1. Introduction

Many Western countries are aware of the problem caused by "driving under the influence of alcohol". Therefore most countries have enforced laws to take action against drunk drivers. This legislation is often based on a certain alcohol limit, above which it is an offence to use a motor vehicle on the roads. It is not important how the driver actually behaves, according to the so-called Per Se Laws (Jones, 1988). The laws can be enforced based on the result of a blood test or a breath analysis. The limits, given as blood alcohol concentration (BAC) or as breath alcohol concentration (BrAC) are often different among different countries.

Since 1 November 1974 it is forbidden in the Netherlands to use the road with a BAC over 0.5 mg/ml. The suspect is obliged to give a blood sample to have the BAC determined. The aim of the blood test was to obtain reliable and objective evidence to prosecute drunken drivers. It appeared necessary to regulate the whole procedure from the first suspicion by the police in the street to the report of the BAC by the forensic laboratory. This led to the description and regulation of the screening breath test, the taking of a blood sample, identification and preservation (additives) of the samples, sending of the samples, methods to determine the alcohol concentration and the laboratory procedure. The correctness of the BAC result could hardly be discussed in court. It gave the suspect a high legal security and it offered the possibility to relate the punishment with the BAC. The blood alcohol test produces reliable and objective results and may be successfully used as evidence for prosecution. The blood test, however, also has some disadvantages: blood sampling is an invasive technique, a medical practitioner is needed for the sampling, the whole procedure is time consuming, the result is not immediately available, and a laboratory is needed to determine the BAC. These disadvantages make the blood test a laborious method and not the most appropriate one to counteract drunken driving effectively. The Dutch Parliament held this opinion in 1974 already, but it found that the breath test techniques had not been sufficiently developed. Parliament did ask the Government to replace the blood test with methods of breath-alcohol analysis as soon as a reliable method became available.

The technological development of breath analysis has been enormous since 1974. This led to the introduction of evidential breath analysis in 1987 in the Netherlands, and to the introduction of the result of the breath analysis as legal evidence. For financial and logistic reasons a transitional period of two years was allowed, in which either breath analysis or blood test results might be used. This means that from 1 October 1989 breath analysis was introduced in the whole country and the blood test will only be used if taking a sample of the breath is not possible for technical or medical reasons.

1) The unmodified term alcohol refers to ethanol
2) SWOV Institute for Road Safety Research, P.O. Box 170, 2260 AD Leidschendam, The Netherlands
3) Forensic Science Laboratory, Volmerlaan 17, 2288 GD Rijswijk, The Netherlands
4) Netherlands Measurements Institute (NMi), P.O. Box 654, 2600 AR Delft, The Netherlands

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2. The making of the breath analysis legislation

The ministers of Justice and of Transport and Public Works installed a committee, comprised of jurists, forensic and technical scientists, police officers and traffic experts. Because the problem was complicated and held many aspects, the work took several years (Neuteboom, 1986). One of the assignments was to formulate detailed technical requirements that the apparatus would have to meet. A secondary committee, with representation from SWOV Institute for Road Safety Research, the National Service of Metrology, and the Forensic Science Laboratory was invited to study the material on which the requirements were based.

To begin with an inventory was made in 1984 of the breath-test equipment available. A selection was made for testing in the laboratory. The results were published in 1987 (Frankvoort et al., 1987; Mulder et al., 1987). The results of the inventory and the tests were discussed with the manufacturers to investigate which changes might be made to meet the Dutch requirements. The experiences in Great Britain, where breath analysis was introduced in 1983 and the USA NHTSA-guidelines were taken into consideration.

3. Breath analysis legislation

3.1. Legal background

The advantages of the blood test are deeply anchored in the Dutch legal system and were to be maintained as far as possible. The aim of the new breath analysis legislation was: to obtain reliable and objective evidence and an accurate measurement of BrAC in the whole measuring range. This philosophy had its consequences for the many decisions to be taken when formulating the law, and, as a part thereof, the technical requirements of the apparatus. It led inevitable to extensive legislation following the same tradition as for the Dutch blood test.

