as the weighted average of errors taking into account the weighted uncertainty values of all Participants Lab1… Lab3) according to equation (2):

$$E_{ref} = \frac{\frac{E_{Lab1}}{u^2_{Lab1}} + \frac{E_{Lab2}}{u^2_{Lab2}} + \frac{E_{Lab3}}{u^2_{Lab3}}}{\frac{1}{u^2_{Lab1}} + \frac{1}{u^2_{Lab2}} + \frac{1}{u^2_{Lab3}}} \quad [\%] \tag{2}$$

where:

E_{ref} is the comparison reference value (CRV),

E_{Lab1} … E_{Lab3} are average errors of indication of the MUT in a given calibration point determined by the given Participant's laboratory,

u_{Lab1} … u_{Lab3} are the standard uncertainties calculated for the given Participant's laboratory referred to calibrations in this ILC.

The uncertainty of the reference value was determined based on equation (3).

$$\frac{1}{u_{ref}^2} = \frac{1}{u_{Lab1}^2} + \frac{1}{u_{Lab2}^2} + \frac{1}{u_{Lab3}^2} \quad (3)$$

The expanded uncertainty of the reference value U_{Eref} is calculated by multiplying standard uncertainty value by coverage the factor k_{95} = 2 (4):

$$U_{\mathrm{ref}} = 2 \cdot u_{\mathrm{ref}} \quad (4)$$

After calculating the reference values U_{ref}, the consistency of the results was assessed using the chi-squared statistic value χ^2 and the Birge coefficient R_B, using the error values for each flow rate. Calculations of χ^2 and R_B were performed according to equations (5) and (6).

$$\chi^2 = \frac{(E_{\mathrm{Lab1}} - E_{\mathrm{ref}})^2}{u_{\mathrm{Lab1}}^2} + \frac{(E_{\mathrm{Lab2}} - E_{\mathrm{ref}})^2}{u_{\mathrm{Lab2}}^2} + \frac{(E_{\mathrm{Lab3}} - E_{\mathrm{ref}})^2}{u_{\mathrm{Lab3}}^2} \quad (5)$$

$$R_{\mathrm{B}} = \sqrt{\frac{\chi^2}{\nu}}, \qquad \nu = n - 1 \quad (6)$$

where: ν – number of degrees of freedom, n – number of ILC Participants

The χ^2 test compares the dispersion of results about the reference value with what would be expected based on the stated uncertainties. In ILC practice, the Birge factor is used to inflate the uncertainty of the reference value when $R_B > 1$, without changing the reference value itself.

So if:

- $R_{\mathrm{B}} \leq 1$ then the results are considered consistent with the uncertainties,
- $R_{\mathrm{B}} > 1$ then there is overdispersion (potential inconsistency).

For measurement points for which $R_B > 1$ was found, uncertainty inflation of the reference value was applied in accordance with ISO 13528 [9]:

$$U_{\mathrm{ref,inf}} = R_{\mathrm{B}} \cdot U_{\mathrm{ref}}, \quad (7)$$

The E_{ref} reference value was not adjusted, only its uncertainty was increased. For those measurement points where $U_{ref,inf}$ was calculated, a new value of E_n had to be determined.

After establishing the CRV and confirming the consistency check, the "Lab-to-CRV" equivalence was assessed based on the DoE limit provisions of the most common EURAMET practices [5], [10]. For each participant, the En_{Lab1}...En_{Lab3} value was determined with respect to the reference values, analogously to Lab1 based on equation (8):

$$E_{\mathrm{nLab1}} = \frac{E_{Lab1} - E_{ref}}{\sqrt{U_{\mathrm{Lab1}}^{2} + U_{\mathrm{ref}}^{2}}} \quad (8)$$

Clause 4.1.2 presents the calculation results and an equivalence assessment for gas meter comparisons. Detailed calculations and source data are provided in an Excel sheet (Appendix 1 to Report D3.2).

4.1.2 Gas meters ILC evaluation

The following sub-items *a*, *b*, *c* and *d* present information on calibrations performed by individual ILC Participants.

a) General information from certificate no. 772025 issued by GAZ-SYSTEM S.A:

- Date of calibration: 07/04/2025
- Environmental conditions:
  - Ambient temperature: 19.8 – 20.0 °C
  - Atmospheric pressure: 0.993 – 0.994 bar
  - Fluid: natural gas (93 % methane)
  - Calibration gas pressure: 16 bar
- Place of calibration: Gas Meter Calibration Laboratory 46 Klepaczew, 08-221 Sarnaki Poland
- Calibration method: the calibration carried out according to the procedure of calibration JB-PW-03, 1st edition of 07/05/2024.
- Traceability: the certificate is issued under the agreement EA MLA in the field of calibration and provides traceability of measurement results to the International System of units (SI).
- Uncertainty of Measurement: uncertainty of measurement has been evaluated in compliance with EA-4/02M:2022. The expanded uncertainty assigned corresponds to a coverage probability of 95% and the coverage factor k = 2.

b) General information from certificate no. 10R089/25 issued by Enagás:

- Date of calibration: 12/03/2025
- Environmental conditions:
  - Mean ambient temperature: 18.97 °C
  - Mean atmospheric pressure: 962.82 mbar
  - Fluid: natural gas
  - Calibration mean gas pressure: 17.31 bara
- Place of calibration: Enagás, Gas meter laboratory, Autovia A-2 Km. 306,4 – 50012 Zaragoza, Spain.
- Calibration method: the calibration carried out according to the procedure of calibration PT/11 (revision 2, November 2020).

