BREATH TESTING

Contribution to OECD Research Group S14
New Research on Alcohol and Drugs

2nd draft

R-77-4

P.C. Noordzij and J.A.G. Mulder

Voorburg, June 1977

Institute for Road Safety Research SWOV, The Netherlands

CONTENTS

Introduction

For research purposes the blood alcohol content (b.a.c.) as a measure of alcohol use has physiological as well as methodological and other practical advantages.
Laboratory and field studies have shown a relation between b.a.c. and performance or accident risk. These findings justify in turn the use of b.a.c. as an element in traffic safety countermeasures.

Compared to blood analysis there are practical advantages in breath testing. There are even some physiological considerations in favor of breath testing. On the other hand all kinds of reasons are conceivable leading to inaccurate results when breath testing is routinely used. Repeatedly it has been shown that the correspondence between b.a.c. from breath, resp. bloodtesting left to be desired. Blood analysis, however, has been accepted for long times.

A historical review and a description of the present state of the art is given by Dubowski (1975). Harger (1974) discusses in detail the blood-breath comparison studies. Both articles show that further improvements are possible and to be expected in the future.
The application of breath analysis is governed by requirements to be met by a measuring instrument in a certain situation on the one hand and the capabilities and limitations of existing apparatus on the other hand. With the present technological state of affairs and experiences in most situations a compromise will have to be made between requirements and possibilities. In seemingly similar situations such a compromise may lead to different outcomes. In Europe for instance the interest in the use of breath testing for police purposes is mostly restricted to chemical test tubes, whereas in North America better screening instruments are required and at the same time evidential breath testers are in use.

The aim of this contribution is to review the available instruments together with a rough evaluation and to present some general background information.

General Description

The further design of a breath testing instrument is to a certain extent influenced by the chosen principle of analysis influences. Mainly (wet or dry) chemical analysis was used. Today the following principles are in use: gaschromatography, infrared absorption, fuel cell, catalytic burning and semi conducting.
Each of these principles have their own specificity, sensitivity, stability, constructional details, operation and maintenance requirements etc. The further design of an instrument refers to a.o. sampling arrangement, presentation of results, built-in checks and automated operation, power supply.

Remaining problems center around sampling arrangements and the transformation of breath alcohol content to b.a.c. Both issues are closely related. Earlier it was assumed that a few seconds of blowing or the discard of ca. 500 cc of breath was a sufficient condition for obtaining a breath sample with constant alcohol content. Several studies have shown larger discard volumes to give more accurate b.a.c. determinations. Recent investigations by Jones e.a. (1975) and Flores (1975) indicate that in order to obtain a constant breath alcohol content a fixed volume of air has to be rebreathed several times or the breath has to be kept for some time.
Jones e.a. (1975) assume that only under such conditions a complete equilibration of alcohol between breath and blood as well as between breath and the mucus of the upper respiratory track is obtained.

The presently available instrument have various arrangements to obtain a sample of deep lung breath after a single expiration:
- operator observation (possibly aided by visual or audible indication of blowing pressure or volume);
- analysis of a total volume of mixed tidal and deep lung air (1 l e.g.);
- automatic sampling after discard of a fixed volume (of say 500 cc or 2 l);

- automatic sampling after a fixed timeperiod of blowing with a minimal blowing pressure (corresponding with a minimal discard volume of 500 cc or 1 l);
- operator monitoring of the rate of change of the alcohol concentration during exhalation.

Attempts to correct the results on basis of a measurement of CO_2 content have been abandoned. Dubowski (1975) concludes that on the average the discard volume should be more than 2.5 l and further suggests simultaneous temperature measurement, a suggestion that has also been made by Wright (1975).

The ratio between alcohol content in breath and blood that is widely used for calculating a b.a.c. from breath analysis is 1:2100. This is a theoretical value which, with present breath sampling arrangements, leads on the average to b.a.c. values that are too low.

Research activities

Research in the field of breath analysis may cover different areas such as technical development work, basic physiological research or evaluation of available instruments. The latter area is of particular interest to prospective users. This in fact relates to a series of research activities:

- general inspection of the instrument. Only simple measurements have to be obtained. Various aspects to be covered include: operation and maintenance instructions, sampling arrangement (volume, time, pressure, temperature), presentation of results, power supply, size, weight, costs, possible failures (as far as can be inferred from the construction).
- research into precision of measurement over a range of b.a.c. values, stability of calibration, influence of factors such as temperature, humidity, vibration, instability of the power supply, air pressure etc.
- laboratory comparison of blood and breath tests with special interest in the effect of e.g. characteristics of test persons, blowing techniques.
- field comparison of blood and breath tests.

The list of aspects to be inspected or tested may be adjusted to the particulars of the instrument and the field of application.

When comparing blood and breath tests a number of things has to be observed. Shortly after alcohol consumption differences may arise from mouth-alcohol, belching or incomplete equilibration of alcohol over body parts. The time between blood and breath sampling should be as short as possible. Errors or variation of results in blood analysis are not necessarily excluded. Rather than a comparison with blood tests the breath tests may be compared to carefully determined alcohol content of rebreathed air. The range of b.a.c. values included in the study may influence the outcome of statistical calculations thus giving a wrong impression in case the b.a.c. range in actual use is quite different.

Remarkable differences can be found among studies with regard to statistical processing, presentation and interpretation of results.
Laboratory tests may closely simulate the actual operational situation with regard to conditions, test subjects and operator characteristics. However, only a field test will enable a complete evaluation of an instrument because unexpected instrument failures, factors affecting the results or other problems may arise.
Field tests of instruments for police purposes present a methodological problem if information is restricted to subjects who are suspected of drunken driving. Persons with positive b.a.c. who are not suspected (possibly on the basis of a screening breath test) are not included in such a study. Moreover the results of blood testing may have been corrected before comparing them with the results of the breath test.

The main purpose of a field-investigation is the comparison of blood and breath testing. Once the results have proved to be satisfactory attention may focus on the effectiveness of (countermeasure) activities where breath testing is applied.

In the United States stringent requirements are drawn up in order to make it possible to strimulate the development of more accurate breath testing instruments. The National Highway Traffic Safety Administration examines the testers on the basis of these requirements.
However when the analysers meet all the performance requirements in the laboratory in practice some problems may occur with accuracy and technical reliability.

Fields of application

Breath analysis is mainly in use for police and research purposes. For police purposes it is customary to differentiate between portable screening or qualitative devices on the one hand and evidential or quantitative devices on the other hand.
A relatively new special type of screening test is the passive breath tester. Remote collection devices form a subclass of quantitative devices. For research purposes the requirements as far as performance is concerned are roughly similar with those for evidential devices. A recent application is formed by the breath self testers. These usually coin operated, public accessible analyzers are developed for use in commercial drinking establishments etc. This concept raises some fundamental questions about the desired accuracy, reliability of results and to what an extent such a device should be "foolproof".
A relatively new special type of screening test is the passive breath tester which is now under development.
Some attempts have been made to develop starter interlock systems which installed us a part of an automobile ignition system preclude operation by the intoxicated driver.

Requirements for breath testers are largely dictated by operational conditions, characteristics of test subjects and the kind of decision to be taken on basis of the test results.
Broadly taken operational conditions include things like:
- location of testing and in close relation to this: temperature, humidity, lighting, power supply, transport.
- qualifications of operators.
- number of tests to be performed during a certain time period.
- acceptable time and effort per test.
- available funds.

Possibly relevant characteristics of test subjects are: range of b.a.c. values, fysical condition which to a certain extent is indicated by age and sex, illness, physical handicaps or injuries, willingness of the test subjects to cooperate.

The kinds of decision to be taken on basis of the test results may vary between:

- b.a.c. definitely above a certain level (accepting a number of cases that go unnoticed).
- b.a.c. definitely below a certain level (idem).
- b.a.c. most certainly within a certain b.a.c. range.
- most accurate determination of b.a.c.

It has been noted before in the introduction that requirements may have to be weakened because of the technological state of affairs, specially in situations where the need for an easy and quick determination of b.a.c. (or quick sampling) is urgent.

LITERATURE

Dubowski, K.M. (1975). Recent Developments in Breath-alcohol Analysis. In: Israelstam, S. & Lambert, S. (eds.), 1975.

Flores, A.L. (1975). Rebreathed air as a reference for breath-alcohol testers. Interim report DOT-TSC-NHTSA-74-4. U.S. Department of Transportation, Washington, D.C., 1975.

Harger, R.N. (1974). Recently published analytical methods for determining alcohol in body materials - Alcohol Countermeasures Literature Review. Report DOT HS-801 242. U.S. Department of Transportation, Washington, D.C., 1974.

Israelstam, S. & Lambert, S. (eds.) (1975). Alcohol, Drugs and Traffic Safety. Proceedings of the Sixth International Conference on Alcohol, Drugs and Traffic Safety, Toronto, September 8-13, 1974. Addiction Research Foundation of Ontario, Toronto, 1975.

Jones, A.W. et al. (1975). A Historical and Experimental Study of the Breath/Blood Alcohol Ratio. In: Israelstam, S. & Lambert, S. (eds.), 1975.

Wright, B.M., Jones, T.P., Jones, A.W. (1975). Breath Alcohol Analysis and the blood breath ratio. Med. Sci. Law (1975), Vol 15, No 3, pp 205-210.

Review of current breath analysing equipment

In the appendix a list is given of current breath testting devices together with the literature on these devices. A discussion on some of the more prominent instruments of the screening and evidential type is given below.

1. Screening breath testers

In respect of the screening breath testers nowadays two basic designs are availaible and in use: disposable chemical test tubes and reusable electromechanical devices.
Evaluating these instruments the two types of error which can occur are important:
the false positive reading- the subject is accused to possess a higher BAC than his actual blood alcohol concentration - and the false negative result when the subject possesses a higher actual BAC than the result of the test showed it to be.

1.1 Disposable screening devices

The disposable chemical reagent screening devices are all similar in design and operation. Each is comprised of a small glass tube containing an alcohol sensitive reagent and a breath volume measurement device (either a rubber balloon, plastic bag or air pump).
Two important studies in which chemical test tubes were tested are those of Goldberg and Bonnichsen (1970) and Prouty and O'Neill (1971).

1.1.1 Goldberg and Bonnichsen studied .5 and .8 $^{o}/oo$ Alcotest tubes with regard to various factors such as rate of breath flow, volume variations and sensitivity to other substances than ethylalcohol.
The Alcotest (fig.1) is used for many years by the police in a number of European countries.
The results of a series of blood and breath tests for the .5 $^{o}/oo$ tubes are compiled in fig.2. As can be seen from this figure, there is a number of measurements which gave no discoloration with actual BAC's up to .5 $^{o}/oo$. In general there is a weak relation between the length of the discoloration and the BAC (r = .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.
In this case there are hardly any false positives against a considerable number of false negatives.

1.1.2 Prouty and O'Neill conducted a study on several devices such as Alcolyser, Sober-Meter, Kitagawa Drunk-O-Tester and Becton-Dickinson devices(fig. 3).
With the exception of the Becton-Dickinson devices which showed a narrow range in which erroneous results were obtained (fig.4) and the Kitagawa Drunk-O-Tester which produced a great number of false negatives and only a small number of false positive results, all other devices produced erroneous results in practically all ranges of BAC which were tested.

It can be concluded that in theory the sensitivity of the chemical test tubes is sufficient for a screening test. Improvements in the design of the tubes and the sampling system are expected to give better results.