3.2. Features

The most important features of the Dutch law on breath analysis are:

- **Per Se law**
  BrAC is considered, analogous to BlAC, as an objective standard to express the degree of alcohol intoxication.

- **Level of BrAC limit**
  The level of the BrAC limit was set at 220 μg alcohol/litre of breath. This value is the result of the Dutch BlAC limit of 0.5 mg alcohol/ml blood and a blood/breath ratio of 2300. Because the blood/breath ratio is not constant but dependent on many factors (Wright et al., 1975, Mason and Dubowski, 1976, Jones, 1978), this determination is somewhat arbitrary. It is based on the English field experiments (Emerson et al., 1980, Paton, 1985) and comes close to the real circumstances for which the legislation was enacted. Use of the dimension "μg alcohol/litre breath" instead of BlAC-equivalent underlines the independent character of the BrAC.

- **No back-calculation**
  BrAC is determined by breath analysis and is not corrected for the time of the actual offense, i.e. the moment of driving under the influence. The same applies for the Dutch blood-alcohol legislation.

- **Screening**
  The evidential breath test may only be taken if a screening test was taken first and gave a
positive result. For the screening test chemical tubes may be used or portable electronic screeners (semi-conductor or fuel-cell).

Random breath testing has been permitted in the Netherlands since 1974.

- Cooperation

A suspect must provide breath for analysis. Refusal to do so is a separate offense, which is punished with the maximum penalty for driving under the influence.

If blowing is not possible for medical reasons, or the suspect is not capable of blowing, a blood sample is taken. If there are medical objections against a blood sample an urine sample is requested.

Neither the suspect nor the police have the right to choose between a blood test or a breath test. The blood test and the urine test are considered as alternatives only if a breath test cannot be taken.

- Standards of the evidential breath analyzers

All instruments meeting the standards, formulated in the legislation, get a type-approval.

The Minister of Justice can authorize the type-approval of instruments for the determination of the legal BrAC.

Besides the type-approval and the first individual approval, an individual re-approval is executed periodically. The validity of the approval is 28 weeks, but this deadline expires when essential repairs are necessary.

- Operation of the apparatus

Not every police officer is allowed to operate the apparatus. The operators must have taken a few-days course in principles and practice of breath testing.

- Waiting time

At least 20 minutes must pass between the first contact with a suspect on the road and the evidential breath test in the police station. This period is sufficient to remove possible mouth alcohol (DENNEY and WILLIAMS 1986; FRANKVOORT et al. 1987).

4. Technical requirements of the evidential breath instruments

4.1. General

The technical requirements for the breath testing apparatus are part of the legislation. They comprise a special section, which also contains rules for evaluation of the apparatus. The requirements have been formulated broadly to give the manufacturer the possibility to choose a certain measuring technique or calibration method and to solve the technical problems in his own way. Besides the definitions of the terminology and general requirements, this section of the law consists of the following parts:

- construction requirements
- approval requirements
- metrological requirements
- calibration gas requirements

The highlights of each of these 4 parts will now be described and explained.
4.2. Construction requirements

4.2.1. Mouth piece
For hygienic reasons a disposable mouth piece must be placed on the blowing tube. It also
serves as a condenser for water and as saliva trap.

4.2.2. Temperature blowing tube
To prevent condensation of alcohol the internal surface of the tube should have a temperature
of 34°C. The temperature of the external surface may be 40°C maximum to keep it manageable.

4.2.3. Tamper-proof operation
The adjustment installation must not be accessible for the normal operator, but only for
specially authorized persons.

4.2.4. Measuring range
The minimum measuring range of alcohol concentration measured is from 0 to 1750 µg/litre
at least. This range conforms to the values found in actual suspects. Values under 50 µg/litre are
rated as 0.

4.2.5. Resolution of indication
The resolution of the indication is 5 µg/litre in the normal situation when testing suspects, i.e.
values such as 525, 530, 535 µg/litre etc. are shown on the display. The values in between are
rounded down to the nearest number.

In the inspection situation (meant for calibration and checks) the resolution is 1 µg/litre.