- Traceability: the certificate is issued in accordance with the conditions of the accreditation granted by ENAC which has evaluated the laboratory's calibration and measurement capabilities and its measurement traceability to the SI system of units or other internationally accepted references (when traceability to SI is not feasible). ENAC is one of the signatories of the Multilateral Agreement of the European Cooperation for Accreditation (EA) and the International Laboratories Accreditation Cooperation (ILAC).
- Uncertainty of Measurement: The reported expanded measurement uncertainty is stated as the standard measurement uncertainty multiplied by the coverage factor k such that the coverage probability corresponds to approximately 95%. The standard uncertainty is determined as specified in the document EA-4/02 M: 2022

c) General information from certificate no. 25-050-15003-R1 issued by CESAME EXADEBIT:
- Date of calibration: 28/01/2025
- Environmental conditions:
    - Ambient temperature: 16.8 – 17.2 °C
    - Mean atmospheric pressure: 0.982 – 0.983 bar
    - Fluid: dry air
    - Calibration gas pressure: 16 bar
- Place of calibration : CESAME EXADEBIT SA, 43 Rue de l'Aérodrome, 86000 Poitiers.
- Calibration method: the calibration c
- in accordance with the internal calibration procedure (based on ISO/IEC 17025) concerning M1 test bench. It is described in a document that has been summarized in deliverable D3.1.
- Traceability: the test method uses sonic nozzles calibrated using COFRAC-accredited test bench.
- Uncertainty of Measurement: Using the uncertainty calculation methods described by the GUM, it has been determined that the uncertainty of the bench is 0.22% (k=2).

Table 16 presents the results of mean indication errors and expanded uncertainties (k=2, p=95%) for all measurement points of the ILC Participants. The Reynolds number (Re) is also shown based on data from the calibration certificates, as the measurements were made for different gases.

Table 16. Calibration results obtained for rotary gas meter G250 (Sample 19)

Enagás Lab1				Gaz System Lab2				Cesame Lab3			
Q [m³/h]	E_{Lab1} [%]	U(E) [%]	Re [-]	Q [m³/h]	E_{Lab2} [%]	U(E) [%]	Re [-]	Q [m³/h]	E_{Lab3} [%]	U(E) [%]	Re [-]
999.19	0.33	0.25	2681959	1000	0.25	0.28	2740000	-	-	-	-
702.84	0.30	0.25	1891251	700	0.22	0.28	1930000	-	-	-	-
399.58	0.25	0.25	1075718	400	0.19	0.27	1100000	398.26	0.15	0.22	1080000
280.67	0.19	0.25	755660	280	0.16	0.27	772000	277.36	-0.07	0.22	759000
159.88	0.25	0.25	430215	160	0.15	0.27	438000	158.23	0.20	0.21	432000
80.28	0.24	0.25	215864	80	0.11	0.27	224000	78.95	0.17	0.21	215000
20	0.21	0.25	53729	20	-0.15	0.30	55500	19.96	-0.24	0.22	54000

Due to the fact that calibrations were performed with different gases and the rotary gas meter may be sensitive to the Reynolds number (Re), which depends on the density ρ and viscosity µ of the medium, the errors for Laboratories 2 and 3 were calculated with reference to the same Reynolds number for which the error was given in Laboratory 1. The E_{Lab2} and E_{Lab3} error values were calculated by linear interpolation for a specific Re value.

Table 17 shows the final error values for further calculations, taking into account the calculated errors E_{Lab2} and E_{Lab3} for the Re number at Laboratory 1.

Table 17. Calibration results for rotary gas meter G250 (Sample 19)

Q [m³/h]	Enagás Lab1		Gaz System Lab2		Cesame Lab3	
	E_{Lab1} [%]	U(E) [%]	$E_{Lab2@Re1}$ [%]	U(E) [%]	$E_{Lab3@Re1}$ [%]	U(E) [%]
999,19	0,330	0,25	0,248	0,28	-	-
702,84	0,300	0,25	0,219	0,28	-	-
399,58	0,250	0,25	0,188	0,27	0,147	0,22
280,67	0,190	0,25	0,160	0,27	-0,067	0,22
159,88	0,250	0,25	0,149	0,27	0,200	0,21
80,28	0,240	0,25	0,097	0,27	0,172	0,21
20	0,210	0,25	-0,153	0,30	-0,241	0,22

Figure 1 presents the gas meter (Sample 19) error curves determined by individual participants.

