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***Installation, Calibration and Validation Guidelines for
Online Hydrocarbon Dew Point Analyzers***

GERG 1.64 PC1 – Phase 2

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1 Executive Summary

In relevant rules and regulations, the condensation behavior of natural gases is described using the hydrocarbon dew point (HCDP) as critical parameter. Often, the HCDP is the basis for gas supply contracts. When applied in HCDP monitoring on gas transmission pipelines, HCDP analyzers are mostly used with their factory settings, i.e. without prior calibration.

The project consisted of two phases. In the first phase /3/, the methods described in ISO/TR 12148 /2/ were applied in parallel for calibration of five commercial HCDP analyzers at 27 bar using a low-calorific pipeline gas. It was found that the measured values indicated by the factory-set measurement instruments deviated by up to 20 K for identical measurement conditions /3/. In the second phase, another measurement instrument was tested in addition to the analyzers already used in phase 1 so that this project phase examined in more detail the measurement behavior of a total of six HCDP analyzers (**Chapter 4.1**). Four pipeline gases (one high- and three low-calorific gases) were available for the tests (**Chapter 5.1**). The results confirmed the significant deviations recorded for operation of the factory-set HCDP analyzers in the first phase. In the tests, the measured values were even found to vary over a range of 14 K to 33 K on average, in some cases even up to 38 K depending on the gas used (**Chapter 5.2.1.1 Table 2**).

The following methods were tested for adjusting the measurement instruments:

In **method A**, the measured value indicated by the HCDP analyzer is corrected by calculation. By this method, it was possible to obtain a reduction of 50% in the range of measured values indicated by the various analyzers in the first project phase /3/. The trend in results recorded in the first phase was confirmed in the second project phase. Depending on the pipeline gas used, the measured value range was narrowed by 21 to 66%. The width of the measured value range in absolute terms continued to be at 26 K on average for two of the available pipeline gases after method A had been applied (**Chapter 5.2.1.2 Table 4**). Adjustment method A was found to be strongly dependent on the used gas in regard to narrowing the measured value range. With adjustment method A, the measurement instruments continued to display strongly varying measurement characteristics, which is due to the still different detection limits of the HCDP analyzers.

In **method B**, the trip point of the analyzer detector is tuned so that the value indicated by the HCDP analyzer corresponds to the temperature at which the condensation rate reaches 5 mg/m³. The measured values indicated by the HCDP analyzers calibrated with pipeline gas were within a range of less than 2 K on average in the first phase of the project /3/. The results obtained from phase 1 indicate that adjustment using method B (tuning of trip value) described in Technical Report ISO/TR 12148 is independent of gas quality.

The results from phase 1 for method B were largely confirmed. Following adjustment, the HCDP analyzers were found to have similar measurement characteristics. Systematic mixtures were produced from a stored L-gas (CB L-gas) and methane 2.5. The average HCDP measured with HCDP analyzers adjusted using method B decreased as the fraction

of L-gas decreased; this trend was found to be largely parallel for all analyzers tested. This confirms the assumption that adjustment using CB H-gas is transferable to other test gases, which means it is independent of the test gas used (**Chapter 5.2.2.2 and 5.2.2.3**).

Testing in practice of the HCDP analyzers adjusted using method B with the four different pipeline gases confirmed, as was already found in phase 1, a clear narrowing of the measured value range delimited by the different HCDP analyzers (**Chapter 5.2.2.4**). The measured value range was reduced by 70 to 91%, i.e. the measured value range was between 3 and 8 K wide on average. The results obtained indicate that adjustment of the HCDP analyzers should be checked at regular intervals.

In conclusion it can be stated that it is basically possible to tune the analyzers tested under the project to a standard detection limit of approx. 5 mg/m³ (method B). For adjustment, a stored gas can be used whose condensation behavior was determined with the automatic gravimetric method pursuant to ISO 6570. Application of method B for the adjustment of field measurement instruments used for monitoring the HCDP as a contract value provides comparable measured data from different measurement instruments.

Adjustment by using method A (**correction of measured value by calculation**) should only be applied where minor deviations from the reference value occur. Method B should be considered preferable in the case of significant deviations from the reference value as the method takes into account the physical circumstances actually existing during the measurement; this means the method allows comparable measurement behavior of different HCDP analyzers to be obtained.

2 Acronyms & Definitions

| | |
|---------------|---|
| Cricodentherm | Maximum temperature at which two phases can coexist |
| HCDP | Hydrocarbon dew point |
| EoS | Equation of state |
| L.E.L. | lower explosion limit |
| OGE | Open Grid Europe |
| PHLC | Potential hydrocarbon liquid content |
| CB | Cylinder bundles |

3 Background

The results obtained from phase 1 indicate that adjustment using method B (tuning of trip value) described in Technical Report ISO/TR 12148 is independent of gas quality. To validate this indication, phase 2 systematically examined the influence of varying gas qualities on HCDP analyzer adjustment using method B. Another result from phase 1 is that adjustment using method A (correction by calculation) is strongly influenced by varying gas qualities. Phase 2 therefore systematically examined the influence of varying gas qualities on measurement behavior to be able to say in what cases method A can nevertheless be used.

The goal of project phase 2 therefore was to systematically validate applicability of the methods presented in project phase 1 /3/ for tuning the HCDP analyzers to a detection limit of 5 mg/m³. It is expressly stated that it was not the goal of the study to compare or evaluate the tested measurement instruments of several manufacturers in regard to suitability for use in practical operations.

4 Test Equipment & Set-up

The following sections describe the test equipment and its set-up.

4.1 HCDP Analyzers

The HCDP analyzers used for this study are standard instruments used in the gas industry for quality assurance with respect to the HCDP.

In some cases, there are fundamental differences between the measurement configurations of HCDP analyzers. In the case of **A4** and **A5**, the sample gas is shut in inside a measurement chamber during the measurement. In contrast, the sample gas flows continuously through the chambers of analyzers **A1**, **A2**, **A3** and **A6** during the measurement. There is a further difference as regards the positioning of the condensation surface. Depending on the individual unit, the condensation of hydrocarbons required for the measurement may take place on a mat or polished steel surface or a silicon surface. The condensate is scanned by a beam of light (monochromatic or achromatic, polarized or non-polarized) and is then detected by a photodiode on the basis of a change in intensity. The gas consumption of measurement systems is significantly affected by gas treatment. Analyzers **A1**, **A2** and **A6** are used without gas treatment. The gas consumption of these units was about 70 l/h. Analyzers **A3**, **A4** and **A5** were operated with the gas treatment systems supplied by the manufacturer.

The following HCDP analyzers were included in testing:

- Cong Prima 10 / Vympel
- Cong Prima 2M / Vympel
- HygroVision BL / Vympel
- Hygrophil HDCT / Bartec
- Condumax II / Michell
- 241CE / Ametek

4.2 Test Set-up

For the tests, the test set-up shown in **Fig.1** was installed at the Werne compressor station. The test set-up consists of three sections.

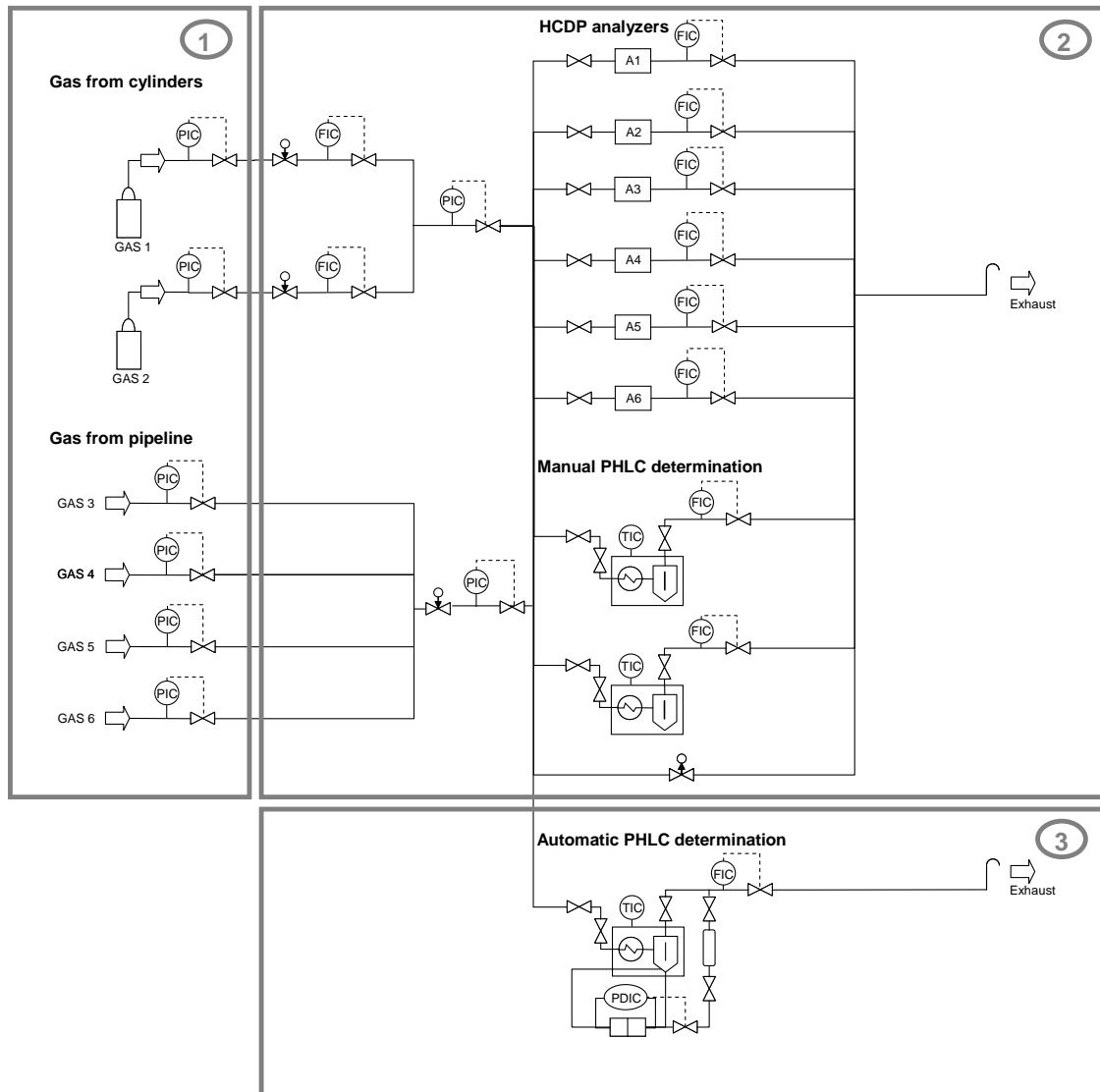


Fig. 1: Flow chart for test set-up at Werne.

Section 1 – Gas Supply

The gas supplied to the measurement instruments can either be natural gases taken directly from the pipeline or gases stored in cylinder bundles. Natural gases from the pipeline are withdrawn centrally from the pipeline with a measurement probe and channeled to the gas sampling box (**Fig. 2**). From there, the gas flows through a stainless steel sample probe (6 mm) at pipeline pressure on to the measurement container. The sample probe is installed without trace heating in a duct sheltered from the wind. One high-calorific (H-gas) and three low-calorific pipeline gases (L-gas) were available for the tests. The pressures of these non-odorized gases were between 42 and 80 bar. To systematically examine the influence of gas quality on the measurement behavior of the HCDP analyzers, two natural gases (L-gas and H-gas) were stored in cylinder bundles (2 x 60 gas cylinders with 50 l each) (**Fig. 3**) at a pressure of 182 bar and 164 bar

respectively. This means a gas volume of approx. 420 m³(n) and 370 m³(n) respectively was available for the tests. Moreover, a bundle with 16 cylinders with methane 2.5 was available for systematically producing the mixtures required (**Chapter 5.2.2.3**).



