BREATH ANALYSIS AND BLOOD ALCOHOL CONCENTRATION

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SUMMARY

Devices for breath analysis are intended to meet the need for a simple method of determining the blood alcohol concentration, and have already been developed for various purposes. In putting breath analysis into effect, a compromise has to be sought between the users' requirements and the technical possibilities of the devices. SWOV laboratory and field tests indicate that devices already exist which can be used for scientific purposes.
Further improvement of devices for breath analyses is possible and can be expected at short notice.

CONTENTS

FOREWORD

For some years the Institute for Road Safety Research SWOV has been investigating drinking by road users and its dangers in road traffic. Results of this research have meanwhile been embodied in a number of reports. The most recent, Breath-Analysis Apparatus, is a report on field tests with various types of devices for breath analysis to determine the extent to which road users are intoxicated. The sole purpose was to assess the value of breath analysis as an alternative to blood tests for scientific research.
Earlier, Drinking and Driving and Drinking by Motorists had been published. The former is a study of the literature on research in The Netherlands and other countries into drinking and driving and its dangers, and activities aimed at decreasing such drinking. The latter contains the results of roadside surveys by SWOV in The Netherlands in 1970, 1971, 1973, 1974 and 1975.
These three reports have been condensed into a brochure, Drinking drivers. This brochure is only available in Dutch.
The reports and brochure are obtainable on request from SWOV, P.O. Box 71, 2270 AB Voorburg, The Netherlands.

This article by J.A.G. Mulder and P.C. Noordzij reports on literature recently published outside The Netherlands on the subject of breath analysis and the principal results of SWOV's research on Breath-Analysis Apparatus.
It can be regarded as a general review of recent developments in breath analysis.

INTRODUCTION

Laboratory and field experiments have shown a relation between drivers' blood alcohol concentration and their driver performance. Field research has also shown a relation between this BAC and their accident risk. These findings justify the use of the BAC as an element in measures aimed at improving road safety.
The following are the main methods for determining the BAC: the long established analysis of a blood sample and the more recent breath analysis. Compared with blood analysis, breath analysis has many practical advantages and some physiological advantages.

Breath analysis is used mainly for enforcement and for research purposes. Breath-analysis apparatus for enforcement purposes can be subdivided into two kinds: (portable) devices for screening, such as the test tube (qualitative measuring), and evidential instruments to which legal force can be attached (quantitative measuring).
For research purposes, especially quantitative measuring instruments are important.
In Europe, interest in the use of breath analysis for screening offenders is largely limited to the test tube. In the United States, better screening devices and also evidential instruments are used for this. A fairly new instrument, still in course of development, is the "passive breath tester". Breath sampling with this type of instrument does not require the subject's active co-operation. Instruments have also been developed for remote sampling. With this method a breath sample is taken that can be analysed afterwards with an instrument for quantitative measurements.

Besides instruments for enforcement and research purposes, self-testers have recently appeared. These have been developed for use in bars and so on where customers can ascertain their own BAC (qualitative or quantitative). Such devices give rise to fundamental questions about the necessary precision and accuracy of the results. Attempts have also been made on the basis of breath analysis to design systems making it impossible for an intoxicated driver to start his car. But the practical possibilities of such systems are not yet clear.

1. PROBLEMS OF BAC MEASUREMENT BY BREATH ANALYSIS

As stated in the Introduction, breath analysis has a number of advantages as compared with blood analysis for BAC determination. Nevertheless, inaccurate results may occur for various reasons when breath analysis is routinely used. A historical review of the development of breath-analysis apparatus is given by Dubowski (1975). Harger (1974) discusses in detail investigations on the comparison of blood and breath analysis. Both articles show that further improvements in breath analysis are possible and are also likely in the near future. Harriott (1973) and Moulden & Voas (1975) review the available instruments. The possibility of applying breath analysis with the present state of the art is a compromise between the requirements a measuring instrument must satisfy under given conditions and the capabilities and limitations of the existing devices.

Major problems in using breath-analysis apparatus relate to sampling and conversion of a measured breath alcohol concentration into a BAC. Both problems are closely related; conversion is appropriate only if the alcohol concentration of a sample of breath is constant. It used to be assumed that a breath sample with a constant alcohol concentration could be taken after about 500 cc of breath had first been exhaled. Several studies, however, have shown larger exhalation volumes to give more accurate BAC determinations. Recent investigations by Jones et al. (1975) and Flores (1975) indicate that in order to obtain a constant breath alcohol concentration a fixed volume of air has to be rebreathed several times. They also consider it a suitable way that the breath is held in for some time and then exhaled. Jones et al. (1975) assume that only in this way equilibration of alcohol can be achieved between breath and blood as well as between breath and the mucus of the upper respiratory track. Attemps to correct breath-analysis results by measuring the CO_2 content have meanwhile been abandoned. Dubowski (1975) concludes that the exhalation volume should generally be more than 2½ litres before a sample is taken. He also suggest simultaneous temperature measurement, a suggestion that has also been made by Wright et al. (1975).