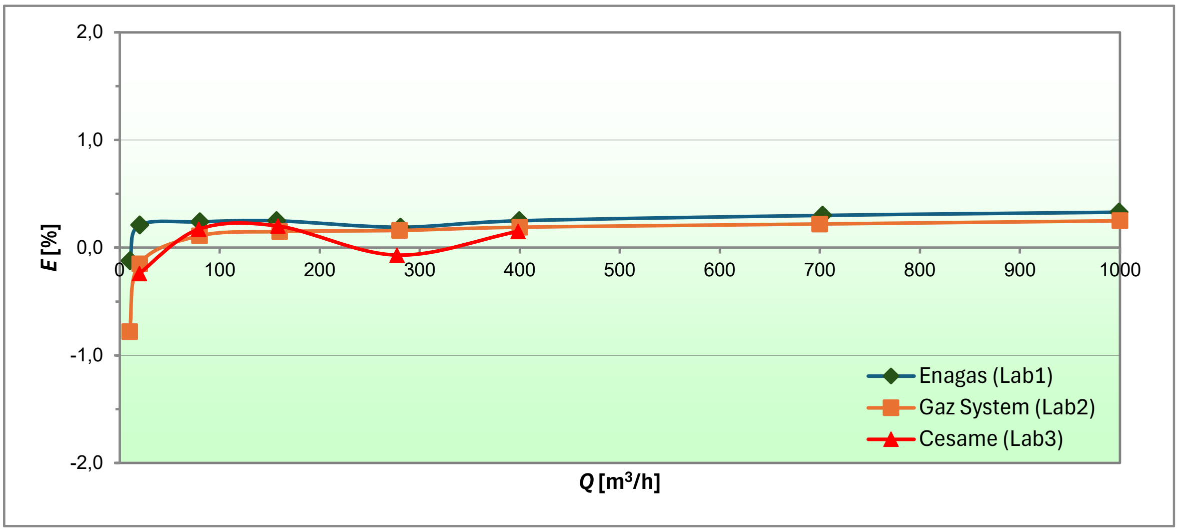

Figure 1. Gas meter (Sample 19) error curves determined by ILC participants

Table 18 presents the calculation results of the reference values E_{ref}, *E*n, Chi-square and the R_B coefficient for the data from Table 17.

Table 18. Initial *En* calculation results for ILC of the gas meter (Sample 19)

Q_{nom} [m^3/h]	Reference value		*En*			χ^2	R_B
	E_{ref} [%]	U_{ref} [%]	En_{Lab1}	En_{Lab2}	En_{Lab3}		
1000	0.33	0.125	0.22	0.22	-	-	-
700	0.30	0.125	0.22	0.22	-	-	-
400	0.19	0.141	0.21	0.01	0.17	0.383	0.44
280	0.08	0.141	0.40	0.27	0.55	2.910	1.21
160	0.20	0.138	0.17	0.18	0.01	0.305	0.39
80	0.18	0.138	0.23	0.25	0.00	0.601	0.55
20	-0.07	0.145	0.97	0.25	0.65	7.730	1.97

For points where $R_B > 1$, was found, uncertainty inflation of the reference value was applied according to equation (7).

The reference value E_{ref} was not corrected, but its uncertainty was increased. Due to the inconsistency for the 280 m^3/h and 20 m^3/h flow rates, a new $U_{ref,inf}$ value was determined and *E*n recalculated for these flow rates. The results are shown in Table 19.

Table 19. Final *En* calculation results for ILC of the gas meter (Sample 19)

Q_{nom} [m³/h]	Reference value		*En*		
	E_{ref} [%]	U_{ref} [%]	En_{Lab1}	En_{Lab2}	En_{Lab3}
1000	0.33	0.125	0.21	0.21	-
700	0.30	0.125	0.21	0.21	-
400	0.19	0.141	0.21	0.01	0.16
280	0.08	0.172*	0.38*	0.26*	0.52*
160	0.20	0.138	0.17	0.18	0.01
80	0.18	0.138	0.23	0.25	0.00
20	-0.07	0.284*	0.74*	0.20*	0.48

* After taking into account uncertainty inflation $U_{ref,inf}$

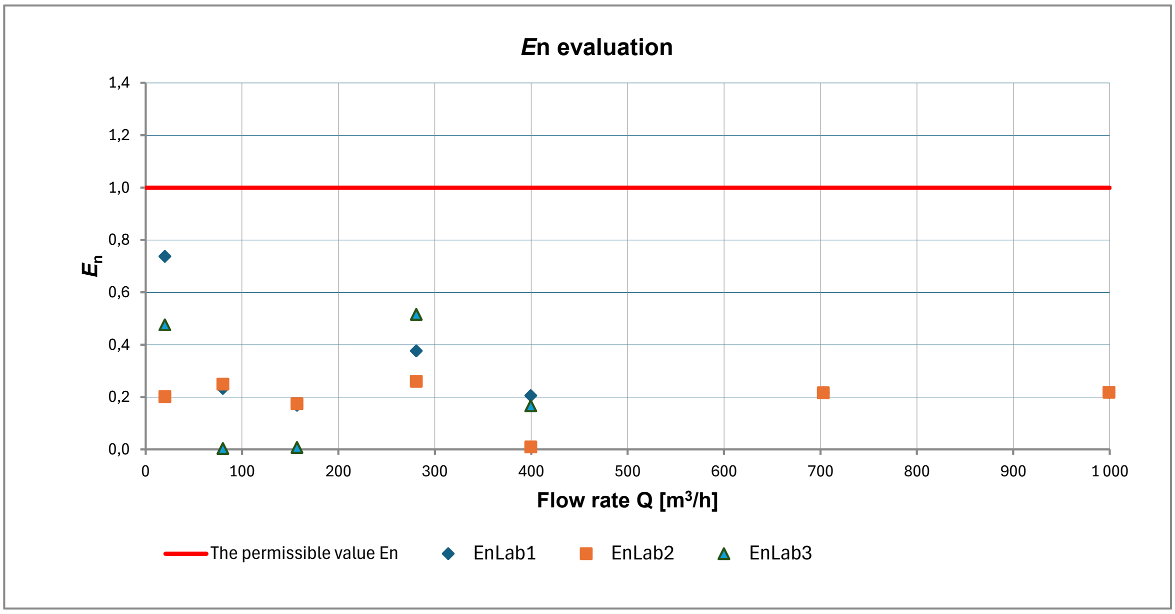

Figure 2. Dependence of the *En* value on flow rate for gas meter (Sample 19)

