Alcohol, Traffic, and Chemical Testing in the United States: A Résumé and Some Remaining Problems

M. F. Mason¹ and K. M. Dubowski²

We give a résumé of "chemical testing" for alcohol in the United States in connection with traffic-law enforcement. Recent procedural and instrumental developments are briefly reviewed. Various factors involved in discrepancies between the results of analyses of near-simultaneous venous blood and breath specimens from the same subject are examined. Because the causes of these discrepancies cannot adequately be controlled in law-enforcement practice, we suggest that calculation of a blood-alcohol concentration based on the result of a breath analysis be abandoned. We recommend that when breath analysis is performed for law-enforcement purposes, the interpretation of the result should be statutorily based on the amount of alcohol found per unit volume of alveolar ("deep-lung") air. Serum or plasma of capillary blood is recommended as the sample when blood is to be analyzed.

Things are seldom what they seem . . .

H. M. S. Pinafore
W. S. Gilbert and A. Sullivan

During 1972 vehicular accidents in the U. S. were responsible for the deaths of 56,300 persons and injury to an additional 2,000,000 (1). Accompanying these was an estimated cost of 17.5 billion dollars, including the extensive property damage reflected in automobile insurance rates, along with public concern about these and the resulting litigation in respect to both property and person. It is of interest to compare this death rate with that of the Armed Services during World War II. The United States was engaged in war for 1346 days and the number of deaths from all causes related to combat was 256,330 (2). The number of civilian vehicular traffic deaths for 1972, prorated to 1346 days, is 207,600.

The inordinate degree of association of the presence of alcohol in the bodies of drivers and pedestrian victims involved in vehicular accidents has long been recognized, and police agencies are required to enforce statutes that forbid driving while under the influence of alcohol. Chemical testing for alcohol in body materials obtained from drivers has been used for about 35 years. The growth and technical developments in chemical testing and its use by individual states culminated in nation-wide application of comparable enforcement procedures in 1969 (see below). This followed Federal Government intervention, beginning in 1965 when the Congress became concerned with various matters having to do with transportation. Thus, the relationship of alcohol to road traffic has now become a major preoccupation of law-enforcement agencies. Most current studies dealing with the biology of alcohol relate directly or indirectly to traffic matters and (or) to the various facets of the problem of chronic alcoholism. It may be now worthwhile to present a brief résumé of this growth and development, along with a consideration of some remaining problems in application of chemical testing and possible solutions to some of them.

¹ Department of Pathology, University of Texas Health Science Center at Dallas and the Institute of Forensic Sciences, Dallas, Tex. 75235.
² University of Oklahoma Health Sciences Center, Oklahoma City, Okla. 73190.

Part of this work was undertaken at the Department of Clinical Pathology, Medical Center Hospital, American University of Beirut, Beirut, Lebanon.

Reprint requests may be addressed to either author.

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In this discussion "chemical testing" refers to chemical testing for the presence of alcohol in body materials in connection with traffic-law enforcement. The unqualified phrase is attaining this meaning by usage in spite of the fact that other types of analyses of such materials had become widespread before alcohol and traffic became a concern of law-enforcement agencies.
Résumé

Initial interest in measuring the concentration of alcohol in body materials was in connection with accounting for coma or death in instances of acute alcoholism. Although Anstie in 1965 (3) had reported a roughly quantitative dichromate coefficient procedure, it was 1898 before Benedict and Norris (4) described a reasonably accurate method.

Concern over traffic and alcohol started in the 1920's with assembly-line production of automobiles and arrangements by banking interests for installment purchase. Suddenly the working man could afford an automobile, and in a few years traffic densities greatly increased. As the total miles driven and the ratio between vehicular miles driven and miles of road increased, vehicular accidents became commonplace.

It was quickly recognized that many vehicular accidents were alcohol-related. Inasmuch as during this period prohibition of the sale and use of alcoholic beverages was in effect in the U. S., the field of personal-injury litigation expanded. Thus a damaged party attempted to obtain a financial settlement from an inebriated driver or his estate, especially in connection with fatal accidents. States began to pass laws such as those requiring that a driver have command of "the normal use of his mental and physical faculties" in order legally to operate a motor vehicle. As signs of alcoholic intoxication can simulate those of a number of natural-disease processes or other intoxications (6), it became of interest to establish with certainty the presence and concentration of alcohol in blood, breath, or urine from an ill or accused subject. Determinations of alcohol in blood date back to 1847 (7); however, in the U. S., and in respect to use for medical purposes, it was the procedure described by Bogen in 1927 (8) that first attracted attention, although little immediate use was made of it.

Prohibition ended in 1933. Even though it was recognized that the incidence of "drunken driving" was increasing, "chemical testing" for alcohol in body materials was infrequently used in law enforcement for at least two reasons:

First, even though the relationships between blood concentration and signs and symptoms of inebriation were already well established and described (9, 10) comparatively few studies had been made under controlled conditions to relate concentration to objective measurements of the early stages of impairment of faculties such as judgment, perception, coordination, and reaction time—these being faculties obviously important to safe driving. Further, there were very few studies [e.g., (11)] relating concentration to defects in actual driving performance.

Second, English Common Law, from which much U. S. law derives, strongly protects an individual from self incrimination, and the early legal views were that consent of the individual would have to be obtained before he could be subjected to a chemical test. For several years during the beginning of use of chemical testing, consent was required even though results of various other kinds of compulsory tests had been held admissible. It was then the experience of law-enforcement officers that the only persons consenting were very ignorant or frightened subjects, or those so drunk that they did not think of the advantage of refusing—a sizeable fraction of apprehended drivers. This need for obtaining consent at the time of apprehension was largely eliminated by later passage of legislation pertaining to "implied consent" (see below).

During 1930–1950 the chief features of the physiology, pharmacology, and pharmacokinetics of alcohol were described. There was (and remains) general agreement regarding absorption, distribution, rate and site of oxidation, excretion, and pharmacological effects. A number of excellent reviews have summarized these matters [e.g., (15–18)]. Several breath-testing devices were described, notably the "Drunkometer" (19), the "Intoximeter" (20), and the "Alcometer" (21).

The police and the judiciary, as well as the public, became increasingly interested in using the results of chemical tests in prosecuting drivers thought to be inebriated. The interpretation of the result of a chemical test was a matter of so-called expert opinion and the need for authoritative guidelines was evident. Hence, during 1938 and 1939 the Committee on Tests for Intoxication of the National Safety Council (22) and the House of Delegates of the American Medical Association (23) saw fit to present recommendations about blood-alcohol concentration in relation to driving. The evidence upon which these were based was sound, although scanty compared to that later developed by numerous investigations. The latter further related concentration to impairment, including impairment of actual driving skills, and the relation of alcoholic influence to vehicular "crashes," including those attended by fatal and nonfatal injuries.

The recommendations in the (1939) Report of the Committee to Study Problems of Motor Vehicle Accidents (23) were to the effect that any individual having a blood-alcohol concentration in excess of 0.15% W/V (1.5 g/liter) was to be considered under the influence of alcohol, and that if values between 0.05 and 0.15% W/V were found he might or might not be under the influence, the decision to rest on other evidence. If the concentration found was less than 0.05% W/V, he was not to be prosecuted for driving while under the influence of alcohol. It was further stated that the recommendations set forth were substantially concurred in by the Committee on the Driver and the Committee on Tests for Intoxication of the National Safety Council.