The most commonly used ratio between breath alcohol concentration and blood alcohol concentration in determining the BAC from breath analysis is 1 : 2100. This is a theoretical value, however, which with present breath-sampling methods generally leads to BAC's that are too low.

In comparing the results of blood and breath analyses a number of things must be watched. In the first place, the time between blood and breath sampling must be as short as possible. If drinking was only very recent, differences may nevertheless occur between the results of blood and breath analyses. Those of blood analysis may be too low owing to imcomplete equilibration of alcohol over the body; or those of breath analysis may be too high owing to alcohol still being in the mouth or to belching. It is also possible for errors to be made in blood analysis; moreover, blood analyses are not perfectly reproducible. Because of these problems it may be better not to compare breath-analyses with blood-analyses results but with a carefully determined alcohol concentration in a given volume of repeatedly rebreathed air.
Lastly, in establishing the accuracy of breath-analysis apparatus by comparison with the results of blood analyses, attention must be paid to the following: in experiments the BAC levels will be within a given range; if this differs much from that within which they occur in practice, the results of statistical calculations may give a wrong impression. Striking differences are found between the various researchers with regard to statistical processing, presentation and interpretation of results.
Laboratory tests may closely simulate operational situations as far as conditions of measurement, characteristics of subjects and operators of the apparatus are concerned. An instrument can only be evaluated completely in a field test, because this can bring to light unexpected instrument failures, factors liable to affect the results, or other problems.
Field tests of instruments for enforcement purposes present a methodological problem if the tests are limited to persons suspected of drunken driving. Persons with a positive BAC but not suspected are

disregarded in such investigations. Moreover, the results of the blood analyses are sometimes corrected in the laboratory. In this way, a certain safety margin is built in to avoid people being wrongly accused. As it is often unclear whether such a correction has been made or not, it seems doubtful whether exact comparison of breath and blood analyses is possible.

2. SWOV RESEARCH

The Institute for Road Safety Research SWOV has investigated the value of breath analysis as an alternative to blood analysis for scientific research. The breath-analysis apparatus studied, therefore, were mainly types for quantitative BAC determination.
After a number of laboratory tests, the instruments were studied in the field. This was combined with SWOV's roadside surveys into drinking and driving by Dutch motorists during week-end nights in the autumn of 1970, 1971, 1973 and 1975 (SWOV, 1977a). A pilot study was carried out in 1968.
In the roadside surveys, the aim was to make two breath analyses per subject and per apparatus, a venous blood sample being taken between the two breath analyses. The test procedure and blood analysis are not discussed in detail now, but can be found in the complete report on the research (SWOV, 1977b).
The measured BAC's are expressed as milligrammes of ethyl alcohol per 100 millilitres of blood.

The breath-analysis apparatus examined in the course of time are listed in Table 1 according to the year in which the field tests were made. The table also contains the principal details of the instrument, such as the principle of analysis, volume of exhaled air, sampling and number of each type tested.
The Breathalyzer 900 was tested in the laboratory only.
The Ethanographe, a Swiss copy of this instrument, was also tested in the field in the pilot study in 1968.
The Alcolinger Automatic is an automatic version of the Ethanographe developed partly on the basis of experience gained in the pilot study. It was tested in the laboratory and in the field (during the first roadside survey into drinking and driving in 1970).
In 1971 a modified version of the Alcolinger Automatic was tested.
In 1973, four fuel-cell instruments were tested; although partly produced in series, at that time they still had to be regarded as prototypes. The Breathalyzer 1000 and the Intoxilyzer, the most expensive of the commercial instruments, were also available.

Lastly, in 1975 modified versions of the Intoxilyzer and the Alcolmeter bench instrument were available.
As a rapid evolution is taking place in breath analysis, with new makes and types of instruments constantly appearing, some of those mentioned above are of historical interest only.

With the chosen research design, information was obtained from the laboratory and roadside surveys on:
a. mechanical reliability of the breath-analysis apparatus, details of operation, maintenance and so on;
b. precision of results of breath analysis (including sampling);
c. accuracy of the BAC predicted from the results of breath analysis (based on breath-blood comparison).
The programme did not include tests of the specificity of breath analysis, or laboratory breath-blood comparisons.

2.1. Laboratory tests

In the laboratory tests, none of the instruments deviated more than 5 mg/100 ml in repeated analysis of standard ethyl alcohol/air mixtures or ethyl alcohol/argon mixtures. In some cases they worked very differently from the manufacturer's specifications - especially in sampling - and improvements had to be made. Proper sampling is essential for reliable BAC measurements.
All except the Ethanographe had been or were calibrated by the breath/blood-alcohol ratio of 1 : 2100. The Ethanographe gave findings 10% lower than the others; its calibration wat not altered. The calibration of the fuel-cell instruments was not as stable as the others.

2.2. Field tests

With the exception of the Breathalyzer 1000 and the Intoxilyzer, all instruments had failures during the field tests. The construction of nearly all of them could have been improved. This could increase their mechanical reliability, ease of operation, presentation of results, stability of calibration and zero setting.