Gas meters ILC final assessment:

- All laboratories meet the criterion | E_n |< 1.
- For low flow rate 20 m³/h a significant overscatter of results was observed.
- The use of uncertainty inflation of the reference value allowed for maintaining a conservative and standard-correct compliance assessment.
- This confirms the reliability of the results of all pressure calibrations carried out as part of WP3 research activities by INIG.
- The ILC results obtained confirm the reliability of all gas meter calibrations carried out as part of WP3 research activities by partners involved in WP3 research.

4.2 Pressure transducers ILC results

4.2.1 Pressure transducers ILC principles

When carrying out ILCs for method and measurement validation purposes, small interlaboratory comparisons will be carried out, following the guidelines outlined in document EA-4/21 INF:2018 [5] "Guidelines for the assessment of the appropriateness of small ILCs within the process of laboratory accreditation". A small comparison program should include the following arrangements:

- purpose and scope of interlaboratory comparison,
- quality standards,
- coordinating the program and participants,
- confidentiality,
- objects for comparison,
- measured quantity and test method,
- time frame,
- reporting of results,
- collusion and falsification of results,
- data analysis and results evaluation.

To evaluate the results of comparisons with the reference laboratory, the E_n index can be calculated in accordance with ISO/IEC 17043:2011 [6]:

$$E_{\mathrm{n}} = \frac{x - X}{\sqrt{{U_{\mathrm{Lab}}}^2 + {U_{\mathrm{ref}}}^2}} \tag{9}$$

where:

x- measurement result of the laboratory participating in the comparison program,
X- assigned value determined by the reference laboratory (with better CMC),
U_{Lab}- expanded uncertainty of determining the Laboratory result,
U_{ref}- expanded uncertainty of determining the result of the reference Laboratory (with better CMC).

ILC Acceptance Criteria $En \leq 1$ for all measurement points in bilateral comparisons.

Detailed calculations and source data are provided in an Excel sheet (Appendix 2 to Report D3.2).

4.2.2 Pressure transducers ILC evaluation

The tests were conducted at INIG and Manufacturer 1. INIG was the reference laboratory, while Manufacturer 1 was the laboratory participating in the comparison program. The objects of comparison were piezoresistive pressure transducers Device 6 and Device 7.

a) Results obtained for transducer Device 6 for current output measurement

General information from certificate no. 902/C/GM/2024 issued by INiG:

- Date of calibration: 11/09/2024
- Environmental conditions:
    - Ambient temperature: 20.5 – 22.3 °C
    - Air humidity: 58.1 – 63.2 %
    - Atmospheric pressure: 984.71 – 984.95 hPa
- Place of calibration: Oil and Gas Institute – National Research Institute 1 Bagrowa Str., 30-733 Krakow Poland
- Calibration method: the calibration carried out according to the procedure of calibration PW LW-C-02, 8th edition of 24/02/2022.
- Traceability: the certificate is issued under the agreement EA MLA in the field of calibration and provides traceability of measurement results to the International System of units (SI).
- Uncertainty of Measurement: uncertainty of measurement has been evaluated in compliance with EA-4/02M:2022. The expanded uncertainty assigned corresponds to a coverage probability of 95% and the coverage factor k = 2.

General information from certificate no. 0208/PCL/2024 issued by Manufacturer 1:

- Date of calibration: 26/07/2024
- Environmental conditions:
    - Ambient temperature: 19.5 – 20.4 °C
    - Air humidity: 63.0 – 67.8 %
    - Atmospheric pressure: 1000.0 – 1003.1 hPa
- Place of calibration: Manufacturer 1 Laboratory.
- Calibration method: the calibration carried out according to the procedure of calibration PR-01, B edition of 14/11/2023.
- Traceability: the certificate is issued under the agreement EA MLA in the field of calibration and provides traceability of measurement results to the International System of units (SI).
- Uncertainty of Measurement: uncertainty of measurement has been evaluated in compliance with EA-4/02M:2022. The expanded uncertainty assigned corresponds to a coverage probability of 95% and the coverage factor k = 2.

Table 20. Results obtained for the transducer Device 6.

