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Investigation of the correlation between increased error in hydrocarbon dew point determination and high CO_2 content in natural gas

Maksym Plaskach[1], Viktor Lutsenko[1], Andrii Levytskyi[1]

[1] *JSC Ukrtransgaz, Ukraine*

ABSTRACT
Hydrocarbon dew point (HCDP) is a critical gas-quality parameter in natural gas transmission and underground storage, because liquid hydrocarbon dropout may affect pipeline integrity, gas metering, and process equipment. This technical note reports preliminary evidence that elevated CO_2 content is associated with abnormal HCDP response in operational monitoring data. The underlying dataset comprised 2,377 accepted time-stamped observations grouped into five anonymized campaigns (BV5-1, BV5-2, BV7-1, MR-1, and MR-2). For inferential analysis, campaign-level means were used to avoid pseudo-replication. The full model yielded *HCDP* = -14.13 + 5.51·CO2, with $R^2 = 0.471$ and $p = 0.201$. An exploratory sensitivity analysis excluding the influential BV5-1 campaign yielded $HCDP = -22.95 + 8.72 \cdot CO_2$, with $R^2 = 0.991$ and $p = 0.004$, but this filtered result is not used as the primary inferential claim. The discussion clarifies analyser measurement principles, proposes a plausible CO_2 interference mechanism, compares the observed bias with typical direct-analyser accuracy, and outlines a laboratory validation roadmap using synthetic gas mixtures. The results support the interpretation that the observed effect is operationally important, while also showing that broader controlled validation is still required.

Section: TECHNICAL NOTE

Keywords: hydrocarbon dew point; natural gas; carbon dioxide; CO_2 cross-sensitivity; DewPoint DUO

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Corresponding author: Maksym Plaskach, e-mail: massimo9867@gmail.com

1. INTRODUCTION

Hydrocarbon dew point (HCDP) remains one of the most important gas quality parameters in transmission and underground storage systems, because hydrocarbon condensation can impair metering, foul regulators and filters, and create operational risks for compressors and downstream equipment. At the same time, the HCDP reported for a natural gas stream is not a purely intrinsic number; it depends on the composition, the sampling chain, the measurement principle, and the interpretation protocol used.

In international practice, HCDP is assessed either by direct, condensation-based measurement or by calculation from extended gas composition. ISO/TR 11150 [1] explains why hydrocarbon dew point is method-dependent, and how direct and calculated approaches should be interpreted together, while ISO 23874 [2] defines the chromatographic requirements for composition-based HCDP calculation up to C12. Earlier studies have also shown that HCDP is sensitive to analytical method and thermodynamic treatment, which makes cross-method comparison a metrological issue rather than a purely operational one [3]–[5].

The present work is therefore framed as a technical note. Its purpose is to report preliminary, but practically important, evidence that elevated CO_2 concentration may bias HCDP indication under field conditions. The manuscript explicitly acknowledges that the inferential dataset is small at campaign level ($n = 5$), while clarifying that the underlying operational evidence was considerably larger: 2,377 accepted time-stamped observations were screened, but only campaign-level summaries are shown, in order to avoid pseudo-replication in the regression and to prevent unnecessary figure overload.

2. DATA AND METHODS

2.1. Operational data basis

Operational monitoring data from JSC Ukrtransgaz were used. The screened descriptive dataset contained 2,377 accepted observations grouped into five anonymized campaigns: BV5-1 (N = 468), BV5-2 (N = 790), BV7-1 (N = 879), MR-1 (N = 96), and MR-2 (N = 144). The corresponding campaign means were: BV5-1 (mean CO_2 $concentration$ = 1.56 %, mean $HCDP$ = 0.5 °C), BV5-2 (1.76 %, -7.9 °C), BV7-1 (1.75 %, -7.1 °C), MR-1 (2.45 %, -2.2 °C), and MR-2 (3.16 %, 4.9 °C). The campaign-level means were used in the inferential regression because repeated time-stamped observations within a campaign are not statistically independent for the present hypothesis test.