These became statutory guidelines that dealt adequately with the well-recognized fact that the effects of alcohol vary a great deal from individual to individual. They were a conservative interpretation of the limited but clear-cut evidence available at the time having to do with the existing concepts of unacceptable degrees of alcoholic influence. The relationships upon which the interpretation was based have been represented in various ways [e.g., a cartoon diagram (24)], but a simple graphical presentation (Figure 1) is perhaps most useful forensically. Later, evi

4 The estimated figure for 1972 is 1.25 trillion vehicle miles (about 79% by passenger vehicles) (5). This compares with 1.02 trillion miles in 1968 and 0.69 trillion miles for 1946.

5 Two especially important decisions of the United States Supreme Court bearing on this were those of Breithaupt v. Abram (12) and Schmerber v. California (13). These have been discussed in some detail by Donigan and Fisher (14).

6 The unit "W/V" is used almost exclusively in literature on traffic-alcohol. For this reason, it is converted here, for clarity and illustration, to the corresponding SI unit, which is not used hereafter in this paper.—Ed.

7 The recommendations (and much subsequent literature dealing with legal matters) also used terms such as being under the influence of "intoxicating liquor" or "alcoholic liquor" rather than uniformly specifying alcohol (or properly, ethanol), which was the item of concern.

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When a chemical test result is first used in court has not been established; however, the first appellate court decisions upholding admission of such tests were noted in 1937 (26). The first state law on admissibility of chemical test evidence was passed in Indiana in 1939. It was to take 25 years for 39 states to acquire chemical test laws, and Federal intervention ultimately resulted in a fair degree of statutory uniformity in all states.

As the use of chemical tests increased, so did the incidence of jury trials in which the validity of the interpretation of chemical tests was challenged, and also and especially, the accuracy of the tests, particularly breath tests.

There was never much real difficulty in respect to interpretation (24). It was already well established that for a lean man of average weight (70 kg, 154 pounds) to attain a blood concentration (postabsorptive) of 0.15% W/V, there has to be in his body water at that time an amount of alcohol equivalent to that in about 6 ounces (177.4 ml) of 100-proof spirit or about 7 ounces (207 ml) of the more common 86-proof beverage. About 4 and 4.5 ounces are the corresponding volumes for a concentration of 0.10% W/V. Depending on the duration of the drinking period, the actual volumes ingested have to be moderately to considerably greater than these volume equivalents in body fluids at that time. Alcoholic beverages are so widely used (27) that most adults know from their own experience that impairment is severe when such quantities are taken during a short time.

The major difficulty was in respect to the accuracy of the chemical test result—especially the accuracy and validity of breath tests, and these matters were challenged vigorously in the courts, and with good reasons. Time after time, methodological errors were revealed under cross-examination—especially where law enforcement agencies used individuals lacking academic training in chemistry as laboratory analysts or supervisors, and attempted to qualify individuals as “expert witnesses” who could quickly be shown to know very little about chemical testing, especially breath testing.

The most trying forensic difficulties were consequent to what now appears to some to be an error in policy made by the pioneers in breath testing. This was in deciding to calculate the blood concentration from a quantity of alcohol found in breath. The many difficulties involved in this will be examined in more detail below, but for the moment only one will be mentioned—the need for knowing the amount of alveolar (“deep-lung”) air in a collected sample.

This quantity is needed because alcohol in the plasma of blood circulating through the lungs obeys Henry’s law and, being freely diffusible, its partial pressure in the alveolar and atrial spaces would be expected to be proportional to its concentration in the pulmonary capillary plasma at a given temperature, which, normally, in the lungs is about 37.5°C. [It should be noted here that fluctuations in arterial-alveolar partial pressures, both positive and negative, have been demonstrated for CO₂, with its admittedly much more complex transport system (31). Apparently, alcohol has not yet been studied by the same techniques. It is possible that the application of Henry’s law in the dynamic pulmonary system may not be as simple and direct as heretofore assumed.]

But a breath specimen as delivered is a mixture of dead space and alveolar air in proportions varying with the depth of expiration. Thus if a 1- to 2-liter specimen is produced and collected from a healthy young adult it will be about 60% to 75% alveolar, and it is only the alveolar fraction in which the alcohol is presumed to be in equilibrium with its plasma concentration. As a further complication, the temperature of the latter portion of a forced expiration of breath upon leaving the mouth is about 34°C, not 37.5°C. Assuming, for the moment, that the partial pressure comes to equilibrium at the lower temperature, the question is how to determine the amount of what was originally alveolar air in a given sample.

It was established during the 1940’s that the amount of alcohol in 1.0 ml of postabsorptive venous blood (i.e., blood drawn when the arterial and venous alcohol concentrations are essentially equal) is that present in about 2000 ml of delivered deep-lung breath. During the following 10 years the value of 2100 ml became generally accepted, this being established by analysis of near-simulta-

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8 By 1958 the zone of increasing-to-universal impairment had been decreed as ranging from 0.05% W/V to 0.10% W/V following a symposium with international attendance at Indiana University (23).

9 A person of average size (150-160 pound lean male) will typically oxidize during an hour the amount of alcohol present in about one ounce of 86 proof whiskey. A normal inter-individual biological variation in oxidation rate of about ±25% of the average has been observed.

10 A typical early paper attacking both accuracy and interpretation of breath tests is that of Gardner (26). It was a commonly used source for preparation of cross-examinations of expert witnesses until the later appearance of a comprehensive text (29). These and other presentations brought out an informative and forensically very useful rebuttal (30).

11 I.e., air such as that obtained only in the terminal portion of a forced expiration or by an appropriately controlled rebreathing process.

12 The widely quoted statement that in the case of a normal resting adult “all the air expired after the first 400 ml is alveolar air” (32) when a larger than tidal inspiration is followed by a forced expiration is generally recognized as being quite incorrect, as had earlier been demonstrated (33, 34).
neous specimens of postabsorptive blood and breath, and by analysis of vapor in equilibrium with blood containing known amounts of alcohol at a given temperature (i.e., about 34 °C) (35, 36). When this figure (2100 ml) is used under controlled conditions to compare the results of breath and near-simultaneous, postabsorptive venous blood analysis, there is a good probability that the result for breath will agree with the result for blood within limits of about ±0.015% W/V (37). (The actual value or, perhaps, the biological and operational variation of this ratio will be discussed further below.)

It can be argued that substantially all of the CO₂ in a breath sample is alveolar in origin. As the partial pressure of CO₂ appeared to be rather closely regulated, alveolar air, at rest, would be expected to have a rather constant fraction of CO₂, and the early measurements—dating back to about 1906 (38)—showed this to average 5.5% by volume so that 2100 ml contains (on the average) 203.05 mg of CO₂. Hence, some early breath-testing devices used the expedient of measuring the CO₂ and the alcohol in a breath specimen. The corresponding blood concentration was then calculated on the presumption that the amount of alcohol associated with 0.2 g of CO₂ was the amount of alcohol in 1.0 ml of blood. [Here an annoying difficulty was encountered: the CO₂ concentration in a specimen depends on the terms by which its volume is defined. Actually, two of the early breath-testing instruments (19, 20) used different weights of CO₂ for the calculation, creating an inordinate diversion during cross-examination by a knowledgeable attorney.]

Meanwhile "modern" techniques for study of pulmonary function were developed, and these showed a great deal of individual variation in the percentage of alveolar CO₂ at rest (39). This variation is also to be seen in the earlier data of Fitzgerald and Haldane (38)—the range being from about 4.3 to 6.3% V/V for presumably normal adults. In law-enforcement practice one is dealing with subjects from various age groups, some with decreased compliance, some emphysematous, some agitated and hyperventilating; and one would expect to encounter even wider ranges of alveolar CO₂ concentrations. Because structural changes in lung tissue are common and are usually accompanied by increases in FCO₂, most of the errors resulting from using the 5.5% V/V average figure would appear as falsely low results, but, in any event, incorrect results.