4.2.6. Acceptable breath sample
A breath sample is only usable if the suspect has blown at least 1.5 litre of air (+ the dead
volume of the tube) into the apparatus in one uninterrupted blow. It is assumed that the alveolar
level will then have been reached (DUBOWSKI 1975; DUBOWSKI and ESARY 1983). Additional
application of a slope detector is permitted, but the primary requirements (1.5 litre in one
uninterrupted blow) remain valid.

The breath analysis apparatus must be designed to limit the blowing resistance to 2 hPa. min/
litre maximum and to permit the actual blowing to take place within 10 seconds.

4.2.7. Measuring cycle
The measuring cycle contains measurements of the zero value, the calibration gas and the air
blown by the suspect in a set order (Table 1).

<table>
<thead>
<tr>
<th>A</th>
<th>C₁</th>
<th>A</th>
<th>S₁</th>
<th>A</th>
<th>S₂</th>
<th>A</th>
<th>C₂</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>A =</td>
<td>air blank</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C =</td>
<td>calibration check</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S =</td>
<td>suspect’s breath</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Measuring sequence

The suspect has to produce two valid breath samples, according to the requirements of 4.2.6.;
he can make four attempts. After a failure the zero-value (air blank) has to be determined again.
The measuring cycle is executed, almost completely, as a dialogue. The zero-measurements and
the calibration checks are done by the apparatus automatically and the display shows when the apparatus is ready to receive the suspect's breath sample. The suspect has 3 minutes to produce the breath sample, otherwise a new air blank is given.

4.2.8. Interruption of the measuring cycle

The measuring cycle has to be interrupted in the following cases:

a. The zero-measurement indicates more than 10 µg/litre.

b. The calibration check deviates more than 5 per cent from the nominal value.

c. The suspect fails to give two valid breath samples.

d. The breath analysis apparatus signals an external interference.

The interruption of the measuring cycle must be executed automatically by the apparatus at one of the 4 (a-d) mentioned occasions.

4.2.9. Print-out

After every measuring cycle a print-out is made, giving the documentation of the measurements and the calculated breath alcohol result with some administrative data (Table 2).

<table>
<thead>
<tr>
<th>Table 2 Information on the print-out</th>
</tr>
</thead>
<tbody>
<tr>
<td>- identity number report</td>
</tr>
<tr>
<td>- identity number breath analysis apparatus</td>
</tr>
<tr>
<td>- location of police station</td>
</tr>
<tr>
<td>- date</td>
</tr>
<tr>
<td>- surname and first name of suspect</td>
</tr>
<tr>
<td>- date of birth of suspect</td>
</tr>
<tr>
<td>- place of birth of suspect</td>
</tr>
<tr>
<td>- name of operator</td>
</tr>
<tr>
<td>- nominal value of the calibration gas</td>
</tr>
<tr>
<td>- zero checks</td>
</tr>
<tr>
<td>- measured values in two calibration checks</td>
</tr>
<tr>
<td>- two measured values from suspect</td>
</tr>
<tr>
<td>- time of beginning and end of the cycle</td>
</tr>
<tr>
<td>- breath alcohol result for prosecution</td>
</tr>
</tbody>
</table>

4.3. Approval requirements

There are three kinds of approvals:

- approval of the type of apparatus

- first approval of an individual apparatus of that type

- periodically repeated individual approval of that apparatus

For the type-approval three breath test apparatus must be made available together with a detailed description, drawings and photographs. Meeting the requirements is a condition for registration by the Minister of Justice as legal evidence. The type-approval is paid for by the manufacturer.

The first individual approval is destined for new breath testing apparatus of a formerly approved type to be used by the police for the first time. The apparatus must conform to the apparatus with type-approval.

If an apparatus meets the requirements it can be used for 28 weeks for legal purposes. The Netherlands Measurements Institute (formerly National Service of Metrology) issues a certificate for this purpose. The testing is repeated periodical if the validity of the certificate expires or if the apparatus was repaired.