Fig. 2: Pipeline gas sampling box.



Fig. 3: Gas cylinder bundles for storing CB L-gas and CB H-gas.

To remove any volatile contamination, a high-vacuum pump was used to evacuate the gas cylinders to a residual pressure of 10 mbar over a period of 14 days prior to filling.

For gas withdrawal from the pipeline or the cylinder bundles, a heated pressure controller (Tescom Model 26-5531-24-001, regulated to 70 °C) was installed to reduce the gas pressure to 40 bar prior to entry of the gases to the measurement container.

Section 2 – Measurement Container

The measurement container accommodated the HCDP analyzers to be calibrated (**Fig. 4**) and the test set-up for manual gravimetric determination of condensation rates pursuant to ISO 6570 as well as the data recording equipment. A gas detection system was installed to detect leaks within the measurement container or gas escaping as a result of operating errors; the system is designed to interrupt power supply to the container as soon as 30% of the lower explosion limit (L.E.L.) is reached. The safety valves installed at the entry to the measurement container will then be closed, the safety valve on the internal distribution line opened and the gas displaced to atmosphere. This ensures that no explosive mixture forms within the measurement container.



Fig. 4: Tested HCDP analyzer.



Fig. 5: Mass flow controller with control calculations for systematic gas mixing.

Where pipeline gas was supplied to the measurement instruments, the gas pressure was reduced to test pressure by another pressure controller (Tescom Model 26-5531-24-001). Where gas was supplied from cylinder bundles, the desired volume flow was set

using a mass flow controller (Brooks SLA 5851) (**Fig. 5**) allowing the two gases to be mixed in any ratio (**Chapter 5.2.2.2**). Following reduction to test pressure (heated pressure controller (Tescom Model 26-5531-24-001, regulated to 70 °C)), the gas was channeled in parallel through the HCDP analyzers and the system for gravimetric determination of condensation rates. Volume flow was set in each case by a rotameter. The measurement container also accommodated two test systems for manual determination of condensation rates pursuant to ISO 6570. The exhaust from the measurement analysis system was collected in a manifold and displaced to atmosphere via a lambda vent.

Section 3 – Test Set-up for Automatic Determination of Condensation Rates

The test set-up for automatic determination of condensation rates pursuant to ISO 6570 (**Fig. 6**) was installed in a trailer (**Fig. 7**).



Fig. 6: Test set-up for automatic condensation rate determination.



Fig. 7: Trailer with test set-up for automatic condensation rate determination.

The test set-up was provided by DBI GUT whose staff also commissioned the system and performed the measurements.

5 Experimental Work

The following chapters will present and discuss the tests made under the project and the results obtained.

5.1 Composition and Calculated Condensation Behavior of the Pipeline Gases Used

To be able to evaluate adjustment in an objective manner, the measurement instruments were operated with their factory settings at a test pressure of 27 bar over several days using the four pipeline gases available.

First, the pipeline gases used will be presented. **Fig. 8** compares their compositions. It is a subject of controversy among experts whether the components > C12 are natural gas constituents or rather oil components carried into the network in connection with natural gas transportation. Experience gained by the OGE Gas Quality Competence Center confirms that the different methods (gravimetric liquid drop-out determination to ISO 6570, chilled mirror-type instruments (HCDP analyzers), and phase behavior calculated on the basis of high-resolution gas analysis) can only be compared if based on components existing in concentrations greater than the single-digit $\mu\text{g}/\text{m}^3$ range. Experience has shown that, for most natural gases, this is the range where the components up to C20 exist.

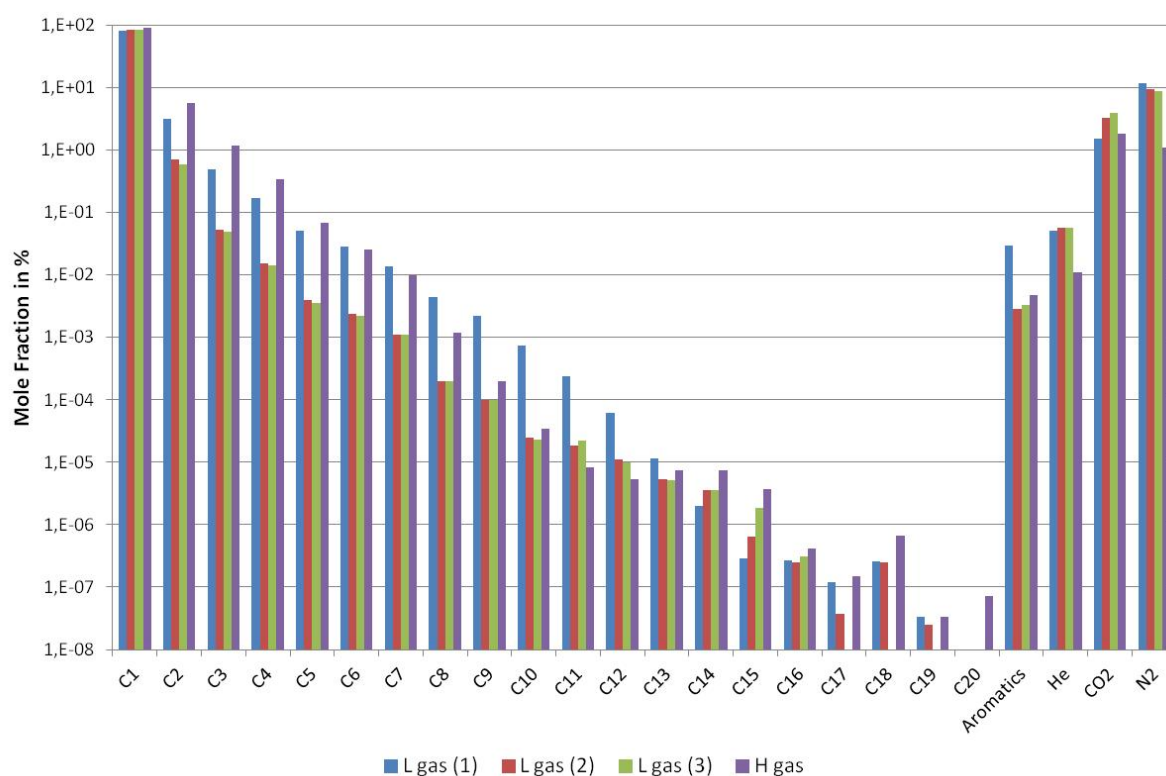


Fig. 8: Compositions of the pipeline gases available.

The pipeline gases available were non-odorized natural gases from the natural gas transmission grid. One H-gas and three low-calorific gases were available; the low-

calorific gases had higher nitrogen fractions than the H-gas. The pipeline pressures of the gases are listed in Table 1.

Table 1: Minimum and maximum pipeline pressures of the pipeline gases used.

| | L gas (1) | L gas (2) | L gas (3) | H gas |
|---------------------------------|------------------|------------------|------------------|--------------|
| Pipeline pressure in bar | 42-56 | 50-60 | 50-60 | 60-80 |

Based on the analyses presented in **Fig. 8** the Peng Robinson equation of state was used to predict the phase behavior of the gases. It is expressly stated that calculation of phase behavior is no absolute method and should therefore not be used as a reference for calibration of the HCDP analyzers. But the method provides an indication of the phase behavior to be expected over a wide pressure and temperature range. As is obvious from **Fig. 9**, the pipeline gases used differ clearly with regard to phase behavior. Moreover, it is obvious that, depending on gas composition, the theoretical HCDP differs clearly from the temperature of the PHLC of 5 mg/m³ at 27 bar. This PHLC was used in the study as reference value for adjustment of the HCDP analyzers. For the gases presented here, the differences are between 5 and 37 K.

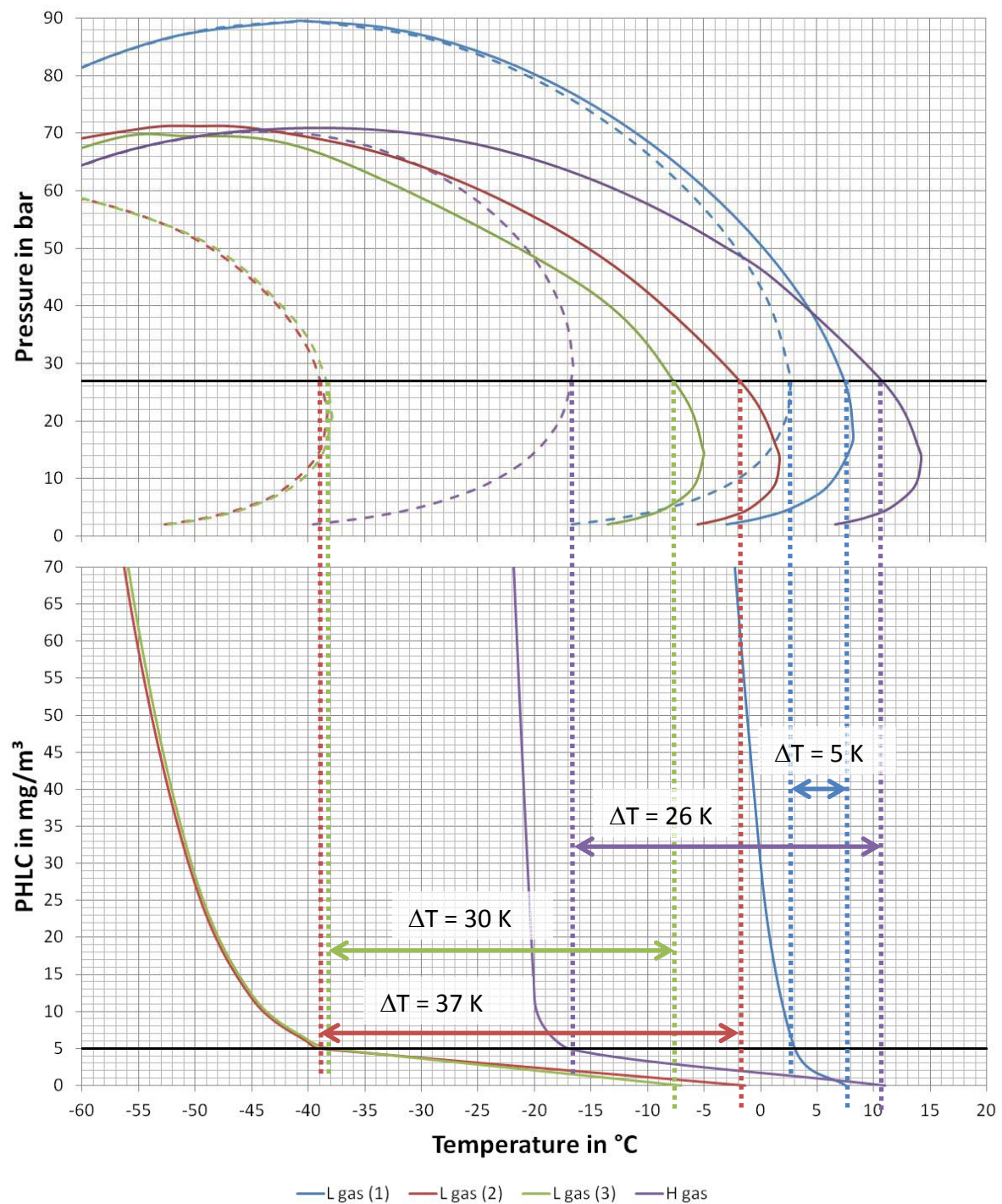


Fig. 9: Phase behavior calculated on the basis of the compositions shown in **Fig. 8** of the pipeline gases used for the tests. Calculated phase behavior only provides an indication of the phase behavior to be expected. **Top graph:** solid lines: phase envelope; broken lines: curves indicating 5 mg/m³ liquid drop-out.