The precision of the results of breath analysis including sampling is expressed as the linear correlation coefficient r_{xx} between two breath analyses of one person. The accuracy of the BAC predicted from breath analysis is expressed as the linear correlation coefficient r_{xy} between breath and blood analyses, as the linear regression formula for predicting the result of the blood analysis $\hat{y}$, and the standard error of estimate sd thereby made. Accuracy of the BAC predicted from breath analysis improves:

a. as the linear correlation coefficient r_{xy} between the results of breath and blood analyses is nearer to 1.0;

b. as the average difference between the uncorrected results of breath and blood analysis is smaller (with the calibration ratio of 1 : 2100); this average difference is smaller as the linear regression formula is nearer to $\hat{y} = x$;

c. as the standard error of estimate sd in BAC prediction is smaller.

Table 2 gives the calculated values for precision of the breath analyses and for accuracy of predicted BAC. It shows that the Intoxilyzer results with regard to precision and accuracy is very good. Consequently, SWOV decided to rely mainly on this instrument in further drinking and driving roadside surveys. Moreover, it indicates the alcohol concentration of the air breathed in right from the moment the person blows.

The Alcolmeter bench instrument is not quite as good as the Intoxilyzer, but is considerable cheaper. On the other hand, the Alcolmeter bench instrument requires greater care in operation and maintenance.

Further discussion of the findings is combined in the next section with a general discussion of a number of well-known screening devices and evidential instruments.

3. REVIEW OF THE BEST KNOWN APPARATUS

3.1. Screening devices

At present there are two basic designs of screening devices: disposable chemical test tubes and electromechanical instruments. Two important types of errors are possible with them:

a. a false positive reading, a person being accused of having a BAC higher than the actual BAC;

b. a false negative reading, the BAC being presumed to be lower than the actual BAC.

3.1.1. Chemical test tubes

These disposable chemical test tubes are all similar in design and operation. They consist of a small glass tube containing an alcohol-sensitive reagent, and a breath-volume measuring device (a rubber balloon, a plastic bag or an air pump).
Goldberg & Bonnichsen (1970) examined Alcotest 50 mg/100 ml and 80 mg/100 ml tubes, with regard to factors such as rate of breath flow, volume variations and sensitivity to substances other than ethyl alcohol. Alcotest tubes have been used for many years by the police in a number of West European countries, since 1st November 1974 including The Netherlands. The results of a series of blood and breath analyses for the 50 mg/100 ml tubes are given in Figure 1. In a number of measurements there was no discoloration at all, though the actual BAC's were up to 50 mg/100 ml. On the whole, there is a weak relation between the length of the discoloration and the BAC ($r = 0.70$). The percentages of false positive and false negative results depend on the interpretation of the length of the discoloration and the distribution of the actual BAC's. Goldberg & Bonnichsen's investigations showed hardly any false positives as against a substantial number of false negatives. It can be concluded that the chemical test tubes are theoretically sensitive enough for screening purposes. Improvements in the design of the tubes and the sampling system are expected to give better results.

3.1.2. Electromechanical instruments

Some years ago the U.S. Department of Transportation decided not to approve tube-type screening devices. Research was then carried out to develop more accurate instruments satisfying a number of stringent requirements. This resulted in a small number of portable instruments meeting the required criteria. They work on various principles, such as fuel-cells, catalytic burners or semi-conductors.
The chemo-electric fuel-cell generates a measurable electric current from oxidation of alcohol in the breath; this current is directly proportional to the amount of alcohol.
In catalytic burning, alcohol is oxidised at a small, catalytically active element. The consequent change in temperature causes a change in the resistance of the element, proportional to the amount of alcohol.
The solid-state semiconductor is usually made of transition metal oxide. Alcohol is absorbed at the surface. The surface is reduced and a temperature change occurs, which causes a change in surface resistance, indicative of the amount of alcohol.

The calibration of fuel-cell instruments is unstable and they require frequent recalibration. Some of them are made in two models, one for screening and one for evidential BAC measuring.
The catalytic burner and the semiconductor do not react specifically to alcohol. With intensive use, all these portable instruments will require frequent recharging.
As instruments based on catalytic burning are still in the development stage, only two instruments will be discussed below, functioning on fuel-cell and semiconductor principles respectively.

A. Alcolmeter

The Alcolmeter (or Alco-Sensor) is probably one of the most advanced fuel-cell instruments and was originally developed as a simple pocket analyser. Later, several versions were developed with an improved sampling system and a different presentation of results. The fuel-cell itself was also improved, resulting in greater stability.

In 1973, SWOV made field tests with an Alcolmeter pocket instrument. The linear regression formula for BAC prediction from breath analysis was $\hat{y} = 0.97x + 21.8$; the linear correlation coefficient between breath and blood analyses was $r_{xy} = 0.905$ and the standard error of estimate was sd = 16 with 33 observations (see Table 2).

