Calibration system for breath-alcohol analysers

Dawid Kucharski, Antoni Lemanik
Division of Metrology and Measurement Systems, Institute of Mechanical Technology, Poznan University of Technology, Jana Pawla II 24 Street, 60-965 Poznan, PL
E-mail: dawid.kucharski@put.poznan.pl

Abstract. We present the construction and testing of the wet bath system for the breath-alcohol analysers calibration. The pressure of the heated compressed air, temperature and humidity were precisely controlled to achieve high accuracy of the measurements with well-known alcohol concentration. To control and data acquisition the Arduino microcontroller was used. The setup consists of eight sockets with four pairs of two serially connected alcohol simulators. That allows increasing the solution total volume and the wet standard amount without a significant change of the ethanol concentration in the liquid. We tested the setup with the electrochemical breathalyser.

1. Introduction
Breath-alcohol analysers (breathalysers) are in use mainly for security in traffic, at work or as health monitors. They could be distinguished, due to the ethanol detection mechanism. One of the group are analysers based on the semiconductor sensor, consisting of a ceramic tube (Al$_2$O$_3$). The alcohol concentration is determined as a conductance changing due to the temperature in a range 350°C ÷ 500°C. Because of high temperature, sensors need an extra heater. This increase the power consumption of the sensor. The semiconductor analysers can achieve accuracy with relative error 20% because they can detect not only the alcohol but also when somebody ate the apple or drunk a coffee [1].

Next group, are the analysers based on the electrochemical sensors. They are made with a porous, chemically inert polymer membrane (PVC), formed in the disk shape, which on both sides is covered with platinum black (finely divided platinum). It is soaked in acidic electrolyte, and platinum wires are lead to each side. When ethanol appears in the introduced sample, it is oxidized on the anode to acetic acid, while at the cathode there is a reduction of atmospheric oxygen to the water. During this reaction, a potential difference is created between the electrodes, and the microprocessor with a signal amplifying system determined the alcohol content in the exhaled air. These analysers (breathalysers) have a measurement error in the range of 5% ÷ 15%. These are mobile, used by the service to check the sobriety of drivers [2, 3]. The last group of the alcohol analysers is based on the IR spectroscopy. They measure the infrared light absorption in the ethanol gas. The measurement error is lowest for all groups of the analysers, but these are not mobile (big dimensions) [4, 3].

From a metrological point of view, breath-alcohol analysers are typical measurement tools needs to be traceable. For calibration procedure a wet bath systems are common in use as an exhaling setup based on the Henry law (eq. 1).
where:
\[ p_b = x_b K_b, \]  
(1)

- \( p_b \) – the partial vapour pressure of \( b \) component,
- \( K_b \) – constant parameter for \( b \),
- \( x_b \) – mole fraction in the liquid.

A constant temperature of the solution is crucial because based on it the ratio of the ethanol concentration in the liquid to the gas concentration is determined. K.M. Dubowski using Henry law experimentally found the equation to calculate this ratio (eq. 2) [5].

\[ y = 0.04145 e^{0.06583 x}, \]  
(2)

where:
- \( x \) – temperature of equilibrium \([\circ C]\),
- \( y \) – coefficient of the alcohol in the water to the alcohol in the air multiplied by 1000 \((k_{a/w} \times 10^3)\).

To calculate the ethanol concentration in the liquid we use the equation 3.

\[ \rho_{\text{air}} = k_{a/w} \times 10^{-3} \rho_{\text{H}_2\text{O}}, \]  
(3)

where:
- \( \rho_{\text{air}} \) – ethanol mass concentration in the air \((g/l)\),
- \( k_{a/w} \) – coefficient of the alcohol in the water to the alcohol in the air, multiplied by 1000,
- \( \rho_{\text{H}_2\text{O}} \) – ethanol mass concentration in the water \((g/l)\).

In this paper, we present the wet bath system, constructed for the accurate breathalysers calibration. We have shown the preliminary measurement results and plans for further investigations [6].

2. Setup

The system layout is given in fig. 1. To eliminate the thermal influences, the plastic shield box was used to cover the system and keep the constant thermodynamics environments (see fig. 2 and 3). To increase the total volume of the solution and the wet standard amount without a significant change of the ethanol concentration in the liquid, we decided to connect two alcohol simulators into the pair. In this way, there are four pairs serial channel simulators. This configuration allowed the faster gas heating by increasing the time for the heat transfer.

The electronic part of the whole system is shown in fig. 4. One of the most important components

![Figure 1. The layout of the constructed wet bath calibration system](image-url)
of the calibration system is the flow sensor\(^1\) which allowed the measurements in a range \(0 \div 20 \text{ l/min}\), and calculate the volume of the produced wet ethanol standard.

3. Preliminary results

Two breathalysers were mounted into the wet bath system. For testing the 0.613 \(g/l\) mass concentration of the liquid ethanol was used. According to the eq. 3 that was corresponded to 0.238 \(mg/l\) (0.5\%) mass concentration of the wet ethanol gas standard.

For experiments the following conditions were kept:

- temperature inside of the system 34\(^{\circ}\)C,
- gas flow 14 \(l/min\),
- measurement time 8.6 \(s\),
- volume of the prepared ethanol gas standard 2.05 \(l\).

\(^1\) Honeywell AWM 5104 VN
The electrochemical breathalyser with 5% measurement error was used for system testing. Tests repeated many times, gives the exact value on the breathalyser screen 0.50‰. That proved the system is constructed well and ready for further metrology investigations.

4. Summary
In this report, we present the construction of the wet bath calibration system for breath-alcohol analysers. The serial connection of the breath simulators increased the total volume of the solution and the amount of the standard without a change of the ethanol concentration in the liquid. The preliminary experimental tests with the electrochemical breathalyser shown, the system is constructed well and programmed for further investigations.

Acknowledgments
The authors wish to thank the SPEED-UP S.C. company for the technical support. A work was supported by grant 02/22/DSPB/1387.

References
[1] Matsushima S, Maekawa T, Tamaki J, Miura N and Yamazoe N 1989 Chemistry Letters 18 845–848 URL http://www.journal.csj.jp/doi/10.1246/cl.1989.845
[2] Rahman M R, Allan J T S, Zamanzad Ghavidel M, Prest L E, Saleh F S and Easton E B 2016 Sensors and Actuators B: Chemical 228 448–457 URL http://linkinghub.elsevier.com/retrieve/pii/S0925400516300624
[3] Kowalski W 2018 private communication
[4] Wigmore J G and Langille R M 2009 Canadian Society of Forensic Science Journal 42 276–283 URL http://www.tandfonline.com/doi/abs/10.1080/00085030.2009.10757614
[5] Dubowski K M 1979 Journal of Analytical Toxicology 3 177–182 URL http://academic.oup.com/jat/article/3/5/177/686322/BreathAlcohol-Simulators-Scientific-Basis-and
[6] Lemanik A 2018 Bachelor’s thesis Poznan University of Technology

2 Sentech Alcoscan ALP-1