5.2 Review of Applicability of Adjustment Methods

The goal of the study was to systematically validate the two methods used in project phase 1 with regard to tuning the HCDP analyzers to a detection limit of 5 mg/m³.

5.2.1 Method A – Correction of Measured Value by Calculation

With method A presented below, Gasunie Transport Services has obtained good results at measurement points where just one type of gas occurs.

5.2.1.1 Testing of Factory-set HCDP Analyzers Using Pipeline Gases

Fig. 10 shows the measurement curves recorded for the factory-set HCDP analyzers tested with the four pipeline gases at a pressure of 27 bar.

Synchronous curves were recorded for analyzers **A2** and **A6**, which are, however, clearly different from the curves recorded for the other analyzers (**Fig. 10**). This clearly different measurement behavior is due to the fact that the measurement instruments have different detection limits. The maximum cooling temperature of analyzer **A4** is limited to -20 °C in most cases to protect the Peltier cooler. Because of this factory-set limitation, the measurement instrument indicates the maximum cooling temperature as measured value even though the HCDPs measured for L-gas (2), L-gas (3), and H-gas would be lower than -20 °C given the factory-set detection limit of analyzer **A4**. Analyzer **A2** has different measurement modes that allow the HCDP and/or water dew point to be measured. When the H-gas measurements were made, analyzer **A2** switched between measurement modes which explains the jumps in measured values.

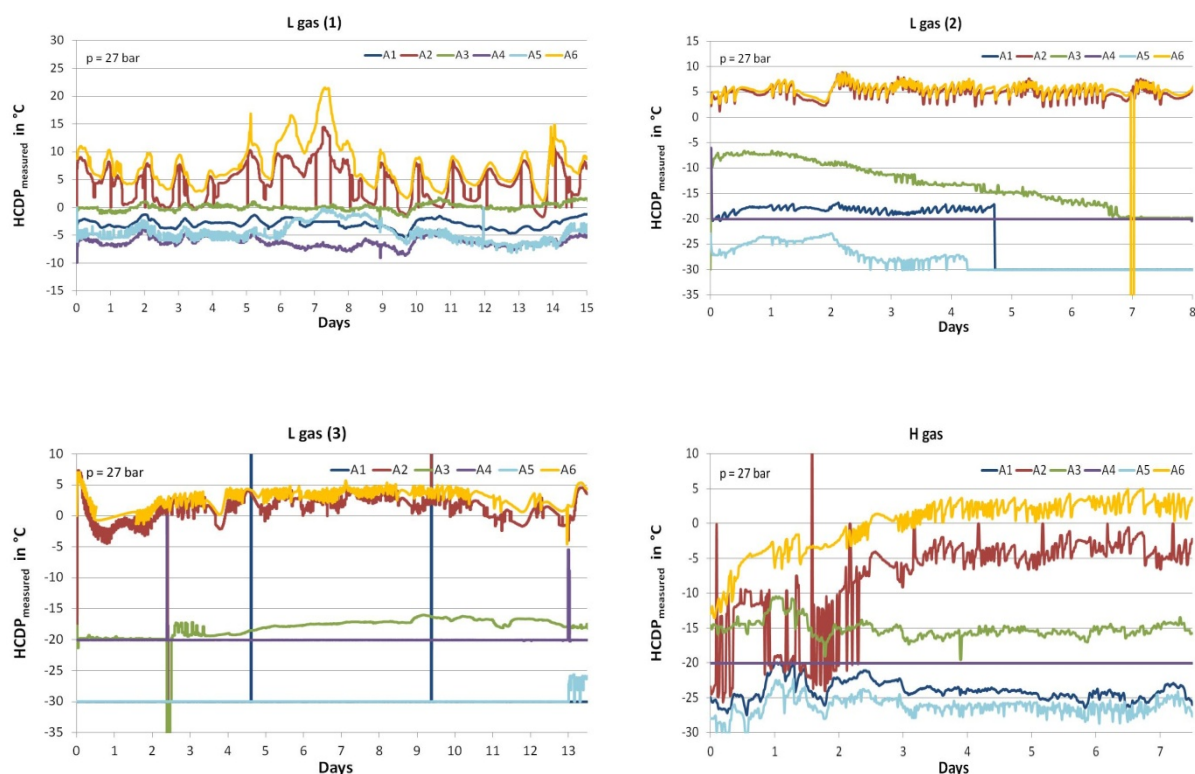


Fig. 10: Performance measurements with the factory-set analyzers using the available pipeline gases at a test pressure of 27 bar.

Depending on the natural gas used, the measured values indicated by the HCDP analyzers differ by double-digit K values (**Table 2**).

Table 2: Measured value ranges delimited by the analyzers when tested with the different pipeline gases.

| HCDP differences in Kelvin | Average | Min. | Max. |
|----------------------------|---------|------|------|
| L-gas (1) | 14 K | 7 K | 28 K |
| L-gas (2) | 34 K | 26 K | 38 K |
| L-gas (3) | 33 K | 29 K | 37 K |
| H-gas | 26 K | 14 K | 33 K |

Based on the manual gravimetric method for determining condensation rates pursuant to ISO 6570, the correction value was determined for *Method A – Correction of measured value by calculation /3/* and applied accordingly.

Fig. 11 shows the HCDP curves measured for the factory-set HCDP analyzers. The test gas was a low-calorific pipeline gas. At the two points shown, the measurement curves delimit a range of 8 and 14.5 K respectively. Over a period of two days, the condensation rates at a pressure of 27 bar were determined for two temperatures (-3 °C and -4 °C) using the manual method for gravimetric condensation rate determination described in ISO 6570.

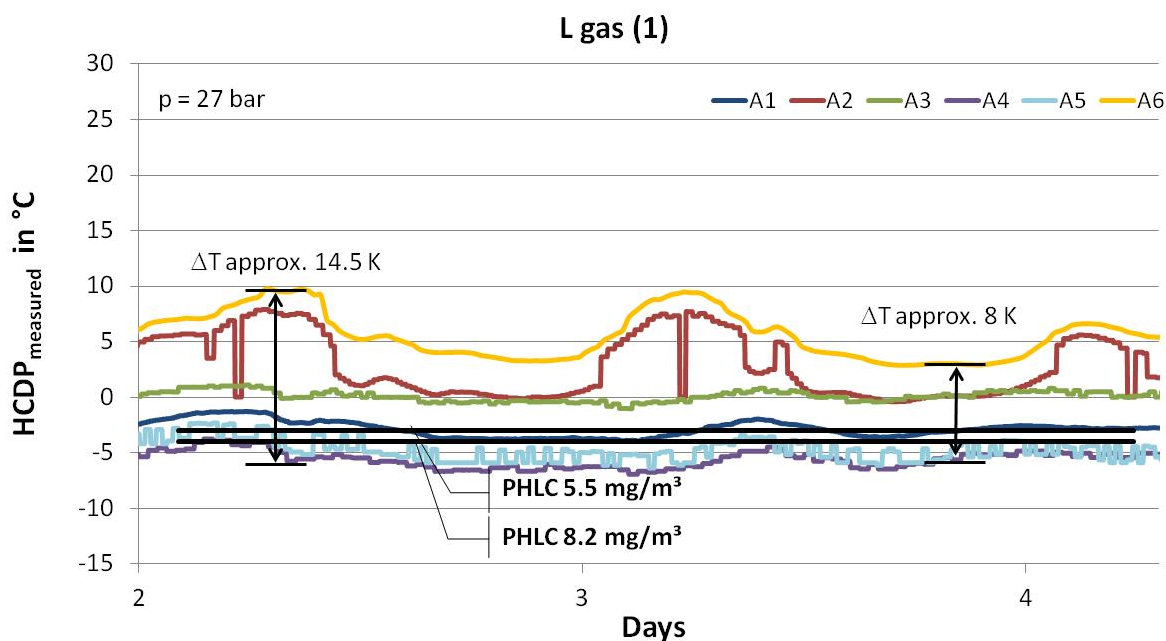


Fig. 11: HCDP curves measured by the factory-set HCDP analyzers at 27 bar. At -3 °C and -4 °C and at a test pressure of 27 bar, the condensation rates were determined manually over a period of two days with the method described in ISO 6570. **Fig. 11** is an excerpt from **Fig. 10 (top left)**.

Based on the two condensation rates, a reference temperature $T_{\text{reference}}$ was determined for a condensation rate of 5 mg/m³ as shown in **Fig. 12**; $T_{\text{reference}}$ derived is -2.8 °C.

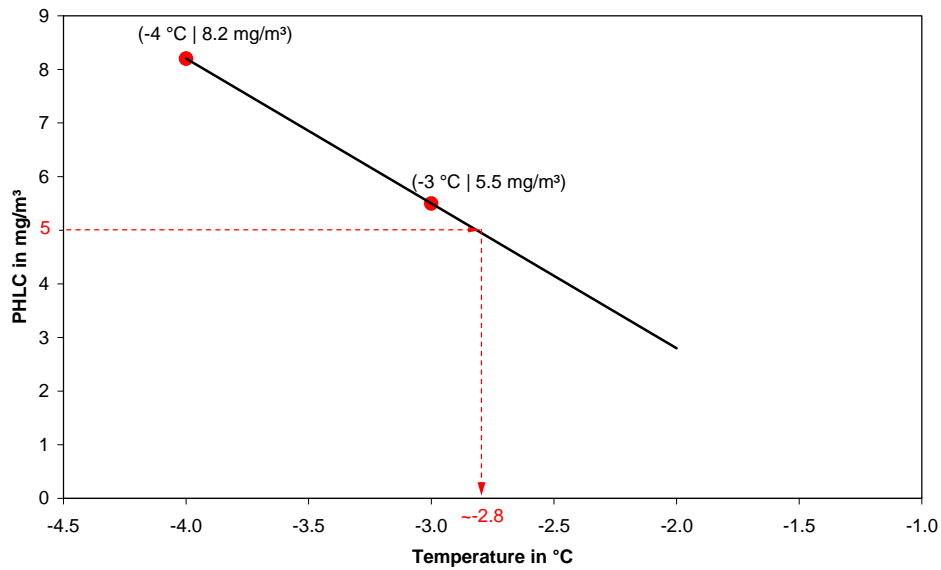


Fig. 12: Determination of reference temperature $T_{\text{reference}}$.

The correction value $T_{\text{correction}}$ is calculated as follows:

$$T_{\text{correction}} = T_{\text{reference}} + \text{HCDP}_{\text{measured, average}}$$

The value $\text{HCDP}_{\text{measured, average}}$ is the average from the HCDPs recorded by an HCDP analyzer over the period during which the condensation rate was determined.