\(^1\) for the calculation see paragraph 6

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4.4. Metrological requirements

The metrological requirements are different for the three kinds of approvals. The type-approval is the most demanding and the requirements get less rigid in the course of the series. Each of the 3 kinds of approvals has its own series of tests. Also the tests get less extensive in the course of the series. All tests are conducted by the Netherlands Measurements Institute. The most important ones will be explained below.

4.4.1. Repeatability

For the type-approval calibration gases with an alcohol concentration of 0, 450, 900, 1350 μg/litre are measured, 10 times each. The standard deviation must not exceed 1 per cent. For the measurement of the zero-concentration an absolute standard deviation of 5 μg/litre is allowed.

For the first individual approval the repeatability is measured by use of 10 tests at short intervals with calibration gases with alcohol concentrations of 0, 10, 25, 40, 60, 80 and 100 per cent of the maximum measuring range (1750 μg/litre) respectively.

For the repeated individual approval the same is done with calibration gases with alcohol concentrations of 0, 220, 440 and 660 μg/litre respectively. For both individual approvals the standard deviation of the average of the 10 measurements must not exceed 1 per cent at each concentration.

4.4.2. Accuracy

The accuracy is not tested during the type-approval, because it is not a relevant item at that stage. As opposed to the type-approval the accuracy is an important testing item for the individual approval. A precise breath analysis result is the basis after all for the prosecution. The average measurement values, obtained in the repeatability tests (4.4.1.) are compared to the value of the calibration gases.

Compared with calibration gas target values the average of the 10 measurements must not exceed 20 μg/litre for the values under 500 μg/litre and 4 per cent for values equal to or over 500 μg/litre for the first individual approval; for the repeated approval these values are 25 μg/litre and 5 per cent respectively.

4.4.3. Linearity

The linearity is only tested in connection with the type-approval. The linearity is tested by measuring calibration gases with an alcohol concentration of 0, 10, 25, 40, 60, 80 and 100 per cent of the maximum measuring range (1750 μg/litre) 10 times, each at short intervals. The average of the 10 measurements must not deviate more than 15 μg/litre from the ideal linear value for measurement values under 500 μg/litre, and not more than 3 per cent for values equal to or higher than 500 μg/litre.

4.4.4. Short-term drift

The short term drift is tested at two alcohol concentrations: 0 and 450 μg/litre. The test is spread over 8 hours. The maximum deviation must not be more than 15 μg/litre, based on the average of 25 measurements. These tests are only done for the type-approval.

4.4.5. Long-term drift

This test takes six months. This period agrees with the frequency of the repeated individual approval. It is tested at 2 alcohol concentrations: 0 and 450 μg/litre. During this testing period
the average of 10 measurements made at short intervals must not exceed 15 µg/litre of the nominal value. The tests must be made at regular intervals over the 6 months and are only done for the type-approval.

4.4.6. Specificity

Because there are many endogeneous components in breath, that might theoretically influence the alcohol (ethanol) measurement it is necessary to set requirements for the specificity of the method of analysis used. These volatile components can, from the metrological point of view, be considered as influencing factors. The approach selected is to require from a breath testing apparatus that the influence of these factors on the reading is limited to an acceptable level. The influence of the components, at the concentrations summarized in table 3, must not exceed a maximum of 10 µg/litre in the tests for the type-approval of the apparatus.

The specificity test for each component is executed by adding the component to a calibration gas and compare the reading with the reading of the calibration gas itself. This is tested by ten consecutive determinations with calibration gases with an alcohol concentration of 0, 450, 900, 1350 µg/litre respectively and comparing the average values with the alcohol concentrations of the calibration gas.

It is unrealistic to consider an extensive list of components, which are seldom found in breath or in very low concentrations only. A choice had to be made: taken into account are the congeners present in alcoholic beverages and the possible presence of metabolic products in human breath. Not only in healthy persons, but also in diabetics and alcoholics who make up a substantial part of the number of drunk drivers (Dunbar et al 1985, Gjerde et al 1986).