1.2 Reusable electromechanical devices

Since the American Department of Transportation some years ago took the decision not to approve tube type screening tests, research was carried out to develop a more accurate instrument type test on the basis of several stringent requirements. This resulted in a limited number of instruments meeting the required criteria.
The recently developed portable self-containing instruments operate with various alcohol sensors such as fuel-cells, catalytic burners, and semi-conductors.
The chemo-electric fuel-cell generates a measurable electric current from the catalytic oxidation of alcohol in the breath, which is directly proportional to the amount of alcohol.
The catalytic burner "burns" alcohol at a small catalytically active element. A change in temperature from this burning induces a change in resistance, which is proportional to the amount of alcohol.

The solid state semi-conductor measures alcohol through the change in surface resistivity with the absorption of alcohol on a transition metal oxide sensor.
The equivalent BAC can be displayed on those instruments either by meter, light or digital readouts.
Fuel-cell instruments require frequent calibration because of a certain instability of the sensor. Some fuel-cell devices are developed in two modes: one for screening purposes and another for the quantitative measurement of the BAC.
The catalytic burner and semi-conducter types are less specific for the determination of alcohol.
With intensive use all these instruments require frequent recharching.

1.2.1 Alcolmeter

The instrument known as Alcolmeter or Alco-Sensor is probably one of the most advanced fuel-cell devices and is originally developed as a simple pocket analyzer (fig.5). Later several versions of this instrument were developed with improved sampling system, different presentation of results and in the meantime the sensor itself was improved, resulting in a greater stability.
Harger (1974) indicates some studies in which the Alco-Sensor was evaluated. Jacobs and Goodson (unpublished) found in the BAC range of 1.12 - 1.32 $^{o}/oo$ with four instruments 18% of false negative readings with only one instrument giving no false readings.
Bailey (unpublished) observed no Alco-Sensor readings of above 1 $^{o}/oo$ where the actual BAC was .8 $^{o}/oo$ or below. With blood-breath pairs where the BAC was close to 1.2 $^{o}/oo$, 10% of the Alco-Sensor readings was below 1 $^{o}/oo$.
Presumably in both studies the instruments were calibrated on 1.0 $^{o}/oo$.

An analogue type of the Alcolmeter pocket screen test was tested in the setting of a road side survey reported by Noordzij (1975).The regression formula for predicting the BAC from the breath test result was found to be $y = .97\,x + .22$ with a correlation coefficient of .905 and a standard error of estimate of .16 $^{o}/oo$ on 33 observations.
Two Alcolmeter evidential M2 instruments were tested under the same circumstances in 1975 (unpublished). The results of one instrument are given in fig.6.

46 observations were made, resulting in a regression formula $y = 1.12x + .04$, a correlation coefficient of .980 and a standard error of estimate of .08°/oo.

1.2.2 Alcohol Screening Device

This fuel-cell instrument is developed under contract for the U.S. Department of Transportation / National Highway Traffic Safety Administration (fig.7).
Harger(1974) presents the results provided by Harriot (unpublished) with the ASD. The results were compared with breath tests using the Gas Chromatograph Intoximeter GCI. 474 observations were made; 5% false positives were found in the BAC range .9 - 1.0°/oo and 37% false negatives in the range 1.0 - 1.1°/oo, with unit calibrated on 1.0°/oo.
The ASD with digital readout was tested by Alha et al(1975) and Noordzij(1975).
Alha et al made their observations in cases of suspected drunken driving and found good results in comparison of blood and breath samples if the BAC was below 1.5°/oo. At higher levels however the ASD showed too low results in most cases.
The results of the field study of Noordzij indicated that the measured BAC by breath was substantially lower over the whole range of actual BAC's (fig.8).
Further field tests with the ASD are underway in several American states.

1.2.3 A.L.E.R.T.

The Alcohol Level Evaluation Road Tester A.L.E.R.T. is a semi-conductor device provided with light-readout,indicating the zones Pass, Warn and Fail(fig.9).
Dubowski (1973) studied the A.L.E.R.T. during the elimination phase of four subjects reaching peak values of 2°/oo.
68 tests were performed. In 27 of them the BAC was below 0.8°/oo with no A.L.E.R.T. test above 1.0°/oo (FAIL) which means no false positives. Five tests were in the BAC range of 0,8 to 1.1°/oo, two of the A.L.E.R.T. readings were FAIL and WARN for the other three For the remaining 36 tests the BAC was above 1,1°/oo with all A.L.E.R.T. readings FAIL.

In Hennepin County Minnesota (1974) a field test program was carried out The results of this study indicate that the tested models functioned accurately and dependably. The A.L.E.R.T. unit was employed in 898 cases of suspected drunken driving. (Rosen et al. 1974)
48% of the tests resulted in a fail (units calibrated on 1.1°/oo), 33% in a warn and 19% in a pass. Of the fail cases 81% were charged with DWI. 298 fail cases were submitted to an evidentiary test which resulted in 37 false positives i.e. failing the screening test but passing the evidential test with a b.a.c. reading less than 1°/oo.
In a limited study Picton (1977) concluded to a higher percentage of 24% false positive readings. He states that screening device results cannot be expected to coincide with subsequent evidential tests especially when the actual b.a.c. is near the level at which the screening device is set. A possibility to decrease the number of false positive readings is to calibrate on a higher level than the legal limit, so increasing the number of "warn" responses.

2. Evidential breath testers

The U.S. Department of Transportation has drawn up a standard for evidential breath testing equipment.
The basic techniques for alcohol detection and quantitation used in evidential breath testers are photometric colorimetry, infrared absorption photometry and gas chromatography. Among the electro-mechanical screening testers there are some which can be used for the quantitative determination of alcohol. At the Seventh International Conference on Alcohol, Drugs and Traffic Safety, Jones et al (1977) reported about a new Alcolmeter evidential instrument. An improved fuel-cell was used resulting in greater stability. Remarkable is the possibility to analyze with this instrument liquids like blood, urine and saliva.
At the same conference, Forrester(1977) reported about the development of another version using the same cell.(fig.10). This instrument is equipped with a complete program for calibration control, air blank and three breath tests and a volume control for the breath sample. The results are printed out.
Most of the evidential instruments need external power supply, either 12 Volts DC or connection to the mains.

2.1 Breathalyzer

The first widely known breath analyser was the Breathalyzer model 900, incorporating colorimetric determination of a discoloration caused by the oxidizing of alcohol in liquid chemicals (fig.11). Harger (1974) reports 15 studies about its accuracy. In most of them the result obtained with the Breathalyzer was lower than the actual BAC by averages ranging from about 8% - 15% and almost never giving erroneously high results.
The instrument has no automatic sampling control and is therefore most useful with cooperative subjects.
A recent adaptation of this model is the Breathalyzer model 1000, fig. 12 which has an almost fully automatic operation. The actual analytical procedure is essentially the same as that of the model 900. A complete test-run takes several minutes. A disadvantage of this type of instrument is the handling of the ampoules with agressive chemicals.
Although as yet no detailed studies about the performance of the model 1000 are known, one would expect that precision and accuracy of the model 1000 are about the same as that of the model 900. Dubowski (1975) presents a series of twenty blood-breath comparisons on ten subjects. No statistical analysis was performed and no conclusions were drawn.

2.2. Intoxilyzer

The Intoxilyzer is a compact infrared spectrophotometer (fig. 13). Harte (1971) describes construction and operation of the Intoxilyzer and gives three scatter diagrams which relate the breath test results with those from simultaneously obtained blood samples, for three subjects and twelve blood-breath pairs. Harger (1974) estimates from these diagrams that the deviation between Intoxilyzer and blood analysis results ranges from +2% to -11% with an arithmetic mean of -3.2%.
The Intoxilyzer normally operates with a fixed blowing time and a minimum blowing pressure, corresponding to a minimum discard volume of approximately 2 litres in order to operate the instrument. For higher BAC's underestimation of the BAC can occur because of this. The study of Noordzij (1975) contains information on 96 subjects

tested on the Intoxilyzer. In contrast to normal operation, each subject was asked to continue blowing until the operator observed the maximum BAC-reading. Particularly for high BAC's the results were obtained with discard volumes up to 3 litres.
The correlation coefficient of the breath test results and the subsequent blood analyses was .985, the linear regression formula $y = 1.16x - .066$, the standard error of estimate .08‰. In this study the correlation coefficient of results of blood samples from both arms was .995 with an standard deviation of .05‰. (fig. 14)

2.3 Gas Chromatograph Intoximeter GCI

Gas chromatography is a well known but complex analytic technique for organic compounds. The latest model of the GC-Intoximeter, the GCI Mark IV looks like a very simple instrument (fig. 15).
An evaluation carried out by Schmutte et al (1972) showed a breath-blood correlation of 45% within 5% accuracy and 82% within 15% accuracy, leaving 23% beyond. The estimated arithmetic mean of blood-breath deviation was -4.4%.
Harger (1974) reports that later studies of Morales (1974) with an improved type showed 34% within 5% accuracy and 90% within 15% accuracy, which indicates that the GCI is capable of yielding a better estimation of the BAC than was found by Schmutte et al.
In a study of Breen et al (1975) the GCI averaged .013 g/100 ml lower than a direct blood analysis with a standard deviation of .014. The range of errors was from -.068 to +.030 g/100 ml, with 91% of the results showing a GCI-result equal to, or less than, its corresponding BAL (fig. 16). Presumably the 206 subjects in this study were suspected drunken drivers.
The GCI can also be used in combination with a field collection kit.

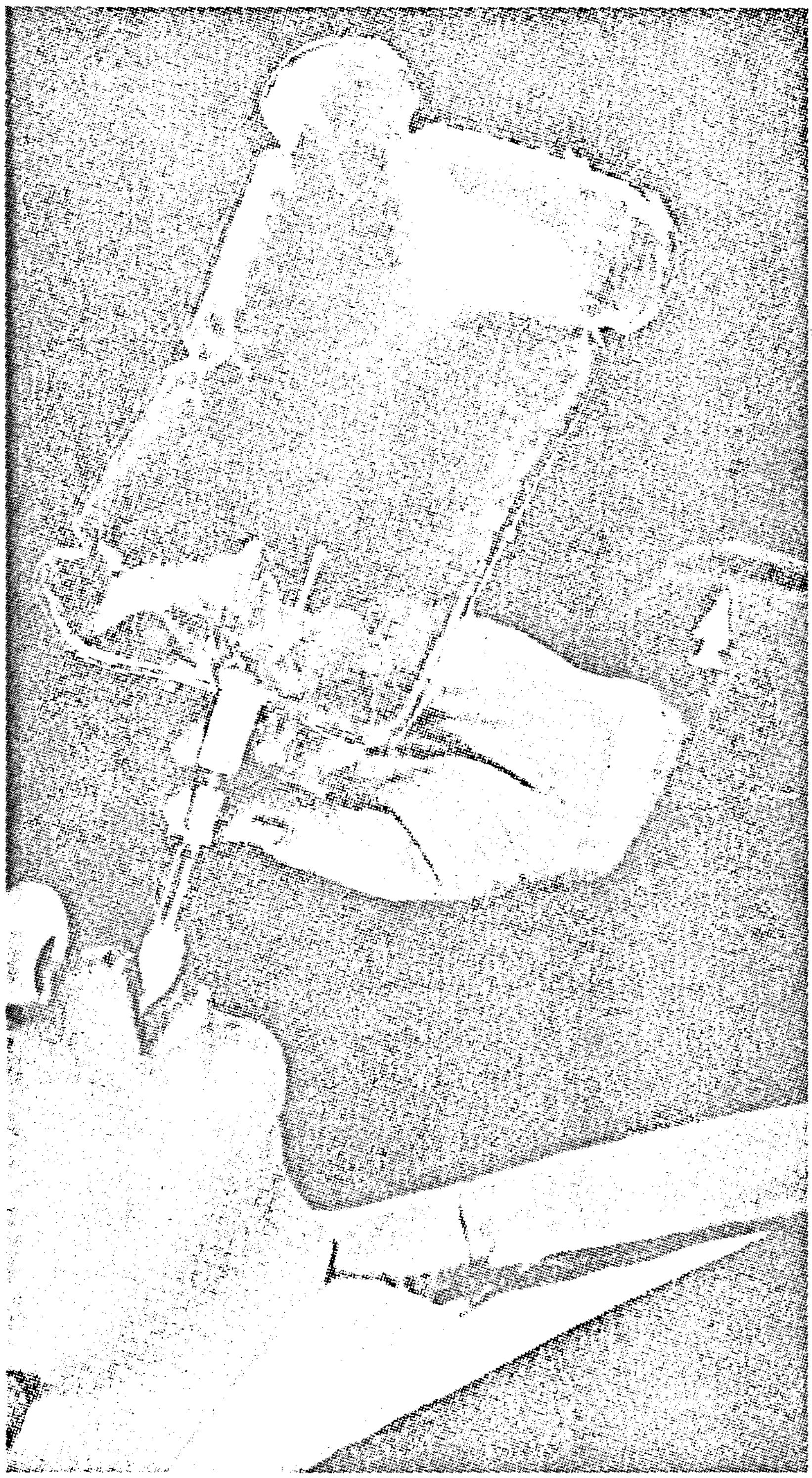


Fig. 1. Alcotest screening test tube.