Described about this time were procedures in which alcohol dehydrogenase (EC 1.1.1.1; ADH) was used for measuring alcohol in blood (40, 41). Here were procedures that had acceptable accuracy and precision and almost complete specificity.

Some of those involved at a policy-making level with the National Safety Council Committee on Tests for Intoxication (now the Committee on Alcohol and Drugs) privately favored discouraging breath testing and instead promoting the application of alcohol dehydrogenase methodology to plasma or serum of blood obtained by an appropriate cut of a finger (see below). This would have had an additional advantage of providing a concentration value that essentially was that of arterial blood, and thus better correlation of alcohol concentration and impairment. Such views were quite unacceptable for many stated reasons, but especially because law-enforcement agencies wanted procedures that could be used in the field and that avoided intervention of health-care personnel—who for the most part preferred to avoid involvement in a legal process.

Concern over the accuracy of breath tests¹⁴ increased as experimental studies of impairment—many involving actual test driving (43)—showed impairment to be universal at blood concentrations much lower than 0.15 W/V—indeed, at somewhat less than 0.10% W/V, with a "gray zone" of increasing frequency of impairment, of 0.05 to 0.08% or 0.10% W/V. These were studies from many sources: the U. S., Canada, Great Britain, Australia, Norway, Sweden, Denmark, Holland, and West and East Germany.

As a result, in 1965, the National Safety Council Committee on Alcohol and Drugs (formerly the Committee on Tests for Intoxication) recommended that the presumptive limit for alcoholic impairment be lowered to 0.10% W/V, and a number of states amended their laws to this effect. A short time later, Great Britain adopted 0.08% W/V as the presumptive limit. In the Scandinavian countries, strict programs for control of alcohol in respect to traffic had been in effect for several years (44-46).

Thus, as lower presumptive limits were adopted, a considerable demand for increased accuracy arose, and a movement was started to discontinue use of breath-testing devices that estimated alveolar air volume by measurement of its CO₂ content (47). It was urged that breath-testing devices used in law enforcement be only those that volumetrically measure a "substantially alveolar" breath specimen. At that time the most widely used production instrument that met this requirement was the "Breathalyzer" (Stephenson Corp., Red Bank, N. J.) (49). Since then, the appearance of instruments not requiring sample-volume measurement [e.g., the "Intoxilyzer" (Omnicon Systems Corp., Palo Alto, Calif.) (50) and the Borg-Warner J-2A (Borg-Warner Corp., Des Plaines, Ill.) (95)] has made it necessary to reconsider this restriction.

During the 1960's the national concern about vehicular death rates intensified. It was realized that the civilian traffic injury and death rates were approximating those experienced from all causes by the Armed Forces during World War II. Medical-examiner records had already indicated that at least 40% of the fatalities were alcohol-related (43). At about the time the death rate reached 40 000 per year, with a rate of injury requiring hospital treatment of nearly 2 000 000 persons per year, a careful study by McCarroll and Haddon (52) showed that in 73% of deaths for which responsibility could be assigned with reasonable certainty, the responsible person had significant amounts

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¹³ Assuming a molecular volume of 22.261 liters for CO₂. If the molecular volume of 22.4 liters is used, the quantity becomes 201.7 mg.

¹⁴ Concern over accuracy in chemical testing, generally, was stated in the Report of the Committee of the American Medical Association to Study Problems of Motor Vehicle Accidents in the Proceedings of the House of Delegates of the American Medical Association in 1944 (42).

Although pulmonary functional disorders and bronchopulmonary disease may still account for discrepancies between near-simultaneous analyses of blood and breath, the magnitude of the discrepancies from these causes is considered less than that resulting from using the CO₂ content as a means of estimating the volume of alveolar air. Haas and Morris (48) found no additional systematic variance in results for alcohol in blood and breath when patients with bronchopulmonary disease were used as subjects. The individual difference ranged from +0.018 to −0.056% W/V with the breath value ("Breathalyzer") averaging about 15% less than the blood value.
of alcohol in his body. As the random incidence of alcohol in drivers ranges from 8–15% during a day, with some cities having higher peak incidences, there was surely a cause–effect relationship. Various other compilations over a period from 1938–1964 [e.g., (53–56)] supported the conclusion that “alcohol has been found to be the largest single factor leading to fatal crashes” (56). Interestingly, this conclusion does not materially differ from that which could be drawn from the earliest known report (57) on alcohol and motor vehicle safety. These data became of special interest to agencies of the Federal Government during the period in which Presidents Kennedy and Johnson were vigorously attempting to implement programs to improve the domestic quality of life.

The result was that in 1966 the Congress passed comprehensive legislation creating a Department of Transportation, having in it a National Highway Safety Agency (later, National Highway Safety Bureau: [NHSB]) with Dr. William Haddon as the first director. The agency was charged with the duty of studying the problem of motor vehicular traffic and arriving at program standards to be recommended to the various states, designed to reduce its hazards. The legislation provided that failure of a state to comply could result in loss of part of its share of Federal highway construction funds. Unfortunately, appropriations contemplated for support of the programs involved were drastically cut because of greatly increased needs by the Defense Department.

The program standards were quickly developed and many were implemented during 1968–9. Volume 8 of the Highway Safety Program Manual (59) deals with “Alcohol in Relation to Highway Safety” and was developed for the NHSB by a consulting firm using, especially, National Safety Council representatives from the Committee on Alcohol and Drugs as consultants. Its seven chapters have to do with purpose, authority, general policy, program development and operations, program evaluation, reports, and local government participation. In addition there are eight appendices, the first being that of Highway Safety Program Standard 4.4.8. This volume was presented to the states in early 1969. Compliance with the standard has required passage of appropriate legislation in each state to implement the standard in respect to statutory, administrative, and technical requirements.

Thus, legislation is mandatory that defines the presumptive impairment limit of blood alcohol concentration as not greater than 0.10% W/V.

In order to prevent refusal to take a test on constitutional grounds of self-incrimination, an “implied consent” law must be passed. This is legislation based on a Supreme Court ruling that operation of a vehicle on a street or highway is a privilege, not a right, and that granting of a driver’s license can include the stipulation that the holder will take a chemical test if requested to do so by a law-enforcement officer. If he resists a test, his driver’s license is subject to revocation for some designated period—usually six months or one year.

(Regrettably, there has been considerable foot-dragging by several states about implied consent—either in terms of passage of the law or, if passed, in enforcement of the revocation feature. The legislation must, of course, include whatever elements are necessary for the implementation of requirements that are administrative or technical.) Each state must have an agency to deal with alcohol and road traffic. The agency can be an independent, “new” governmental unit or can be a subdivision of an existing appropriate state agency such as the state health department or state police department. The agency is responsible for the planning and operation of the state program. Details are specified regarding planning, chemical tests and their use, behavioral testing, technical qualifications of operative personnel, procedure after fatal crashes, and reporting. The requirements in respect to breath testing are particularly detailed.

Technical details in respect to performance of tests of both blood and breath include specification of analysis of reference materials, accuracy and sensitivity of procedures used, and the mandatory requirement that breathing instruments volumetrically measure the volume of substantially alveolar air that is analyzed. A reporting system is required that includes information on program evaluation and the results of its operation. By the end of 1971 most states had complied with most of the requirements specified or implied in Standard 4.4.8 and detailed in Volume 8 of the program manual.

