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# CALIBRATION AND VERIFICATION OF BREATH ALCOHOL DETECTORS IN PORTUGAL

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**Abstract** − In recent decades the ethanol metrology has became of significant importance, particularly in the area of individual's blood alcohol control.
Portuguese Institute for Quality is responsible for the calibration and metrological control of breath analyzers. This is done by means of comparison with mixtures of certified reference materials, which are traceable to IPQ and NMi primary standards.
This work aims to demonstrate the importance that the operations of calibration and metrological control of breath analyzers has in our society today, and also to present the calibration and verification procedure, errors calculations and the estimation of expanded uncertainties.

**Keywords**: breath alcohol detector, calibration, metrological verification, traceability, error.

## 1. INTRODUCTION

In today's society often alcohol rate control is a way of trying to reduce the number of individuals under the influence of alcohol act in certain areas causing danger to themselves or to others, especially while driving.
The driving low has thresholds for the differentiation of penalties depending on the measurement of the blood alcohol content, in g/l. The imposition of fines and penalties is regulated by Legal Decree nº 2/98.
The operation principle of breath analyzers is a physiological relationship between the concentration of ethanol in breath and the concentration of ethanol in blood, according to the following relationship:

$$BAC = BrAC \times conversion\ factor \quad (1)$$

where BAC is blood alcohol content and BrAC is breath alcohol content.
In qualitative breath analyzers, subject to calibration, conversion factor is a particular characteristic of each instrument and must be specified by the manufacturer.
In evidential breath analyzers within legal metrology the conversion factor is defined by each country and that is based on physical constitution of the individuals. In Portugal conversion factor is 2300.

There are two types of breath analyzers:

1. The qualitative breath analyzers: the quantification method is through a fuel cell.

2. The evidential breath analyzers do the determination of TAS through an electrochemical cell and through a circuit based on the infrared spectroscopy.

## 2. CALIBRATION OF BREATH ALCOHOL DETECTOR

The calibration of qualitative breath analyzers is not yet regulated by the state, however they should be regularly calibrated in order to maintain the reliability of results issued. These equipments are used mostly by private entities.
The calibration is done using the comparison method and measurements are performed in the range 0 g/l to 3 g/l of BAC. Certified reference binary gas mixtures (ethanol in nitrogen) are used. These mixtures are traceable [1] to IPQ and to NMi (National Metrology Institute - The Netherlands) primary standards.
The calibration is performed with one to five concentrations, depending on the instrument application and the customer choice. The results must meet the errors specified by the manufacturer. If the criterion is not accomplished, an adjustment is made to the breath analyzer.
Table 1 shows the results of a qualitative breath analyzer. In this case the equipment did not accomplish the criterion, so an adjustment was required.

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Table 1. Results of breath analyzer calibration, before and after the adjustment.

| Reference Concentration (g/l BAC) | Average indication before adjustment (g/l BAC) | Expanded Uncertainty (±) (g/l BAC) | Average indication after adjustment (g/l) | Expanded Uncertainty (±) (g/l) |
|---|---|---|---|---|
| 0,303 | 0,26 | 0,01(*k*=2,00) | 0,31 | 0,01(*k*=2,00) |
| 0,492 | 0,41 | 0,02(*k*=2,07) | 0,48 | 0,01(*k*=2,00) |
| 0,802 | 0,67 | 0,02(*k*=2,04) | 0,79 | 0,02(*k*=2,04) |
| 1,190 | 1,01 | 0,02(*k*=2,00) | 1,20 | 0,02(*k*=2,01) |
| 1,870 | 1,57 | 0,02(*k*=2,00) | 1,87 | 0,03(*k*=2,06) |

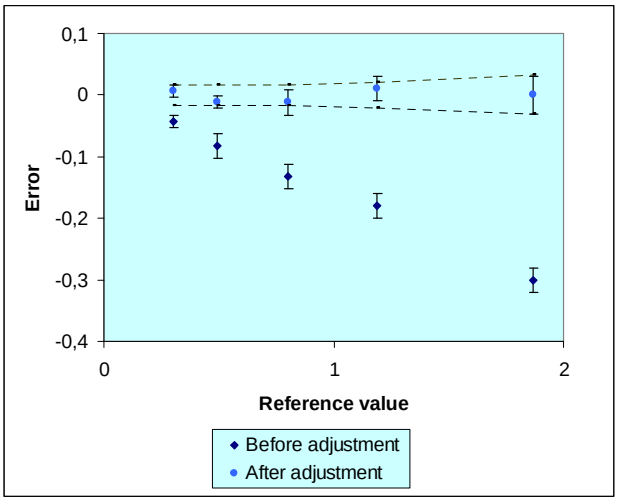


Fig. 1. Graphical representation of the breath analyzer calibration results in g/l BAC, before and after the adjustment.

The graph represents the equipment errors, before and after the adjustment. The error is the difference between the average indication of equipment and the reference value. The dotted lines represents the errors specified by the manufacturer that are allowed to meet the metrological criteria required.
The graph shows that after adjusting the cell, the breath analyzer meets the metrological requirements, so a calibration certificate can be issued.
The vertical bars in the graph correspond to the uncertainty of each measurement, which is calculated in accordance with the "Guide to the expression of uncertainty in the measurement of calibration laboratories" [2].
The expanded uncertainty, presented in the calibration certificate is expressed by the combined uncertainty of measuring multiplied by the expansion factor in order to correspond to a confidence interval of approximately 95 %.
Combined uncertainty is calculated according to:

$$u^2(y) = \sum_{i=1}^{n} u_i^2(y) \qquad (2)$$

where $u_i$ is the standard uncertainly contribution.