2.2. Analyser principles

The online analyser used in this study was DewPoint DUO, the manufacturer of which describes the instrument as a CEIRS-based system that combines a chilled optical surface with infrared spectroscopic discrimination of the condensate phase, and reports hydrocarbon and water dew points separately [6]. By contrast, conventional direct HCDP analysers based on the chilled-mirror principle determine the onset of condensation optically on a cooled surface and do not intrinsically classify the condensate species [7], [8]. This distinction is important, because CO_2-related interference is expected to be technology-dependent.

2.3. QA/QC and statistical treatment

As the study is retrospective and field-based, quality assurance (QA)/quality control (QC) are described in terms of data acceptance and metrological plausibility control, rather than as a dedicated calibration campaign. Only periods with valid gas-quality records and no documented analyser alarms, maintenance events, start-up or shutdown transients, or internally coherent operational behaviour were retained. Where available in routine practice, composition-based expectations and spot laboratory checks were used as supporting plausibility references.

A univariate linear regression of the form $HCDP = \beta_0 + \beta_1 \cdot CO_2$ was applied to the five campaign means. The reported outputs are slope, intercept, R^2, p-value, and the 95 % confidence interval for the slope. Residual normality was checked with the Shapiro–Wilk test, independence was assessed with the Durbin–Watson statistic, and influential observations were examined using externally studentized residuals and Cook's distance. The full five-campaign model is treated as the primary inferential model, whereas any filtered model is presented only as an exploratory sensitivity analysis.

3. RESULTS AND DISCUSSION

3.1. Descriptive evidence

The five campaigns represent different operational regimes. Mean CO_2 varied from 1.56 % to 3.16 %, while mean HCDP varied from -7.9 °C to 4.9 °C. BV5-1 is notable because it combines the lowest mean CO_2 with the widest HCDP span (-7.3°C to 8.0 °C), which indicates the presence of an additional uncontrolled factor beyond CO_2 alone. For this reason, BV5-1 is not discarded from the primary analysis, but it is legitimately flagged as influential in the exploratory sensitivity test.

Figure 1 summarises the range-preserving comparison of HCDP across the five anonymized campaigns, and retains the extreme observations explicitly.

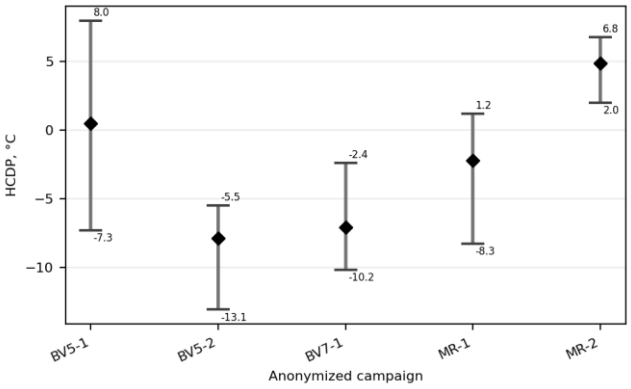

Figure 1. Range-preserving comparison of HCDP across anonymized campaigns; minimum and maximum values are explicitly retained to show extreme observations and the unusually broad spread of BV5-1.

3.2. Campaign-level regression

The full campaign-level regression model was $HCDP$ = -14.13 + 5.51 · CO_2. Quantitatively, the slope was β_1 = 5.51 °C/%CO_2 (95 % CI: -5.22 to 16.24), the intercept was β_0 = -14.13 °C, the coefficient of determination was R^2 = 0.471, and the p-value for the slope was 0.201. Accordingly, the full model indicates a positive trend, but it should be interpreted as preliminary rather than conclusive.

Residual diagnostics for the full model showed no evidence against normality at campaign level (Shapiro–Wilk p = 0.367), and the Durbin–Watson statistic was 1.69. However, BV5-1 had a comparatively large influence on the fitted line. An exploratory sensitivity analysis excluding BV5-1 yielded $HCDP$ = -22.95 + 8.72 · CO_2, with β_1 = 8.72 °C/%CO_2 (95 % CI: 6.24 to 11.20), R^2 = 0.991, and p = 0.004. This filtered model is reported only to demonstrate that a strong underlying effect may exist once the mixed-regime campaign is removed; it is not used as the primary evidential claim of the paper.