B. A.L.E.R.T.

The Alcohol Level Evaluation Road Tester A.L.E.R.T. is a semiconductor instrument with light-readout, indicating the zones Pass, Warn and Fail. The boundaries between the zones can be adjusted, for instance depending on the legal BAC level in a particular country.

Dubowski (1973) studied the A.L.E.R.T. with four subjects during the elimination phase; i.e. the alcohol had been totally assimilated by the body and breaking down had already started. Peaks of 200 mg/100 ml were reached. The instrument was set that the reading would be "Warn" at BAC's of 50 mg/100 ml or more and "Fail" at 100 mg/100 ml or more. 68 breath samples were taken. In 27 of them the BAC was below 80 mg/ 100 ml; there was not a single "Fail" reading, which means there were no false positives. Five tests readings were in the BAC range of 80 mg to 100 mg/100 ml; two were "Fail" and the other three "Warn". For the remaining 36 cases the BAC was above 110 mg/100 ml with all readings "Fail".

In Hennepin County, Minnesota, in 1974 a field test programme was carried out by Rosen et al. (1974). The results indicate that the tested models functioned accurately and reliable. They were set for the "Fail" reading at BAC levels of 110 mg/100 ml or more. The A.L.E.R.T. unit was employed in 898 cases of suspected drunken driving. 48% of the cases resulted in a "Fail", 33% in a "Warn" and 19% in a "Pass". Of the "Fail" cases, 81% were charged with driving while intoxicated. 298 "Fail" cases were submitted to evidential breath analysis; this showed 37 of the A.L.E.R.T. readings to be false positives, or about 12%.

In a limited study, Picton (1977) found a higher percentage of false positives: 24%. He states that screening device results cannot be expected to coincide with subsequent evidential breath analysis, especially when the actual BAC is near the level at which the screening device is set. The number of false positives could be reduced by setting the "Fail" limit on the instrument higher than the legal BAC limit, so increasing the number of "Warn" responses.

In The Netherlands SWOV made, at the request of the Forensic Laboratory of the Ministry of Justice, a limited number of observations with the A.L.E.R.T. The failures that occurred and the results obtained gave the impression that the instrument was not in optimum condition when supplied by the manufacturer (SWOV, 1975).

3.2. Evidential instruments

The U.S. Department of Transportation has drawn up a standard for evidential breath-analysing equipment.
The basic analysis techniques of the instruments developed are photometric colorimetry, infrared absorption photometry or gas chromatography. Among the electromechanical screening devices are some which can be used for evidential measurements.
Most of the instruments need an external power supply (a 12-Volt battery or the mains).

A. Alcolmeter

In 1975, SWOV made field tests with two Alcolmeter bench instruments (later called Alcolmeter evidential M2 instruments).
They work on the fuel-cell principle and are derived from the Alcolmeter pocket instrument discussed above. The results are given in Table 2. The findings with one of them are also given as a graph in Figure 2. The 46 observations with this instrument resulted in a linear regression formula $\hat{y} = 1.12x + 0.4$; a linear correlation coefficient $r_{xy} = 0.980$ and a standard error of estimate sd = 8.
At the Seventh International Conference on Alcohol, Drugs and Traffic Safety, Jones et al. (1977) reported on a new Alcolmeter evidential instrument with an improved fuel-cell resulting in greater stability. Its notable feature is that it can also analyse blood, urine and saliva.

At the same conference Forrester (1977) reported on the development of yet another new version based on the same fuel-cell. This instrument is fully programmed for checking calibration and zerosetting, taking three breath samples and checking their volume. The results of the three analyses are printed out in succession.

B. Breathalyzer

The first widely known evidential instrument was the Breathalyzer Model 900 based on photometric colorimetry. The alcohol in the breath reacts with a liquid reagent in which a colour reaction occurs. The degree of discoloration is determined with a photometric colorimeter and indicates the amount of alcohol. Harger (1974) reports fifteen studies about the accuracy of the Breathalyzer Model 900. In most of them the result obtained with this instrument was 8 to 15% lower than the actual BAC's; the results were hardly ever higher than the actual levels. The instrument had no automatic sampling control and was therefore useful only with co-operative subjects.

A recent adaptation of this model is the Breathalyzer Model 1000, which is almost fully automatic. The analysis technique is essentially the same as that of the Model 900. A complete breath analysis takes several minutes. A disadvantage is that ampoules of aggressive chemicals have to be used with them.

Although no detailed studies of the performance of the Model 1000 are known so far, it can be expected to be about as accurate as the Model 900. Dubowski (1975) presents a series of twenty blood-breath comparisons with ten subjects. But no statistical analysis was made nor are any conclusions drawn.

In SWOV research with one of the first available specimens of the Breathalyzer Model 1000 sampling was not entirely correct. After modification, resulting in expiration of 750 ml of air, the linear regression formula for BAC prediction was $\hat{y} = 0.88x + 15.8$ with a linear correlation coefficient $r_{xy} = 0.957$ and a standard error of estimate sd = 14 (See Table 2).

