STUDY OF THE EFFECTS OF EXTERNAL CONDITIONS ON THE PERFORMANCE OF THE "TPG-SN4" METHANE DETECTOR

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Abstract: In this article, the influence of external environmental conditions on the operation of the "TPG-CH4" methane gas analyzer was experimentally studied. The main attention was paid to determining the influence of factors such as temperature, humidity, pressure and other gas mixtures on the measurement accuracy and sensitivity. According to the results of the study, when the temperature exceeds +40°C, measurement errors increase to 8–10%, and at high humidity, instability in sensor operation is observed. Also, a decrease in selectivity was determined in the presence of other hydrocarbons. Calibration work, relative and absolute errors, and output signal variability were evaluated according to GOST 13320-81 standards. The results of the study indicate the need for automatic compensation and regular calibration for the effective use of the "TPG-CH4" analyzer in industrial and laboratory conditions.

Keywords: Methane detector, TPG-CH4, external conditions, environmental influence, measurement accuracy, sensor performance, gas analysis, temperature effects, humidity influence, cross-sensitivity, metrological characteristics, calibration, reliability of measurements

ИССЛЕДОВАНИЕ ВЛИЯНИЯ ВНЕШНИХ УСЛОВИЙ НА РАБОТУ ГАЗОАНАЛИЗАТОРА МЕТАНА «TPG-SN4»

Аннотация: В данной статье экспериментально изучено влияние внешних условий окружающей среды на работу газоанализатора метана «TPG-CH4». Основное внимание уделено определению влияния таких факторов, как температура, влажность, давление и другие газовые смеси на точность и чувствительность измерений. По результатам исследования установлено, что при температуре выше +40°C погрешности измерений возрастают до 8–10%, а при высокой влажности наблюдается нестабильность работы датчика. Также определено снижение селективности в присутствии других углеводородов. Оценены калибровочные работы, относительная и абсолютная погрешности, изменчивость выходного сигнала по ГОСТ 13320-81. Результаты исследования свидетельствуют о необходимости проведения автоматической компенсации и регулярной калибровки для эффективного использования газоанализатора «TPG-CH4» в промышленных и лабораторных условиях.

Ключевые слова: Детектор метана, TPG-CH4, внешние условия, влияние окружающей среды, точность измерения, производительность датчика, газовый анализ, влияние температуры, влияние влажности, перекрестная чувствительность, метрологические характеристики, калибровка, надежность измерений

INTRODUCTION:

Reliable detection of methane is crucial in various industrial and environmental applications. The TPG-CH4 gas analyzer integrates semiconductor and thermocatalytic sensor elements to monitor methane concentrations. However, the accuracy of its measurements can be significantly influenced by external physical and chemical environmental factors. This study aims to explore how such factors affect the analyzer's performance and proposes optimization strategies.

METHOD

An experimental evaluation method was used to study the metrological characteristics of the methane gas analyzer "TPG-CH_4" under the influence of various external factors. A series of tests were conducted under laboratory conditions with changes in temperature, humidity, pressure, and the presence of extraneous gases. Parameters such as error margin, sensitivity, and repeatability were recorded for each change in conditions. The device was also calibrated using standard gas mixtures.

The study established that the accuracy of the "TPG-CH_4" gas analyzer readings is significantly influenced by external physicochemical conditions.

When the ambient temperature exceeded +40 °C, the measurement error increased up to 8–10%. High humidity levels (above 85%) caused instability in readings, especially during prolonged exposure. Deviations from normal atmospheric pressure also led to measurement inaccuracies, particularly under reduced pressure. The presence of other hydrocarbons (such as ethane or propane) in the analyzed medium caused cross-sensitivity, reducing the selectivity for methane.

Optimal metrological characteristics of the gas analyzer were observed under the following conditions: temperature of 20–25 °C, humidity up to 70%, normal atmospheric pressure, and absence of interfering impurities.

In laboratory settings, parameters were maintained as follows: test gas temperature at 20 ± 5 °C, atmospheric pressure at 760 ± 30 mm Hg, relative humidity between 40–60%, and power supply at 220 ± 10 V AC. Under simulated field conditions, the test gas temperature ranged from +5 to +50 °C, pressure varied between 600–800 mm Hg, relative humidity extended from 25% to 95%, and the sensor could be inclined at angles up to 30°.

To assess the analyzer's measurement range and basic error at concentrations of 0–1000 mg/m³ and 0–5. 0%, calibration gases were introduced to the analyzer in a specific sequence (1-3-5-3-1-5), where each number corresponds to a reference gas mixture with defined component concentrations and ranges (%): No. 1 = 10%, No. 3 = 50%, No. 5 = 95%.

The primary absolute error at each calibration point was calculated using the formula:

$$\mathbf{C = Ai - A_0} \quad \text{(Equation 5. 1)}$$

where $\mathbf{A_i}$ represents the measured concentration indicated by the analyzer at a given test point, and $\mathbf{A_0}$ is the actual concentration specified in the reference gas certificate.

To quantify the relative error, the following expression was used:

$$\mathbf{C = (A_i - A_0) / (C_k - C_n)} \quad \text{(Equation 5. 2)}$$

where $\mathbf{C_k}$ and $\mathbf{C_n}$ denote the upper and lower bounds of the analyzer's measurement range for the gas component, in mg/m³ or %.