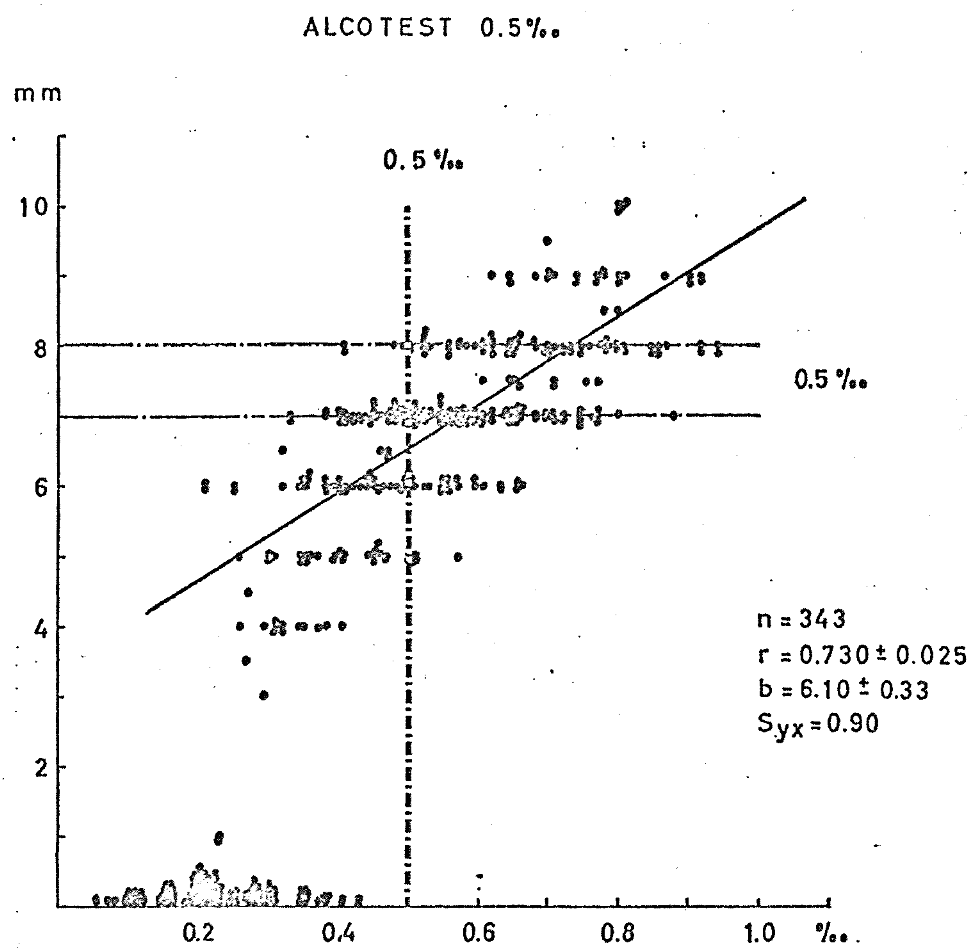


Fig. 2. Relation between BAC and length of discoloration for Alcotest .5^{o}/oo tubes.

Source: Goldberg, L. & Bonnichsen, R. (1970).

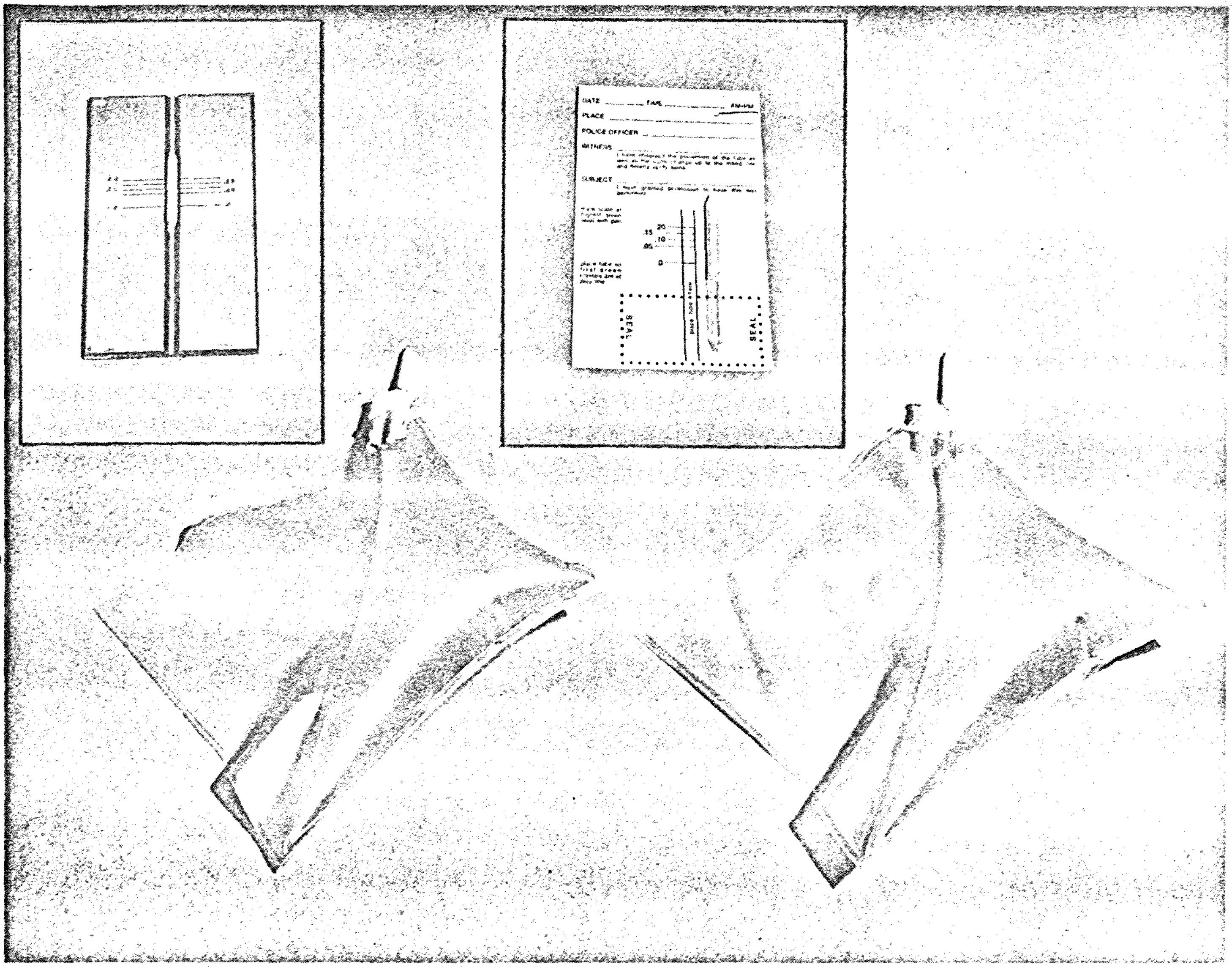


Fig. 3. Becton-Dickinson screening test tubes.

Source: Prouty, R.W. & O'Neill, B. (1971).

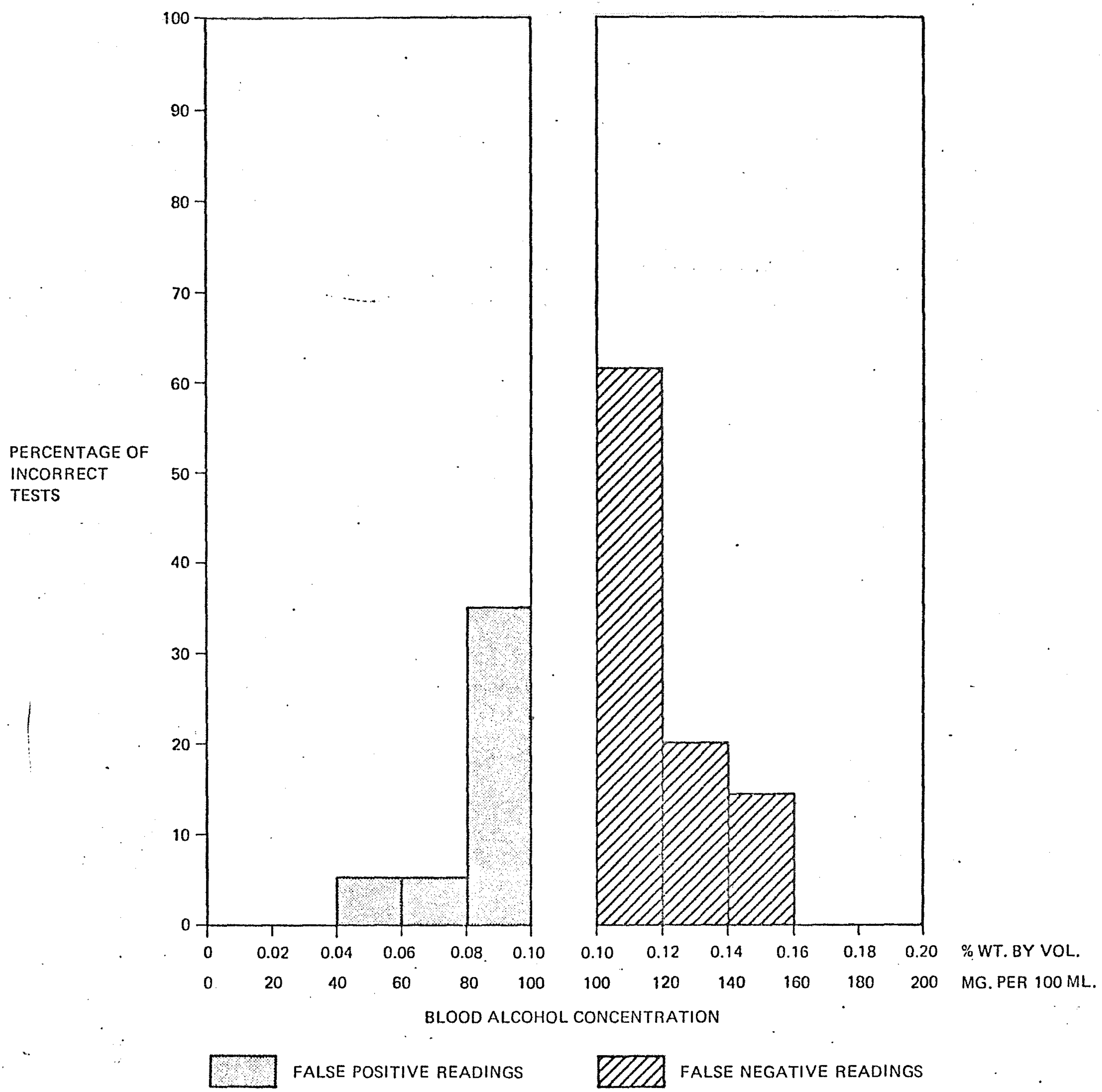


Fig. 4. Relation between BAC and percentage of incorrect tests for Becton-Dickinson device 1.