The corrected measured HCDP ($\text{corrHCDP}_{\text{measured}}$) calculated on this basis is defined as follows:

$$\text{corrHCDP}_{\text{measured}} = T_{\text{correction}} + \text{HCDP}_{\text{measured}}$$

The values for the measured value curves shown in **Fig. 11** are as follows (**Table 3**):

Table 3: $\text{HCDP}_{\text{measured, average}}$ for the HCDP analyzers tested and calculated correction value $T_{\text{correction}}$. $T_{\text{reference}}$ derived from Fig. 12 is -2.8 °C.

| | $\text{HCDP}_{\text{measured, average}}$ in °C | $T_{\text{correction}}$ in K |
|-----------|--|--|
| A1 | -2.83 | 0.03 |
| A2 | 2.81 | -5.61 |
| A3 | 0.10 | -2.90 |
| A4 | -5.58 | 2.78 |
| A5 | -4.75 | 1.95 |
| A6 | 5.58 | -8.38 |

As shown in **Fig. 13**, the measurement curves clearly differ at the times also shown in **Fig. 11** because of the different measurement characteristics. The range delimited by the measurement curves is approx. 5 K for the respective times presented.

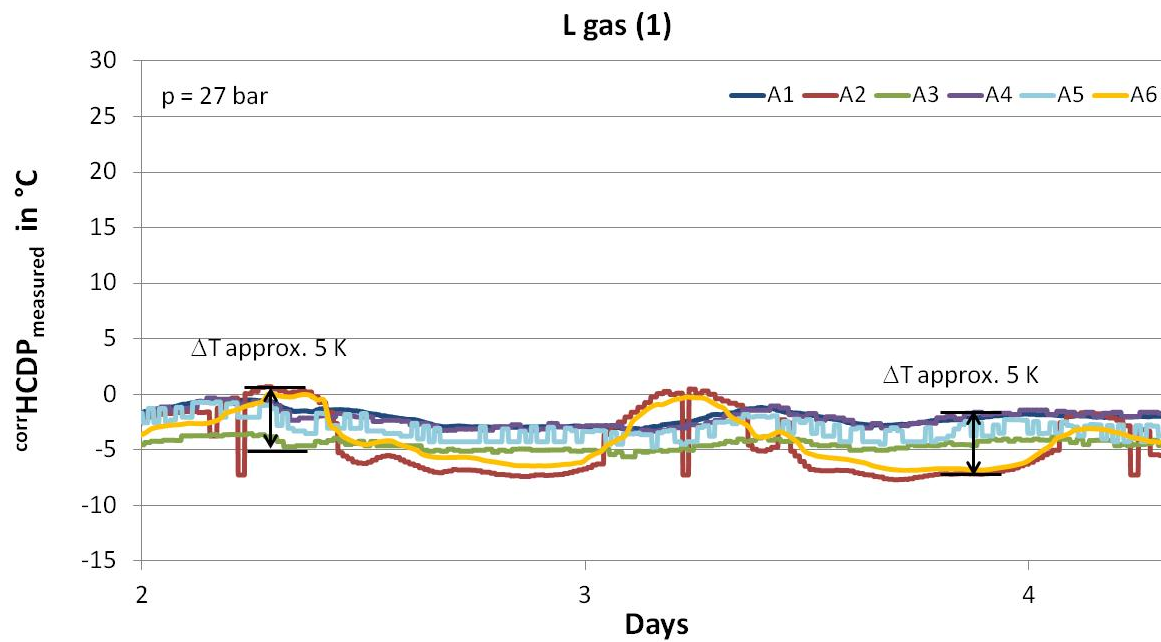
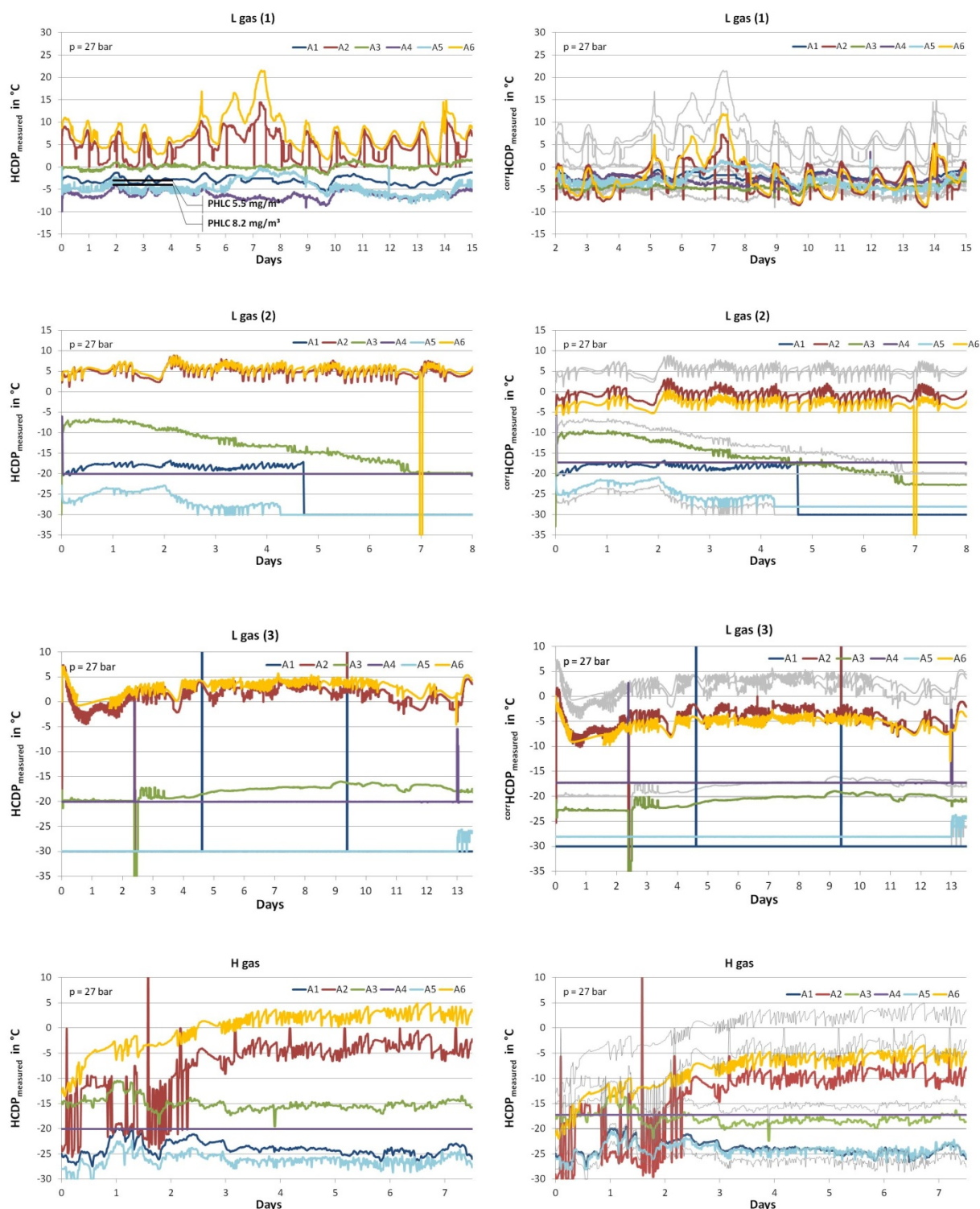


Fig. 13: Correction value applied to the data shown in **Fig. 11**.

5.2.1.2 Validation of Method A Using Pipeline Gases

Fig. 14 shows the measurement curves recorded for the factory-set HCDP analyzers tested with different pipeline gases – on the *left* without, on the *right* with correction to method A. To be able to better evaluate the changes resulting from correction, the graphs on the *right* contain the measurement curves (colored grey) from the graphs on the *left*.



Left: Factory-set HCDP analyzers.

Right: Factory-set HCDP analyzers with correction by calculation. Grey measurement curves from graphs on the left.

Fig. 14: Calculated correction values applied to HCDP analyzer measurement curves.

As already presented in project phase 1 /3/, correction by calculation reduces the difference between the HCDPs measured. Depending on the natural gas used, the

difference can be reduced by approx. 20 to 65%; but it is still greater than 20 K for two of the four gases (**Table 4**). As the condensation rate required for triggering the measured value is the same with this adjustment method, the method does not affect HCDP analyzer measurement characteristics, which means the measurement curves still differ.

It is expressly stated that Gasunie Transport Services has obtained good results with method A at measurement points where only one type of gas occurs as regards comparability of the measured values obtained with the automatic gravimetric condensation rate determination to ISO 6570 and the measured values obtained with the HCDP analyzers.

The method can also be helpful in HCDP analyzer fine tuning; but it should not be used where the gravimetrically determined reference value ($T_{\text{reference}}$) deviates significantly from the value indicated ($\text{HCDP}_{\text{measured,average}}$).

Table 4: Range of HCDP analyzer measured values using different pipeline gases and correction by calculation.

| HCDP differences after correction by calculation in Kelvin / improvement in percent | Average | Min. | Max. |
|--|----------------|-------------|-------------|
| L gas (1) | 5 K / 66% | 1 K / 80% | 12K / 59% |
| L gas (2) | 26 K / 22% | 18 K / 32% | 32 K / 15% |
| L gas (3) | 26 K / 21% | 20 K / 29% | 31 K / 15% |
| H gas | 17 K / 36% | 7 K / 49% | 22 K / 31% |

5.2.2 Method B – Calibration by Adjustment of Trip Point

HCDP analyzers detect condensation by a change in the intensity of a light beam directed towards the condensation surface as a result of the presence of condensed hydrocarbons. This change is detected by a phototransistor or photodiode. In simplified terms, the measured value is determined by the given trip point of the phototransistor or photodiode. When this trip value is reached, the mirror temperature is outputted as a measured value. The HCDP can therefore be calibrated by adjusting the trip point. For this purpose, a characteristic curve of the analyzer is defined by plotting the mirror temperature against the phototransistor or photodiode output signal for a sample gas of constant composition. The temperature dependence function of the PHLC can be defined by using the gravimetric method for condensation rate determination. In this way, the trip value required can be deduced directly by defining a given PHLC. The procedure is illustrated schematically in **Fig. 15**. If this trip point is assigned to the HCDP analyzer, the temperature at which the given condensation rate is reached is outputted as a measured value during measurements with this gas.

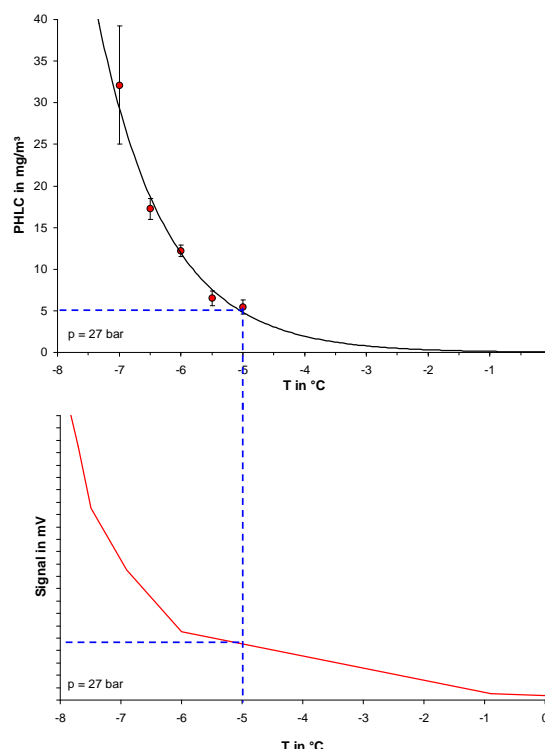


Fig. 15: Determination of trip value for a given PHLC.