Meanwhile, divisions of the National Highway Traffic Safety Administration were developing “counter-measure” programs to control or minimize the consequences of drunken driving and to obtain detailed information concerning the characteristics of the drinking driver population. It was already recognized that this population had distinctive features, one of which is a relatively high incidence of compulsive drinkers. Some years ago it had become clear that in apprehended drivers there was an astonishing frequency of blood alcohol concentrations that were far higher than those attained in ordinary “sensible” social drinking (62, 63). Figure 2 shows the range of blood alcohol concentrations encountered in Dallas County, Texas, during 1966. The median value in 2330 apprehended and tested drivers was 0.22% W/V and 64% of all results were greater than 0.20% W/V and 30% were in excess of 0.25% W/V. These sorts of findings have been further confirmed and make it unsurprising that heavy drinkers are over-represented in accidents accompanied by injury (53, 54, 56, 64) and that this is also the case for subjects who have a “drinking problem” (65), i.e., compulsive drinkers and alcoholics. In addition, repeating offenders have a high frequency of very high blood-alcohol concentrations upon apprehension.

It is unusual to attain any such concentration as 0.20 to 0.30% W/V in the course of ordinary social drinking, and

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18 Still later (1971), the National Highway Traffic Safety Administration (NHTSA).

17 An extensive brochure dealing with Highway Safety Program Management based upon Regional Safety Program Management Seminars conducted for the NHSB, Federal Highway Administration under contract FH11-6537 was prepared by the Automotive Safety Foundation to aid state officials in implementing programs (58).

19 Blood and breath are specified as preferred samples. During development of the standard and after strenuous debate, specification of serum or plasma rather than blood was denied. Use of urine was merely designated as to be discouraged rather than being specified as unsuitable, which is surely the case (39).

20 Mason, M. F., address delivered to the Dallas Society of Analytical Chemists, 1969.
any person frequently doing so usually exhibits other signs supporting a clinical diagnosis of abnormal compulsive use of beverage alcohol. Concentrations accompanied by behavior generally considered socially acceptable are seldom greater than 0.08 to 0.09% W/V.

It is estimated that at least 65% of American adults use alcoholic beverages to some extent, and this percentage is considered to be rising in the English-speaking nations.\textsuperscript{21} The lowering of the age of majority to 18 years and the permissive attitude now prevalent in respect to use of alcoholic beverages on or near educational institutional property has accompanied and perhaps encouraged this. In Great Britian, recently enacted legislation has lowered the age limit for entry and purchase in "pubs."

Thus the earlier public educational effort—which was to the effect that "if you drive, don't drink and if you drink, don't drive"—largely has been abandoned, and the present question is how to deal with the problem, given a population of whom about 5% are compulsive drinkers or frank alcoholics, most of whom drive. Law-enforcement personnel and social scientists are diametrically opposed in their present views. Law-enforcement people, generally, want rigidly defined rules, rigidly enforced, with certain and severe punishment for violations. They appear to be sympathetic with the recent position taken by the Committee on Alcohol and Drugs of the NSC that a blood concentration of 0.08% W/V in any driver indicates impairment in driving performance (67), in part because this would subject a greater fraction of apprehended drivers to deterrent measures.

On the other hand, social scientists tend to favor approaching the problem in other ways, because most offenders either will not or cannot abide by such rules—to accept the increasing use of alcohol as a regrettable social trend and to minimize its effects on traffic by such measures as improving safety of automobiles in crashes, reduction of speed, improvement of roads, "defensive" driving, provision of psychiatric care for compulsive drinkers and alcoholics, and extensive educational programs, especially directed toward the younger age groups.\textsuperscript{22}

The present goal of the National Highway Traffic Safety Administration is to reduce traffic fatalities to about 25,000 per year by these and other measures. Only further experience will tell whether this can be achieved. Certainly there is very little evidence that measures used during the previous 30 years have had any significant effects in terms of reducing the frequency of driving while under the influence of alcohol.

Some Remaining Problems and Possible Solutions

With implementation of NHSB Highway Safety Program Standard No. 8, it might be thought that matters having to do with chemical testing would have become stabilized, so that little further change would occur. This has not been the case, for at least three reasons: (a) Since about 1966 a number of additional analytical devices and techniques have been applied to the measurement of alcohol in both blood and breath and are now appearing as production instruments, accessories, or items. (b) Federal intervention resulted in a large increase in use of chemical-test equipment, and numerous companies quickly developed, promoted, and sold various devices—especially for use in breath testing—which were of unproven value. Need became apparent for requiring performance standards for such equipment, if it were to be used in law enforcement. (c) It was becoming more widely recognized that there are now apparently insurmountable difficulties encountered in the precise calculation of a blood-alcohol concentration from a quantity found in the breath.\textsuperscript{23}

These matters will now be examined in more detail.

Additional devices and techniques include those for sampling for both immediate and delayed analysis ("remote sampling"). Collection of a measured quantity of "substantially alveolar" air for immediate analysis is a feature of various recent breath-testing instruments [e.g., (74-80)]. Devices used in delayed analysis capture a portion of the terminal fraction of an expiration at ambient pressure that in part or in whole is subsequently analyzed (81-83) or the measured specimen may be passed through an appropriate adsorbent to trap any alcohol (84-88). In the latter case the adsorbent is redissolved in a measured aqueous volume for analysis by any of several techniques (see below), or alcohol is eluted from the column by means of a heated air stream (84). If a breath-delivery tube is heated to above 34 °C up to the mouthpiece, loss by condensation of alcohol from the delivered breath should be diminished. A volume of breath that has been brought to equilibrium (in respect to alcohol) with blood by re-breathing can be used as a sample (83, 90), and it is likely that such breath-testing instruments will soon appear.

\textsuperscript{21} The magnitude of the alcoholic beverage industry in the U. S. is emphasized by the statement that "One in Every Forty-Two Working Americans is Employed in the Alcoholic Beverage Industry" (66).

\textsuperscript{22} The interpretation of data that have been used to substantiate the degree of involvement of alcohol in fatal and nonfatal "crashes" is also being questioned by social scientists; e.g., Zylman, R., address delivered to the Annual Conference of Int. Ass. Chiefs of Police, 1973; see Newslett. No. 328, Licensed Beverage Industries, Oct. 1973, p 2.

\textsuperscript{23} Early published articles [e.g., (68-70)] informal presentations, or court testimony indicating that large discrepancies might occur in the results of blood-alcohol concentrations calculated from near-simultaneous analyses of blood and breath brought out spirited responses [e.g., (71-73)], and it was some time before it became clear that although many of these discrepancies were the consequence of technical, operational or other errors in procedure or interpretation, some were not.
The sampling procedures and performance of several "screening" devices have been discussed in a recent monograph published by the Insurance Institute for Highway Safety (91).

In some instruments the sampling device collects a fixed but unmeasured volume followed by electrochemical analysis (fuel cell) or catalytic oxidation or measurement of infrared absorbance (50, 51, 92-95).

The most exploited technique for final measurement has been gas chromatography applied to both blood (or serum or plasma) and breath.

Numerous methods for blood have been described, in which direct liquid sampling [e.g., (96, 97)], headspace analysis [e.g., (98, 99)], and analysis of filtrates [e.g., (100-102)] are used. Direct injection and headspace analysis may also be used to analyze solutions of adsorbates obtained in "remote" (i.e., on-site) sampling (103), and the former technique may be applied to breath.

Mechanized headspace sampling and transfer into a gas-chromatograph injection port permits complete "automation" of blood-alcohol analysis except for any initial sample preparation involved (104, 105), as is also the case for automated gas-chromatographic analysis of liquid samples (106, 107).