Source: Prouty, R.W. & O'Neill, B. (1971).

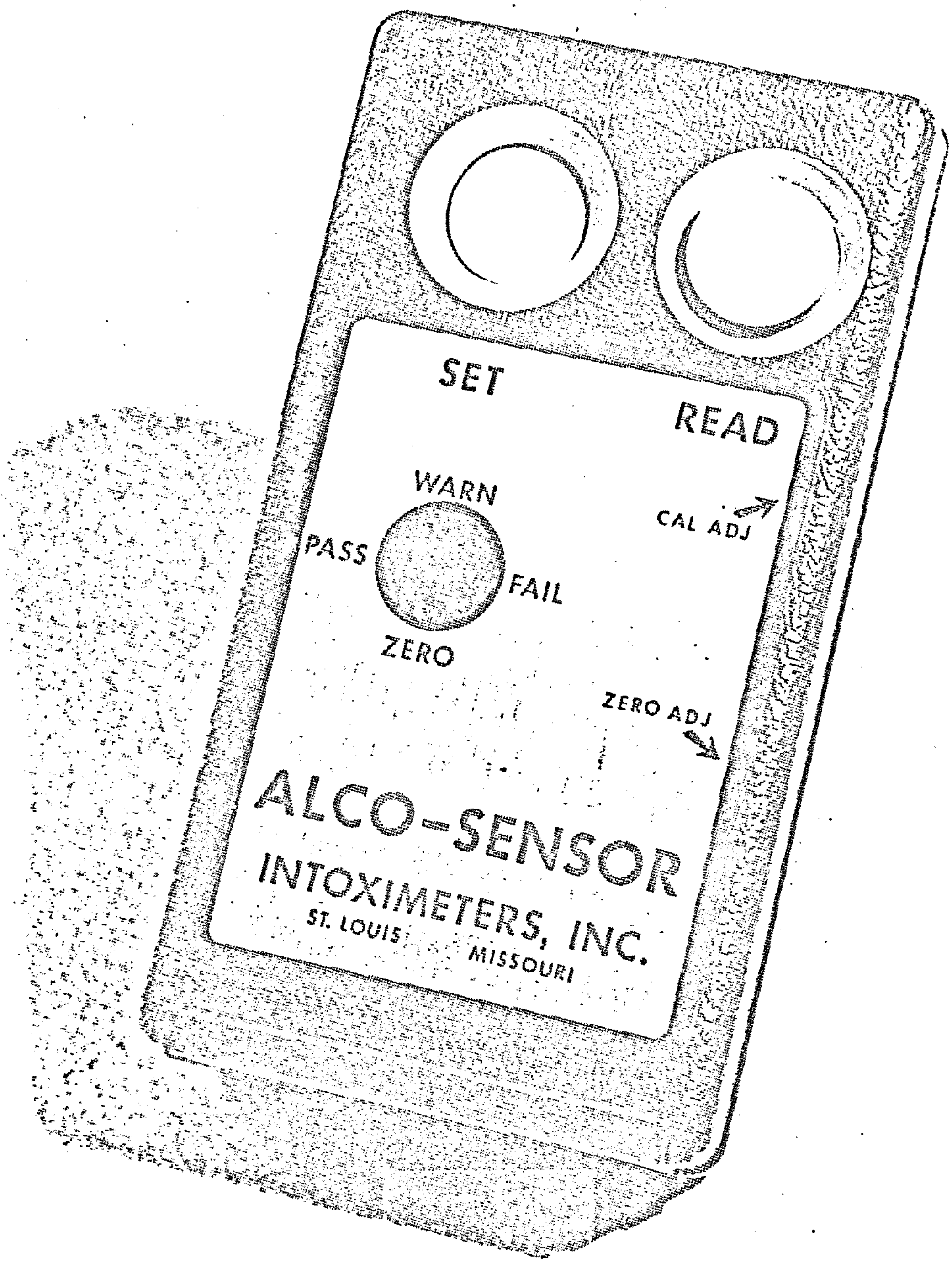


Fig. 5. Alco-Sensor (Alcolmeter provided with meter read out).

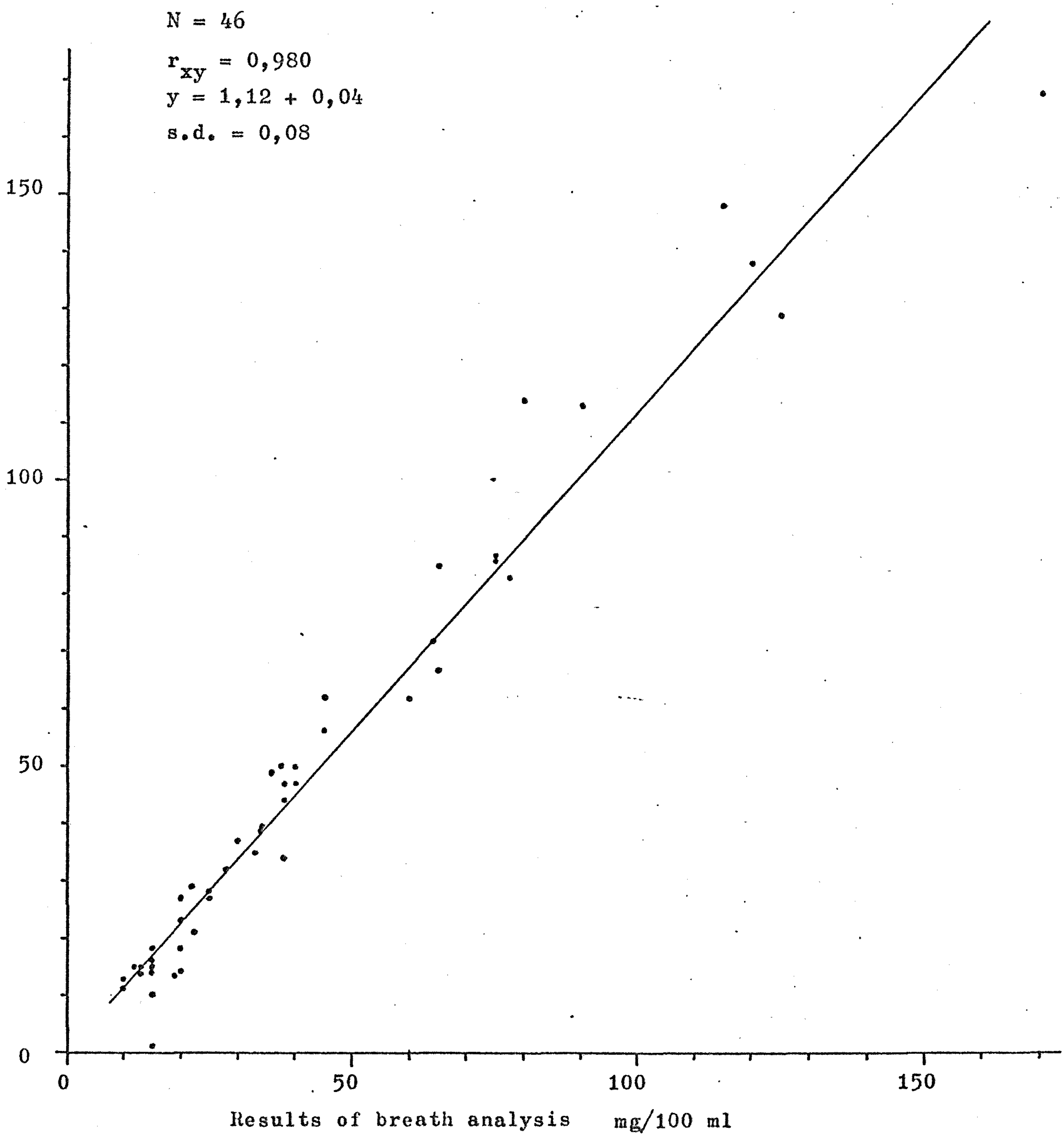


Fig. 6. Relation between results of breath and blood analysis for Alcolmeter evidential M2 instrument.

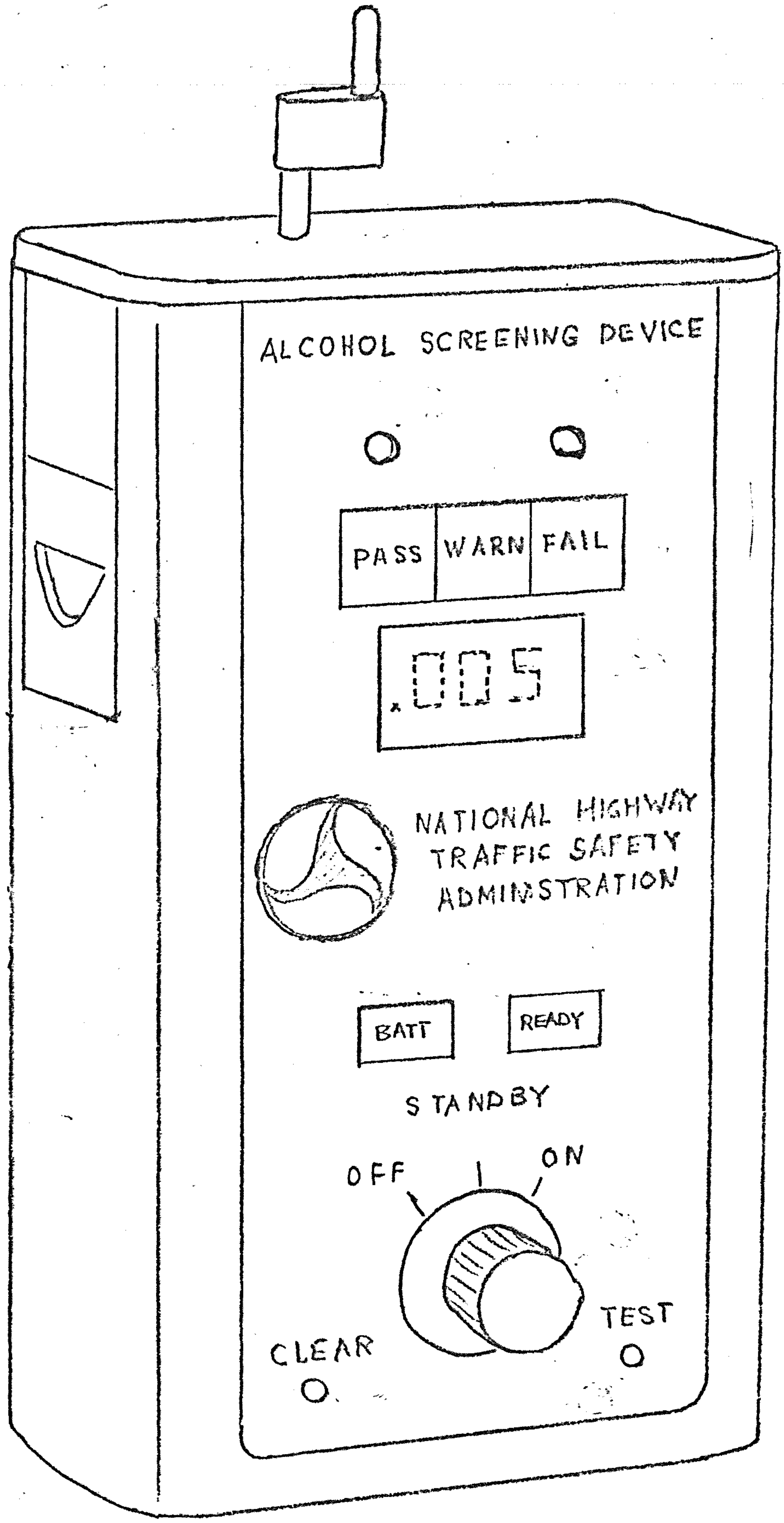


Fig. 7. Alcohol Screening Device.