Method B requires a gas with known condensation behavior.

5.2.2.1 Requirements for Calibration Gas Used in HCDP Analyzer Adjustment

As in the present study, a trip point of 5 mg/m^3 of hydrocarbon condensate for adjustment is assumed in the following. Considering that the condensation rate can be determined with an accuracy of $\pm 1 \text{ mg/m}^3$ with the method described in ISO 6570 and further considering that the accuracy required in HCDP analyzer adjustment is $\pm 1 \text{ K}$, the condensation rate in the temperature range relevant to calibration should not exceed $1 \text{ mg m}^{-3} \text{ K}^{-1}$.

A gas with a condensation rate of 5 mg/m^3 between 0.2 and $2 \text{ mg m}^{-3} \text{ K}^{-1}$ is therefore recommended for calibration of the HCDP analyzers. The value of $2 \text{ mg m}^{-3} \text{ K}^{-1}$ should not be exceeded to ensure accurate adjustment.

These calibration gas requirements can only be met by a multi-component mixture such as real natural gas.

For this purpose, two cylinder bundles with $60 \times 50 \text{ l}$ gas cylinders each were filled with H-gas and L-gas respectively. Then the automatic gravimetric method to ISO 6570 was applied to determine the temperature dependence of the condensation rate at 27 bar.

Fig. 16 shows the gas compositions determined for the two stored cylinder bundle gases, CB H-gas and CB L-gas.

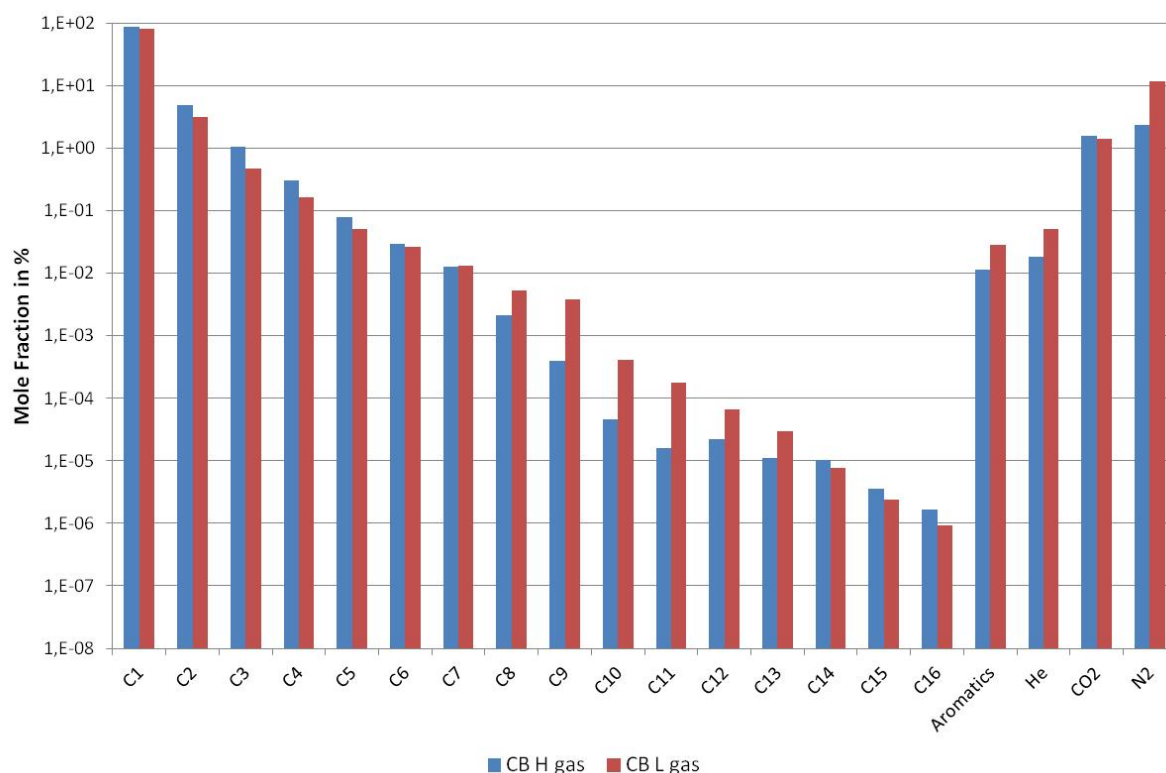


Fig. 16: Compositions of stored gases.

Fig. 17 shows their calculated condensation behavior. As is obvious from **Fig. 17 below**, the liquid drop-out curve is clearly flatter for CB H-gas than for CB L-gas; the gradient is

approx. $0.3 \text{ mg m}^{-3} \text{ K}^{-1}$ for CB H-gas, while it is $1 \text{ mg m}^{-3} \text{ K}^{-1}$ for CB L-gas; this means CB H-gas allows more sensitive adjustment of the HCDP analyzers pursuant to method B.

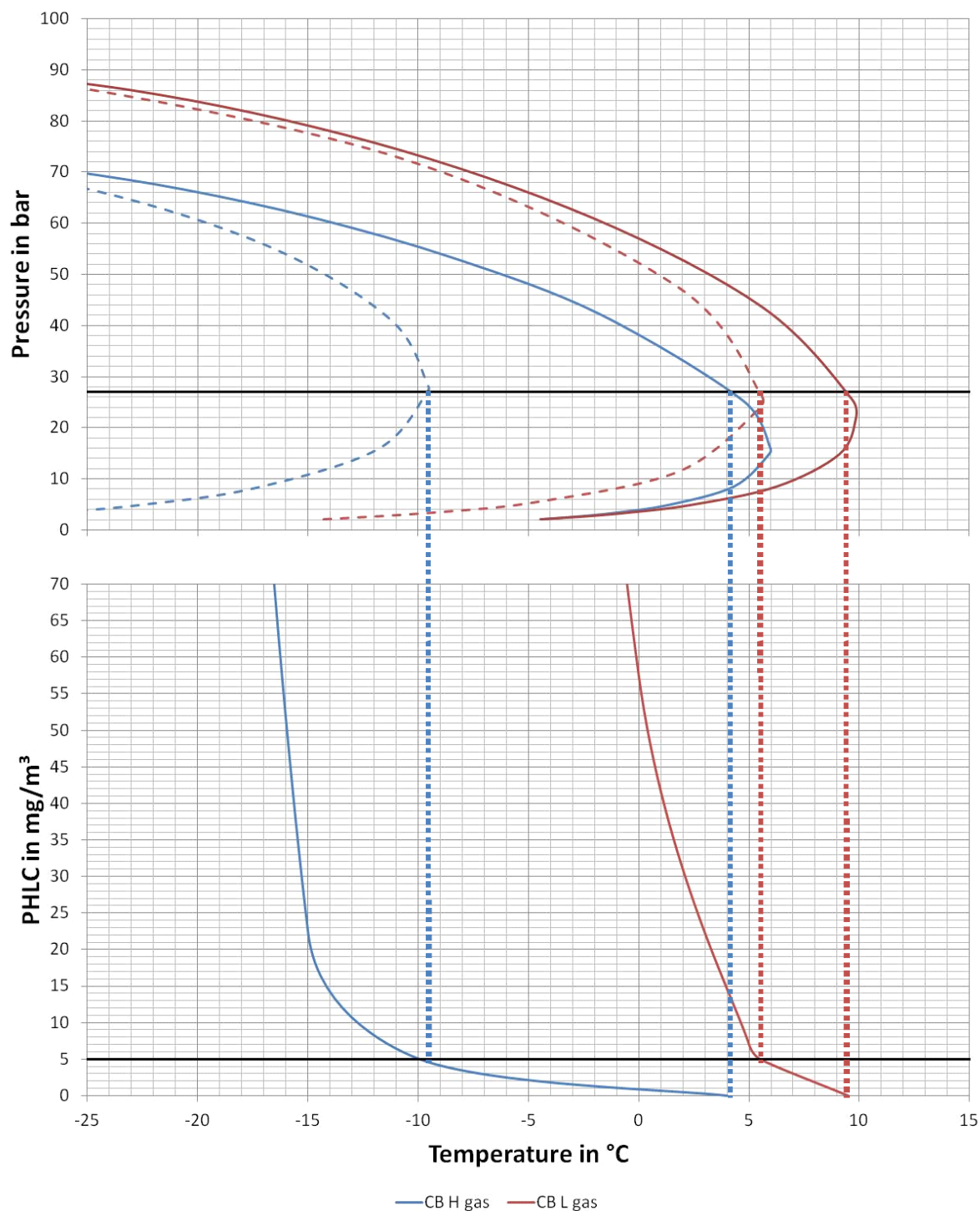


Fig. 17: Based on the phase behavior calculated from the compositions shown in **Fig. 16** for the stored gases used for the tests. Calculated phase behavior is only indicative of the phase behavior to be expected. **Graph, top:** solid lines: phase envelope; broken lines: 5 mg/m^3 liquid drop-out curves.

5.2.2.2 Testing of HCDP Analyzers Using Stored Gases

Fig. 18 shows the measurement curves for the factory-set HCDP analyzers tested with the two stored gases at a test pressure of 27 bar. The measured HCDPs vary over a range of 26.5 K for H-gas and a range of 14.5 K for L-gas. The HCDP analyzer manufacturers do not specify detection limits in regard to the condensation rate in mg/m^3 required for triggering a measurement signal.

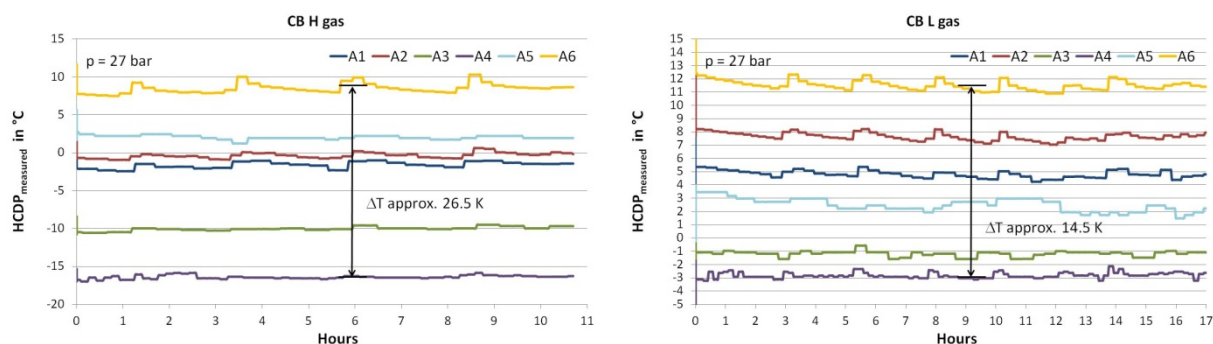


Fig. 18: Testing of HCDP analyzers with stored gases.

Based on the calculated liquid drop-out curves shown in the **Fig. 19** the trip values for the factory-set HCDP analyzers vary between $< 0.5 \text{ mg}/\text{m}^3$ and $142 \text{ mg}/\text{m}^3$ (see **Table 4**).

Based on the liquid drop-out curves determined in accordance with ISO 6570 shown in **Fig. 19** the trip values for the factory-set HCDP analyzers vary between $< 0.5 \text{ mg}/\text{m}^3$ and $25 \text{ mg}/\text{m}^3$ (see **Table 4**).