These restrictions led to the components in Table 3 and is explained below. The concentrations have been set at rather high levels to contradict any technical argument even in the most improbable defences challenges.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Maximum concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>50,000 µg/litre</td>
</tr>
<tr>
<td>carbon monoxide</td>
<td>50</td>
</tr>
<tr>
<td>carbon dioxide</td>
<td>100,000</td>
</tr>
<tr>
<td>acetone</td>
<td>100</td>
</tr>
<tr>
<td>methanol</td>
<td>40</td>
</tr>
<tr>
<td>isopropanol</td>
<td>100</td>
</tr>
<tr>
<td>acetaldehyde</td>
<td>100</td>
</tr>
<tr>
<td>methane</td>
<td>200</td>
</tr>
<tr>
<td>isoprene</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 3 Considered interfering substances

**Water**

Exhaled breath is always saturated with water. The reason to put water on the list is that there would be a difference when calibrating with dry gases compared to measurements on breath samples.

**Carbon monoxide**

Carbon monoxide is a compound being made in incomplete combustion processes, e.g. when smoking tobacco.

**Carbon dioxide**

Exhaled breath always contains of carbon dioxide.
Acetone

Acetone may be present in higher concentrations in diabetics and dieters. The presence of acetone in blood and breath under various circumstances is described in the literature (Rooth and Ostenso 1966, Tassopoulos and Barnett 1969, Sulway and Malins 1970, Dubowski and Essary 1983, 1984, Flores and Frank 1985, Jones 1987). The selected value of 100 µg/litre is high and is seldom described for drivers under the influence of alcohol.

Methanol

Small amounts of methanol are present in most alcoholic drinks. The concentrations vary widely for each beverage (Glig and von Meyer 1987). Alcoholics have an accumulation of methanol in the body. This is caused by the fact that the same enzymes are responsible for the elimination of methanol and of ethanol. The affinity for ethanol however, is much greater, so that the elimination of methanol is blocked as long as there is ethanol in the body, which often is the case for alcoholics. Furthermore the speed of elimination of methanol is slower than of ethanol (Jones 1987).

Bonte (1985 and 1987) found methanol concentrations of up to 40 µg/litre in alcoholic’s blood. Jones and Löwinger (1988) found concentrations of up to 24 µg/litre (in breath) in Swedish drunken drivers. The value in table 3 (40 µg/litre) must be viewed at from this perspective.

Isopropanol

On the basis of a possible biochemical conversion of acetone into isopropanol the concentration of isopropanol is made equal to that of acetone (Lewis et al. 1984). Isopropanol may be present in higher concentrations in chronic alcoholics as well (Iffland et al. 1988).

Acetaldehyde

Acetaldehyde is the first product when the body is eliminating ethanol. The elimination of acetaldehyde by aldehyde dehydrogenation has a faster progress than the elimination of ethanol and does not set the speed for the overall process. Usually there is no accumulation of acetaldehyde and its concentration remains verly low: about 1–2 µg/litre. There are exceptions, however. The first one is for persons using disulfiram, blocking the elimination of acetaldehyde; the second is for persons of the Oriental race who by nature lack the enzyme acetaldehyde dehydrogenase (flush reaction). In both cases a strongly increased concentration of acetaldehyde is present when alcohol is used (Stowell 1980, Jones 1986).

Methane

Methane may develop in low concentrations in the anaerobic fermentation of sugars in the body. These concentrations can be higher in certain circumstances (illness, use of laxatives) (Marks 1984).

Isoprene

Isoprene (2-methyl 1,3 butadiene) is a hydrocarbon compound generally present in breath (Krotoszynski 1977, Jones 1985, Kerr, Wilson 1986).

4.4.7. Other influencing factors

Several other factors, besides volatile substances, may interfere with a measurement: environmental temperature, humidity, power supply, and alcohol concentration in the envi-
The approach selected for these factors is identical to that of the volatile components: to require from a breath testing apparatus that the influence of these factors on the reading is limited to an acceptable level. The separate factors must also not exceed a maximum of 10 µg/litre in the test for the type-approval of the apparatus.