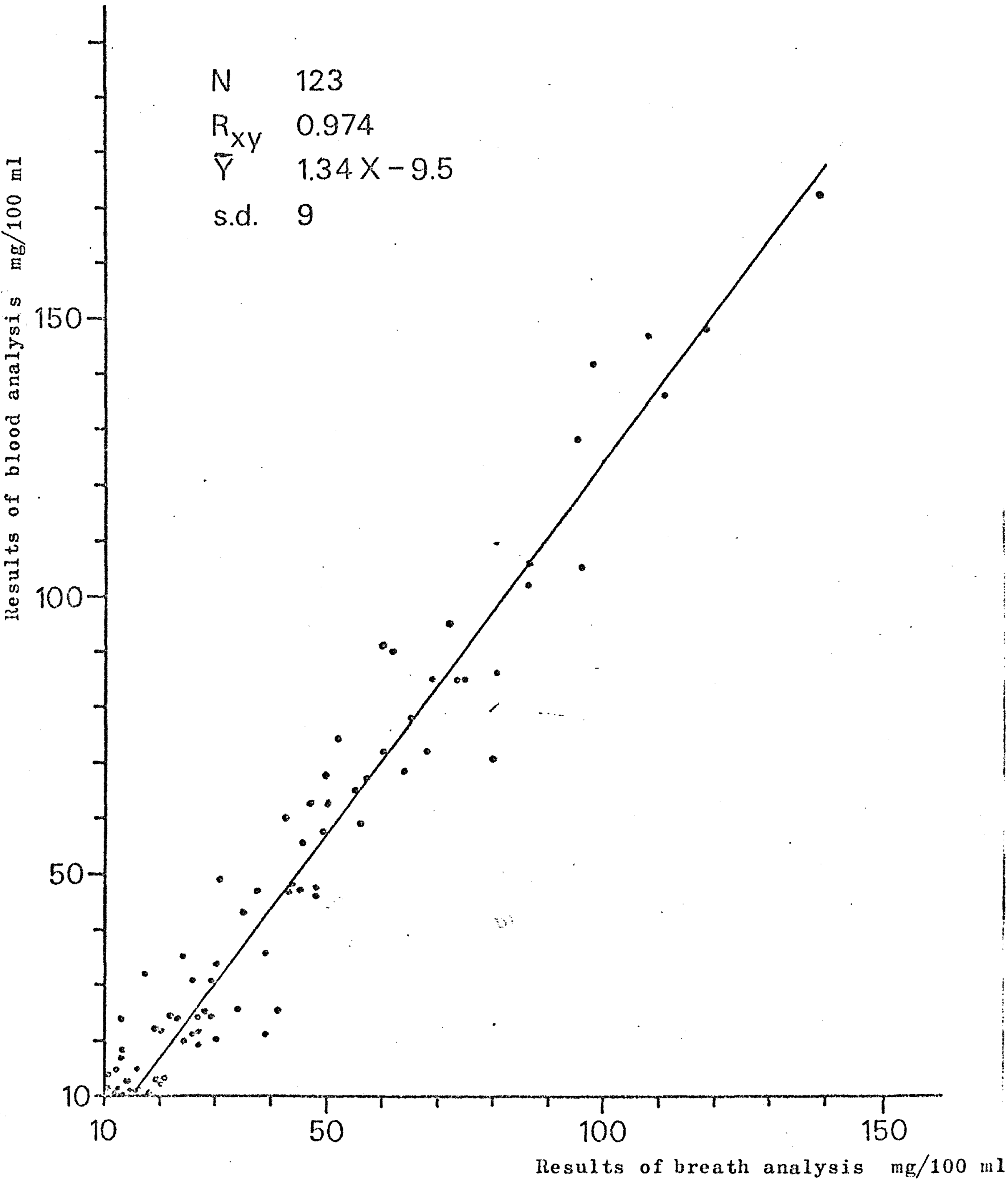


Fig. 8. Relation between breath and blood analysis for Alcohol Screening Device ASD.

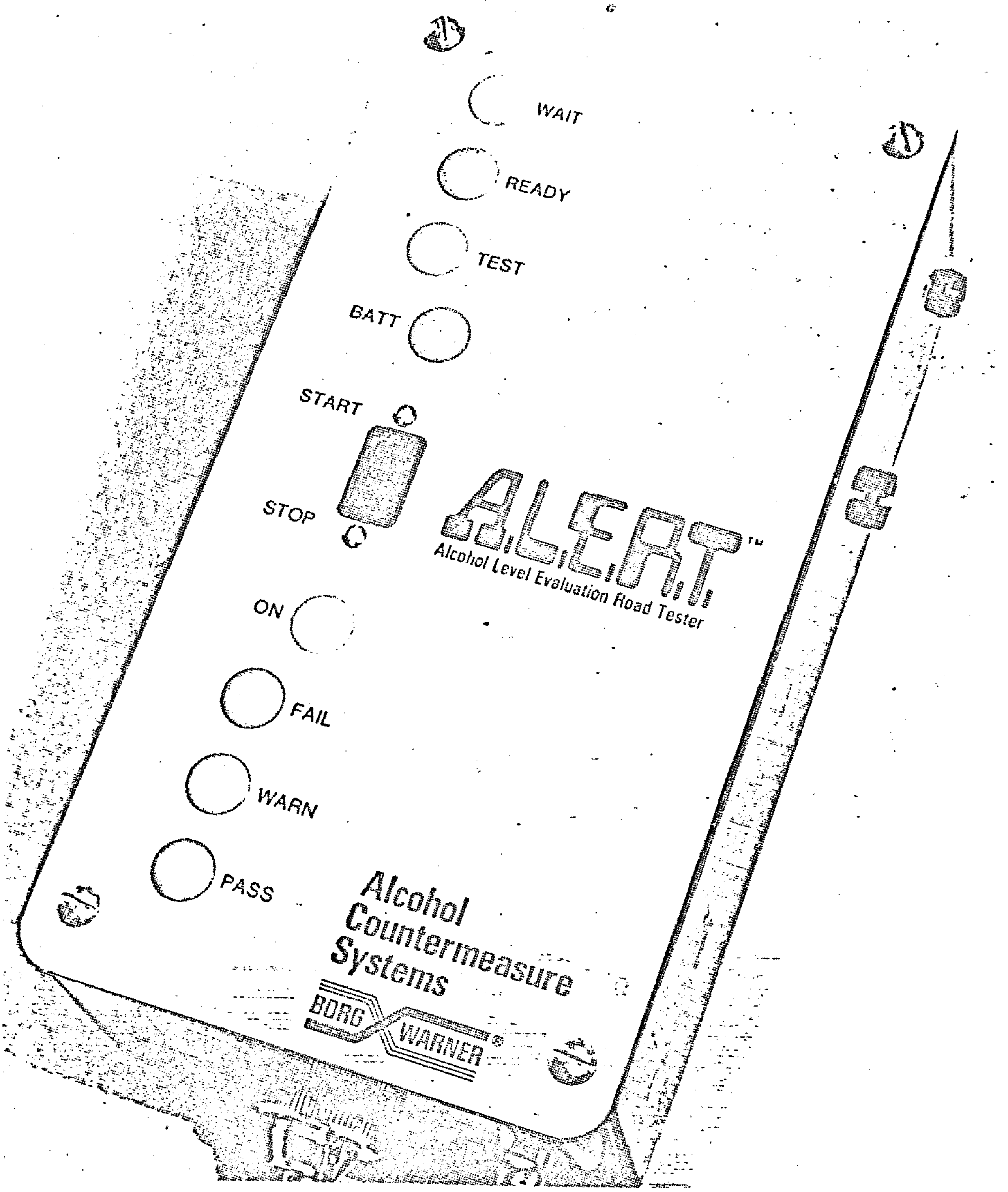
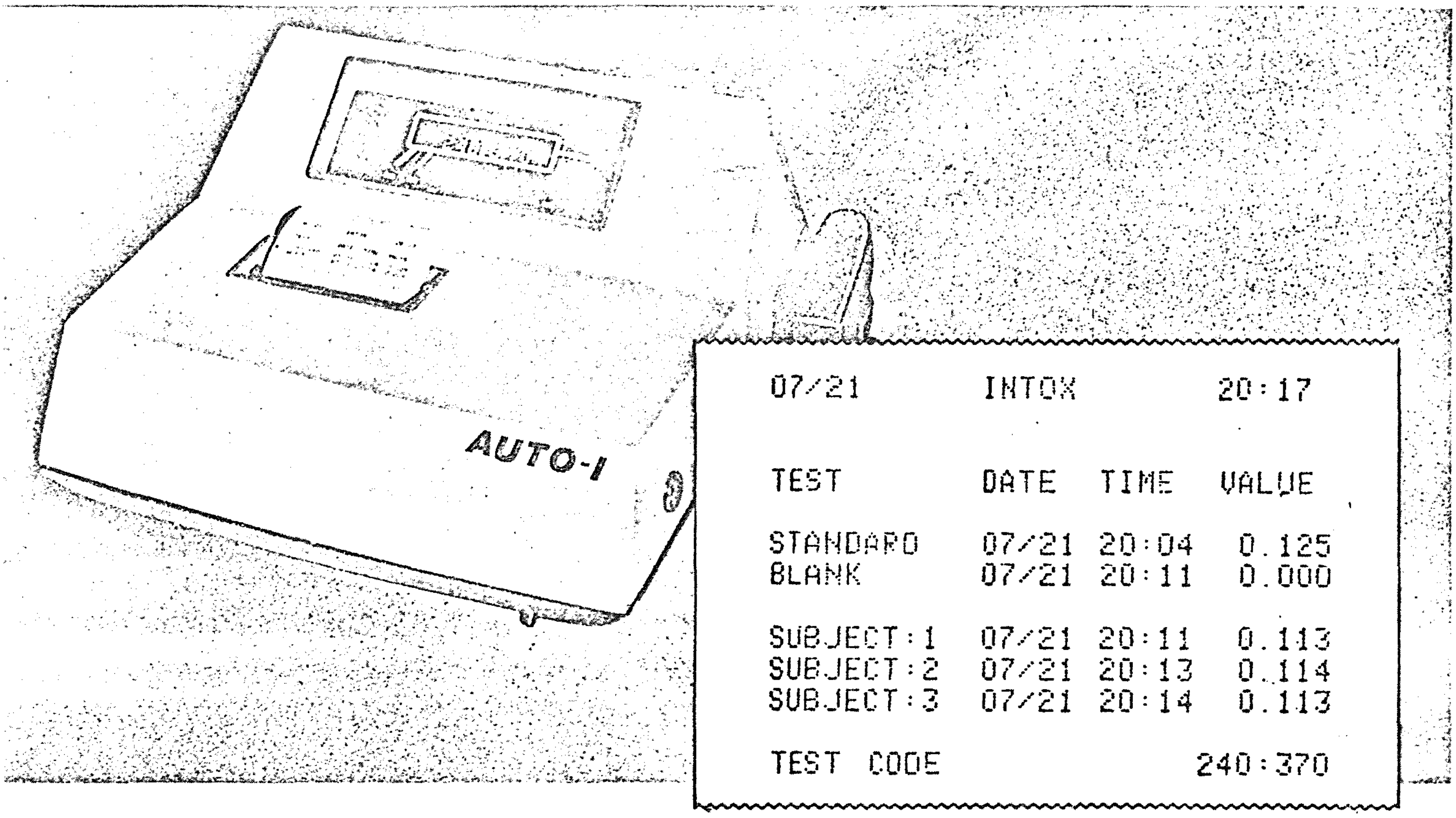


Fig. 9. A.L.E.R.T. model I 2A-1000.