Table 4: Trip values predicted on the basis of the liquid drop-out curves calculated or determined in accordance with ISO 6570 (**Fig.19**) for the factory-set HCDP analyzers tested with the two stored gases (CB H-gas and CB L-gas).

| | CB H gas | | | CB L gas | | |
|-----------|-----------------------------------|---|--|-----------------------------------|---|--|
| | HCDP _{measured} in °C | PHLC _{calculated} in mg/m^3 | PHLC _{ISO6570} in mg/m^3 | HCDP _{measured} in °C | PHLC _{calculated} in mg/m^3 | PHLC _{ISO6570} in mg/m^3 |
| A1 | -1.6 | < 5 | < 2 | 4.8 | 8 | < 5 |
| A2 | -0.3 | < 5 | < 2 | 7.6 | < 5 | < 5 |
| A3 | -10.0 | 5 | 2 | -1.1 | 85 | 6 |
| A4 | -16.4 | 48 | 7 | -2.8 | 142 | 25 |
| A5 | 2.0 | < 5 | < 2 | 2.5 | < 5 | < 5 |
| A6 | 8.4 | < 5 | < 2 | 11.5 | < 5 | < 5 |

The automatic gravimetric method to ISO 6570 was applied to determine the temperature dependence of liquid drop-out at 27 bar for the two gases.

Fig. 19 compares the liquid drop-out curves determined experimentally with the liquid drop-out curves calculated on the basis of GC analyses and shown in **Fig. 17**.

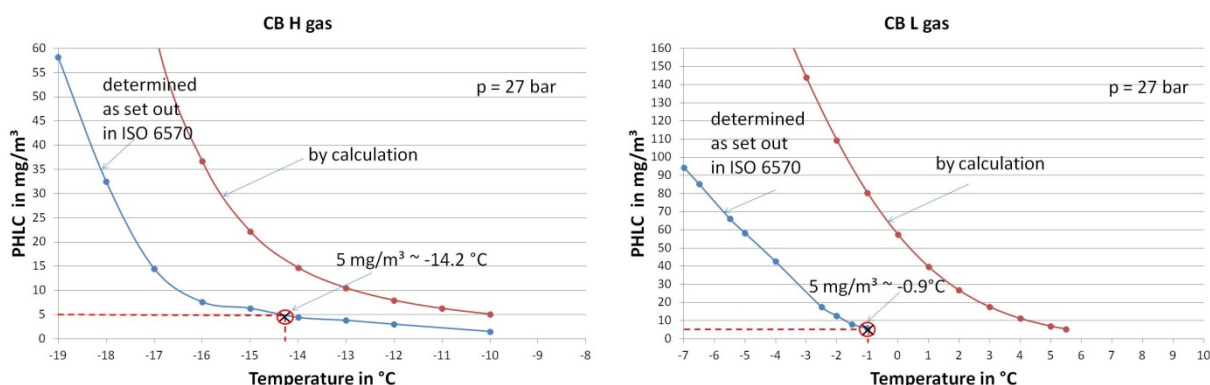


Fig. 19: Liquid drop-out curves determined with the automatic gravimetric method to ISO 6570 compared with the calculated liquid drop-out curves for the two stored gases at a test pressure of 27 bar.

As shown in **Fig. 19**, the calculated liquid drop-out curves follow a similar trend as the liquid drop-out curves determined experimentally with the gravimetric method to ISO 6570, but they are 4 to 6 K higher in absolute terms. In the case of CB H-gas, the PHLC of 5 mg/m³ was determined with the automatic gravimetric method to ISO 6570 at a temperature of -14.2 °C, in the case of CB L-gas at a temperature of -0.9 °C. Because of the flatter trend in its liquid drop-out curve, CB H-gas allows more sensitive adjustment of the HCDP analyzers. Therefore, the gas was made available to the measurement instrument manufacturers on site at Werne, where the test set-up was located (**Chapter 4**), for adjustment at a test pressure of 27 bar indicating the reference temperature of -14.2 °C. The manufacturers were requested to tune the sensitivity of the detectors on their measurement instruments in such a way that they indicated a measured value of ideally -14.2 K for the gas made available.

The result is shown in **Fig. 20 on the left**. After adjustment, the HCDP analyzers delimit a range of approx. 5 K or even of < 1 K if analyzer **A3** is not included. Compared with the starting situation (**see Fig. 18 on the left**) this means the measured value range has been narrowed from 26.5 K to 5 K, corresponding to an 80% reduction, or from 26.5 K to 1 K if analyzer **A3** is not included, corresponding to a reduction of approx. 96%.

To obtain an initial indication in regard to the influence of gas composition on adjustment, the analyzers adjusted using CB H-gas were tested with CB L-gas at a test pressure of 27 bar. The measurement instruments were expected to indicate a measured value of around -0.9 °C, which would correspond to a trip value of 5 mg/m³. On average, the values measured by the analyzers were within a range of 3 K. This means adjustment helped to narrow the measured value range from 14.5 K to 3 K, thus achieving an approx. 79% reduction in the case of CB L-gas.

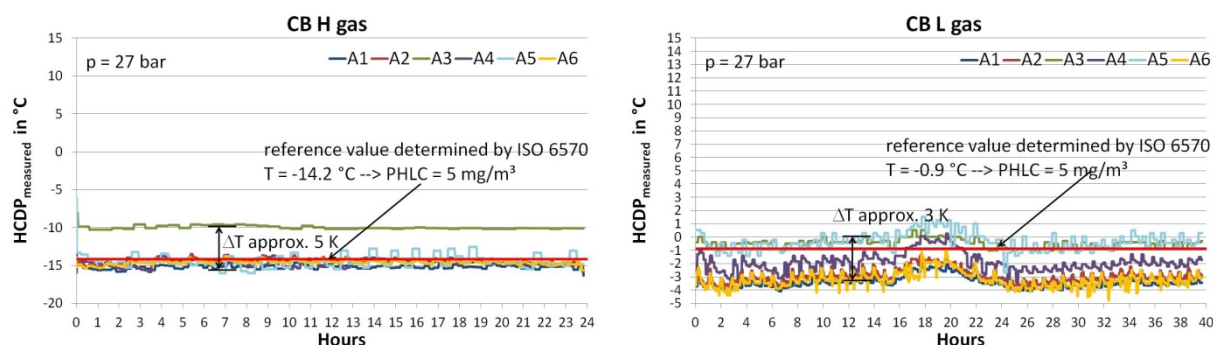


Fig. 20: Measurement curves for HCDP analyzers adjusted using CB H-gas and tested using CB L-gas.

5.2.2.3 Validation of Method B Using Gas Mixtures

Mixtures were produced from the stored CB L-gas and methane 2.5 to systematically examine and evaluate the influence of gas quality on the measurement behavior of the adjusted HCDP analyzers.

As an example, **Fig. 21** shows the HCDPs measured by the adjusted analyzers when tested with a mixture of 72.7% CB L-gas und 27.3% methane 2.5. Switching operations of the HCDP analyzers with closed measurement chamber interfered with the mass flow controllers, causing the measured values to fluctuate periodically.

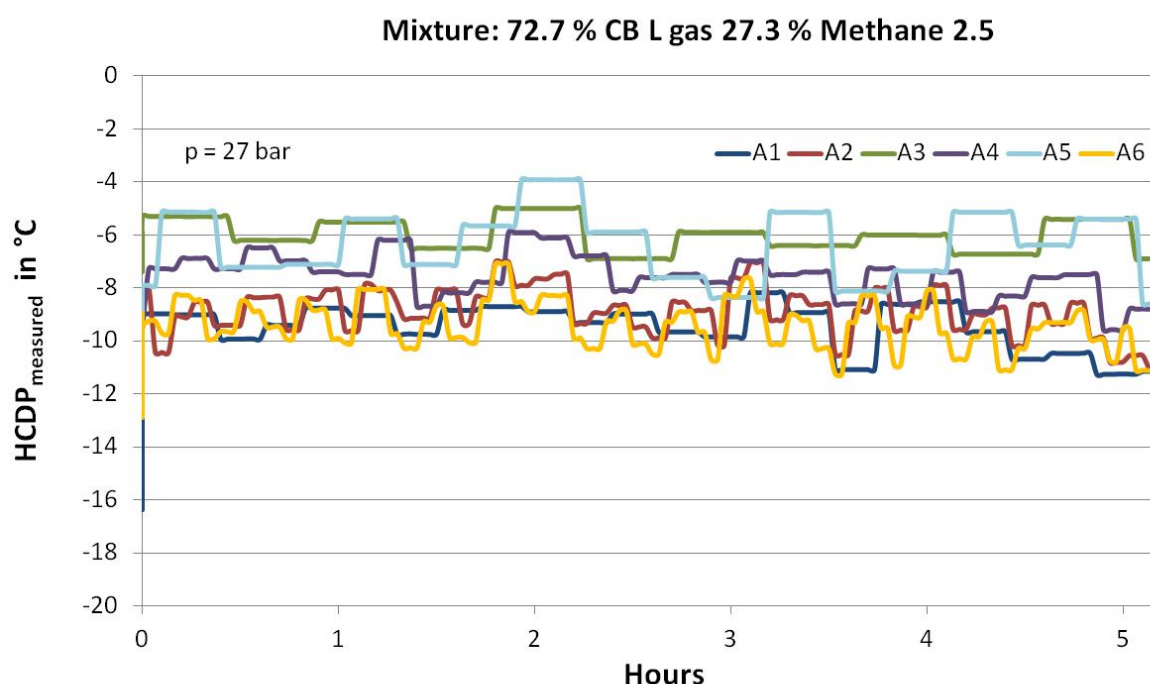


Fig. 21: HCDP_{measured} curves for adjusted HCDP analyzers tested with a mixture of 72.7% CB L-gas and 27.3% methane 2.5 at a test pressure of 27 bar.

Fig. 22 shows the values measured by the adjusted HCDP analyzers for the different gas mixtures averaged over the test period. As expected, the measured HCDP decreases as the

fraction of methane in the mixture increases. Also, the measured HCDP decreases by approximately the same amount for the different gas mixtures in the case of all HCDP analyzers, which is obvious from the approximately parallel trend in the curves plotted. This supports the observation from project phase 1 that adjustment using method B is independent of gas quality.