The tests are executed by varying one of these factors in successive tests, when the other factors are kept at a constant standard value. The influence of each factor is, analogue to 4.4.6., determined by making ten consecutive determinations of calibration gases with an alcohol concentration of 0, 450, 900, 1350 µg/litre respectively and comparing the average values with the alcohol concentrations of the calibration gas.

The factors are varied between the following limits:
- Environmental temperature between 10 and 33 °C
- Relative humidity between 10 and 90 per cent
- Power supply, variations in the mains supply between −15 and +10 per cent of the nominal power supply voltage; variation in frequency between −2 per cent and +2 per cent.
- Alcohol contents of environmental air: up to 50 µg/litre

4.4.8. Interferences

The influencing factors mentioned in 4.4.6. and 4.4.7. may have a more or less permanent character. Other possible influences have a more incidental character:
- Short time power reduction
- Voltage bursts from the mains
- Electrostatic discharge
- Electromagnetic external radiation RFI; electromagnetic susceptibility

The tests conform to O.I.M.L.3)-documents, following the IEC-publications, where possible. The requirement for type-approval is that the breath analysis apparatus remains working within an accuracy of 10 µg/litre of indicates that there is an interference. In that case the breath testing apparatus must be switched off automatically.

The same interferences considered for the type-approval are also tested during the individual approvals. Not every new breath analysis apparatus, however, is subjected to this test. A random sample of 10 per cent is taken.

The tests are the same as for the type-approval, but the demands are less rigid. They are the same as for the accuracy: 20 µg/litre for values under 500 µg/litre and 4 per cent for those higher than or equal to 500 µg/litre.

5. Calibration gases

5.1. General

The calibration gases referred to, are meant for the calibration checks, which belong to the measuring cycle (see 4.2.7). There are 2 methods to execute calibrations: (a) the liquid simulator and (b) the cylinder filled with a gas (nitrogen or air), containing a constant alcohol concentration.

The manufacturer is free to choose either method, if the following requirements are met:
- The calibration gas must have a nominal alcohol concentration between 400 and 500 µg/litre.
- The real alcohol concentration must not deviate more than 2 per cent from the nominal value.
- The temperature of the calibration gas must be at least 34 °C when fed to the apparatus.

1) Organisation Internationale de Métrologie Légale

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The calibration gas must meet these three requirements during a period of 21 days or 100 measuring cycles at least.

5.2. Conditions
The calibration gas must meet the general demands (see 5.1.) under the conditions:
- environmental temperature from 10 to 34 °C.
- relative humidity between 5 and 95 per cent.
- atmospheric pressure between 970 and 1050 hPa.

5.3. Atmospheric pressure
The BrAC-unit is µg/litre. This unit is linear pressure-dependent, influencing the measuring result with fluctuations in the atmospheric pressure, inclusive of the calibration check. Between the highest (1050 hPa) and the lowest (970 hPa) values of the atmospheric pressure there is a difference of 8 per cent. This means that measurements of the same calibration gas in these extremes give a difference of about 8 per cent. This difference is high compared to the required accuracy of 2 per cent of the calibration gas and of a maximum deviation of 5 per cent of the nominal value demanded in the measuring cycles (see 4.2.8. b). It would mean that the calibration check might fall outside the range of 5 per cent. The problem is solved by defining the nominal alcohol concentration of the calibration gas for the average atmospheric pressure in the Netherlands (1013.25 hPa). The atmospheric pressure at each calibration check is measured routinely with a built-in barometer and the result of the measurement of the alcohol concentration during the calibration check is corrected automatically.

6. The calculation of the breath alcohol result
The breath analysis result used in the prosecution of the suspect for drunk driving is calculated from the average of the two measured values. The values by themselves do not have a legal meaning.

Two valid measured values from a complete cycle are used and a correction is applied to this average. The calculation must not be made if the difference between the 2 results is higher than 10 per cent of the lowest value. This restriction is meant to prevent the use of extreme deviations in duplicate readings.

This situation may arise if the suspect gets a belch during the cycle, so that alcohol from the stomach gets into the mouth. This might produce a big difference between both values within a cycle. The phenomenon is detected by the requirement of 10 per cent deviation before a breath analysis result is calculated. The selection of the 10 per cent value is arbitrary.