C. Intoxilyzer

The Intoxilyzer is a compact infrared spectrophotometer. It normally operates with a fixed blowing time and a minimum blowing pressure; this means a exhalation volume of about 2 litres to obtain a measurement. For high BAC's, however, this volume is not enough and leads to underestimation of the BAC. During SWOV's investigations when various Intoxilyzers were tested, each subject was therefore asked to continue blowing until the BAC reading did not increase any further.
Especially with high BAC's, the exhalation volume was up to 3 litres.
The results obtained with the Intoxilyzer are given in Table 2. Those obtained with the instrument tested in 1973 are given as a graph in Figure 3. For this instrument the linear regression formula was $\hat{y} = 1.16x - 6.6$ with a linear correlation coefficient $r_{xy} = 0.985$ and a standard error of estimate sd = 8. Table 3 shows per BAC category the extent to which the results with all Intoxilyzers tested in 1973 and 1975 differed from the actual BAC.
The Intoxilyzer has given the best results of all instruments tested by SWOV regarding their value for scientific purposes.

D. Gas Chromatograph Intoximeter GCI

Gas chromatography is a well-known but complex method of analysing organic compounds. The latest model of the GCI, the GCI Mark IV, however, is easy to operate. Experiments by Schmutte et al. (1972) showed that 45% of the results of breath analysis correlated with the results of blood analysis within 5% accuracy and 77% within 15%. In later studies by Morales (1974) with an improved type 34% showed a correlation within 5% accuracy and 90% within 15%.
In a study by Breen et al. (1975) the GCI averaged 13 mg/100 ml lower than the blood analyses, with a standard deviation of 14. The range of differences was from -68 mg/100 ml to +30 mg/100 ml; 91% of the GCI results were equal to or less than the actual BAC's. Table 4 shows per BAC category the mean deviation and the range of differences from the blood analyses. The 206 subjects in this study were probably suspected of driving while intoxicated. This can be inferred from the number of very high BAC's. The GCI can also be used in combination with a field collection kit, making subsequent laboratory analysis possible.

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FIGURES 1 - 3

Figure 1. Relation between BAC measured directly and length of discoloration (mm) for Alcotest 50 mg/100 ml tubes (n = number of observations; r = linear correlation coefficient). Source: Goldberg & Bonnichsen (1970).

Figure 2. Relation between BAC's measured directly and results of breath analysis with Alcolmeter bench instrument.

Figure 3. Relation between BAC's measured directly and results of breath analysis with Intoxilyzer tested by SWOV in 1973.