(Actual size sample of print-out.)

Fig. 10. Auto-Intoximeter.

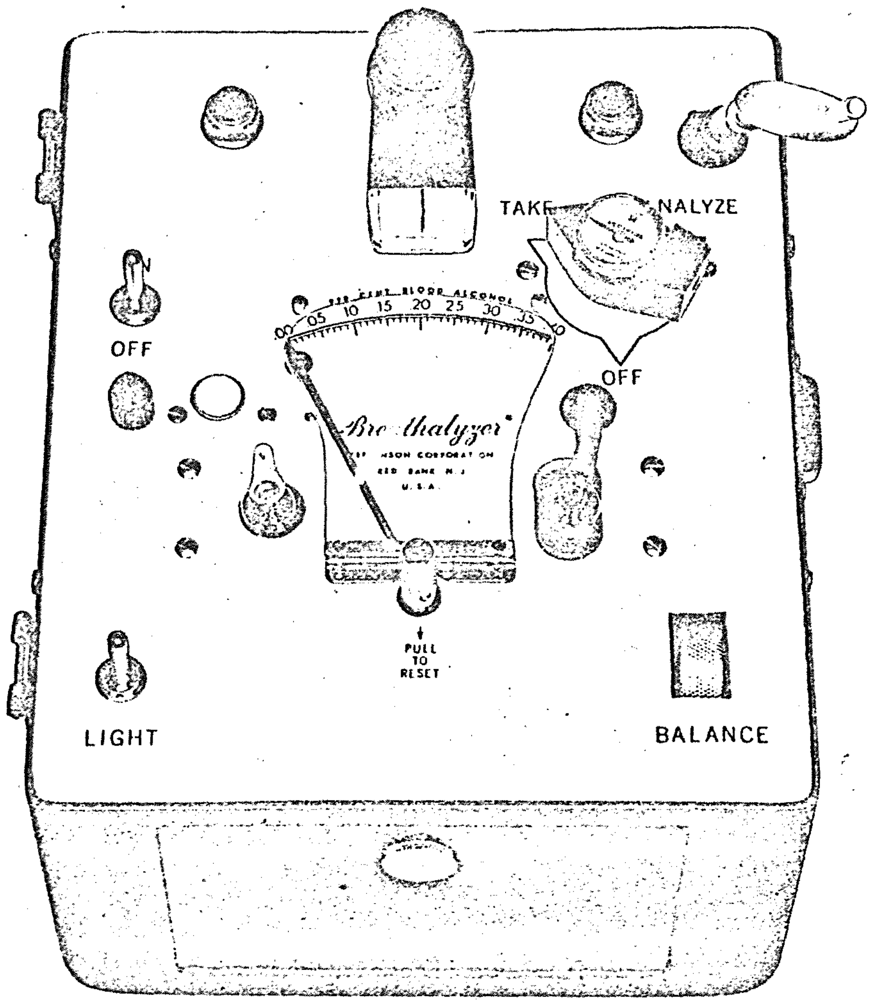


Fig. 11. Breathalyzer model 900.

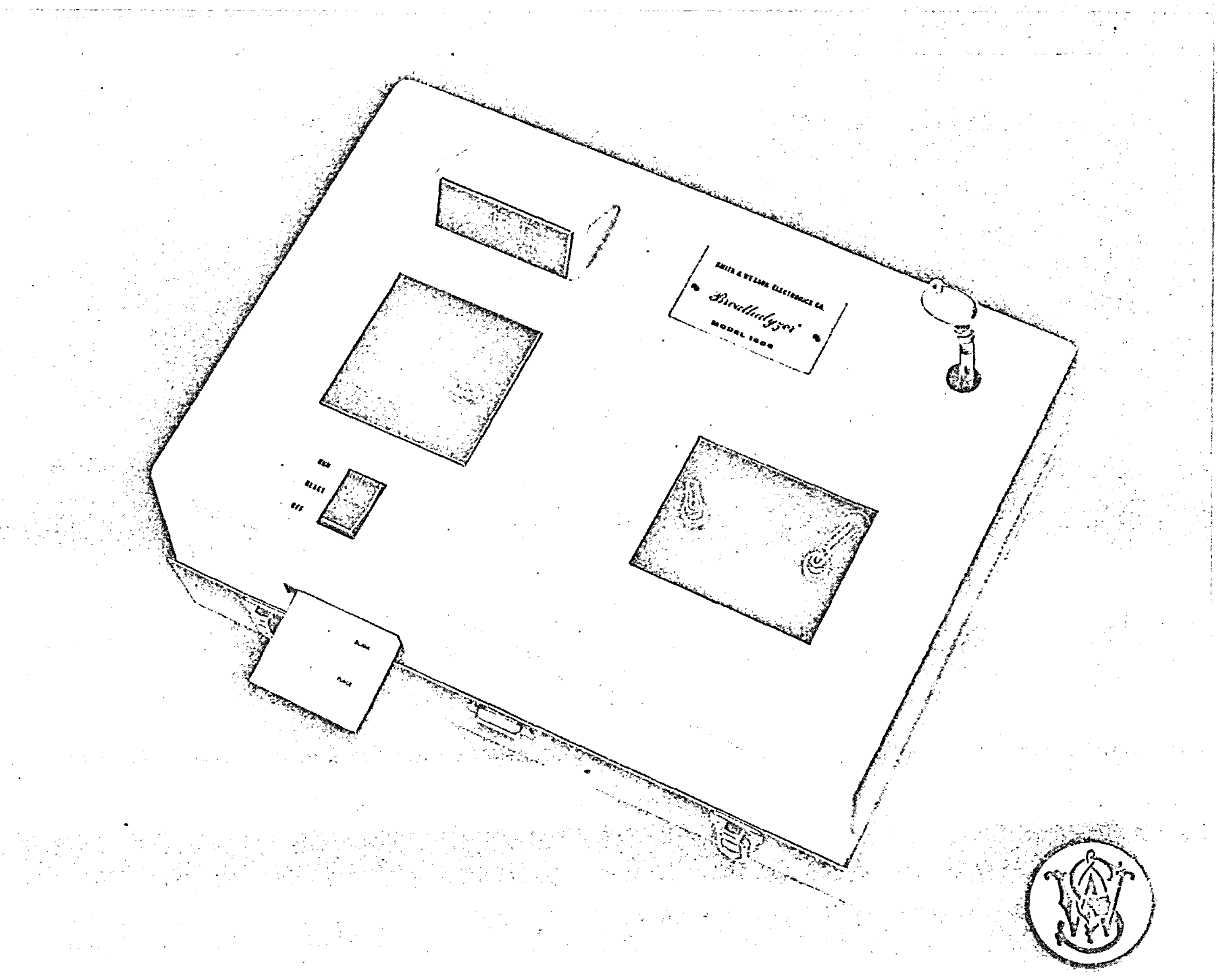


Fig. 12. Breathalyzer model 1000.

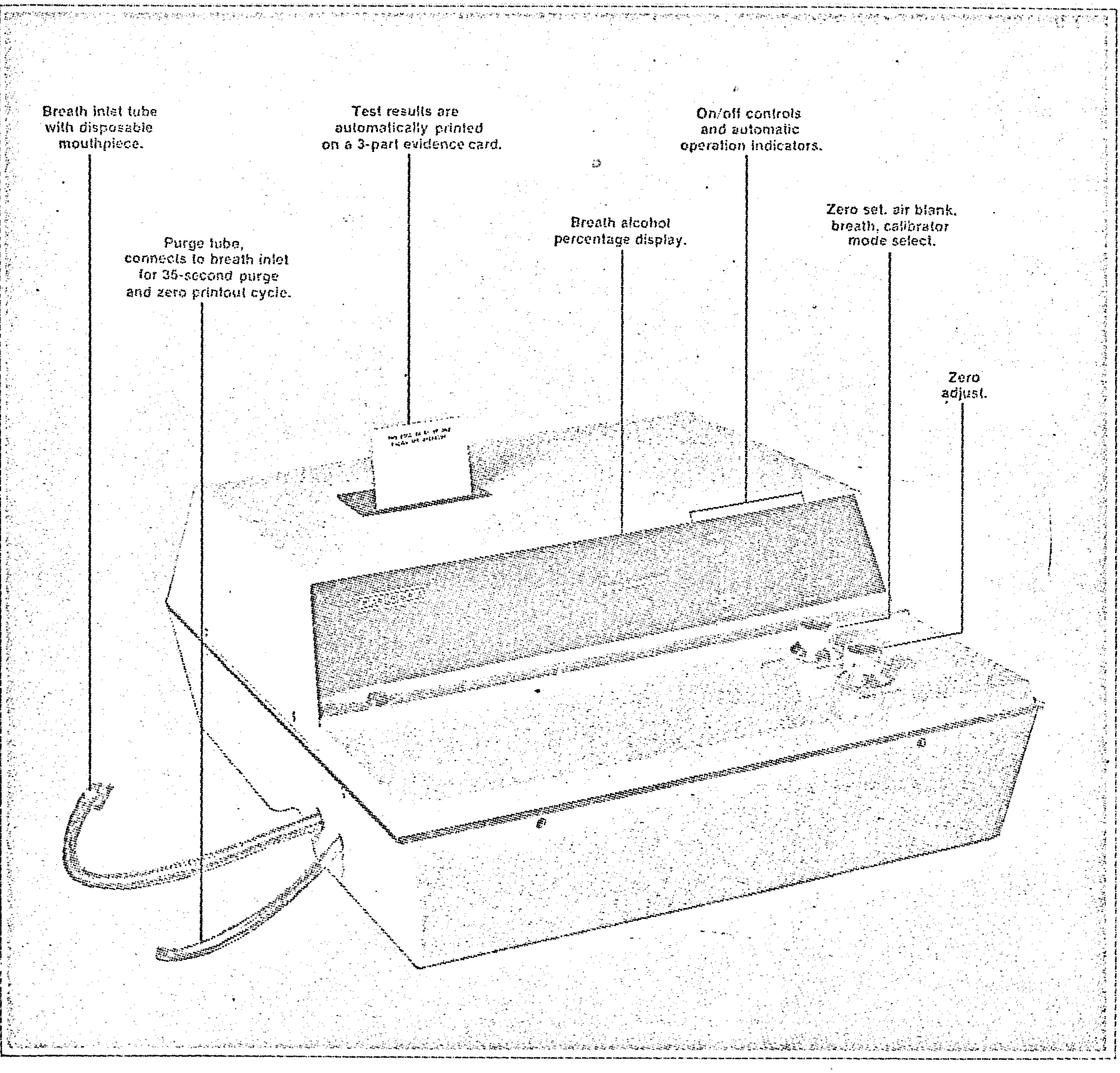


Fig. 13. Intoxilyzer.