Reference ethanol-vapor standards, stored under pressure, are now available (108-110) for use in gas chromatography. Strictly speaking, gas chromatography is not a specific identifying technique when a single measurement of a retention time agreeing with that of a reference standard analyzed immediately afterwards is used as the sole criterion. It may, however, be made to have high-probability specificity by demonstrating a similar agreement with the reference standard under different column conditions, or with a different column. In law-enforcement practice, especially in analysis of breath or blood headspace by use of an inert column packing, the analysis may be considered specific if the retention time is matched in an immediately subsequent analysis of a reference standard containing ethanol because other interfering volatile compounds having retention times identical with those of ethanol are not encountered in the blood of motor-vehicle operators. When the injected sample is small (i.e., a few microliters), the use of an internal standard in quantitative analysis is highly desirable, to eliminate the need to accurately measure such small volumes. n-Propanol, dioxane, and acetonitrile, which are not likely to be encountered in a biological specimen, have appropriate properties for such use.

Several breath-testing instruments in which fuel cells or catalytic oxidation detectors or metal-oxide semiconductor gas sensors are used have been described (51, 92-95, 111). The alcohol present in a substantially alveolar breath sample of fixed volume is adsorbed upon a surface and undergoes electrochemical oxidation, the current or voltage produced being linearly related to the amount of ethanol. In the semi-conductor gas sensors, tin dioxide elements are used, the conductivity of which increases in a predictable manner upon surface adsorption of combustible gases and vapors. Instrumental responses are rapid, about 3 min being required to complete an analysis. Details of instrument design other than in patent filings were not generally available as of September 1, 1972.

Mechanized ("automated") continuous-flow enzymatic measurements of blood alcohol have been available for several years (112, 113). More recently, an alcohol dehydrogenase procedure has been adapted for use in a discrete automatic analyzer (114).

The useful operational features present in some breath-alcohol instruments include print-out of the analytical result (50, 80) and interlocks so that the analytical sequence and print-out cannot be interrupted or altered by the operator. The addition of read-out (in final concentrations) and (or) print-out devices to instruments requires addition of an analog computing device, which materially increases the cost.

Additional operational features that may possibly become obligatory requirements in the near future include items such as a breath temperature (at the mouth) recorder, a tamper-proof sequence that in addition provides a sealed record of all actions of the instrument so that no operative function may be concealed or expunged from the record, and, perhaps, a mechanized device providing a portion of the collected deep-lung breath in a stored form (e.g., as an adsorbate) for use by the defendant, if he so desires.

It is now generally agreed that law-enforcement agencies should not be burdened with the necessity of proving adequacy of purchased instrumentation, but rather should emphasize local monitoring of performance in use of devices known to be capable of achieving specified degrees of precision, accuracy and specificity to the extent necessary for traffic alcohol analyses, and to have other features relevant to convenience, safety, etc.24 Consideration of this matter was started by the Committee on Alcohol and Drugs of the National Safety Council and by the Office of Alcohol Countermeasures of the National Highway Traffic Safety Administration during 1969 and 1970. A report of an ad hoc committee appeared during 1971 (115), dealing with standards for quantitative breath-alcohol instruments and recommendations regarding the type and nature of an approving and monitoring authority that would be concerned. Following the research report evaluating the performance of some breath alcohol screening devices (91) another NSC ad hoc committee developed a series of performance standards and evaluation criteria for such devices (116). Subsequently the Committee on Alcohol and Drugs developed a comprehensive statement, yet to be released (117), consolidating the material in these two ad hoc reports and in an additional earlier one (39) dealing with testing and training. The purpose of the statement is to provide guidelines and criteria to manufacturers, program directors, and user agencies. It deals with definitions, personnel selection, training and functions, quantitative

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24 For blood analysis the NSC "Model Program ..." (47) recommended that procedures used should meet the requirements specified by the NHSB. The NHSB requirement for accuracy is that a procedure should be consistently capable of giving results within ±0.010% W/V of the known value of reference materials over the range of 0-0.30% W/V (59). Although lack of specificity in procedures such as those involving dichromate oxidation has not in the past posed a significant operational or forensic difficulty (see below) it is likely that, in the future, specificity for ethanol will become an obligatory requirement for methods used in chemical testing.
analysis, breath-alcohol screening tests, compliance test procedures and approval, and monitoring and control of breath-testing devices. Standards of accuracy and precision for quantitative breath-testing instruments are, properly, in terms of analysis of vapors of known alcohol concentration (i.e., reference standards) and not in terms of agreement of breath tests with near-simultaneous blood analyses. The statement recommends that instruments must be capable of determining the alcohol in a vapor sample over a blood-alcohol equivalent range of 0.05-0.30% W/V within ±5% of the true concentration. Precision of a minimum of 50 consecutive determinations in the range of 0.05-0.15 W/V must have a standard deviation not exceeding 0.0025% W/V, and from 0.15%-0.30% W/V the standard deviation of 50 consecutive tests shall not exceed 2% of the true value.

In the meantime the NHTSA arranged with the Investigative Aids Division of the Law Enforcement Standards Laboratory of the National Bureau of Standards also to develop performance standards for quantitative breath-alcohol measuring instruments. This agency proceeded with an interchange of information and views with the Committee on Alcohol and Drugs of the NSC. The first draft of the proposed standards (118) was made available to the Committee on Alcohol and Drugs in late October 1972, and appears adequately to specify a good many requirements and the precise way in which the performance tests must be conducted and the results expressed by the manufacturer. Whether further consideration will lead to revision of the section dealing with what amounts to a comparison of near-simultaneous venous blood and breath tests on subjects given alcoholic beverage under controlled conditions remains to be seen, for such comparisons are fraught with difficulty, as is to be shown below. It would seem better to specify requirements for the individual instrumental features having to do with such items as the presentation of the sample to the analytical system; e.g., for the sample indeed being deep-lung air, its volume, temperature at the mouth, intra-instrumental sample temperature, precision and accuracy of analysis of reference vapor standards containing known concentrations of alcohol, specificity, etc.

In comparing the concentration of alcohol obtained by a direct analysis of venous blood with the blood concentration calculated from the result of an analysis of a near-simultaneous breath specimen from the same subject, there are at least two categories of factors that may contribute to discrepancy in the values obtained.

The first of these includes the accuracy and precision of the method used for determination of alcohol in each medium; i.e., that claimed by the authors and (or) found by experienced analytical chemists using the procedure concerned. Also included are the usually different degrees of precision and accuracy experienced in day-to-day (“field”) use of a method. Blood- and breath-alcohol determinations are not noted for their precision and accuracy, and this has been recognized in the development of performance standards. For most of the presently acceptable methods described for law enforcement use, mean deviations from a known value of ±2 to 3% are reported, or recoveries of 95-105%, or standard deviations from a known concentration of 1 to 2% or the like. Monitoring the performance of blood-alcohol analyses in a number of forensic laboratories has shown that the results reported have a range of error far beyond that inherent in the analytical method used. Similar deficiencies in accuracy were noted in the analyses for alcohol performed by clinical laboratories, public health laboratories, and some forensic laboratories (119). Results of the Alcohol Testing Evaluation Program of the Wisconsin State Laboratory of Hygiene illustrate the need to monitor performance: in 18 months, participant laboratories improved from an initial 70% to a final 90% acceptable results (120).

The second category includes various factors that relate to the validity of calculating a blood-alcohol concentration from the quantity in the breath. Are these generally understood, and in law-enforcement practice are they kept sufficiently under control? It should be emphasized that discrepancies arising from this category are additive to the already possibly considerable discrepancies of purely analytical origin. The chief items are as follow:

1. The breath/blood alcohol ratio. It is usually stated that this is about 2100:1; i.e., 2.1 liters of originally alveolar air saturated with water vapor and at 34 °C contains the same amount of alcohol as 1.0 ml of circulating pulmonary arterial whole blood with an average hematocrit reading.