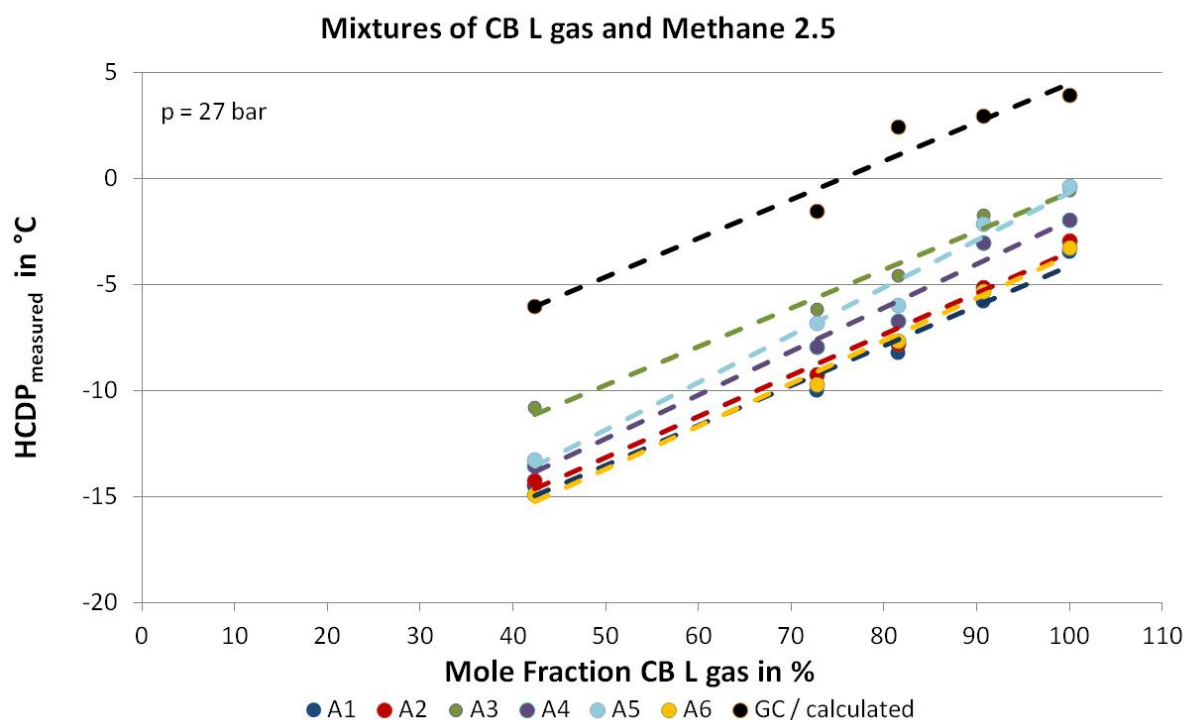


Fig. 22: Average measured HCDP as a function of CB L-gas and methane 2.5 mixture ratio.

Table 5 lists the linear equations for the curves in **Fig. 22** adjusted to the measurement points.

Table 5: Linear equations for curves in **Fig. 22**.

| Method / measurement instrument | |
|---------------------------------|------------------------|
| GC /calculated | $y = 0.1828x - 13.760$ |
| A1 | $y = 0.1882x - 22.932$ |
| A2 | $y = 0.1939x - 22.844$ |
| A3 | $y = 0.1816x - 18.788$ |
| A4 | $y = 0.2055x - 22.511$ |
| A5 | $y = 0.2241x - 23.028$ |
| A6 | $y = 0.2020x - 23.779$ |

5.2.2.4 Validation of Method B Using Pipeline Gases

The adjusted HCDP analyzers were operated with different pipeline gases to be able to evaluate suitability for use in practice and the quality of adjustment using method B. As already mentioned in the beginning, four different pipeline gases were available for the tests (see Chapter 5.1). The following shows the measurement curves obtained for the analyzers adjusted using method B. To provide a qualitative idea of better comparability of the measured values indicated by the HCDP analyzers tested, the scaling of the ordinates in Figs. 23 to 26 is the same as in the graphs shown in Fig. 10.

Firstly, it should be pointed out that the measurement curves shown in Figs. 23 to 26 are approximately synchronous for all tested HCDP analyzers as was expected; this is because the analyzers tested have approximately the same trip values.

The measured value range delimited by the factory-set HCDP analyzers for L-gas from the pipeline (1) at a test pressure of 27 bar was 14 K on average (see Table 2); the range was approx. 4 K on average for the adjusted measurement instruments (Fig. 23). This corresponds to an approx. 71% reduction in the width of the measured value range.

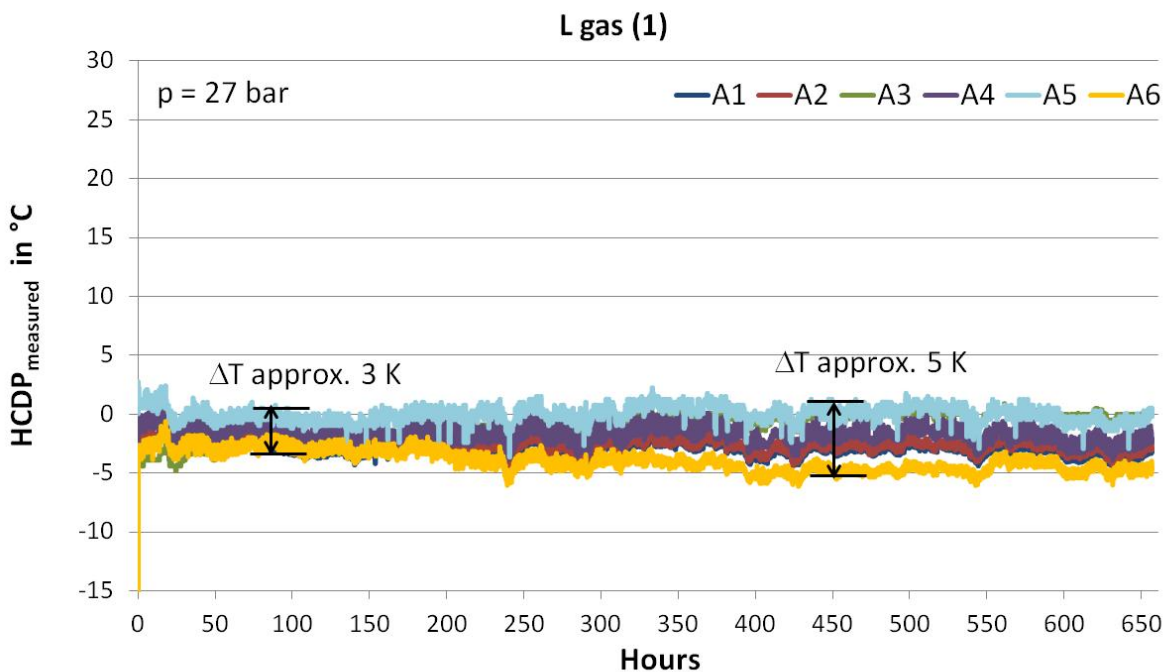


Fig. 23: Measurement curves recorded for HCDP analyzers adjusted using method B when tested with L-gas (1) at a test pressure of 27 bar over a period of 650 hours.

The measured value range delimited by the factory-set HCDP analyzers for L-gas from the pipeline (2) at a test pressure of 27 bar was 34 K on average (**see Table 2**); the range was approx. 3 K on average for the adjusted measurement instruments (**Fig. 24**). This corresponds to an approx. 91% reduction in the width of the measured value range. Analyzer **A5** was defective when the measurements presented in **Fig. 24** were made.

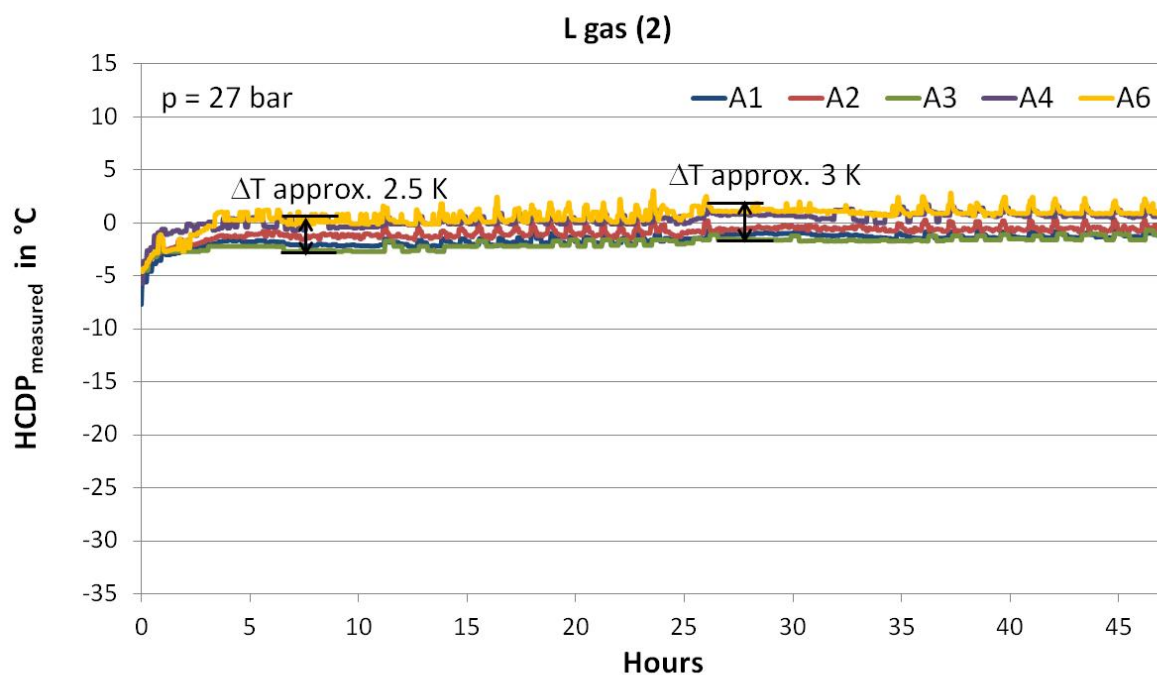


Fig. 24: Measurement curves recorded for HCDP analyzers adjusted using method B when tested with L-gas (2) at a test pressure of 27 bar over a period of 45 hours.

The measured value range delimited by the factory-set HCDP analyzers for L-gas from the pipeline (3) at a test pressure of 27 bar was 33 K on average (see Table 2); this range was approx. 6 K on average over the entire test period for the adjusted measurement instruments (Fig. 25). This corresponds to an approx. 83% reduction in the width of the measured value range. As is obvious from Fig. 25, the condensation behavior of the test gas changed significantly after 165 hours for a period of 135 hours. Over this test period, it was not possible with some measurement instruments to measure HCDP because of the extremely low HCDP. The width of the measured value range is approx. 12 K over this period. Considering that the HCDP is far outside the range relevant to contracts, this range is acceptable.

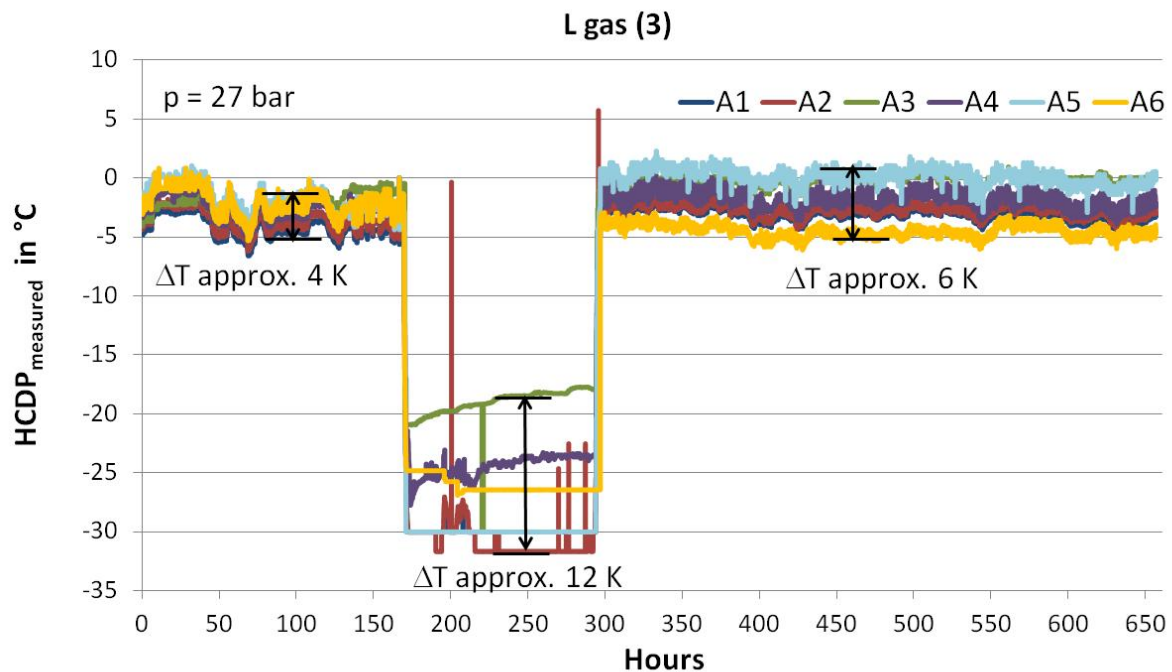


Fig. 25: Measurement curves recorded for HCDP analyzers adjusted using method B when tested with L-gas (3) at a test pressure of 27 bar over a period of 650 hours.