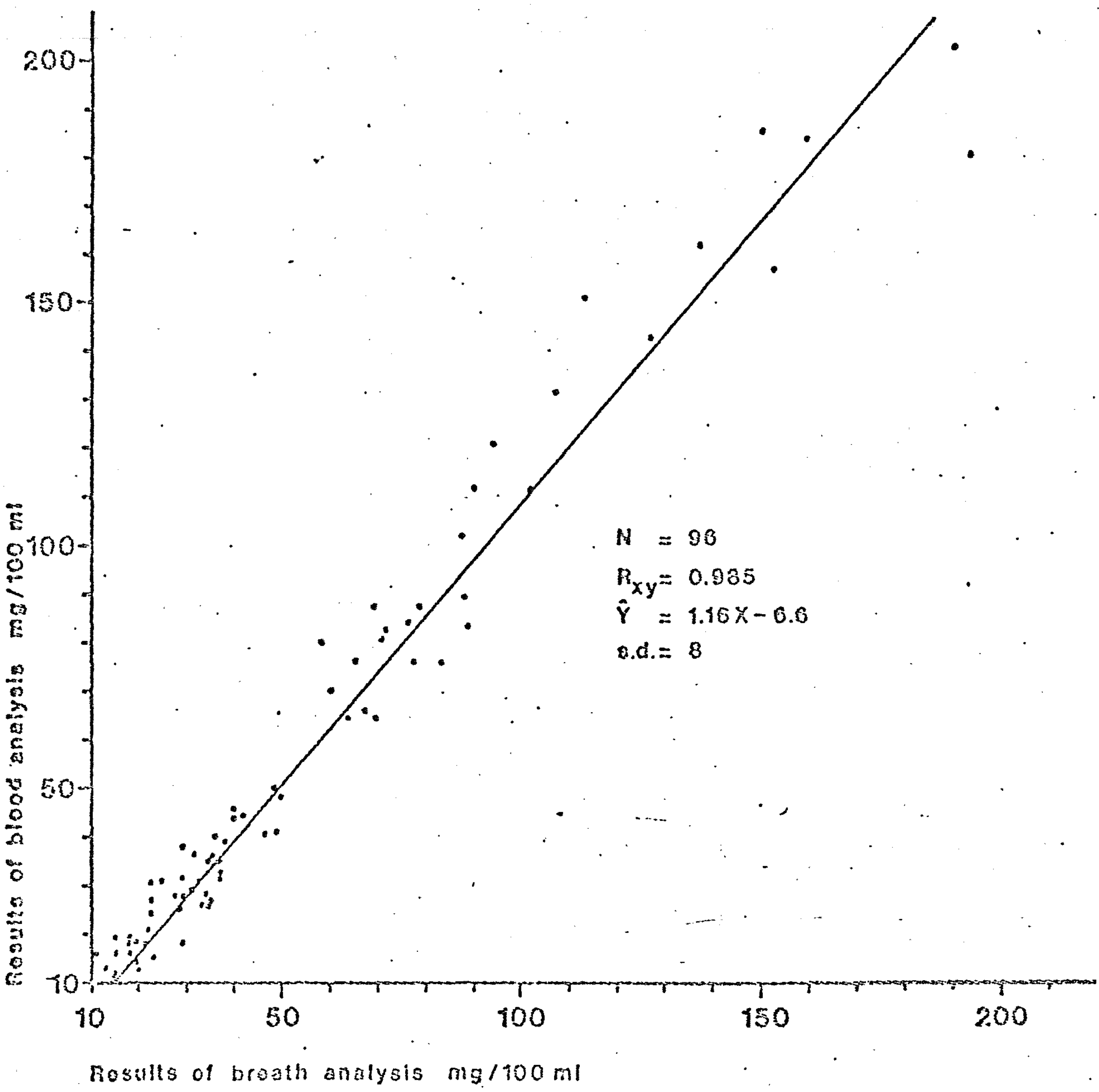


Fig. 14. Relation between BAC and Intoxilyzer-reading.

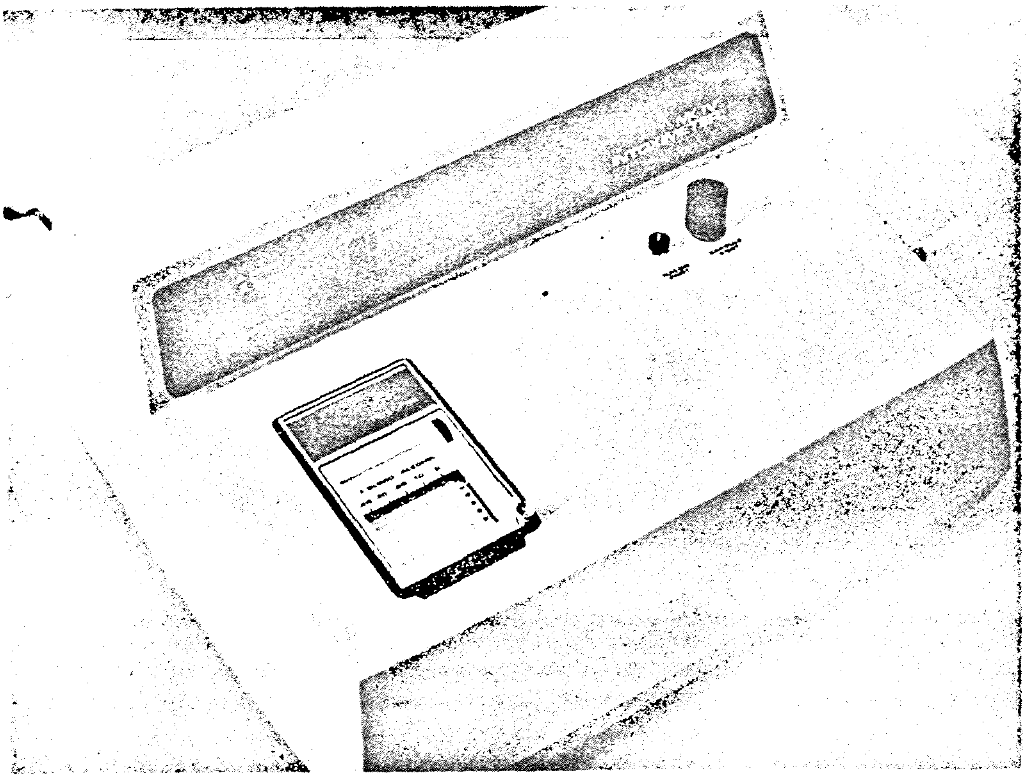


Fig. 15. Gas Chromatograph Intoximeter Mark IV

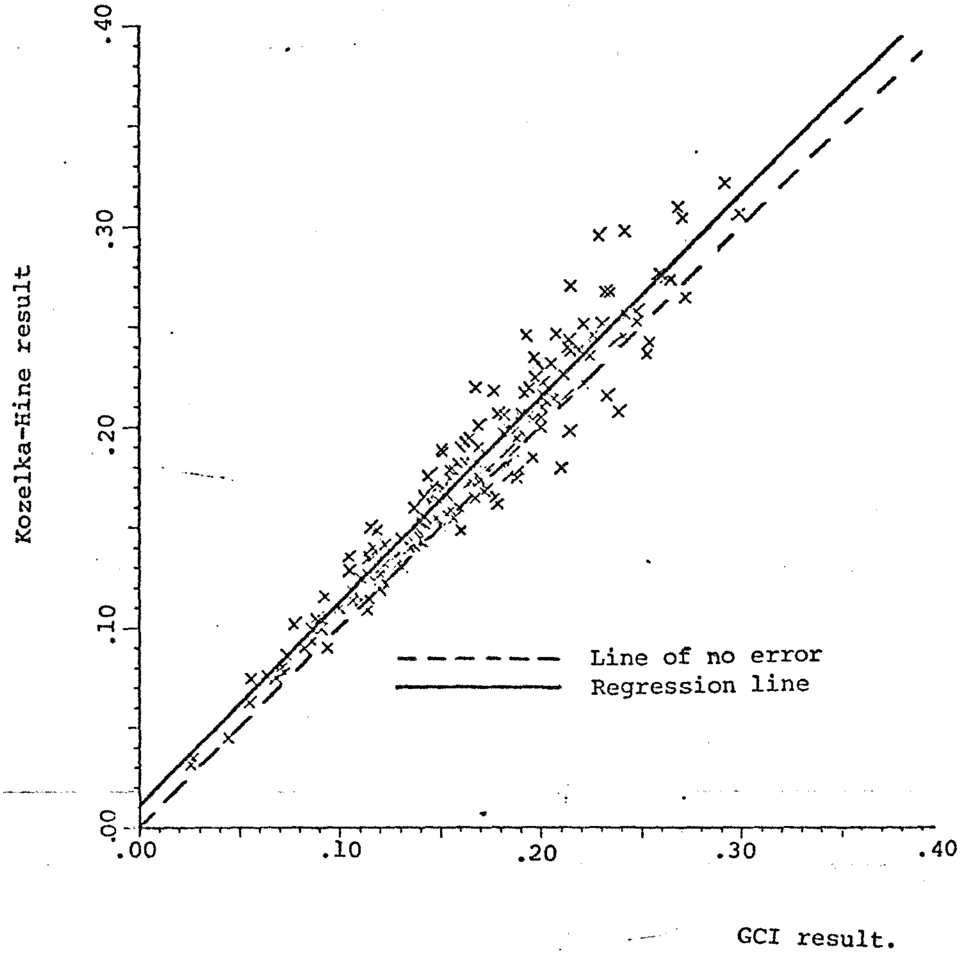


Fig. 16. Relation between BAC and GCI-reading.

Source: Breen, M.H. et al.(1975)

APPENDIX

List of breath testing devices and literature

NAME AND MANUFACTURER	LITERATURE
Screening tests	
Chemical type	
Alcotest (Dräger, Western Germany	- Bjerver, K., Andréasson, R., & Bonnichsen, R. (1966). A Field Study of the Use of "Alcotest" in Sweden. In: Harger, R.N. (ed.), 1966. - Cremers, H.T.P. (1968). Alcotest blaaspijpjes. Algemeen Politieblad, 117 (1968) no. 26: 612-613. - Day, M., Muir, G.G., & Watling, I. (1968). Evaluation of Alcotest R80 Reagent Tubes. Nature, 219 (1968): 1051-1052. - Dubowski, K.M. (1975). Recent Developments in Breath-Alcohol Analysis. In: Israelstam, S. & Lambert, S. (eds.), 1975. - Froentjes, (1968). Het bewijs van alcoholgebruik. In: Buikhuisen, W. (ed.), 1968. Alcohol en Verkeer; een studie over het rijden onder invloed. Boom, Meppel, 1968. - Goldberg, L. & Bonnichsen, R. (1970). Bestämning av noggranheten i Alcotestmetoden och vissa andra utandningsmethoder. In: Trafiknykterhetsbrott, Statens offentliga utredningar SOU 1970:61. - Harger, R.N. (ed.), 1966. Alcohol and Traffic Safety. Proceedings of the Fourth International Conference on Alcohol and Traffic Safety, Bloomington, December 6-10, 1965. Indiana University, Bloomington, Indiana.