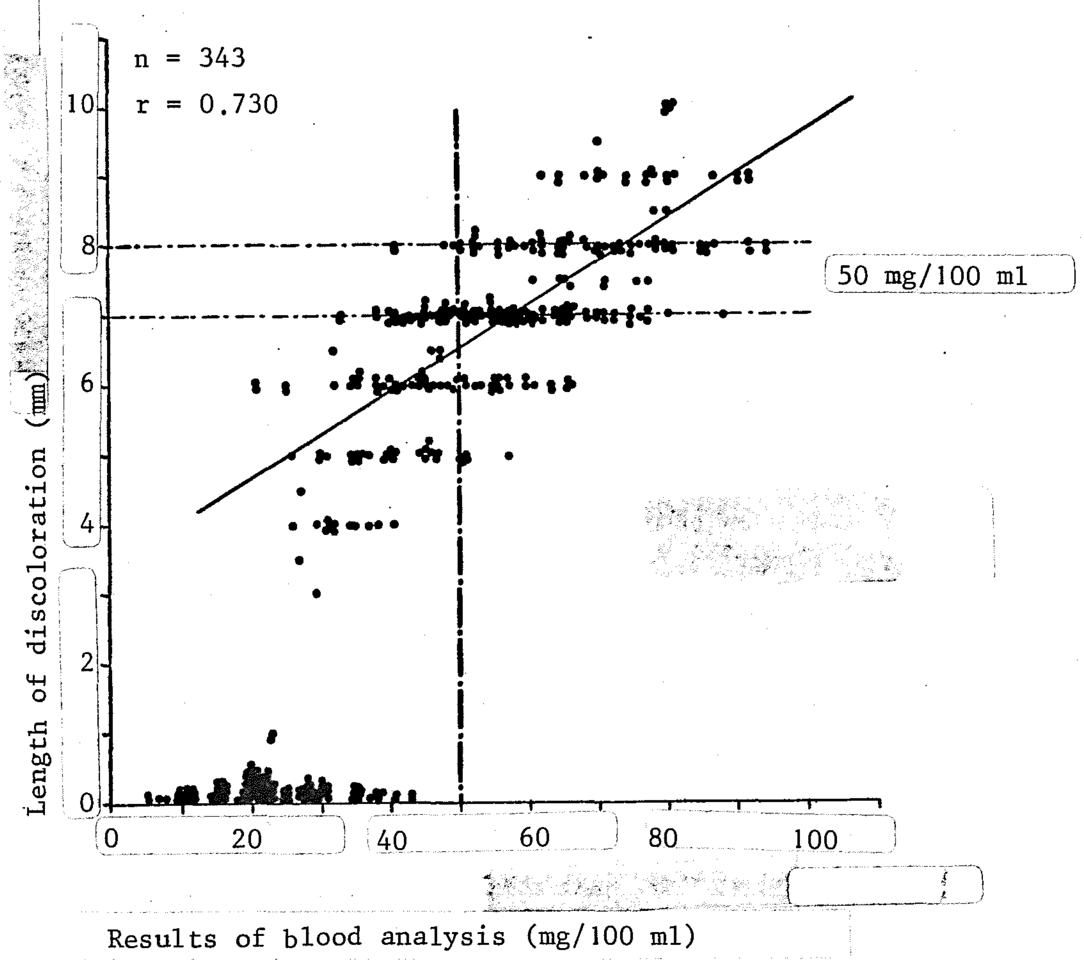

Figure 1. Relation between BAC measured directly and length of discoloration (mm) for Alcotest 50 mg/100 ml tubes (n = number of observations; r = linear correlation coefficient). Source: Goldberg & Bonnichsen (1970).

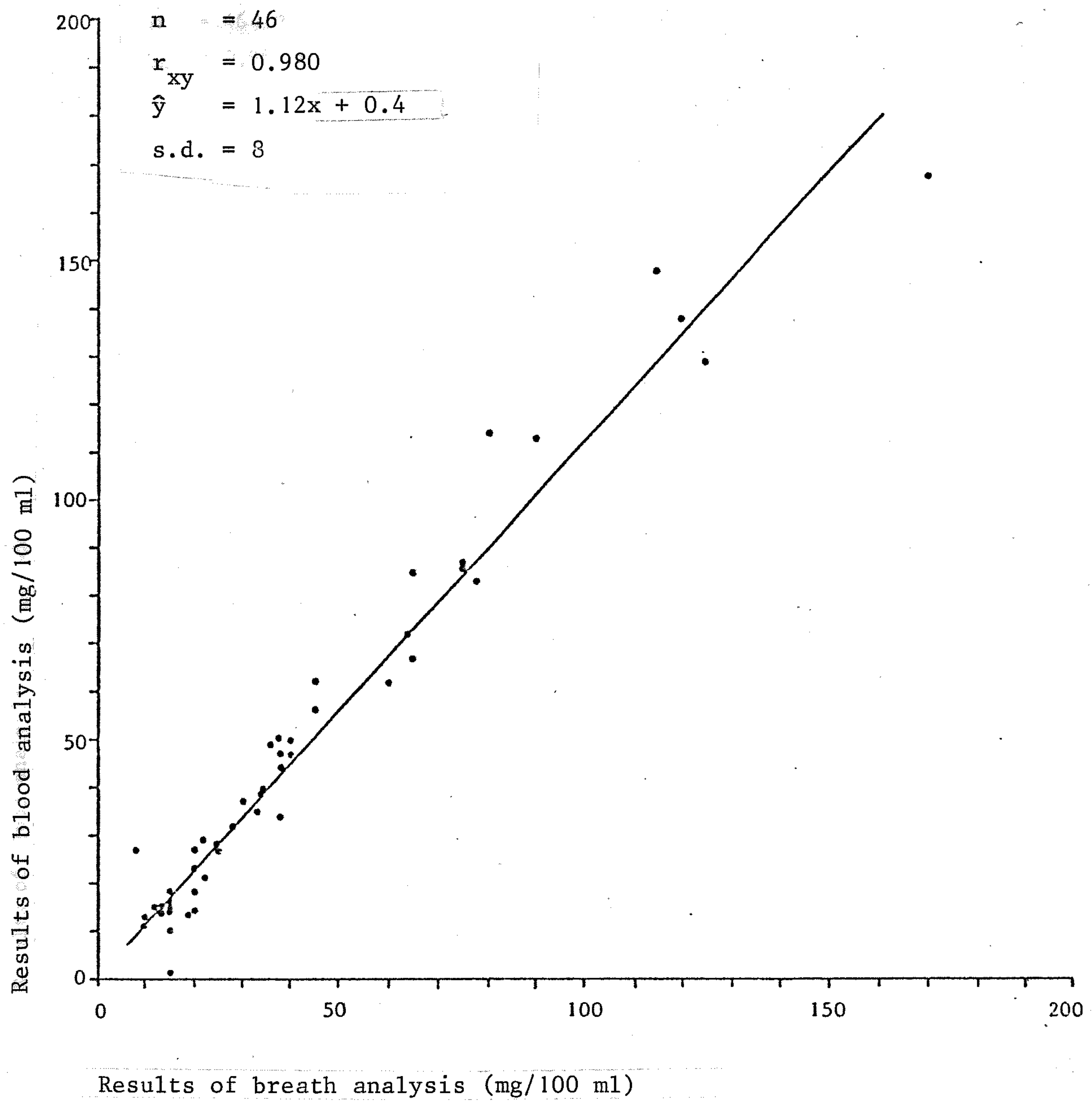

Figure 2. Relation between BAC's measured directly and results of breath analysis with Alcolmeter bench instrument.

