**11th International Research/Expert Conference**
**"Trends in the Development of Machinery and Associated Technology"**
**TMT 2007, Hammamet, Tunisia, 05-09 September, 2007.**

# PREPARATION AND VERIFICATION OF LABORATORY FERMENTER FOR INSTALATION OF GAS SENSORS

**Radek Sedlačík, Marie Dvořáčková**
**Thomas Bata University**
**Faculty of Technology**
**Department of Environmental Protection Engineering**
**Nam. TGM 275, Zlin 76001**
**Czech Republic**

**František Hruška**
**Thomas Bata University**
**Faculty of Applied Informatics**
**Department of Electronic and Measurement**
**Nad Stranemi 4511, Zlin 76005**
**Czech Republic**

## ABSTRACT
*Laboratory fermenter is a technological device for carrying out, monitoring and studying biochemical processes. Five water quality parameters can be measured: concentration of dissolved oxygen, oxidation-reduction potential, turbidity, conductivity and pH. On the other hand, the output values which can be detected are concentrations of methane and carbon dioxide, pressure and gas flow. In the study, suspension of aerobic activated sludge was used in the process, and the fermenter performance was verified by a classical titration method for determination of carbon dioxide concentration. The results of titrations were applied to adjust the range of the carbon dioxide sensor. The calibration of methane and carbon dioxide sensors was carried out with a standard gas pressure bottle. The contribution describes construction and installation of a new gas measuring instrument, including its verification. The results of pilot test are also presented in the paper.*
**Keywords:** measurement, biochemical processes, fermenter, methane, carbon dioxide, gas sensor verification.

## 1. INTRODUCTION
The measurement of important parameters in fermenters (bioreactors) has been the aim of many research papers [1,2]. The gas phase composition is usually measured by gas chromatography. This analytical method is exact and can determine "every" important compound in a fermenter tank. However, gas chromatography is expensive and involves specific operations, while ordinary bioprocesses produce a narrow group of gases which can be detected by simple sensors. For example, Dvorackova [3] tested MicroOxymax, a device for automatic measurement of oxygen, $CH_4$ and $CO_2$ concentrations in gas phase. Gas sensors included in this device utilized infrared spectrophotometry to determine the concentration of $CO_2$ and $CH_4$. Nevertheless, the study was limited to a small volume (less than 1 litre) of sludge; furthermore, MicroOxymax measured only the gas phase parameters.
The purpose of the present paper is to describe the installation and verification of the gas sensors on a laboratory fermenter. We carried out a pilot experiment and validated the fermenter with new gas sensors (based on infrared spectrophotometry) for the use in further research and in education.

## 2. EXPERIMENTAL

### 2.1. Materials

Approximately 10 litres of mixture of the return aerobical activated sludge and a bio-medium ($MgSO_4$; $CaCl_2$; $FeCl_3$; $(NH_4)SO_4$; phosphoric buffer; trace elements: $B^{3+}$, $Fe^{2+}$, $Zn^{2+}$, $Mn^{2+}$, $Cu^{2+}$, $Co^{2+}$, $Mo^{6+}$) were utilized in the research. Acid (0.1M HCl) and alkali (0.1M NaOH) solutions were dosed via peristaltic pumps automatically according to the requested pH value. Dosing of sugar solution (40 $g.l^{-1}$) was remote-controlled by the operating staff. Phosphoric buffer and ammonium solutions were batched manually to increase phosphor and organic nitrogen concentrations. These solutions were the same as in bio-medium.

A standard gas bottle (Linde Gas, UN 1956, 4.07 % $CH_4$, 0.815 % $CO_2$, the rest nitrogen) was utilized for gas sensor calibration.

### 2.2. Methods

Figure 1 shows the scheme of the tested device. The procedure was follows: Firstly, the air was divested of $CO_2$ by absorbing this gas in 5M NaOH solution (1). Then, 0.05M $Ba(OH)_2$ solution (2) was used for indication of residual $CO_2$. Secondly, the air passed through the fermenter (3) and $CO_2$ was absorbed into the 2M NaOH solution (4). Finally, the concentration of produced $CO_2$ was determined by acidimetric titration of the 2M NaOH solution.