Uncertainly contributions are from, standard deviation of measurements, equipment resolution and reference material.

k depends on the degrees of freedom effective number. The dispersion results variation produces changes in the number effective degrees of freedom, which in turn influences the k. The number effective degrees of freedom is calculated by Welch-Satterthwaite formula:

$$\nu_{eff} = \frac{u^4(y)}{\sum_{i=1}^{n} \frac{u_i^4(y)}{\nu_i}} \qquad (3)$$

where:
$u_i$ is the standard uncertainly contribution
$u$ is the combined uncertainty
$\nu_i$ is the degrees of freedom number

## 3. METROLOGICAL VERIFICATION OF BREATH ALCOHOL DETECTOR

The metrological control [3], [4] of breath analyzers falls within the legal metrology, since these instruments are used by entities with legal competence as GNR and PSP. The legal metrology is to defend the interests of citizens.
The metrological control may be regarded as a particular case of calibration, consists of a series of operations to see whether or not the compliance of the measuring equipment. This is made in Portugal since the 80s, but it was in 1990 that was regulated.
The metrological control of the measuring devices is regulated by Legal Decree nº 291/90 of 20 September and by Decree 962/90 of 9 October. The evidential breath analyzers in particular, must meet the requirements within the Decree 1556/2007 of 10 December and the characteristics and technical specifications defined by recommendation OIML R126 [5]. In this context are made annually nearly 700 legal metrological verifications in IPQ Laboratory. The metrological control involves several operations, including type approval, initial verification, periodic and extraordinary verification.
The type approval is made before the placement of the measuring instrument on the market and is valid for a 10 years period. An initial verification is done before being placed in service, after a repair and when the sealed system is broken. In other situations is made a periodic verification, which is valid since its implementation until 31 December of the following year. The extraordinary verification can be claimed at any moment by breath alcohol detector owner.
The method used compares the device indication with the conventionally true value of the reference gas. The gases are reference mixtures of ethanol in nitrogen, certified and traceable to IPQ and NMi primary standards.
The metrological control begins with the selection of five mixtures with different concentrations of ethanol in nitrogen covering the verification range of the equipment, 0 g/l to 2 g/l BAC. Tests are carried out and repeated for each concentration in ascending order. Then the results are analyzed.
Table 2 shows us the maximum permissible errors to the blood alcohol rate, in g/l, for all metrological control operations.

Table 2: Table of EMA according to OIML R126

| BAC–Blood alcohol rate (g/l) | EMA | |
|---|---|---|
| | Type approval/ initial verification | Periodic verification/ Extraordinary verification |
| BAC< 0,920 | ±0,046 g/l | ±0,074 g/l |
| 0,920≤BAC≤4,600 | ±5 % | ±8 % |
| BAC > 4,600 | ±20 % | ±30 % |

Table 3: Results of a breath alcohol detector verification (g/l).

| Reference value | Reference uncertainly | Average indication | Error | Standard deviation |
|---|---|---|---|---|
| 0,335 | 0,0046 | 0,336 | 0,00 | 0,01 |
| 0,539 | 0,0083 | 0,548 | 0,01 | 0,01 |
| 0,883 | 0,0124 | 0,91 | 0,03 | 0,00 |
| 1,310 | 0,0166 | 1,35 | 0,04 | 0,00 |
| 2,052 | 0,0249 | 2,13 | 0,08 | 0,02 |

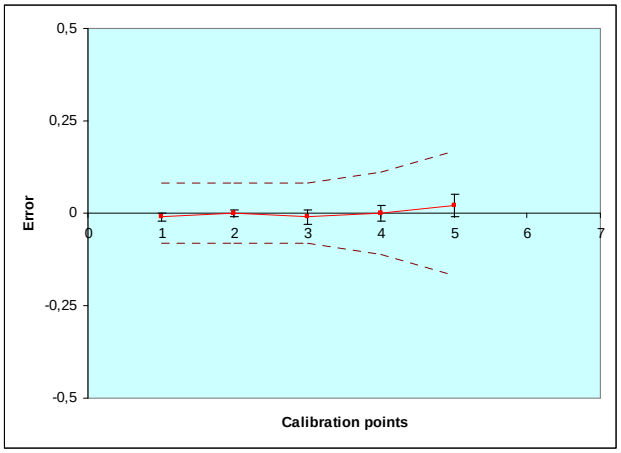


Fig. 2. Graphical representation of the breath analyzer verification results in g/l BAC. The red line represents the errors for each equipment indication and dotted line represents permissible maximum errors.

The error is the difference between the average indication of equipment and reference value.
Analysing the chart we can see that the breath analyzer meets the established by Decree 1556/2007 of 10 December. The analysis of this equipment in particular has shown also that meet the metrological and technical requirements defined by Recommendation OIML R 126. So the instrument is sealed and a verification certificate is issued. If not meet the requirements is issued a rejection report and the instrument cannot be used in the following year, until be repaired.

## 4. CONCLUSIONS

In recent decades has been remarkable increase in the use of breath analyzers either by private entities or by entities with legal competence. This reflects an increased surveillance in the blood alcohol content of individuals, which carries a greater security for society, especially in the context of driving under the influence of alcohol.
The improvement of methods for quantification of alcohol concentration in blood and the easy way they can be implemented has contributed to a greater use of these resources and a more frequent monitoring.
As the tests are carried out with gas mixtures prepared and certified by IPQ laboratory, the national traceability is thus ensured.

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