The calculation is done automatically by the instrument on the basis of formulae (1) or (2) in Table 4 and remains visible on the display for 3 minutes at least.

\[ \text{breath test result} = \begin{cases} 0.90 \times Y - 30 & \text{for } Y < 500 \mu g/litre \\ 0.85 \times Y - 5 & \text{for } Y \geq 500 \mu g/litre \end{cases} \]

\( Y \) is the arithmetic average of the results of 2 valid measured values.

<table>
<thead>
<tr>
<th>Table 4 Calculation of the breath alcohol result based on two valid readings</th>
</tr>
</thead>
</table>

The aim of the calculation is to protect the suspect against possible measurement errors, inherent in the method. Such calculations are well established in forensic blood alcohol analyses. In the Dutch blood test 6 per cent is deducted from the average test result (N=4), which is equal to 3 times the theoretical standard deviation.
The sources of error in the breath analysis can be divided into fluctuations caused by sampling (1), and fluctuations caused by the actual measurement (2):

1. Sampling fluctuations are an extra source of error compared with blood testing, because a vena puncture produces a well defined and reproducible blood sample (Gostomczyk et al. 1974; Teige et al. 1974). Breath samples cannot be defined so precisely because of the influence of human factors (Đubowski 1975). For an estimation of fluctuations of breath samples in practice the Paton-report was used (tables A21 und A35). This gave an average difference between 2 measurements within a few minutes of about 6 per cent. This dispersion is made up from the real difference in BrAC between the two samples and the repeatability of the measurement with the breath testing apparatus. The standard deviation of the repeatability is known (ca. 1 per cent) from earlier experiments (Frankvoort et al. 1987). Possible systematic deviations of the correct measurement value are not important here.

These figures prove that the physical-biological mechanism in the sampling is the main source of errors. If the dispersion in the duplicate samples is assumed to have a normal distribution, this means that the standard deviation of the samples is about 5 per cent, owing to human factors.

The breath analysis result is based on 2 measured values, which means that the standard deviation is ca. 3.5 per cent (5√2). Analogous to the blood test a deduction of the average measured value (N = 2) of 3 times the standard deviation, i.e. 3 * 3.5 per cent = 10 per cent is applied on the breath analysis result.

2. The fluctuations owing to the actual measurement by the apparatus consist of several elements: accuracy (1), influencing factors (b), and interferences (c) all play a role. Compensating for these elements, the metrological requirements set for the repeated individual approval are the basis for the correction, because here the practical situation is described. If no special requirements have been set for the repeated individual approval, the requirements for the first individual approval or the type-approval respectively must be applied.

   a. For the accuracy a deviation of 25 µg/litre is allowed for measured values below 500 µg/litre, and 5 per cent for values equal to or higher than 500 µg/litre (see 4.4.2).

   b. The deviation allowed regarding the different interferences amounts to 20 µg/litre for measured values below 500 µg/litre and 4 per cent for values equal to or higher than 500 µg/litre (4.4.8.).

   c. The deviation allowed regarding influencing factors (including volatile substances) is 10 µg/litre for all measured values (see 4.4.6. and 4.4.7.).

   If the allowed deviations of a, b and c are summed, and only one influencing factor is taken into account, a total error is composed of:

   \[25 + 20 + 10 \mu g/litre = 55 \mu g/litre\]

   for measured values smaller than 500 µg/litre and

   \[5 \text{ per cent } + 4 \text{ per cent } + 10 \mu g/litre = 9 \text{ per cent } + 10 \mu g/litre\]

   for measured values equal to or higher than 500 µg/litre.