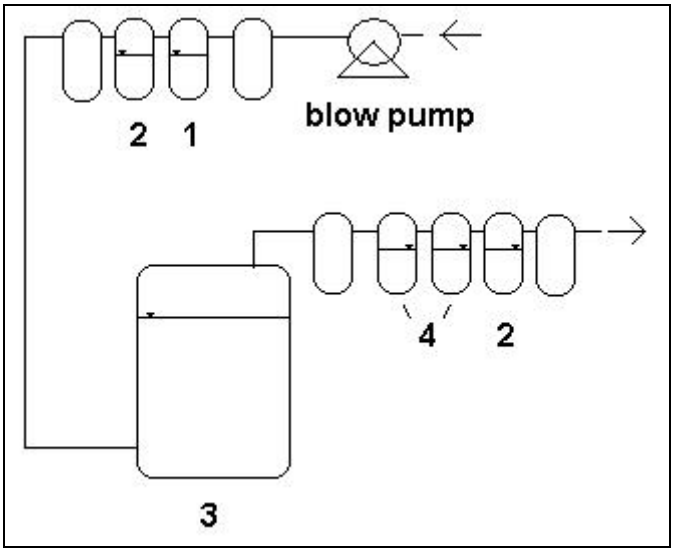


*Figure 1. Scheme of the gas testing arrangement.*

After this experiment, the mass flow meter (Bronkhorst, Holland) was tested with air pressure bottle. The flow rate of the air was set up with a needle valve and verified by soap bubble flow meter (Hewlett-Packard, 1-10-100ml). The gas sensors were calibrated by gas standard. A single-point calibration was carried out and the flow independence of measurement was tested too. Then, the sensors and the flow-meter were arranged in a wiring unit chamber and installed on the fermenter.

## 3. RESULTS AND DISCUSSION

Figure 2 illustrates the variations in $CO_2$ production depending on dosing the sugar, phosphates and ammonium solutions during the pilot experiment. As can be seen, the dosing of sugar solution usually stimulates the microbes´ activity and increases the level of $CO_2$ in the bioreactor. However, this connection was partially negated in the last part of the experiment. The microbes´ population gained probably the maximum grade under given conditions (the volume, sort and age of sludge, temperature and concentrations of micronutrients). Furthermore, the growing microbes´ population produce some metabolite (for example ethanol), which inhibit microbes´ activity. If concentration of these metabolite reach critical limit, the most of microbes disregards the dosed sugar. In contrast, a small group of slow-growing microbes reduce gradually the concentration of the inhibit metabolite. The

unstable equilibrium between these two diametrical processes was constituted in the last part of the experiment.