The measured value range delimited by the factory-set HCDP analyzers for H-gas from the pipeline at a test pressure of 27 bar was 26 K on average (**see Table 2**); this range was approx. 8 K on average over the entire test period for the adjusted measurement instruments (**Fig. 26**). This corresponds to an approx. 70% reduction in the width of the measured value range.

As is obvious from **Fig. 26**, analyzer **A3** causes the range of measured HCDPs to be expanded. In practice therefore HCDP analyzers used for monitoring contract values should be checked on a regular basis using a test gas with a known liquid drop-out curve analogous to the CB L-gas or CB H-gas used. The test interval should be determined on the basis of experience in the field.

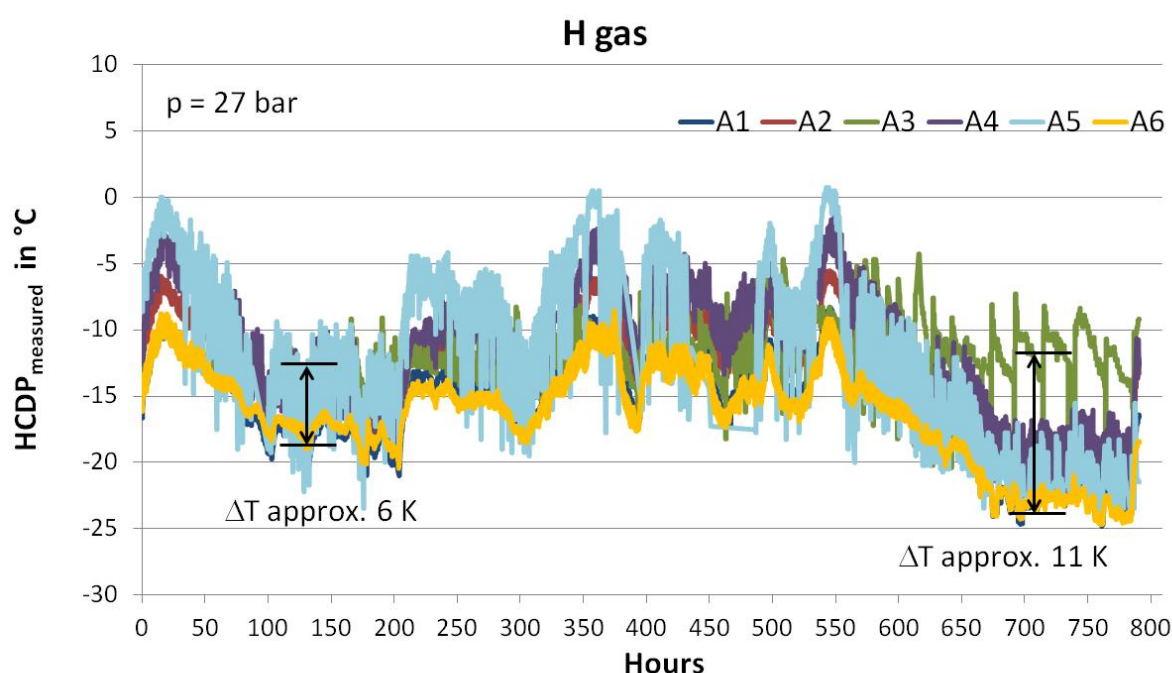


Fig. 26: Measurement curves recorded for HCDP analyzers adjusted using method B when tested with H-gas at a test pressure of 27 bar over a period of 800 hours.

By adjustment of the HCDP analyzers using method B the measured value range delimited by the HCDP analyzers was reduced by 70 to 91% or to between 3 and 8 K in absolute terms. The HCDP analyzers adjusted using method B display approximately synchronous measurement behavior because their trip values are approximately the same.

6 Summary

In relevant rules and regulations, the condensation behavior of natural gases is described using the hydrocarbon dew point (HCDP) as critical parameter. Often, the HCDP is the basis for gas supply contracts. When applied in HCDP monitoring on gas transmission pipelines, HCDP analyzers are mostly used with their factory settings, i.e. without prior calibration.

The project consisted of two phases. In the first phase /3/, the methods described in ISO/TR 12148 /2/ were applied in parallel for calibration of five commercial HCDP analyzers at 27 bar using a low-calorific pipeline gas. It was found that the measured values indicated by the factory-set measurement instruments deviated by up to 20 K for identical measurement conditions /3/. In the second phase, another measurement instrument was tested in addition to the analyzers already used in phase 1 so that this project phase examined in more detail the measurement behavior of a total of six HCDP analyzers (**Chapter 4.1**). Four pipeline gases (one high- and three low-calorific gases) were available for the tests (**Chapter 5.1**). The results confirmed the significant deviations recorded for operation of the factory-set HCDP analyzers in the first phase. In the tests, the measured values were even found to vary over a range of 14 K to 33 K on average, in some cases even up to 38 K depending on the gas used (**Chapter 5.2.1.1 Table 2**).

The following methods were tested for adjusting the measurement instruments:

In **method A**, the measured value indicated by the HCDP analyzer is corrected by calculation. By this method, it was possible to obtain a reduction of 50% in the range of measured values indicated by the various analyzers in the first project phase /3/. The trend in results recorded in the first phase was confirmed in the second project phase. Depending on the pipeline gas used, the measured value range was narrowed by 21 to 66%. The width of the measured value range in absolute terms continued to be at 26 K on average for two of the available pipeline gases after method A had been applied (**Chapter 5.2.1.2 Table 4**). Adjustment method A was found to be strongly dependent on the used gas in regard to narrowing the measured value range. With adjustment method A, the measurement instruments continued to display strongly varying measurement characteristics, which is due to the still different detection limits of the HCDP analyzers.

In **method B**, the trip point of the analyzer detector is tuned so that the value indicated by the HCDP analyzer corresponds to the temperature at which the condensation rate reaches 5 mg/m³. The measured values indicated by the HCDP analyzers calibrated with pipeline gas were within a range of less than 2 K on average in the first phase of the project /3/. The results obtained from phase 1 indicate that adjustment using method B (tuning of trip value) described in Technical Report ISO/TR 12148 is independent of gas quality.

The results from phase 1 for method B were largely confirmed. Following adjustment, the HCDP analyzers were found to have similar measurement characteristics. Systematic mixtures were produced from a stored L-gas (CB L-gas) and methane 2.5. The average HCDP measured with HCDP analyzers adjusted using method B decreased as the fraction

of L-gas decreased; this trend was found to be largely parallel for all analyzers tested. This confirms the assumption that adjustment using CB H-gas is transferable to other test gases, which means it is independent of the test gas used (**Chapter 5.2.2.2 and 5.2.2.3**).

Testing in practice of the HCDP analyzers adjusted using method B with the four different pipeline gases confirmed, as was already found in phase 1, a clear narrowing of the measured value range delimited by the different HCDP analyzers (**Chapter 5.2.2.4**). The measured value range was reduced by 70 to 91%, i.e. the measured value range was between 3 and 8 K wide on average. The results obtained indicate that adjustment of the HCDP analyzers should be checked at regular intervals.

7 Conclusion

In conclusion it can be stated that it is basically possible to tune the analyzers tested under the project to a standard detection limit of approx. 5 mg/m³ (method B). For adjustment, a stored gas can be used whose condensation behavior was determined with the automatic gravimetric method pursuant to ISO 6570. Application of method B for the adjustment of field measurement instruments used for monitoring the HCDP as a contract value provides comparable measured data from different measurement instruments.




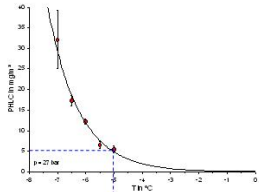


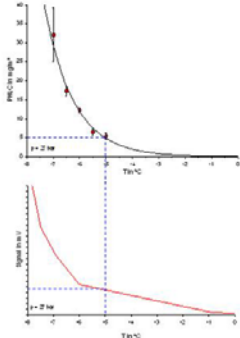


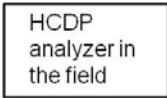


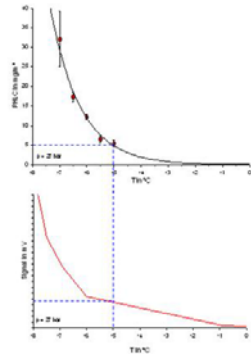
Adjustment by using method A (**correction of measured value by calculation**) should only be applied where minor deviations from the reference value occur. Method B should be considered preferable in the case of significant deviations from the reference value as the method takes into account the physical circumstances actually existing during the measurement; this means the method allows comparable measurement behavior of different HCDP analyzers to be obtained.

8 Outlook

8.1 Proposed Practical Implementation of Calibration Method

To achieve the goal of comparable measurement performance, it is necessary, in a first step, to calibrate HCDP analyzers as described in **Chapter 5.2.2**. At many measurement points where HCDP analyzers have been installed to monitor contract values, gases exist with values clearly different from contract values and often outside the measurement ranges of the HCDP analyzers installed. It is therefore necessary to make gases available at the respective measurements points that are suitable for calibration or functional checks.

For example, the procedure described below could be applied:

| | | | |
|---|---|--|--|
| 1 | Provide large volumes of suitable stored gases. |  | |
| 2 | Characterize condensation behavior using the method described in ISO 6570. |  +  =  | |
| 3 | Calibrate mobile reference unit using the gas described in Item 2. |  +  =  | |
| 4 | Fill gas cylinders with stored gases. |  →  | |
| 5 | Calibrate field measurement instruments on site using the reference unit and test gas and check function. |  +  +  +  | |

Some of the questions that arise in this connection are:

- Influence of cylinder pressure on test gas condensation behavior (adsorption/desorption)
- Influence of gas withdrawal rate
- Gas stability (cylinder material, storage temperature, etc.)
- Re-calibration intervals for reference unit and measurement instruments installed in the field

8.2 Proposed Re-specification of Condensation Behavior in Rules and Regulations

Today, the HCDP is normally used to describe the condensation behavior of natural gas. This may lead to misunderstandings as the values obtained are influenced by both the measurement method and the measurement instrument used.

Therefore, the following re-specification is proposed:

The measured value is to be a temperature at a pressure level of the cricondentherm at which an amount of 5 mg/m³ of condensate is formed.

The benefit of the specification is that application of the method described in this study allows measured values to be compared independently of the HCDP analyzer used as well as independently of the gas existing at the measurement point, thus allowing traceable measurement of contract values.

9 References

- /1/ ISO 6570:2001; Natural gas – Determination of potential hydrocarbon liquid content - Gravimetric methods
- /2/ ISO/TR 12148:2009; Natural gas – Calibration of chilled mirror-type instruments for hydrocarbon dewpoint (liquid formation)
- /3/ Technical Report GERG PC1 / Project 1.64 - Installation, calibration and validation guidelines for online hydrocarbon dew point analyzers, 2010