3.3. Practical interpretation

The Authors also pondered whether the observed effect exceeds instrument uncertainty. Manufacturer information for both CEIRS-based and chilled-mirror hydrocarbon dew point analysers typically state an HCDP accuracy on the order of ± 0.5 °C [6], [7]. In the present data, the campaign means differ by several degrees, and the within-campaign HCDP spans reach approximately 5 °C to 15 °C. Even allowing for site-specific uncertainty budgets that were unavailable for this retrospective study, the magnitude of the observed deviations is clearly larger than ordinary single-instrument accuracy alone.

The interpretation is that elevated CO_2 concentration is associated with abnormal HCDP response in the field data, but the statistical strength of this statement remains limited by the small number of campaign-level units. This is why the manuscript has been framed as a technical note rather than a full research paper.

A plausible technology-based interference mechanism can nevertheless be proposed. In species-nonselective condensation-based instruments, the reported HCDP depends on the first optically detectable change on the cooled surface [7], [8]. When CO_2 content is elevated, the composition and morphology of the incipient condensed phase may change, and mixed or non-target condensation effects can alter the apparent onset temperature. By contrast, the CEIRS principle is designed to spectroscopically

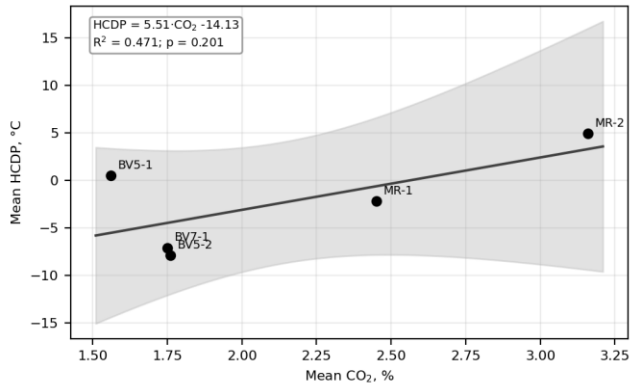

Figure 2. Campaign-level mean HCDP versus mean CO2 with linear regression line and 95 % confidence band for the full five-campaign model.

distinguish hydrocarbon condensation from water/glycol-related events [6], which provides a plausible reason why the two measurement chains may diverge under CO_2-rich conditions. Figure 2 presents the campaign-level mean HCDP values against mean CO_2 content, together with the fitted linear regression and its 95 % confidence band for the full model.

3.4. Limitations and future validation

The available evidence therefore supports a metrological warning rather than a universal law: under CO_2-rich operating conditions, direct HCDP indication should be interpreted together with composition-based calculations and careful QA/QC of the sampling and analyser chain. The results also show why hiding extreme values would be counterproductive: those extremes are part of the metrological evidence that points to mixed operational regimes or cross-sensitivity.

4. CONCLUSIONS

This technical note reports preliminary field evidence that elevated CO_2 content may bias hydrocarbon dew point indication in natural gas monitoring. The primary five-campaign model shows a positive but statistically non-significant trend, whereas an exploratory sensitivity analysis suggests that the underlying effect may be much stronger once the mixed-regime BV5-1 campaign is removed.

The manuscript explicitly recognises the main limitation of the present evidence: although 2,377 accepted observations were screened descriptively, the inferential dataset consists of only five campaign-level summaries. The current results should therefore be interpreted as preliminary and hypothesis-generating rather than definitive.

A practical laboratory validation roadmap is proposed below.

1) Prepare synthetic natural gas mixtures with a fixed hydrocarbon background and stepwise CO_2 levels spanning the operational range of interest.
2) Test, under the same pressure, temperature, and sample-conditioning conditions, a chilled-mirror measurement chain and a CEIRS-based analyser in parallel.
3) Repeat measurements sufficiently to estimate repeatability, bias, and uncertainty at each CO_2 level, and compare observed HCDP with composition-based calculations according to ISO 23874.
4) Extend the test matrix with controlled additions of water, methanol, or glycol in order to separate true CO_2 effects from other cross-sensitivities.
5) Use the resulting laboratory matrix to confirm whether the field-observed bias systematically exceeds the uncertainty of the individual analysers and under which gas-composition regimes this occurs.

Until such laboratory validation is completed, the safest operational practice is to treat elevated-CO_2 cases as requiring enhanced QA/QC, explicit comparison with chromatographic predictions, and cautious interpretation of direct HCDP readings.

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