INiG Certificate No. 902/C/GM/2024			Manufacturer 1 Certificate No. 0208/PCL/2024			|*En*|
Reference pressure value	Correction	Measurement uncertainty	Reference pressure value	Correction	Measurement uncertainty	
p_w	Δp	U	p_w	Δp	U	
[bar]	[bar]	[bar]	[bar]	[bar]	[bar]	
0.000	0.001	0.002	0.000	0.000	0.004	0.22
16.200	0.000	0.002	16.200	-0.001	0.008	0.12
32.500	0.000	0.002	32.500	-0.004	0.012	0.33
48.700	0.000	0.003	48.700	-0.001	0.012	0.08
65.000	-0.001	0.007	65.000	0.000	0.016	0.06

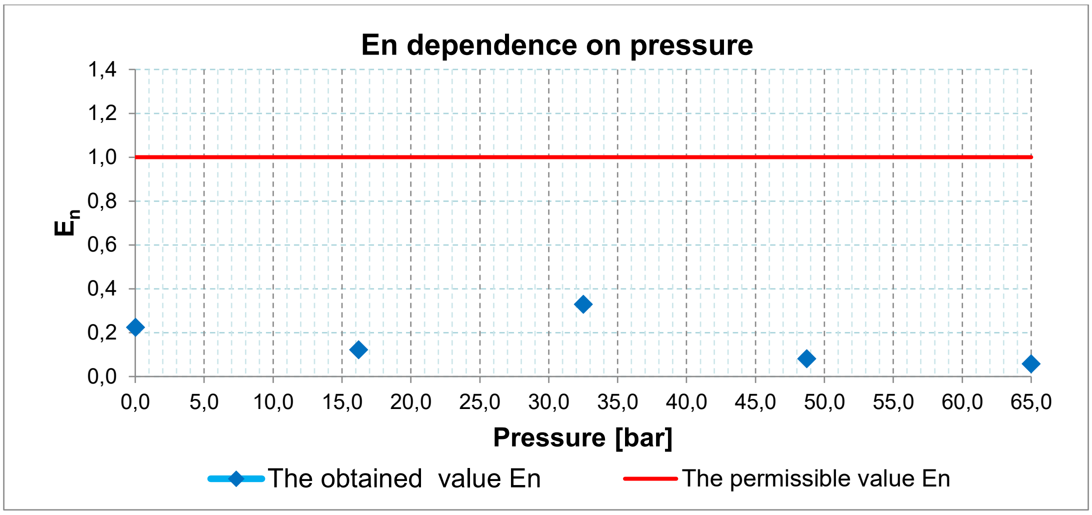

Figure 3. Dependence of the En value on pressure for transducer Device 6

b) Results obtained for transducer Device 7 for current output measurement

General information from certificate no. 903/C/GM/2024 issued by INiG:

- Date of calibration: 11/09/2024
- Environmental conditions:
  - Ambient temperature: 20.7 – 21.9 °C
  - Air humidity: 57.5 – 61.7 %
  - Atmospheric pressure: 984.31 – 984.55 hPa
- Place of calibration: Oil and Gas Institute – National Research Institute 1 Bagrowa Str., 30-733 Krakow Poland

- Calibration method: the calibration carried out according to the procedure of calibration PW LW-C-02, 8th edition of 24/02/2022.
- Traceability: the certificate is issued under the agreement EA MLA in the field of calibration and provides traceability of measurement results to the International System of units (SI).
- Uncertainty of Measurement: uncertainty of measurement has been evaluated in compliance with EA-4/02M:2022. The expanded uncertainty assigned corresponds to a coverage probability of 95% and the coverage factor k = 2.

General information from certificate no. 0207/PCL/2024 issued by Manufacturer 1:

- Date of calibration: 26/07/2024
- Environmental conditions:
    - Ambient temperature: 19.5 – 20.4 °C
    - Air humidity: 63.0 – 67.8 %
    - Atmospheric pressure: 1000.0 – 1003.1 hPa
- Place of calibration: Manufacturer 1 Calibration Laboratory.
- Calibration method: the calibration carried out according to the procedure of calibration PR-01, B edition of 14/11/2023.
- Traceability: the certificate is issued under the agreement EA MLA in the field of calibration and provides traceability of measurement results to the International System of units (SI).
- Uncertainty of Measurement: uncertainty of measurement has been evaluated in compliance with EA-4/02M:2022. The expanded uncertainty assigned corresponds to a coverage probability of 95% and the coverage factor k = 2.

Table 21. Results obtained for the transducer Device 7.

INiG Certificate No. 903/C/GM/2024			Manufacturer 1 Certificate N. 0207/PCL/2024			|*En*|
Reference pressure value	Correction	Measurement uncertainty	Reference pressure value	Correction	Measurement uncertainty	
p_w	*Δ*p	*U*	p_w	*Δ*p	*U*	
[bar]	[bar]	[bar]	[bar]	[bar]	[bar]	
0.000	0.002	0.002	0.000	0.000	0.004	0.45
16.200	0.001	0.002	16.200	-0.001	0.008	0.24
32.500	0.002	0.002	32.500	0.000	0.012	0.16
48.700	0.002	0.003	48.700	-0.001	0.012	0.24
65.000	0.000	0.007	65.000	0.000	0.016	0.00