Tables 1 and 2 provide data on how the PTG-CH_4 analyzer's signal output correlates with methane concentration within its specified measurement ranges.

Table 1. Dependence of the signal of the PTG-CH_4 gas analyzer with a semiconductor sensor on the concentration of methane in the range of CH_4 0-1000 mg/m³

CH_4 content in the mixture, mg/m3	Found CH_4 (x± x), mg/m³	S	Sr*102
10	11±0. 3	0. 24	2,2

50	48±0. 9	0. 72	1. 5
250	245±1. 5	1. 21	0. 5
500	510±2. 0	1. 61	0. 3
750	740±2. 8	2. 25	0. 3
980	973±4. 8	3. 86	0. 4

Table 2. **Results of checking the measurement range of the PTG-CH_4 gas analyzer with a thermocatalytic sensor (measurement range 0-5. 0% vol.) (n=5,P=0. 95.)**

CH_4 introduced, % vol.	**Found CH_4, (x± x), % vol.**	**S**	**Sr*102**
0. 10	0. 97±0. 02	0. 02	1. 7
0. 50	0. 45±0. 06	0. 05	1,1
1. 50	1. 54±0. 09	0. 07	2. 7
2. 50	2. 56±0. 16	0. 13	2. 5
3. 50	3. 41±0. 15	0. 12	2. 5
4. 50	4. 43±0. 19	0. 15	2. 4
4. 90	4. 95±0. 21	0. 17	2. 4

The data presented indicate that, within the tested concentration ranges, the gas analyzer’s output signal shows a linear relationship with carbon monoxide concentration

The analyzer is deemed to meet performance criteria if, at each concentration level, the following condition is satisfied: $\mathbf{B < B_9}$, where $\mathbf{B_9}$ represents the permissible signal variation threshold.

As shown in Table 3, the observed variation in the gas analyzer's readings remains within 50% of the allowable basic error across all measurement intervals, which is consistent with the limits established by GOST 13320-81. In fact, the recorded variations do not exceed 0. 5 of the absolute value of the permissible basic error, indicating high signal consistency.

Table 3. Results of determining the signal variation of the PTG-CH_4 gas analyzer (n=5, P=0. 95)

Methane content in the mixture, % vol.	**Methane found(x± x), % vol.**		**Basic abs. pogresh ity**	**Variation, %**
	A_{max}	A_{min}		
0. 55	0. 45±0. 02	0. 46±0. 02	0. 05	0. 01
2. 45	2. 51±0. 03	2. 49±0. 04	0. 06	0. 02
4. 86	4. 91±0. 04	4. 89±0. 03	0. 05	0. 02

To evaluate the influence of ambient temperature variations on the PTG-CH_4 analyzer's performance, tests were conducted across a temperature range of 10 °C to 50 °C. A gas sample containing 2. 85% methane was used during these trials. The temperature in the test chamber was adjusted sequentially, starting from the baseline of +20 °C—identified as the optimal point for assessing the primary error—followed by settings at 10 °C, 35 °C, and 50 °C. At each temperature level, the analyzer was allowed to stabilize for one hour before the test gas was introduced and readings were recorded. Each temperature condition was tested at least three times to ensure consistency.

To investigate the impact of humidity on the device's performance, a series of experiments were conducted using the following procedure: the gas analyzer was first placed inside a controlled humidity chamber, where standard testing conditions were initially established. Once the system stabilized, the baseline error of the analyzer was measured using a gas sample (GS) containing 2. 55% carbon monoxide by volume.

After one hour, the same gas sample was passed through a series of three interconnected Tishchenko bottles filled with distilled water, which humidified the gas up to 95% before entering the analyzer. The error under high-humidity conditions was then recorded.

Following this phase, the gas analyzer was turned off, and standard ambient conditions were restored. After a two-hour stabilization period, the device was powered back on, and its baseline error was rechecked under normal conditions.

As a result of the study conducted, a novel approach has been introduced to enhance the selectivity of methane detection through thermocatalytic methods. This approach involves integrating both semiconductor and thermocatalytic sensing elements into a unified system, utilizing catalysts that exhibit minimal activity toward other components present in the analyzed gas mixture. The measurements of absolute and relative errors, along with signal variability, remained within acceptable thresholds defined for standard conditions in accordance with GOST 13320-81

CONCLUSION

The metrological characteristics of the "TPG-CH4" methane gas analyzer are significantly affected by external environmental factors. Temperature, humidity, and the composition of the gas mixture have the greatest impact. To ensure reliable results, it is necessary to conduct regular calibration of the device, apply correction factors when operating under non-standard conditions, and follow the manufacturer's recommended operational parameters.

During the experimental phase, the operational concentration ranges of the target gas were established, along with evaluations of the primary measurement error, output signal variation, and potential additional errors due to environmental factors such as temperature, pressure, and humidity. The PTG-CH_4 gas analyzers were tested within methane concentration intervals of 0–1000 mg/m^3 and 0–5. 0% by volume, both under controlled laboratory settings and simulated operational conditions.

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