It was obtained by analysis of near-simultaneous specimens of postabsorptive blood and breath, and from a curve established by equilibrating air with blood containing known concentrations of alcohol at temperatures near those at which breath leaves the mouth, followed by analysis of the headspace vapor for alcohol content. The data most extensively quoted are those of Harger et al. (35) and Grosskopf (36).

However, not all recent studies agree with this value, and during the last three years presumably competent laboratories have reported values for the ratio that range from about 1900 to 2400 [e.g., (121-123)]. Early in 1972 a selected international group met at Indianapolis, Indiana, and considered the value of the ratio. The 2100:1 value was reaffirmed, but essentially by fiat (124).

It is highly likely that this is, indeed, the substantially correct mean value of the ratio when it is calculated from data obtained in carefully controlled studies. It may differ somewhat and show less apparent variation than values of the ratio calculated from measurements made under “field” conditions. The “operational” value required to adjust some analytical data obtained with breath-instruments to the correct blood-alcohol equivalent may also be different.

When the ratio is used to calculate a blood-alcohol concentration, the result is the concentration in pulmonary arterial blood (or post-absorptive venous blood) with an average hematocrit reading and at normal body temperature, i.e., 37.0 °C (98.6 °F) with the delivered breath temperature at the mouth being 34 °C.

29 Confidential Reports of Results of Analyses; Toxicology Section, American Academy of Forensic Sciences (1956 et seq.).
Temperature affects the ratio. Between 30 °C and 39 °C (86–102 °F) the vapor pressure curve for ethanol is very steep, and the partial pressure of alcohol (Paicap) changes about 9% per degree of increase. Thermistor measurements of the temperature of the breath of normal subjects (i.e., with mouth temperatures close to 37.0 °C) as it leaves the mouth yield values that are close to the mean. There is, however, some normal body temperature variation, ranging from 35.8 °C (96.5 °F) to 37.2 °C (99.0 °F) (125, 126). Further, the enormous consumption of aspirin in the U. S. (128) and the frequency of headache and symptomatic arthritis, which may be treated by use of a high salicylate dosage, should result in a considerable incidence of mild salicylate-induced hypothermia. In addition, exaggerated fluctuations in temperature in either direction may be observed in the alcoholic, and many individuals pay little attention to fever of less than 38.9 °C (102 °F). It would be expected that more than occasional instances of hypothermia down to 35.0 or 35.5 °C (95 or 96 °F) or hyperthermia up to about 38.9 °C (102 °F) would be encountered in apprehended drivers along with corresponding directional changes in breath temperature at the mouth. It appears that the incidence of temperature deviations in drivers has not been studied. The error that would result, in calculating the blood concentration, could be very considerable—to the advantage of a suspect with hypothermia and to his disadvantage in the case of fever.

The use of a blood/breath ratio of 2100:1 also presumes that "substantially deep-lung (alveolar) air" has been delivered by the subject and subjected to analysis. In law-enforcement practice it is unlikely that this is consistently achieved. Indeed, it is often difficult to get a truly deep-lung specimen from healthy volunteers without some practice—repeated attempts. In a random driver population one encounters subjects with structural disease (e.g., emphysema) and largely functional disease (e.g., decreased compliance), subjects too much under the influence of alcohol (see Figure 2) to provide a deep expiration, or placed by the tester in a position not conducive to providing a deep-lung specimen. In "field testing" these problems appear insoluble, except perhaps by use of re-breathed air.

The errors introduced always lead to falsely low results. A means of avoiding this matter from controversy by statutory phraseology is suggested below.

2. Variation in hematocrit reading does not measurably affect the plasma/breath-alcohol ratio but does affect the calculated blood concentration. This is because alcohol is distributed in the water of blood and the ratio is used to calculate the alcohol concentration in whole blood, assuming a normal hematocrit reading (47% erythrocytes by volume). Thus for otherwise-normal whole blood with an alcohol concentration of 0.100% W/V the concentration in plasma is about 0.112% W/V. For specimens of whole blood having concentrations of 0.100% W/V, but hematocrit readings of 24% and 76%, the corresponding plasma concentrations are 0.105% W/V and 0.120% W/V. The alcohol in breath is proportional to its concentration in plasma. The potential error is not likely to be a large one. The difficulty is forensic: an assumption is involved when the concentration in blood is calculated indirectly by use of information on the concentration in breath.

3. Status of absorption and distribution of alcohol. When a breath quantity is converted to a blood concentration, it is the presumed concentration in pulmonary arterial blood that is calculated unless it is known that the subject was in the postabsorptive state. During absorption of alcohol from the gastrointestinal tract and its subsequent distribution in body water, large arteriovenous concentration differences may occur; e.g., as much as 0.06–0.09% W/V. The data of Forney et al. (129), obtained immediately after a 30-min period of dosage with 1.03 g of alcohol per kilogram body weight, show that blood-alcohol concentrations in blood from the cubital vein were 12 to 40% smaller than those in fingertip blood. Fifteen minutes later the range of difference was −2 to −29%, and 30 min later +7 to −24%. In law-enforcement practice, the interval allowed between apprehension of the suspect and taking of a breath test avoids the maximum arteriovenous difference being encountered in a given individual unless he has taken a large dose of beverage just before apprehension. This interval (20–30 min) is to allow any alcohol remaining in the mouth from previously introduced beverage to be completely removed (largely by formation of saliva and involuntary swallowing) so as not to cause a falsely high result in the breath test. The allowed interval may often work against the public interest, because impairment of the nervous system correlates best with arterial concentration of alcohol, a consequence of the enormous blood flow (about 25% of the cardiac output) to the brain and the anatomical features of the cerebral circulation, which together reduce the lag between arterial concentration and extravascular water concentration to as little as 2 or 3 min. Thus, late in absorption, when the arteriovenous difference is lessening, the interval may give time for the arterial concentration to decline materially from its value at the time of apprehension. The interval may be shortened by rinsing the mouth with water, but if this is done a period of about 10 min should elapse before giving a breath test in order for mouth temperature and mouth fluid alcohol concentration to return to equilibrium.

When a blood test is taken by a defendant it is venous blood that is drawn, and this is clearly to his advantage until absorption and distribution are completed. In a sense, when a blood test is allowable, an administered breath test is discriminatory, because in law-enforcement practice the status of absorption is always uncertain. With a presumptive limit for impairment of 0.10% or 0.08% W/V one would expect a considerable frequency of instances in which individuals who were prosecuted after a breath test would not have been prosecuted had a concentration in venous blood been the only value determined.

At trial the testimony of an expert witness is often led in such a way that in order to be accurate he must engage in explanation of these matters that may be quite confusing to a jury (and annoying to the prosecutor, or even the judge). To avoid doing so, even with good intention, is to take the risk of entrapment by a knowledgeable cross-examiner. Also, prosecutors often persist in asking the witness to engage in retrograde extrapolation of a blood concentration calculated from a breath quantity to a blood concentration at some prior time. This, of course, can-
not be done without certain detailed information about the status of absorption and distribution of alcohol; this information usually is nonexistent in a given case. Unfortunately, some expert witnesses, perhaps unaware of these matters, respond to such a question without explanation that certain presumptions are contained in the answer given.

It follows that unless arterial blood is analyzed, one cannot expect consistent reasonable agreement between near-simultaneous blood and breath analyses if the subject is not in the post-absorptive state; i.e., unless the arteriovenous difference for alcohol is essentially zero.

4. Specificity, or at least high-probability selectivity for ethanol in breath analysis can be attained by use of various techniques, including infrared photometry and gas chromatography. The latter two are presently used in production instruments. For analysis of blood, use of gas-chromatographic or alcohol dehydrogenase (ADH) procedures provides similar high-probability selectivity. Until now, however, specificity has not posed a significant problem in respect to traffic alcohol analyses in blood from living subjects, as judged from trial experience.