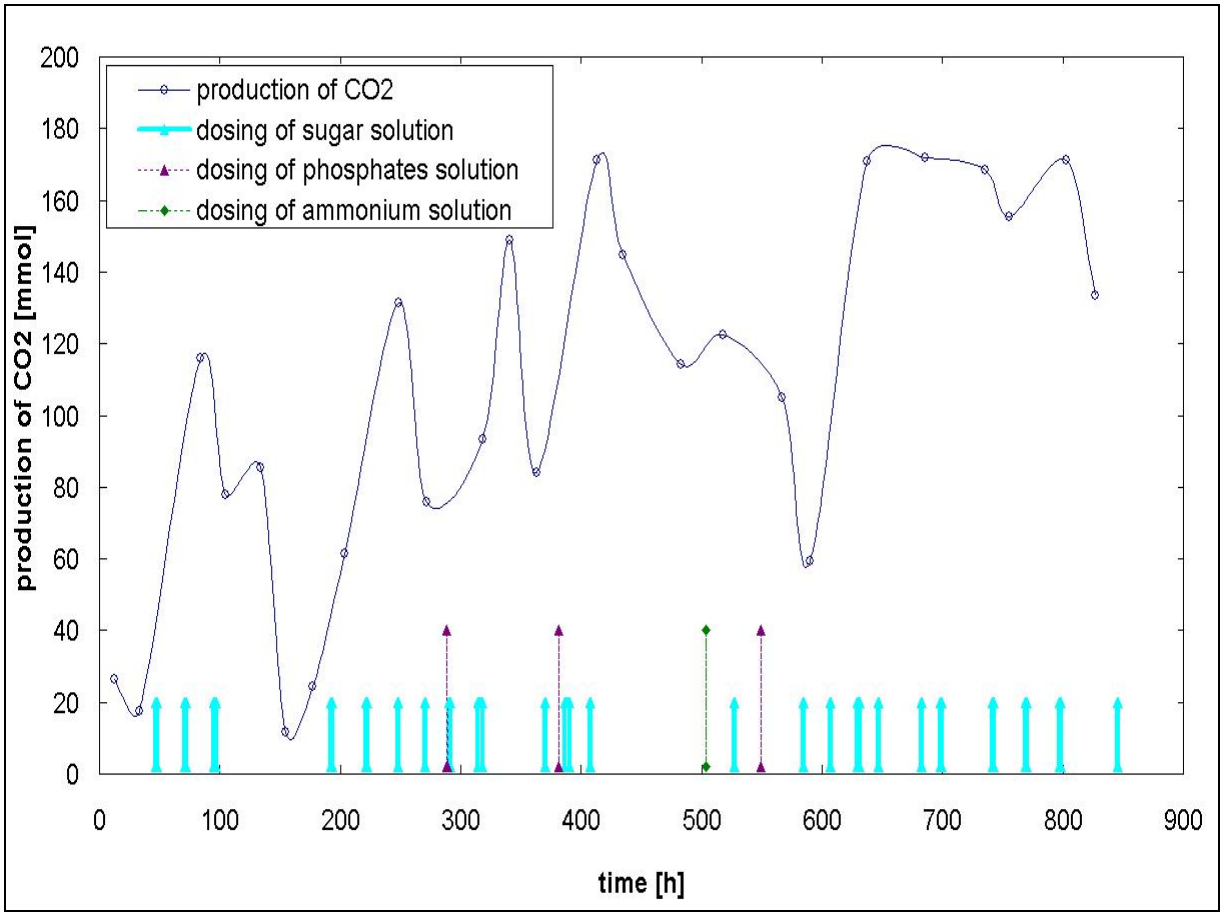


*Figure 2. The relation between the $CO_2$ production and the dosing of sugar, phosphates and ammonium solutions.*

The dosing of ammonium or phosphates solutions had arguably a little positive effect on microbes´ environment. Ammonium and phosphate ions are a convenient source of nitrogen and phosphorus for microbes while the sugar solution does not contain any nitrogen/phosphorus. These elements called macronutrients are very important for microbes, since they are necessary to synthesize DNA (genes) and proteins. On the other hand, the batching of phosphates solution inhibited presumably the $CO_2$ production in the second half of experiment, because of the specific microbes´metabolic pathways. Microbes probably discontinued their growth and drawn on the phosphorus to synthesis high-energy compounds, which are very good source of energy in the "bad time".

Figure 3 shows the flow-meter calibration curve with its equation. This formula will be applied in control software to calculate the gas flow. The flow-meter will be used in anaerobic experiments. If the pressure of produced biogas reaches the set level, safety valve blows off a small amount of biogas. This small amount of gas will be measured by calibrated flow-meter. The knowledge of biogas production is very important for studying the anaerobic bioprocesses. These processes reduce a quantity of biodegradable waste and give biogas, an expediential renewable energy source.

Figure 4 presents data from the verification of gas sensors. A single-point calibration was carried out by gas standard. The concentration was stable in contrast to variable gas flow. The range of output voltage was from 0 to 20 V and the measured values corresponded to standard concentrations of $CO_2$ and $CH_4$. A few differences were observed in low flow of $CO_2$. These variations were might caused by low gas flow, because minimal flow for producer guaranteed measurement is 20l/h.