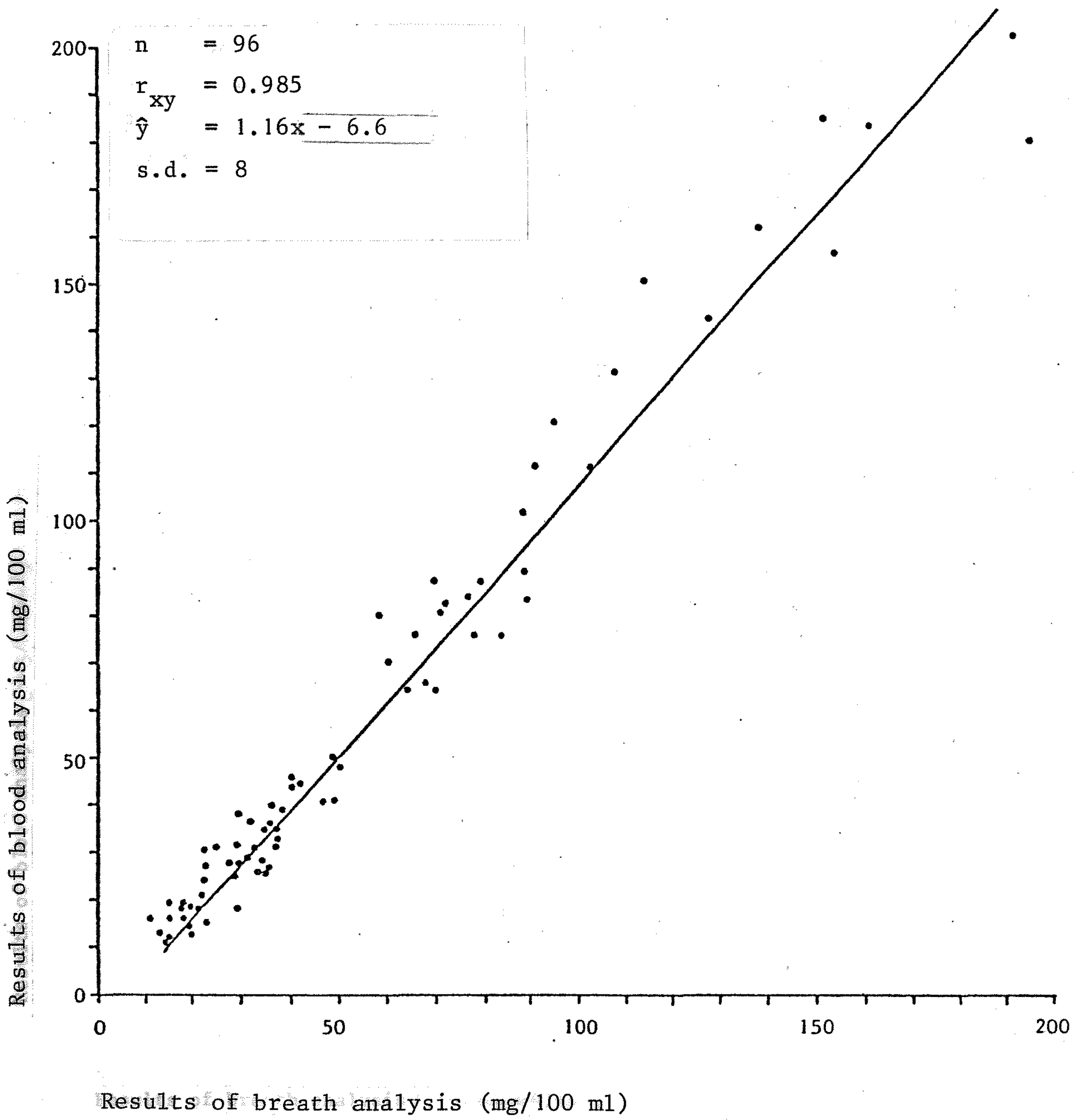

Figure 3. Relation between BAC's measured directly and results of breath analysis with Intoxilyzer tested by SWOV in 1973.

TABLES 1 - 4

Table 1. Breath-analysis apparatus, and their characteristics; classified by year of testing in SWOV roadside surveys.

Table 2. Precision per instrument of breath tests (r_{xx}), accuracy of predicted BAC (r_{xy}), linear regression formula ($\hat{y}$), standard error of estimate (sd) and number of observations (n) in SWOV roadside surveys.

Table 3. Deviations in BAC results with four Intoxilyzers (tested by SWOV in 1973 and 1975) compared with actual levels (n = number of observations).

Table 4. Deviations in BAC results with GCI compared with actual levels (n = number of observations). (Source: Breen et al. (1975).

