Multichannel NDIR Methane Sensor for Soil Probes

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***Abstract*—The goal of this study was to examine a multichannel device using five commercial Non-Dispersive Infra-Red (NDIR) heads for the sensing of methane concentration changes in soil probe. The presented device consists also of a temperature and humidity sensing unit, a gas chamber equipped with a micro-fan, automated gas valves and a microcontroller that controls the measuring procedure. The temperature and humidity sensors are used to control working conditions. A redundant sensor unit is used to improve the measurement accuracy. The device worked in maintenance-free mode installed on soil probe for six hours. The main development of the proposed sensor included measurement procedures and proposition of errors corrections.**

Keywords- methane sensor; NDIR sensor.

I. INTRODUCTION

The analysis of methane concentration in natural systems is becoming an important task for environmental research. Its leakage will result in explosion and fire disaster. Methane is the main constituent of natural gas, the fuel which is supplied to many domestic homes and industries. It is often released from the walls of coal mines and, when un-monitored, it can accumulate, causing dangerous explosions. The soil examination for methane emission is important from property owners' point of view, as well as from gas and oil field parameters investigation.

Several techniques have been successfully used to detect methane. Optical methods can produce very precise results [1][2]. But, at present, the main problem of methane measurement is reliability and precision of medium and long term detecting in maintenance-free mode [3]. In order to improve the available methane sensor, a new methane detection device based on a five non-dispersive infrared heads was set up and examined.

The paper consists of 4 sections. The first section is the introduction, where the problems of the methane measurement are discussed. The second section describes the measurement system construction. The experiment and the results of the methane concentration measurements are presented in section three. The conclusion is gathered in section four.

II. MEASUREMENT SYSTEM CONSTRUCTION

The measurement system (Fig. 1) consists of a methane sensing unit integrated in the gas chamber with humidity and temperature sensors, a micro-fan, a microprocessor controller and an RS485 transmitter. The measuring chamber is closed on both sides by shut-off servos [4]. The sensor head (Fig. 2) includes a set of five methane concentration units (TDS0034 type MSH-P/HC/5/V/P from Dynament Limited). The TDS0034 heads operate by using the non-dispersive (NDIR) principle. The concentration of the gas is obtained from the head output voltage using the equation:

$$C[\text{ppm}] = 25\cdot(S[\text{mV}] - V_0),$$

where: S is the output voltage, V_0 is the reference value of the concentration (0 ppm), under factory adjustment V_0=400 mV.

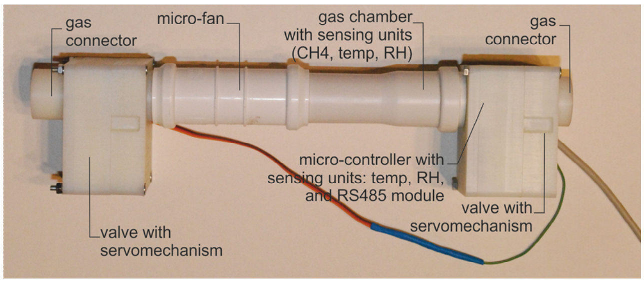

Figure 1. External view of sensor [4].

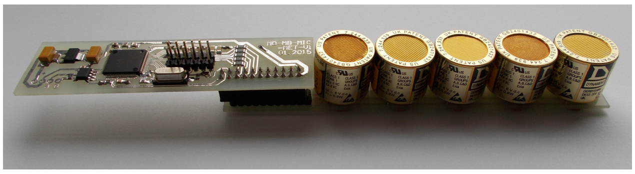

Figure 2. Sensor head: microprocessor unit, NDIR heads, and temperature plus humidity sensing unit.

The microprocessor module was built using the Texas Instruments MSP430F5529. The microprocessor controls the operation of the sensors, the air inlet and outlet and the micro-fan that can be used for equalization of concentration of gases in the chamber, gas chamber ventilation or gas pumping.

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III. EXPERIMENT AND RESULTS

The developed measurement system was justified in horizontal position then installed on a soil probe in the village of Lublin.

A. System justification

System justification was performed with gas chamber positioned horizontally, with two ends gas valves open and with working micro-fan. The micro-fan enables movement of air compared to human breath speed. The indicative value of V_0 was 500 mV. The measured in 6 hours concentrations and temperature in gas chamber are presented in Figure 3.