It is well recognized that almost the only volatile reducing substances other than ethanol encountered in significant concentrations in the blood or breath of subjects operating motor vehicles are acetone, acetaldehyde, methanol, isopropanol, and paraldehyde. Reduction of acetone by commonly used oxidants (dichromate, permanganate) is so slight under the usual analytical conditions that the mild acetonemia encountered in ambulatory subjects are of no consequence. Subjects substituting methanol or isopropanol for licensed beverage are unlikely to be indulging in the relative luxury of driving an automobile. Paraldehyde in sufficient quantities to interfere significantly has a distinct odor that can be recognized in both breath and blood. Acetaldehyde in more than negligible concentrations is found only in blood containing paraldehyde.

It is unlikely that the free-acetone content of plasma from ketotic subjects who are still capable of operating a motor vehicle can be sufficient to result in breath-acetone concentrations that significantly interfere with the determination of ethanol as measured from its infrared absorbance at 3.39 μm. Methanol and, especially, isopropanol could occur in amounts that could cause significantly falsely high estimates of the concentration of ethanol.

In law-enforcement practice, the claim that these nonethanol volatiles are present is usually made under circumstances permitting such a claim to be checked (by separate testing of blood, breath, or urine). In the case of breath, a separate sample for delayed analysis (84–88) needs to be collected. Simple tests for these interfering substances in blood have been described [e.g., (43, 103)].

Methods used for analysis of specimens taken at autopsy from victims of fatal accidents must be specific (59).

5. Continuous monitoring of blood-alcohol concentrations by an "AutoAnalyzer" methodology has shown surprising short-interval fluctuations in blood-alcohol concentration (131, 132). This has also been observed in subjects starting with high blood-alcohol concentrations by discrete analyses (130, 133). These do not appear to be artifacts and if confirmed they would provide yet another reason why discrepancies appear in the results of near-simultaneous analyses of blood and breath.

6. Application of Henry's law may not be as simple and straightforward as has been previously thought in connection with the behavior of alcohol in the blood of the pulmonary circulation and alveolar spaces. Surprisingly large arterial-to-alveolar Pco₂ differences, both positive and negative, have been reported (31), suggesting that the partial-pressure-concentration relationships might be more complicated that those dealt with in an equilibrator or simulator system. Alcohol was not studied, and any future findings dealing with it will be of considerable interest.

7. The literature on correlation between near-simultaneous test results for alcohol in blood and breath has been summarized up to 1970 in the monograph, "Alcohol and the Impaired Driver," prepared by the American Medical Association (43). In many instances, the comparisons were made under circumstances in which the subjects were postabsorptive, or nearly so. Examination of these summaries and the original papers support a conclusion that considering the range of error to be expected in each of the two kinds of analysis, tests of blood and breath made under carefully controlled conditions agree satisfactorily [see Coldwell and Smith (134), in 43, p 101; and Fox et al. (135), in 43, p 102]. In many of the other correlation studies, discrepancies of considerable magnitude appear with disturbing frequency [e.g., Scroggie (136), in 43, p 102, Beg et al. (137), in 43, p 1022]. The first part of one summary statement (43, p 102), that "There is an excellent correlation of results obtained . . . ." may well be true from the standpoint of contemporary experimental physiology, but not so when viewed from within the framework of our system of criminal justice. Thus, for example, in trial, the acceptance of a breath test from which the calculated blood concentration was 0.11% W/V in a jurisdiction in which the impairment limit is 0.10% W/V, implies that beyond reasonable doubt the blood concentration was in excess of 0.10%. This is not the case. A contemporary example of correlation data obtained in the laboratory is illustrated by a scatter diagram from which degrees of discrepancy may be estimated (123). It is of interest because the conditions of the experiments were representative of those that would obtain if random field comparisons were made in the course of routine traffic enforcement.

The reliability of properly performed breath tests for the purpose of determining alcohol in breath is, indeed, adequate. It is the transmutation of a breath quantity to a blood concentration that is less than satisfactory. These considerations lead us to conclude that in actual law-enforcement practice, when

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27 Mason, M. F., personal experience arising from participation in about 1000 trials involving chemical-test evidence.
28 At least in urban centers. Isopropanol is said to be more than occasionally encountered in some rural or semi-rural areas (Arthur McBay, Raleigh, N. C., personal communications).

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29 Table V in the excellent review by Harger and Forney (17, p 56) tabulates data on "Accuracy of Estimating Blood Alcohol Level from Analysis of Breath for Blood Alcohol Concentrations of 100 mg% or Above." Footnotes b, c, and d dealing with corrections made to the instrumental readings to obtain the data tabulated are of particular interest. In field use of a breath-testing instrument, a breath-test operator in a given case would be less than happy with the prospect of explaining under cross-examination why it was that the blood concentration he had reported was actually the "Instrument reading +11.7 mg% x 0.892." Note also that the data deal with blood alcohol concentrations greater than 0.10% W/V.
a breath sample is analyzed for alcohol, the quantity found cannot be used to calculate the simultaneously existing actual blood alcohol concentration without making assumptions having uncertain validities in any given case because they have not been assessed.

It would appear to the advantage of all concerned to remedy these accumulated defects in the application of breath testing to the problems of alcohol and traffic and to do this by whatever means are found necessary. To attempt remedy "to whatever extent is practicable" is to invite the usual resistance to the slightest change in human affairs, such resistance having in the past been evident in the case of matters having to do with alcohol and traffic.

A constructive approach to remedy would be to make use of the large amount of competent study and investigation that has already been applied to chemical testing. Thus, it is generally agreed that the blood:breath alcohol ratio is close to 2100:1. Over a considerable period of time, use of this ratio in large numbers of tests has demonstrated that under controlled conditions the average of calculated postabsorptive venous blood concentrations (= pulmonary arterial blood concentrations) of alcohol closely approaches the average value obtained by near-simultaneous direct analysis of blood, even though individual values may vary considerably for reasons already discussed. For a given present statutory definition of impairment in terms of percent blood alcohol, W/V, (or g/0.1 liter) the corresponding amount of alcohol per unit volume of what was substantially alveolar air as delivered at the average temperature at the mouth may be directly calculated by using this ratio. There is, therefore, no need to convert a breath quantity to a blood concentration, and the offense may be defined in terms of the weight of alcohol in a unit volume of such a breath specimen. Breath alcohol quantities already have been directly used in enforcement in one jurisdiction for several years (138). The ranges of precision and accuracy for determination of this quantity are those in turn determined by the analytical measurement of alcohol in the sample, the temperature of the specimen as delivered at the mouth, and the proportion of the specimen that is actually deep-lung air. The temperature can (and should) be measured by breath-testing instruments, and a correction may be applied for observed deviation from the established mean. When a breath specimen is less than substantially alveolar, it is a falsely low value for ethanol that is always obtained, but this is no longer a forensically troublesome difficulty, for an incorrect value is not to be used to calculate another quantity, which is then offered as being correct.

Some say that the certainty of obtaining a sample of substantially alveolar air is now an insoluble problem in law-enforcement practice with present production instruments. But this could easily be dealt with, without subterfuge or unintentional deception, by statutory phraseology that could require that "the alcohol in breath be measured in a sample collected by a procedure capable of providing substantially alveolar air when applied to normal young adults."

Note that in the unlikely event of a change in the accepted blood:breath alcohol ratio, it would not be necessary to alter the statutorily defined breath quantity, because the latter has been derived from previous experience with measured breath quantities and, in a sense, is now independent of the "true" value of the ratio.