	- Havard, J.D.J. (ed.), 1963. Alcohol and Road Traffic. Proceedings of the third International Conference on Alcohol and Road Traffic, London, September 3-7, 1962. British Medical Association 1963. - Israelstam, S. & Lambert, S. (eds.) (1975). Alcohol, Drugs and Traffic Safety. Proceedings of the Sixth International Conference on Alcohol, Drugs and Traffic Safety, Toronto, September 8-13, 1974. Addiction Research Foundation of Ontario, Toronto, 1975. - Leithoff, H. & Weyrich, G. (1959). Praktische Erfahrungen mit dem atem alkohol-Prüfröhrchen "Alcotest". Archiv für Kriminologie 123 (1959) no 5 + 6. - Lereboullet, I & Leluc, R. (1963). Le dosage de l'Alcool dans l'air Expiré - sa Valeur. In: Havard, J.D.J. (ed.), 1963. - Prouty, R.W. & O'Neill, B. (1971). An Evaluation of some Qualitative Breath Screening Tests for Alcohol, Research Report, May 1971. Insurance Institute for Highway Safety, Washington, D.C. 1971.
Alcolyser (Lion Laboratories, Great Britain)	- Goldberg, L. & Bonnichsen, R. (1970). - Dubowski, K.M. (1975). - Prouty, R.W. & O'Neill, B. (1971).
Alcomille (Etzlinger, Switzerland)	- Goldberg, L. & Bonnichsen, R. (1970).

Alcolor/Promillor (VEB East Germany)	-
Pluralcol (Medicor Hungary)	- Nagy, J. (undated). The medico-legal aspects of acute ethyl alcohol poisoning. From: Morphologiai és Igarságügyi orvosi szemle (Review of Morphology and Forensic Medicine (undated).
Detalcol (Tsjecho slovakia	-
Becton-Dickinson devices (Becton-Dick inson U.S.A.)	- Prouty, R.W. & O'Neill, B. (1971).
Kitagawa Drunk - 0 - Tester (Komo Company Japan)	- Prouty, R.W. & O'Neill, B. (1971).
Sober-Meter (Luckey Laboratories U.S.A.)	- Prouty, R.W. & O'Neill, B. (1971).

Electromechanical type

Alcolmeter/Alco-Sensor (Lion Laboratories, Great Britain)	- Jones, T.P. & Williams, P.M. (1972). Evaluation of the Alcolyser FCD (fuel-cell detector) for breath alcohol analysis. Paper presented at the Sixth International Meeting of Forensic Sciences, Edinburgh, September, 1972. - Jacobs, W.B. & Goodson, L.H. (unpubl.). Evaluation of the Intoximeter Fuel Cells for Breath Alcohol Testing. Report of Midwest Research Institute, Kansas City, Mo, to Intoximeters Inc, 1973.

- Harriot, W.F. (1973). Status Report on Portable Breath Testers. Transportation Systems Center, U.S. Dept. of Transportation, Cambridge, Massachusetts, 1973.
- Bailey, D.J. (unpublished). Evaluation of the Production Type Intoximeter Fuel cell Alco-Sensors for Breath Alcohol Testing. Report of a Study at the University of Wales to Intoximeters Inc, 1973.
- Noordzij, P.N. (1975). Comparison of blood and breath testing under field conditions. In: Israelstam, S. & Lambert, S. (eds.), 1975.
- Harger, R.N. (1974). Recently published analytical methods for determining alcohol in body materials - Alcohol Countermeasures Literature Review. Report DOT HS-801 242, U.S. Department of Transportation, Washington, D.C., 1974.
- Moulden, J.V. & Voas, R.B. (1975). Breath Measurement Instrumentation in the U.S. Report DOT HS-801 621, U.S. Department of Transportation, Washington, D.C., 1975.

Alcohol Screening Device (ASD)
Road Side Breath Tester

- Harriot, W.F. (1973).
- Harger, R.N. (1974).
- Noordzij, P.N. (1975).
- Moulden, J.V. & Voas, R.B. (1975).
- Alha, A., Laiho, K. & Linnoila, M. (1975). Blood alcohol in Breath determined by ASD and in Blood by Widmark and ADH methods. A Comparative Study Blutalkohol 12 (1975), 360-364.

A.L.E.R.T. (Borg-Waner USA)	- Dubowski, K.M. (1973). Studies in breath-alcohol analysis: Evaluation of the Borg-Warner breath-alcohol screening device (model J2A-1000) with respect to the specifications of the National Highway Traffic Safety Administration procurement request of August 30, 1973. University of Oklahoma College of Medicine, Oklahoma, 1973. - Rosen, S.D., et al (1974). Evaluation of portable breath test devices for screening suspected drunken drivers by police in Hennepin County, Minnesota. Report DOT HS-801 161, U.S. Department of Transportation, Washington, D.C., 1974. - Picton, W.R. (1977). An evaluation of the alcohol level evaluation roadside tester (ALERT) under laboratory and field conditions. Paper presented to the Seventh International Conference on Alcohol Drugs and Traffic Safety, Melbourne, 1977. - Moulden, J.V. & Voas, R.B. (1975).
Aldet (Tsjechoslovakia	-
Alco-Limiter (Energetics Science Inc. U.S.A.)	- Noordzij, P.N. (1975 - Leavitt, W. et al. (1972). Evaluation of Energetics Science Inc. Alco-Limiter. Report of Transportation Systems Center, U.S. Dept. of Transportation, Cambridge, Mass., 1972.

Alcohalt (USA)	-
Breath Alcohol Tester (USA)	-

<u>Evidential testers</u>

Ethanographe (Etzlinger Switzerland)	- Cremers, H.T.P. (1969). De aethanograaf of wel vertaald: de alcohol schrijver - Algemeen Politieblad, 118 (1969) no 19, 457-459. - Noordzij, P.N. (1975).
Alcolinger Automatic (Etzlinger Switzerland)	- Bonte, W., Philipp, J.H. & Berg, S. (1970). Ergebnisse der Atemalkoholbestimmung mit dem Alcolinger Automatic in der Resorptionsphase. Blutalkohol 7 (1970) no 6, 454-462. - Mebs, D., Goetze-Stelner, C. & Gerchow, J. (1975). Die Atemalkoholbestimmung mit dem Alcolinger Automatic. Blutalkohol 12 (1975) no 5, 315-318. - Monnier, D., Etzlinger, L. & Mussano, F. (1969). New apparatus for the determination of breath alcohol: Alcolinger Automatic. Alkohol und Verkehrssicherheit, 1969, II, 27-31. - Noordzij, P.N. (1975).
Kitagawa-Wright/ Hermes (Great Britain)	- Wright, B.M. (1963). Breath alcohol analysis. In: Havard, J.D.J. (ed.), 1963. - Begg, T.B., Hill, I.D. & Nickolls, L.C. (1973). A Statistically Planned Comparison of Blood and Breath Alcohol Methods. In: Havard, J.D.J. (ed.), 1963.

- Begg, T.B., Hill, I.D. & Nickolls, L.C. (1964). Breathalyzer and Kitagawa-Wright methods of measuring breath alcohol. British Medical Journal 1 (1964), 9-15.
- Goldberg, L. & Bonnichsen, R. (1970).
- Noordzij, P.N. (1975).

Breathalyzer (USA)

- Harger, R.N. (1974).
- Howes, J.R., Hallett, R.A. & Lucas, D.M. (1967). A study of the Accuracy of the Breathalyzer as Operated by Police Personnel. Journal of Forensic Sciences 12 (1967), 444-453.
- Roberts, D.L. & Fletcher, D.C. (1969). A Comparative Study of Blood Alcohol Testing Devices. Rocky Mountain Med. J. 66, (1969), 37-39.
- Preston, W.L.K. (1969). The validity of the Breathalyzer. Med. J. Australia, I (1969), 286-289.
- Milner, G. & Landauer, A.A. (1971). Breathalyzer Faults: Principles and Practice. Med. J. Australia I (1971), 1280-1284.
- Landauer, A.A. & Milner, G. (1971). The Breathalyzer Test and True Blood Alcohol Level. The Australian Law Journal 45 (1971), 360-362.
- Noordzij, P.N. (1975).
- Moulden, J.V. & Voas, R.B. (1975).

Intoxilyzer (USA)

- Harte, R.A. (1971). An Instrument for the Determination of Ethanol in Breath in Law Enforcement Practice - Journal of Forensic Science, 16 (1971), 493-510.

	- Noordzij, P.N. (1975). - Moulden, J.V. & Voas, R.B. (1975). - Harger, R.N. (1974).
Gaschromatograph Intoximeter GCI	- Penton, J.R. & Forrester, M.R. (1970). A Gaschromatograph Breath Analysis System with Provisions for Storage and Delayed Analysis of Samples. In: Proceedings of the Fifth International Conference on Alcohol and Traffic Safety, Freiburg, W. Germany, September 22-27, 1969. Hans Ferdinand Schulz Verlag, Freiburg im Breisgau, W. Germany, 1970. - Schmütte, P. et al (1972). Comparative Studies of Blood Alcohol and Breath Alcohol Concentrations with Gas Chromatographic Breath Test (Intoximeter). Blutalkohol 9 (1972), 392-399. - Morales, D.R. (1972, 1974). Summary of Activities Relating to Evaluation of Instruments and Related Accessoires for Breath Alcohol Analysis. Clinical Chemistry Laboratory, California State Dept. of the Alth. Report 1: 1972, Report 2: 1974. - Harger, R.N. (1974). - Moulden, J.V. & Voas, R.B. (1975). - Breen, M.H., Siler, K.F. & Pearce, D.S. (1975). A comparison between the Gas Chromatograph Intoximeter and a Direct Blood Analysis. In: Israelstam, S. & Lambert, S. (eds.), 1975.
Alcolmeter (Lion Laboratories, Great Britain)	- Noordzij, P.N. (1975). - Jones, T.P., Jones, A.W. & Williams, P.M. (1977). A New Method for the Rapid Analysis of Ethanol in Breath, Blood, Urine and Saliva using the Alcolmeter Evidential Instrument. Paper presented at the Seventh International Conference on Alcohol,

Drugs and Traffic Safety, Melbourne, January 23-28, 1977.

Auto-Intoximeter (Intoximeters Inc USA)	- Forrester, M.R. (1977). A New Breath Testing Instrument for the Patrol Car. Paper presented at the Seventh International Conference on Alcohol, Drugs and Traffic Safety, Melbourne, January 23-28, 1977.

Remote Sampling

Alcolyser (Lion Laboratories, Great Britian)	- Jones, T.P. (1970). Breath alcohol analysis with the "Alcolyser ASC" (Alcohol sample collector). In: Proceedings of the Fifth International Conference on Alcohol and Traffic Safety, Freiburg, W. Germany, September 22-27, 1969. Hans Ferdinand Schulz Verlag, Freiburg im Breisgau, W. Germany, 1970.
Breath alcohol indium tube encapsulation	- Hoday, J. (unpublished). Chairman, Canadian Special Committee on Breath Testing. Unpublished.report to M.R. Forrester. - Harger, R.N. (1974). - Morales, D.R. (1974).

Breath Self Testers

Alco-Meter
(O-Eight Electronics Ltd
Canada)

A.L.A.R.M. (Alcohol Level Awareness
Reporting Mechanism)
(CEB Industries Inc, USA)