Instrument	Year	Basic analysis technique	Total volume exhaled	Sample	Check	Number
- Breathalyzer 900	1968	photometric colorimetry	variable	last 52.5 ml	by operator	2
- Ethanographe	1968	photometric colorimetry	variable	last 52.5 ml	by operator	2
- Alcolinger Automatic 1st version [1)]	1970	photometric colorimetry	min. 750 ml	last 52.5 ml	automatic	8
- Alcolinger Automatic 2nd version	1971	photometric colorimetry	min. 500 ml	last 52.5 ml	automatic	8
- Kitagawa-Wright	1971	chemical	max. 750 ml	last 100 ml	automatic	2
ditto if defective			1000 ml			
- Alco-Limiter 1)	1973	fuel-cell	ave. 950 ml	last 20 ml	automatic	3
- Alcolmeter bench instrument	1973/75	fuel-cell	ave. 2000 ml	last 1.5 ml	by operator	3
- Alcolmeter pocket instrument	1973	fuel-cell	ave. 2000 ml	last 1.5 ml	by operator	1
- Alcohol Screening Device	1973	fuel-cell	min. 2500 ml	during blowing	automatic	3
- Breathalyzer 1000 1)	1973	photometric colorimetry	min. 750 ml	last 52.5 ml	automatic	1
- Intoxilyzer 2)	1973/75	infrared absorption	min. 2000 ml	last 600 ml	automatic	4
- Aldet	1975	catalytic burning	variable	last 20 ml	automatic	1
- A.L.E.R.T.	1975	semiconductor	650-1500 ml	during blowing	automatic	3

[1)] The stated total volume of air was reached only after modifying the instrument.

[2)] Operating instructions were not followed; the operator ensured that the maximum reading was reached per subject. The average volume exhaled was therefore greater than 2000 ml.

Table 1. Breath-analysis apparatus, and their characteristics; classified by year of testing in SWOV roadside surveys.

Instrument	Year	r_{xx}	r_{xy}	$\hat{y}$ (mg/100 ml)	sd (mg/100 ml)	n
- Ethanographe	1968	-	0.978	1.35x - 9.5	9	39
- Alcolinger Automatic 1st version	1970	0.979	0.959	1.30x - 11.5	12	113
- Alcolinger Automatic 2nd version	1971	0.975	0.876	1.32x + 0.0	23	253
ditto excluding extremes	1971	-	0.933	1.40x - 5.0	17	245
- Kitagawa-Wright	1971	0.974	0.865	1.64x - 2.7	22	35
ditto if defective	1971	0.954	0.949	1.01x + 4.2	11	21
- Alco-Limiter	1973	0.977	0.969	1.35x - 8.5	9	132
- Alcolmeter bench instrument	1973	0.932	0.958	1.22x - 0.8	12	70
- Alcolmeter bench instrument 106	1975	-	0.962	1.22x - 3.3	10.8	49
- Alcolmeter bench instrument 122	1975	-	0.980	1.12x + 0.4	8	46
- Alcolmeter pocket instrument	1973	-	0.905	0.97x + 21.8	16	33
- Alcohol Screening Device	1973	0.947	0.974	1.34x - 9.5	9	123
- Breathalyzer 1000	1973	0.987	0.957	0.88x + 15.8	14	25
- Intoxilyzer	1973	0.991	0.985	1.16x - 6.6	8	96
- Intoxilyzer 5	1975	-	0.994	1.13x - 8.6	3.5	47
- Intoxilyzer 101	1975	-	0.986	1.07x - 5.5	7.5	92
- Intoxilyzer 1102	1975	-	0.981	1.05x - 5.1	6.2	52
- A.L.E.R.T.	1975	-	0.862	0.66x + 20.3	19.7	38

Table 2. Precision per instrument of breath tests (r_{xx}), accuracy of predicted BAC (r_{xy}), linear regression formula ($\hat{y}$), standard error of estimate (sd) and number of observations (n) classified by year of testing in SWOV roadside surveys.

BAC category (mg/100 ml)	n	mean deviation	range of differences	standard error of estimate
20 - 49	97	+ 2	-19 — +12	5
50 - 79	34	- 1	-15 — + 9	6
80 - 99	23	- 4	-22 — +10	8
100 - 149	27	- 5	-27 — +14	10

Table 3. Deviations in BAC results with four Intoxilyzers (tested by SWOV in 1973 and 1975) compared with actual levels (n = number of observations).

BAC category (mg/100 ml)	n	mean deviation	range of differences	standard deviation
32 - 99	13	- 8	-20 — + 4	6
100 - 149	47	-11	-32 — +11	9
150 - 199	82	-11	-38 — +30	13
200 - 249	45	-17	-54 — +30	17
250 - 299	15	-25	-68 — + 7	21
300 - 322	4	-29	-42 — - 8	14

Table 4. Deviations in BAC results with GCI compared with actual levels (n = number of observations). (Source: Breen et al. (1975).