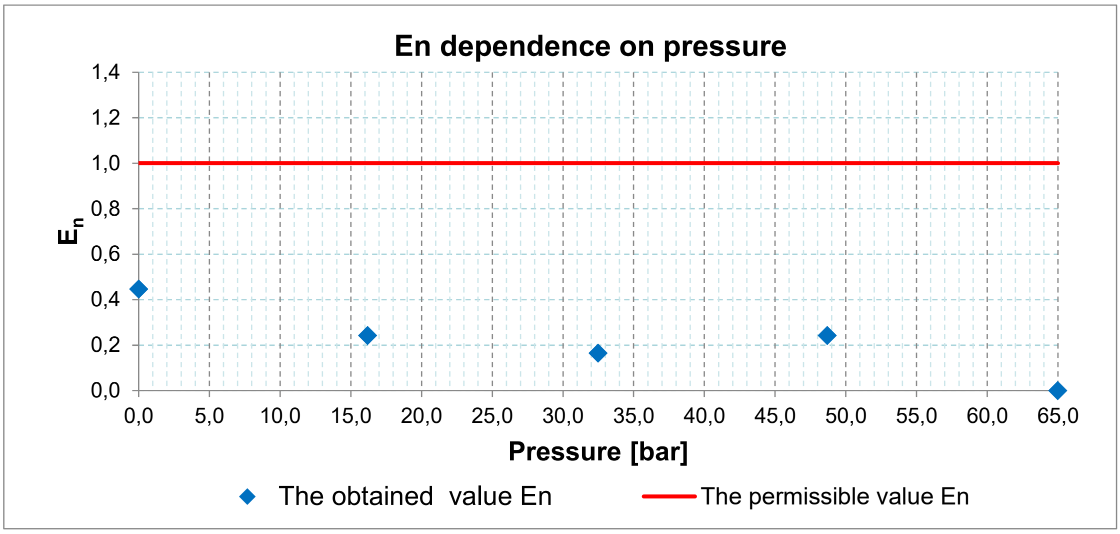

Figure 4. Dependence of the En value on pressure for transducer no. 02241348

Pressure transducers ILC final assessment

- Calibration results meet the criterion | E_n |< 1.
- The maximum value of the |E_n| was 0.45, which indicates a correct comparison between laboratories. This criterion was met for all measurement points.
- This confirms the reliability of the results of all pressure calibrations carried out as part of WP3 research activities by INIG.

4.3 Calculation of compression factor ILC results

4.3.1 Calculation of compression ILC principles

Section 3.3.3 presents selected algorithms and a range of parameters for comparisons between participants involved in volume conversion tests. Calculations are performed using the application tools of each Participant. Table 22 presents ILC criterion for calculation of compression factor *Z* between Participants.

Table 22. Detailed data for ILC tests of calculation of compression factor

ILC test method	Participants	ILC Acceptance Criterion
SGERG-88	Enagás INIG	- no Z-factor difference at the 5th decimal place for Gas 1 without H_2 - maximum Z-factor difference at the 5th decimal place 0.00001 for Gas 1 with H_2 addition
AGA8-92DC	Enagás INIG	
GERG-2008	Enagás INIG	

The composition and parameters of the gases used for the calculations are presented in Table 23.

Table 23. Composition and parameters of the gases used for *Z* calculations during ILC

Hydrogen [vol-%]	0	5	10	15	20	25	30
Carbon dioxide [mol-%]	0.00600	0.00570	0.00540	0.00510	0.00480	0.00450	0.00420
Nitrogen [mol-%]	0.00300	0.00285	0.00270	0.00255	0.00240	0.00225	0.00210
Hydrogen [mol-%]	0.00000	0.04984	0.09969	0.14956	0.19945	0.24935	0.29928
Carbon monoxide [mol-%]	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Methane [mol-%]	0.96500	0.91691	0.86880	0.82067	0.77253	0.72437	0.67620
Ethane [mol-%]	0.01800	0.01710	0.01621	0.01531	0.01441	0.01351	0.01261
Propane [mol-%]	0.00450	0.00428	0.00405	0.00383	0.00360	0.00338	0.00315
i-Butane [mol-%]	0.00100	0.00095	0.00090	0.00085	0.00080	0.00075	0.00070
n-Butane [mol-%]	0.00100	0.00095	0.00090	0.00085	0.00080	0.00075	0.00070
i-Pentane [mol-%]	0.00050	0.00048	0.00045	0.00043	0.00040	0.00038	0.00035
n-Pentane [mol-%]	0.00030	0.00029	0.00027	0.00026	0.00024	0.00023	0.00021
Hexane [mol-%]	0.00070	0.00067	0.00063	0.00060	0.00056	0.00053	0.00049
Heptane [mol-%]	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Octane [mol-%]	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
TOTAL	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
Carbon dioxide [mol-%]	0.006	0.006	0.005	0.005	0.005	0.005	0.004
Hydrogen [mol-%]	0.000	0.050	0.100	0.150	0.199	0.249	0.299
Relative density [-]	0.581	0.556	0.530	0.504	0.479	0.453	0.428
Hs [MJ/m^3]	40.66	39.26	37.86	36.47	35.07	33.67	32.27

Detailed calculations and source data are provided in an Excel sheet (Appendix 3 to Report D3.2).

4.3.2 Calculation of compression ILC evaluation

Table 24 to Table 25 present the calculation results of the compressibility factor Z calculated using algorithms according to the ILC comparison program specified in points 3.3.3 and 4.3.1.