   It is virtually improbable that the allowed deviations of a, b and c work at their maximum in the same direction at the same moment, and therefore arbitrarily, a lower total value is chosen as the prescribed deduction. It means that the corrections applied are 30 µg/litre for measured values under 500 µg/litre, and 4.5 per cent + 5 µg/litre for values equal to or higher than 500 µg/litre. These corrections added to the correction of 10 per cent for the sampling error lead to the formulae (1) and (2).
In the corrections on which the formulae are based a deviating body temperature (fever) is not taken into account, but the influence is significant 6.5 per cent per °C (Dubowski 1979). Several (extreme) breathing techniques like hyper-ventilation, are not taken into account either, and they may also considerably influence the result (Jones 1982, Mulder and Neuteboom 1987, Schoknecht and Kophamel 1988, Schoknecht et al. 1989). The influence of "natural" variations in body temperature and breathing frequency are taken into account in the dispersion found in the results from field trials.

7. Conclusions

There were various reasons in the Netherlands to replace the blood test by a legislation based on breath analysis. These reasons were summarized in the Introduction.

One of the most important goals the new legislation had to satisfy was: the BrAC-value must be correct and accurate over the full measuring range in order to enable a strict relation between the BrAC-value and the punishment in court.

This goal had a lot of consequences for the legislation itself as well as for the technical requirements the apparatus have to meet, because the correct measuring of the BrAC can be disturbed by many different human and instrumental factors. It was tried to draw up a complete inventory of these factors. Human factors can be e.g. the presence of mouth alcohol or - interfering substances in the breath, an insufficient volume of breath or (invisible) interruption of the blowing. Instrumental factors can be e.g. incorrect calibration, lack of specificity for ethanol or long-term drift. All these factors were taken into account and translated into technical requirements as much as possible.

More provisions were made to assure the correctness of the measurement:
- It is well established in analysing a blood sample for alcohol to base the reported result on, at least, duplicate analyses. The same is here demanded in measuring the BrAC: the reported result is always based on two valid measurements.
- Also analogous to BlAC-determinations is a deduction from the average BrAC-value. This calculation is described extensively in paragraph 6.
- A type approval guarantees that the instrument meets the legal requirements and the periodic testing of the individual instruments must prevent malfunctioning in police stations.
- Only qualified police officers are allowed to operate the apparatus.

The original idea that breath analysis could be formulated in a simple law appeared to be an illusion during the making of this law. An extensive and detailed breath analysis legislation was inevitable in order to have about the same reliability as the (former) blood test which is anchored so deep in the Dutch legal system.

A striking issue in the new legislation is the large deduction in calculating the breath alcohol result from the two valid measurements. Applying the formula mentioned above shows that the deduction from the average result is 15 to 20 per cent in advantage of the suspect. This is a high price for the high standard of reliability of the method and is caused by the fact that the benefit of the doubt is given very generously to the suspect.

Nevertheless it is hoped that this legislation will have a positive effect on traffic safety in The Netherlands.

Summary

In October 1987 the legislation on driving under the influence of alcohol has been changed thoroughly in The Netherlands. From that date breath analysis was introduced to obtain legal evidence for prosecuting drunken drivers. For financial and logistic reasons a transitional period of two years was allowed which means that from October 1989 breath analysis was completely introduced.
One of the features of this legislation is that the suspect has no choice between breath – or blood analyses. The blood test will only be used if there is a technical or medical reason which prevents that a breath sample is collected.

The legal limit is set at 220 μg/litre, which is equivalent to the Dutch blood alcohol limit of 0.5 mg/ml at a assumed blood/breath ratio of 2300.

Key words:
Alcohol, legislation, in The Netherlands – drunk driving – breath analysis – breath test apparatus, technical requirements.

Zusammenfassung

Der gesetzliche Grenzwert liegt bei 220 μg/l, was dem niederländischen Blutalkoholgrenzwert von 0.5 Promille entspricht, setzt man ein Blut-/Atemalkohol-Verhältnis von 2300 voraus. Von entscheidender Bedeutung für den Erfolg dieser Gesetzgebung ist jedoch die Genauigkeit und Reproduzierbarkeit der Atemalkoholmessung, wobei auf die technischen Voraussetzungen hierfür besonders hingewiesen wird.

Schlüsselwörter:
Alkoholgesetzgebung, Niederlande – Fahren unter Alkoholeinfluß – Atemalkoholanalyse – Testgeräte, Atemalkoholanalyse

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