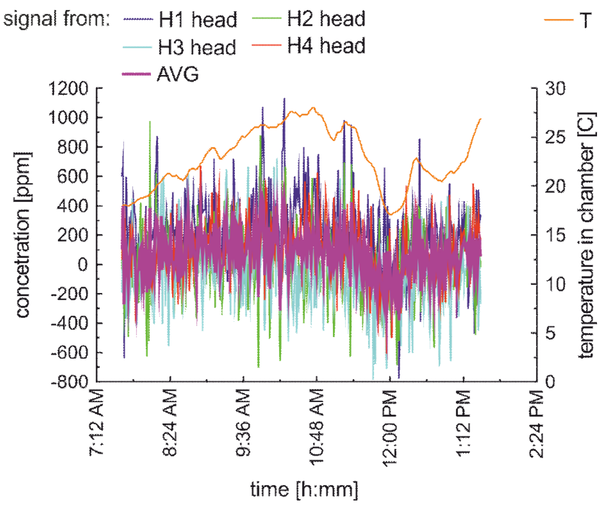

Figure 3. Results of system justification at free air where methane concentration is close to 0ppm.

The simple error concentration of correction measurement was performed using accepted results from 4 heads discarding the least likely one of a measurement result. The average signal was calculated for 5 heads. The calculated distance between each head in set and average signal was used to select 4 heads from which data are used for subsequent averaging and then for presentation. The raw data shows that heads are characterized with ±1000 ppm accuracy. The accuracy of the system with the proposed data analysis procedure is in ±400 ppm range. Because the range of humidity didn't exceed the permissible levels, the results of the measurement of the humidity was not used in the presentation data. The temperature compensation of the heads works well. But, the correlation of the signal concentration with temperature is visible.

B. System testing with forced air movement in soil probe

For system testing, the sensor was installed on a soil probe. The initial situation with open valve of the gas chamber to air and working micro-fan was used to set V_0 values of each sensor. Then, the valve to air was closed and the valve to soil was opened. The analysis of the results of this experiment (presented in Figure 4) shows that an initial dose of methane released into chamber at the beginning of the measurement was at a level of 130 ppm.

The increase of methane concentration in probe may be measurable on the interpolation base. In the presented case, the concentration is of 50 ppm during 6 hours.

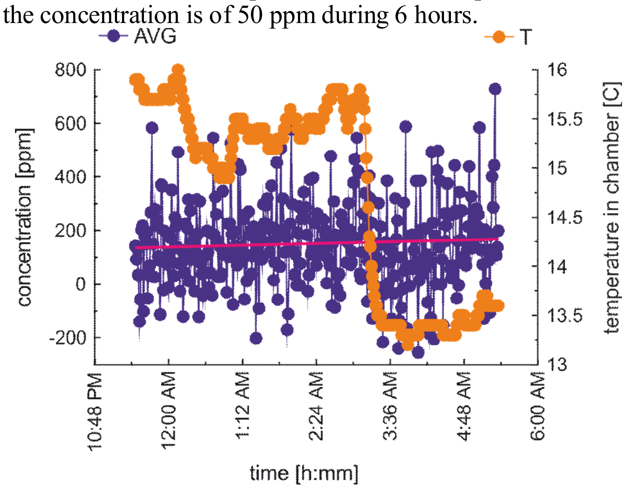

Figure 4. Results of system testing.

C. System testing with initial CH4 dose at air inlet system

The last system test was performed with initial methane dose given from the cloud at sensor air inlet. At the beginning of the procedure, the sensor valves were opened and the micro-fan was working. Next, the small methane cloud was generated at the small distance from soil probe. Then, the air inlet valve was closed and the micro-fan stopped. The registered values are presented in Figure 5.

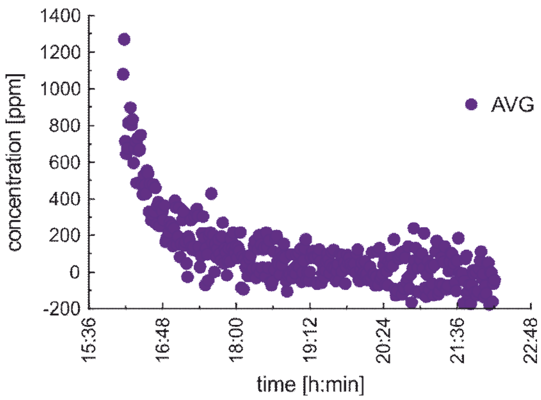

Figure 5. System testing with initial CH4 dose at air inlet system.

The classical exponential concentration damping is visible. Therefore, the examined soil can work as a gas absorber, what is quite usual phenomenon. The measured concentration dispersion increases when absolute value of the concentration decreases.

IV. SUMMARY

The soil probe installation procedure may affect the examination of methane concentration in a short time. The correction of the initial value for data processing of the methane concentration (0 ppm) has to be confirmed before tracking of the environment concentration. The medium-term examination of the methane concentration is possible with a multichannel NDIR methane sensor when it is based on error correction procedures and data analysis.

ACKNOWLEDGMENT

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