Table 24. Calculation results of the compressibility factor *Z* in Task 3.2

Hydrogen [vol-%]	0	5	10	15	20	25	30
Pressure [bar]	60	60	60	60	60	60	60
Temperature [°C]	-3.15	-3.15	-3.15	-3.15	-3.15	-3.15	-3.15
Z [-] (AGA8) - Enagás	0.84053	0.86039	0.87863	0.89541	0.91090	0.92521	0.93843
Z [-] (AGA8) - INIG	0.84053	0.86040	0.87863	0.89542	0.91091	0.92521	0.93844
***Z* value DIFFERENCE**	0.00000	0.00001	0.00000	0.00001	0.00001	0.00000	0.00001
Z [-] (SGERG-88) - Enagás	0.84084	0.86125	0.87993	0.89683	-	-	-
Z [-] (SGERG-88) - INIG	0.84084	0.86125	0.87993	0.89683	-	-	-
***Z* value DIFFERENCE**	0.00000	0.00000	0.00000	0.00000	-	-	-
Z [-] (GERG-2008) - Enagás	0.84091	0.86075	0.87900	0.89581	0.91130	0.92558	0.93876
Z [-] (GERG-2008) - INIG	0.84091	0.86075	0.87901	0.89581	0.91130	0.92558	0.93876
***Z* value DIFFERENCE**	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000

Table 25. Calculation results of the compressibility factor *Z* in Task 3.2

Hydrogen [vol-%]	0	5	10	15	20	25	30
Pressure [bar]	60	60	60	60	60	60	60
Temperature [°C]	56.85	56.85	56.85	56.85	56.85	56.85	56.85
Z [-] (AGA8) - Enagás	0.93011	0.93987	0.94903	0.95763	0.96567	0.97320	0.98023
Z [-] (AGA8) - INIG	0.93011	0.93987	0.94903	0.95763	0.96567	0.97320	0.98023
***Z* value DIFFERENCE**	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Z [-] (SGERG-88) - Enagás	0.92996	0.94028	0.94993	0.95881	-	-	-
Z [-] (SGERG-88) - INIG	0.92996	0.94028	0.94993	0.95881	-	-	-
***Z* value DIFFERENCE**	0.00000	0.00000	0.00000	0.00000	-	-	-
Z [-] (GERG-2008) – Enagás	0.93033	0.93998	0.94909	0.95765	0.96568	0.97320	0.98022
Z [-] (GERG-2008) - INIG	0.93033	0.93998	0.94909	0.95765	0.96568	0.97320	0.98022
***Z* value DIFFERENCE**	0.00000	0.00000	0.00000	-0.00001	0.00000	0.00000	0.00000

Calculation of compression factor ILC Final assessment

- Both laboratories meet the criterion ΔZ.
- This confirms the reliability of the calculation methods for the algorithms used during the research in Task 3.4 by INIG.

4.4 Leak detectors ILC results

4.4.1 Leak detectors ILC principles

As reported in Deliverable D2.2, the suitability of the testing protocol is evaluated by replicating three specific measurements at both the FBK and INIG sites using two comparable testing benches. The data collected at the two locations are subsequently compared in order to validate the testing protocol. The inter-laboratory comparison (ILC) comprises the following three tests: (i) calibration curve, (ii) short-term stability, and (iii) alarm setpoint verification.

Although three detectors were originally planned for inclusion in the ILC, constraints associated with the long-term stability tests, requiring the detectors to remain under controlled conditions at FBK for a period of six months, necessitated limiting the ILC to a single detector by 31 January (deadline for D3.2 submission). The tested detector was the Device 4 Semiconductor + catalytic + thermal conductivity sensor. The remaining two detectors will be tested in the coming weeks, once their long-term stability tests at FBK are completed. Accordingly, the present deliverable will be updated following the completion of these additional measurements.

Furthermore, the ILC acceptance criterion of 5% proposed in Deliverable D3.5 has been revised. This revision is necessary to account for the intended application of the Device 4 and the Device 1 detectors, which are designed for qualitative gas leak detection rather than for quantitative methane (CH_4) concentration measurements. Manufacturer specifications indicate an accuracy ranging from ±3% to ±10% of the measured value up to the methane lower explosive limit (LEL). In addition to instrument-

related uncertainty, it is essential to consider the contribution of local setup errors. While such contributions were accounted for other devices investigated within the project, they were not included in the original 5% ILC acceptance criterion for leak detectors.
Consequently, the acceptance criterion will be relaxed to reflect these considerations and will be recalculated based on the combined contributions of instrument and local setup errors. Deliverable D3.5 will be updated accordingly.

To evaluate the results of comparisons with the reference laboratory, the E_n index can be calculated in accordance with ISO/IEC 17043:2011

$$E_n = \frac{R_{INIG} - R_{FBK}}{\sqrt[2]{(U_{INIG}^2 + U_{FBK}^2)}} \tag{10}$$

Uncertainty has been evaluated in compliance with EA-4/02M:2022. The expanded uncertainty assigned corresponds to a coverage probability of 95% and the coverage factor k = 2.

4.4.2 Leak detectors ILC evaluation

The tests were conducted at FBK and INIG. FBK was the reference laboratory, while INIG was the laboratory participating in the comparison program. The results of the methane calibration curve are reported in Table 26 and performed at standard ambient conditions. Measurements were obtained fluxing different concentrations of methane from certified sources, FBK gas streams were obtained from certified gas bottles while INIG gas mixture starting from 99.9 % pure target gas, sampled and analysed using a flame ionization detector (FID) to determine the methane concentration.
Due to discrepancies from FBK and INIG concentration sources, relative % deviation (RPD) and *E*n were calculated according to the fitting equation of both the datasets plotted in Figure 5.

$$RPD = \left| \frac{R_{FBK} - R_{INIG}}{R_{FBK}} \right| \times 100 \tag{11}$$

Where R_{FBK} and R_{INIG} are the instrument response obtained by both the laboratories involved in the ILC. The *RPD* between the data collected at FBK and INIG is about 8%.