Further, a trying burden, tentatively proposed for incorporation into a performance standard for breath-testing devices (118) is at once relieved: the requirement that the manufacturer undertake blood-breath alcohol correlation studies and show that defined correlation requirements are met. It should be clear that if a device is capable of collecting a sample of substantially alveolar air at a known temperature at the mouth and can determine the ethanol in it with sufficient accuracy and precision, there is no need for correlation studies. Any deviation of a calculated blood concentration from that determined by near-simultaneous direct analysis of blood is related to matters beyond control by the instrument.

In actual figures, for a jurisdiction with a present statutory presumptive limit for impairment of 0.10% W/V blood-alcohol concentration, the offense could be defined as that of having, at the time of the test, a quantity of alcohol in excess of 476 μg/liter of deep-lung air in a sample collected by a procedure designed to provide substantially alveolar air when applied to young adults, and having been delivered at a temperature at the mouth of 34.0 (±0.5) °C (the result obtained for a specimen with a temperature at the mouth of more or less than 34.5 °C and 33.5 °C, respectively, having been appropriately corrected). The inclusion of the phrase "at the time of the test" is an example of use of statutory phraseology to deal with another matter involving the impossible task of back-extrapolation of alcohol concentrations. The corresponding breath quantities for other presumptive limits, or ranges of possible impairment are, of course, to be calculated on the same basis.

There remains the question as to whether the requirements dealing with the use of blood should be revised, to make testing of blood and breath equivalent. Statutorily to eliminate the use of blood as a sample for traffic alcohol analysis would be an extreme approach. In many instances blood is the only usable specimen available (e.g., in an unconscious driver) or is desirable for other reasons.

The simplest but least satisfactory proposal is to make no changes except statutorily to define the offense as being concerned with the concentration of alcohol in the blood drawn, and at the time of drawing, only (perhaps specifying this to be within 30 min of the time of apprehension). An objection to doing nothing is that when both blood and breath tests are available to a subject, the breath test can be discriminatory in yielding a higher result than a blood test during absorption.

The analysis of arterial plasma or serum would require arterial puncture, a mildly unpleasant procedure generally requiring the intervention of more experienced health-care personnel than is the case for obtaining capillary or venous blood. If used, the statutory definition of the offense (in a jurisdiction with a whole blood presumptive limit of 0.10% W/V), would be that of having an alcohol concentration in arterial serum or plasma in excess of 0.112%, or 0.11% W/V when expressed to the nearest decimal place.

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30 It has been suggested that it would be helpful to round this quantity off to, say, 400 or 500 μg/liter. It seems unlikely that any convenience resulting could counterbalance the consequent forensic confusion. The "0.10% W/V" figure now used in the statutes of most states to define the evidential significance of blood alcohol concentrations could, however, be retained by specifying the breath alcohol concentration corresponding to a blood alcohol of 0.10% W/V as 0.10 g alcohol per 210 liters of deep-lung air.
Whereas it is generally agreed that use of arterial blood for analysis is impractical, a case may be made for use of serum or plasma of capillary blood that is easily obtainable by the same personnel required for drawing venous blood. When a small but appropriately deep cut is made in a finger tip, the blood obtained is mostly that freely flowing from arterioles, and has a composition approaching that of arterial blood. The collection of up to about 0.5 ml of such blood in a small tube permits the separation of about 0.3 ml of serum after clotting (or plasma if an anticoagulant is used), quite sufficient for analysis by gas chromatography or microchemical procedures.

It should be noted that failure to obtain 100% arterial blood may result in a falsely low value for the ethanol concentration in arterial blood. Capillary blood obtained by "finger-stick" is generally considered to be 65–85% arterial in composition. Thus, with a true arterial alcohol concentration of 0.100% W/V and a considerable arterial-venous difference of 0.025% W/V, the found value in finger-stick capillary blood would be expected to range between 0.091 and 0.096% W/V. Larger absolute discrepancies would be found only at concentrations well above the impairment limits obtaining in the various states and would have no forensic significance. It would appear that statutory phraseology such as "when blood is analyzed the specimen shall be taken from a finger tip by a technique that is capable of providing a specimen having a composition approaching that of arterial blood" might be sufficient to deal with the fact that the actual specimen may be less than arterial in composition.

It is seen that there still remain some imperfections in this attempt to make the testing of blood and breath essentially equivalent law-enforcement methodologies, but at least these imperfections are minimized. Our system of criminal justice does not require perfection when science is applied to legal processes. It does, we hope, impose the requirement that imperfections are not obscured.

Once accepted as scientifically valid, implementation of the changes suggested (with appropriate improvements resulting from further consideration) would in fact not be difficult. Because of Federal intervention in matters having to do with alcohol and traffic safety, amendment of Standard 4.4.8 and the National Highway Safety Bureau Program Manual would be the primary requirement, these providing the guidelines for action by the various states. Subsequent amendment of the Uniform Vehicle Code (139) need not be a lengthy or difficult process when a sufficient body of scientific and legal authority supports a proposal; e.g., the Traffic Conference of the National Safety Council. Judging by what happened when Performance Standard 4.4.8 was first adopted, the response of state legislatures to suggested change should, on the whole, be quick and gratifying.

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78. Ibid., p 19, ("Gas Chromatographic Intoximeter").

79. Ibid., pp 24-27, ("Photo-Electric Intoximeter").


81. Ref. 74, p 32, ("Field Crimper, Gas Chromatographic Intoximeter").

82. Ibid., p 28, ("Accutube").


Ed. note: Because of its relevance to the preceding review, the following news release from the National Bureau of Standards, received Dec. 3, 1973, is printed here.

The NBS Law Enforcement Standards Laboratory (LESL) is providing technical backup to the Department of Transportation (DOT) in a combined effort to curb the traffic death toll which claims approximately 30,000 lives each year due to drunkenness.

Aim of the program is to provide reliable standards for the five basic types of breath-testing devices being used to determine a suspect's blood alcohol content. An increasing number of police jurisdictions throughout the country are equipped with the devices.

Breath testers meeting the standards will be placed on DOT's National Highway Traffic Safety Administration qualified products list. Federal funds used by police under the Highway Safety Act will be expended only for purchase of the listed devices.

The first standard—on "evidential breath testers" used for obtaining courtroom evidence—was published by DOT in the Federal Register on November 5. Completion of the five-part performance package will make available an effective means for protecting law-abiding citizens from drunken drivers.

All 50 states now have "implied consent" laws requiring that drivers, in order to obtain and keep their licenses, must be willing to submit to chemical tests when requested by police.

Police and prosecutors, however, confronted with an increasing array of breath testing equipment, can encounter difficulty in gaining drunk driving convictions because no national standards have been developed to assure the accuracy, reliability and validity of the tests.

Performance standards are being developed at NBS for:

- Evidential breath testers—for obtaining courtroom evidence.
- Screening breath testers—small, portable units carried by law enforcement officers.
- Breath test calibrating units—designed to provide samples of known alcohol concentration for calibrating breath testers.
- Remote breath collectors—used to collect breath samples for later laboratory analysis.
- Passive breath testers—used to collect a breath sample from in front of a suspect's face without the need for his cooperation.

Based on laboratory comparisons with results from venous and capillary blood analyses, the output indication of most breath testers is given in units of blood alcohol concentration.

The level of blood alcohol content at which a suspect is presumed to be legally drunk in most states is [1 g of alcohol per liter] of blood. That level is reached by a 160-pound man consuming seven 1-ounce drinks of 86-proof whiskey within 2 h after eating.

Various tests to determine blood alcohol level deal with blood, breath, urine or saliva. Breath testing is the method of widest choice.