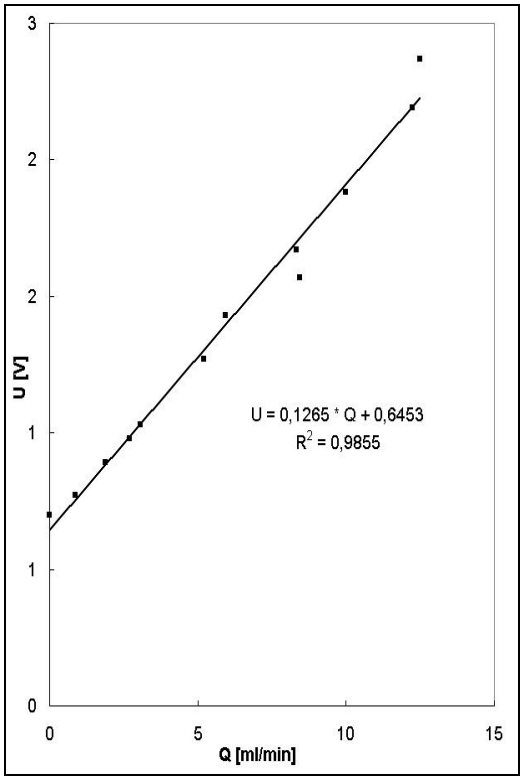


*Figure 3. The mass flow-meter calibration curve.*

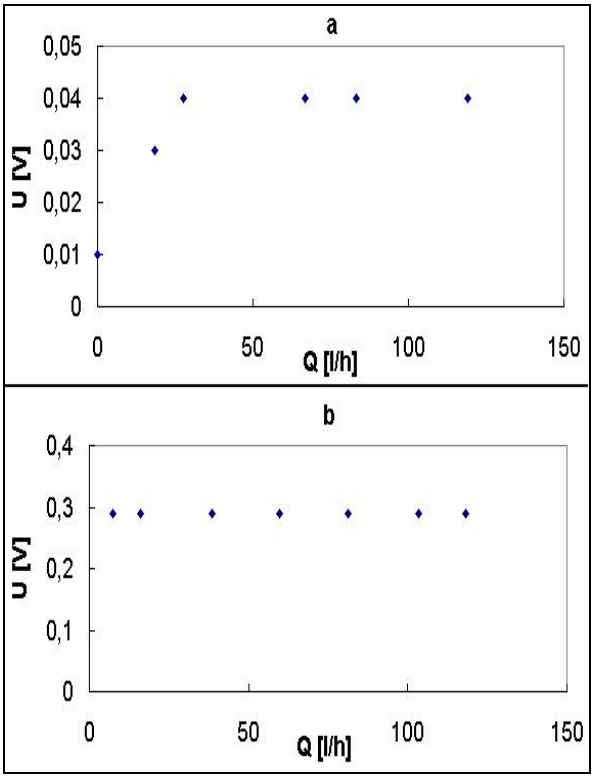


*Figure 4. The verification of $CO_2$ (a) and $CH_4$ (b) sensor.*

## 4. CONCLUSION

The objective of this work was to install and verify gas ($CO_2$, $CH_4$) sensors on the laboratory fermenter. From the measurement point of view, the aim of this work has been fulfilled. The sensors measure concentrations of the two gases independently of the gas flow and each other. The input air is free of $CO_2$ and as a result, only $CO_2$ produced by microbes is determined. However, the findings of this paper are restricted to aerobical conditions. Some interference caused by methanol or ethane/ethanol might occur under anaerobic conditions.

## 5. ACKNOWLEDGEMENT

This work was supported in part by the Ministry of Education, Youth and Sports of the Czech Republic under grant FRVS, No. MSM 281100001 and MSM 7088352101.

## 6. REFERENCES

[1] Diamantis, V.; Melidis, P.; Aivasidis, A.: Continuous Determination of Volatile Products in Anaerobic Fermenters by On-line Capillary Gas Chromatography. Analytica Chimica Acta. 2006, vol. 57, no. 3, p. 189-194. ISSN 0003-2670

[2] Liu, Y.C.; Wang, F.S.; Lee, W.C.: On-line Monitoring and Controlling System for Fermentation Processes. Biochemical Engineering Journal. 2001, vol. 7, no. 1, p. 17-25. ISSN 1369-703X

[3] Dvořáčková, M.; Julinová, M.; Hoffmann, J.; et al.: New Trends of Characterisation of Polymers Biostability under Aerobic and Anaerobic Conditions. In TMT. 10th International Research/expert Conference: "Trends in the Development of Machinery and Associated Technology". Barcelona-Lioret de Mar (Spain), 2006, p. 1143-1146. ISBN 9958-617-30-7

[4] Šrámek, J.: Verification of Laboratory Operation for Education. Diploma Thesis, UTB in Zlín, 2007.