Table 26. Results obtained for the device under test

FBK		INIG		ILC	
CH_4 Source signal	Detector response	CH_4 Source signal	Detector response	Relative % Deviation (RPD)	|*En*|
[ppm]	[ppm]	[ppm]	[ppm]	[%]	[-]
0	0	0	0	0	0
2000	4060	1954	4140	7.0	0.21
4000	6180	1964	4050	4.3	0.13
6000	9170	4120	6100	8.9	0.29
10000	12490	4640	7300	0.1	0
12000	14709	6081	8130	8.8	0.28
14000	16360	9945	12050	5.9	0.19
18000	20170	13920	15110	7.9	0.25
20000	21640	17712	17110	12.6	0.41
-	-	20016	18050	15.8	0.52

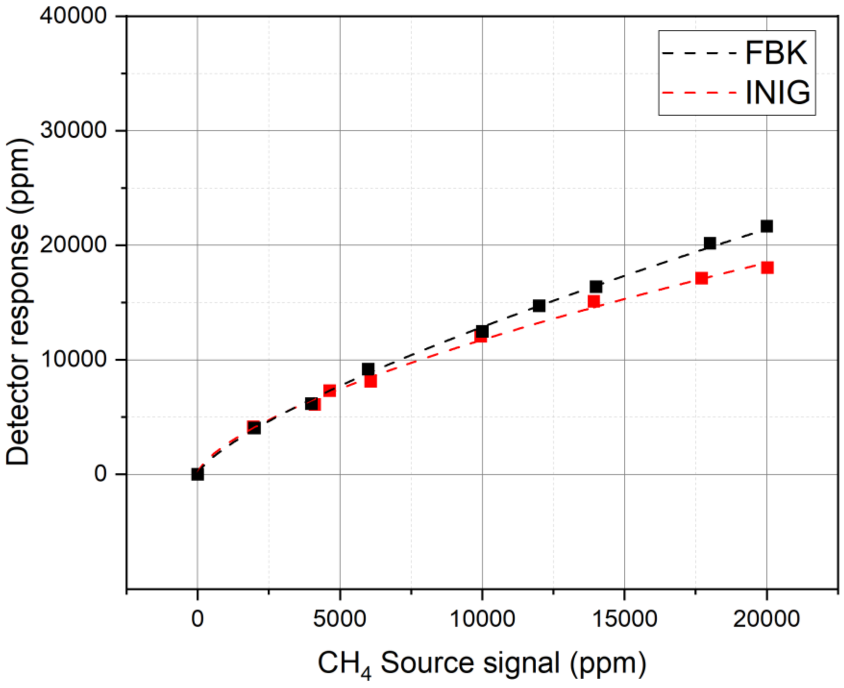

Figure 5. Device 4 calibration curve performed at FBK and INIG

Short term stability measurements were performed exposing the tested device to a fixed concentration of 10000 ppm of methane 6 repeated tests. Standard deviation at FBK and INIG was 399 and 616 ppm, respectively. Relative % error at FBK and INIG was 3.2 % and 5.6 %, respectively.

Table 27. Short term stability measurements results

	FBK		INIG	
Number of measurements	CH_4 Source signal	Detector response	CH_4 Source signal	Detector response
	[ppm]	[ppm]	[ppm]	[ppm]
1	10000	11850	9973	12170
2	10000	12500	10003	11360
3	10000	12380	10021	11150
4	10000	12630	10065	10900
5	10000	12640	10082	11100
6	10000	13070	10081	10700
7	-	-	10094	10170

Alarm set test was performed setting the instrument to 15000 ppm obtaining a detector alarm response at 13300 ppm at FBK and 15200 ppm at INIG.

Leak detector ILC final assessment

- Both laboratories meet the criteria.
- The maximum value of the $|E_n|$ was 0.52, which indicates a correct comparison between laboratories. This criterion was met for all measurement points.
- This confirms the reliability of the testing protocol drafted and reported in D2.2, as well as results of leak detector tests carried out as part of WP3 research activities by FBK.

5. CONCLUSION

After analyzing the research capabilities of individual partners in the project and selecting samples for testing, the method of conducting interlaboratory comparisons was performed for each type of device covered by the project. In some cases, comparisons cannot be made due to the feasibility of conducting tests only in one laboratory.

Below are the key takeaways for experimental validation:

- For gas meters used with TSO, it was possible to carry out ILC tests only with the use of natural gas in Enagás, GAZ SYSTEM and with dry air in CESAME. Calibration using hydrogen and H2NG mixture will only be performed by DNV.
- For pressure transmitters, it was possible to carry out ILC tests at INIG by comparing the manufacturer's calibration with the testing laboratory calibration.
- For volume conversion devices (flow computer), ILC test was carried out in the form of comparisons of the calculations of the compression *Z*-factor at INIG and Enagás.

- ILC tests are not possible for trace water sensors. The tests will be performed only by the National Metrology Institute INRIM.
- For leak detectors, it was possible to carry out ILC tests at INIG and FBK.

As presented in Chapter 4, the validation tests carried out in the form of ILC resulted in pass results, which confirms the reliability of the measurements performed as part of the THOTH2 WP3 research campaign, which was the aim of Task 3.2.

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